

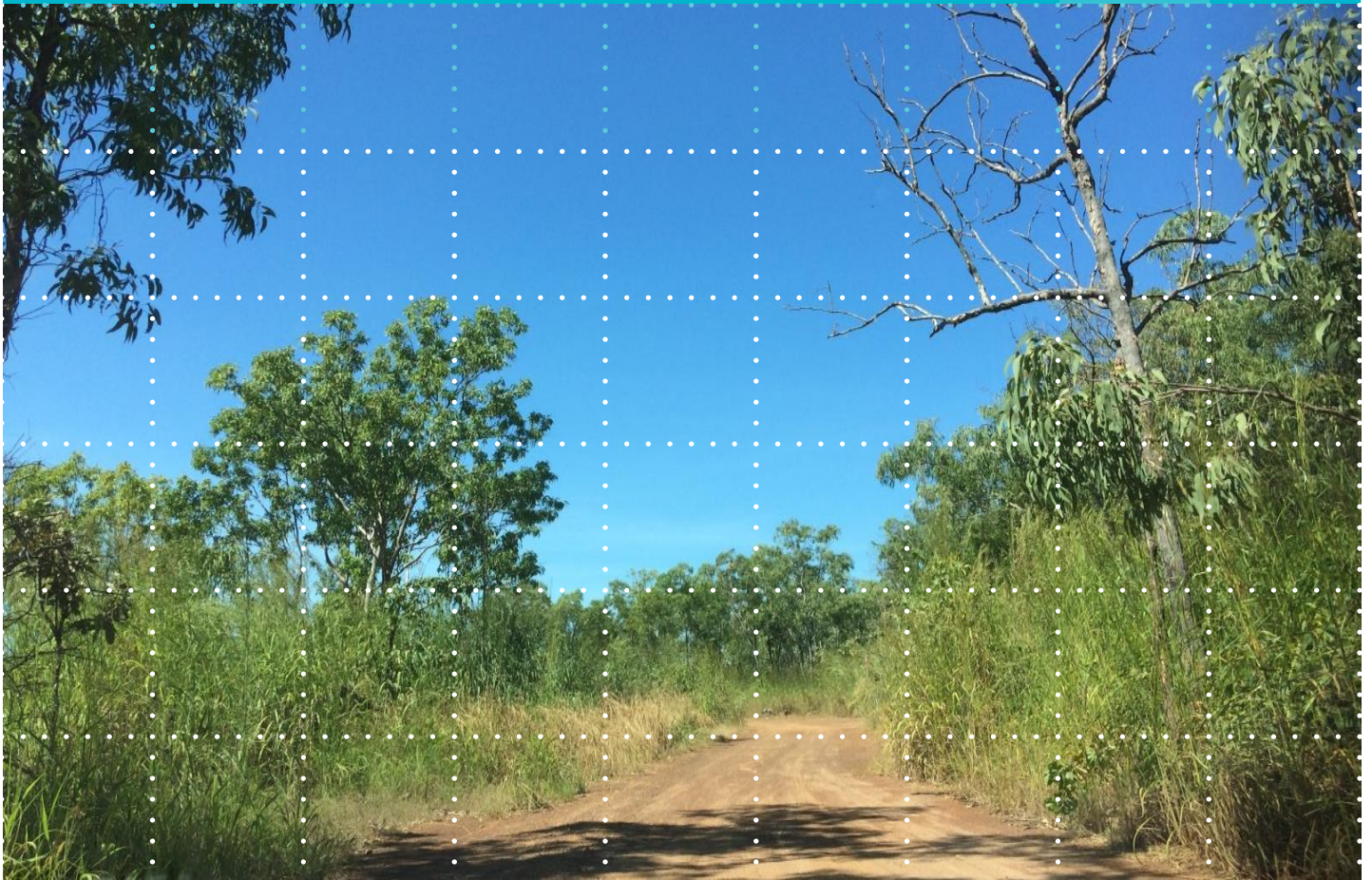
Final Report

Environmental Impact Statement: Lee Point Master-planned Urban Development

Prepared for

Defence Housing Australia

July 2018



Ecology and Heritage Partners Pty Ltd

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ACRONYMS AND ABBREVIATIONS

2CRU	2 Control and Reporting Unit
AAPA	Aboriginal Areas Protection Authority
ABS	Australian Bureau of Statistics
AHD	Australian Height Datum
BOM	Bureau of Meteorology
C	Commercial (Planning Zone)
CBD	Central Business District
CDU	Charles Darwin University
CEMP	Construction Environment Management Plan
CN	Conservation (Planning Zone)
CP	Community Purpose (Planning Zone)
CV	Caravan Park (Planning Zone)
DCA	Development Consent Authority (Darwin Division)
Defence	Department of Defence
DENR	NT Department of Environment and Natural Resources
DHA	Defence Housing Australia
DIPL	Northern Territory Department of Infrastructure, Planning and Logistics
DoEE	Commonwealth Department of the Environment and Energy
DoS	Degree of Saturation
DoT	Department of Transport
DRLUP	Darwin Regional Land Use Plan
EA Act	Northern Territory <i>Environment Assessment Act 1982</i>
EIS	Environmental Impact Statement
EP	Equivalent Persons
EPA	Northern Territory Environment Protection Authority
EPANGDS	Environment Protection Authority's Noise Guidelines for Development Sites in the Northern Territory
EPBC Act	Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i>
ESCP	Erosion and Sediment Control Plan
ESC	Ecological Sustainable Development
FD	Future Development (Planning Zone)
GDE	Groundwater Dependent Ecosystem
GP	Gross Pollutants
ha	Hectare
HR	High Density Residential (Planning Zone)
km	Kilometre

KPI	Key Performance Indicator
LOS	Level of Service
m	Metre
MD	Multiple Dwelling (Planning Zone)
MDR	Medium Density Residential (Planning Zone)
MSDS	Material Safety Data Sheet
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NAFI	Northern Australia Fire Information
NES	National Environmental Significance
NRET	NT Natural Resources, Environment and the Arts
NT	Northern Territory
OR	Organised Recreation (Planning Zone)
PER	Public Environment Report
PMST	Protected Matters Search Tool
The Project	Lee Point Master-planned Urban Development
Project footprint	Areas that could potentially be impacted by the project, i.e. 2CRU, Muirhead North, Sandy Creek, Buffalo Creek and Casuarina Beach.
Project site	2CRU (Lot 04873) and Muirhead North (Lot 09370)
PS	Public Open Space (Planning Zone)
PWC	Northern Territory Power and Water Corporation
SD	Special Use Darwin (Planning Zone)
SPS	Sewer Pump Station
TC	Tourist Commercial (Planning Zone)
TIA	Traffic Impact Assessment
TN	Total Nitrogen
ToR	Terms of Reference
TP	Total Phosphorous
TPWC Act	NT <i>Territory Parks and Wildlife Conservation Act</i>
TSS	Total Suspended Solids
UDIA	Urban Development Institute of Australia
WQO	Water Quality Objective
WM Act	NT <i>Weed Management Act 2001</i>
WoNS	Weed of National Significance
WSUD	Water Sensitive Urban Design

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1 INTRODUCTION

1.1 Background

Defence Housing Australia (DHA) is proposing the Lee Point Master-planned Urban Development (the project) which will establish a residential, tourism, community and commercial precinct on a 132.5 hectare (ha) site (the project site) located on the outskirts of Darwin, in the suburb of Nightcliff. The project site consists of two properties bisected by Lee Point Road, including a former Department of Defence (Defence) installation that was operated by the 2 Control and Reporting Unit (2CRU) on the western side of Lee Point Road (referred to as the 2CRU site), and vacant crown land on the east side of Lee Point Road (referred to as Muirhead North). The project will provide for residential lots at a range of densities, providing much needed affordable housing for Defence families and for members of the public. The project will involve a Main Street precinct that will include a tourism activity centre containing restaurants, cafes, hotels, self-contained apartments and retail shops which will capitalise on its close proximity to Lee Point and the Casuarina Coastal Reserve, Darwin's most popular area of public open space. The project will also deliver serviced allotments to the NT Government that will be dedicated to a primary school, child-care centre and sporting oval.

The project will generate much needed economic stimulus for the Darwin region which is suffering declining growth as a result of the downturn in the mining, and oil and gas industries. It is estimated that the project will contribute \$350 million to the local economy, and provide full-time employment for up to 964 employees in the construction industry, 117 full-time and part-time employees in the hospitality industry and 40 full-time employees in education. There will also be a focus on employing and training indigenous people.

Environmental impacts were considered during the planning phase, and the project was referred under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC 2015/7591). It was assessed on 18 December 2015 as a controlled action due to likely impacts on listed threatened and migratory species and as a Commonwealth action, and would be further assessed by Public Environment Report (PER). The project was also assessed under the Northern Territory *Environmental Assessment Act 1982* (EA Act) and the preparation of an Environmental Impact Statement (EIS) was requested on 18 January 2016 by the Northern Territory *Environment Protection Authority* (EPA) to assess the impacts of the project on threatened species, erosion, the Casuarina Coastal Reserve and biting insects.

While the bilateral assessment agreement between the Northern Territory and Australian Governments does not take effect in this instance, the NT EPA and Australian Government have coordinated the preparation of a combined Terms of Reference (ToR) which address both Commonwealth and Northern Territory assessment requirements. A draft ToR for the project was released for public comment on 23 April 2016 and finalised on 20 May 2016. A copy of the final ToR is provided in Appendix A.

1.2 Purpose

The EIS for the Lee Point Master-planned Urban Development (2CRU) has been prepared to address the ToR and thereby satisfy approval conditions under the EPBC Act and EA Act. The ToR broadly requires further information on the following matters:

- The existing environmental conditions of the project footprint
- Infrastructure requirements to service the local community
- Assessment of impacts and risks to the environment, economy and local community
- Management measures to mitigate or avoid the likely impacts of the project.

Specialist consultants were engaged to undertake detailed engineering, environmental and social-economic studies and prepare reports that specifically address the ToR. The reports are included as appendices to the EIS. Information has also been drawn from previous assessments that were undertaken to support the initial EPBC Act referral and Notice of Intent lodgement.

To identify the key risks to the environment, community, economy and existing infrastructure, a detailed risk assessment was undertaken using international best practice standards (Australian and New Zealand Risk Management Standard AS/NZS ISO 3100:2009). This process informed the project activities that would require avoidance and mitigation measures to ensure impacts remained within regulatory requirements and where possible, community's expectations. The avoidance and mitigation measures proposed are detailed in a Construction and Environmental Management Plan (CEMP) that will be implemented during the construction phase of the project. The CEMP is supported by a number of sub-plans that relate to each environmental discipline that the CEMP addresses.

1.3 Structure

The EIS has been structured in a logical manner to reflect the information requested as part of the ToR, and to facilitate a range of different readers (e.g. referral agencies, utility companies, environmental groups and members of the community) to easily locate information in the EIS that is relevant to them. A detailed project description is provided in Chapter 2. The main technical chapters covering hydrology, air quality, utilities and infrastructure, biodiversity and heritage, social and economic and noise, can be found in Chapters 4 to 9 respectively. Each of these chapters is structured in the following manner:

1. Existing conditions
2. Project impacts
3. Risk assessment
4. Avoidance and mitigation measures.

Detailed technical reports supporting the findings and recommendations in the main body of the EIS are provided in Appendix E to Appendix O. The detailed risk assessment results are provided in Appendix C and summarised in each technical chapter, while Chapter 3 provides a description of how the risk assessment was applied. As requested by the NT EPA and DoEE, the final copy of the ToR is included in Appendix A and a list of contributors that assisted with the preparation of the EIS including the technical studies and risk assessments is provided in Appendix B.

Table 1. EIS Structure

Chapter No.	Title	Scope
1	Introduction	Introduction to the project, justification for preparing the EIS and basic information on the proponent.
2	Project Description	Describes in detail all aspects of the project including site history, development stages and timelines.
3	Risk Assessment	Methodology for completing the risk assessment
4	Hydrology	Technical chapter addressing existing surface water and groundwater conditions and proposed stormwater management plan.
5	Air Quality	Technical chapter addressing noise and odour impacts.
6	Utilities and Infrastructure	Technical chapter addressing potable water, sewerage, traffic, power and telecommunications.
7	Biodiversity and Heritage	Technical chapter addressing impacts to threatened species, migratory shorebirds land condition, and cultural and historic heritage.
8	Social Economic	Technical chapter addressing the social and economic impacts (positive and negative) of the project.
9	Noise	Technical chapter addressing the potential noise and vibration impacts associated with the project.
9	Conclusion	Summarises the key impacts of the project and how they will be addressed.
10	References	List of references cited in the EIS.
Appendix A	Terms of Reference	Copy of the final ToR and tabulated response to how each criteria in the ToR has been addressed.
Appendix B	Contributors	List of people who contributed to the preparation of the EIS
Appendix C	Risk Assessment	Detailed results of the Risk Assessment
Appendix D	CEMP	Construction Environmental Management Plan with sub-plans
Appendix E	Stormwater Management Plan – 2CRU	Technical document supporting Chapter 4
Appendix F	Stormwater Management Plan – Muirhead North	Technical document supporting Chapter 4
Appendix G	Biting Insect Report	Technical document supporting Chapter 4 and general design of Area Plan.
Appendix H	Noise Impact Assessment report – 2CRU	Technical document supporting Chapter 5
Appendix I	Noise Impact Assessment report – Muirhead North	Technical document supporting Chapter 5
Appendix J	Odour Impact Assessment report	Technical document supporting Chapter 5
Appendix K	Traffic Impact Assessment report – 2CRU	Technical document supporting Chapter 6
Appendix L	Traffic Impact Assessment report – Muirhead North	Technical document supporting Chapter 6
Appendix M	Black-footed Tree-rat Report	Technical document supporting Chapter 7
Appendix N	Migratory Shorebird report	Technical document supporting Chapter 7

Chapter No.	Title	Scope
Appendix O	Water Quality Monitoring Plan	Monitoring plan to assess impact of the development on adjoining waterways.
Appendix P	EIS Supplement	Response to comments received during the public exhibition period of the EIS.
Appendix Q	Correspondence	Copy of letter received from Parks and Wildlife Commission
Appendix R	Site Auditors Report	Auditors report for 2CRU
Appendix S	Muirhead North: Stage 1 Preliminary Site Investigation	Stage 1 contaminated land investigation for Muirhead North
Appendix T	Water Discharge Licence WDL 147-05 Annual and Compliance Report	Most recent monitoring report for Leanyer Sanderson Wastewater Treatment Plant
Appendix U	Water Discharge Licence 147-08	Conditions of current Water Discharge Licence for Leanyer Sanderson Wastewater Treatment Plant

1.4 Defence Housing Australia (the proponent)

Defence Housing Australia is a Commonwealth Government business responsible for providing housing and related services for Department of Defence members and their families. This includes providing an active role in the residential housing market by acquiring and developing land, and constructing and purchasing houses. They have undertaken a number of projects that have been referred and approved under the EPBC Act , including:

- North Weston Residential Development, ACT (EPBC# 2011/6163)
- Muirhead Subdivision, Northern Territory (EPBC# 2010/5525)
- RM Military College Duntroon, ACT (EPBC# 2001/374)
- Stirling – Weston Creek, ACT (EPBC# 2001/218)
- Darwin Residential Complex NT (EPBC# 2001/163).

In addition to the Lee Point Master-planned Urban Development, the Rawlings Road Deebling Heights project in Queensland (EPBC# 2016/7723) is currently being assessed under the EPBC Act.

Defence Housing Australia has shown to be an environmentally responsible organisation by complying with environmental approval and regulatory conditions for all their projects. They also show a commitment to the principles of Ecological Sustainable Development (ESD), as demonstrated at the Muirhead Breezes residential development which adjoins the Muirhead North site to the south. Muirhead Breezes has orientated lots to align with the prevailing breeze (hence the name ‘Muirhead Breezes’), and focussed on a climatically-responsive small lot housing, which has resulted in a corresponding reduction in energy consumption. This innovative approach to environmentally sensitive housing has been recognised with the following industry awards:

- 2016 Urban Development Institute of Australia (UDIA) Northern Territory Award for Environmental Excellence
- 2016 UDIA Northern Territory Awards for Innovation in Design

- 2015 UDIA Northern Territory Award for Excellence in Masterplanned Development
- 2015 UDIA Northern Territory Award for Excellence for Environmentally Sustainable Development.

This approach to ESD has been carried through to the Lee Point Master-planned Urban Development.

Table 2. Proponents details

Title	Lee Point Master-planned Urban Development
Location	544 (Lot 9370) and 577 (Lot 4873) Lee Point Road, Nightcliff, Northern Territory
Proponent	Defence Housing Australia 1 Carey Street, Darwin, Northern Territory T 08 8901 7107 Contact: Chris Grimm

1.5 Supplement

In accordance with NT EPA and Commonwealth guidelines, the draft EIS was on display for public exhibition between 18 November 2017 and 1 February 2018. During this period, the public had an opportunity to review and provide comment on the draft EIS with comments received from ten Northern Territory Government advisory bodies and seventeen submissions from members of the public and non-government organisations. Comments received by DoEE were addressed prior to the draft EIS going on public exhibition.

The current version of the EIS has been updated to address comments received during the public exhibition period. A supplement to the EIS has been prepared and details how all comments received have been addressed (Appendix P).

2 PROJECT DESCRIPTION

2.1 General Information

Defence Housing Australia (DHA) is proposing the Lee Point Master-planned Urban Development to provide housing, a tourism precinct, community infrastructure and public open space on a 132.5 ha site located at 544 and 577 Lee Point Road, Nightcliff, North Territory. The project site is located approximately 14 kilometres (km) north-north-east of the Darwin Central Business District (CBD) and covers Lot 4873 (2CRU) and Lot 9370 (Muirhead North).

The project site is bisected by Lee Point Road with 2CRU located on the western side of Lee Point Road and Muirhead north on the eastern side. It is adjoined to the south of 2CRU by the Lyons residential development and by the Muirhead Breezes residential development to the south of Muirhead North. The Casuarina Coastal Reserve including Sandy Creek border the western boundary of 2CRU and the reserve extends to the northern boundary of 2CRU. Casuarina Coastal Reserve is Darwin's most popular public area of natural public open space and provides recreation facilities and public amenity including walking and mountain-bike trails (formal and informal), a surf-life saving club, military history, car-parking, toilets and access to the Casuarina Beach. Sandy Creek enters the Beagle Gulf through Casuarina Coastal Reserve and receives run-off from the western half of the 2CRU site.

The Lee Point Village Resort fronts onto the northern boundary of Muirhead North. Buffalo Creek is located to the east of Muirhead North and receives run-off from Muirhead North and the eastern half of 2CRU through culverts which drain into Muirhead North. Buffalo Creek flows into Shoal Bay and is considered to be the most polluted tributed discharging into Darwin Harbour.

2.2 Project Site

The Larrakia people are the traditional owners of the project site. The Larrakia Nation Aboriginal Corporation and Larrakia Development Corporation have been consulted during the development of the EIS.

The project site is zoned Future Development (FD) under the City of Darwin Planning Scheme (Figure 1).

The 2CRU site is located at Lot 04873 Town of Nightcliff, 577 Lee Point Road and was owned by the Commonwealth Department of Defence (Defence) until recently, when ownership transferred to DHA. The project site was used by Defence as a communication facility and was operated by 2CRU between 1959 and 2002. During this period it had an important role in the Malayan Emergency and also supported Australia's involvement in the Konfrontasi conflict. The project site was inactive between 1974 and 1981 as a result of the considerable damage caused by Cyclone Tracy. The site was purchased by DHA in May 2014. Since then the site has remained vacant; however, there are ongoing issues with illegal site access for motorbike riding and dumping of household and industrial waste. There is also a historical problem with gully erosion in the south-west of the project site that is contributing sediment to the nearby Sandy Creek and providing habitat for biting insects.

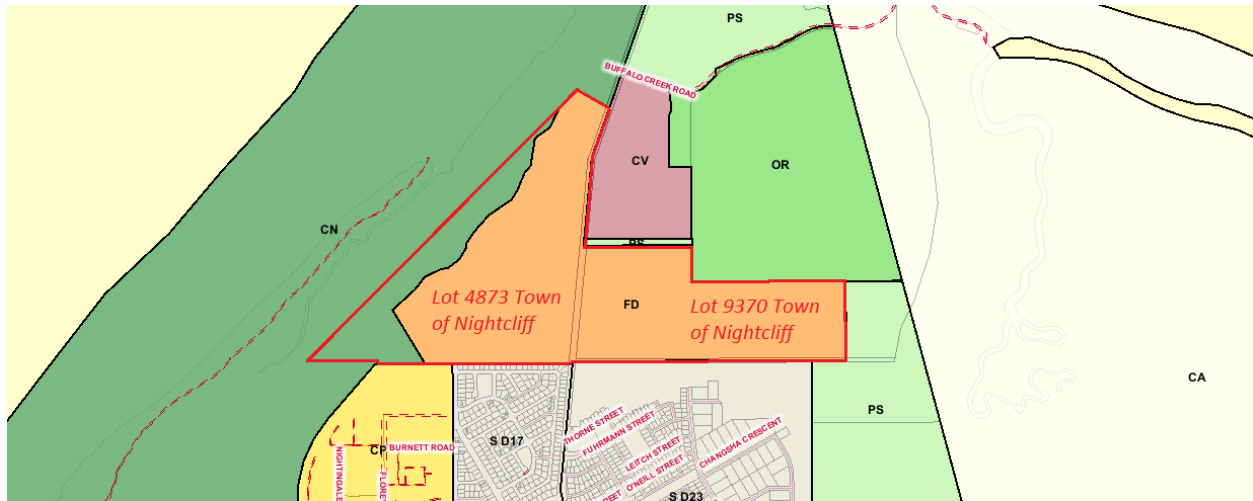


Figure 1. Planning zones

Most of the communication facilities installed by Defence have been removed from the project site, except for a cruciform anti-battery site located in the centre of the site, and an area to the north referred to as 'The Bunkers' which contains remnants of missile foundations, a concrete bunker and explosives/ammunitions store. Most of the project site is covered by introduced grassland, or degraded bushland that has regenerated since Defence operations ceased, although the western boundary of the site is covered in mature Monsoon Vine-thicket.

There is a formal vehicle track from Lee Point Road into the middle of the site where a compound was once situated, with other less formal tracks, including from the former compound heading in a southerly direction, ultimately running adjacent to the southern site boundary and connecting with the trails in the Casuarina Coastal Reserve. Vehicle tracks and firebreaks are present along the eastern and southern property boundaries. There are numerous informal vehicle tracks within the site, along with evidence of itinerant camps. Fencing along the road frontage has been repeatedly vandalised to allow illegal access.

The adjoining Muirhead North site is located at Lot 09370 Town of Nightcliff, 544 Lee Point Road, on the eastern side of Lee Point Road. It is identified as vacant crown land, and with the exception of the telecommunications tower and associated equipment shelter, is void of built form. The site is covered with remnant vegetation, with natural and modified drainage paths occurring across the site to the Leanyer Swamp further east. There is some seasonal inundation in the very eastern extent of the site, although the majority of the site consists of well-drained soils. There are numerous informal vehicle tracks within the site, and evidence of recreational four-wheel drive and/or motorcycle/quad bike access.

Muirhead North gently slopes towards the east with small localised undulations located throughout the property. The eastern portion of 2CRU is similar, with a ridge line extending north-south in close parallel to Lee Point Road. The western portion of 2CRU falls sharply from an escarpment, with vegetation below the escarpment comprising Monsoon Vine-thicket that continues into the coastal reserve.

2.3 Climate

The project site experiences a tropical savannah climate, with a dry season extending from May to September and a wet season running from October to March. During the dry season, mean monthly rainfall varies between 1.1 millimetres (mm) in July and 21.6 mm in May and mean monthly relative humidity is below 50% and as low as 37% in July (see Figure 2). At the beginning of the wet season, mean monthly relative humidity continually rises until peaking in February at 72%. This pattern is broadly consistent with the mean monthly rainfall pattern which is also unimodal and peaks at 423.7 mm in January (see Figure 3). Monsoon conditions prevail from December to March when the mean monthly rainfall exceeds 250 mm and most days during this period receive rain.

Mean monthly maximum temperatures are warmest in the wet season and coolest in the dry season, but vary little between months ranging between 30.6 °C in July and 33.3 °C in October and November (Figure 2). The onset of monsoons results in a small but noticeable decrease in mean maximum temperatures between December and March. There is a larger variation in mean minimum temperatures which range between 19.3 °C in July and 25.3 °C in November and December.

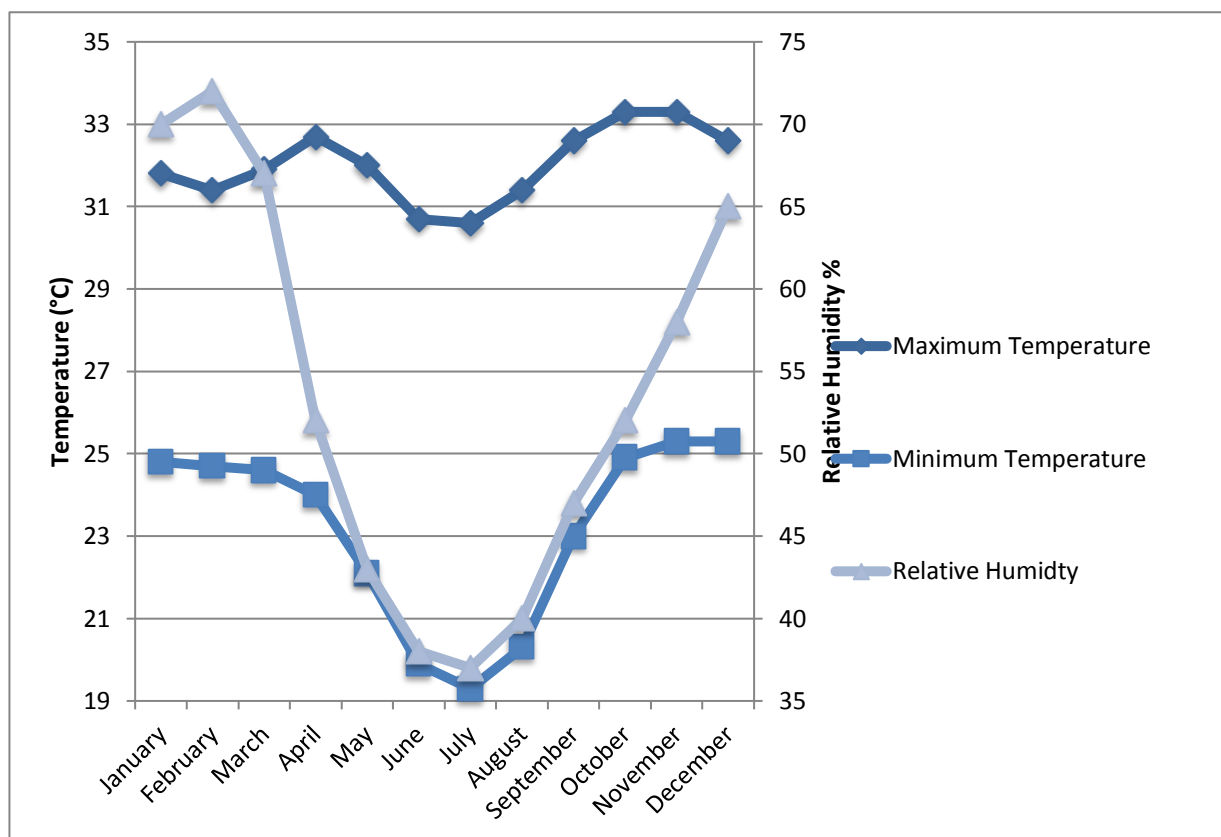


Figure 2. Temperate and relative humidity data (Bureau of Meteorology Darwin Airport)

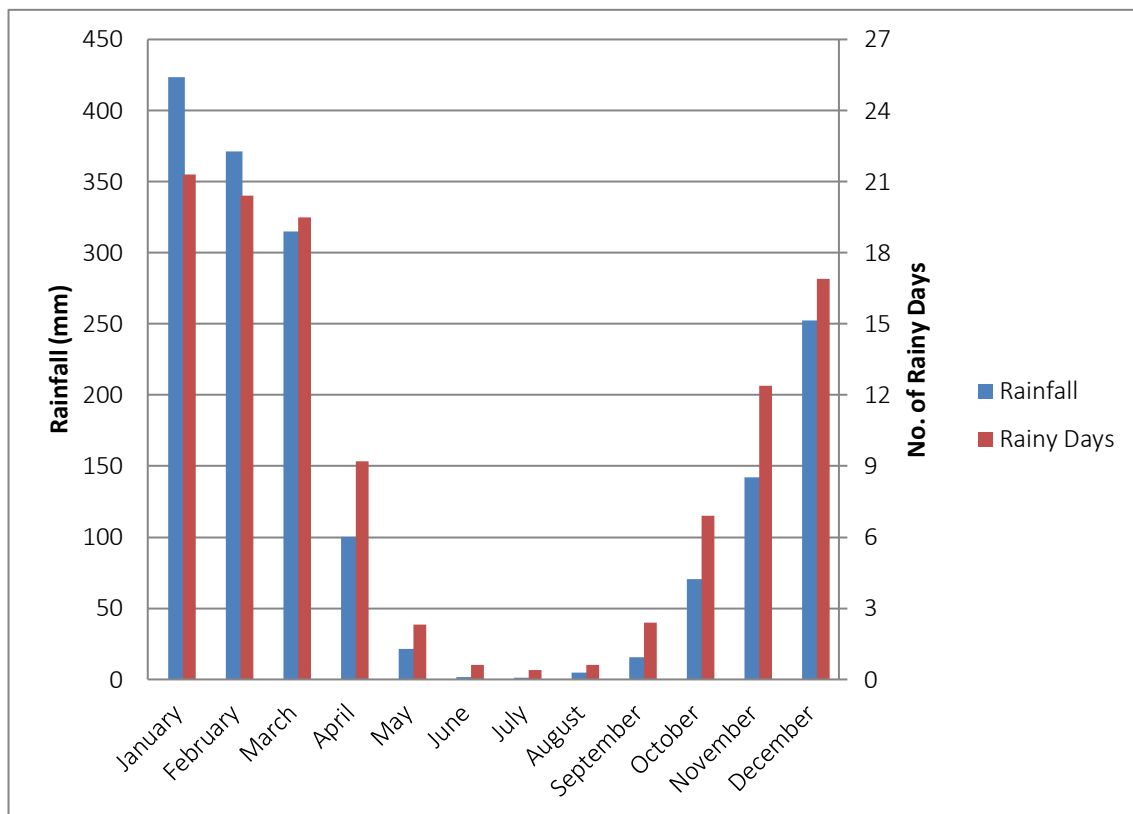


Figure 3. Rainfall data (Bureau of Meteorology Darwin Airport)

2.4 Project Description

The Lee Point Master-planned Urban Development will be developed in accordance with the Lee Point Area Plan and Planning Principle's as described in DHA's application to amend the NT Planning Scheme (PA2014/0922). It will accommodate approximately 700 ground-level dwellings, between 30 and 40 rural residential lots, and between 200 and 250 apartments (see masterplan and site plans overleaf).

The Lee Point Area Plan identifies a tourism and mixed use centre situated along a Main Street precinct in 2CRU running from Lee Point Road through the site in a north-westerly direction where it will terminate at a coastal esplanade. The area will provide most of the high density residence in 3-6 storey apartments. The coastal esplanade runs perpendicular to the Main Street precinct and parallel to the Casuarina Coastal Reserve. It will be an important area of public open space and provide bicycle and walking paths and other recreation facilities. There will also be a small area of open space in the north of the site as part of the preservation of local military history.

The Main Street precinct will provide a mixture of commercial, retail and community services. There are also four tourist sites to be established along the Main Street that will be transferred to the NT Government and will provide for hotel and apartment accommodation in buildings between 2-12 stories.

A Community Hub will be located in Muirhead North, and will include a primary school, child-care facility and sports facilities, covering approximately 3.7 ha. Immediately adjacent to the Community Hub will be an active recreation reserve including an AFL/cricket oval.

In addition to the coastal esplanade in 2CRU, other areas of public open space will include the preservation of 21.95 ha of Monsoon Vine-thicket and eucalypt woodland on the western side of 2CRU to conserve habitat for the endangered Black-footed Tree-rat and expand the area of the existing Casuarina Coastal Reserve. A further 1.6 ha within Muirhead North supporting sensitive Monsoon Rainforest vegetation will be protected. The treatment train of bioretention and detention basins to manage stormwater will be integrated into public open space, contributing an additional 10 ha (approximate). A series of parks and playground areas will be set-aside across the project site.

The current staging plan for the projects proposes a seven staged development, with commencement of civil works scheduled to commence in April 2019 (Table 3). Buildings and other facilities will be established once civil construction works are completed.

Table 3. Staging plan for Lee Point Master-planned Urban Development (dates are subject to change)

Stage	Estimated Start Date	Estimated Completion Date
1A	April 2019	November 2018
1B	April 2019	November 2019
2A	March 2020	December 2020
2B	March 2021	November 2021
3	March 2022	October 2022
4	April 2023	November 2023
5	March 2024	November 2024

NOTES

- (1)

This plan was prepared for the purpose and exclusive use of DEFENCE HOUSING AUSTRALIA as an Investigation into the Development Potential of the land described in the plan and is not to be used for any other purpose or by any other person or corporation.

JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this plan in contravention to the terms of this clause or clauses 2, 3, 4, 5, 6 or 7 hereof.
- (2)

The contours on this plan are approximate and are suitable only for the purpose of this application. The accuracy of the contours has not been verified and no reliance should be placed upon such contours for any purpose other than for the purpose of this application.
- (3)

JFP takes no responsibility for any changes to the design concept that may arise as a consequence of the detailed vegetation assessment undertaken in the future. To increase certainty JFP recommends the appointment of suitable vegetation professionals to complete the vegetation assessment as soon as practical.
- (4)

This plan shall be read in conjunction with the JFP preliminary planning assessment prepared in relation to the site.
- (5)

The dimensions, areas, size and location of improvements, flood information (if shown) and number of lots shown on this plan are approximate only and may vary.
- (6)

Information sourced from third-parties has been utilised in the preparation of this plan.

JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for the accuracy of the information sourced from third-parties. Furthermore it is noted that the boundaries and extents of the site have not been confirmed by survey and therefore cannot be relied upon until such survey is undertaken.
- (7)

This plan may not be photocopied unless this note is included.

LEGEND

	SUBJECT SITE
	LOTS 600m ² & larger (20m x 30-31m) - 135 (28%)
	LOTS 540-599m ² (18-19m x 30-31m) - 157 (32%)
	LOTS 450-539m ² (15-17m x 30-31m) - 106 (22%)
	LOTS 300-449m ² (10-12m x 30-31m) - 88 (18%)
	PARK/OPEN SPACE
	CONSERVATION AREA
LC	LOCAL CENTRE (0.51 ha)
TP	TOURISM PRECINCT (2.78 ha)
MU	MIXED USE RESIDENTIAL (1.39 ha)
GU	MEDIUM DENSITY RESIDENTIAL (1.57 ha)
	BIO-DETENTION BASIN
	WWII HERITAGE AREA
	PROPOSED MOUNTAIN BIKE TRAIL
	ACCESS TO BEACH

PROPERTY DESCRIPTION

LOT 4873 ON S78/107

TOTAL AREA 81.33 ha

OVERALL PROPOSAL PLAN

LEE POINT ROAD, LEE POINT, DARWIN

DEFENCE HOUSING AUSTRALIA



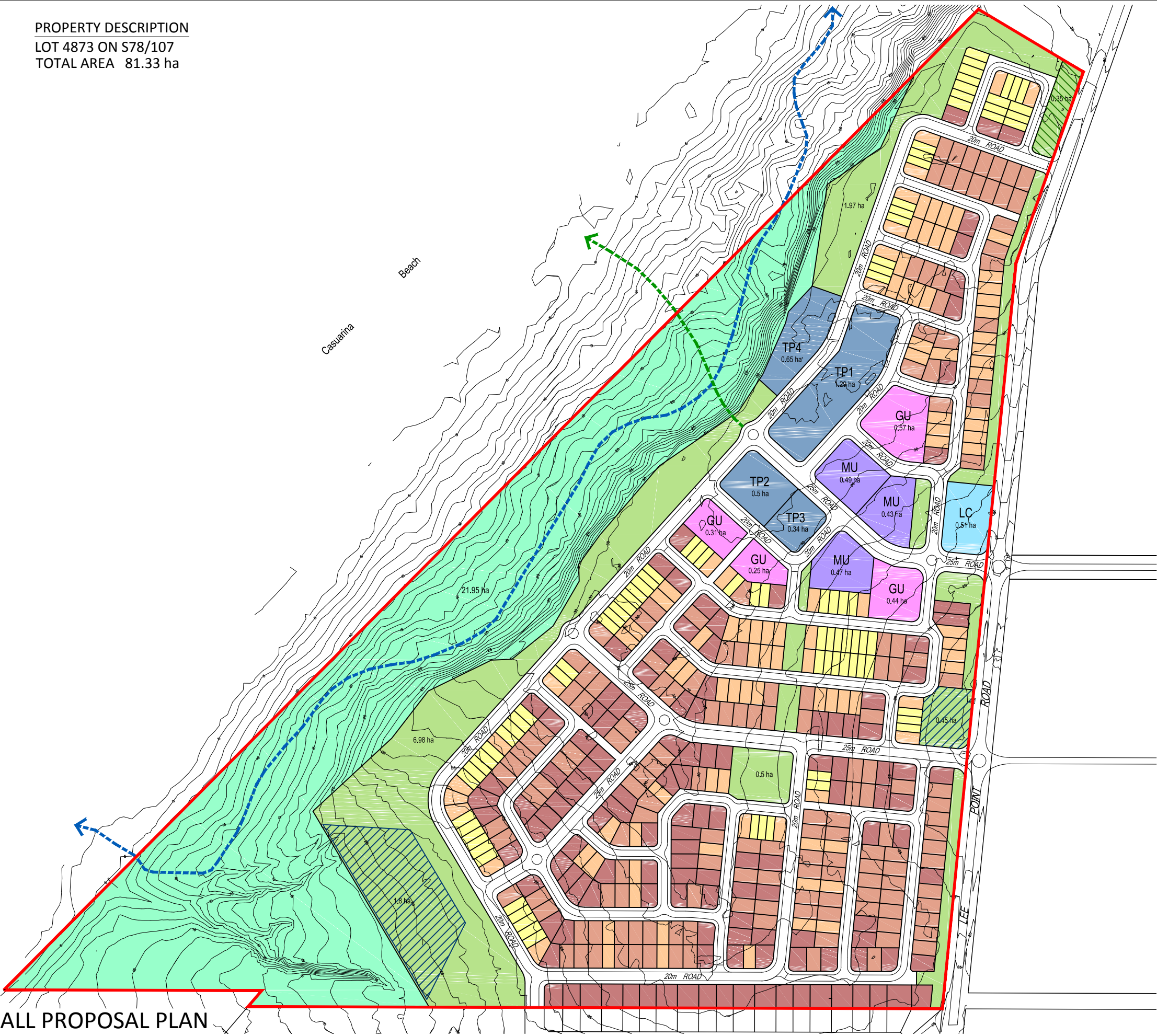
PLANNERS

URBAN DESIGNERS

SURVEYORS

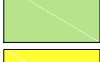
ENGINEERS

LANDSCAPE ARCHITECTS



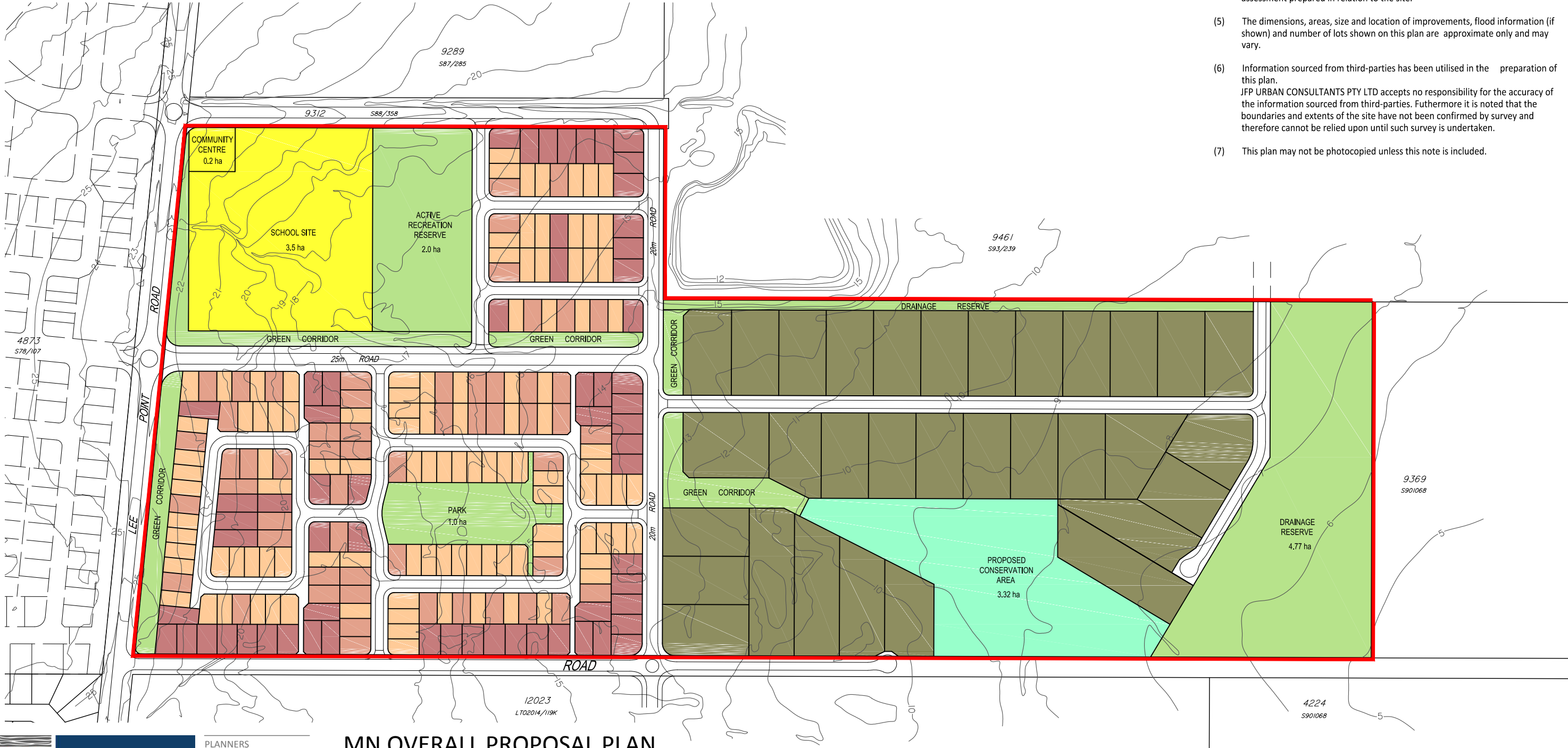
PROPERTY DESCRIPTION
LOT 9370 ON S901068
TOTAL AREA 51.17 ha

LEGEND

	SUBJECT SITE
	LOTS 4000m² & larger (45m frontage min.) - 32 (12%)
	LOTS 600-700m² (20m x 30-31m) - 62 (24%)
	LOTS 540-599m² (18-19m x 30-31m) - 56 (22%)
	LOTS 450-539m² (15-17m x 30-31m) - 110 (42%)
	PARK/OPEN SPACE
	COMMUNITY USES

NOTES

- (1) This plan was prepared for the purpose and exclusive use of DEFENCE HOUSING AUSTRALIA as an Investigation into the Development Potential of the land described in the plan and is not to be used for any other purpose or by any other person or corporation.
JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this plan in contravention to the terms of this clause or clauses 2, 3, 4, 5, 6 or 7 hereof.
- (2) The contours on this plan are approximate and are suitable only for the purpose of this application. The accuracy of the contours has not been verified and no reliance should be placed upon such contours for any purpose other than for the purpose of this application.
- (3) JFP takes no responsibility for any changes to the design concept that may arise as a consequence of the detailed vegetation assessment undertaken in the future. To increase certainty JFP recommends the appointment of suitable vegetation professionals to complete the vegetation assessment as soon as practical.
- (4) This plan shall be read in conjunction with the JFP preliminary planning assessment prepared in relation to the site.
- (5) The dimensions, areas, size and location of improvements, flood information (if shown) and number of lots shown on this plan are approximate only and may vary.
- (6) Information sourced from third-parties has been utilised in the preparation of this plan.
JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for the accuracy of the information sourced from third-parties. Furthermore it is noted that the boundaries and extents of the site have not been confirmed by survey and therefore cannot be relied upon until such survey is undertaken.
- (7) This plan may not be photocopied unless this note is included.





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PLANNERS
URBAN DESIGNERS
SURVEYORS
ENGINEERS
LANDSCAPE ARCHITECTS

MN OVERALL PROPOSAL PLAN

544 LEE POINT ROAD, LEE POINT, DARWIN

DEFENCE HOUSING AUSTRALIA

JOB NUMBER: M2737P MN_Overall Proposal A

SCALE: 1:4000 @ A3

DATE: 29th September 2017

ISSUE: NORTH: A





LEGEND

- SUBJECT SITE
- PROPOSED STAGING BOUNDARY
- COMMUNITY USE - SCHOOL SITE
- COMMUNITY USE - COMMUNITY CENTRE
- OPEN SPACE
- ENCUMBERED OPEN SPACE
- PROPOSED CONSERVATION AREA
- MOUNTAIN BIKE TRAIL (INDICATIVE LOCATION)
- PARKING (WITHIN BASEMENT)
- PARKING (WITHIN CARCOURT)

DWELLING YIELD SUMMARY TABLE			
LOT YIELD	TOTAL AREA (Ha)	NO. LOTS	AVERAGE LOT SIZE (m2)
Standard Residential Lots	35.30	704	494
Rural Lots	14.19	32	4305
STANDARD LOT TYPES	TOTAL AREA (m2)	NO. LOTS	% (TOTAL STANDARD RES. LOTS)
240 - 360 m2 (Medium Density)	30,000	100	14%
360 - 450 m2 (Small Lot)	63,990	158	22%
450 - 550 m2 (Medium Lot)	85,000	170	24%
550 - 650 m2 (Large Lot)	114,600	191	27%
650 - 750 m2 (Duplex)	59,500	85	12%
TOTAL STANDARD LOTS	353,090	704	100%
SPECIAL SITES - APARTMENTS	SITE AREA (m2)	DWELLINGS	TYPE
TOURISM PRECINCT - ACCOMMODATION	2.70	300	
TP1 - Height Limit 12 Storeys	1.12	180	Hotel/ serviced apartments
TP2 - Height Limit 12 Storeys	0.51	80	Hotel/ serviced apartments
TP3 - Height Limit 8 Storeys	0.42	40	Hotel/ serviced apartments
TP4 - No Residential Included	0.65	0	
MIXED USE - HEIGHT LIMIT 4 STOREYS	1.00	60	Private apartments
GENERAL URBAN - HEIGHT LIMIT 3 STOREYS	3.00	160	Private apartments
TOTAL APARTMENTS		520	

3 RISK ASSESSMENT

3.1 Introduction

A comprehensive risk assessment of all potential project impacts has been undertaken in accordance with Australian and New Zealand Risk Management Standard AS/NZS ISO 3100:2009. The risk assessment provides a systematic process to quantify the severity of impact to the environment, community and local infrastructure the project is likely to cause, and identifies which project activities will require management controls or avoidance measures to ensure that any impact does not exceed regulatory thresholds and meets the public's expectations (where possible). The risk assessment was undertaken in the following manner:

1. Identify the risks to the environment
2. Identify the likely causes for risks to occur
3. Establish likelihood and consequence descriptors
4. Establish outcome descriptors
5. Quantify risk
6. Determine appropriate controls to reduce risk level to an acceptable level.

3.2 Method

The risk assessment was completed by specialist consultants responsible for preparing the detailed technical reports (Appendix B). After determining the potential risks to the environment, and what factors contribute to the risk, the risk level was quantified by determining the outcome, where outcome is calculated as:

$$\text{Outcome} = \text{Likelihood} \times \text{Consequence}$$

The tables below provide descriptions for the different levels of likelihood, consequence and outcome.

A description of the project activities that may contribute to impacts and were considered during the risk assessment is provided in Table 7.

3.3 Results

The detailed results of the risk assessment, including the recommended mitigation and avoidance measures are provided in Appendix C, and further explained in each relevant technical chapter of the EIS. A total of 98 risks were identified that have been assigned a management control.

Table 4. Consequence rating descriptors

Consequence	Hydrology	Air Quality	Utilities and Infrastructure	Biodiversity	Heritage	Social	Noise
Minimal	Negligible effect to the environment	Impacts to air quality below detectable levels.	No discernible impact on quality of service.	Small scale native vegetation or habitat loss.	Low-level repairable damage to commonplace structures.	Some people indirectly impacted.	Noise can barely be detected.
Minor	Minor effect, complaint from adjacent neighbours or community. Temporary impact on subterranean conditions, aquifer or Sandy Creek without long-lasting effects. Temporary disruption to water supply or effect on water quality.	Impact on local air quality is within allowable limits, no discernible impacts on health.	Available services cannot meet the need of local residents.	Small to medium scale native vegetation/habitat loss. Fragmentation of habitat for native species.	Minor damage to items of low cultural heritage significance. Mostly repairable. Minor infringement of cultural heritage values.	Some people directly impacted or several indirectly.	Noise detected, low-level of nuisance
Moderate	Localised impact, local media coverage, may trigger regulators involvement. Short term impact on sensitive environmental features, aquifer resource or Sandy Creek.	Temporary impact on local air quality exceeds allowable limit,, impact on respiratory health, loss of native vegetation.	Additional demand results in decline in service quality for wider community.	Potential significant impact on special/ecological communities, medium to large scale native vegetation loss/habitat fragment for native species.	Substantial damage to items of moderate cultural or heritage significance. Infringement of cultural heritage/sacred locations.	Several people directly impacted or many indirectly.	Temporary sleep disturbance, potential hearing injury, complaints from adjoining residents..
Major	Major impact, national media coverage, would	Damage to respiratory health	Additional demand results in health impacts for residents and wider	Significant impact on species/ecological communities	Major permanent damage to	Large number of people	Temporary hearing loss, ongoing sleep

Consequence	Hydrology	Air Quality	Utilities and Infrastructure	Biodiversity	Heritage	Social	Noise
	trigger regulators involvement.	requiring specialist medical treatment, local-regional media coverage, significant remediation works required.	community. Local/regional media attention.		items of high cultural or heritage significance. Significant infringement and disregard of cultural heritage values.	directly impacted.	disturbance, damage to buildings and structures, local/regional media attention.
Catastrophic	Extensive off-site contamination and changes to level of groundwater, or quality of Sandy Creek. Sustained damage to the environment/human health and remediation not possible. National to international media coverage, regulators involved.	Permanent damage to respiratory health, national media coverage, irrevocable damage to regional air quality.	Additional demand results in deaths in local community. National media attention.	Extinction of species/ecological communities	Total destruction of items of high cultural or heritage significance. Highly offensive infringements of cultural heritage.	Loss of life.	Permanent hearing loss, damage to buildings. National media attention.

Table 5. Likelihood rating descriptors.

Likelihood	Description	Probability	Community attitude
Remote	May occur in exceptional circumstances	<1%	Few people interested
Unlikely	Not expected to occur in most circumstances	1-20%	Some people affected
Possible	May occur	21-49%	Many people affected
Likely	Probability will occur	50-85%	Most people affected
Almost Certain	Expected to occur	>85%	Almost everyone affected

Table 6. Environmental outcome descriptors

LIKELIHOOD	OUTCOME					
		MINIMAL	MINOR	MODERATE	MAJOR	CATASTROPHIC
	REMOTE	Negligible	Negligible	Very low	Low	Medium
	UNLIKELY	Negligible	Very low	Low	Medium	High
	POSSIBLE	Very low	Low	Medium	High	Very high
	LIKELY	Low	Medium	High	Very high	Significant
	ALMOST CERTAIN	Medium	High	Very high	Significant	Significant

Table 7. Project activities considered as part of the risk assessment

Biodiversity	Heritage	Hydrology	Noise and Air Quality	Social and Economic	Utilities
Habitat loss	Ground excavation	Surface water quality	Traffic (operation)	Housing and accommodation	Potable water
Habitat fragmentation	Site occupation	Surface water flow rates	Plant (construction)	Workforce	Sewerage
Habitat degradation		Erosion	House lighting	Social Infrastructure	Traffic
Edge effects		Flooding	Acid sulphate soils	Amenity and Safety	Telecommunications
Altered hydrology		Groundwater depth	Chemical spills	Economic/Business Development	Power
Water quality		Groundwater contamination	Odour (Leanyer Sanderson Wastewater Treatment Plan)		
Erosion and sedimentation		Acid sulphate soils			
Soil compaction		Litter, rubbish entering creeks and eventually Bay.			
Inappropriate/ineffective rehabilitation					
Groundwater contamination					
Impacts on surface and groundwater systems					
Waste material					
Traffic (construction)					
Traffic (occupancy)					
Weeds and pest animal invasion					

Biodiversity	Heritage	Hydrology	Noise and Air Quality	Social and Economic	Utilities
Dust					
Noise					
Human disturbance					
Domestic pets					

4 HYDROLOGY

4.1 Introduction

This chapter addresses the hydrological criteria of the ToR. Information has been collected from a number of sources including desktop review, field assessments and modelling. The chapter is presented in the following structure:

- Section 4.2 – Existing Conditions. This section focusses on the pre-development condition of the project site and adjoining water bodies. Details are provided of the current condition of groundwater and surface water including description of any dependent ecosystems. Information on the likelihood of flooding is also provided.
- Section 4.3 – Risk Assessment. Identifies the key risks to surface water and groundwater based on the detailed hydrological risk assessment (Appendix C) and describes the avoidance and mitigation measures that are proposed to reduce the risk of any impacts occurring to water values including off site at Sandy Creek and Buffalo where stormwater from the detention basin will be discharged. The mitigation measures are included in the Stormwater Management Plans (Appendix E and Appendix F), Erosion and Sediment Control Plan (ESCP), Water Quality Monitoring Plan (Appendix O) and CEMP (Appendix D).

4.2 Existing Conditions

4.2.1 Geology

According to the Darwin 1:250 000 Geological Series map, the project site is underlain by late cretaceous kaolinitic claystone and Tertiary pisolitic and mottled laterite (Figure 7). Quaternary alluvium, when found in drainage line and lower elevations are sand, silt and clay.

A review of the Northern Territory bore database identified a number of bores in the neighbourhood. The stratigraphy information associated with the bore records supported the understanding of the regional hydrostratigraphy.

The regional hydrogeology is defined by an upper lateritic clay formation of up to 40 m depth which has the potential to be water bearing. It is underlain by consolidated fine alluvium formations, reportedly shales, siltstones, slate or conglomerates.

Groundwater was encountered regionally in some of the consolidated formation, however, bore yields have reportedly been limited. A few bores in the database and the newly drilled bores at the site reported shallow groundwater in the laterite.

Previous site geotechnical studies reported the absence of groundwater in nearby bores. This is inconsistent with the records, however, the observations could simply be associated to the slow recovery of newly built bores (i.e. not yielding water quick enough to observe on the day) or the need for redevelopment of older bores.

Testing for acid sulphate soils has not been undertaken. Despite the proximity of the project site to the coastline, the elevation of the site is likely to preclude the presence of acid sulphate soils (GHD 2010). If present, acid sulphate soils are most likely to occur in the lowest elevations of the site, which occurs in the south-east of Muirhead North. It should be noted that no acid sulphate soils were encountered in the adjoining Muirhead Breezes development. Nonetheless, test pits will be dug in the south-east of Muirhead North prior to any soil disturbance occurring as part of Stage 2B, to determine the presence of acid sulphate soils. If acid sulphate soils are encountered than an acid sulphate soils management plan will need to be prepared.

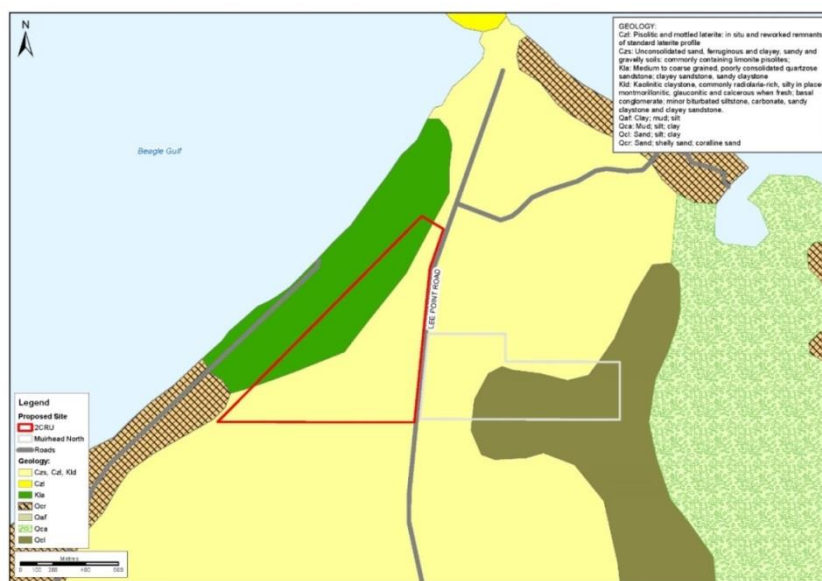


Figure 7. Site geology

4.2.2 Project Site

4.2.2.1 Groundwater

Site geology is informed by borehole information collected during previous investigations (Douglas Partner 2009, SMEC 2015) and in the recent investigation. The geotechnical investigations over the Muirhead North and 2CRU sites documented the site geology to a maximum depth of three metres. The spread of the boreholes provides a relatively good site cover. The geological settings are consistent across 2CRU and Muirhead North. On the Muirhead North site, a recent investigation focused on the area up-gradient of the Monsoon Rainforest and investigated the site geology to depth of 12 metres, which contributed to the assessment of this site by providing a reference depth to groundwater for the area.

The project site geology can be summarised as follow:

- An upper sand and silt unconsolidated formation of brown, yellow or red colour observed up to 4.5 m depth, but more generally to 2-3 m depth. Small gravels of ferricrete (locally referred to as coffee rock) or layers of ferricrete can be found in the first couple of metres. At the site, their distribution appears to be quite discontinuous.
- An underlying clay formation, forming the upper part of the laterite profile. The clay can be silty at times, mottled, with gravels or “coffee rock” gravels. The clay is not cohesive and shows heavy staining between small pieces. The colour of the clay is predominantly brown and white but was also found to be red and grey in places. The thickness of the clay in the closest bore (RN22618) was reported to reach 33 metres.
- Underlying siltstones and shales.

The aquifer of interest is associated with the laterite profile. The finding is consistent with the heavy staining observed through the mottled clay during drilling and the signs of hydro-chemical processes associated with the presence of groundwater. Based on the nature of the formation and the slow recovery of the wells during development and testing, the laterite aquifer would be associated with low yields. A deeper aquifer has been reported within the fractured consolidated rock formation in some of the bores drilled in the area. Again here, yields were rather low.

The aquifer is expected to respond to rainfall events, especially those of the wet season. The water table level can be expected to increase a few metres after recharge (Foo, 2004, Foo1987, Vanden Broek 1980). Groundwater is expected to be discharged through evaporation and through direct discharge at Sandy Creek (western section of 2CRU), and Buffalo Creek (Muirhead North and eastern section of 2CRU). Discharge is expected to be greater in the first part of the dry season due to higher water table levels and thus, stronger hydraulic gradients.

In terms of discharge through groundwater usage, the supply bores located in close vicinity of the site have either been decommissioned or are abandoned.

The Bureau of Meteorology (BOM) Groundwater Dependent Ecosystems (GDE) Atlas was accessed to inform the potential presence of GDEs within the project site. Parts of the western and southern sections of 2CRU as well as large portions of the adjoining Casuarina Coastal Reserve, are identified as having a moderate potential

to support GDEs reliant on subsurface expression of groundwater (Figure 8) which is broadly consistent with the extent of high ecological value Monsoon Vine-thicket identified by EcOZ (2014) who postulated that the community may be groundwater dependent. Sandy Creek, located west of 2CRU site is not classified as a GDE. Most of Muirhead North is mapped as having a potential to sustain GDEs. The potential for groundwater interaction is variable over the site, with a low potential on the western part of the site corresponding with the most elevated part of the site, a medium potential for groundwater dependent ecosystems in the north-east section and a high potential in the south east corner of the site (Figure 8). The mapping of potential GDEs does not match well with the location of the Monsoon Rainforest patch however it highlights the potential for groundwater dependency of vegetation in the lower slopes of the site, which were mapped by EcOz (2014) as supporting *Lophostemon* and *Pandanus* Open Woodland.

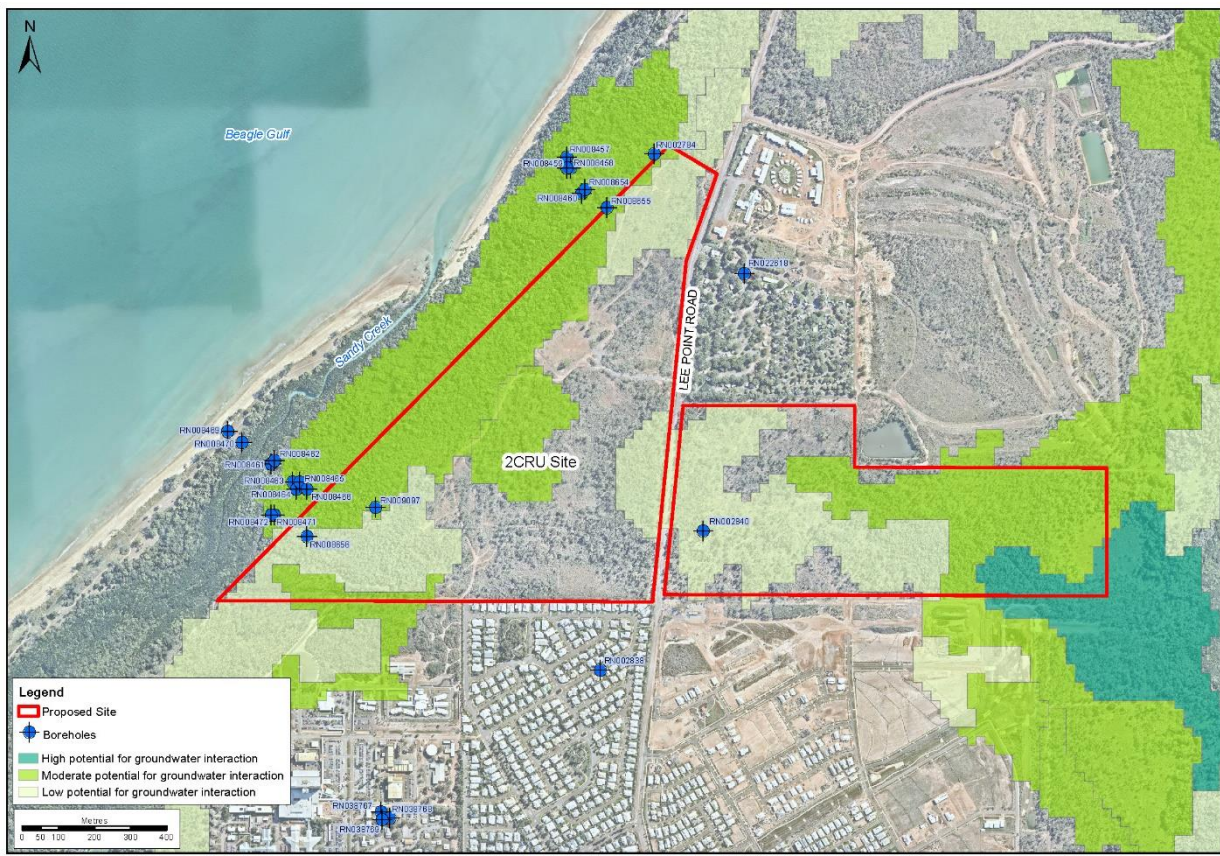


Figure 8. Bureau of Meteorology GDE Atlas and borehole locations

The characteristics of the groundwater system are provided in the below groundwater conceptual model (Table 8) and illustrated in Figure 9.

All the elements of the groundwater system were assembled together in a hydrogeological conceptual model. A hydrogeological conceptual model is a representation of a groundwater system in words, figures and/or maps. The hydrogeological conceptual model is then used as a key tool for the assessment of the risk to

groundwater from the project and, if necessary, the development of suitable management and mitigation measures where an impact or potential impact associated with the project has been identified.

Consistent with the data and information available, a simplified conceptual hydrogeological model was prepared. The hydrogeological conceptual model describes the following:

- The aquifer(s) and aquitard(s) of the study area
- The groundwater flow (depth to water and flow direction)
- The groundwater recharge and discharge process, and connectivity between water bodies
- The groundwater environmental values.

Table 8 – Groundwater Conceptual Model – 2CRU

Element of the conceptual model	Characteristics
Hydrostratigraphy (aquifers & aquitards)	The aquifer of concern is the water table aquifer found in the upper part of the lateritic profile. The laterite clays are some 30 m deep and are underlain by shales and siltstones formations. Some of those consolidated formations support minor aquifers.
Water table	The water table can be expected to be found in excess of seven metres depth at the end of the dry season over the elevated section of the site. The water table is expected to rise significantly during the wet season. No data is available at this stage to characterise the seasonal variability. The water table aquifer is separated from underlying aquifers through the presence of aquitard formations. Deeper aquifers are not of interest to this assessment as they do not interfere with environmental values due to depth from surface.
Groundwater quality	A review of site activities and site contamination was performed by GHD (2014). The report indicates there is no gross contamination of soils or groundwater. The site has been unoccupied since this assessment and the situation would have remained unchanged since.
Groundwater use	Bores located in close vicinity of the site have either been decommissioned or are abandoned.
Groundwater values	The monsoon vine thicket area located on the western slope was identified in previous studies as likely to be groundwater dependent. This is most likely in the lower half of the slope. The GDE would be supported by the water table aquifer, accessed by the plants through their root systems. The GDE is not a Matter of National and Environmental Significance Due to low yield, groundwater bore usage is not a groundwater value in the area of the proposed development. There are no groundwater values of national environmental significance in the project site.
Groundwater flow direction	Groundwater flow is inferred to mirror the topography. On the project site, the topographical high will act as a groundwater divide, with groundwater flow to the west being inferred towards the coastal plains and groundwater flows to the east of the divide being directed to the Muirhead North site.
Groundwater recharge	The site area is recharged directly through rainfall infiltration. The upper unconsolidated silty formation is highly permeable and will transmit groundwater flows to the underlying weathered laterite.
Groundwater discharge	Groundwater is expected to discharge through seepage at the foothill of the hill. The water table at the end of the dry season appears to be fairly flat resulting in reduced discharge towards the coastal plain. Following recharge, a higher groundwater gradient will result in added flow, however, due to the nature of the laterite, the flow is expected to remain small.

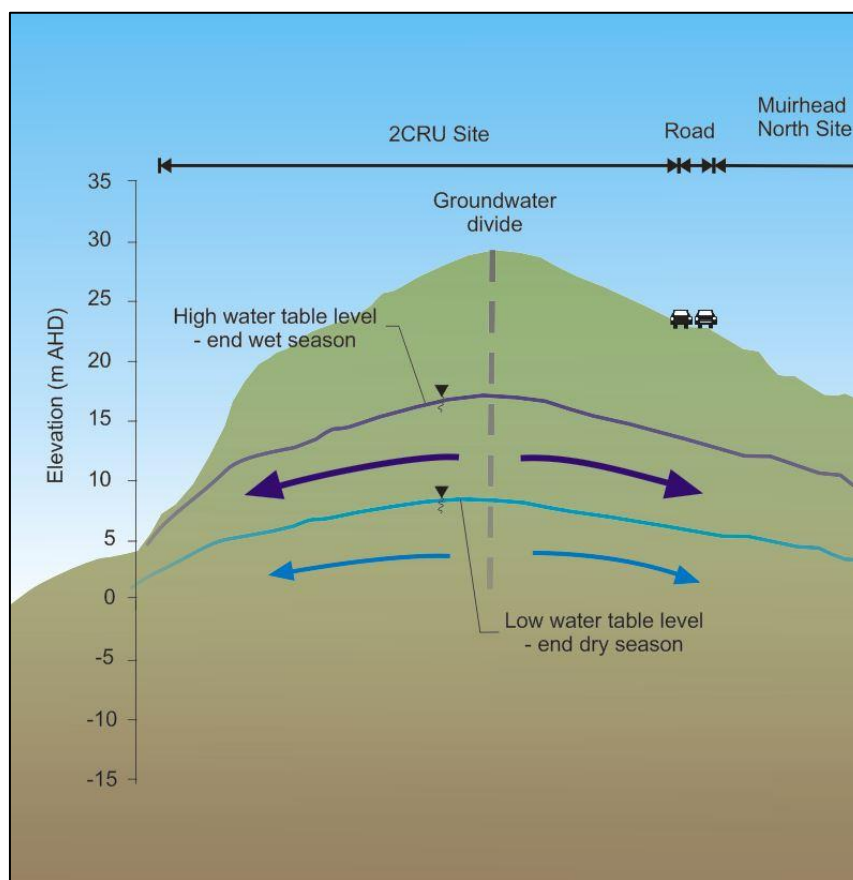


Figure 9. Groundwater Model Cross Section

Table 9. Groundwater Conceptual Model - Muirhead North

Element of the conceptual model	Characteristics
Hydrostratigraphy (aquifers & aquitards)	The aquifer of interest is the water table aquifer found in the upper part of the lateritic profile. Deep aquifers are not of interest to this assessment as they do not interfere with environmental values due to depth from surface. The laterite clays are some 30 m deep and are underlain by shales and siltstones formations. Some of those consolidated formations support minor aquifers. The water table aquifer is separated from underlying aquifers through the lower part of the laterite profile which acts as an aquitard and the presence of aquitard formations further at depth.
Water table	Depth to the water table has been measured at the end of the dry season and found to be 5 to 7 m below ground directly upgradient of the rainforest patch. The water table is expected to be very close to ground level in the eastern part of the site corresponding with the lower part of the rainforest and low lying area.
Groundwater quality	No groundwater contamination is known on site.
Groundwater use	There are no remaining groundwater users in the vicinity of the site.
Groundwater values	A patch of monsoon rainforest has been identified in the eastern part of the site along the drainage line. In its lower reaches, it is expected to be groundwater dependent. The GDE would be supported by the water table aquifer during the dry season. During the wet season water ponding in the rainforest would be the primary source of water supply. The GDE is not Matter of National and Environmental Significance

Element of the conceptual model	Characteristics
	Due to low yield, groundwater bore usage is not a groundwater value in the area of the proposed development. Buffalo Creek is another sensitive value. Due to low yield, groundwater bore usage is not a groundwater value in the area of the proposed development.
Groundwater flow direction	Groundwater flow is inferred to mirror the topography, i.e. a general eastwards direction.
Groundwater recharge	The site area is recharged directly through rainfall infiltration. The upper unconsolidated silty formation is highly permeable and will transmit groundwater flows to the underlying weathered laterite. Higher recharge is expected in the rainforest area during the wet season when water ponding is observed.
Groundwater discharge	Groundwater discharges through seepage at the foothill as observed in the area between the eastern site boundary and the rainforest patch. The water table at the end of the dry season appears to be fairly flat resulting in reduced discharge towards the Buffalo Creek. Following recharge, a higher groundwater gradient will result in added flow.

4.2.2.2 Surface water

2CRU

The 2CRU site is currently unoccupied but previously was used for a Royal Australian Air Force transmission facility situated in the northern half of the site. This facility previously included buildings, sealed roads and car parking together with cleared unsealed areas. The buildings and car parking areas have since been removed with only some sealed roads remaining. A number of unsealed tracks also traverse the site. The vegetation on the project site is predominantly casuarina forest and open woodland with densities increasing along the western boundary where the land drops off sharply towards Sandy Creek and Beagle Gulf. .

Topography across the site ranges from approximately 33 m (Australian Height Datum 'AHD'), at the highest point of the ridge which traverses the middle of the site in a roughly south to north alignment, down to the lowest point of 4.5 m AHD in the south west corner. The lowest point along the Lee Point Road eastern frontage is approximately 22.5 m AHD located 200 m to the south of the Lee Point Village Resort southern boundary. Gradients across the site are generally less than 3%, although there are steep slopes along the western boundary and within the south western corner where runoff from the local site catchment conveys flows to Sandy Creek.

While the majority of surface runoff across the site is conveyed as relatively shallow sheetflow and surface flow, there are some minor gullies where surface runoff is concentrated in defined gullies and excavated drains. These include natural gullies within the south west corner and also open drains located along the former sealed road entrance to the former RAAF facility. The drain along the former RAAF facility entry road conveys flows to Lee Point Road via twin box culverts and a lined opened drain.



Figure 10. Entry road to 2CRU

Flows are conveyed across Lee Point Road via 2 x 1200W x 450H RCBCs into an unlined drain that runs along the Lee Point VillagevResort southern boundary before discharging into a large rural dam. A second culvert crossing of Lee Point Road is located 115m further south and consists of 5 x 750 RCPs that conveys flows collected within the road side drain to the east. The second culvert crossing is shown in the figure below.



Figure 11. Culvert cross of Lee Point Road 115m south of the Lee Point Resort (Nearmap 2016).

The local catchment conveying flows to the south west corner via local gullies discharges into Sandy Creek which runs parallel to the coast in a north-easterly direction before joining the Beagle Gulf. There is also a relative small catchment in the northwest corner of the site which conveys local runoff via the Casuarina Coastal Reserve and beach frontage to Beagle Gulf. It appears that this flow is conveyed as relatively shallow sheet flow down the escarpment.

There are no identifiable external catchments contributing to flows across the site with the Royal Darwin Hospital and Lyons Estate adjacent to the southern boundary effectively forming a catchment divide with flows from the site being conveyed via open drains along this boundary to both Sandy Creek and Lee Point Road.

Muirhead North

The site is currently undeveloped, predominately consisting of casuarina forest and open woodland. An environmentally significant rainforest area exists within the centre of the site. A number of unsealed tracks traverse the site, and a rural dam exists immediately to the north.

Topography across the site ranges from approximately 5 to 25 m AHD, generally grading from west to east before discharging into Buffalo Creek. Surface runoff from the site is relatively shallow, and is mainly conveyed via sheet flow and surface flow, in some areas runoff is concentrated in defined gullies. These include naturally occurring gullies within the centre of the site.

A proportion of the 2CRU catchment drains through the subject site, via 3 culverts as can be seen in Appendix F – Figure 2.

4.2.2.3 Flooding

Notwithstanding inundation across the project site from local catchment runoff resulting in shallow sheet flow and concentrated gully flows, other potential sources of inundation could occur due to storm tide inundation given the proximity of the site to Beagle Gulf.

Reference to the *'High Resolution Storm Tide and Climate Change Impacts Study – 2010'* prepared by System Engineering Australia for the Northern Territory Department of Lands and Planning identifies the following storm tide levels for Lee Point detailed in Table 10.

Table 10. Total Storm Tide Level (m AHD) at Lee Point

Year	Estimated Return Period of Total Storm Tide Level				
	50y	100y	500y	1000y	10000y
2010	4.5	4.7	5.2	5.4	5.8
2050	4.9	5.1	5.6	5.8	7.1
2100	5.4	5.6	6.1	6.5	7.4

The above levels for 2100 have been mapped by GHD in 2014 based on the latest topographic information (2009 and 2011) as part of the Northern Territory Storm Surge Mapping with the area containing the site extracted below in Figure 12. The storm surge mapping shows that the entire site is above the 100 year

Average Recurrence Interval (ARI) storm tide level for 2100, except for a small area in the south-west corner of 2CRU and south-east corner of Muirhead North.

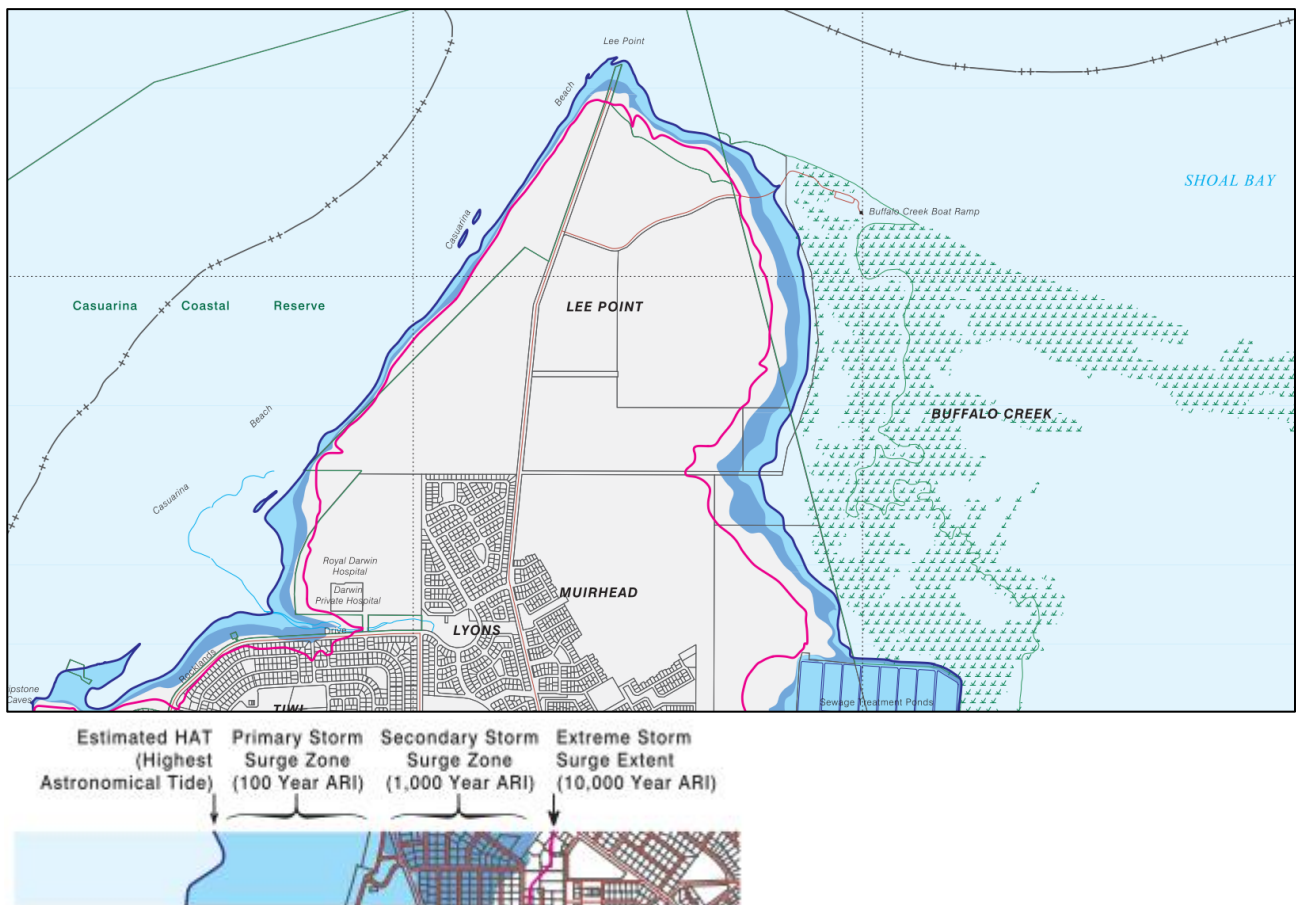


Figure 12. Darwin Area Storm Surge Inundation for 2100 (Copyright: Northern Territory Government, GHD and SEA)

4.2.3 Casuarina Coastal Reserve

The Casuarina Coastal Reserve comprises 1,361 ha and includes a strip of 8 km of coastline to the west of Lee Point (Figure 13). The Reserve includes extensive sandy beaches, tidal flats, estuaries, dune systems, mangrove communities, Casuarina forests, fringing monsoon forest and an offshore marine area. As noted in the Management Plan, “*The hydrological resources of a park are a critical element of the park’s ecosystems and the maintenance of their integrity is crucial*” (Parks and Wildlife Commission of the Northern Territory, 2002).

Large portions of the reserve are identified by the Australian Groundwater Dependent Atlas as having a moderate potential to support GDEs reliant on subsurface expression of groundwater. The mapping of GDEs across the reserve is broadly consistent with the extent of high ecological value Monsoon Vine-thicket.

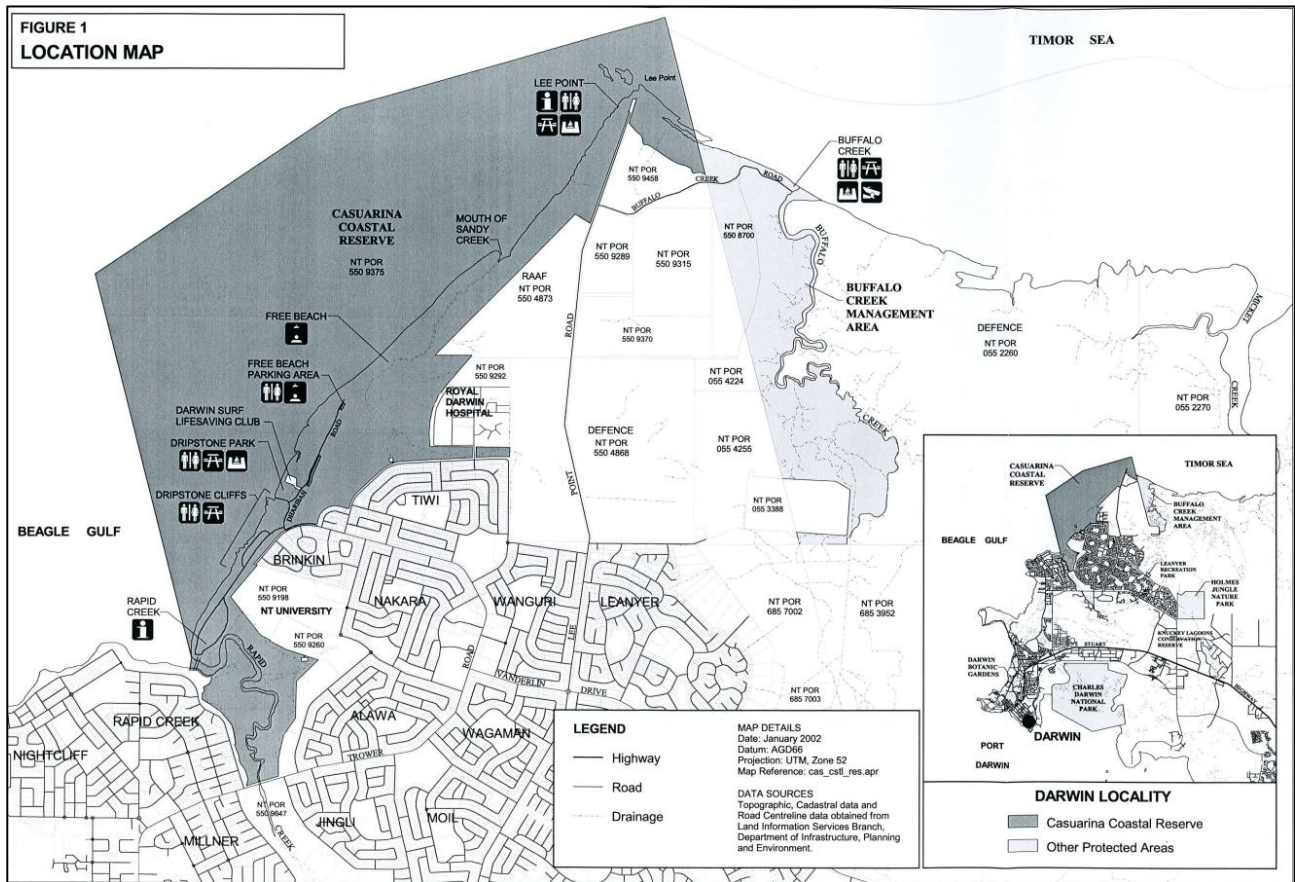


Figure 13, Casuarina Coastal Reserve (Casuarina Coastal Reserve Management Plan: Parks and Wildlife Commission of the Northern Territory 2002).

4.2.4 Sandy Creek

Sandy Creek is a sensitive ecosystem containing some mangroves, rainforest and dense vegetation and forms part of the Casuarina Coastal Reserve described above. The Sandy Creek catchment area includes the urbanised areas of Muirhead (South), Tiwi, Lyon and the Royal Darwin Hospital precinct. The western portion of the project site discharges to the Sandy Creek catchment at the south-west corner of the 2CRU site where the creek continues in a northerly direction for approximately 1 km parallel to Casuarina Beach before discharging into the sea.

The Northern Territory Government does not collect any water quality data on Sandy Creek. Upstream, the creek receives discharge from Royal Darwin Hospital, urban areas and roads. It is assumed that the water quality is similar to the ANZECC parameters for a slightly-moderately disturbed waterway in tropical Australia.

4.2.5 Buffalo Creek

The Buffalo Creek catchment flows into Shoal Bay to the north-east of Muirhead North. It is understood to be the most polluted tributary discharging into Darwin Harbour. This is due to the following present and past land-uses within the catchment:

- The Leanyer-Sanderson Sewerage Treatment Plant that discharges treated sewage directly into Buffalo Creek
- Discharge of untreated urban stormwater from existing urban development
- Construction activities
- Existing and historic landfills
- Recreational activities
- A historic quarry mine.

The latest 2016 report card for Darwin Harbour which includes monitoring of Buffalo Creek and Shoal Bay is shown below:

Indicator	Harbour region								
	Outer Harbour			Inner Harbour				Tidal creeks	
	Outer Darwin Harbour	Shoal Bay	Middle Darwin Harbour	Blackmore	East Arm	Elizabeth	West Arm	Buffalo Creek	Myrmidon Creek
Water clarity	✓	✓	✓	✓	✓	✓	✓	✗	✓
Dissolved oxygen	✓	✓	✓	✓	✓	✓	✓	✗	✓
Algae	✓	✓	✓	✓	✓	✓	✓	✗	✓
Nutrients	✗	✗	✓	✓	✓	✓	✓	✗	✗
Report Card grades									
2016	B	B	A	A	A	A	A	E	B
2015	B	A	B	B	B	B	B	E	B

Figure 14. Darwin Harbour Region Report Card 2016

Treated sewerage from Leanyer Sanderson Wastewater Treatment Plant is discharged into Buffalo Creek in accordance with Water Discharge Licence WDL 147-08. In accordance with licence condition 18, Power and Water Corporation are responsible for ensuring that discharges must not:

- Contain any visible matter, floating oil and grease or petroleum hydrocarbon sheen or scum, or litter or other objectionable matter;
- Cause or generate odours which would adversely affect the use of surrounding waters;
- Cause visible change in the behaviour of fish or other aquatic organisms;
- Cause mortality of fish or other aquatic organisms; or,
- Cause adverse impacts on plants.

In accordance with the WDL, Power and Water Corporation are required to undertake period monitoring and report of water quality of Buffalo Creek. The last annual audit and compliance report available for Leanyer Sanderson Wastewater Treatment Plant is from December 2014 and relates to WDL 147-05. Condition 8 of the report addresses the following requirement *‘the licensee must, without limiting any other condition of this Licence in conducting the Activity do all things reasonable and practicable to ensure the Activity does not adversely affect the Declared Beneficial Uses and Objectives as declared from time to time...’*. Power and Water Corporation provided the following response:

‘PWC does all things reasonable and practical to protect BUs (Beneficial Uses) within the constraints of the existing WSP technology and for discharge in this location i.e. poorly flushed estuary (legacy issues over 40 years). The WwTP performs well in reduction of loads and prevention of direct faecal contamination. PWC periodically undertakes necessary operational changes to ensure the optimum capacity and functioning of the WSPs. Major operational changes such as desludging of ponds are accompanied by tasks specific ERAs prior to commencement to prevent environmental harm...Buffalo Creek is considered a highly disturbed aquatic ecosystem and likely to remain in this state without significant infrastructure investment that will require government/public consultation’.

There are no other publicly available monitoring reports related to WDL 147. Power and Water Corporation have also not provided any additional monitoring reports or other information on the condition of Buffalo Creek to DHA.

4.3 Risk Assessment

4.3.1 Risk assessment summary

A summary of the risk assessment findings of the potential impacts the project will have on hydrological values is provided below in Table 11. The summary includes those impacts which are considered to be of High or Medium risk and necessitates mitigation measures to reduce the risk to an acceptable level. The full results of the risk assessment are provided in Appendix C. The risk assessment was completed in accordance with the methods described in Section 3.

Further information on the nature of the potential impacts and the type of mitigation measures proposed is provided below in Section 4.3.2.

The potential for further decline in the health of Buffalo Creek as a result of increased effluent discharge is low. Please see Section 6.3.1.1 for further information.

Table 11. Summary of risk assessment

Impact	Description	Mitigation measures
Surface water quality	The development of the site has the potential to impact on the water quality of the downstream receiving waters. Typical pollutants generated from development of the site include an increase in nutrient loads, sediments, gross pollutants and heavy metals and hydrocarbons for commercial/industrial land uses.	To mitigate the impacts of the development on discharged water quality it is proposed to incorporate Water Sensitive Urban Design (WSUD) principles and a stormwater treatment strategy that includes the use of bioretention basins, and vegetated swales/buffers for treatment. For more intense land-uses or areas that have limited space for treatment there is the potential to use proprietary treatment devices. Water Quality Monitoring will be undertaken to ensure the project does not impact Sandy Creek.
Surface water flow rates	The increased impervious areas and drainage network incorporating underground pipes has the potential to increase peak flows discharging from the site into Sandy Creek..	It is proposed to incorporate on-site detention measures in the form of end-of-line detention basins and online detention utilising internal road crossings of drainage channels.
Erosion	Erosion and sedimentation during construction and post-development	Erosion and Sediment Control Plan (ESCP), which will also include rehabilitation of large erosion gullies in the south-west of 2CRU.
Flooding	Notwithstanding inundation across the site from local catchment runoff resulting in shallow sheet flow and concentrated gully channel flows, other potential sources of inundation could occur due to storm tide inundation given the proximity of the site to Beagle Gulf.	The detailed drainage design of the development will incorporate both underground pipes and open channels to convey the site runoff through the development. To mitigate the potential increases in peak flows, on-site detention measures are also proposed. The design levels for the adjacent lots and roads will ensure adequate freeboard and trafficability

Impact	Description	Mitigation measures
		respectively during the applicable design flood events. The majority of the site is above the 100 year Average Recurrence Interval (ARI) storm tide level for 2100.
Litter, rubbish entering creeks and eventually Bay.	The development of the site has the potential to impact on the water quality of the downstream receiving waters. Typical pollutants generated from development of the site include gross pollutants.	The stormwater quality treatment measures proposed include the use of bioretention basins and vegetated swales/buffers. In addition, for more intense land uses, proprietary products including Gross Pollutant Traps (GPTs) are proposed. .
Groundwater quality	Contamination through uncontrolled release during construction works	Preparation & implementation a CEMP which would include special response spill containment and response measures
Groundwater quality	Contamination through sewage leaks/release	Site residences are connected to main sewage network, no septic systems. Design of sewerage system in accordance with City of Darwin and PWC's requirements.
Lower groundwater recharge	Lower groundwater recharge as a result of reduction of natural surfaces over the site potentially affecting GDEs	Reserve area on western side of the development. Retain Monsoon Rainforest patch in Muirhead North. Optimise natural areas throughout the area by the presence of natural reserves, parks and gardens. Water recharge increased through water infiltration at stormwater detention basin.
Acid sulphate soils	Acid sulphate soils have a low-medium potential to occur at the lowest elevations of the project site, that being the south-east corner of Muirhead North.	Complete test drilling in south-east corner of Muirhead North prior to commencing construction. If acid sulphate soils are encountered, prepare an acid sulphate soils management plan.

4.3.2 Description of impacts and mitigation

Mitigation measures proposed for the development include the use of WSUD principles.

The stormwater quality treatment measures to be adopted for the development include the use of bioretention basins and vegetated swales/buffers. High density areas within the development such as the commercial precinct may also incorporate proprietary treatment devices such as the Stormwater360 treatment system.

The impact of the development on stormwater quantity is to be mitigated by on-site by detention measures in the form of end-of-line detention basins and online detention utilising internal road crossings of drainage channels. Suitable scour and erosion protection measures will be incorporated at the outlets to any basins and

at locations where velocities are such that they have the potential to cause significant scour, such as downstream of culvert crossings of roads. These scour protection measures will be in the form of a combination of rock protection, gabions and/or flow spreaders.

The risks to groundwater are considered to be low. Standard spill management procedures will be implemented as part of the CEMP. In the highly unlikely event that pollutants enter the groundwater they could be removed using standard remediation procedures. There is unlikely to be any change in recharge, and as such GDEs should not be affected.

4.3.2.1 Groundwater

Potential impacts from groundwater can be classified in three chronological categories:

- Impacts arising from previous activities, primarily associated with potential contamination
- Impacts to groundwater during construction activities
- Impacts to groundwater arising from residential use of the site.

The risks associated with previous site activities have been assessed (GHD 2014). GHD reviewed the site historical activities and potential contamination and concluded that there was no soil and groundwater contamination at the site.

Risks to groundwater during construction activities are associated with accidental spills and contamination. The contaminant would need to enter the subsurface and then propagate down through the laterite profile to the water table and affect water quality of the aquifer and receiving water bodies.

The risk to groundwater from residential activities lays more with the disposal of sewage than inhabitants' activities themselves.

Impacts to water quality groundwater during construction activities

The site auditors report for 2CRU considered that the risks to groundwater from site activities as low and that no further investigation was necessary (AECOM 2016). However, some uncertainty remains around the quality of groundwater on site and the use of groundwater for beneficial uses should be prohibited until further investigation is undertaken (AECOM 2016).

In the case of uncontrolled spills, the chemical characteristics of the contaminant are most likely to be from the hydrocarbons family and as such can easily be identified from natural groundwater and surface water settings.

It is highly unlikely that an accidental spill would result in an impact on groundwater quality at the site for the following reasons:

- Any construction activity would have to follow the CEMP which would include special response spill containment and response measures.
- The contamination would initially be limited to the soil and upper unsaturated aquifer profile, where remediation by removal of the contaminated soil/rock is very effective.

- Should the regional groundwater be affected, the chemical release is estimated to be quite minor (small source of contamination over a very short period) and through natural attenuation would rapidly become insignificant or undetectable.

For the same reasons, it is highly unlikely that an accidental spill would result in an impact to aquifer water quality.

As a result, there will be no impact to groundwater from construction activities provided suitable spill response and control measures are in place during construction.

Impacts to water quality arising from residential use of the site

The project site is planned to be developed as residential development, commercial development, community facilities and conservation areas. The development will benefit from the connection to main sewer services. As a consequence, there is no risk associated with on-site treatment of sewage.

Impacts to groundwater dependent ecosystems

Impacts to GDEs that potentially occur along the western boundary of 2CRU, and the eastern section of Muirhead North, could be associated with a decrease of supply (i.e. decrease of the level of the water table) due to a reduced area for groundwater recharge. The development proposal will retain the Monsoon Vine-thicket area as part of the Casuarina Coastal Reserve, and the Monsoon Rainforest patch in Muirhead North. The GDE Atlas identifies other vegetation types in the eastern section of Muirhead North, which is likely to be partially cleared as part of the rural allotments. It should be noted that groundwater dependency will require the rooting system to reach to the water table. This is only likely to occur at low and mid-slope in the Monsoon Vine-thicket area.

The reduction in recharge due to the replacement of permeable surfaces with hardstand areas will reduce recharge, although this will be counterbalanced by reduced evapotranspiration and localised recharged at utility trenches. In addition, the proposed development optimises the use of natural areas and the presence of bio-retention basins upstream of the Monsoon Vine-thicket and Monsoon Rainforest patch (see Figure 5 in Appendix E and Appendix F) will provide added recharge to the groundwater system. As a result, the likelihood of a significant recharge reduction is estimated to be low. The risk of impact to GDEs is rated low (Rare likelihood x Major consequence). The “major” consequence classification relates to the interest of the Northern Territory in maintaining this type of vegetation.

Ongoing monitoring of the health of the Monsoon Vine-thicket and Monsoon Rainforest patches will be conducted to infer any potential impact associated with reduced groundwater recharge (see Section 7.3.2.10).

4.3.2.2 Stormwater

Development of the project site has the potential to:

- Release sediment and potential contaminants into receiving waters as a result of vegetation clearing and/or excavation
- Adversely impact fish and other aquatic species that may inhabit Sandy Creek due to increased turbidity and/or release of contaminants during construction, or increased pollutant loads from road runoff during operation

- Impact roosting and feeding habitat for migratory shorebirds at the mouth of Sandy Creek
- Contaminate water in the event of fuel or oil spills during construction and operation.

The potential for the development to impact on Buffalo Creek is considered low, given the existing poor condition of Buffalo Creek, and stormwater treatment and ESCP measures that will be implemented.

The majority of potential water quality and quantity related impacts can be adequately managed with effective implementation of the mitigation measures outlined in the following section to meet specific Water Quality Objectives (WQOs). These measures include bioretention systems, vegetated swales/buffers, erosion and sediment control and proprietary devices. Water quality will also be monitored at the three discharge locations as well as in Sandy Creek and Buffalo Creek (Appendix O).

Construction Phase Water Quality

During the construction phase, the potential exists for increases in the amount of pollutants, particularly sediment, exported from the site. During this period, an ESCP will be referred to as part of the overall CEMP prepared for the construction phase.

It is considered that the completion of construction activities in accordance with an ESCP developed using latest version of the following guidelines will minimise the nature of any adverse impacts during the construction phase and allow the design objectives to be achieved:

- IECA.2008, *Best Practice Erosion and Sediment Control- Engineering Guidelines for Queensland Construction Sites*.
- Institution of Engineers Australia.1996, *Soil Erosion and Sediment Control, Engineering Guidelines for Queensland Construction Sites*. June.

Please refer to Appendix D for further details of the ESCP.

Post-Construction Phase Water Quality

The formulation and implementation of the stormwater quality management plan for the development is based on the following key principles:

- Adoption of WSUD principles where feasible.
- Management and control of water quality both during and after construction. A detailed ESCP will be developed in accordance with recognised standards during the detailed design phase and implemented on site during the subdivision construction process.

A copy of the Stormwater Management Plan is provided in Appendix E (2CRU) and Appendix F (Muirhead North).

Proposed Stormwater Quality Treatment Train

The treatment measures outlined in the Stormwater Management Plan include the use of Ecosol Net Guards, bioretention basins and vegetated swales/buffers. High density areas within the development such as the tourism/commercial precinct may also incorporate proprietary treatment devices such as the Stormwater360 treatment system. The preliminary locations for the proposed treatment measures are shown in the Stormwater Management Plans (Appendix E and Appendix F).

To minimise the size of the bioretention areas, it is proposed to incorporate the proprietary treatment product by Ecosol being the Net Guard as pre-treatment to the bioretention basins. The Net Guard will primarily treat the Total Suspended Solids (TSS) and Gross Pollutants (GP) with some additional pollutant removal of Total Nitrogen (TN) and Total Phosphorus (TP). The recommended pollutant removal efficiencies have been provided by the manufacturer and listed below:

- TSS – 40% removal
- TN – 30% removal
- TP – 35%
- GP – 93%

The preliminary details of the bioretention basins are detailed in Table 12 with the locations of the bioretention basins are shown in the Stormwater Management Plans (Appendix E and Appendix F).

The bioretention basins and stormwater treatment devices will be designed to allow for effective maintenance. The maintenance of stormwater management assets will be considered as part of the Conservation and Offset Management Plan to be prepared for the Conservation Area, so as not to compromise to ability undertake management and address any biting insect issues.

Table 12. Bioretention details for 2CRU (Bio-Basin A-E) and Muirhead North (Bio-Basin F-I)

Parameter	Bio-Basin A	Bio-Basin B	Bio-Basin C	Bio-Basin D	Bio-Basin E	Bio-Basin F	Bio-Basin G	Bio-Basin H	Bio-Basin I
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Surface Area (m ²)	900	700	700	900	650	750	1050	600	600
Filter Media Surface Area (m ²)	900	700	700	900	650	750	1050	600	600
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200	200	200	200	200	200
Filter Depth (m)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
TN Content (mg/kg)	400	400	400	400	400	400	400	400	400
Orthophosphate Content (mg/kg)	30	30	30	30	30	30	30	30	30

It should be noted that the maximum bioretention area is recommended to be 800m² for both ease of maintenance and to aid the survival of bioretention vegetation during extended dry periods. The limiting pollutant in sizing most of the bioretention areas is TSS, with the use of proprietary pre-treatment devices such as Ecosol's Net Guard product, the overall size of the bio-retention basins could be reduced.

It is noted that the use of rainwater tanks for re-use of rainwater could also potentially reduce the pollutant loads discharging from the site while also reducing demand on town water supply. However, imposing this requirement on potential property buyers is not easily enforced and has therefore not been included as part of the treatment train.

The stormwater treatment train has been designed to discourage breeding and providing habitat for biting insects. The Stormwater Management Plans have been developed to comply with the recommendations set out in the Biting Insect Report prepared specifically for this project (Appendix G). This includes by ensuring all water within the detention basin drains within 24 hours of a rain event, that stormwater is discharged within the tidal section of both creeks (i.e. less than 3 m AHD).

Design and Performance of Treatment Measures

In order to determine the effectiveness of the adopted treatment train in meeting the WQOs, a stormwater quality analysis was performed using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6.

The model requires the user to specify meteorological data (rainfall and evaporation), soil properties and pollutant loads for each catchment. Suitable parameters for the MUSIC model have been adopted in accordance with the recommendations within the *Water Sensitive Urban Design Stormwater Quality Modelling Guide, May 2009* prepared by the Northern Territory Department of Planning and Infrastructure.

The Urban Residential Source node has been adopted within the MUSIC modelling. Further, the development has been divided into roof areas, road areas and general urban based on the applicable Source Node land use. The pollutant export parameters adopted are shown in Table 13.

The rainfall data applied to the MUSIC model was for the Darwin Airport rainfall station for the period 1987-1996. A 6 minute time step was considered for the analysis.

Table 13. Stormwater Quality Parameters for MUSIC Source Nodes

Source Node		TSS (log ₁₀ values)		TP (log ₁₀ values)		TN (log ₁₀ values)	
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Baseflow	Roof	1.1	0.17	-0.82	0.19	0.32	0.12
	Roads	1.1	0.17	-0.82	0.19	0.32	0.12
	General Urban	1.1	0.17	-0.82	0.19	0.32	0.12
Stormflow	Roof	1.55	0.39	-0.92	0.29	0.42	0.19
	Roads	2.38	0.40	-0.60	0.50	0.42	0.19
	General Urban	2.20	0.32	-0.45	0.25	0.42	0.19

Catchment Areas

Catchment areas and percentage impervious values were determined as part of the Stormwater Management Plans (see Appendix E and Appendix F). The adopted catchment characteristics are given in Table 14.

Table 14. Catchment areas for 2CRU (Catchment A-E) and Muirhead North (Catchment F-I)

Catchment	Total	% Impervious
A	14.33	42
B	11.91	49
C	9.43	67
D	12.26	67
E	9.37	60
F	12.20	50
G	16.24	57
H	10.70	16
I	9.81	17

The results of the MUSIC modelling, shown as total annual loads, are presented in Table 15 (2CRU) and Table 16 (Muirhead North). The results demonstrate that the proposed stormwater treatment measures for the development will satisfy the adopted WQO for all pollutants modelled in MUSIC. Stormwater Quality and therefore the COD criteria for water quality have been appropriately addressed.

Table 15. Predicted Pollutant Load Reductions – 2CRU

Parameter	Generated Load	Post-development (Mitigated) Load	% Reduction
TSS (kg/yr)	123000	24200	80.3
TP (kg/yr)	256	71.3	72.1
TN (kg/yr)	1850	791	57.1
Gross Pollutants (kg/yr)	14100	1.24	99.9

Table 16. Predicted Pollutant Load Reductions – Muirhead North

Parameter	Generated Load	Post-development (Mitigated) Load	% Reduction
TSS (kg/yr)	83000	16100	80.6
TP (kg/yr)	177	48.1	72.8
TN (kg/yr)	1300	545	58
Gross Pollutants (kg/yr)	9460	0	100

Stormwater Quantity

The intensified development of the site has the potential to increase local site runoff due to the increase in impervious areas associated with the development. This potential increase in local peak flows can ultimately result in increased peak discharges within the adjacent waterways that can result in increased flood levels, erosion of the waterway and affect bank stability.

To limit the adverse impacts external to the developed site, it is required to limit post-development flows from the site to less than pre-development levels using appropriate mitigation measures where possible.

To mitigate the potential increase in flows discharging from the project site, it is proposed to include end-of-line detention basins at the outlet to the site's three major outlets located as shown in the Stormwater Management Plan for 2CRU (Appendix E) and Muirhead North (Appendix F).

Modelling undertaken as part of the Stormwater Management Plans showed that without mitigation the peak flows would increase at three out of five of the outlets (Table 17). When considering the impact of the development on both the rainforest patch and rural dam, it is anticipated that the volume of the more frequent runoff events would be the critical hydrologic factor in maintaining the health and demand for the respective receiving environments. Given that the antecedent catchment condition is considered the same in both the pre and post-development scenarios, there should ultimately be no impact on runoff volume to the respective receiving locations if the contributing catchment area is maintained.

It should be noted that the health of the Monsoon Rainforest patch will be monitored to infer whether stormwater flows are appropriate for sustaining the patch. If the stormwater flows are not considered tolerable than changes to the stormwater treatment system will be considered, which most likely would include removing bioretention basins and replacing with Gross Pollutant Traps to increase baseflows in to the Monsoon Rainforest whilst still treating stormwater for nitrogen and phosphorous pollution.

Table 17. Impact on 100 Year ARI Peak Flows for 2CRU (RP01 and RP04) and Muirhead North (RP05, RP06 and RP5)

Sub-catchment Outlet	Pre-development XPRAFTS Q100 Peak Flow (m ³ /s)	Post-development (Unmitigated) XPRAFTS Q100 Peak Flow (m ³ /s)	Increase in Peak Flows (m ³ /s)	Impact (%)
RP01 – North West	2.51	4.50	1.99	79
RP04 – South West	9.46	19.26	9.80	104
RP05 – To Rainforest Patch	7.44	3.46	-3.98	-53
RP06 – To Rural Dam	3.92	1.86	-2.06	-53
RP5 – Buffalo Creek outlet	27.07	31.23	4.16	15.4

The Stormwater Management Plans includes mitigation in the form of bioretention and detention basins to ensure that peak flows are not impacted by the project. To ensure the rural dam supply is maintained by regular runoff from the upstream catchment, it is proposed to divert all flows up to the 2 year ARI event (1.86m³/s and 3.46m³/s) to the existing drains that conveys flows to the rural dam and rainforest patch in Muirhead North respectively. The 2 year ARI peak flow was selected based on the existing cross drainage culvert of Lee Point Road expected to have a minimum 2 year ARI capacity and preliminary estimates of the capacity of the drain. The balance flows from the developed catchment will be diverted to link with the main drainage path to the south.

Preliminary design of the detention basins has been undertaken assuming the following criteria:

- 1 in 6 batters to facilitate maintenance of the batters, assumed to be turfed;
- Basins initially assumed to be trapezoidal with a width:length ratio of 1:2;
- Maximum depth within each basin to be 1.2m for the 20 year ARI event for public safety. Deeper basins may be possible with appropriate signage and fencing and approval from the City of Darwin; and
- Post-development peak flows to be mitigated to pre-development peak flows for all events from the 2 to 100 year ARI.

For the catchment discharging to the south-west corner of the 2CRU, two individual detention basins have been designed to maintain existing peak flows in the two defined gullies immediately downstream rather than a single outlet which would potentially result in additional erosion in a single gully.

For the catchment discharging to the north of the project site, a detention basin has been designed to maintain existing peak flows.

The detention basin outlets are detailed in Table 18 with the stage-storage relationships shown in Table 19.

Table 18. Detention Basin Details

Basin ID	Outlet Pipes	High Flow Weir Width at 100 Year Level (m)	20 Year Depth in Basin (m)	100 Year Depth in Basin (m)	Surface Area at 100 Year Level (m ²)	Volume at 100 Year Level (m ³)
Basin 1	1 / 1200 x 600 RCBC	1.80	1.07	1.33	3,300	3,600
Basin 2	1 / 1200 x 600 RCBC	1.80	1.04	1.25	3,200	3,350
Basin 3	2 / 1200 x 600 RCBC	1.80	1.04	1.45	15,950	22,050
Basin 4	7 / 1.5 x 0.9 RCBC	1.80	1.18	1.26	12,800	15,714

Table 19. Proposed Detention Basin Stage-Storage Relationships

Stage (m)	Basin 1 Storage (m ³)	Basin 2 Storage (m ³)	Basin 3 Storage (m ³)	Basin 4 Storage (m ³)
0.00	0	0	0	0
0.20	511	511	3,451	3,451
0.40	1,021	1,021	6,696	6,696
0.60	1,526	1,526	9,702	9,702
0.80	2,018	2,018	12,422	12,422
1.00	2,551	2,551	15,194	15,194
1.20	3,149	3,149	18,177	18,177
1.40	3,799	3,799	21,277	21,277
1.60	4,508	4,508	24,500	

The resulting mitigated peak flows at each reporting point for all design events are presented in Table 20 to Table 22 and demonstrate that the detention basins will attenuate the increase in run-off associated with the increase in impervious areas, and maintain peak flows at or slightly below pre-development levels.

Table 20. 100 and 50 Year ARI Peak Discharge (m³/s)

Reporting Point	100 Year ARI			50 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	2.51	2.05	-0.46	2.21	1.88	-0.33
RP02	2.91	2.27	-0.64	2.58	2.09	-0.49
RP03	6.38	4.70	-1.67	5.67	4.15	-1.53
RP04	9.46	6.90	-2.56	8.44	6.17	-2.27
RP05	7.44	3.46	-3.98	6.58	3.46	-3.12
RP06	3.92	1.86	-2.06	3.48	1.86	-1.62

Table 21. 20 and 10 Year ARI Peak Discharge (m³/s)

Reporting Point	20 Year ARI			10 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	1.85	1.66	-0.19	1.56	1.46	-0.10
RP02	2.25	1.89	-0.36	1.94	1.67	-0.28
RP03	4.83	3.44	-1.39	4.09	2.66	-1.43
RP04	7.27	5.24	-2.03	6.22	4.22	-2.00
RP05	5.64	3.46	-2.18	4.84	3.46	-1.38
RP06	3.02	1.86	-1.16	2.59	1.86	-0.73

Table 22. 5 and 2 Year ARI Peak Discharge (m³/s)

Reporting Point	5 Year ARI			2 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	1.41	1.32	-0.09	1.11	1.05	-0.06
RP02	1.76	1.51	-0.24	1.44	1.21	-0.23
RP03	3.66	2.01	-1.66	2.97	0.75	-2.23
RP04	5.60	3.39	-2.21	4.54	2.05	-2.49
RP05	4.33	3.46	-0.87	3.46	3.46	0.00
RP06	2.32	1.86	-0.46	1.86	1.86	0.00

Staging

The proposed staging plan (Table 3) implies the commencement of civil works prior to proper construction of a functioning stormwater management system. Construction of the detention basins and drainage system as outlined in the Stormwater Management Plans (Appendix E and Appendix F) will be brought forward to ensure compliance with the Stormwater Management Plan during construction. Run-off from Stage 1A and 3 will be diverted to Muirhead North, and therefore will require development of the detention basin in Stage 2B beforehand. Likewise, the detention basin in Stage 4 would need to be functioning prior to development of Stage 2A.

4.3.2.3 *Acid Sulphate Soils*

Testing for acid sulphate soils has not been undertaken. Despite the proximity of the project site to the coastline, the elevation of the site is likely to preclude the presence of acid sulphate soils (GHD 2010). If present, acid sulphate soils are most likely to occur in the lowest elevations of the site, which occurs in the south-east of Muirhead North, which relates to Stage 2B. It should be noted that no acid sulphate soils were encountered in the adjoining Muirhead Breezes development. Nonetheless, test pits will be dug in the south-east of Muirhead North to determine the presence of acid sulphate soils prior to the development of Stage 2B. If acid sulphate soils are encountered then an acid sulphate soils management plan will need to be prepared and implemented.

5 AIR QUALITY

5.1 Introduction

This chapter assesses the potential impacts of the project on air quality, or existing air quality issues that may affect the amenity for future residents. The chapter specifically focusses on dust generation and odour and addresses the following criteria of the EIS ToR:

- Potential impact from odour related to the proximity to the Leanyer Sanderson Wastewater Treatment Ponds, supported by on site sampling and undertaken by a suitably qualified and experienced consultant in accordance with AS/NS 4232.3:2001 or other demonstrated industry best practice methodology.
- Discuss the risks from dust and other particulate matter during construction activities and the proposed mitigation of those risks.

The chapter is structured in the following manner:

- Description of the methods used to model the magnitude of odour impacts, and likely impacts from dust (Section 5.2).
- A summary of the Identified odour and dust risks to sensitive receivers and future residents and a list of practical and appropriate mitigation measures to avoid any unacceptable dust or odour disturbance that may occur during the construction or operation phase of the project (Section 0).

The full risk assessment is provided in Appendix C. The findings of odour impacts are based on the Odour Impact Assessment prepared by The Odour Unit (2017), which is provided in Appendix .

5.2 Existing Conditions

5.2.1 Odour methods

The methods used to establish the impact from odour focussed on the plume extent and odour intensity, both of which were undertaken using industry best-practice standards. Field staff who undertook odour measurements in the field are registered assessors in accordance with AS/NZS4323.3:2001 Dynamic Olfactometry. Meteorological data was also recorded during the assessment to aid interpretation.

5.2.1.1 Plume extent

Establishing the plume extent was based on the internationally recognised European Standard: EN 16841-2:2016 using the dynamic plume method. At least 20 single measurements were taken at different distances downwind from the Leanyer Sanderson Wastewater Treatment Plant by at least two assessors in order to define at least six transition points and the odour plume extent. Assessors walked in a zig-zag fashion into and out of the defined plume to prevent adaptation to the odour. The maximum extent of the plume is determined by assessors repeatedly crossing the plume at different distances from the source. The spatial location of each measurement point is recorded, along with the time and whether or not the odour could be detected.

5.2.1.2 Odour Intensity

Once the plume extent was defined, the assessors determine the odour intensity based on the internationally recognised German Standard: VDI 3940, 3882 Part 1. Assessors conducted measurements at discrete points downwind of the Leanyer Sanderson Wastewater Treatment Plant, involving 60 grab measurements for 10 sections for a single measurement cycle of 10 minutes. Each measurement provided a single odour sample, where assessors determined the presence, character and intensity of the odour.

The odour intensity is determined using the categories in the table below.

Table 23. German Standard VDI 3940, 3882 Part 1 – Odour Intensity Categories

Odour Strength	Intensity Rank (code)	Interpretation
Not detectable	0	No odour detected.
Very weak	1	Odour recognised and assigned to the odour source (recognition).
Weak	2	Odour is weak but not yet distinct.
Distinct	3	Odour is clearly distinct.
Strong	4	Strong odour detectable.
Very strong	5	If offensive, observer may consider moving from the area.
Extremely strong	6	Odour is sufficiently over-powering that assessor moves from area.

5.2.2 Odour impacts

The potential odour impacts from Leanyer Sanderson Waste Treatment Plant were determined in accordance with the methods specified in the ToR. An independent odour specialist (The Odour Unit) completed an odour impact assessment for the project, focussing on odour emanating from the Leanyer Sanderson Wastewater Treatment Plant. The odour assessment was completed over six days between 23 and 28 February 2018 and in accordance with the methods outlined in the following international standards:

- Determination of Plume Extent (European Standard EN: 16841-2:2016).
- Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1).

The timing of the assessment was considered optimal for establishing the extent and intensity of the plume, due to the lack of rainfall preceding the assessment which would limit dilution of odour. The assessments were also undertaken between 6 am and 9 am to coincide with peak morning inflows.

The odour assessment noted that the conditions at the Waste Treatment Plant were essentially baseline, that is, the process conditions were static with no process maintenance taking place, and in particular no noticeable sludge cleanout activities. The findings of the odour assessment therefore reflected an odour emissions scenario where there no upset conditions or any type of process interruptions of maintenance.

An odour plume was detected on 25 and 26 February when prevailing winds were from the east and south-east. On both days the plume extent was determined to be approximately 600 metres length by 150 metres width. This plume extent was found to be consistent with the odour extent determined by GHD (2015) from the Leanyer Sanderson Wastewater Treatment Plan for or a proposed subdivision in Sanderson.

It was concluded that based on the results of the assessment, under those process conditions at the time of the odour assessment, the likelihood of odour impact on 2CRU or Muirhead Development was negligible or nil (Appendix J). However, it was acknowledged by The Odour Unit that the extent and intensity of odour impacts may increase under certain upset conditions that would relate to process operations of the treatment plant and not the typical day-to-day running of a modern waste-water treatment plant and infiltration and evaporation ponds. The Odour Unit identified the following upset conditions as factors that could lead to a greater plume extent or intensity than assessed:

- Poor performance of Leanyer Sanderson Wastewater Treatment Plant.
- Inlet works breakdown.
- Drying out of ponds where sludge may be exposed.
- Poor control of sludge.
- Presence of anaerobic conditions where algal blooms may occur.

The NT EPA released the Recommended Land Use Separation Distance Guidelines in October 2017 (NT EPA 2017) to provide guidance on potential impacts of emissions from industrial sources on sensitive land-uses. Specifically, the guidelines purpose is *“to recommend separation distances between industry and sensitive land uses to ensure off-site emissions of offensive odour, noise, smoke, dust or fumes do not adversely impact on people”* (NT EPA 2017). It is primarily for the use of the NT EPA when preparing advice on development plans

and strategic land use plans but can also be used by the NT EPA during environmental assessments to minimise off-site emissions and impacts.

The proposed separation distance for odour impacts from sewerage treatment plants using pond systems is based on the following formula which has been adopted from the Victorian EPA:

$$= 10 \times (EP)^{0.5}$$

Based on this formula the proposed separation distance from the Leanyer Sanderson Wastewater Treatment Plant is 2,236 metres and 2,300 metres based on current EPs (50,000 EPs) and at project completion (52,904 EPs) respectively. Under both scenarios the proposed separation distance would cover all the Muirhead North site and most of 2CRU in addition to other sensitive land-uses in the local area including existing residential developments, schools and the Darwin Hospital. It is important to note that no odour was recorded in these areas during the assessment by The Odour Unit (Appendix J – Figure 5). These separation distances are also nearly four-fold greater than the plume extent established by The Odour Unit (Appendix J) and GHD (2015), and the PWC's 700 metre odour buffer around Leanyer Sanderson Wastewater Treatment Plant.

Site-based assessment data can be used instead of the separation distance specified in the guidelines to inform the appropriate land-use separation distance. For instance, page 9 of the guidelines states that *"The Guideline is not intended to replace site-specific assessments or the consideration of site-specific circumstances which may result in a requirement for a separation distance which is larger or smaller than the distance proposed in the Guidelines"* (NT EPA 2017). As such, the plume extent determined by The Odour Unit (Appendix J) is considered a more accurate assessment of the appropriate land-use separation distance from Leanyer Sanderson Wastewater Treatment Plan under standard operating conditions than what is specified in the guidelines.

The NT EPA have provided information that odour complaints have been received in suburbs outside the plume extent determined by The Odour Unit as well as the separation distances inferred from the guidelines (NT EPA 2017). As these complaints are part of an ongoing EPA investigation, information on the location, date and time of day of the complaints cannot be disclosed until the investigation has been concluded. It is therefore not possible to establish the cause of the odour impacts, although, it is speculated that they are likely to be the result of one or more of the upset conditions listed above, or odour emanating from other sources such as stagnant water.

Subsequent to the odour assessment completed by The Odour Unit and the complaints received by the NT EPA, Power and Water Corporation have committed to improving infrastructure at the Leanyer Sanderson Wastewater Treatment Plant that are expected to substantially reduce the odour impacts. Works have commenced on a \$16.2 million inlet works upgrade that will remove unwanted bathroom products and kitchen waste that restricts the natural treatment process of the ponds and contributes substantially to odour impacts. The upgrade is expected to be completed by November 2018.

In addition to specifying land-use separation distances for wastewater treatment ponds, the guidelines also specify separation distances from sewerage pumping stations (NT EPA 2017). The Lyons and Muirhead sewerage pumping stations are within the general vicinity of the project. The guidelines propose a separation distance of 100 metres from these types of pumping stations (NT EPA 2017). It is shown below (Figure 15) that the 2RU and Muirhead North are well outside the separation distances for both pumping stations.

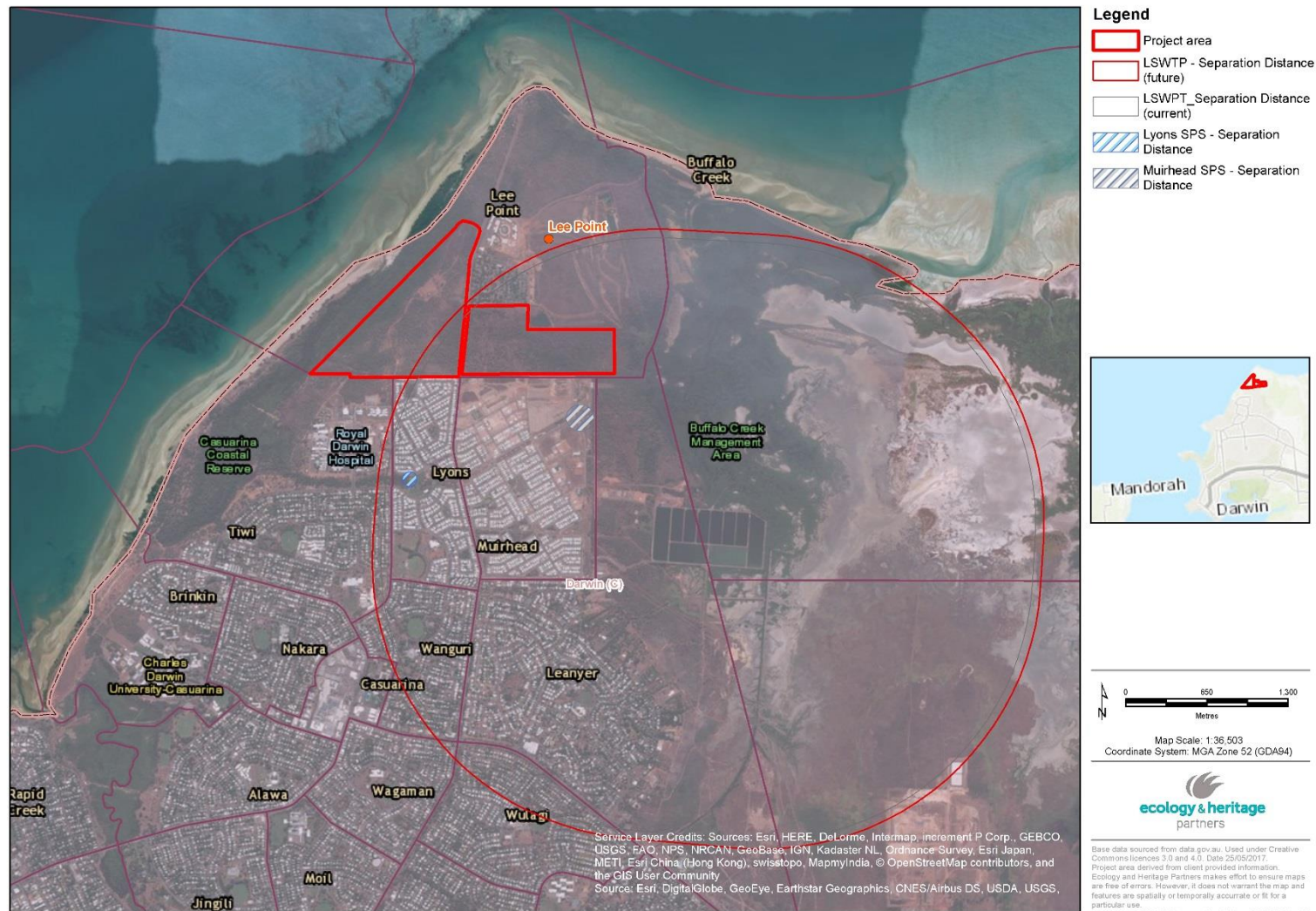


Figure 15. Land use separation distances for Leanyer Sanderson Wastewater Treatment Plant, and Sewerage Pumping Stations

5.2.3 Dust

5.2.3.1 Overview

Dust generation can occur during the construction phase of urban development projects. It is more likely to occur in the dry season when drier soils and particulate matter more readily become airborne during disturbance. The likely causes of dust generation for this project are:

- Clearing vegetation
- Construction works
- Vehicle movements
- Erosion.

The risks and impacts of dust generation associated with this project have been established from referring to projects of a similar nature and guidelines for dust prevention in Australia. The potential impacts of dust generation can include:

- Human health (respiratory problems)
- Exposure to contaminants (e.g. asbestos)
- Vegetation smothering restricting carbon uptake and transpiration
- Loss of amenity
- Sedimentation leading to reduced water quality.

Depending on the extent of the dust plume, onsite workers and adjoining residents can be affected during construction, while if proper remediation and mitigation solutions are not in place, dust management problems can remain after the construction phase.

5.2.3.2 Potential contamination

Contamination from asbestos and other pollutants that could potentially become airborne during construction were considered from 2CRU by GHD (2010). Twenty-five shallow soil boreholes were drilled across 2CRU to a maximum of 0.8 metre depth and analysed for potential contaminants including within the Conservation Area and Casuarina Coastal Reserve. No imported fill materials were noted within the boreholes; however, some surface soil samples appeared to be reworked natural material.

GHD (2010) found that heavy metals concentrations did not exceed the Health-based soil Investigation Levels (HILs) for residential use as per the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM 1999). They also did not identify any hydrocarbon odours or soil staining.

Given the low contaminant levels at 2CRU, GHD (2010) did not recommend any further investigate Source – Pathway – Receptor linkages as part of a Conceptual Site Model.

Asbestos containing materials were not observed within soils during the investigation, although it was noted that asbestos is known to occur within site compound (GHD 2010). Areas of Potential Environmental Concern (APEC), including potential asbestos containing material (ACM) have subsequently been removed from 2CRU.

DHA engaged SERS to remediate contamination at 2CRU. These works were undertaken in a staged manner as follows:

- Stage 1 – removal of all observed ACM prior to the demolition of above ground structures as per the Asbestos Removal Control Plan (ARCP) protocols:
 - All ACM products present within the buildings were removed by licences asbestos removalist in accordance with current legislation and Worksafe NT and Comcare procedures.
 - Any ACM observed was collected and placed in a plastic asbestos disposal bag and sealed with PCV tape then placed into another bag of same quality and sealed (double bagged).
 - Upon completion of the ACM removal works the building and structures were inspected by a qualified asbestos assessor and any open space grid walked three time in each axis to confirm successful removal of all AMC prior to demolition.
 - Once asbestos assessor was satisfied that all ACM had been removed, a clearance certificate was issued and the demolition work proceeded.
- Stage 2 – demolition of building and structures with the exception of APEC G (Electrical Transformer), APEC J (Underground Petroleum Storage System) and APEC K (Septic System) to the following protocols:
 - All demolition activities were carried out in accordance with NT and federal legislation.
 - Above ground structures were deconstructed first, followed by concrete slabs and hard standing areas.
 - All demolition works were notified to Worksafe NT and undertaken by SERS nominated subcontractor BDS in accordance with the safety documentation provided.
- Stage 3 -removal of APEC G (Electrical Transformer), APEC J (UPSS) And APEK K (Septic System) structures and associated contaminated soil under the supervision and direction of SERS as follows:
 - Prior to the remediation of the APEC's, SERS surveyed and pegged the site structures in preparation of demolition to ensure that all impacted areas would be addressed during the remediation.
 - Two steel twin skinned tanks were removed from APEC J (UPSS – both tanks were noted to being empty prior to removal) and inspected for breaches prior to being loaded onto a truck for disposal at Shoal Bay Waste Facility.
 - Removal of one concrete dual chamber tank from APEC K (Septic System). The chambers were excavated using the onsite excavator and placed on adjacent hard standing area for inspection prior to crushing. No liquid was noted as being present in the septic system prior to removal.
 - Excavation of contaminated soils from the relevant APEC (G, J and K) to a depth of 300 mm below any structure or observed visual or olfactory evidence of contamination. All excavated materials were placed on plastic sheeting lined hard stand and covered with plastic sheeting

while laboratory analysis were performed on representative samples. Soils excavated from each APEC were stockpiled separately to prevent cross contamination.

- Sampling and analysis of the excavations were performed from the base and side walls to validate that any potential contamination has been removed from the APEC. Upon completion of the remedial works, all final samples recorded concentrations below the adopted soil criteria.
- Upon receipt of the chemical analysis, results for the stockpiled soils were compared to the ASC NEPM 2013 threshold values. Results determined:
 - Soils from APEC J (UPSS) and APEC K (Septic System) were considered suitable for reuse on site and used to back fill respective excavation pit.
 - Soils from APEC G (Transformer) were considered unsuitable and underwent waste classification and ultimately offsite disposal at Shoal Bay Waste Facility.
- Stage 4, Stage 5 and Stage 6 – upon completion of the building and infrastructures, each APEC was cleared for near surface ACM to the following protocols:
 - The entire site was separated into seven areas to make asbestos remediation manageable.
 - Each area in turn was grid walked three times in each axis in line formation by a team of no less than three competent asbestos removalist/assessors.
 - Any ACM observed was collected and placed within a plastic asbestos disposal bag and sealed with PVC tape and then placed into another bag of the same quality and sealed.
 - During the process, ACM recovered was weighed and aesthetic quality (colour, foreign material) were visually assessed. Once no ACM was observed, this stage of the asbestos remedial works was considered complete and validation sampling of exposed soils were undertaken.

During the decommission of the 2CRU site, there was an unexpected find of ACM piping, which was removed by SERS and their subcontractor BDS in the following manner:

- Soils from above the ACM piping were carefully removed using an excavation and shovels and stockpiled adjacent to the sludge beds.
- All ACM pipes were then removed manually as to prevent breakages and placed directly into lined bins for removal from site and disposal to landfill.
- Approximately 98% of pipeline was removed with no minor breakages. In case of minor breakages, which occurred in particular areas around the joints of the pipeline, BDS and SERS personnel manually removed any remaining fragments by hand picking and the was inspected by SERS post removal of ACM fragments.
- In area where ACM pipeline came into direct contact with soil surrounding area was manually dug out to 300 mm below impacted area and disposed as asbestos waste.

The Site Auditor confirmed that the remediation works were generally undertaken in accordance with the Remediation Action Plan and NT guidelines (AECOM 2016). A copy of the Site Auditors reports is provided in Appendix .

A Stage 1 Preliminary Site Investigation has been completed for Muirhead North (EcOz 2015) and is included in Appendix S. It found Muirhead North has always been Vacant Crown Land and there has been no significant developments within the area. Illegally dumped household rubbish, car bodies, soil piles and building materials (i.e. steel, concrete, etc) were observed in some areas, which were mainly concentrated near access tracks, particularly in the western section of the site. A small amount of ACM was observed at one location. EcOz (2015) concluded that it is unlikely that there is any extensive contamination of ACM (but noted the possibility of additional areas of minor ACM contamination) and did not recommend a Stage 2 Detailed Site Investigation.

The NT Parks and Wildlife Commission have also noted areas within the Conservation Area where there has been rubbish dumped. The Commission is unaware of the source of this rubbish, given the history of illegal access to the site. Risk Assessment

5.2.4 Risk assessment summary

The section summarises the findings of the detailed risk assessment, and identifies those risks which require management and mitigation measures to reduce the level of risk of dust generation and odour to the environment and human health, to an acceptable level.

Based on the results of the odour assessment, the risk of odour impact on the project development is low-negligible during normal operating procedures. The odour plume was measured as extending up to 600 metres from the Leanyer Sanderson Wastewater Treatment Plant, and at low intensity (i.e. distinct/not very distinct and not offensive). The closest point-to-point distance between the project site and the Leanyer Sanderson Wastewater Treatment plant is approximately 1 km. The NT EPA have received odour complaints likely to originate from the treatment plant from suburbs outside the established odour plume, and the separation distances designated in the Recommended Land Use Separation Distance Guidelines(NT EPA 2017). It is assumed that these complaints were received during maintenance periods (e.g. sludge removal) or a breakdown in treatment processes. Current inlet work upgrades are likely to substantially reduce the odour impacts from the plant. Further mitigation measures to reduce odour impacts are proposed below; however, given that sewerage treatment is the responsibility of Power and Water Corporation, DHA cannot provide certainty that the proposed mitigation measures would be implemented.

A summary of the moderate to high risks of dust impacts are summarised in Table 24. The potential for dust generation to result in contamination is unlikely, as the original site sheds have been demolished and removed in accordance with standard Occupational Health and Safety procedures to avoid any potential exposure to contaminants, such as asbestos. However, two 450 metre long parallel asbestos pipes remain in 2CRU and will be removed as part of the development. The site auditors report for 2CRU assessed the site as suitable for residential purposes subject to the preparation of a CEMP that addresses potential for unexpected findings including asbestos containing materials (AECOM 2016).

The full risk assessment results for dust impacts are provided in Appendix D.

Table 24. Summary of risk assessment for dust impacts and recommended mitigation measures

Impact	Description	Considered Mitigation Measures
Human health (workers and adjoining residents).	Dust plumes causing respiratory problems.	• An emu bog grid walk to identify any asbestos containing materials within 2CRU, Muirhead North and Conservation Area • All rubbish to be removed and site audit completed of Conservation Area completed prior to Parks and Wildlife Commission hand-over • Removal of 450 m long parallel asbestos pipes in 2CRU to be done by a trained and certified asbestos removal company. • Notify adjoining residents prior to works commencing • Vegetation cleared in a staged manner • Limit the amount of excavation required to clearing vegetation • Watering on haul roads, and exposed areas • Vehicles obey speed limits and stick to formed road • Trafficable areas clearly marked • Stabilise long exposed areas • Rehabilitate as soon as possible.
Vegetation	Dust plumes smother vegetation preventing adequate carbon sequestration and transpiration.	• Vegetation cleared in a staged manner • Limit the amount of excavation required to clearing vegetation • Watering on haul roads, and exposed areas • Vehicles obey speed limits and stick to formed road • Trafficable areas clearly marked • Stabilise long exposed areas • Rehabilitate as soon as possible. • Water foliage of affected vegetation as part of watering plan.
Sedimentation of waterways	Reduction in water quality due to erosion and sedimentation.	• Vegetation cleared in a staged manner • Limit the amount of excavation required to clear vegetation • Watering on haul roads, and exposed areas • Vehicles obey speed limits and stick to formed road • Trafficable areas clearly marked • Stabilise long exposed areas • Rehabilitate as soon as possible • WSUD • Avoid clearing in wet season during monsoonal rains • Water quality monitoring of detention basins and Sandy Creek.

Impact	Description	Considered Mitigation Measures
Human health (future residents)	Exposed areas remain after construction has been completed causing ongoing dust impacts	- All exposed soil areas are covered either by hard surface (roads, pathways or buildings) or vegetation. - Ongoing maintenance of public open space will include rehabilitation of any exposed areas through revegetation or passive regeneration of existing vegetation.
Human health (existing and future residents)	Odour impacts from Leanyer Sanderson Wastewater Treatment Plant	- Current inlet upgrade works are expected to substantially reduce odour impacts recorded around the treatment plant. - DHA to lobby Power and Water Corporation to undertake activities which are likely to increase odour impacts when prevailing wind is from the west, or on mostly still days.

5.2.5 Description of impacts and mitigation measures

The types of mitigation measures proposed are consistent with responses for other urban development projects of a similar scale in the Northern Territory. The potential of dust impacts are most prevalent during the construction phase, when plant operation and vegetation clearing can result in dust generation particularly during the dry season. To ensure that dust generation is contained and that site workers and adjoining residents are not affected, the following mitigation measures are considered sufficient:

- Complete an emu bob grid walk to identify any asbestos containing materials
- Notify residents prior to works commencing
- Clearing vegetation in a staged manner
- Water haul roads and exposed areas
- Vehicles obey speed limits and stick to form roads
- Stabilise any long-exposed areas
- Rehabilitate as soon as possible.

The emu bob grid walk will be undertaken in accordance Western Australian Asbestos Guidelines (WA DoH 2009) where accredited asbestos assessors will walk across a grid-formation manually picking up any fragments of asbestos containing materials. The inspections will be undertaken on a monthly basis until no asbestos is detected. The inspections will occur in 2CRU, Muirhead North and the Conservation Area. Any asbestos identified will need to be removed by a licensed asbestos contractor in accordance with NT WorkSafe requirements.

In addition, the proposed removal of 450 m long parallel asbestos pipes in 2CRU represents a significant risk to human health and will only be done by a trained and certified asbestos removal company.

These mitigation measures are further detailed in the ESCP which forms part of the over-arching CEMP (Appendix D).

Dust generation can also result in the sedimentation of waterways. The treatment train of bioretention and detention basins that will be established throughout the project site have been designed to remove up to 80%

of the sediment captured from the project area, and will assist with mitigating any dust impacts from the project. See the Stormwater Management Plan for 2CRU (Appendix E) and Muirhead North (Appendix F) for further detail.

Dust generation can also impact on biodiversity by smothering vegetation and preventing adequate exchange of carbon and water through leaf stomata. The retention of 21.95 ha of remnant vegetation along the western boundary of the site will buffer the interior of the Casuarina Coastal Reserve against any dust impacts. Any affected vegetation along the edge of the retained area, and any other areas where native vegetation will be retained, will be watered if signs of dust impacts become apparent.

Prior to the Conservation Area being handed over to the Parks and Wildlife Commission for management, DHA will remove any litter and rubbish. A site audit will also be completed of the Conservation Area for asbestos and any other contaminants.

Power and Water Corporation is responsible for the operation of the Leanyer Sanderson Wastewater Treatment Plant, and therefore ultimately responsible for addressing odour impacts emanating from the plant. The current inlet upgrade works that will remove items from sewerage which interfere with the natural treatment process is expected to substantially reduce the size of the odour plume. Another practical measure would be for any maintenance works that may contribute to odour impacts, be staged to occur on days when wind is predominantly still or from the west. DHA will lobby Power and Water Corporation on behalf of existing and future residents in Lee Point, for this to occur.

6 UTILITIES AND INFRASTRUCTURE

6.1 Introduction

This chapter describes the utilities and infrastructure that will be required to service the future inhabitants and users of the project site. It covers the following service requirements:

- Potable water
- Sewerage
- Transport
- Power
- Telecommunications.

The chapter is structured in the following manner:

- Existing conditions and impacts – an assessment of the future demand requirements for potable water (see Section 6.2.1), sewerage (see Section 6.2.2), transport (see Section 6.2.3), power (see Section 6.2.4) and telecommunications (see Section 6.2.5); whether existing services can meet this demand, and what impact increased demand is likely to have on the local community.
- Risk assessment – a summary of the detailed risk assessment identifying key risks that require mitigation or management measures, such as augmenting existing services or improving traffic safety (see Section 6.3).

As part of the preparation of this chapter, the following people from Power and Water Corporation (PWC) were consulted:

- Ian Jong – Services Development Engineer
- Jack Foster – Water Systems Engineer.

Further consultation was undertaken with the following PWC staff following public exhibition period for the EIS on 26 March 2018:

- Ian Jong
- Bokhtiar Meelky
- Teresa Tian

6.2 Existing Conditions and Impacts

6.2.1 Potable Water

The proposed development is located within the Casuarina Water Supply Zone (WSZ). Storage for the zone is facilitated by the Marrara and Casuarina Reservoirs. A trunk network extends along Lee Point Road to supply

the network. In particular a DN (Diameter Nominal/Nominal Diameter) 450 main extends along Lee Point Road in the vicinity of the existing Lyons and Muirhead developments.

In regard to network planning, PWC has advised that no new trunk services are proposed in the vicinity of the site. This includes both storages and trunk mains. New storages are proposed at the Marrara Complex; however, no bulk strategic planning will impact the proposed development.

Supply to the proposed development will be via the existing trunk main network along Lee Point Road.

PWC provided boundary conditions that reflected hydraulic grades at the agreed offtake points to the development. PWC provided boundary conditions for both the existing and ultimate network conditions. The existing conditions nominally represent the network as it is in operation now. The ultimate conditions represent network conditions infrastructure to service demand up to 50 years in the future. The advised grades are:

- Existing: Peak Hour 51.4m Australian Height Datum (AHD), Fire Flow 53.9m AHD
- Ultimate: Peak Hour 48.46m AHD, Fire Flow 51.6m AHD.

Based on this information, a water supply network model has been developed that includes the agreed offtake points, supply mains from the offtake point to the development and an internal reticulation network.

The water supply network was built in the hydraulic modelling software, Bentley WaterGEMS. This software allows the infrastructure to service the development to be sized according to the PWC design criteria.

A new DN450 trunk main was assumed to continue from the proposed connection along Lee Point Road to the second proposed junction, corresponding to a location immediately south of the Lee Point Village Resort. In addition, a second connection to the existing DN300 main along Damabila Drive (south of the project site in the Lyons development) was also assumed. An internal trunk main connected both the DN450 and DN300 mains via a looped DN300 trunk main.

Smaller reticulation services ranging in size from DN200 to DN150 are proposed. The network in the vicinity of the proposed tourist precinct includes looped DN300 and DN200 mains to maintain fire flow requirements.

The analysis of the existing network against the full demand indicated that sufficient pressure can be maintained for both peak hour and fire flow events in the described network without augmentation. It is noted that areas above 28 m AHD experienced pressures in the order of 19 m and 20 m. These are limited to the northern lots. Headwork upgrades are required to service development about 28.0 m AHD. DHA will be responsible for any headwork upgrades.

The network proposed for the existing scenario was assessed for the ultimate scenario with the reduced level of hydraulic grade at the nominated offtake point. Analysis has indicated that the minimum level of service could not be maintained, based on both growth and topography. Based on the adopted development layout and external supply configuration, the creation of a high level zone (HLZ) for the entire site is proposed.

Advice from PWC indicates a preference for storage over direct inline pressure boosting only. To accommodate this preference the use of a break of head tank prior to boosting is proposed.

It is proposed that a HLZ be created to ensure the entire site receives a service level that satisfy PWC's requirements. This HLZ will be serviced via a small break of head tank with 650 kL storage, based on the minimum fire flow requirements.

6.2.2 Sewerage

The existing wastewater network in the vicinity of the project site includes the Lyons and Muirhead sewer pump stations (SPS). These pump stations convey flows to the trunk sewer mains that discharge to the Leanyer Sanderson Wastewater Treatment Plant. Treated effluent will be discharged from Leanyer Sanderson Wastewater Treatment Plant into Buffalo Creek in accordance with Waste Discharge License (WD147).

PWC adopt Equivalent Persons (EP) as the basis for sewerage planning. Based on the adopted master plan, the proposed development comprises 2,904 EP.

PWC has advised that no future trunk network augmentations have been identified downstream of the site and that there are no plans to upgrade the existing plant apart from its current investment of \$15.4 million in constructing new inlet works. The existing capacity of the plant is approximately 72,000 EPs.

Based on the topography of the site, the development site falls within two pump station catchments, the Muirhead SPS and the Lyons SPS. The majority of the development (2,053 EP) will discharge to the existing Muirhead SPS catchment and the remainder (567 EP) will discharge to the Lyons SPS catchment. The EP loading discharging to the Lyons SPS exceeds the capacity of the pump station by 3%. Minor upgrade works will be undertaken by DHA to increase the capacity of the Lyons SPS to accommodate any exceedance of EP load due to the project.

A network model of the reticulation internal to the development site and the gravity mains connecting the development to the two sewer pump stations was developed in Microsoft Excel to allow the gravity network to be sized utilising the PWC design criteria. The gravity mains were sized based on the following assumptions:

- Gravity mains at minimum grade
- Sized for pipe full.

An internal gravity network ranging in size from DN150 to DN375 is proposed for the site. The eastern part of the catchment (2,106 EP) will drain to the Muirhead SPS via a DN375 trunk main and the western part of the catchment (410 EP) will drain to the Lyons SPS via a DN225 trunk main.

An assessment was undertaken to determine the impact of the development on the existing infrastructure.

The existing Muirhead SPS was designed with consideration for the proposed development. The design of the Muirhead SPS adopted a load of 2,747 EP for all future development in the catchment. The proposed development, a projected 2,106 EP, will be discharging to the Muirhead SPS. Therefore the existing pump station is within the original limits. The pump station was designed for a peak design flow of 103 L/s and an emergency storage volume of 331 m³. The requirement (incorporating the reduction in the allowance from the proposed development) is a peak design flow of 92 L/s and an emergency storage volume of 273 m³. Therefore, the existing Muirhead SPS can accommodate the sewerage load from the proposed development.

The existing Lyons SPS was also designed with consideration for the proposed development. The design of the Lyons SPS adopted a load of 550 EP from the proposed development, compared with the 410 EP for this

assessment. Therefore the existing pump station is within the original limits. However, a number of issues were raised with the design as shown in Table 25. The analysis shows that although the design allowed for up to 550 EP from the proposed development, this was not allowed for in construction. Therefore additional emergency storage is required to satisfy PWC's design criteria.

Table 25. Analysis of Lyons Sewer Pump Station (SPS)

Parameter	Design	Requirement	Comment	Recommendation
Peak Design Flow	88 L/s	85 L/s	Projected design flow is below previous design. However, installed capacity is below design capacity.	
Design Capacity	61 L/s (Single Pump) 88 L/s (Projected Dual Pump)	85 L/s	Installed design capacity based on single pump capacity	Confirm pump arrangement. To accommodate peak design flow a duty/assist configuration would be required.
Emergency Storage Volume	290 m ³	305 m ³	Installed storages below original design requirement 315m ³	Install additional 15m ² of emergency storage. Additional redundancy may be included with provision of a hardstand for mobile generator for power outage.

6.2.3 Transport

A full Transport Impact Assessment (TIA) was conducted with the purpose of determining the overall impact of the development on the surrounding road network along with the performance of nearby intersections and the overall amenity of the area. The TIA has been prepared in accordance with the Austroads Guide to Traffic Management Part 12: Traffic Impacts of Development. A summary of the main findings of the report have been provided in the section below with the full reports available in Appendix .

6.2.3.1 Existing Traffic Conditions

The existing road network within the vicinity of the project site is limited, with the main road network formed by Lee Point Road located to the east and Buffalo Creek Road located to the north.

A direct count traffic survey for the access to Lee Point Village Resort was conducted by SMEC in March 2015 (SMEC 2015). The traffic surveys indicated that the AM and PM peak hours for the Lee Point Resort access road occurred from 7:30am – 8:30am and 5:45pm – 6:45pm, respectively. Traffic volumes at the Lee Point Road/Buffalo Creek Road intersection were estimated using the volumes collected for the Lee Point Resort access. The table below provides a summary of the existing traffic volumes.

Table 26. Traffic volumes for surrounding road network (SMEC 2015).

Location	Date	Average Two-way Traffic Volumes	
		Vehicles per AM Peak Hour	Vehicles Per PM Peak Hour
Lee Point Village Resort	March 2015	16	15
Buffalo Creek Road	March 2015	28	58

Location	Date	Average Two-way Traffic Volumes	
Lee Point Road (At Lee Point Village Resort)	March 2015	35	94
Lee Point Road (At Buffalo Creek Road)	March 2015	18	48

These traffic volumes indicate that congestion is not an issue in its current form for day-to-day operation. This is a result of low levels of development within the area with the only traffic generators being the Lee Point Village Resort, the beach at the northern end of Lee Point Road and the fishing spot at the western end of Buffalo Creek Road.

6.2.3.2 *Future Traffic Conditions (Post development)*

The proposed development at 2CRU is expected to generate approximately 753 vehicles (two-way) to and from the development during the peak hour periods. The Muirhead North development is expected to generate approximately 409 vehicles (two-way) during the AM peak period and 319 vehicles (two-way) during the PM peak to peak to period. The distribution of traffic to/from the 2CRU and Muirhead North has been determined based on the location of the site in relation to nearby employment/commercial areas and attractions. As the project site is located on the northern fringe of Darwin, it is assumed that the majority of traffic generated will likely travel south towards the Darwin Town Centre. A small percentage of traffic is expected to travel north to the Casuarina Coastal Reserve and Buffalo Creek boat ramp. In addition, vehicle trips between the Muirhead North and 2CRU sites have only been considered for the school and active recreation reserve land uses.

SIDRA Intersection 6.1 was used to evaluate the impact of the increased volumes anticipated for background and full buildout scenarios. SIDRA Intersection is a software package used to analyse the capacity and performance of road intersections. SIDRA outputs for each approach are presented in the form of Degree of Saturation (DOS), Average Delay, Level of Service (LOS) and 95th Percentile Queue. These characteristics are defined as follows:

- Degree of Saturation (DOS): is the ratio of the arrival traffic flow to the capacity of the approach during the same period. The Degree of Saturation ranges from close to zero for varied traffic flow up to one for saturated flow or capacity. The theoretical intersection capacity is exceeded for an un-signalised intersection where $DOS > 0.80$.
- 95% Queue: is the statistical estimate of the queue length up to or below which 95% of all observed queues would be expected.
- Average Delay: is the average of all travel time delays for vehicles through the intersection. An unsignalised intersection can be considered to be operated at capacity where the average delay exceeds 40 seconds for any movement.
- LOS: is the qualitative measure describing operational conditions within a traffic stream and the perception by motorists and/or passengers. The different levels of service can generally be described in the table below.

Table 27. Level of Service (LOS) descriptions

LOS	Description	Signalised Intersection	Unsignalised Intersection
A	Free-flow operations (best condition)	≤10 sec	≤10 sec
B	Reasonable free-flow operations	10-20 sec	10-15 sec
C	At or near free-flow operations	20-35 sec	15-25 sec
D	Decreasing free-flow levels	35-55 sec	5-35 sec
E	Operations at capacity	55-80 sec	35-50 sec
F	A breakdown in vehicular flow (worst condition)	≥80 sec	≥50 sec

The following intersections were analysed:

- Lee Point Road/Buffalo Creek Road
- Lee Point Road/Lee Point Village Resort
- Lee Point Road/Access Road 1
- Lee Point Road/Access Road 2
- Lee Point Road/Access Road 3.

A summary of the LOS outputs for 2CRU have been provided in the table below (Table 28). The results show that all intersections performed satisfactorily in the AM and PM peak periods for all analysis scenarios. For further details in regards to degree of saturation, 95% queue and average delay outputs, refer to the full TIA report for 2CRU (Appendix).

Table 28. Summary of Level of Service Outputs – 2CRU

INTERSECTION	LEVEL OF SERVICE (LOS)			
Intersection	2017 without development (AM/PM)	2027 without development (AM/PM)	2017 with development (AM/PM)	2027 with development (AM/PM)
Lee Point Road / Buffalo Creek Road	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Lee Point Village Resort	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 1	N/A	N/A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 2	N/A	N/A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 3	N/A	N/A	LOS A/LOS B	LOS A/LOS B

A summary of the LOS outputs for Muirhead North have been provided in the table below. For further details in regards to degree of saturation, 95% queue and average delay outputs, refer to the Muirhead North Transport Impact Assessment report (Appendix L). The results show that all intersections performed satisfactorily in the AM and PM peak periods for all analysis scenarios.

Table 29. Summary of Level of Service Outputs – Muirhead North

Intersection	Level of Service (LOS)			
Intersection	2019 without development (AM/PM)	2029 without development (AM/PM)	2019 with development (AM/PM)	2029 with development (AM/PM)
Lee Point Road / Buffalo Creek Road	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Lee Point Village Resort	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 1	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 2	LOS A/LOS A	LOS A/LOS A	LOS B/LOS A	LOS B/LOS A
Lee Point Road / Access Road 3	LOS A/LOS B	LOS A/LOS B	LOS B/LOS B	LOS B/LOS B
Lee Point Road / Access Road 4	N/A	N/A	LOS C/LOS C	LOS C/LOS C

6.2.3.3 Proposed Road Network Upgrades – 2CRU

The proposed development at 2CRU introduces several upgrades within the surrounding area which include the following:

- Three new accesses to the project site along Lee Point Road. The configuration of these accesses are as follows:
 - Lee Point Road/Access 1 – stop priority intersection
 - Lee Point Road/Access 2 – roundabout intersection
 - Lee Point Road/Access 3 – roundabout intersection
- An additional fourth access south of the project site connecting to Damabila Drive.
- Improved amenity for right turn movements along Lee Point Road with the construction of medians and right turn pockets at existing and proposed stop and give way priority intersections.
- Cycling lanes along both side of Lee Point Road, this includes lanes passing through the roundabouts.
- Shared/pedestrian footpaths along both sides of the road.
- A local road network providing access to the residential dwellings as shown in the Site plan (Figure 16).

The locations of the existing and proposed intersections near the project site are shown in Figure 17.



Figure 16. Internal road network – 2CRU



Figure 17. Existing and proposed access points – 2CRU

The timing for construction is intended to commence in the 2017 dry season and nominally one stage per year to be released. The staging and timing are subject to change due to the environmental approvals process and commercial assessment. It is likely that all transport related infrastructure listed above will be constructed alongside the development.

The road network, bus routes, pedestrian paths and bicycle paths will be constructed by the developer in conjunction with each stage of the development over a nominal 4 year period. The City of Darwin will be responsible for maintenance of the road and path network. Public bus services are provided by the NT Government. The proposed bus route is along the collector road on the western perimeter of the development.

The Northern Territory's public transport services are managed by the Department of Transport (DoT) and operated by a range of contractors. There are currently no public transport services along the section of Lee Point Road fronted by the proposed development. Future development within the area may create opportunities for new services or extensions of existing services towards the project site.

A bus route has been proposed by the DoT connecting with Lyons development along Damabila Drive and Coastal Esplanade.

There is currently no pedestrian and cycling infrastructure along the section of Lee Point Road fronted by the proposed development. The master plan promotes a sense of cycling, walkability and accessibility throughout the area. Shared pedestrian/cycling paths have been included in the illustrative master plan on the eastern boundary of the proposed site. The adjoining Casuarina Coastal Reserve Experience Development Plan (2015) has proposed the following:

- Construction of a new track from Lee Point through to Buffalo Creek allowing for visitors to ride or walk from Rapid Creek to Lee Point and onto Buffalo Creek.
- A mountain bike trail along the western boundary of the proposed development.¹

6.2.3.4 *Proposed Road Network Upgrades – Muirhead North*

The proposed development at Muirhead North introduces several road infrastructure upgrades which include the following:

- Upgrades along Lee Point Road expected to be completed during the construction of the 2CRU development
- Three new accesses to the Site along Lee Point Road. The configuration of these accesses are as follows (note Access 1 will not serve the Muirhead development, it is only for access to the 2CRU development):
 - Lee Point Road/Access 2 – addition of the eastern leg at the roundabout intersection
 - Lee Point Road/Access 3 – addition of the eastern leg at the roundabout intersection
 - Lee Point Road/Access 4 – new give way priority intersection
- An additional fourth access south of the Site connecting to an unnamed road.
- A local road network providing access to the residential dwellings as shown in the Site plan detailed below.

The locations of the existing and proposed intersections near the Muirhead development are shown in the figure below.

¹ The Northern Territory Department of Infrastructure, Planning and Logistics is proposing the construction of a mountain bike through Casuarina Coastal Reserve. DHA has discussed providing assistance to the project; however, the NT Government will be responsible for separate environment and planning approvals for the project.



Figure 19. Internal road network Muirhead North



Figure 18. Existing and proposed access points – Muirhead North

The Muirhead North development is intended to commence after the completion of the 2CRU development and nominally one stage per year to be released. The staging and timing are subject to change due to the environmental approvals process and commercial assessment. It is likely that all transport related infrastructure listed above will be constructed alongside the development.

The road network, bus routes, pedestrian paths and bicycle paths will be constructed by the developer in conjunction with each stage of the development over a nominal 4 year period. The City of Darwin will be responsible for maintenance of the road and path network. Public bus services are provided by the NT Government. The proposed bus route is along the collector road on the western perimeter of the development.

There are currently no public transport services along the section of Lee Point Road fronted by the Muirhead North development. Future development within the area may create opportunities for new services or extensions of existing services towards Muirhead North.

There is currently no pedestrian and cycling infrastructure along the section of Lee Point Road fronted by the Muirhead North development. The master plan promotes a sense of cycling, walkability and accessibility throughout the area. Shared pedestrian/cycling paths have been included in the illustrative master plan on the eastern boundary of the 2CRU development and on the western boundary of the Muirhead North development.

6.2.4 Power

The project will require 3.6 Megavolt amperes (MVA) of load to service 400 residential lots and the proposed commercial and neighbourhood precincts. This demand is likely to exceed the capacity of existing circuits for Muirhead and Lyons. It is understood that PWC is planning a Lee Point Zone substation that is expected to provide additional capacity to service the proposed development, and other future developments in the area.

Design of the internal High Voltage and Load Current reticulation will be undertaken once base supply has been determined.

6.2.5 Telecommunications

The proposed development will be serviced by the National Broadband Network (NBN Co). The rollout of services in the northern suburbs of Darwin has commenced. Compliant pit and pipe infrastructure will be provided as part of the development and will be designed in conjunction with electrical reticulation.

6.3 Risk Assessment

6.3.1 Risk assessment summary

A detailed risk assessment has been undertaken to identify the potential risks associated with the infrastructure requirements for the project (Appendix C). A summary of the risk assessment is presented below (Table 30), along with mitigation measures that have been identified to ensure future residents infrastructure needs are adequately met, safe use of roads and paths, and there is no impact to the wider community.

6.3.1.1 Sewerage discharge into Buffalo Creek

During the public exhibition period, further information was requested on the potential for further deterioration in the quality and health of Buffalo Creek due to increased effluent discharge. It is unlikely that any additional effluent discharged from the project would cause further decline in the quality and health of Buffalo Creek for the following reasons:

- Buffalo Creek is the most polluted tributary of Buffalo Creek and consistently fails water quality standards assessed as part of the Darwin Harbour water quality monitoring (see Figure 14).
- The project is likely to increase sewerage volumes by only 6% (i.e. 47,000 EPs pre-construction versus 51,000 EPs post-construction).
- The Leanyer Sanderson Wastewater Treatment Plant reduces pollutants discharging into Buffalo Creek including nitrogen (57% reduction), phosphorous (34%), ammonia (75%), biochemical oxygen demand (67%) and copper (94%) and a four order decrease in the prevalence of *E. coli*. The plant also has capacity of 72,000 EPs and therefore can treat the increase sewerage inflows from the project.
- Power and Water Corporation are responsible for ensuring discharge of treated sewerage into Buffalo Creek does not exceed the conditions of Water Discharge Licence WDL 147-08 (see Appendix U).. These conditions include ensuring no objectionable matter is discharge, no adverse odours are generated, and the health of flora and fauna dependent on the creek is maintained.
- In accordance with licence conditions for WDL 147-08, Power and Water Corporation are required to undertake fortnightly/monthly monitoring of water quality and submit periodic reports at the end of the wet season (June) and dry season (November), and notify the NT EPA of any non-compliance (see Appendix U)..
- In accordance with licence condition 38 of WDL 147-08, Power and Water Corporation must develop and implement a plan to conduct further investigations to characterise the risk to human health relating to algal toxins in aquatic fauna harvested from Buffalo Creek for human consumption (see Appendix U).
- In addition to the monitoring required by Power and Water Corporation, DHA will be undertaken independent studies of Buffalo Creek water quality (see Appendix O).

Table 30. Risk assessment summary for infrastructure requirements

Impact	Description	Mitigation measures
Sewerage – surface and groundwater	Sewer overflows from development caused by extreme weather events, including first flush and wet season influences	Lyons SPS - Capacity upgrade (by DHA) to buffer the inadequate emergency storage. LSWTP proposed augmentation (by PWC) has allowed for development load.
Sewerage disruption of service	Disruption of existing sewerage service with the provision of sewerage to the development	Lyons SPS - Capacity upgrade (by DHA) to buffer the inadequate emergency storage. LSWTP proposed augmentation (by PWC) has allowed for development load.
Sewerage capacity	Inadequate capacity and/or treatment of wastewater treatment facilities	PWC have advised that the Leanyer STP will be included in planned augmentations within the next five (5) years. Additional ponds are proposed to accommodate growth in the catchment. PWC future planning has accounted for projected loads from the development.
Potable Water – security of supply	Disruption of existing potable water supply with the provision of reticulated water to the development	Existing network - adequate. Ultimate network - proposed new service reservoir and booster pump station to service a small elevated area within the site (by DHA).
Potable Water – source water availability	Inadequate source water capacity	The proposed development is located within the Casuarina Water Supply Zone (WSZ), where water is supplied by the Marrara and Casuarina Reservoirs. Source water is obtained from the Darwin River Dam, which offers a secure water supply. There is a low risk of inadequate supply from this catchment.
Potable Water – capacity	Inadequate capacity and/or treatment of water treatment facilities	PWC have not identified or advised of any deficiency in regard to the provision of treated water within the supply network.
Traffic - Future Road Capacity	Traffic growth over a long period of time may result in the road network being unable to accommodate with the traffic demand.	The traffic analysis shows that the road network is able to accommodate the traffic demand 10 years after the completion of the development. However if additional developments are to be proposed within the area a separate traffic assessment is required to determine its impacts.
Traffic - Road Safety	Increased frequency of road accidents.	The design of roads and intersection will follow the relevant standards and guidelines.
Traffic Accessibility	Inconvenience for drivers.	Multiple Site accesses are available and are conveniently located.
Traffic – Wayfinding	Poor wayfinding and longer travel times for drivers.	Ensure appropriate wayfinding and signage strategies are implemented.
Traffic - Cyclist Safety	Increased risk of accidents and deters cyclists from riding due to perceived hazards.	Dedicated cycling infrastructure has been proposed along Lee Point Road.
Traffic - Pedestrian Safety	Increased risk of accidents.	Safe pedestrian infrastructure such as crossings and good quality paths shall be provided.
Traffic - Peak Period Traffic	Peak road network operation leading to increased congestion.	The traffic analysis shows that the road network is able to accommodate the peak period traffic without issues.

Impact	Description	Mitigation measures
Traffic - Traffic Speeds	Higher speed increase the risk and severity of accidents.	The speed limit is suitable for the surrounding environment. Lower speed limits should be applied to residential access roads and areas where a school is located.
Traffic - Heavy Vehicles Access	Accessibility constraints for heavy vehicles.	Road and intersection geometry to be capable of accommodate heavy vehicle turning movements.
Traffic - Public Transport	Over-reliance on private vehicular transport.	Explore potential opportunities to extend bus service to the 2CRU Site.
Traffic Construction	Road improvements on existing roads may lead to delays, congestion and overall inconvenience for other drivers.	Ensure that a construction traffic management plan is implemented during the construction phase.
Power supply	Power demand to exceed the available capacity within the network.	Consult with PWC to determine the timing of the Lee Point Zone substation.

6.3.2 Description of impacts and mitigation measures

6.3.2.1 Potable water

The assessment of the development for both the existing and ultimate potable water network identified that the supply to the surrounding community within the Casuarina Water Supply Zone can be maintained at all times. However, a new onsite service reservoir and booster pump station is required to service the development area. No further network augmentations are required to service the site. The identified infrastructure provides capacity for the ultimate development yield.

Headwork upgrades are required to service development above 28.0 m AHD.

Supply to existing properties in the vicinity of the network remains as per the current configuration, with no augmentation required.

6.3.2.2 Sewerage

The Leanyer Sanderson Water Treatment Plant has enough capacity to accommodate the existing 2,904 EP generate from the project (the plant has capacity for an additional 22,000 EPs). Minor upgrade works will be required to increase the capacity for the Lyons SPS. Additional EP loading to the Muirhead SPS will not exceed the capacity of the pumping station.

6.3.2.3 Traffic

As is common with many non-strategic roads (e.g. local roads, access roads), there is always a risk of infrequent congestion occurring due to extreme or unforeseen circumstances (e.g. extreme weather, road accident, traffic signal failure). The occurrence of these circumstances is extremely rare and unpredictable which makes it difficult to manage practically. Therefore the most effective method is to manage this on a case by case basis. Through this method, a database of mitigation measures can be accumulated for extreme cases which can be referenced to when similar congestion issues occur somewhere else.

Road safety is another residual risk which cannot be completely mitigated even when a road is well designed and meets standards. Driver judgement and behaviour plays an important role in this and is not easily changed.

The most effective method of managing this residual risk is to continually promote safe driving habits. Examples include ongoing media campaigns, driver education classes, promoting the dangers of drinking and driving and harsher consequences during public holiday periods (e.g. double demerit points).

Other road safety measures which could be implemented include the installation of traffic calming devices such as speed humps, slow points and roundabouts.

6.3.2.4 Power

The lack of capacity within the existing power grid to service the proposed development is likely to be addressed through the new Lee Point Zone sub-station which is scheduled for construction in 2017-2018. Ongoing consultation with PWC will ensure that the power requirement post construction can be achieved.

7 BIODIVERSITY AND HERITAGE

7.1 Introduction

This chapter addresses the biodiversity and heritage criteria of the ToR. Information has been collected from several sources, including biodiversity databases, previous surveys of the project site, field assessments and consultation with species' experts. The chapter is presented in the following structure:

- Section 7.2 – Existing Conditions. Details the pre-development biodiversity and heritage values found at the site, describes how the methods used as part of desktop and field studies confirm with Government guidelines.
- Section 7.3 – Risk Assessment. Identifies the key risks to biodiversity and heritage values based on the detailed risk assessment (Appendix C) and describes the avoidance and mitigation measures that are proposed in the CEMP (Appendix D) to reduce the level of risk to an acceptable level.
- Section 0 – Significant Impact Assessment. Describes the biodiversity impacts of the project in accordance with the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and the NT *Territory Parks and Wildlife Conservation Act* (TPWC Act), *Weed Management Act 2001* (WM Act) and *Aboriginal Sacred Sites Act*.

7.2 Existing Conditions

7.2.1 Background

The project site lies within the Darwin Coastal bioregion, which comprises gently undulating plains on lateritised Cretaceous sandstones and siltstones. Soils are sandy and loamy, red and yellow earths and siliceous sands. The most notable feature of the bioregion is the extensive and diverse floodplain environment associated with the lower reaches of the many large river systems. There are also extensive areas of mangroves, and rainforest and other riparian vegetation fringing the rivers. Inland from the coast the main vegetation type is eucalypt tall open forest, typically dominated by Darwin Woollybutt *Eucalyptus miniata* and Darwin Stringybark *Eucalyptus tetradonta*. The Darwin Coastal bioregion is not divided into sub-bioregions.

The project site occurs on land that slopes gently from undulating upland areas in the west (2CRU) to lowland coastal plains in the east (Muirhead North). The key landscape features of the site are:

- A known population of the threatened flora species – Darwin Cycad *Cycas armstrongii*.
- Suitable habitat for the endangered Black-footed Tree-rat *Mesembriomys gouldii gouldii*
- A low escarpment (a few metres high) that separates the project site from Casuarina Coastal Reserve.
- Sandy Creek, which lies adjacent to the project site and receives surface-water runoff from the site. Sandy Creek flows into Darwin Harbour at Casuarina Beach, which is considered to have international significance due to the number of migratory shorebirds it supports.
- A minor drainage line that flows through Muirhead North into a monsoon rainforest patch located towards the centre of the site, prior to discharge across the southern site boundary.
- Casuarina Coastal Reserve which directly adjoins the western boundary of 2CRU and protects 1,368 ha of coastal habitats between Rapid Creek and Buffalo Creek (of which 1026 ha are marine habitats). The reserve features 8 km of sandy beaches, as well as mangroves, Monsoon Vine-thicket and eucalypt woodlands. At high tide, migratory shorebirds roost near the mouth of Sandy Creek, and at low tide they forage in the inter-tidal zone of the reserve and surrounds.
- Military heritage items along Lee Point Road and Aboriginal stone scatters.

7.2.2 Survey summary

Between 2008 and 2016 there have been 15 desktop and field-related biodiversity and heritage studies across 2CRU and Muirhead North (Table 31). The methodologies used in these surveys are presented in Section 7.2.3 and the results are presented in Section 7.2.4.

Table 31. Biodiversity and heritage assessments undertaken within, or in the vicinity to the project site

Site	Survey type	Year	Source
Desktop assessments			
2CRU	Archaeological Sites Register, Australian Heritage Council heritage lists and Northern Territory Heritage Register.	2010	Begnaze Pty Ltd (2010)
Muirhead North	NT <i>Heritage Conservation Regulations 1999</i> , NT heritage register, register of the National Estate	2015	Ellengowan Enterprises (2016)

Muirhead North	Flora and fauna records, threatened species likelihood of occurrence	2008	VDM-EcOz (2008)
2CRU	Flora and fauna records, threatened species likelihood of occurrence	2010	GHD (2010)
Muirhead North and 2CRU	Updating flora and fauna records, threatened species likelihood of occurrence	2014	EcOz (2014)
Muirhead North and 2CRU	Updated Protected Matters Search	2016	DoE (2016)
Field assessments			
2CRU	Archaeological survey	2010	Begnaze Pty Ltd (2010)
Muirhead North	Archaeological survey	2015	Ellengowan Enterprises (2016)
Muirhead North	Flora, fauna and vegetation	2008	VDM-EcOz (2008)
2CRU	Ecology (baseline)	2010	GHD (2010)
Casuarina Beach/Sandy Creek	Shorebird counts of Sandy Creek	2013-16	Lilleyman (2016) – see Appendix N
Muirhead North	Vegetation mapping	2014	EcOz (2014)
Muirhead North and 2CRU	Cycad density mapping	2015	EcOz (2015)
Muirhead North	Rainforest hydrology review	2015	SMEC (2015)
Muirhead North and 2CRU	Targeted search for <i>Typhonium praetermissum</i>	2015 (Feb)	EcOz (2015)
Muirhead North and 2CRU	Black-footed Tree-rat camera trapping and habitat assessment	2016	EcOz (2016) – see Appendix M
Muirhead North and 2CRU	Recording of bat calls to detect Bare-rumped Sheath-tailed Bat	2015-16	Specialised Zoology (2015, 2016)

7.2.3 Methods

This section describes the survey methods undertaken to establish the ecology of the project site, determine the likelihood that threatened and migratory species are present, and to address any other information requirements of the EIS/PER.

7.2.3.1 Desktop assessment

Data sources

The biodiversity and heritage desktop studies that have been undertaken across the project site have used the following publically-available resources:

- Archaeological Sites Register held by the Department of Tourism and Culture.
- The Heritage list maintained by the Australian Heritage Council.
- The Northern Territory Heritage Register held by the Heritage Branch of the Department of Tourism and Culture.

- The EPBC Act Protected Matters Search Tool (PMST), an online tool managed by the Commonwealth Department of the Environment and the Environment (DoEE), which identifies the presence of likely presence of matters of National Environmental Significance (NES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The search area was based on a 5 km buffer from a centroid within the project site (-12.3457 130.8912) to ensure that all relevant matters of NES were included. In July 2016, EcOz acquired an up-to-date EPBC Protected Matters Search Report.
- The NT Department of Environment and Natural Resources (DENR) Flora and Fauna Atlas – a dataset of point location records for flora and fauna species (and other details) identified through biological surveys (either as validated observations or voucher specimens) conducted in the Northern Territory under a Wildlife Permit. This was applied over a tailored search area that covers the project footprint.
- The Atlas of Living Australia – an online enquiry tool containing information on all the known species in Australia aggregated from a wide range of data providers: museums, herbaria, community groups, government departments, individuals and universities. Australia-wide, it contains more than 50 million occurrence records based on specimens, field observations and surveys. This was applied over a tailored search area that covers the project footprint.
- Google Earth imagery to delineate potential vegetation communities for ground-truthing.
- *Conservation Values of the Parks and Reserves of the Greater Darwin Area Report* (Armstrong and Price 2007) – a report containing a list of the species recorded in Casuarina Coastal Reserve.
- The Atlas of Groundwater Dependent Ecosystems that displays the ecological and hydrogeological information on both known groundwater-dependent ecosystems and ecosystems that potentially use groundwater.

Threatened species' likelihoods

Following completion of the desktop assessment, the following procedure was used to determine the likelihood of occurrence of threatened species within the project site and adjoining areas that could potentially be impacted (i.e. Casuarina Beach), and thereby identify which species should be included for targeted field surveys:

- 1) Describe habitat types of the sites using land unit and vegetation mapping (refer to Section 7.2.4.2).
- 2) Tabulate all threatened species known to occur in the Darwin Coastal bioregion, along with any extra species identified in the EPBC Protected Matters Search Tool (DoEE 2016).
- 3) Eliminate from further assessment all species that have a very low likelihood of occurring within the project area – i.e. there is no suitable habitat and it is not expected that the species will pass through (because they are habitat specialists or have a restricted range), or they are extinct from the bioregion – as per Baker et al. (2005).
- 4) For the remaining species, apply and justify the likelihood of occurrence based on a combination of ecological knowledge of the area and species, and records from the NT Flora and Fauna Atlas, using the following categories:
 - Known – there are recent records of the species occurring within the footprint.

- Likely – core habitat for the species occurs within the footprint and there are recent records of the species occurring in the surrounding areas.
- May – core habitat for the species occurs within the footprint but there are no recent records of the species occurring within the footprint or in the surrounding areas.
- Unlikely – there is no core habitat for the species within the footprint and recent records of the species occurring within the footprint or in the surrounding areas.

The results of this assessment are presented in Section 7.2.4.3.

7.2.3.2 Field assessment

General flora and fauna survey

There have been two field studies undertaken to describe the general flora and fauna attributes of the site. Details of this study are provided in Table 32.

Table 32. Description of general flora and fauna surveys

Survey	Location	Date	Objectives	Survey techniques
VDM-EcOz (2008)	Muirhead North	8 – 11 December 2008	Determine the dominant flora. Undertake a comprehensive baseline fauna survey.	Two quadrats (50m x 50m) surveyed by a botanist in accordance with <i>Guidelines for the Terrestrial Biodiversity Component of Environmental Impact Assessment</i> (the relevant document at the time of the surveys). Both quadrats were also surveyed using 20 Elliot traps, 4 cage traps and 4 pitfall traps over 3 nights; as well as active searches, bird surveys and spot-lighting – in accordance with the abovementioned guidelines.
GHD (2012)	2CRU	20 August 2010	Describe the fauna diversity.	A combination of habitat assessments, standardised bird surveys, opportunistic fauna observations, records of wildlife traces, spotlighting and call-playback for nocturnal fauna, remote cameras and Anabat detectors.

Threatened ecological communities and vegetation-type survey

Two field studies have been undertaken to map the extent of vegetation communities and identify the presence of threatened ecological communities on the site. Consideration was given to relevant policy statements and listing advice when determining the presence of threatened ecological communities

In the NT vegetation can be classed as a ‘sensitive vegetation type’, which includes monsoon rainforest, riparian vegetation, mangrove, sandsheet heath and wetlands. These vegetation types are either unique to the region and/or have high biodiversity values. Sensitive vegetation types are considered significant under the *Northern Territory Land Clearing Guidelines 2009*.

Table 33. Description of vegetation type surveys

Survey	Location	Dates	Objectives	Survey techniques
GHD (2012)	2CRU	20 August 2010	Map the type and extent of vegetation communities.	The characteristics of vegetation communities were recorded using the NRETAS 'road notes' method (Brocklehurst <i>et al.</i> 2007) and the boundaries of the habitat types were ground-truthed where possible.
EcOz (2014)	Muirhead North	26 June 2014	Map the type and extent of vegetation communities.	Twenty representative vegetation sites were chosen within the lot boundary, and information was collected on the dominant flora species and structural formation. Sites were selected based on preliminary vegetation polygons that were created using high resolution aerial imagery and previous vegetation mapping of the Darwin municipality (Brocklehurst 1991)

Threatened species' survey

A preliminary threatened species 'likelihood of occurrence' assessment (using the methodology detailed in Section 7.2.4) identified that the following threatened species had a reasonable potential (i.e. Likely or Known) to occur on site or in areas that could potentially be impacted by the project, i.e. Sandy Creek, Casuarina Beach and Buffalo Creek:

- Two plant species
 - Darwin Cycad *Cycas armstrongii* (EPBC Act - not listed; TWPC Act - Vulnerable)
 - *Typhonium praetermissum* (EPBC Act not listed; TWPC Act – Vulnerable)
- Three marine turtle species
 - Olive Ridley *Lepidochelys olivacea* (EPBC Act – Endangered; TWPC Act – Vulnerable)
 - Green Turtle *Chelonia mydas* (EPBC Act – Vulnerable; TWPC Act – Near Threatened)
 - Flatback Turtle *Natator depressus* (EPBC Act – Vulnerable; TWPC Act – Data Deficient)
- Up to eight migratory shorebird species
 - Eastern Curlew *Numenius madagascariensis* (EPBC Act – Critically Endangered/Migratory; TWPC Act – Vulnerable)
 - Curlew Sandpiper *Calidris ferruginea* (EPBC Act – Critically Endangered/Migratory; TWPC Act – Vulnerable)
 - Bar-tailed Godwit subspecies *Limosa lapponica baueri* and *Limosa lapponica menzbieri* (EPBC Act – Vulnerable/Migratory; TWPC Act – Vulnerable)
 - Great Knot *Calidris tenuirostris* (EPBC Act – Critically Endangered/Migratory; TWPC Act – Vulnerable)
 - Greater Sand Plover *Charadrius leschenaultii* (EPBC Act – Vulnerable/Migratory; TWPC Act – Vulnerable)
 - Lesser Sand Plover *Charadrius mongolus* (EPBC Act – Endangered/Migratory; TWPC Act – Vulnerable)

- Red Knot *Calidris canutus* (EPBC Act – Endangered/Migratory; TWPC Act – Vulnerable)
- Asian Dowitcher *Limnodromus semipalmatus* (EPBC Act – Migratory; TWPC Act – Vulnerable)
- Three fish species
 - Dwarf Sawfish *Pristis clavata* (EPBC Act – Vulnerable; TWPC Act – Vulnerable)
 - Green Sawfish *Pristis zijsron* (EPBC Act – Vulnerable; TWPC Act – Vulnerable)
 - Freshwater Sawfish *Pristis microdon* (EPBC Act – Vulnerable; TWPC Act – Vulnerable)
- Two mammal species
 - Black-footed Tree-rat *Mesembriomys gouldii gouldii* (EPBC Act – Endangered; TWPC Act – Vulnerable)
 - Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus nudiclunatus* (EPBC Act – Vulnerable; TWPC Act – Near Threatened)

Targeted surveys for most of these species were undertaken to determine presence/absence and map suitable habitat. The methods undertaken in these targeted surveys are presented below.

Targeted surveys were not undertaken for several threatened/migratory species listed above for the following reasons:

- 1) For migratory shorebirds, there is sufficient data collected by shorebird experts as part of regional counts (summarised in Section 7.2.4.3 and presented in Appendix N).
- 2) For marine turtles, there is sufficient existing data. Casuarina Beach has been monitored by Parks and Wildlife for turtle nesting each year since the mid-1990's, with all nests being recorded from the 1999 season to present (Chatto and Baker 2008, Chatto pers. comm.).
- 3) Surveys for sawfish are difficult as these species have a very low detectability; most records come from the netting activities of fishermen (DSEWPAC 2011). It is more efficient to assume some sawfish species are occasionally present within the project footprint, and undertake a risk assessment accordingly.

Black-footed Tree-rat

Status

The Kimberley and mainland Northern Territory sub-species of Black-footed Tree-rat *gouldii* is listed as Endangered under the EPBC Act and Vulnerable under the TPWC Act.

Description and ecology

The Black-footed Tree-rat is a large (500 to 900 g), nocturnal rodent, that is restricted to open forests and woodlands near coastal areas in the Kimberley and the Northern Territory (Friend and Calaby 1995, Rankmore 2003). The species has a robust body with grizzly grey fur, and large black feet and ears (see Figure 20). The most distinctive feature is a long hairy tail, 30 to 40 cm long, that has a brush of white hairs at the end.

Black-footed Tree-rats forage on the ground and in trees, with an average home range in un-fragmented open forests of 67.3 ± 10.4 hectares and in fragmented habitat of 27.1 ± 8.4 ha (Rankmore 2006). They are predominantly frugivorous – preferring both fleshy and hard fruits and seeds, with Pandanus *Pandanus spiralis*

fruit a particular favourite (Friend and Calaby 1995). The diet also includes some invertebrates, flowers and grass (Morton 1992, Rankmore 2006, Rankmore and Friend 2008).

Being nocturnal, Black-footed Tree-rats prefer to nest in tree hollows during the day, but have also been recorded nesting in Pandanus where hollows are limited (Pittman 2003). The species prefers open forests and woodlands dominated by Darwin Woollybutt and Darwin Stingybark with a developed shrubby understorey (Friend and Taylor 1985, Friend 1987). A well-formed understorey with large diameter trees is typical of a low frequency or intensity of fires; and frequent, intense fires may be detrimental to this species by reducing the abundance of hollow-bearing large trees (Price et al. 2005).

Originally considered to be a solitary species (Friend 1987), evidence now suggests Black-footed Tree-rats are more gregarious. During a radio-tracking study of the species, the majority of radio collars removed were damaged through chewing, which could not be attributed to the collared individual (Rankmore pers. comm.). Moreover, recent camera trapping studies have frequently captured images of multiple individuals at a bait station (Brydie Hill, Flora and Fauna Branch of the NT DENR, pers. comm.).

Distribution

The Kimberley and mainland Northern Territory sub-species of Black-footed Tree-rat occur in the Top End of the Northern Territory and the Kimberley in the Western Australia (Hill 2012). Early distribution records from Eastern Arnhem Land and the Gulf of Carpentaria suggest that the species' distribution has contracted in the Northern Territory (Friend and Calaby 1995).

Threats

Declines in the population of Black-footed Tree-rat have been reported for the Kakadu area (Woinarski *et al.* 2001, Woinarski *et al.* 2010), and more broadly across the Top End of the Northern Territory (Ziembicki *et al.* 2013). The driver for this decline is unknown, but is thought to be related to changes in fire regime. In contrast to other parts of its range, the Black-footed Tree-rat may be relatively abundant in the Darwin rural area (Price et al. 2005). In an analysis of small mammals in the Darwin region from 2001 to 2014, Stokeld and Gillespie (2015) found that capture rates of Black-footed Tree-rat have been relatively consistent around Darwin, in comparison to most other species which had declined.



Figure 20. Black-footed Tree-rat (Brooke Rankmore 2016)

Survey methodology – presence

Because of the species' recent listing under the EPBC Act (the species was listed in June 2015), there are no Commonwealth-approved survey methods specifically for Black-footed Tree-rat. The *Survey Guidelines for Australia's Threatened Mammals* (DSEWPac 2011) presents an overview of survey techniques to detect medium-sized ground-dwelling mammals. Advice on minimum sampling requirements was also sought from the NT DENR. It was advised that a suitable survey methodology should be based on the use of camera traps as Black-footed Tree-rat is likely to have a high detectability on camera traps (e.g. Stokeld and Gillespie 2015). The NT DENR recommended that the methodology should include one site per 20 ha of suitable habitat, with one camera installed per site for 4 weeks. As the survey site is located on the edge of suburban Darwin, there is a high level of people utilising the area for recreational activities and as an itinerant camping site.

A survey methodology was designed and implemented by EcOz (2016) that complied with the *Survey Guidelines for Australia's Threatened Mammals* (DSEWPac 2011) and the advice provided by NT DENR. Twenty-four cameras were installed across 20 sites, of which eight cameras were installed at 2CRU and sixteen cameras were installed at Muirhead North. To reduce interference and theft of camera traps the number of cameras per unit area was increased to reduce the length of survey required to four days/nights. This approach was discussed with NT DENR before proceeding. In total there were 96 camera trap days with 32 camera trap days for 2CRU and 64 camera trap days for Muirhead North. The greater intensity of survey effort at Muirhead North reflected greater availability of suitable habitat for Black-footed Tree-rat then at 2CRU.

Camera installation was based on Gillespie et al. (2015), with reference to Meek and Fleming (2014). Cameras were predominantly located in areas that were considered likely habitat for Black-footed Tree-rats (abundance of mid-storey fruiting trees, and/or large hollows in Darwin Stringybark and Darwin Woollybutt and were also located to give a spread across the project area.

In addition to camera trap surveys, ecologists kept a look-out for chewed Pandanus seeds (EcOz 2014, 2016), which are a useful indicator of the presence of Black-footed Tree-rat.

Survey methodology – habitat assessment

Using vegetation mapping (i.e. GHD 2012, EcOz 2014) and field observations of the location and extent of Gamba Grass *Andropogon gayanus* infestations – the project site was divided into broad categories of Black-footed Tree-rat habitat quality. Thirteen sites were selected to undertake on-ground habitat quality assessment of which three sites were located within 2CRU and ten site were located in Muirhead North. Sites were selected to provide replication across the broadly-defined habitat quality categories and to provide a spread across the project site. As 2CRU comprised recently burnt and/or low diversity vegetation, less detailed habitat assessments were undertaken than at Muirhead North.

Three key habitat criteria were selected to measure the quality of habitat available for Black-footed Tree-rat:

- Presence and availability of denning/nesting sites – measured by the number of large trees, number of hollows observed, and presence of Pandanus.
- Presence of plant species known to be food resources for Black-footed Tree-rat.
- Density and composition of ground cover and grassy weed cover (high-density ground-cover restricts the mobility of Black-footed Tree-rat).

Each habitat survey site was ranked out of a score of three, with the highest quality habitat onsite receiving a score of three and the poorest quality habitat a score of zero. To receive a habitat quality score of three, the site had to have many large trees with hollows present and/or the presence of Pandanus, known food plants present at the site, and lower levels of ground cover and limited invasion by grassy weeds.

While ranking the sites provides information on the distribution and quality of habitat within the site, it does not inform how the habitat compares in a broader context. Using expert knowledge of Black-footed Tree-rat habitat requirements, habitat quality categories were developed using a scale of one to ten (with ten the highest possible quality). The habitat at the site was then compared against these broader habitat quality categories.

Table 34. Survey methodology for Black-footed Tree-rat

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
<i>Guidelines for the Terrestrial Biodiversity Component of Environmental Impact Assessment</i> (the relevant document at the time of the surveys)	EcOz (2008) in Muirhead North only as part of a baseline fauna survey.	Two sites using 20 Elliot traps and 4 cage traps over 3 nights; as well as active searches and spot-lighting	3 nights	Survey complied with guidelines; however, subsequent studies for Black-footed Tree-rat (i.e. Stokeld and Gillespie 2015) indicates a more intensive survey effort using camera traps is required to detect Black-footed Tree-rat.

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
Survey Guidelines for Australia's Threatened Mammals (DSEWPaC 2011) Interim advice provided by DENR (Brydie Hill)	EcOz (2016)	Camera trapping and habitat quality assessment	96 camera trap days	Yes (the species was detected at Muirhead North)

Bare-rumped Sheath-tail Bat

Status

The Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus* is listed as Vulnerable under the EPBC Act and Data Deficient under the TPWC Act.

Description and ecology

The Bare-rumped Sheath-tailed Bat is a microbat with reddish-brown to dark brown fur that has white flecking. Specimens in the NT often lack a pronounced bare rump.

This is a nocturnal, high-flying species that feeds predominantly on insects using echo-location techniques. It is known to roost during the daytime in hollow trees and has been found in Pandanus woodland, eucalypt forests/woodlands, rainforests and caves (Friend and Braithwaite 1986, Churchill 1998, Duncan et al. 1999). Little is known about other behavioural aspects such as home range, preferred foraging height (although it is thought to forage for insects at, or above, the canopy level), seasonal activity and breeding.

Distribution

The Bare-rumped Sheath-tailed Bat is widely distributed from India through south-eastern Asia to the Solomon Islands, including north-eastern Queensland and the Northern Territory. The north-eastern Australian population is described as the subspecies *Saccolaimus saccolaimus nudicluniatus*, although it is not clear whether this should be applied to the NT population which is currently known as *Saccolaimus saccolaimus saccolaimus* (Milne et al. 2009). Within the NT this species is known from a few records from Pandanus woodland and eucalypt tall open forests (Friend and Braithwaite 1986, Churchill 1998, Milne et al. 2009) where it roosts in tree hollows and caves (Duncan et al. 1999). The most recent local records of this species came from Howard Springs in December 2006, where a dead tree containing a colony of about 100 individuals was blown over during a storm (Milne et al. 2009). This colony is considered highly significant as it is the only known roost site in the NT, and contained neonates and juveniles (Milne et al. 2009).

Threats

As the distribution, habitat preferences and biology of the Bare-rumped Sheath-tailed Bat are poorly known, the identification of known and likely threats facing this species are incomplete (DoE 2015). Habitat loss is identified as a threat; particularly as it relates tree hollow availability. There is a recovery plan for this species (Schulz and Thompson 2007).

Survey methodology

The following survey method for Bare-rumped Sheath-tailed Bat is based on information presented in the *Survey Guidelines for Australia's Threatened Bats* (DEWHA 2010). For previous surveys for this species by

ecological consultants EcOz in the Darwin region, advice has been sought from experts (Damian Milne of DENR and Dr Kyle Armstrong of Specialised Zoological) to design a survey program that provides the optimal opportunity for detecting this species.

Bare-rumped Sheath-tailed Bat is difficult to detect due to the high-flying nature of this species (which complicates capture in mist or harp nets) and that calls of this species are similar to the more common species Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris*. Recent advances in the use of broadband bat detectors for distinguishing calls of Bare-rumped Sheath-tailed Bat have greatly increased the capability of detecting this species (Dr Kyle Armstrong, Specialised Zoological pers. comm.). Additionally, Dr Kyle Armstrong has created a set of criteria to attribute indicative and diagnostic call types related to Bare-rumped Sheath-tailed Bat.

Surveys were carried out 15 May 2015 at 2CRU and 25 July 2016 at Muirhead North by Specialised Zoological and EcOz. The following techniques were conducted to detect the species and to identify the extent of its potential occurrence throughout the project site

- Target habitat. Land unit and vegetation maps were inspected to identify potential roosting areas, which for this project area was identified as open forest with Darwin Woollybutt where hollows were abundant. Therefore, the entire project site was assumed to be potential foraging habitat for the species.
- Acoustic detection. Wildlife Acoustics SM2BAT+ bat detectors were used to record bat calls within the project site, and were programed to optimise the chance of detecting the Bare-rumped Sheath-tailed Bat. Detectors were set to automatically record between sunset and sunrise. Four sites were surveyed for one night each. Site selection was focused on Darwin Woollybutt forest.
- Analysis of calls. The recordings were analysed using specialised software (SCAN'R version 1.7.7 – Binary Acoustic Technology) by Specialised Zoological. This was then compared to representative and reference calls from northern Australia. Species were identified based on accepted literature (i.e. Milne 2002, Van Dyck *et al.* 2013, Reardon *et al.* 2015) and unpublished reference calls (Dr Kyle Armstrong pers. comms.).

Table 35. Survey methodology for Bare-rumped Sheath-tailed Bat

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
Survey Guidelines for Australia's Threatened Bats (Commonwealth of Australia 2010) Advice from experts (Damian Milne of NT DENR and Dr Kyle Armstrong of Specialised Zoological)	Specialised Zoology (2015, 2016)	Acoustic detection using Wildlife Acoustics SM2BAT+ bat detectors.	4 nights	Yes – this methodology is in line with that previously accepted for similar projects.

Migratory shorebirds

Status and ecology

The Darwin region supports a high diversity of migratory shorebirds. There have been 25 migratory shorebird species recorded within the Darwin Harbour region, of which eight are also listed as threatened under the EPBC Act (Table 36).

Most shorebirds in Australia are long-distance migrants that breed in the northern hemisphere and visit Australian shores in their thousands in the austral summer. On arrival in Australia, shorebirds spend the duration of the summer seeking out high-quality food resources on the intertidal zone of coastlines. Tidal cycles dictate foraging and roosting times for most coastal shorebirds that feed on exposed mudflats during low tide. At high tide, when the foraging grounds are submerged, shorebirds retreat to roosts on sandy beaches, mangroves, rocky reefs and ponds, where they typically rest.

Distribution

The shorebirds that occur in Darwin Harbour also occur in suitable habitat throughout Australia, although the abundances of some species are higher in the tropics.

Threats

Migratory shorebirds are a highly threatened group of birds. In the East Asian-Australasian Flyway these birds are rapidly declining largely due to the loss of intertidal habitat through reclamation development projects in the Yellow Sea region (MacKinnon *et al.* 2012, Moores *et al.* 2016, Murray *et al.* 2014). They also face threats such as hunting, impacts from climate change and sea-level rise, pollution and disturbance (Harding *et al.* 2007). In Australia, the key threats to migratory shorebirds are coastal development that destroys habitat and disturbance that disrupts their normal activities (Harding *et al.* 2007).

Survey methodology

Information on migratory shorebirds presence adjoining Sandy Creek along Casuarina Beach was compiled by Lilleyman (2016) as part of a broader study of the Darwin harbour. Data was collected between 2013 and 2016. Data collected by Lilleyman (2016) for the Sandy Creek area is considered more comprehensive than previous survey work undertaken as part of the Shorebirds 2020 program (Figure 21). The survey methodology used for the collection of the dataset is described in detail in Appendix N and is more than adequate to meet the requirements of the EPBC Act Policy Statement 3.21 – *Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (DoE 2015b).

Table 36. Migratory shorebird species that have been recorded in Darwin Harbour

Common name	Scientific name	EPBC Act	TPWC Act
Pacific Golden Plover	<i>Pluvialis fulva</i>	-	-
Grey Plover	<i>Pluvialis squatarola</i>	-	-
Little Ringed Plover	<i>Charadrius dubius</i>	-	-
Lesser Sand Plover	<i>Charadrius mongolus</i>	EN	VU
Greater Sand Plover	<i>Charadrius leschenaultii</i>	VU	VU

Common name	Scientific name	EPBC Act	TPWC Act
Oriental Plover	<i>Charadrius veredus</i>	-	-
Black-tailed Godwit	<i>Limosa limosa</i>	-	-
Bar-tailed Godwit (Northern Siberian sub-species)	<i>Limosa lapponica menzbieri</i>	CR	VU
Bar-tailed Godwit (Western Alaskan sub-species)*	<i>Limosa lapponica baueri</i>	VU	VU
Little Curlew	<i>Numenius minutus</i>	-	-
Whimbrel	<i>Numenius phaeopus</i>	-	-
Eastern Curlew	<i>Numenius madagascariensis</i>	CR	VU
Terek Sandpiper	<i>Xenus cinereus</i>	-	-
Common Sandpiper	<i>Actitis hypoleucos</i>	-	-
Grey-tailed Tattler	<i>Tringa brevipes</i>	-	-
Common Greenshank	<i>Tringa nebularia</i>	-	-
Marsh Sandpiper	<i>Tringa stagnatilis</i>	-	-
Wood Sandpiper	<i>Tringa glareola</i>	-	-
Ruddy Turnstone	<i>Arenaria interpres</i>	-	-
Asian Dowitcher	<i>Limnodromus semipalmatus</i>	-	VU
Great Knot	<i>Calidris tenuirostris</i>	CR	VU
Red Knot	<i>Calidris canutus</i>	EN	VU
Sanderling	<i>Calidris alba</i>	-	-
Red-necked Stint	<i>Calidris ruficollis</i>	-	-
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	-	-
Curlew Sandpiper	<i>Calidris ferruginea</i>	CR	VU

* The two subspecies of Bar-tailed Godwit are known to occur in the Darwin region but were not distinguished during the 2013-2016 surveys. Subspecies *menzbieri* is considered more common.

Table 37. Survey methodology for migratory shorebirds

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species (DoE 2015b)	Lilleyman (2016)	High tide roost surveys by an experienced surveyor	55 counts (Sandy Creek)	Yes – presence, abundance and behaviour all determined

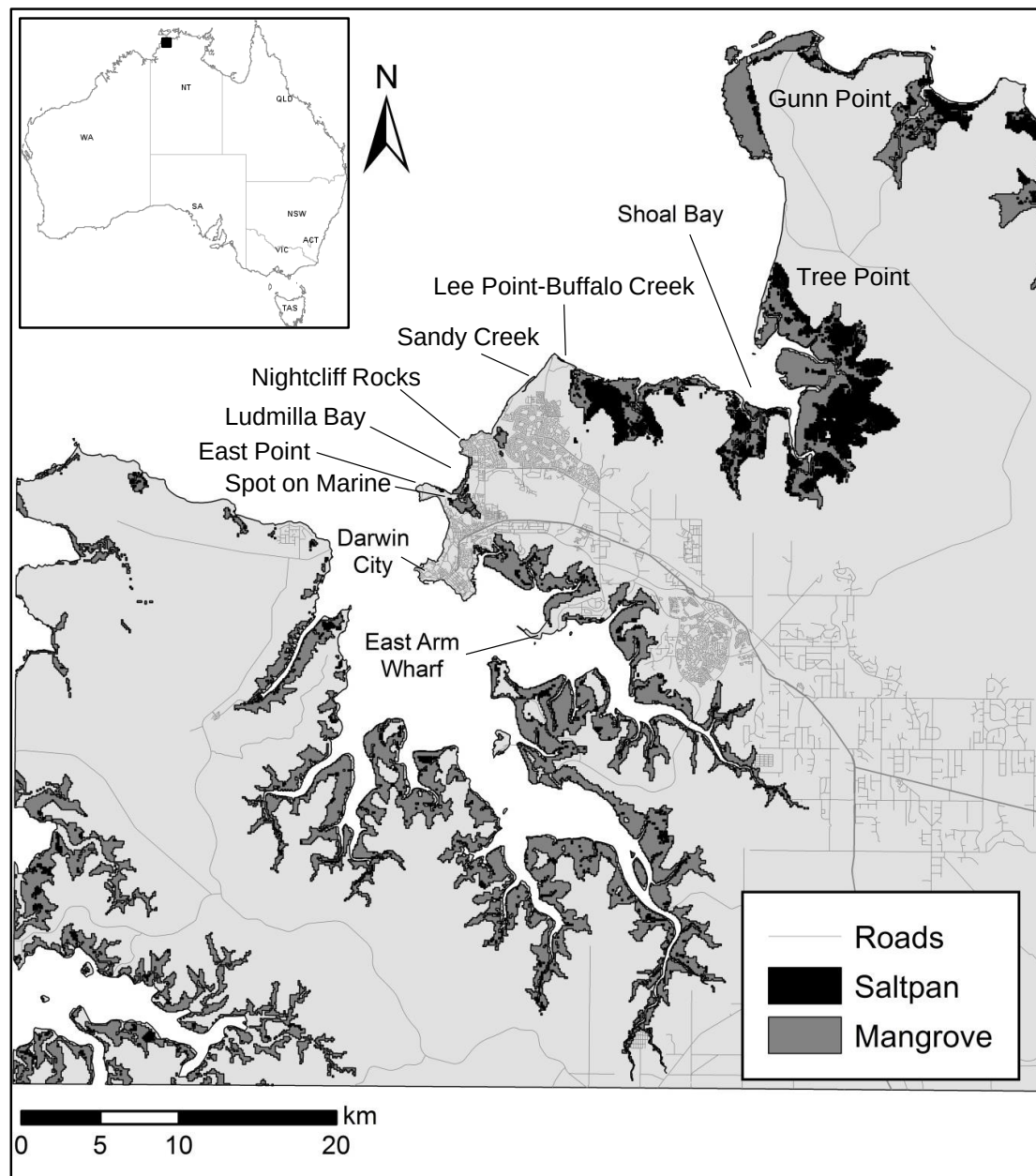


Figure 21. Map of the monitored shorebird roosting and feeding sites in the Darwin Harbour region (reproduced from Lilleyman 2016)

Darwin Cycad

Status

The Darwin Cycad is classified as Vulnerable under the TPWC Act, and is not listed under the *EPBC Act*.

Description and ecology

This species is a small to medium-sized cycad with a slender trunk (Kerrigan *et al.* 2006) – Figure 22.

The species occurs in open grassy woodlands where adequate draining appears to be a limiting factor (Kerrigan *et al.* 2006), and on rocky outcrops, undulating hills and plains (Holmes *et al.* 2005). Prime cycad habitat has deep loamy, well-drained soil, and the species is frequently associated with Darwin Woollybutt and Darwin Stringybark (Liddle 2009).

Distribution

The Darwin Cycad is endemic to the Top End – with abundant populations occurring throughout the greater Darwin region, often forming dense stands (Kerrigan *et al.* 2006). Current distribution of the species extends from the Adelaide River west to the Finnis River and south to the township of Adelaide River, with patchy occurrences further south to Hayes Creek. Additional populations also occur on the Tiwi Islands and Cobourg Peninsula (Kerrigan *et al.* 2006).

Threats

The main threats associated with this species are land clearing for urban development in Darwin, horticulture, agriculture and forestry. The species' prime habitat comprises deep, loamy soil which is considered suitable for horticulture and agriculture (Kerrigan *et al.* 2006). Altered fire regime and introduced perennial grasses also appear to be threatening processes (Kerrigan *et al.* 2006). Although the Darwin Cycad is locally abundant in the Darwin region, long-term conservation has to be considered as the species is long-lived, has a slow reproductive rate and a localised distribution (Liddle 2009). Moreover, less than 1 % of the Darwin Cycad population is included in conservation reserves.



Figure 22. Photograph of a Darwin Cycad

Survey methodology

EcOz (2015) assessed cycad density within the proposed development area based on habitat mapping and field observations, and assigned each land unit a density class:

- None
- Low (less than 1 plant per 75 m²)
- Moderate (between 1 plant per 25 m² and 1 plant per 50 m²)
- High (greater than 1 plant per 50 m²).

Table 38. Survey methodology for Darwin Cycad

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
None	EcOz (2015)	Desktop density mapping using observed associations in the field between land units and abundance.	N/A	Yes – this methodology is in line with that previously accepted for similar projects by NT DENR.

Typhonium praetermissum

Status

The species is listed as Vulnerable under the TPWC Act. It is not listed under the EPBC Act.

Description and ecology

Typhonium praetermissum is a small, herbaceous geophyte (Holmes *et al.* 2005) – Figure 23. The species is seasonally-dormant, emerging annually from underground tubers, bulbs or corms (Cowie and Westaway 2012). Fruits occur at ground level and, in some cases, are found partially underground. Fruiting takes place during the beginning of the wet season between November and January (Holmes *et al.* 2005), which constitutes the best time for the species' detection. Field identification is often difficult due to the very short flowering period. Most *Typhonium praetermissum* plants are sterile when encountered and leaf material must be collected for correct identification using DNA analysis (Cowie and Westaway 2012).

Suitable habitat for *Typhonium praetermissum* is open woodland in soil types ranging from red-brown, clay soil to shallow or gravelly lateritic soil, either on the plateau edge or bordering with sandsheet and drainage areas, which occur in localised areas in lowlands (Cowie and Westaway 2012).

Distribution

Typhonium praetermissum is endemic to the Top End. It has been recorded in at least eight locations within the Darwin-Litchfield region including Virginia, Karama, the Palmerston escarpment, Holtze, Mandorah, Lloyd Creek and Humpty Doo (Cowie and Westaway 2012). Only a small number of populations have been found within these areas, and most are located in areas suitable for rural or residential development (Cowie and Westaway 2012).

Threats

Current populations are vulnerable to impacts from habitat loss and fragmentation due to development of the greater Darwin region (Cowie and Westaway 2012). Invasive weed species that out-compete post-fire regeneration and altered fire regimes also pose a threat (Cowie and Westaway 2012).



Figure 23. *Typhonium praetermissum* (David van der Hoek, 2015)

Survey methodology

There are no formalised survey guidelines available for *Typhonium praetermissum*. To inform previous surveys of this species, EcoZ has consulted with the NT Herbarium (Ian Cowie) and DENR (David Liddle) about an optimal methodology. The advice of those experts informed the survey for this development. It was decided that surveys within the project area should take place on the edges of Eucalypt woodlands with potentially suitable habitat, and in similar habitat bordering on drainage areas.

Surveys for *Typhonium praetermissum* were conducted within the project area on 18 February 2015 by EcoZ (2015). The surveys were not aligned with the fruiting period for this species; however, leaf samples would be collected for identification via DNA analysis.

Reference was also made to this species' 'Known Extent of Occurrence' map recently produced by the Flora and Fauna Division of DENR (DENR 2015), which includes known records, confirmed absences and potential habitat.

Table 39. Survey methodology for *Typhonium praetermissum*

Survey guidelines	Survey completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
Advice provided by NT Herbarium (Ian Cowie) and DENR (David Liddle).	EcOz (2015)	Transect undertaken by a botanist experienced in assessing habitat suitability for this species.	1 day	Yes – this methodology is in line with that previously accepted for similar projects.

Archaeological survey

Separate archaeological surveys were completed for 2CRU and Muirhead North. The archaeological survey for 2CRU was completed by Begnaze Pty Ltd (2010) to locate and record any archaeological objects or places and comply with the objects of the *Northern Territory Heritage Conservation Act 1999*, EPBC Act and *Environment and Heritage Legislation Amendment Act (No 1) 2003*.

The survey involved a qualified archaeologist working transects 50 metres apart searching for:

- Artefact scatters which may contain flaked or ground artefacts and hearthstones. They occur as surface scatters of materials or as stratified deposits when they have been prepeated occupations.
- Stone arrangement which range from simple cairn to more elaborate arrangements. These stone arrangements were used in ceremonial activities and represent sacred or totemic sites. Other stone arrangements were constructed for route or territory markers, the walls of huts, fish traps or small walls to stop water from entering a rock shelter or retain the floor.
- Stone quarries are generally sites where stone for flaked or edge ground artefacts have been extracted from an outcropping source of rock.
- Knapping sites are discrete scatters of artefacts consisting of the remains of a single reduction event associated with the fabrication of implements.
- Shell middens contain mollusc material in the form of surface scatters or mounded deposits and represent the remains of human meals.

The archaeological survey for Muirhead North was completed by Ellengowan Enterprises (2016). The purpose of the assessment was to:

- Identify and prescribed archaeological object or places as defined under the *Northern Territory Heritage Act 2012*, and any archaeological sites located within the survey area.
- Assess the nature, distribution and significance of these objects or places and discuss possible constraints to the works posed by the presence of archaeological and historic sites and an indication of what sites are likely to the most sensitive in this respect.

The study included a review of the National Trust heritage register, the Register of the National Estate, and places and objects prescribed under the *NT Heritage Conservation Regulations 1999*. A field survey was conducted on 31 May 2015, by walking along tracks, laterite ridges and creek banks and walking transects through areas of open field.

Table 40. Survey methodology for archaeology

Site	Survey guidelines	Survey completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
2CRU	Based on past survey techniques approved by regulatory authorities.	Begnaze Pty Ltd (2010)	Transect survey undertaken by experienced archaeologist.	1 day	Yes – sufficient effort to identify any sites of heritage significance.
Muirhead North	Based on past survey techniques approved by regulatory authorities.	Ellengowan Enterprises (2016)	Transect survey undertaken by experienced archaeologist.	1 day	Yes – sufficient effort to identify any sites of heritage significance.

7.2.4 Results

7.2.4.1 General flora and fauna

The *Conservation Values of the Parks and Reserves of the Greater Darwin Area Report* (Armstrong and Price 2007) contains a list of the flora and fauna species recorded in Casuarina Coastal Reserve. It is considered that this list, combined with the results of desktop and field surveys, is indicative of the species suite for the project site and surrounds, given that analogous habitats are present.

The flora and fauna assemblages identified from desktop and field surveys are largely typical of those found in the savannah woodlands of tropical Australia, albeit somewhat depauperate due to the high degree of weed infestation and fire frequency across the project area. Although much of the area proposed for development has evidently experienced burning at a high frequency, the small-scale of this burning means it does not show up on Northern Australia Fire Information (NAFI) fire mapping.

There have been no systematic surveys of the marine and aquatic environments that occur around the project site, i.e. Sandy Creek, Buffalo Creek and Casuarina Beach. There are; however, some species records for the marine environment and these are discussed in the relevant sub-sections of Sections 7.2.4.3.

Weeds and pest animals

Three exotic fauna species have been recorded within the project site. One dog *Canis familiaris* was photographed by a remote camera. Cane Toads *Rhinella marina* are common in the area. The Asian House Gecko *Hemidactylus frenatus* was heard and is likely to be ubiquitous, especially given the project site's proximity to urban areas.

Weeds are widespread across the project site, although weed infestations are more extensive at 2CRU, and are most prevalent along tracks and in previously cleared and disturbed areas. Grassy weeds make up the majority of the weed impact – particularly Gamba Grass and Mission Grass *Cenchrus polystachios*. These two species are declared under the NT WM Act as Class A (to be eradicated) and Class B (to be controlled), respectively. Gamba Grass is also a Weed of National Significance (WoNS). Hyptis *Hyptis suaveolens* and Snakeweed *Stachytarpheta* spp. are also Class B weeds and have been recorded in the project area.

Non-declared weed species recorded in the project area include:

- Red Natal Grass *Melinis repens*
- Purple Top Chloris *Chloris inflata*
- Wild Passion Fruit *Passiflora foetida*
- Stylos *Stylosanthes* sp.
- Centro *Centrosema molle*
- Calopo *Calopogonium mucunoides*
- Coffee Bush *Leucaena leucocephala*.

The majority of these introduced plants are located along the highly disturbed boundaries of the sites.

7.2.4.2 Threatened ecological communities and vegetation types

The project area contains a mix of remnant and regenerated vegetation communities that are common in the Top End; however, not all are well-represented in the Darwin area because of previous clearing for urban development.

GHD (2010) identified five vegetation communities within the project site:

- Monsoon vine forest² (20.6 ha)
- *Eucalyptus tetradonta* woodland (11.7 ha)
- Low *Eucalyptus tetradonta* woodland (15.6 ha)
- Disturbed *Eucalyptus tetradonta* woodland with *Calytrix exstipulata* shrubland (28.1 ha)
- Disturbed *Acacia auriculiformis* woodland with grassy weeds (2.9 ha).

EcOz (2014) identified eight vegetation communities within the Muirhead North site:

- Dry monsoon rainforest (mixed species) (0.88 ha)
- *Eucalyptus tetradonta* and *Eucalyptus miniata* open forest with *Sarga intrans* and *Heteropogon contortus* grassland understorey (9.3 ha)
- *Eucalyptus tetradonta* open woodland with *Sarga intrans* grassland understorey (5.0 ha)
- *Eucalyptus sp.* and *Corymbia sp.* open woodland (mixed species) over introduced grasses (5.0 ha)
- *Melaleuca viridiflora* woodland over introduced grasses (7.0 ha)
- *Lophostemon lactifluus* and *Pandanus spiralis* Woodland over *Sarga intrans* and introduced grasses (11.6 ha)
- *Acacia* shrubland with scattered *Eucalyptus tetradonta* over introduced grassland (8.4 ha)
- Grassland (introduced species) (3.7 ha).

The Atlas of Groundwater Dependent Ecosystems indicates that portions of the project site mapped as supporting Monsoon Vine-thicket and Eucalypt woodland have a moderate to high potential for groundwater interaction (Figure 27).

² This is better described as monsoon vine thicket given the low canopy height of 7 m and dense shrub layer.

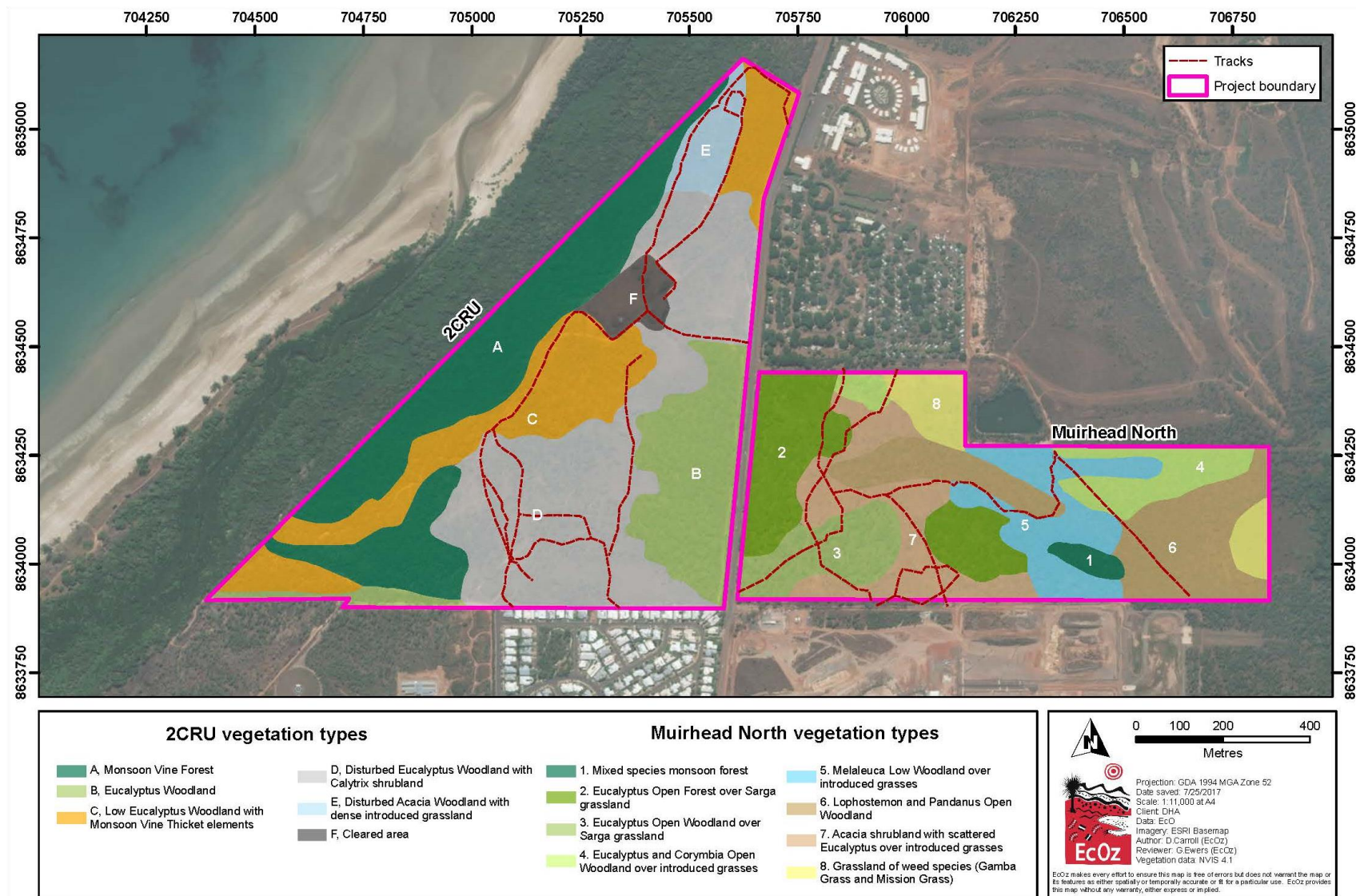


Figure 24. Map of vegetation communities within the project site

Environment Protection and Biodiversity Conservation Act 1999

No ecological communities listed as threatened under the EPBC Act were recorded on the project site (GHD 2010, EcOz 2014). Furthermore, the PMST does not predict the presence of any listed ecological communities within the project area (DoE 2016).

Northern Territory

The *Map of Remnant Vegetation Darwin Municipality* compiled by Brock (1995) identified monsoon vine thicket on the western edge of 2CRU and a small patch of monsoon forest centrally located within Muirhead North. Field surveys confirmed the existence and extent of this sensitive vegetation type – Figure 25.

The 2CRU site contains 20.6 ha of Monsoon Vine-thicket (canopy to 7 m) on the western side that adjoins the vine-thicket community within Casuarina Coastal Reserve. There is an isolated patch of monsoon rainforest (canopy 15 to 20 m) present in Muirhead North. Although small (0.88 ha), this patch is significant because its structure and the species present (especially the presence of native palms) resemble the spring-fed rainforests of Holmes Jungle and Howard Springs; however, no permanent freshwater is evident. The monsoon rainforest patch is fed by a seasonal drainage line that transects the lot from the north-west to south-east. This seasonal watercourse would appear to have a role in providing the water required to sustain the species of plants within the patch. This onsite vegetation is considered to be of high ecological value because of its limited distribution in the greater Darwin region.



Figure 25. Monsoon Vine-thicket (2CRU)



Figure 26. Monsoon Rainforest (Muirhead North)

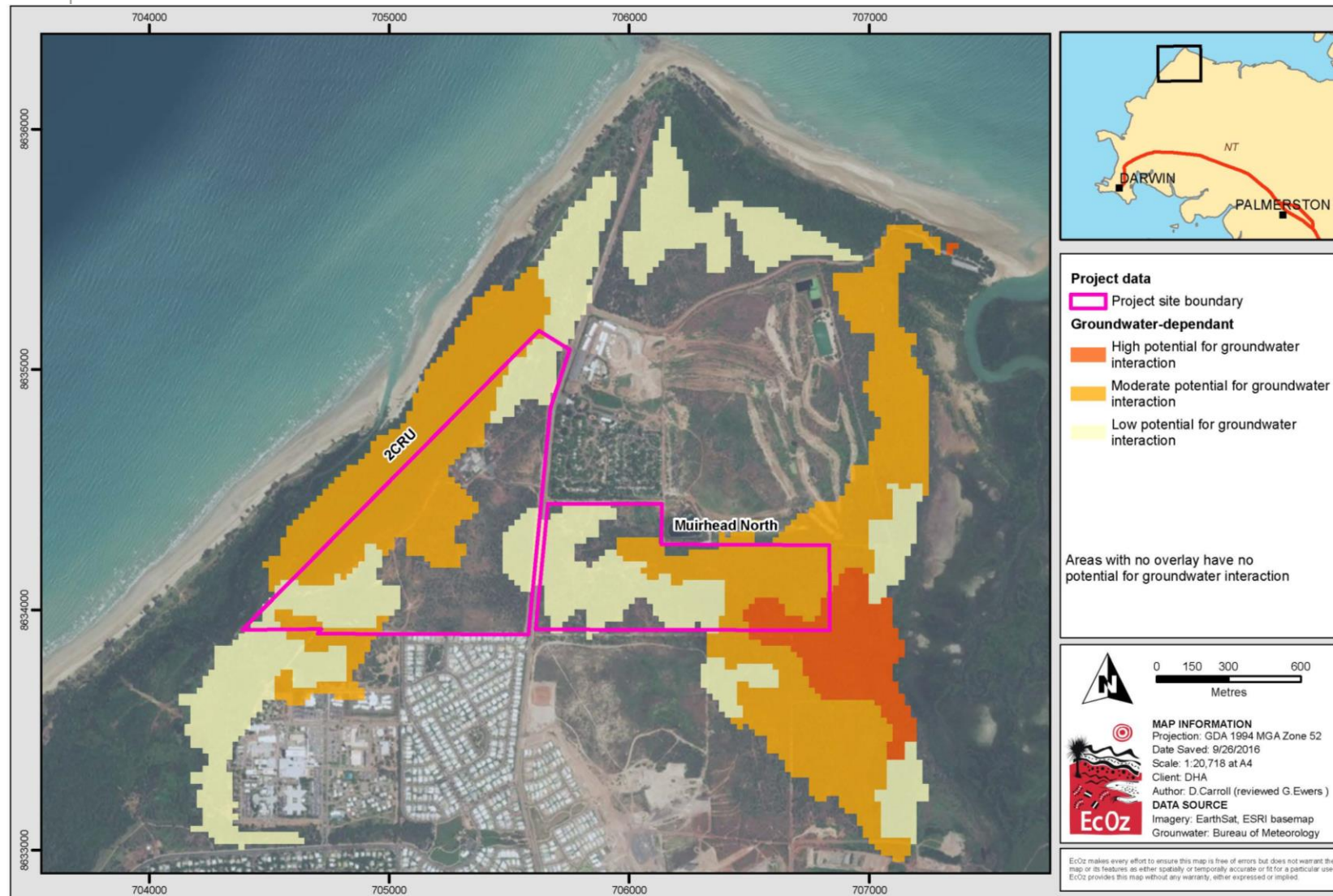


Figure 27. Map showing possible groundwater-dependent ecosystems within and surrounding the project site

7.2.4.3 *Threatened and Migratory species*

This section presents the results of the targeted surveys that were undertaken for the threatened and migratory species identified in a preliminary ‘likelihood of occurrence’ assessment as having a reasonable chance of occurring (i.e. known or likely to occur) within the project footprint. It also includes the results of previous targeted surveys that were not commissioned as part of this project, but focussed on threatened or migratory species considered as having a reasonable change of occurring (see Section Likelihood of occurrence below). The findings of the targeted surveys detailed in this Section inform the likelihood of a ‘significant impact’ on threatened and migratory species in accordance with the EPBC Act (Section 7.4.1).

Environment Protection and Biodiversity Conservation Act 1999

Black-footed Tree-rat

Detailed findings of the Black-footed Tree-rat survey is contained in Appendix M. Black-footed Tree-rat was recorded at three sites on four cameras in Muirhead North. Two of the sites are located in the west of Muirhead North near Lee Point Road. The third site where Black-footed Tree-rat was recorded was located along the south-eastern boundary of Muirhead North. No Black-footed Tree-rats were recorded in 2CRU. All records for Black-footed Tree-rat were in areas with a habitat quality score of 5-7/10 (Figure 29).

To ascertain the potential for Black-footed Tree-rat to occur in 2CRU, additional information sources were reviewed as explained in the Black-footed Tree-rat report (Appendix M) including:

- Radio-tracking study of Black-footed Tree-rats around 2CRU and adjoining Defence land (Griffiths *et al.* 2002).
- Live trapping study of 2CRU and adjoining Defence land (Rankmore *et al.* 2001).
- Live trapping and camera trapping of small-mammals in the Lee Point area including 1 kilometre south-west of the study area (Stokeld and Gillespie 2015).
- Consultation with CDU who undertake periodic monitoring of Black-footed Tree-rat in woodland adjoining their campus.

The radio-tracking study by Griffiths *et al.* (2002) tracked three Black-footed Tree-rats moving between the current Lyons residential development, Royal Darwin Hospital and 2CRU. From 92 observations over a four month period, Griffiths *et al.* (2002) located Black-footed Tree-rat in the development section of 2CRU on six occasions, while the majority of records were in the Monsoon Vine-thicket section of 2CRU (45 observations) which will be protected and Royal Darwin Hospital (33 records). The tracked animals showed a high fidelity to nesting trees, with two animals returning to the same eucalypt trees on numerous occasions. The six records from within habitat to be removed at 2CRU were in the south of the site.

The trapping study by Rankmore *et al.* (2001) did not identify Black-footed Tree-rat in 2CRU, but did locate the species in the adjoining Lyons site, in a similar location to Griffiths *et al.* (2002) highlighting the importance of this area for Black-footed Tree-rat. Stokeld and Gillespie (2015) did not record Black-footed Tree-rat at a study site near 2CRU on the opposite side of Sandy Creek using both live and camera-trapping methods. Although Stokeld and Gillespie (2015) did record the species near the Buffalo Creek boat ramp on camera traps but not

via live trapping. Charles Darwin University recorded Black-footed Tree-rat using both camera traps and live-trapping methods in woodland adjoining the campus as recently as October 2016 (Appendix M).

The habitat assessment identified that Muirhead North has better quality habitat than 2CRU for Black-footed Tree-rat (Table 41; Figure 29), which is reflected in the results of the camera-trap surveys and the number of habitat assessments undertaken across the two sites.

Based on the descriptions of the habitat categories and results of the targeted surveys, habitat with a quality score of 5/10 or greater is potentially suitable habitat for Black-footed Tree-rat. Habitat with a quality score of 4/10 or less does not have any large trees, and has a high cover of Gamba Grass with limited or no food plants (Table 41). It is unlikely that Black-footed Tree-rat would persist in these locations due to the absence of nesting trees, while the dominance of Gamba Grass is likely to limit or preclude the movement of Black-footed Tree-rat.

While Black-footed Tree-rat was not recorded in 2CRU during camera-trap surveys, there is potential (albeit low) that the species may occur on the site in areas to be developed given the previous findings of Griffiths *et al.* (2002). If present, the species is likely to occur in patches of better quality habitat that adjoin the Royal Darwin Hospital, the Lyons Development and Casuarina Coastal Reserve. Areas of suitable habitat for Black-footed Tree-rat in 2CRU that will be removed include an isolated 5.5 ha patch along Lee Point Road.

There is also suitable habitat in the south-west of the site and along the western boundary abutting the Monsoon Vine-thicket, and linking up with Royal Darwin Hospital and the Lyons Development covering approximately 7.5 ha (Figure 29). This area will be retained as public open space; however, some modification, including removal of some trees, may be required to comply with the Biting Insect Management Plan (Appendix G). The Biting Insect Management Plan recommends that canopy cover be reduced to approximately 10% to act as a buffer against biting insect moving into the development site for potential breeding locations along Sandy Creek. It is estimated that half of the overstorey trees would need to be removed to achieve 10% canopy cover, noting that many of the trees in this area are small and that the smallest trees will be selected for removal.

The majority of 2CRU is highly degraded as a result of past and ongoing disturbance (e.g. illegal site access and use such as off-road driving, rubbish dumping and camping), and does not support any large trees. The ground-layer is devoid of Black-footed Tree-rat's preferred food plants, and is dominated by dense Gamba Grass restricting the movement of the species through this area.

Across the 51.7 ha Muirhead North site, there is approximately 17.5 ha of suitable habitat for Black-footed Tree-rat (i.e. habitat quality score of 5/10 or greater; Figure 29). Habitat is confined to approximately two patches, located along the western boundary with Lee Point Road that connects up to Lee Point Resort Village, and in the central-eastern sections connecting up with Lee Point Resort Village and suitable habitat along Buffalo Creek.

Based on the results of this study as well as Stokeld and Gillespie (2015), Griffiths *et al.* (2002) and ongoing monitoring by Charles Darwin University, it is assumed that the Black-footed Tree-rat population occurs as two distinct sub-populations separated by Lee Point Road. To the west of Lee Point Road, the species moves throughout the Casuarina Coastal Reserve linking up with areas of eucalypt woodland at Charles Darwin University, The Royal Darwin Hospital and potentially 2CRU. East of Lee Point Road, there are extensive areas of eucalypt woodland along Buffalo Creek, the back of Lee Point Village Resort as well as Muirhead North. The

population(s) at Lee Point are likely to be isolated from populations elsewhere. Areas adjoining Lee Point to the south such as Rapid Creek, Tiwi, Wulagi, Nakara, Casuarina and Alawa are heavily developed with no suitable habitat for the species. While Buffalo Creek would provide a natural barrier to the species moving east of Muirhead North.

The closest Stokeld and Gillespie (2015) record of Black-footed Tree-rat to the population at Lee Point is at Darwin Airport, approximately seven kilometres to the south. The population west of Lee Point Road is unlikely to be connected to this population. While the airport links up to Rapid Creek, the habitat along Rapid Creek is dominated by Monsoon Vine-thicket and unlikely to support Black-footed Tree-rat dispersal. The distance between the two populations is also greater than the species' range of dispersal (Rankmore 2006).

The results of Stokeld and Gillespie (2015) also suggest that the population of Black-footed Tree-rat east of Lee Point Road is also unlikely to be connected to the nearest known population at Darwin Airport. Areas of suitable habitat between Muirhead North and Darwin Airport located within Holmes Jungle Nature Reserve were included in targeted surveys; however, Black-footed Tree-rat was not recorded.

A map showing the area of suitable habitat for Black-footed Tree-rat within the greater Darwin region is shown below (Figure 29). It is overlaid with the results of the Stokeld and Gillespie (2015) survey, showing areas where Black-footed Tree-rat was recorded. This map shows the location of Black-footed Tree-rat populations at Lee Point within a regional context, and shows there is a lack of habitat/records providing connectivity for populations at Lee Point with other populations in the wider Darwin region.

Table 41. Black-footed Tree-rat habitat quality assessment (see Appendix M)

Site	Rank	Quality score*	Description
M01	3.00	7	Many large trees & hollows, food, high mobility, low Gamba Grass
M02	2.75	7	Some large trees & hollows, food, high mobility, low Gamba Grass
M14	2.75	7	Some large trees & hollows, food, high mobility, low Gamba Grass
M18	2.50	6	Few large trees & hollows, food, mobility, low Gamba Grass
M11	2.25	6	Few large trees & hollows, food, moderate mobility, moderate Gamba Grass
M12	2.00	5	No large trees but pandanus, no hollows, food, mobility, moderate Gamba Grass
M03	2.00	5	Few large trees, no hollows, food, mobility, low Gamba Grass
M09	1.75	4	No large trees but pandanus, no hollows, food, reduced mobility, moderately high Gamba Grass
M07	1.50	4	No large trees but pandanus, no hollows, food, low mobility, moderately high Gamba Grass
M13	1.25	4	No roosting sites, food, moderate mobility, moderate Gamba Grass
M05	1.00	3	Few large trees, limited hollows, no food, low mobility, high Gamba Grass cover
M06	0.50	3	A large tree, no pandanus, no hollows, no food, low mobility, moderate Gamba Grass
M08	0.25	2	No large trees, no pandanus, no hollows, no food, limited mobility, total Gamba Grass cover
M17	0.00	1	No large trees, no pandanus, no hollows, no food, limited mobility, total Gamba Grass cover



Figure 28. Photograph of potentially-suitable Black-footed Tree-rat habitat that is infested by Gamba Grass

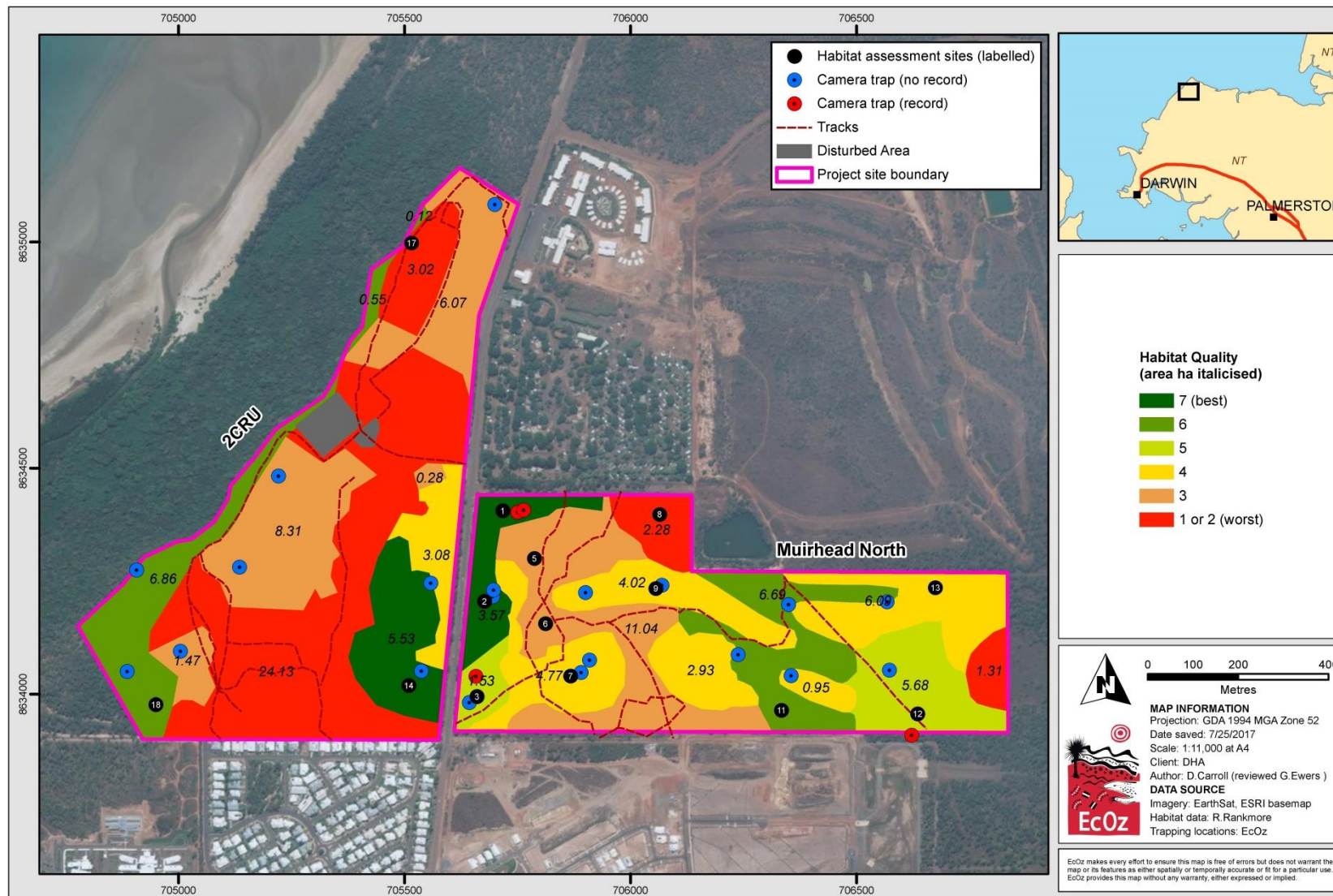


Figure 29. Map of Black-footed Tree-rat survey results (records and habitat quality)

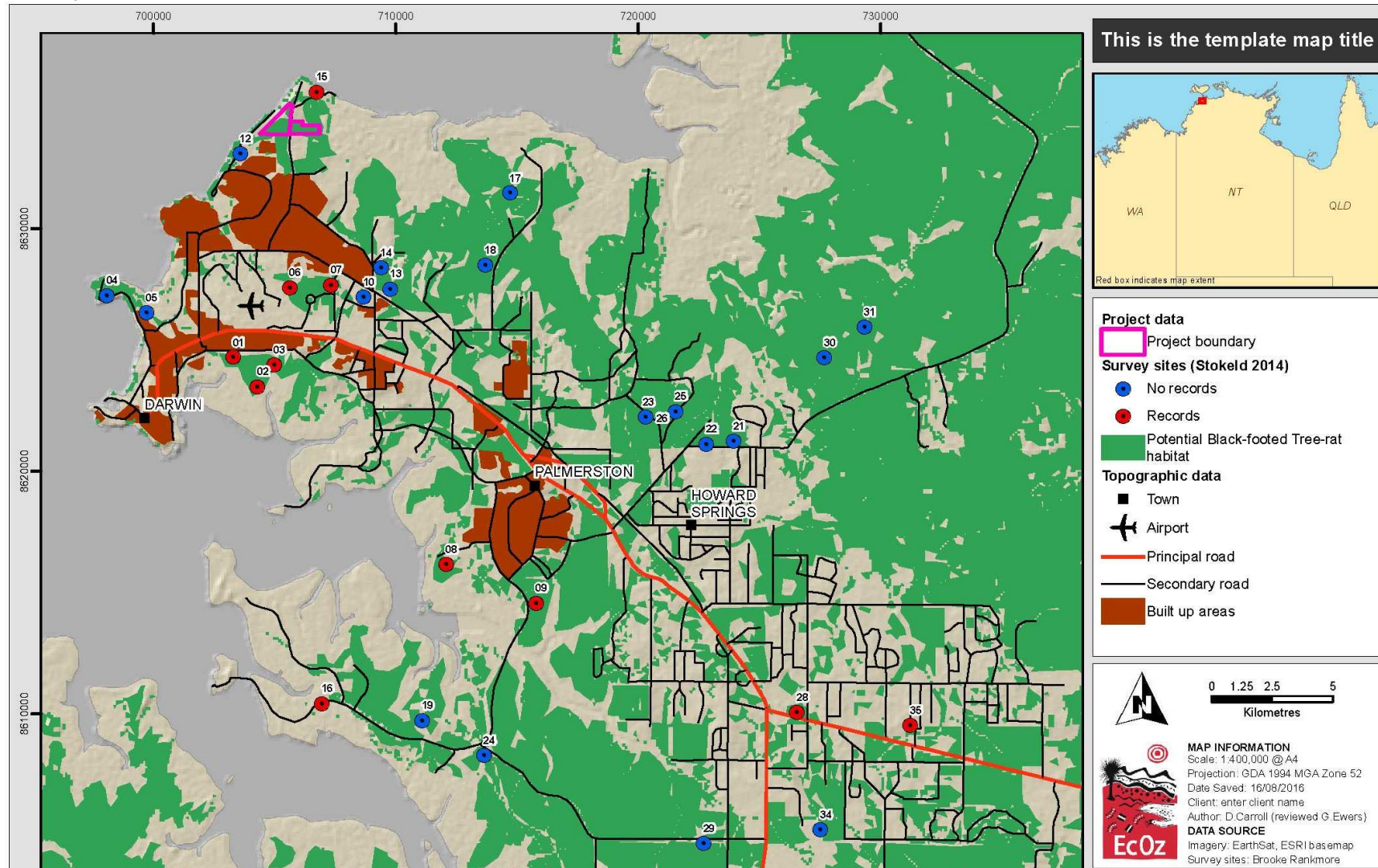


Figure 30. Black-footed Tree-rat potential habitat (eucalypt woodland) in greater Darwin region. Site numbers refer to survey locations from Stokeld and Gillespie (2015).

Bare-rumped Sheath-tailed Bat

Bare-rumped Sheath-tailed Bat was not detected during the survey program. Anabats were located in the project site in suitable habitat for the species, but none of the recordings were consistent with the Bare-rumped Sheath-tailed Bat call (Figure 32). The conclusion is that it is unlikely that the species roosts within the project site, but it may forage on occasion.

Shorebirds

Results of the migratory shorebird study for Sandy Creek by Lilleyman (2016) are summarised below (see Table 42). These results show that habitat along Casuarina Beach near the mouth of Sandy Creek would be considered under the *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (Commonwealth of Australia 2015) as ‘internationally important’ habitat for Great Knot and ‘nationally important’ habitat for Greater Sand Plover, Red Knot and Sanderling. A number of migratory species also listed as threatened under the EPBC Act were recorded near the mouth of Sandy Creek, including:

- Bar-tailed Godwit
- Eastern Curlew
- Great Knot
- Greater Sand Plover
- Lesser Sand Plover
- Red Knot.

Lilleyman (2016) states that shorebirds prefer to roost along Casuarina Beach on the western side of Sandy Creek in mangroves and Casuarina trees (Figure 33). Roosting can also occur on the eastern side of Sandy Creek but is rare. In addition, while shorebirds usually select Buffalo Creek tidal flats at low tide for feeding, the extensive tidal flats along Casuarina Beach are important feeding grounds at certain times of the year, possibly due to unreliable food resources at other sites.

Lilleyman (2016) also found that shorebirds move between the Sandy Creek and Lee Point at high tide if there is a disturbance at a site and the birds are seeking refuge elsewhere, or if the tide becomes too high at Sandy Creek and the birds have no space to roost.

In regards to site fidelity, Lilleyman (2016) refers to catch and banding results which showed that most tagged shorebirds return to monitored sites, and also high fidelity of birds within the austral summer, with records of individual birds feeding at low tide at Buffalo Creek and Sandy Creek and then roosting at high tide at Lee Point and at the Sandy Creek roost.

Table 42. Frequency and abundances of shorebird records (2013-2016) at Sandy Creek

Shorebird	EPBC Act	TWPC Act	Maximum count [^]	No. times counted	% present in counts	1 % threshold*	0.1 % threshold**
Bar-tailed Godwit	CR/VU	VU	13	34	62	3000	300
Black-tailed Godwit	-	-	14	3	5	1470	147

Common Greenshank	-	-	6	20	36	660	66
Common Sandpiper	-	-	3	15	27	2520	252
Eastern Curlew	CR	VU	8	44	80	310	31
Great Knot	CR	VU	4640	28	51	3250	325
Greater Sand Plover	VU	VU	980	37	67	1660	166
Grey Plover	-	-	14	39	71	790	79
Grey-tailed Tattler	-	-	9	12	22	610	61
Lesser Sand Plover	EN	VU	31	7	13	1470	147
Marsh Sandpiper	-	-	5	1	2	940	94
Oriental Plover	-	-	1	1	2	2320	232
Pacific Golden Plover	-	-	12	3	5	1250	125
Red Knot	EN	VU	390	15	27	1010	101
Red-necked Stint	-	-	114	21	38	4660	466
Ruddy Turnstone	-	-	17	6	11	300	30
Sanderling	-	-	139	36	65	340	34
Sharp-tailed Sandpiper	-	-	3	2	4	850	85
Terek Sandpiper	-	-	4	8	15	460	46
Whimbrel	-	-	8	34	62	640	64

^ Values in red represent counts that exceed 0.1 % and/or 1% of the flyway population of the species.

* Internationally important habitat for migratory shorebirds is recognised if the habitat supports at least 1 per cent of the flyway population of a single species.

** Nationally important habitat for migratory shorebirds is recognised if the habitat supports at least 0.1 per cent of the flyway population of a single species



Figure 31. Photograph of migratory shorebirds feeding at Sandy Creek intertidal sand flats in March 2015, 10 days before departing for their northward migration

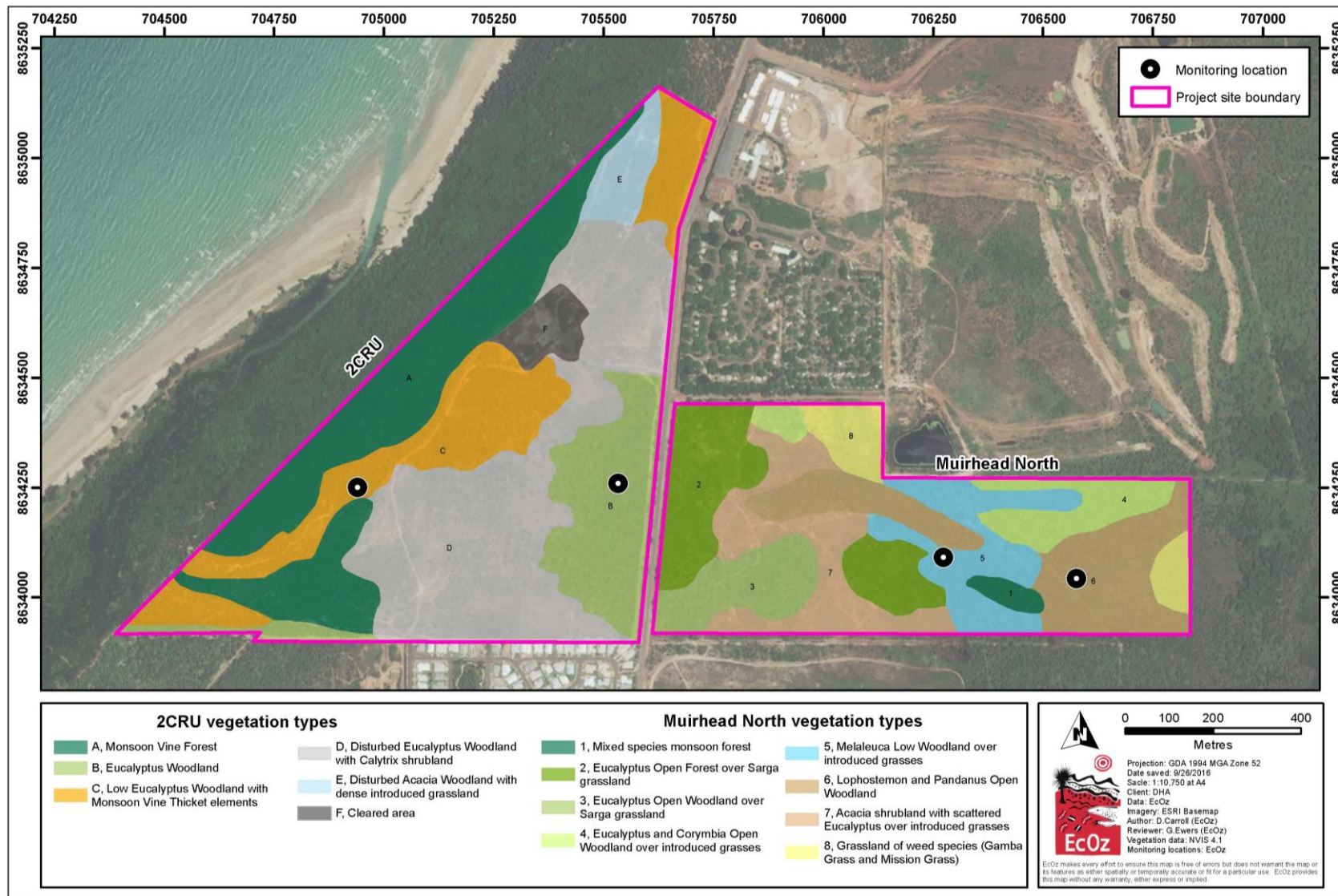


Figure 32. Location of anabat and songmeters for Bare-rumped Sheath-tail Bat survey

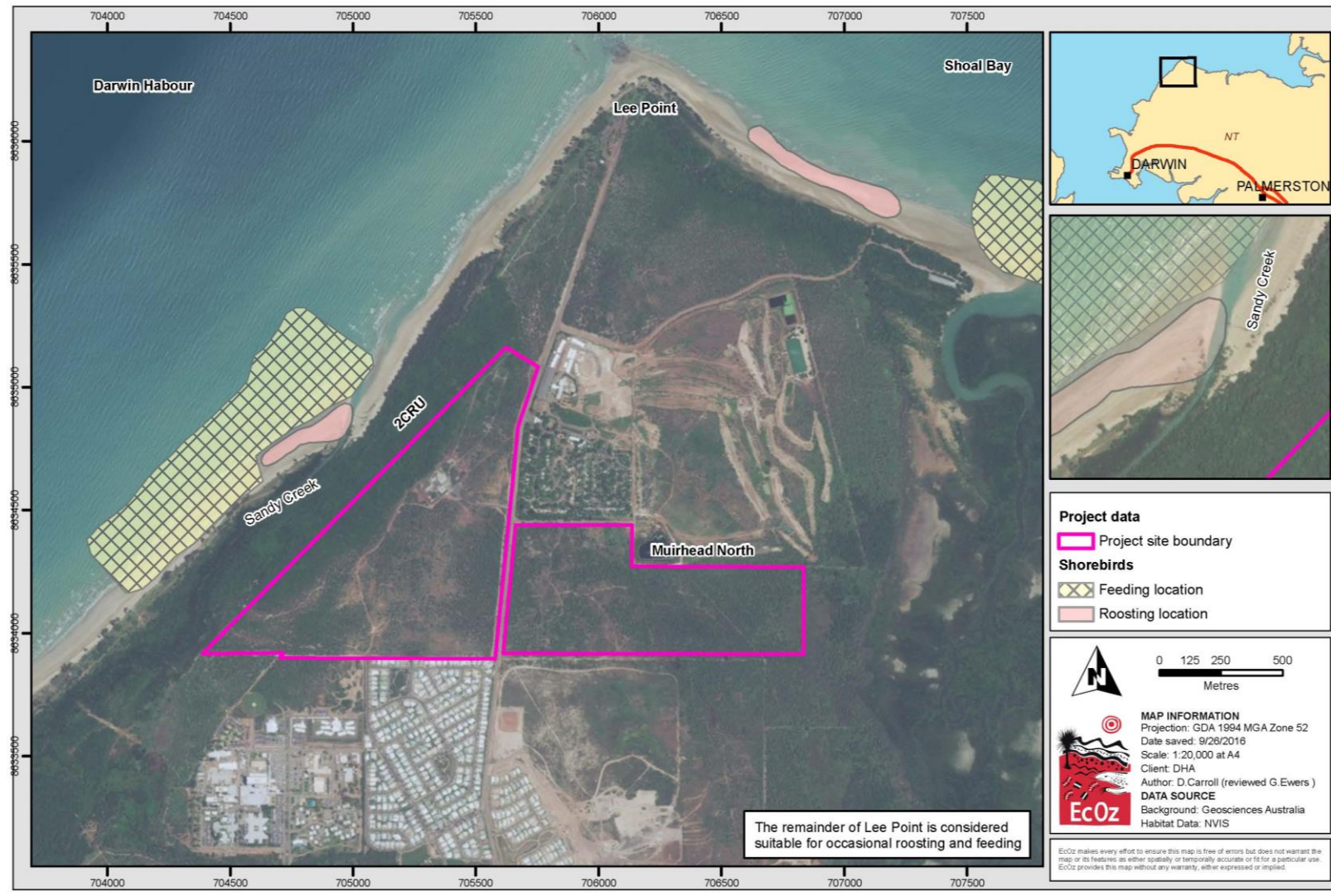


Figure 33. Feeding and roosting locations of migratory shorebirds in the Lee Point area.

Marine turtles

The turtle nesting data compiled by the NT Parks and Wildlife show that turtle nesting may occur anywhere in the Lee Point area between Rapid Creek and Buffalo Creek side. Since consistent monitoring of Casuarina Beach began in 1999, the number of Flatback Turtle nests recorded during each dry season (all months between March and November) varied from 5 (in 2012) to 20 (in 2006). Most nesting occurred in the month of September (39), followed by August (26), October (18), June (17), May (15) and July (15). Fewer nests were found in March (7) and April (1).

Given that over a period of at least 15 years, there are only three nesting records (out of 155 records) for Olive Ridley on Casuarina Beach, it is reasonable to consider that this species occurs only as a vagrant within the area.

Since 1999, there have been between 7 and 20 nesting records for Green Turtle and Flatback Turtle on Casuarina Beach.

Sawfish

Sawfish generally inhabit both marine and estuarine habitats, entering estuarine or fresh waters to breed during the wet season and moving into marine waters following the wet season (Peverell 2005). The main threatening processes for sawfish in Australia are fishing (targeted and incidental capture) and habitat degradation (Cavanagh *et al.* 2003).

Two specimens of Dwarf Sawfish were recovered from Buffalo Creek in 1997, as were five specimens of Green Sawfish – four in 1997 and one in 2002. Green Sawfish was also recorded in 2016 near the mouth of Sandy Creek. The Freshwater Sawfish has not been recorded in the area, but has similar habitat requirements and so would likely occur in Buffalo Creek.

Sandy Creek is much shorter and more affected by tides than Buffalo Creek. Nonetheless, given the recent record for Green Sawfish near the mouth of Sandy Creek, there is potential for threatened sawfish species to utilise the creek although the likelihood of breeding in the creek is low due to the tidal nature of the creek.

Territory Parks and Wildlife Conservation Act

This section addresses species listed as threatened under the *TPWC Act* only. NT-listed species that are also listed under the *EPBC Act* have already been considered.

Typhonium praetermissum

Typhonium praetermissum was not detected within the project area and a field habitat assessment concluded that there is no suitable habitat within the project footprint (Figure 34). This finding concurs with the 'Known Extent of Occurrence' map recently produced by the Flora and Fauna Division of DENR (www.ntlis.nt.gov.au/mpds/get_file?file_id=7085) which does not show any potential habitat within the project site.

Darwin Cycad

Darwin Cycad density across the 2CRU and Muirhead North sites is provided in Figure 35. The species is present in low to medium densities across 2CRU, and in low densities in the western half of Muirhead North – with a

medium density cycad patch in the centre of the Muirhead North. Darwin Cycads do not occur in the eastern parts of Muirhead North, probably due to the presence of poorly-drained soils.

Darwin Cycad occurs throughout the project site as part of a population that is likely isolated from other populations in the Darwin area because of the urban development to the south, the sea to the west, and the mangrove and riverine habitat to the east. As this isolation has occurred only recently it is unlikely for this long-lived species, that the Darwin Cycad population present in the proposed development area contributes significantly to the species' genetic diversity, or that the population has any significance by being at the limit of its northern mainland range. Likewise, this populations' isolation precludes it from being a key source population either for breeding or dispersal. For the above reasons, any population within the area proposed for development is not considered necessary for a species' long-term survival and recovery.

Table 43. Summary of Darwin Cycad results.

Density	Area (ha)
Low (<1 plant per 75 m ²)	61.0
Moderate (>1 plant per 75 m ² ; <1 per 50 m ²)	4.4

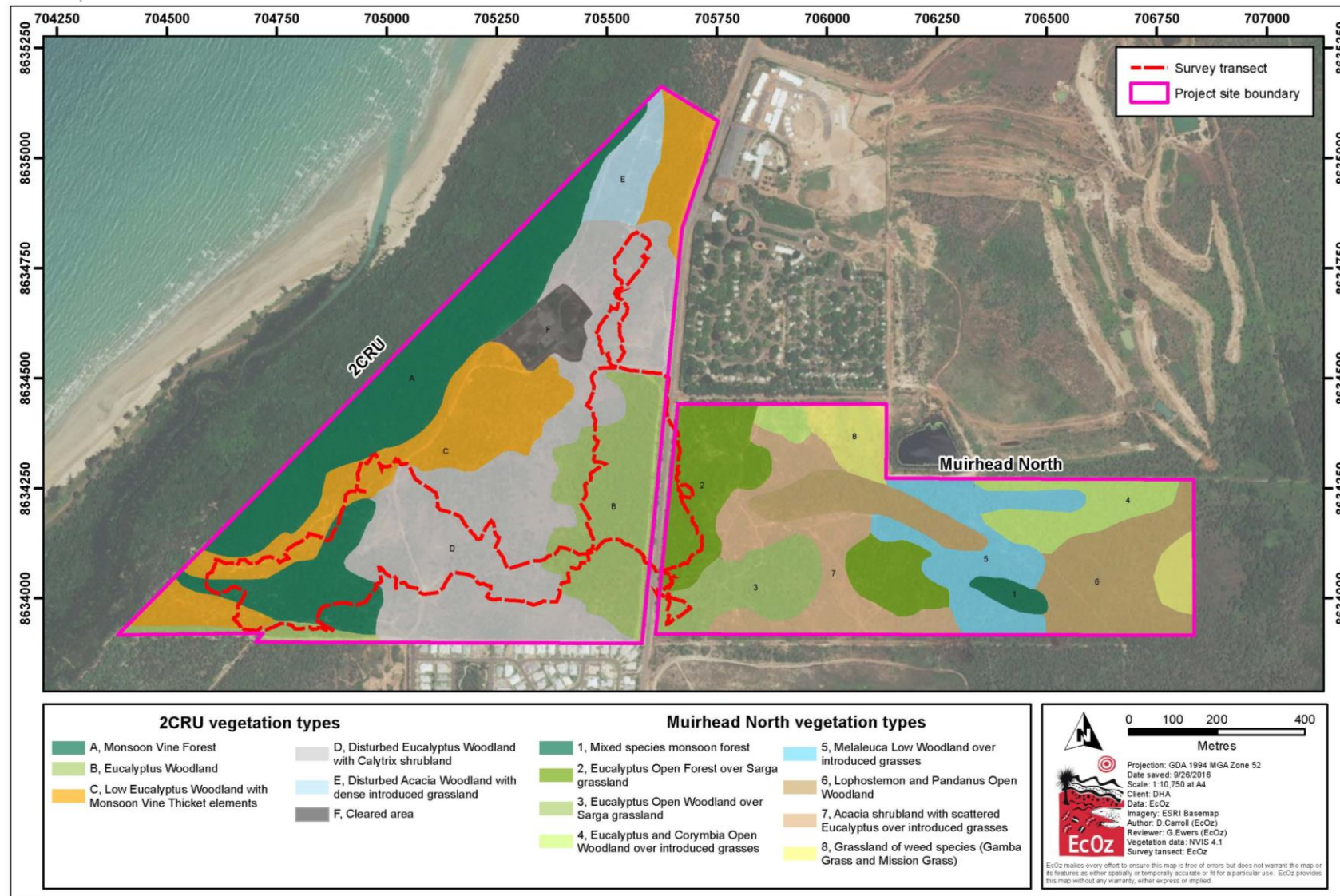


Figure 34. *Typhonium praetermissum* survey transects

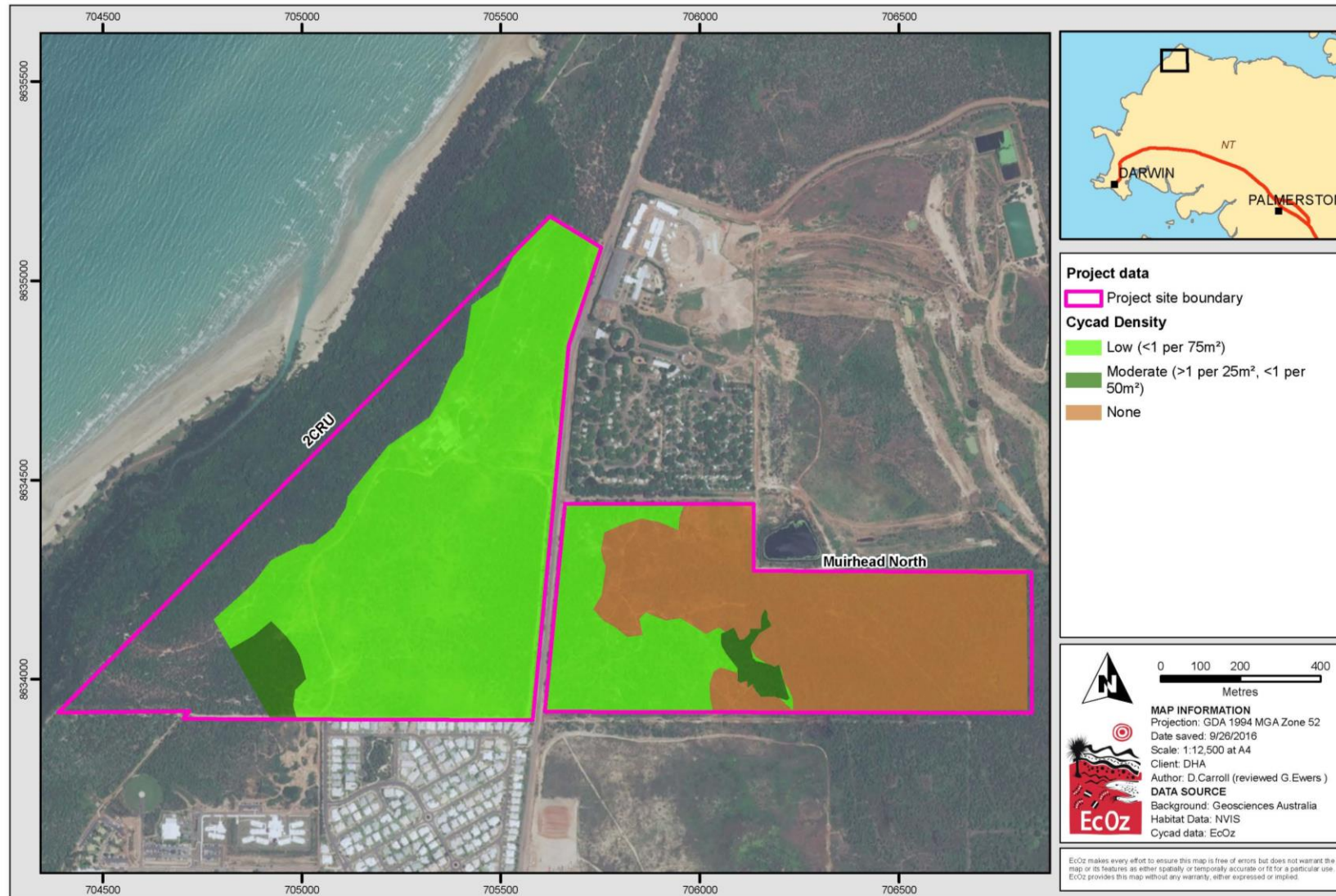


Figure 35. Darwin Cycad density within the project site

7.2.4.4 *Likelihood of occurrence*

Threatened species

Seventy-one threatened species were identified during a desktop study as occurring or potentially occurring within close proximity to the project site. Some of those species are considered very unlikely to occur within the project site, due to one or more of the following factors:

- There is no suitable habitat for the species
- The species is only an occasional visitor to the area
- The species is considered to be locally-extinct.

Therefore, those species were discarded from further assessment (see Table 45 for a justification).

The remainder of the species – together with those identified in the PMST and ToR – were assigned one of the following rankings of likelihood of occurrence within the project footprint (using the methodology described in Section 7.2.3.1):

- Known – there are recent records of the species occurring within the project footprint
- Likely – core habitat for the species occurs within the project footprint and there are recent records of the species occurring in the surrounding areas
- May – core habitat for the species occurs within the project footprint, but there are no recent records of the species occurring within the project footprint
- Unlikely – there is no core habitat for the species within the project footprint; however, the species may be present on occasion.

The results of the assessment are detailed in Table 44.

Table 44. Threatened species' likelihood of occurrence assessment

Species	Conservation status		Habitat description	Within the project area, Sandy Creek, Buffalo Creek and Casuarina Beach			
	EPBC	TWPC		Desktop records ¹	Surveys undertaken ²	Recorded	Likelihood of occurrence
PLANTS							
<i>Typhonium praetermissum</i>	-	VU	Open woodlands in soil types ranging from red brown clay soil and shallow or gravelly lateritic soil, either on the plateau edge or bordering with sandsheet and drainage areas, which occur in localised areas in the lowlands.	-	Yes	No	NOT PRESENT – critical habitat for the species was not detected within the project footprint during the targeted survey.
Darwin Cycad <i>Cycas armstrongii</i>	-	VU	Occurs in open, grassy woodland where adequate drainage appears to be a limiting factor (Kerrigan <i>et al.</i> 2006). Prime habitat has deep, loamy soil (Liddle 2009).	3, 1968	Yes	Yes	KNOWN – this species is widespread in Muirhead North and in patches on 2CRU.
REPTILES							
Flatback Turtle <i>Natator depressus</i>	VU	DD	Prefers shallow, soft-bottomed, sea-bed habitats away from reefs (DoE 2014). Nests on virtually all nesting beaches around the entire NT coastline and offshore islands. Has the most widespread breeding range in the NT of all sea turtle species (Chatto 1998).	18, 1977	Yes	Yes	KNOWN – there are many nesting records of this species for Casuarina Beach.
Green Turtle <i>Chelonia mydas</i>	VU	NT	Occurs in tropical and subtropical waters. In the NT, nests mainly on wide beaches backed by large dune systems (Chatto 1998).	1, unknown	Yes	Yes	LIKELY – there is a single nesting record of this species for Casuarina Beach (Chatto 1998).
Olive Ridley <i>Lepidochelys olivacea</i>	EN	VU	Occurs in tropical and subtropical, preferring shallow protected waters. In the NT, breeds at a wide range of sites on islands and less commonly, mainland beaches (Chatto 1998).	4, 1991	Yes	Yes	KNOWN – there are a few nesting records of this species for Casuarina Beach.

Loggerhead Turtle <i>Caretta caretta</i>	EN	VU	Pelagic feeder, nests on sandy beaches.	-	Yes	No	UNLIKELY – although this species occurs in NT waters, and there are two records a few kilometres off Casuarina Beach, there are no records of it nesting on Casuarina Beach or approaching near to shore.
Hawksbill Turtle <i>Eretmochelys imbricata</i>	VU	VU	Tropical, sub-tropical and temperate waters. Nests mainly on narrow beaches where they frequently go under vegetation to nest.	-	Yes	No	UNLIKELY – although this species occurs in NT waters, and there are few records in Darwin Harbour, there are no records of it nesting on Casuarina Beach or approaching near to shore.
Mertens' Water Monitor <i>Varanus mertensi</i>	-	VU	This semi-aquatic monitor occupies edges of watercourses and lagoons, but is seldom seen far from water (Christian 2004).	-	No	No	UNLIKELY – this species requires extensive freshwater areas and there are no verified records of it occurring in the coastal Darwin area (Trembath pers. comm. 2015). Apparent records of this species in suburban Darwin are of the similar Mitchell's Water Monitor (Trembath pers. comm. 2015).
Floodplain Monitor <i>Varanus panoptes</i>	-	VU	Occurs in broad range of habitats – from coastal beaches to savannah woodlands (Christian 2004).	2, 2001	No	No	MAY – suitable habitat occurs within the project footprint and there are records in greater Darwin; however, numbers have significantly reduced since the arrival and establishment of Cane Toads. Not recorded during field surveys or camera trap surveys. Occurs close to Darwin, persistence is generally in coastal areas (unsuitable for Cane Toads) or those protected by development from Cane Toads. Anecdotal information suggests the species can prosper in residential areas due to cane toad management. Most likely to be found in wetter areas along Buffalo Creek and Sandy Creek that won't be developed. Species likely to disperse from site at its own accord.
Mitchell's Water Monitor <i>Varanus mitchelli</i>	-	VU	Swamps, lagoons, inland rivers, and other bodies of water.	2, 1997	No	No	UNLIKELY – the riparian zone of Buffalo and Sandy Creeks comprises suitable habitat but, due to the nature of project activities, is not

							considered part of the project footprint (only the waters of those creeks are).
BIRDS							
Masked Owl (northern) <i>Tyto novaehollandiae kimberli</i>	VU	VU	Occurs mainly in eucalypt tall open forests (especially those dominated by <i>Eucalyptus miniata</i> and <i>Eucalyptus tetradonta</i>), but also roosts in Monsoon Rainforests, and forages in more open vegetation types, including grasslands (Woinarski and Ward 2006).	-	No	No	UNLIKELY – there are a few records within Darwin, but core nesting or foraging habitat does not occur within the project footprint.
Eastern Curlew <i>Numenius madagascariensis</i>	CE	VU	Coasts and estuaries, as well as mangroves. Also occurs in salt lakes and brackish wetlands near coasts. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide (Higgins and Davies 1996).	44 ³	Yes	Yes	KNOWN – there are many records of this species roosting at Sandy Creek.
Curlew Sandpiper <i>Calidris ferruginea</i>	CE	VU	Coasts and estuaries, especially intertidal mudflats, as well as beaches, rocky shores and around lakes, dams and floodwaters (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	Yes	No	UNLIKELY – there are no records of this species roosting at Sandy Creek.
Bar-tailed Godwit <i>Limosa lapponica baueri</i>	VU	VU	Coasts and estuaries, especially intertidal sand flats and mudflats, and coastal lagoons. Also occurs in salt lakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms, and coral reef-flats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	34 ³	Yes	Yes	KNOWN – there are many records of this species roosting at Sandy Creek. These records have not been identified to the subspecies level.
Bar-tailed Godwit <i>Limosa lapponica menzbieri</i>	CR	VU					
Great Knot <i>Calidris tenuirostris</i>	CE	VU	Sheltered coasts and estuaries with intertidal mudflats and sand-flats, especially in mangrove areas (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	28 ³	Yes	Yes	KNOWN – there are many records of this species roosting at Sandy Creek.

Greater Sand Plover <i>Charadrius leschenaultii</i>	VU	VU	Coasts and estuaries with intertidal sand and mudflats as well as nearby beaches, rocky shores, salt lakes, brackish swamps and shallow freshwater wetlands (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	37 ³	Yes	Yes	KNOWN – there are many records of this species roosting at Sandy Creek.
Lesser Sand Plover <i>Charadrius mongolus</i>)	EN	VU	Coastal littoral and estuarine, especially large intertidal sand flats or mudflats in sheltered bays, harbours and estuaries, and occasionally sandy ocean beaches, coral reefs, wave-cut rock platforms and rocky outcrops (Marchant and Higgins 1993). Sometimes in short saltmarsh or among mangroves. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide	7 ³	Yes	Yes	KNOWN – there are a few records of this species roosting at Sandy Creek.
Red Knot <i>Calidris canutus</i>	EN	VU	Coasts and estuaries with tidal mudflats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	15 ³	Yes	Yes	KNOWN – there are some records of this species roosting at Sandy Creek.
Asian Dowitcher <i>Limnodromus semipalmatus</i>	-	VU	Sheltered coastal environments, such as bays, coastal lagoons, estuaries and tidal creeks, also in exposed mudflats or sand flats or at near-coastal swamps, lakes or beaches (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	Yes	No	UNLIKELY – there are no records of this species roosting at Sandy Creek.
Red Goshawk <i>Erythroriorchis radiatus</i>	VU	VU	Prefers tall open eucalypt forest and riparian areas. Nests in large trees, frequently the tallest and most massive in a tall stand, and nest trees are invariably within 1 km of permanent water (Debus <i>et al.</i> 1988; Aumann <i>et al.</i> 1991).	-	No	No	UNLIKELY – despite a few records within Darwin, and suitable habitat occurring within the project footprint, this species' current geographic extent indicates a low probability for its occurrence within the project footprint.

Partridge Pigeon (eastern) <i>Geophaps smithii</i>	VU	VU	Occurs in open forests and woodlands with an understorey of grasses (Woinarski 2006).	2, 2009	No	No	UNLIKELY – there are a few records surrounding Darwin, but core habitat does not occur within the project footprint. The nearest recent records are from Noonamah.
Gouldian Finch <i>Erythrura gouldiae</i>	EN	VU	Prefers annual and perennial grasses (especially Sorghum), a nearby source of surface water and, in the breeding season, unburnt hollow-bearing <i>Eucalyptus</i> trees (especially <i>E. ucalyptus tintinnans</i> , <i>E. ucalyptus brevifolia</i> and <i>Eucalyptus leucophloia</i>) (Tidemann 1996; Higgins <i>et al.</i> 2006).	-	No	No	UNLIKELY – there are a few records within Darwin, but core feeding and breeding habitat does not occur within the project footprint.
FISH							
Dwarf Sawfish <i>Pristis clavata</i>	VU	VU	Marine and estuarine habitats, entering estuarine or fresh waters to breed during the wet season and moving into marine waters following the wet season (Peverell 2005)	2, 1997	No	Yes	KNOWN – two specimens have been recovered from Buffalo Creek.
Green Sawfish <i>Pristis zijsron</i>	VU	VU	A range of aquatic habitats, including marine inshore waters, estuaries, lagoons and freshwater. However, the majority of records are from marine or estuarine waters (Thornburn <i>et al.</i> 2003). Enters estuarine or fresh waters to breed during the wet season and moves back into marine waters following the wet season (Peverell 2005).	6, 2016	No	Yes	KNOWN – five specimens have been recovered from Buffalo Creek. One recent record from mouth of Sandy Creek.
Large-tooth Sawfish <i>Pristis pristis</i> – EPBC Freshwater Sawfish <i>Pristis microdon</i> – TWPC	VU	VU	Range of habitats, including marine inshore waters, estuaries, lagoons and freshwater. However, the majority of records are from marine or estuarine waters (Thornburn <i>et al.</i> 2003). The species enters estuarine or fresh waters to breed during the wet season and moves back into marine waters following the wet season (Peverell 2005).	-	No	No	LIKELY – closely-related species have been recorded in Buffalo Creek (see above).
MAMMALS							

Black-footed Tree-rat <i>Mesembriomys gouldii gouldii</i>	EN	VU	Inhabits tropical woodlands and open forests, with hollow-bearing trees and a well-developed mid-storey.	5, 2016	Yes	Yes	KNOWN – species recorded on four occasions in Muirhead North. Suitable habitat for the species in Muirhead North and 2CRU (Section 7.2.4.3)
Bare-rumped Sheath-tailed Bat <i>Saccolaimus saccolaimus nudiclunatus</i>	VU	NT	NT records are from pandanus woodland and eucalypt tall open forests (Friend <i>et al.</i> 1986; Churchill 1998). Roosts in tree hollows and caves (Duncan <i>et al.</i> 1999).	-	Yes	No	UNLIKELY – suitable habitat occurs within the project footprint; however, it was not recorded during targeted surveys and appears to be a naturally-rare species in the Top End.
Pale Field-rat <i>Rattus tunneyi</i>	-	VU	Historically occurred in a wide range of habitats, but is now primarily found in dense vegetation along creeks (Aplin <i>et al.</i> 2008).	-	No	No	UNLIKELY – the riparian zone of Buffalo and Sandy Creeks comprises suitable habitat but, due to the nature of project activities, is not considered part of the project footprint (only the waters of those creeks are).
Water Mouse <i>Xeromys myoides</i>	VU	DD	Requires mangrove communities and associated saltmarsh, sedgelands, clay pans, heathlands and freshwater wetlands with intact hydrology that provide adequate nest sites and prey resources (DEWHA 2009).	-	No	No	UNLIKELY – there is no suitable habitat within the project footprint.
Fawn Antechinus <i>Antechinus bellus</i>	-	EN	Occurs in tall open forest dominated by eucalypts (Friend 1985) where it was historically quite common (Watson <i>et al.</i> 2008).	-	No	No	UNLIKELY – suitable habitat occurs within the project footprint; but a declined range from this species' historical extent, and the poor condition of the project area, indicates a relative low probability for its occurrence within the project footprint.

¹ Desktop records (3, 1979) = 3 records since 1979; ² From Lilleyman (2016) ³ From Lilleyman (2016).

Table 45. Threatened species that occur within the bioregion but have a very low/no likelihood of occurrence within the project footprint

Scientific name	Common name	Status		Reason for not occurring in the project footprint
		EPBC	TPWC	
PLANTS				
<i>Atalaya brevialata</i>	a sub-shrub	CR	-	Restricted range – known from only five places near Elizabeth River (Virigina) and Amy’s Creek
<i>Cleome insolata</i>	Spiderflower	-	VU	Restricted range – known from only a few locations in the Elizabeth River catchment
<i>Crepidium marsupichila</i>	an orchid	-	VU	Restricted range – known in NT from one population at Gunn Point
<i>Endiandra limnophila</i>	Native Walnut	-	VU	Restricted range – mainland specimens only from Wadeye
<i>Freycinetia excelsa</i>	Narrow-leaf Climbing Pandan	-	VU	No habitat – occurs in spring-fed, lowland rainforest
<i>Habenaria rumphii</i>	a ground orchid	-	EN	No habitat – occurs in sand plains adjacent to spring-fed rainforest
<i>Luisia corrugata</i>	Luisia Orchid	-	VU	Restricted range – mainland specimens only from Black Jungle Conservation Reserve.
<i>Dienia montana</i>	a ground orchid	-	VU	Restricted range – single known population in Kakadu
<i>Monochoria hastata</i>	Arrowleaf Monochoria	-	VU	Restricted range – floodplains of the Finniss, Reynolds and Wildman River
<i>Ptychosperma macarthurii</i>	Darwin Palm	-	EN	No habitat – occurs in spring-fed dense rainforest
<i>Stylidium ensatum</i>	a trigger plant	EN	EN	No habitat – wet margins of drainage flats in heavy clay or peaty soils that are damp well into the dry season (June-Aug)
<i>Typhonium taylori</i>	a typhonium	EN	EN	Restricted range – grassland on the edge of the Howard River floodplain
<i>Utricularia dunstaniae</i>	a bladderwort	-	VU	No habitat – occurs in <i>Melaleuca nervosa</i> woodland
<i>Utricularia singeriana</i>	a bladderwort	-	VU	No habitat – occurs on margins of wet sandy flats and swamps
<i>Zeuxine oblonga</i>	a ground orchid	-	VU	Restricted range – nearest population Adelaide River
AMPHIBIANS				
<i>Uperoleia daviesae</i>	Howard River Toadlet	-	VU	Restricted range – Howard Springs area
REPTILES				
<i>Acanthophis hawkei</i>	Plains Death Adder	VU	VU	No habitat – occurs on large floodplains
<i>Bellatorias obiri</i>	Arnhem Land Skink	EN	EN	No habitat – occurs in sandstone country

<i>Dermochelys coriacea</i>	Leatherback Turtle	EN	CR	Vagrant – there are only a few records of this species in NT waters, and none of these are of individuals feeding or nesting near Darwin
<i>Morelia oenpelliensis</i>	Oenpelli Python	-	VU	No habitat – occurs in sandstone country
<i>Lucasium occultum</i>	Yellow-snouted Gecko	EN	VU	Restricted range – Wildman River and north-west Kakadu
BIRDS				
<i>Epthianura crocea tunneyi</i>	Yellow Chat (Alligator Rivers)	EN	EN	No habitat – occurs in wetlands within floodplain depressions and channels
<i>Rostratula australis</i>	Australian Painted Snipe	EN	VU	No habitat – occurs in wetlands
<i>Falcunculus frontatus whitei</i>	Crested Shrike-tit (northern)	VU	NT	Reduced range – nearest records are Kakadu and Pine Creek
<i>Falco hypoleucos</i>	Grey Falcon	-	VU	Vagrant – there is one record for Darwin, but core foraging and nesting habitat for this species does not occur within the development footprint
<i>Fregata andrewsi</i>	Christmas Island Frigatebird	VU	NE	Vagrant – there are only a few records of this species in NT waters; if present in the area, this species would only be flying over and would not land on site.
<i>Amytornis woodwardi</i>	White-throated Grasswren	VU	VU	No habitat – occurs in sandstone country
FISH				
<i>Carcharodon carcharias</i>	Great White Shark	VU	-	Vagrant – there have been no verified sightings of this species in the NT
<i>Glyphis glyphis</i>	Speartooth Shark	CR	VU	Vagrant – there are only a few records of this species in NT waters; these are in proximity to large rivers, and none of the records are from near Darwin
<i>Glyphis garricki</i>	Northern River Shark	EN	EN	Vagrant – there are only a few records of this species in NT waters; these are in proximity to large rivers, and none of the records are from near Darwin
<i>Rhincodon typus</i>	Whale Shark	VU	DD	Vagrant – there are only a few records of this species in NT waters and none of the records are from near Darwin
MAMMALS				
<i>Conilurus penicillatus</i>	Brush-tailed Rabbit-Rat	VU	EN	Locally extinct
<i>Balaenoptera musculus</i>	Blue Whale	EN	-	Vagrant – there are only a few records of this species in NT waters and none of the records are from near Darwin
<i>Dasyurus hallucatus</i>	Northern Spotted Quoll	EN	CR	Locally extinct – historic records exist around the development footprint; but, since the arrival of Cane Toads, this species has experienced a marked decline in range

<i>Megaptera novaeangliae</i>	Humpback Whale	VU	LC	Vagrant – there are only a few records of this species in NT waters and none of the records are from near Darwin
<i>Phascogale pirata</i>	Northern Brush-tailed Phascogale	VU	EN	No records near Darwin – mostly Kakadu
<i>Zyzomys maini</i>	Arnhem Rock-rat	VU	VU	No habitat – occurs in sandstone country
<i>Macroderma gigas</i>	Ghost Bat	VU	NT	Vagrant – there are only a few records of this species in the greater Darwin region, and no known roost sites
<i>Hipposideros inornata</i>	Arnhem Leaf-nosed Bat	EN	VU	No habitat – occurs in sandstone country
<i>Hipposideros stenotis</i>	Northern Leaf-nosed Bat	-	VU	No habitat – occurs in sandstone country
<i>Petrogale concinna</i>	Nabarlek	EN	VU	No habitat – occurs in sandstone country

Migratory species

The PMST identified 44 species of migratory species listed under the EPBC Act (not including the threatened species examined above) that may occur in the project site or adjoining areas such as Casuarina Beach. They include:

- 26 migratory wetlands species
- 2 migratory marine birds
- 10 migratory marine species
- 6 migratory terrestrial species.

These species were assigned one of the following rankings of likelihood of occurrence within the project footprint (using the methodology described in Section 7.2.3):

- **Known** – there are recent records of the species occurring within the footprint.
- **Likely** – core habitat for the species occurs within the footprint and there are recent records of the species occurring in the surrounding areas.
- **May** – core habitat for the species occurs within the footprint, but there are no recent records of the species occurring within the footprint or in the surrounding areas.
- **Unlikely** – there is no core habitat for the species within the footprint; however, the species may be present on occasion.

The results of the assessment are summarised in Table 46.

When assessing if a project will significantly impact upon a migratory species, the key consideration under the *EPBC Act Significant Impact Guidelines 1.1* (DoE 2013) whether the action will significantly impact on important habitat or an ecologically-significant proportion of a population of a migratory species is involved.

An area of important habitat for a migratory species is:

- Habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically-significant proportion of the population of the species, and/or

- Habitat that is of critical importance to the species at particular life-cycle stages, and/or
- Habitat utilised by a migratory species which is at the limit of the species range, and/or
- Habitat within an area where the species is declining.

What constitutes an ecologically-significant proportion of a population of a listed migratory species varies species to species. Relevant factors include the species' population status, genetic distinctiveness and species-specific behavioural patterns (e.g. site fidelity and dispersal rates).

For 37 migratory shorebird species, the definition of important habitat is defined in *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (Commonwealth of Australia 2015). For these 37 species, important habitat can be of international importance or national importance, whereby 'international important habitat' is defined as:

- 1 per cent of individuals in a population of one species or subspecies, OR
- a total abundance of at least 20,000 birds (Commonwealth of Australia 2015).

'Nationally important habitat' is defined as:

- 0.1 per cent of the flyway population of a single species or migratory shorebird, OR
- 2,000 migratory shorebirds, OR
- 15 migratory shorebird species.

Table 46 includes an assessment of whether important habitat or an ecologically-significant proportion of a population of each species occurs within the project footprint.

Table 46. Likelihood of occurrence of EPBC Act listed migratory species

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Migratory wetlands species ²					
Eastern Curlew ³ <i>Numenius madagascariensis</i>	Coasts and estuaries, as well as mangroves. Also occurs in salt lakes and brackish wetlands near coasts. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide (Higgins and Davies 1996).	44	KNOWN – there are many records of this species roosting at Sandy Creek.	No	No
Curlew Sandpiper ³ <i>Calidris ferruginea</i>	Coasts and estuaries, especially intertidal mudflats, as well as beaches, rocky shores and around lakes, dams and floodwaters (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	UNLIKELY – there are no records of this species roosting at Sandy Creek.	No	No
Bar-tailed Godwit ³ <i>Limosa lapponica baueri</i>	Coasts and estuaries, especially intertidal sand flats and mudflats, and coastal lagoons. Also occurs in salt lakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms, and coral reef-flats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	34	KNOWN – there are many records of this species roosting at Sandy Creek. These records have not been identified to the subspecies level.	No	No
Bar-tailed Godwit ³ <i>Limosa lapponica menzbier</i>				No	No

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Great Knot ³ <i>Calidris tenuirostris</i>	Sheltered coasts and estuaries with intertidal mudflats and sand-flats, especially in mangrove areas (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	28	KNOWN – there are many records of this species roosting at Sandy Creek.	Yes (see Table 42)	N/A
Greater Sand Plover ³ <i>Charadrius leschenaultii</i>	Coasts and estuaries with intertidal sand and mudflats as well as nearby beaches, rocky shores, salt lakes, brackish swamps and shallow freshwater wetlands (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	37	KNOWN – there are many records of this species roosting at Sandy Creek.	Yes (see Table 42)	N/A
Lesser Sand Plover ³ <i>Charadrius mongolus</i>	Coastal littoral and estuarine, especially large intertidal sand flats or mudflats in sheltered bays, harbours and estuaries, and occasionally sandy ocean beaches, coral reefs, wave-cut rock platforms and rocky outcrops (Marchant and Higgins 1993). Sometimes in short saltmarsh or among mangroves. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	7	KNOWN – there are a few records of this species roosting at Sandy Creek.	No	No
Red Knot ³	Coasts and estuaries with tidal mudflats (Higgins and Davies	15	KNOWN – there are some records of this species roosting at Sandy Creek.	Yes (see Table 42)	N/A

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
<i>Calidris canutus</i>	1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.				
Asian Dowitcher ³ <i>Limnodromus semipalmatus</i>	Sheltered coastal environments, such as bays, coastal lagoons, estuaries and tidal creeks, also in exposed mudflats or sand flats or at near-coastal swamps, lakes or beaches (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	UNLIKELY – there are no records of this species roosting at Sandy Creek.	No	No
Black-tailed Godwit <i>Limosa limosa</i>	Coastal, wetlands	3	KNOWN – three roosting records at Sandy Creek	No	No
Common Greenshank <i>Tringa nebularia</i>	Coastal, inland lakes	20	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Common Sandpiper <i>Actitis hypoleucos</i>	Banks, rocks near water	15	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Grey Plover <i>Pluvialis squatarola</i>	Beaches, mudflats, may be inland	39	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Grey-tailed Tattler <i>Tringa brevipes</i>	Estuaries, rocky coasts, reefs	12	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Oriental Plover <i>Charadrius veredus</i>	Dry inland plains, occasionally coastal	1	KNOWN – one roosting record at Sandy Creek	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Red-necked Stint <i>Calidris ruficollis</i>	Coastal, inland shorelines	21	KNOWN – roosts at Sandy Creek and likely forages along the Casuarina Coastal Reserve coastline	No	No
Ruddy Turnstone <i>Arenaria interpres</i>	Rocky shores	6	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Sanderling <i>Calidris alba</i>	Beaches, rarely inland	36	KNOWN – roosts at Sandy Creek and likely forages along the Casuarina Coastal Reserve coastline	Yes (see Table 42)	N/A
Sharp-tailed Sandpiper <i>Calidris acuminata</i>	Inland waters, coastal	2	KNOWN – some roosting records at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Terek Sandpiper <i>Xenus cinereus</i>	Coastal mudflats, occasionally inland	8	KNOWN – some roosting records at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Whimbrel <i>Numenius phaeopus</i>	Estuaries, mudflats, mangroves, sand spits, occasionally inland	34	KNOWN – roosting records at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Great Egret <i>Ardea alba</i>	Floodwaters, rivers, shallows of wetlands, intertidal mudflats	-	UNLIKELY – the seasonally-inundated areas within Muirhead North comprises monsoon rainforest and Melaleuca wetland with a grass understorey, and so are too densely vegetated to support this species	No	No
Pectoral Sandpiper <i>Calidris melanotos</i>	Prefers inland swamps	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant	No	No
Long-toed Stint <i>Calidris subminuta</i>	Inland swamps, rarely coasts	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
			Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant		
Little Ringed Plover <i>Charadrius dubius</i>	Shores, marshes. Vagrant in Australia.	-	UNLIKELY – the only known location in the NT is at Leanyer Sewage Works and so a record attributed to the project footprint is probably a geo-spatial error	No	No
Swinhoe's Snipe <i>Gallinago megala</i>	Wet grasslands; open, wooded swamps	-	UNLIKELY – the seasonally-inundated areas within Muirhead North comprises Monsoon rainforest and Melaleuca wetland with a grass understorey, and so are too densely vegetated to support this species	No	No
Pin-tailed Snipe <i>Gallinago stenura</i>		-			
Oriental Pratincole <i>Glareola maldivarum</i>	Open plains, bare ground around swamps, claypans	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant	No	No
Wandering Tattler <i>Tringa incana</i>	Reefs, rocks	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant	No	No
Broad-billed Sandpiper <i>Limicola falcinellus</i>	Coastal mudflats, occasionally inland	-	UNLIKELY – no records at Sandy Creek or along the Casuarina Coastal Reserve coastline	No	No
Little Curlew <i>Numenius minutus</i>	Open plains, grasslands, mudflats	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline	No	No
Pacific Golden Plover <i>Pluvialis fulva</i>	Beaches, mudflats, may be inland	3	KNOWN – a few records at Sandy Creek	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Wood Sandpiper <i>Tringa glareola</i>	Fresh water, marsh with light cover	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline	No	No
Marsh Sandpiper <i>Tringa stagnatilis</i>	Coastal, inland lakes	1	KNOWN – one record at Sandy Creek	No	No
Oriental Reed-Warbler <i>Acrocephalus orientalis</i>	Dense reedy vegetation near water	-	UNLIKELY – no suitable habitat or records	No	No
Osprey <i>Pandion haliaetus</i>	Mangroves, rivers and estuaries, inshore seas, coastal islands	58, 1982	KNOWN – forages in the waters of Casuarina Coastal Reserve; may roost at both Muirhead North and 2CRU, but no nests observed	No	No
Migratory marine birds					
Little Tern <i>Sterna albifrons</i>	Coasts, sometimes inland watercourses	227, 1982	KNOWN – forages (and may roost) along the Casuarina Coastal Reserve coastline	No	No
Fork-tailed Swift <i>Apus pacificus</i>	Aerial, over a variety of habitats	-	LIKELY – regularly recorded flying over Darwin during its north-south migration	No	No
Migratory marine species					
Salt-water Crocodile <i>Crocodylus porosus</i>	Brackish waters along the coastlines, freshwater rivers, swamps and billabongs	-	LIKELY – regularly recorded in Darwin Harbour, and occasionally on or near the Casuarina Coastal Reserve coastline	No	No
Indo-Pacific Humpback dolphin <i>Sousa chinensis</i>	Shallow near shore waters, often at the mouths of estuaries and in tidal channels	21, 2000	KNOWN – regularly recorded in Darwin Harbour, and occasionally Casuarina Coastal Reserve	No	No
Bryde's Whale <i>Balaenoptera edeni</i>	Tropical and warm temperate oceans	-	UNLIKELY – rarely recorded in NT waters	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Dugong <i>Dugong dugon</i>	Shallow coastal waters	5, 1988	KNOWN – regularly recorded in Darwin Harbour, and occasionally Casuarina Coastal Reserve	No	No
Irrawaddy Dolphin <i>Orcaella brevirostris</i> / Australian Snubfin Dolphin <i>Orcaella heinsohni</i>	Riverine, estuarine and coastal waters	2, 2008	KNOWN – occasionally recorded in Darwin Harbour, including Casuarina Coastal Reserve	No	No
Giant Manta Ray <i>Manta birostris</i>	Tropical and temperate waters	-	UNLIKELY – rarely recorded in NT waters	No	No
Reef Manta Ray <i>Manta alfredi</i>	Tropical and subtropical waters	-	UNLIKELY – rarely recorded in NT waters	No	No
Killer Whale <i>Orcinus orca</i>	All oceans and most seas	-	UNLIKELY – rarely recorded in NT waters	No	No
Spotted Bottlenose Dolphin <i>Tursiops aduncus</i>	Inshore areas such as bays and estuaries, near shore waters, open coast environments, and shallow offshore waters including coastal areas around oceanic islands	5, 2004	KNOWN – regularly recorded in Darwin Harbour, and occasionally Casuarina Coastal Reserve	No	No
Narrow Sawfish <i>Anoxypristis cuspidata</i>	Inshore waters including bays and estuaries	1, 1997	KNOWN – there is a record from the mouth of Buffalo Creek	Yes	Yes
Migratory terrestrial species					
Barn Swallow <i>Hirundo rustica</i>	Open country, cultivated land, urban areas	-	LIKELY – suitable habitat but no records	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records ¹	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Rufous Fantail <i>Rhipidura rufifrons</i>	Wet forests, occasionally more open forests. Resident in the Top End.	1, 2009	KNOWN – suitable habitat and records	No	No
Red-rumped Swallow <i>Cecropis daurica</i>	Open areas, woodlands	-	MAY – suitable habitat but no records and a rare vagrant to the Top End	No	No
Oriental Cuckoo <i>Cuculus optatus</i>	Forests and woodlands (in the summer)	2, 1999	KNOWN – suitable habitat and records	No	No
Grey Wagtail <i>Motacilla cinerea</i>	Prefers higher altitudes near water but may be found elsewhere	-	UNLIKELY – no suitable habitat and a rare vagrant to Australia	No	No
Yellow Wagtail <i>Motacilla flava</i>	Salt works, paddocks, marshes	1, 2000	UNLIKELY – no suitable habitat and so the record is probably a geo-spatial error, given that the main locations for this vagrant to the Top End are Leanyer Sewage Works and Knuckeyes Lagoons	No	No

¹ Desktop records (3, 1979) = 3 records since 1979; ² From Amanda Lilleyman's dataset (2012-2016) described in Appendix N.

7.2.4.5 *Heritage*

No natural places with protection under the EPBC Act or NT Heritage Act occur within or near the project site. There are no places or items of cultural heritage listed under the EPBC Act or NT Heritage Act within the project site.

The Larrakia People are the traditional owners of the project site. The AAPA have confirmed that there are no registered sacred sites on the project site. The AAPA have been approved by DHA to commence liaising with traditional owners to identify any sacred sites yet to be identified/registered on the site. Following consultation with the Larrakia Development Corporation (Nigel Browne – Chief Executive Office) on 13 March 2018, areas of cultural significance including registered sacred sites in areas adjacent to the project site including along Casuarina Beach and at Lee Point were discussed. These sites will be further investigated by AAPA. Actions to preserve and protect sites identified by AAPA are discussed further below (Section 7.3.2.12) .

The project was presented to the Larrakia Nation Aboriginal Corporation at their board meeting on 25 June 2018 to receive feedback on the proposal. The Larrakia Nation Aboriginal Corporation did not provide any comments regarding the project.

A background scatter of isolated Aboriginal stone artefacts was recorded in the northern section of 2CRU. Military instalments that remain on the project site and are considered to provide heritage value include the Konfrontasi Cruciform anti-aircraft gun position and the Lee Point Bunkers within 2CRU. There is a heritage site identified in Muirhead North also belonging to the Konfrontasi period, that being a defensive gun pit surrounded by 44 gallon drums located along Lee Point Road.

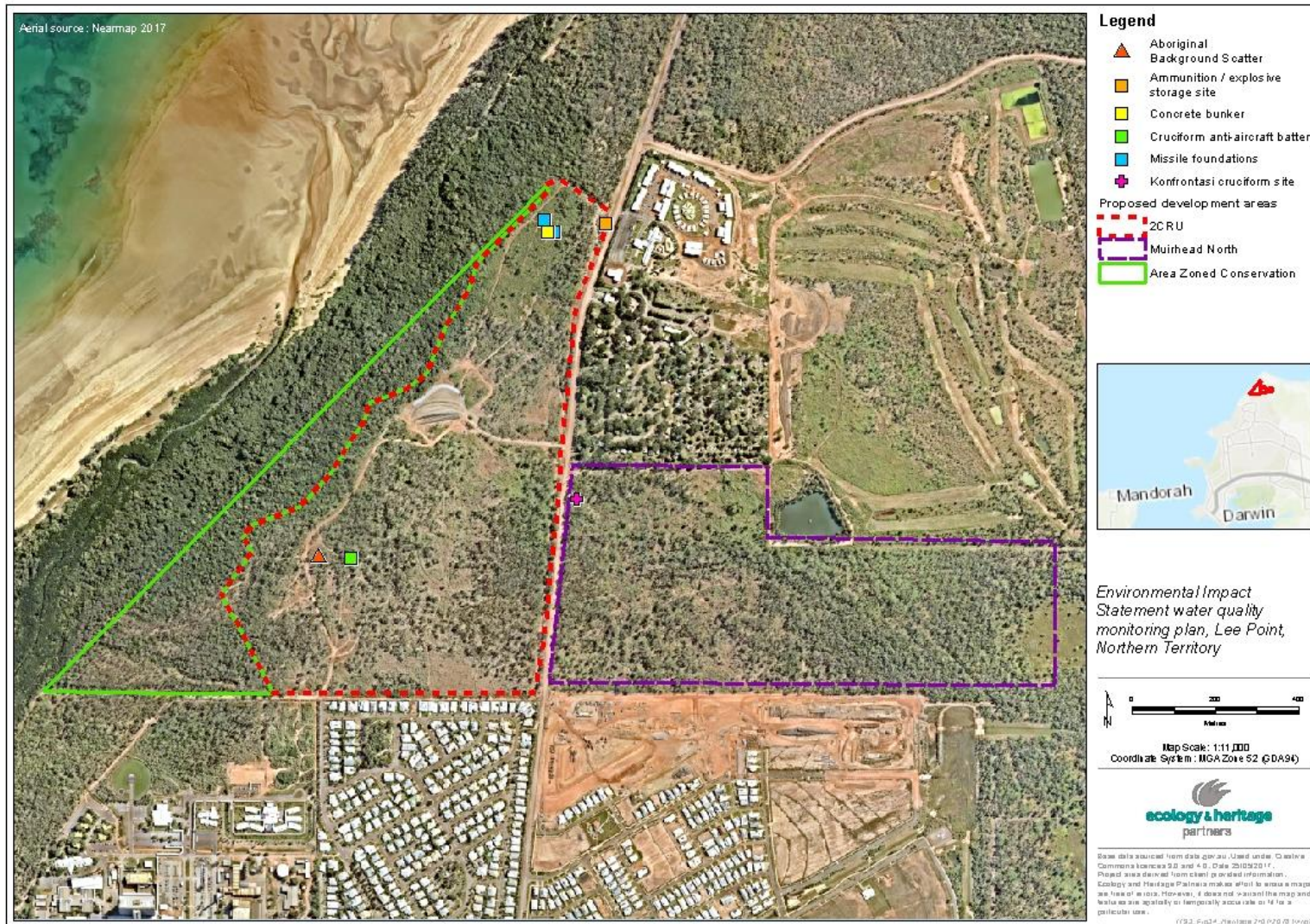


Figure 36. Historical sites

7.3 Risk Assessment

7.3.1 Risk assessment summary

A summary of the risk assessment findings of the potential impacts the project will have on biodiversity and heritage values is provided below (Table 47). The summary includes those impacts which are considered to be of High or Medium risk. The full results of the risk assessment are provided in Appendix C. The risk assessment was completed in accordance with the methods described in Section 3.

Table 47. Summary of potential impacts and mitigation measures

Impact	Description	Mitigation measures
<i>Biodiversity</i>		
Vegetation clearance	Loss of a sensitive vegetation type (Monsoon Rainforest and Vine-thicket). Loss of habitat and flora species.	Protect 21.95 ha area of Monsoon vine thicket and Low Eucalyptus Woodland in 2CRU and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve. Reserve the Monsoon rainforest (0.88 ha) within a 1.5 ha area zoned Conservation (CN) in Muirhead North Survey and peg site boundaries prior to construction. Fence areas of native vegetation to be retained. Retain native vegetation within Open Space areas and parkland, where practical. Revegetate along the erosion gullies in the south-west of 2CRU, and areas of disturbance within the 21.95 ha of Monsoon vine thicket and Low Eucalypt Woodland in 2CRU.
Direct mortality	Loss of individual Darwin Cycads due to land-clearing activities. Loss of individual Black-footed Tree-rats due to land-clearing activities. Loss of sawfish species due to increased fishing rates in Sandy Creek and Buffalo Creek.	Salvage, and relocate Darwin Cycad plants for use in landscaping Open Space areas and parkland. Ongoing management of relocated Darwin Cycad plants. Utilise a fauna spotter-catcher during construction activities to relocate individual Black-footed Tree-rats or other native fauna that might be harmed. Remove habitat in a staged manner to give fauna an opportunity to relocate at their own accord. Include educational signage to assist with identification of threatened sawfish species and to describe appropriate capture and release technique. Animal proof fencing to be established around each stage with identified Black-

Impact	Description	Mitigation measures
		footed Tree-rat habitat, to prevent species from accessing site during construction.
Habitat fragmentation	Increased isolation of native vegetation adjoining the project site.	Protect 21.95 ha area of Monsoon Vine-thicket and Low Eucalyptus Woodland in 2CRU and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve. Use native canopy species in landscaping where practical.
Edge effects	Reduced quality of a sensitive vegetation type (monsoon rainforest and vine thicket) due to increased exposure.	Protect 21.95 ha area of Monsoon Vine-thicket and Low Eucalyptus Woodland in 2CRU and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve.
Water quality impacts	Reduced threatened and migratory shorebird roosting and feeding habitat quality due to reduced surface water quality in Sandy Creek and Buffalo Creek from onsite contaminants. Reduced quality of riparian, wetland and aquatic habitat that receive water from the project area due to onsite contaminants.	An ESCP will be implemented to prevent erosion and remediate areas where erosion is an issue (Appendix D). Discharge flows into Sandy Creek and Buffalo Creek will be maintained at pre-construction levels. Water Sensitive Urban Design (WSUD) initiatives that remove sediment, pollutants and contaminants from water run-off will be implemented (see Appendix E and Appendix F). Construction spill management. Rehabilitation of erosion gullies in south-west of 2CRU.
Groundwater contamination	Impacts to GDE (Monsoon Vine-thicket and Monsoon Rainforest) due to reduced groundwater water quality from onsite contaminants.	Construction spill management
Weed and pest invasion	Reduced quality of sensitive vegetation types (Monsoon Rainforest and Monsoon Vine-thicket) due to weed infestation and/or proliferation. Reduced habitat quality in surrounding areas due to the introduction and/or proliferation of weeds. <u>Note:</u> The area, being proximate to urban development, already suffers from broad scale weed infestations and feral cats/dogs.	Weed infested areas will be removed during construction (control of Gamba Grass has been ongoing since early 2016). Ensure all plant, equipment, vehicles and soil coming to and from site is treated for noxious weeds. Control Gamba Grass on site along the boundary that interfaces with the Casuarina Coastal Reserve. Ongoing weed management within the expanded Casuarina Coastal Reserve will be the responsibility of the NT Government.
Dust (during construction)	Reduced quality of sensitive vegetation types (Monsoon Rainforest and Monsoon Vine-thicket), as well as vegetation in general, due smothering of vegetation.	Dust control measures (e.g. water-trucks, protection of soil stock-piles) will be implemented during the dry season.

Impact	Description	Mitigation measures
Human disturbance	Loss of shorebird roosting and feeding habitat due to disturbance by recreational beachgoers from increased use of Casuarina Beach. Reduced habitat quality in Casuarina Coastal Reserve due to increased human visitation.	Implement community awareness and engagement program involving pamphlets and public information sessions. Provide one formal access point from the project site to Casuarina Beach, and rehabilitate all informal tracks between the project site and Casuarina Beach.
Domestic pets <u>Note:</u> Currently dogs must be on a lead when on the beach 100 m either side of Sandy Creek (to protect shorebirds)	Loss of shorebird roosting and feeding habitat due to disturbance by pet dogs from increased human use of Casuarina Beach. <u>Note:</u> The shorebirds roost on the south-western side of Sandy Creek at high tide. However, dogs have been observed swimming across the creek and harassing roosting birds.	Install barrier fencing 100 metres on the western and eastern side of Sandy Creek. Install signage at beach access point from project site, as well as other access points off site, to inform beach users of the threat posed by human disturbance (walking, driving, motorbike riding) and dogs on roosting and feeding shorebirds. Undertake shorebird monitoring project.
Biting Insects	Dense vegetation can aid the dispersal of biting insects across the landscape.	Create a 50 metre buffer between conservation reserve and buildings at 2CRU, within which overstorey cover will be thinned to 10%.
Lighting	Light from commercial buildings in 2CRU impact turtles.	Buildings taller than four storeys will be fitted with special lighting (reduced brightness) and will face downward to reduce impacts to turtles
<i>Heritage</i>		
Construction	Destruction of Aboriginal stone scatters or unidentified items of cultural significance.	Apply for a work approval under Section 72 of the NT <i>Heritage Act</i> before carrying out any works within the area of the stone scatters. The stone scatters will be removed by the Larrakia Development Corporation (LDC). The LDC will also undertake heritage monitoring during initial clearing to identify any salvage any artefacts that were not identified during the initial heritage assessment. Aboriginal Areas Protection Authority (AAPA) is liaising with traditional owners to identify any sacred sites not currently registered.
Post-construction	Destruction of military heritage sites.	Retain the Lee Point bunkers and Konfrontasi Cruciform. Work with local NT Heritage Branch to develop signage and interpretation material of Lee Point Bunkers and Konfrontasi Cruciform.

7.3.2 Description of impacts and mitigation measures

This sections describes the management actions that will be implemented to mitigate impacts to biodiversity and heritage. Threats associated with increased domestic animals, particularly cats, are not considered to be a High or Medium Risk, which is discussed further in Section 7.3.2.13.

7.3.2.1 *Conservation areas and retention of native vegetation*

The most significant mitigation measure for this project is the retention of 21.95 ha of Monsoon Vine-thicket and Low Eucalyptus Woodland in 2CRU which was rezoned to Conservation as part of the rezoning process and will be eventually handed over to NT Parks and Wildlife Commission. Works will be carried out by DHA to reduce the spread of noxious weeds, rehabilitate areas that have been damaged by erosion and revegetate with indigenous species to improve the quality of habitat for native fauna including the Black-footed Tree-rat. To assist with preventing human disturbance to the conservation area a fence will be established along the top of escarpment separation the conservation area from the esplanade. The escarpment fence is planned to be a 1.3 m high balustrade style fence with vertical panelling to ensure it complies with Australian standard safety design whilst considering the use of appropriate materials for the Darwin Coastal region and maximising airflow and environmental visibility. Fencing will be similar to what has been installed along the Nightcliff foreshore which meets both City of Darwin and NT Government approval.

In addition, a further 1.57 ha of native vegetation supporting 0.88 ha of Monsoon Rainforest will be protected in Muirhead North. Monsoon Rainforest is considered a sensitive vegetation type in NT. In addition to preserving the patch, works will be undertaken to sustain the species hydrological requirements. This includes designing stormwater drainage up-catchment of the Monsoon Rainforest patch (including within 2CRU) to maintain similar flow volumes as pre-development conditions. While stormwater peak flows are estimated to be lower at 5, 10, 20, 50 and 100 year ARI peak discharge events post-development, there is expected to be no impact of the project on the most frequent 2 year ARI peak discharge events (see Table 20 to Table 22). Furthermore, the volume of flow is considered to be the critical hydrological factor for sustaining the ecological requirements of the Monsoon Rainforest patch, which is expected to be unaltered given that no change in the catchment conditions is proposed. A bioretention basin is located immediately upstream of the Monsoon Rainforest patch which will assist with managing peak flows and removing pollutants.

Native vegetation will also be retained in areas of public open space where practical. A linear park will run parallel to the boundary of the conservation area, referred to as a coastal esplanade, and most vegetation will be retained in this area. Approximately half the trees will need to be removed to comply with the Biting Insect Management Plan, which recommends a tree canopy cover of 10% or less to act as a buffer (see Appendix G). In addition, it is expected that native vegetation in the rural lots located on the eastern section of Muirhead North, will be partially retained given the large size of the lots, although this cannot be enforced.

The protection of all sensitive vegetation within the project site into conservation areas, as well as the retention of native vegetation elsewhere is an important avoidance and mitigation measure to reduce the extent of vegetation loss, as well as minimise the impacts of fragmentation and edge-effects, and conserve the integrity of significant areas of biodiversity values in adjoining areas, such as Casuarina Coastal Reserve.

A detailed Conservation and Offset Management Plan will be prepared prior to construction commencing outlining works to be carried out in the conservation reserve and other areas to be retained across the project site. The plan will include:

- Objectives.
- Management actions.
- Responsibilities (i.e. DHA, City of Darwin, NT Parks and Wildlife or Casuarina Coastal Reserve Landcare Group).
- Timing.
- Monitoring and Review.

The plan will be prepared in consultation with City of Darwin, NT Parks and Wildlife Commission and Casuarina Coastal Reserve Landcare Group. Prior the Parks and Wildlife Commission taking responsibility for management, all rubbish and litter will be removed and a site audit will be done to determine exposure to asbestos. The Conservation Area will be managed by DHA until an agreed hand-over to Parks and Wildlife Commission take responsibility.

The Parks and Wildlife Commission have given their in-principal support for the mitigation measures proposed in the Conservation and Offset Management Plan (see correspondence in Q)

7.3.2.2 *Darwin Cycad salvage and translocation*

Darwin Cycads are a threatened species that can be successfully salvaged and translocated as demonstrated during the Lyons and Muirhead Breezes residential development projects. While it will not be possible to preserve all Darwin Cycads on site, it is expected that most will be able to be salvaged and reincorporated into landscaping and areas of public open space.

7.3.2.3 *Fauna salvage and translocation*

During vegetation clearance, there is potential for native fauna to be harmed or killed. Prior to the commencement of each stage, animal proof fencing will be established around each stage to prevent ground-based fauna from accessing area. Tree collars will be established around any tree outside of fenced area that has connecting canopy with trees inside fenced area, to prevent animals accessing site.

A fauna spotter will be on site immediately prior to vegetation clearance, and after animal-proof fencing has been established, to salvage and relocate any native fauna that could potentially be harmed or injured. The fauna spotter will require a permit under the *Territory Parks and Wildlife Conservation Act* to undertake any salvage and translocate any native fauna, and will take records of any animals handled including species, number and location of salvage and translocation. Species will be relocated into suitable habitat nearby, e.g. Conservation Area or habitat alongside Buffalo Creek.

7.3.2.4 *Erosion and Sediment Control Plan*

The ESCP will be prepared to address how the risk of erosion and sedimentation will be managed during construction, so as to preserve the quality of sensitive receptors such as Sandy Creek and Buffalo Creek. The ESCP will also detail how the erosion gullies in the south-west of the 2CRU will be rehabilitated. These gullies

are a major source of sediment to Sandy Creek, and once rehabilitated there is likely to be an improvement in water quality in Sandy Creek. There is some minor gully erosion in Muirhead North, but not to the significant extent as at 2CRU.

The ESCP will be approved by the Parks and Wildlife Commission and the Land Management Unit of DENR.

Both the gully erosion at both sites is close to Sandy Creek and Buffalo Creek and enhances conditions for biting insect breeding. The infilling and rehabilitation of gully erosion will address the recommendations within the biting insect report (Appendix G).

7.3.2.5 *Water Quality Monitoring Plan*

The Water Quality Monitoring Plan (Appendix O) will be implemented at Sandy Creek to monitor the physical and chemical parameters to establish whether there have been any changes in the creek as a result of the project. The parameters to be monitored will help understand what impact (if any) there has been to migratory shorebird habitat. Monitoring will be done at several locations in the vicinity of the discharge point into Sandy Creek due to the mixing influence of tides.

It is expected that due to the rehabilitation of erosion gullies, and other erosion and sediment control actions carried out across 2CRU, the quality of water entering Sandy Creek will improve.

Due to the existing poor condition of Buffalo Creek (see Section 4.2.5), water quality monitoring is not proposed as it is highly unlikely that monitoring would detect any changes that could be attributed to the project.

7.3.2.6 *Weed control*

Weeds are prevalent throughout the project area, although more prominent at 2CRU. A weed eradication program at 2CRU has been in place for over twelve months and will continue during the construction phase of the project and be expanded onto Muirhead North. The objectives of weed control will be to control and eradicate noxious weeds in accordance with the WM Act, as well as to improve habitat for Black-footed Tree-rat in the Conservation Area adjoining the Casuarina Coastal Reserve.

7.3.2.7 *Migratory shorebird disturbance avoidance*

The location of the access track³ between 2CRU and Casuarina Beach has been decided after considering expert advice from a local migratory shorebird expert (Appendix N). While migratory shorebirds can be found feeding or roosting all along Casuarina Beach, the main area of sensitivity is on the western side of Sandy Creek (see Figure 33). As such, the access track will be located on the eastern side of Sandy Creek and will access the beach at least 100 m away from the mouth of Sandy Creek which is considered to be a safe buffer to avoid disturbance (Appendix N).

There will also be barrier fencing installed between the access point onto the beach and the mouth of Sandy Creek to minimise human disturbance to migratory shorebirds in this area.

³ There will be no net loss of vegetation within the Conservation Area due to the construction of the access track. Informal tracks will be revegetated. The access track will follow already disturbed areas to minimise impacts to native vegetation.

The barrier fencing will be funded by DHA and will be designed and installed in consultation with NT Parks and Wildlife Commission who have experience implementing similar barrier fencing in the Lee Point area.

The NT Parks and Wildlife Commission have given their in-principal support for the mitigation measures designed to avoid and minimise disturbance to migratory shorebirds (see correspondence in Appendix Q).

7.3.2.8 *Migratory shorebird education and monitoring*

The project will invest in improving the local community's knowledge on the importance of Casuarina Beach as habitat for migratory shorebirds. Signage is located throughout the Casuarina Coastal Reserve and Casuarina Beach focussing on the military history, mountain-bike facilities, public access and beach safety, but surprisingly there is nothing informing the community that Casuarina Beach is 'internationally important' habitat for migratory shorebirds. There is some signage that informs the public that dogs must be on lead near the mouth of Sandy Creek, but these signs do not make any connection with migratory shorebird habitat and the threat posed by dogs (Figure 37).

The project will fund the installation of signage at four existing access points to Casuarina Beach that are the focal point for the estimated 935,000 visitors that Casuarina Coastal Reserve receives each year. In addition, signage will also be constructed along the proposed access track between 2CU and Casuarina Beach. The signage will include information on:

- List of migratory shorebird species that occur in Casuarina Beach area.
- Description of the migration patterns of shorebirds, including breeding grounds in northern hemisphere.
- Type of threats to migratory shorebirds both locally (e.g. human disturbance, dogs off lead, off-road driving, pollution) and at breeding grounds (e.g. habitat loss), and what can be done to preserve migratory shorebird habitat and minimise disturbance.

A 'citizen science' monitoring program will also be undertaken along Casuarina Beach and between Lee Point and Buffalo Creek to assess whether there has been any impact on migratory shorebirds due to the project. The framework for a monitoring program has been developed as part of the independent Migratory Shorebird report (Appendix N). The monitoring program will involve monthly visits around dawn and dusk during the peak periods that migratory shorebirds are present, with the program to continue for five years after the access track between 2CRU and Casuarina Beach has been opened. The monitoring will be undertaken by local bird-watching groups, with DHA lending financial support and resources to assist with organising monitoring and to encourage local residents and visitors to participate in the monitoring events.

The shorebird education and monitoring program will be implemented in consultation with NT Parks and Wildlife Commission, who have considerable experience addressing migratory shorebird issues and interaction with human disturbance in the Lee Point area.



Figure 37. Sign at access point to Casuarina Beach at Lee Point (left) and information sign on mountain bike trails within Casuarina Coastal Reserve (right).

7.3.2.9 Sawfish education

Several threatened sawfish species occur, or have potential to occur in Sandy Creek and Buffalo Creek, such as Dwarf Sawfish and Green Sawfish. There is likely to be an increase in fishing levels at Sandy Creek and Buffalo Creek as a result of the project, which would increase the probability of threatened sawfish being caught or potentially injured or killed. Signage will be installed at local popular fishing spots informing the public about the threatened status of sawfish found in the creeks, identification guide, catch and release methods and contact details of NT Government to report siting.

7.3.2.10 *Monitoring health of remnant vegetation*

While it is unlikely that changes in groundwater recharge and surface-water flows would impact on native vegetation to be retained within the site, monitoring is proposed given the sensitive vegetation types on site. The Monsoon Rainforest patch in Muirhead North and Monsoon Vine-thicket in 2CRU will be monitored twice a year (once in the wet season and once in the dry season) for a ten year period to determine if changes in hydrology are impacting on the health of these communities. Monitoring will be completed by trained botanists to be appointed by DHA and will focus on monitoring changes in the health of species most susceptible to hydrological changes.

For the Monsoon Vine-thicket patch in 2CRU, monitoring will involve:

- Establishing two transects running from the top of the slope to the bottom
- One transect will be located immediately downstream of the detention basin in the south-west corner, the other transect will be located approximately half-way between the detention basin in the south-west corner and the detention basin in the north-west corner
- At one metre interval along the transect, the following parameters will be recorded
 - Percentage cover of total cover and percentage live/dead cover within the following strata:
 - Ground layer
 - Shrub layer
 - Overstorey layer.

The findings will be compared separately for the two transects between seasons and between years to see if there has been any change in species composition, and in what location. If changes are driven by groundwater recharge then shallow-rooted species are likely to be replaced by deeper-rooted species over time.

For the Monsoon Rainforest patch, monitoring will involve:

- Establish permanent monitoring points at five locations throughout the patch and collect a chronosequence of photos over the 10 year monitoring period
- Mapping the boundary of Monsoon Rainforest
- Estimated the canopy cover of the overstorey species
- Identify all species present and allocate a cover abundance rating using the Braun-Blanquet method (i.e.. + = < 5% cover few individuals, 1 = < 5% cover many individuals, 2 = < 25% cover, 3 = < 50% cover, 4 = < 75% cover, 5 = < 100% cover).

The findings will be compared between seasons and between years to see what change (if any) there has been in the composition of the Monsoon Rainforest patch. If the patch is affected by groundwater recharge than signs of poor health would be apparent during the dry-season in shallow-rooted species, whereas deeper-rooted overstorey species should persist. If the changes are being driven by lack of surface water flows, than the extent of the patch is likely to diminish, and shallow and deeper-rooted specie may be equally affected.

The trigger for a management response is a 10% or greater decline in any of the measured parameters for any monitoring event. The management response will be formulated in conjunction with experts on groundwater

dependent ecosystems from DENR, and may result in changes to Stormwater Management Plan to alter volume/frequency of flow to Monsoon Rainforest patch or groundwater inception for the benefit of the Monsoon Vine-thicket.

An annual report will be prepared by an independent consultant appointed by DHA, describing the results of the monitoring for the previous twelve months. The report will be provided to the NT EPA and DoEE.

7.3.2.11 Lighting impacts to turtles

Artificial light in coastal environments is recognised as a known disturbance to migratory turtle species. Flatback Turtle and Olive Ridley are known to nest on Casuarina Beach. Most light pollution emanating from the project site will be buffered by Casuarina Coastal Reserve and Conservation Area. However, it is possible that buildings that are taller than vegetation within the reserve may have light shining directly on Casuarina Beach.

For these reasons, any building over four storeys in height will have its lighting adapted in accordance with the Western Australian Environmental Assessment Guidelines for Protecting Marine Turtles from Light Impacts (WA EPA 2010). This is likely to include all lighting directed downwards or away from the beach, and to be of a reduced brightness.

7.3.2.12 Heritage preservation

There are several places of heritage significance located throughout the project site related to the Konfrontasi period of military activity in the area that will be preserved. Local military historians will be engaged to assist landscape architects develop preservation areas and signage that will maintain the connection of the site with its military history. This approach has been used by DHA for the Lyons development.

The LDC will be engaged to collect and store the stone scatters recorded on site. In addition, the LDC will be engaged during clearing to identify any items of cultural significance not detected during the initial heritage assessment.

The LDC will be engaged to prepare interpretive signage around the project site to inform residents of the cultural significance of the area.

As part of the process to obtain an Authority Certificate from AAPA, AAPA consults with custodians of sacred sites to include conditions of what activities cannot be undertaken within registered sacred sites. It is understood that AAPA will discuss with custodians any approval conditions to ensure the protection of sacred sites outside of the project site along Casuarina Beach.

7.3.2.13 Increased population of domestic cats

Concern was raised during the public exhibition period about the impact increased numbers of domestic cats would have on native fauna within the Casuarina Coastal Reserve. Cats are already abundant throughout Casuarina Coastal Reserve. The Reserve is located in an urbanised environment and backs onto residential development at Rapid Creek, Nakara, Tiwi, Alawa, Jingili and Lyons. The NT Parks and Wildlife Commission (Dean McKay pers. comm. A/District Manager Darwin Urban Parks) advised that many of the cats within Casuarina Coastal Reserve are likely to have come from these areas. The proposed development at Lee Point

may increase the number of cats in Casuarina Coastal Reserve, but only marginally given the territorial nature of cats, and would not greatly increase the threat to native fauna.

- Cat owners will be required to comply with Darwin City Council By-Laws regarding the registration and containment of cats. The City of Darwin Animal Management Plan (City of Darwin 2014), explains how these by-laws are implemented and what actions are being taken by Council to improve animal management. The Animal Management Plan states that cats must be: Registered with Council;
- Micro-chipped;
- Properly contained within the owner's property; and,
- Require a license to keep more than two cats.

Rangers from Council are responsible for trapping cats at large if a complaint is received from the public and the owner will not cooperate or be identified. Owners of cats at large can be fined in accordance with By Law 67(1).

7.4 Significant Impact Assessment

The purpose of this section is to describe the impact of the project under relevant environmental legislation and policy. The impacts considered are those which have come out of the risk assessment as of highest risk, after avoidance and mitigation measures have been considered, and have potential to trigger a significant impact on biodiversity and heritage.

7.4.1 *Environment Protection and Biodiversity Conservation Act 1999* – matters of National Environmental Significance

The EPBC Act establishes a Commonwealth process for the assessment of proposed actions (i.e. project, development, undertaking, activity, or series of activities) that are likely to have a significant impact on matters of national environmental significance (NES). An action, unless otherwise exempt, requires approval from the Commonwealth Environment Minister if it is likely to have a significant impact on a matter of NES.

7.4.1.1 *Threatened ecological communities*

No ecological communities that are listed as threatened under the EPBC Act occur on the project site, or are likely to occur in the adjoining areas. In addition, the PMST report did not identify any threatened ecological communities. As such, the project will not have a significant impact on threatened ecological communities.

7.4.1.2 *Threatened species*

Through a combination of detailed review of desktop information, targeted field surveys and habitat assessments, the following EPBC Act-listed threatened species were assessed as having potential to occur (i.e. likelihood of occurrence rating 'Known', 'Likely' or 'May' – Section 7.2.3):

- Black-footed Tree-rat
- Six migratory shore-bird species:
 - Bar-tailed Godwit
 - Eastern Curlew
 - Great Knot
 - Greater Sand Plover
 - Lesser Sand Plover
 - Red Knot.
- Three sawfish species in Buffalo Creek
 - Dwarf Sawfish
 - Green Sawfish
 - Freshwater Sawfish.

An assessment of whether the project will have a significant impact on these species is provided in the subsection below in accordance with the EPBC Act significant impact guidelines for threatened species (DoE 2013).

These assessments have been made after taking into consideration the avoidance and mitigation measures proposed in Section 7.2.4.5.

Black-footed Tree-rat

The likelihood of the project having a significant impact on Black-footed Tree-rat has been assessed below (Table 48) in accordance with the EPBC Act Significant Impact Guidelines for Critically Endangered and Endangered species (DoE 2013). It is concluded that the proposed action is likely to have a significant impact on Black-footed Tree-rat due to the loss of habitat. The species was recorded in Muirhead North during targeted surveys, and suitable habitat for the species occurs on both Muirhead North and 2CRU.

Table 48. Significant impact assessment for Black-footed Tree Rat

Action is likely to...	Response
Lead to a long-term decrease in the size of a population.	No. Black-footed Tree-rat was recorded in Muirhead North but not 2CRU. There is suitable habitat for the species on both sites. Black-footed Tree-rat was recorded on four cameras in Muirhead North over the four day survey period. The purpose of the survey was to establish presence and not population size; however, based on the number of records and non-records, as well as the findings of Stokeld and Gillespie (2015), it is expected that the population of Black-footed Tree-rats in the vicinity of the project site is small (i.e. <5 individuals). Based on the area of habitat to be removed, and the availability of Black-footed Tree-rat habitat in the surrounding landscape, there is unlikely to be a long-term decrease in the size of the population, as the species could be sustained in adjoining areas.
Reduce the area of occupancy of the species.	Yes. The project would result in the loss of approximately 23 ha of suitable habitat for Black-footed Tree-rat including 5.5 ha in 2CRU and 17.5 ha in Muirhead North. There would also be the removal of approximately half the canopy trees along the western boundary of 2CRU with the conservation reserve to comply with the Biting Insect Management plan recommendation to provide a buffer against biting insect migratory by reducing the canopy cover to 10%. Specifically, smaller trees will be selected for removal to minimise impact to Black-footed Tree-rat habitat.
Fragment an existing population into two or more populations.	No. The Lee Point population of Black-footed Tree-rat would retain connectivity to areas north and south of the project site, due to availability of habitat corridors along Casuarina Coastal Reserve (west of 2CRU) and Buffalo Creek (east of Muirhead North). The Casuarina Coastal Reserve is part of the Connecting Coastal Corridors of Green program acknowledging the role it plays in facilitating wildlife movements through the landscape (Parks and Wildlife Commission of the Northern Territory 2016).
Adversely affect habitat critical to the survival of a species.	No. The project site contributes medium quality, fragmented habitat for Black-footed Tree-rat. Better quality habitat occurs in adjoining areas (e.g. Royal Darwin Hospital) which is more important to the survival of the species.
Disrupt the breeding cycle of a population.	No. There is a sufficient area of habitat in areas adjoining the project site to sustain breeding. Rankmore (2006) determined that Black-footed Tree-rat could persist in an area of 27.1 ha in a fragmented landscape such as Lee Point.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	No. There is a sufficient area of habitat in areas adjoining the project site to sustain any individuals using habitat to be removed.

Action is likely to...	Response
Result in the invasive species that are harmful to the species becoming established in the species' habitat.	No. Predation by Feral Cats is considered a plausible but not demonstrated threat to Black-footed Tree-rat (DoE 2015). Feral Cats are already well-established in the area. Clearing vegetation as part of the project may reduce the area of occupancy of Feral Cats in the region.
Introduce disease that may cause the species to decline.	No. Disease is not listed as a threatening process for this species. There is no literature on diseases that could be introduced by the project and that would detrimentally affect this species.
Interfere with the recovery of the species.	No. There is no approved recovery plan for Black-footed Tree-rat.

Shorebirds

Six shorebird species listed as threatened under the EPBC Act have been recorded roosting and feeding along Casuarina Beach near the mouth of Sandy Creek. The potential for the project to have a significant impact on the threatened shorebirds is assessed below (Table 49). Bar-tailed Godwit, Eastern Curlew, Great Knot, Lesser Sand Plover and Red Knot have been assessed against the Significant Impact Guidelines (DoE 2013) for Critically Endangered and Endangered species.

Greater Sand Plover is listed as Vulnerable under the EPBC Act. The EPBC Act Significant Impact Guidelines (DoE 2013) assess significant impacts to 'important populations' of Vulnerable species, where important populations are defined as:

- Key source populations either for breeding or dispersal
- Populations that are necessary for maintaining genetic diversity, and/or
- Populations that are near the limit of the species range (DoE 2013).

The population of Greater Sand Plover along Casuarina Beach is not considered to qualify as 'important population' of Vulnerable Species, and as such a significant impact assessment was not undertaken. However, as the species is also listed as migratory under the EPBC Act, a significant assessment was undertaken in accordance with the EPBC Act significant impact guidelines for migratory species (Section 7.4.1.3).

It is concluded that the project is unlikely to have a significant impact upon threatened shorebirds. The project will not result in the loss or degradation of habitat to shorebirds; however, there will be an increase in the number of people visiting Casuarina Beach due to population growth within the area.

Casuarina Coastal Reserve has approximately one million visitors a year and the project is predicted to result in a 2% increase in the number of visitors to Casuarina Coastal Reserve (see Section 8.5.1.4). This increase would be concentrated near the project site due to the access track to be provided between 2CRU and Casuarina Beach, whereas visitors predominantly access Casuarina Coastal Reserve from Lee Point or the Surf Life Saving Club. Any impact to shorebirds as a result of the project would be addressed by the proposed avoidance and mitigation measures, which include locating the beach access to areas of less sensitivity for threatened shorebirds (i.e. east of the mouth of Sandy Creek), enforcing fencing barricades around the mouth of Sandy Creek, undertaking a community education program through better signage throughout the entire Casuarina Coastal Reserve, and involving the local community in a 'Citizen Science' program to assist with the ongoing monitoring of shorebird populations in the Lee Point area.

Table 49. Significant impact assessment for Critically Endangered and Endangered shorebirds: Bar-tailed Godwit, Eastern Curlew, Great Knot, Lesser Sand Plover and Red Knot.

Action is likely to...	Response
Lead to a long-term decrease in the size of a population.	No. There are no envisaged impacts on the population size of Bar-tailed Godwit, Eastern Curlew, Great Knot, Lesser Sand Plover and Red Knot would be sustained.
Reduce the area of occupancy of the species.	No. Project unlikely to increase visitation rates to the west of Sandy Creek mouth, which is the most sensitive habitat for migratory shorebirds along Casuarina Beach.
Fragment an existing population into two or more populations.	No. Threatened shorebirds are highly mobile, and currently move between local habitat sites within Darwin Harbour. Any increased anthropogenic disturbance is unlikely to fragment the regional population into two or more populations.
Adversely affect habitat critical to the survival of a species.	No. The most important habitat for threatened shorebirds in the Lee Point area is between Lee Point and Buffalo Creek, which is outside the project footprint. The most sensitive area near the project site is west of the mouth of Sandy Creek. Access to the beach from the project will be to the east of the Sandy Creek mouth. In addition, local signage and community education programs are intended to dissuade local residents and visitors from taking dogs too close to Sandy Creek.
Disrupt the breeding cycle of a population.	No. Threatened migratory shorebirds use Darwin beaches as roosting and feeding sites during the non-breeding season. Potential anthropogenic disturbance of roosting sites from increased pedestrian traffic would not affect the species' breeding habitat or breeding cycle, unless individual birds are unable to obtain sufficient body mass (through feeding) prior to migrating to northern hemisphere breeding grounds. There is no evidence to suggest that the situation in the region is so dire that this will be the case.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	No. The avoidance and mitigation measures proposed are considered sufficient to prevent any impacts to threatened migratory shorebirds as a result of increased visitation. In the unlikely event that increased visitation rates disturb migratory shorebirds, birds are expected to fly to Lee Point or other suitable roosting/feeding habitat nearby as they have already been observed to do (Lilleyman 2016).
Result in the invasive species that are harmful to the species becoming established in the species' habitat.	No. There are no invasive species that are considered a threat to migratory shorebirds, which may establish as a result of the project.
Introduce disease that may cause the species to decline.	No. There is no information to suggest that diseases could be introduced or would be detrimental to the species.
Interfere with the recovery of the species.	No. Appropriate measures will be taken to avoid impacts to threatened migratory shorebirds. Furthermore, the communication, education and monitoring program will assist with the species' recovery beyond the potential impacts of the project, and will encompass the entire Lee Point area.

Sawfish

Dwarf Sawfish and Green Sawfish have been recorded within Buffalo Creek. Freshwater Sawfish has not been recorded in the area, but has similar habitat requirements and so is likely to occur in Buffalo Creek. All three species are listed as Vulnerable under the EPBC Act, and if present would be considered to constitute important populations.

The main potential impact to these species associated with project activities is reduced water quality entering Buffalo Creek as a result of sedimentation, erosion and pollution during construction and from stormwater discharge.

The potential for the project to have a significant impact on threatened sawfish is assessed below (Table 50). It is concluded that it is unlikely that the project would have an impact on threatened sawfish. Buffalo Creek is already a highly polluted water-way as a result of industrial and other developments upstream, and effluent discharge from the Leanyer Sewerage Treatment Plant. Stormwater run-off from the project site would be treated through a series of retention basins, and the quality of water being discharged into Buffalo Creek from the project site would be of better quality than *in situ* conditions.

Table 50. Significant impact assessment for Dwarf Sawfish, Green Sawfish and Freshwater Sawfish

Action is likely to...	Response
Lead to a long-term decrease in the size of a population.	No. The only way in which project activities might lead to a long-term decrease in the size of a population is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries. With the mitigation measures proposed including WSUD, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no long-term decrease in the size of any sawfish populations.
Reduce the area of occupancy of the species.	No. The only way in which project activities might reduce the area of occupancy of these species is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries. With the mitigation measures proposed including WSUD, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no reduction in the area of sawfish occupancy
Fragment an existing population into two or more populations.	No. This consideration is of low relevance for marine species such as sawfish.
Adversely affect habitat critical to the survival of a species.	No. Buffalo Creek may be critical habitat during certain stages of a sawfish's lifecycle – particularly breeding. The only way in which project activities might adversely affect that habitat is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries. With the mitigation measures proposed including WSUD, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no adverse effect to critical habitat or the breeding cycle.
Disrupt the breeding cycle of a population.	
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	No. The only way in which project activities might affect the availability or quality of habitat to these species is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries (Section XX). With the mitigation measures proposed in Section XX, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no reduction in the availability or quality of habitat to these species.
Result in the invasive species that are harmful to the species becoming established in the species' habitat.	No. Invasive species are not listed as a threatening process for these species. There is no literature on invasive species that could be introduced by the project and that would detrimentally affect these species.
Introduce disease that may cause the species to decline.	No. Disease is not listed as a threatening process for these species. There is no literature on diseases that could be introduced by the project and that would detrimentally affect these species.
Interfere with the recovery of the species.	No. Because there will not be any significant impact on the water quality of Buffalo Creek, sawfish species will not be affected and so the recovery of these species will not be interfered with.

7.4.1.3 Migratory species

As described in Section 7.2.4.3, a detailed and thorough assessment process led to the conclusion that areas directly adjoining the project site, namely Sandy Creek and Casuarina Beach, provides important habitat for migratory shorebirds. Buffalo Creek, which is located directly to the east of Muirhead North, is also considered important habitat for the Narrow Sawfish.

An assessment of whether project activities will have a significant impact on migratory shorebird species and on the Narrow Sawfish is undertaken below.

Migratory shorebirds

Twenty migratory shorebird species have been recorded roosting and feeding along Casuarina Beach (see Table 42).

The potential for the project to have a significant impact on migratory shorebirds has been assessed in accordance with *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (DoE 2015). These guidelines consider significant impacts to important populations of migratory shorebirds of which the following four species have internationally or nationally important populations along Casuarina Beach:

- Great Knot
- Greater Sand Plover
- Red Knot
- Sanderling.

The significant impact guidelines have been applied to these four species (Table 51 below). It is concluded that it is unlikely the project will significantly impact upon migratory shorebirds.

Table 51. Significant impact assessment for migratory shorebirds with important populations recorded near Sandy Creek (Great Knot, Greater Sand Plover, Red Knot and Sanderling).

Significant impact	Response
Loss of habitat	No. There will not be any direct loss of habitat for migratory shorebirds due to this development.
Degradation of habitat leading to a <i>substantial reduction*</i> in migratory shorebird numbers	No. Stormwater management and remediation of erosion gullies is expected to increase the quality of habitat near the mouth of Sandy Creek for migratory shorebirds.
Increased disturbance leading to a <i>substantial reduction*</i> in migratory shorebird numbers	No. The project is expected to increase visitation to Casuarina Beach by approximately 2%, albeit most of the additional visits will be concentrated near Sandy Creek. The proposed mitigation measures which include locating the access path to the east of Sandy Creek and away from areas of sensitivity, increased signage, barrier fencing, community education and citizen science, will appropriately avoid and mitigate any potential disturbance to migratory shorebirds. If migratory shorebirds are disturbed, they would move temporarily up beach to Lee Point as they are already observed to do (Lilleyman 2016).

Significant impact	Response
Direct mortality of birds leading to a <i>substantial reduction</i> * in migratory shorebird numbers	No. Project activities will not impact on migratory shorebird habitat. Traffic, noise and light pollution during construction and operation will be buffered by the Casuarina Coastal Reserve and unlikely to impact on migratory shorebirds. In terms of predation, although the development is likely to lead to an increase in the number of dogs that occur on Casuarina Beach, and possibly of cats in the surrounding area, predation of shorebirds by these species is not identified as a threat to migratory shorebirds. Furthermore, the areas adjoining Sandy Creek are already on dog-on-lead area, and increased signage will ensure this occurs.

* A 'substantial reduction' includes the number of migratory shorebirds using an area

7.4.1.4 Actions on Commonwealth Land or by Commonwealth Agencies

As the proposed development will be undertaken on Commonwealth land (2CRU) and by a Commonwealth agency, an assessment has been made as to whether the project has an impact on the 'environment as a whole' in accordance with Section 26-28 of the EPBC Act. The assessment has been made in accordance with the *EPBC Act 1.2 Actions on, or impacting upon, Commonwealth land or by a Commonwealth Agency* (DSEWPaC 2012).

The results of the significant impact assessment are provided in the sub-sections below. Based on these findings which account for the avoidance and mitigation measures described in Section 7.2.4.5, it is considered unlikely that the project will have a significant impact upon the environment.

Landscape and soils

The potential for project activities to significantly impact upon landscapes and soils is assessed in Table 52.

Table 52. Significant impact assessment on landscapes and soils

Is there a real chance or possibility that the action will...	Response
Substantially alter natural landscape features?	No. The project would result in the replacement of woodland habitat with a housing and commercial development, but this is not considered to be a substantial alteration given that native vegetation that will be removed is heavily degraded, not threatened or sensitive, and occurs in adjoining areas. The most important natural landscape features are considered to be 20.6 ha of Monsoon Vine-thicket in 2CRU which will be retained and annexed as part of the Casuarina Coastal Reserve (although 0.5 ha will be removed for the detention basin), and 0.9 ha of Monsoon Rainforest in Muirhead North that will be retained and incorporated into public open space.
Cause subsidence, instability or substantial erosion?	No. An ESCP will be prepared by an appropriately-qualified person in accordance with the International Erosion and Association Guidelines to manage erosion and sedimentation across the development site for each stage of construction. ESCP will be reviewed by Parks and Wildlife Commission and approved the Land Management Unit of DENR before commencement. Areas of high erosion risk, i.e. the escarpment area along the western boundary, will not be developed. In addition, the inclusion of open space buffers between developed areas and the escarpment, and the establishment of a formal access point (staircase) into the Casuarina Coastal Reserve, will

Is there a real chance or possibility that the action will...	Response
	further mitigate erosion risks. Furthermore, the erosion gullies in the south-west of 2CRU will be rehabilitated.
Involve medium or large-scale excavation of soil or minerals?	No. The proposed development does not involve medium or large-scale excavation of soils, as the levels required for construction can be achieved by re-contouring. Excavations for services will be shallow (typically within 3 m of the ground surface) and there is no identified requirement for importation of fill material.

Coastal landscapes and processes

The potential for project activities to significantly impact upon coastal landscapes and processes is assessed below (Table 53).

Table 53. Significant impact assessment on coastal landscapes and processes

Is there a real chance or possibility that the action will...	Response
Alter coastal processes, including wave action, sediment movement or accretion, or water circulation patterns?	No. The development is terrestrial and will not cause off-site physical impacts that would alter the coastal or estuarine environment. Erosion and sediment controls will ensure that there is no significant increase in sedimentation entering Sandy Creek and Buffalo Creek, and would likely result in a net improvement in the quality of Sandy Creek due to the existing erosion issues on this site. That will be treated.
Permanently alter tidal patterns, water flows or water quality in estuaries?	No. The development is terrestrial and will not cause off-site physical impacts that would alter the coastal or estuarine environment. The Stormwater Management Plans (Appendix E and Appendix F) shows a series of water-sensitive urban design treatment trains and retarding basins designed to reduce the amount of sediment leaving the site and assist in reducing nutrient load. The Stormwater Management Plans for the development area entails: – Maximising on site storage and recharge of surface run-off into existing aquifers – Limiting run-off to pre-development conditions by promoting filtration of run-off through enhanced natural vegetation and storage systems – Provide erosion and sediment control by incorporating measures during construction and permanent sediment basins at outlets to natural waterways.
Reduce biological diversity or change species composition in estuaries?	No. With the mitigation measures proposed there should not be any significant decrease in the water quality of Sandy Creek or Buffalo Creek that may impact on biological diversity. Nonetheless, water-quality monitoring is proposed in Sandy Creek due to the lack of existing data and the importance of the creek on supporting migratory shorebirds at the confluence with Casuarina Beach. Water monitoring will be undertaken in accordance with the Water Quality Monitoring Plan (see Appendix O) at Sandy Creek. Due to the poor quality of Buffalo Creek, monitoring within this water-body is not considered necessary.
Extract large volumes of sand or substantially destabilise sand dunes?	No. There will be no direct disturbance of beach, dune or intertidal areas.

Ocean forms, ocean processes and ocean life

The potential for project activities to significantly impact upon ocean forms, ocean processes and ocean life is assessed in Table 54.

Table 54. Significant impact assessment on ocean forms, ocean processes and ocean life

Is there a real chance or possibility that the action will...	Response
Reduce biological diversity or change species composition on reefs, seamounts or in other sensitive marine environments?	No. The project footprint does not include any sensitive marine environments.
Alter water circulation patterns by modification of existing landforms or the addition of artificial reefs or other large structures?	No. The development is on land and will not cause off-site physical impacts that would alter the coastal or estuarine environment.
Substantially damage or modify large areas of the seafloor or ocean habitat, such as sea grass?	No. The development is on land and will not cause off-site physical impacts that would alter the coastal or estuarine environment.
Release oil, fuel or other toxic substances into the marine environment in sufficient quantity to kill larger marine animals or alter ecosystem processes?	No. The development does not involve any significant quantities of toxic substances. A spill management plan will be in place during construction, and pollutants from run-off will be treated as part of treatment train described in the Stormwater Management Plan (Appendix E and Appendix F).
Release large quantities of sewage or other waste into the marine environment?	No. Sewerage will be treated at the Leanyer Sewerage Treatment Plant. The sewerage network that will be constructed for the project has sufficient storage capacity for emergency situations and complies with PWC requirements (Section 6).

Water resources

The potential for project activities to significantly impact upon water resources is assessed in Table 55.

Table 55. Significant impact assessment on water resources

Is there a real chance or possibility that the action will...	Response
Measurably reduce the quantity, quality or availability of surface or ground water?	No. The Stormwater Management Plans shows that a treatment train of bioretention and detention basins will ensure the quality and quantity of water discharging into Sandy Creek and Buffalo Creek meets NT Guidelines. Furthermore, given the extent of erosion that has occurred on 2CRU, the Stormwater Management Plans along with remediation of the erosion gullies is likely to improve the quality of water discharging into Sandy Creek. The project is unlikely to have any interaction with ground water (see Section 4.3.2.1).
Channelise, divert or impound rivers or creeks or substantially alter drainage patterns?	No. The project will not involve any modifications to Sandy Creek or Buffalo Creek.
Measurably alter water table levels?	No. Increasing the area of impenetrable surface is likely to reduce the infiltration from rainfall and recharge of groundwater levels. However, the local groundwater system is unlikely to be measurably altered and recharge will occur in other parts of the catchment (see Section 4.3.2.1).

Pollutants, chemicals and toxic substances

The potential for project activities have a significant impact regarding pollutants, chemicals and toxic substances is assessed in Table 56.

Table 56. Significant impact assessment regarding pollutants, chemicals and toxic substances

Is there a real chance or possibility that the action will...	Response
Generate smoke, fumes, chemicals, nutrients, or other pollutants which will substantially reduce local air quality or water quality?	No. The CEMP will involve standard mitigation measures to ensure all equipment, plant and machinery are maintained and operated in suitable manner to ensure air quality and water quality is maintained in accordance with NT Guidelines.
Result in the release, leakage, spillage, or explosion of flammable, explosive, toxic, radioactive, carcinogenic, or mutagenic substances, through use, storage, transport, or disposal?	No. All chemicals will be used and stored in accordance with the MSDS. A spill management plan will be in place in the unlikely event a spill of toxic substances occurs.
Increase atmospheric concentrations of gases which will contribute to the greenhouse effect or ozone damage?	No. The quantity of greenhouse gases released from vegetation clearing or during construction would not have any impact on the global warming. The use of Chlorofluorocarbons will be in accordance with international guidelines.
Substantially disturb contaminated or acid-sulphate soils?	No. It is unlikely that acid-sulphate soils will be disturbed during the development (see Section 4.2.1).

Plants

The potential for project activities to significantly impact upon plants is assessed in Table 57.

Table 57. Significant impact assessment on plants

Is there a real chance or possibility that the action will...	Response
Involve medium or large-scale native vegetation clearance?	No. Approximately 110 hectares of degraded native vegetation that is common in the region will be cleared. All sensitive vegetation-types (i.e. Monsoon Vine-thicket and Monsoon Rainforest), which cover approximately 22.5 ha of the project site, will be retained, except for 0.5 hectares of Monsoon Vine-thicket to be removed for the detention basin. There will also be opportunities to retain native vegetation within the areas of public open space.
Involve any clearance of any vegetation containing a listed threatened species which is likely to result in a long-term decline in a population or which threatens the viability of the species?	No. There are no EPBC Act-listed threatened plant species or ecological communities within or surrounding the area proposed for development. One NT-listed threatened flora species – the Darwin Cycad– occurs in patches throughout the area proposed for development. However, the population of this species within the project footprint does not constitute an ‘important population’. Moreover, where possible, individual plants will be retained <i>in situ</i> or relocated to public open spaces within the development. Sensitive Monsoon Vine-forest and Monsoon Rainforest that occurs on the project site will be protected (except for 0.5 hectares of Monsoon Vine-thicket to be removed for a detention basin on 2CRU).
Introduce potentially invasive species?	No. The site is heavily disturbed. It has been subjected to significant disturbance in the past and weeds are widespread along tracks and in

Is there a real chance or possibility that the action will...	Response
	previously cleared and disturbed areas. Grassy weeds make up the majority of the weed impact – particularly Gamba Grass and Mission Grass. An active program to control the extent of weeds on 2CRU, particularly Gamba Grass, commenced in 2015 and will continue through the construction phase of the project and be extended into Muirhead North. Post construction, areas of open space will be managed for weeds.
Involve the use of chemicals which substantially stunt the growth of native vegetation?	No. The development will not involve the use of chemicals which substantially stunt the growth of native vegetation.
Involve large-scale controlled burning or any controlled burning in sensitive areas, including areas which contain listed threatened species?	No. No control burning will occur as part of the project. The project area has previously been subjected to a damaging fire regime, to the detriment of ecological values. Once the site is developed and native vegetation cleared, the adjacent rainforest and vine thicket within the Casuarina Coastal Reserve will become better protected from fire.

Animals

The potential for project activities to significantly impact upon animals is assessed in Table 58.

Table 58. Significant impact assessment on animals

Is there a real chance or possibility that the action will...	Response
Cause a long-term decrease in, or threaten the viability of, a native animal population or populations, through death, injury or other harm to individuals?	No. Habitat clearing will lead to the loss of habitat for native animals. The potential for construction activities to cause death or injury to fauna will be mitigated through the use of fauna spotter-catchers during land clearing. Apart from the Black-footed Tree-rat, all the fauna species that occur within the areas to be cleared are common and abundant in analogous habitat within the greater Darwin region.
Displace or substantially limit the movement or dispersal of native animal populations?	No. The project will result in the loss of habitat for native fauna. However, the species affected are common and widespread across the northern suburbs of Darwin and should not be isolated as a result of the project.
Substantially reduce or fragment available habitat for native species?	No. The project will result in the loss of habitat for native fauna. However, the species affected are common and widespread across the northern suburbs of Northern Territory and should not be isolated as a result of the project. The project would result in the loss of approximately 23 ha of fragmented, Black-footed Tree-rat habitat including approximately 5.3 ha of habitat on 2CRU and 17.5 ha of habitat on Muirhead North. Habitat will also be diminished in a 7.5 ha of habitat along the boundary with 2CRU and the conservation area to comply with the Biting Insect Management plan. Given the availability of suitable quality elsewhere in Lee Point, including at the CDU campus and near the Buffalo Creek ramp where the species has been previously recorded, the loss of habitat within a local context is not considered to be substantial. The links between Black-footed Tree-rat habitat, 2CRU and Casuarina Coastal Reserve will be maintained by preserving and rehabilitating habitat in the south-west corner of 2CRU.
Reduce or fragment available habitat for listed threatened species which is likely to displace a population, result in a long-term	No. Black-footed Tree-rat was recorded during targeted surveys in Muirhead North and suitable habitat for the species occurs in Muirhead North and 2CRU. The project would result in a reduction of 23 ha of fragmented, Black-footed Tree-rat habitat including approximately 5.3 ha of habitat on 2CRU and

Is there a real chance or possibility that the action will...	Response
decline in a population, or threaten the viability of the species?	17.5 ha of habitat on Muirhead North. The links between Black-footed Tree-rat habitat, 2CRU and Casuarina Coastal Reserve will be maintained by preserving and rehabilitating habitat in the south-west corner of the 2CRU. The development of Muirhead North is unlikely to fragment populations on the eastern side of Lee Point Road as continuous habitat along the eastern boundary connecting areas to the north and south of Muirhead North will be sustained. In addition, the eastern section of Muirhead North will be developed as larger, rural lots, that could potentially support Black-footed Tree-rat dispersal. The number of Black-footed Tree-rats that are likely using the project site is expected to be low based on the results of the targeted surveys, and other information sources. There is considered to be sufficient habitat in the adjoining landscape to support any individuals displaced by the project.
Introduce exotic species which will substantially reduce habitat or resources for native species?	No. The site is adjacent to developed areas. It is already heavily infested with weeds and supports feral species such as cats and wild dogs. Weed control has already commenced on 2CRU and will be extended to Muirhead North throughout the construction phase of the project.
Undertake large-scale controlled burning or any controlled burning in areas containing listed threatened species?	No. No control burning will occur as part of the project. The project area has previously been subjected to a damaging fire regime, to the detriment of ecological values. Once the site is developed and native vegetation cleared, the adjacent rainforest and vine thicket within the Casuarina Coastal Reserve, and Monsoon Rainforest within Muirhead North, will become better protected from fire.

People and communities

The potential for project activities to significantly impact upon people and communities is assessed in Table 59.

Table 59. Significant impact assessment on people and communities

Is there a real chance or possibility that the action will...	Response
Substantially increase demand for, or reduce the availability of, community services or infrastructure which have direct or indirect impacts on the environment, including water supply, power supply, roads, waste disposal, and housing?	No. Water, power and sewerage services will be provided to satisfy the projected demands and meet NT and PWC requirements. The commercial precinct will provide a number of community services including health care, a primary school, child-care facilities, a sports oval and other community services to meet the demand for the northern suburbs of Darwin including for new residents at the project site.
Affect the health, safety, welfare or quality of life of the members of a community, through factors such as noise, odours, fumes, smoke, or other pollutants?	No. The project is unlikely to produce environmental pollution that may affect the health of the community. The CEMP includes measures to avoid and mitigate any potential impacts due to noise (machinery) or pollutants (chemical spills and water run-off). An odour assessment found that the project site is not within the odour footprint of the Leanyer Treatment Plant.
Cause physical dislocation of individuals or communities?	No. The site currently does not provide any housing or other forms of accommodation. No adjoining residents will have to relocate during construction. The project will provide affordable housing options for the local community.

Is there a real chance or possibility that the action will...	Response
Substantially change or diminish cultural identity, social organisation or community resources?	No. The site is not considered to be of cultural or social importance to the local community. The 2CRU site has been used for Defence purposes, and therefore has not been available to the community for social or recreational purposes. Muirhead North is vacant crown land.

Heritage

The potential for project activities to significantly impact upon heritage is assessed in Table 60. The proposed development will not impact on any sites listed on the NT Heritage Register, National Heritage List, World Heritage List or Commonwealth Heritage List. There are also no registered or recorded Aboriginal Sacred Sites protected under the NT *Aboriginal Sacred Sites Act* in the areas proposed for development.

Table 60. Significant impact assessment on heritage

Is there a real chance or possibility that the action will...	Response
Permanently destroy, remove or substantially alter the fabric (physical material including structural elements and other components, fixtures, contents, and objects) of a heritage place?	No. The Proponent proposes to retain the sites referred to as the 'Bunkers' located along Lee Point Road. There is no other heritage or cultural sites within the project area including known sacred sites. An Aboriginal Areas Protection Authority Certificate will be obtained by the Proponent prior to commencement of construction.
Involve extension, renovation, or substantial alteration of a heritage place in a manner which is inconsistent with the heritage values of the place?	
Involve the erection of buildings or other structures adjacent to, or within important sight lines of, a heritage place which are inconsistent with the heritage values of the place?	
Substantially diminish the heritage value of a heritage place for a community or group for which it is significant?	
Substantially alter the setting of a heritage place in a manner which is inconsistent with the heritage values of the place?	
Substantially restrict or inhibit the existing use of a heritage place as a cultural or ceremonial site?	

7.4.2 Northern Territory

7.4.2.1 Territory Parks and Wildlife Conservation Act

The *Territory Parks and Wildlife Conservation Act* makes provision for the establishment of Territory Parks, other Parks and Reserves, and the study, protection, conservation and sustainable utilisation of wildlife. A permit would be required to take or interfere with protected wildlife during habitat clearing, where protected wildlife includes all vertebrate animals that are indigenous to Australia.

7.4.2.2 Weed Management Act 2001

Certain plants are declared as weeds under the WM Act. Under the Act, landowners must take all reasonable measures to prevent their land being infested with a declared weed, and take all reasonable measures to prevent a declared weed on their land spreading to other land.

The following declared weeds have been found within the project site:

- Gamba Grass
- Mission Grass
- Hyptis
- Snakeweed.

Under the Act, Gamba Grass is classified as a Class A weed (to be eradicated), and the other species are classified as Class B weeds (to be controlled). In accordance with the Act, works will be undertaken to eradicate Gamba Grass from the site (which has already commenced on 2CRU), while actions are included in the CEMP to ensure Class B weeds will not be spread off-site.

7.4.2.3 *Heritage Act 2011*

The *Heritage Act 2011* provides for the conservation of cultural and natural heritage within the Northern Territory, where cultural heritage refers to places or objects that have been created or modified by humans. It includes a wide range of structures and places associated with European settlement, including maritime heritage. All Aboriginal and Macassan archaeological sites are protected under the Act.

The project will destroy a background scatter of stone artefacts recorded in the west of 2CRU (EcOz 2015). In accordance with Section 72 of the Act, DHA will apply for a works approval to carry out work on this scatter.

7.4.2.4 *Aboriginal Sacred Sites Act*

The *Northern Territory Aboriginal Sacred Sites Act* affords protected all Aboriginal Sacred Sites, whether they have been recorded or not. Under the Act, the Aboriginal Areas Protection Authority (AAPA) is responsible for the protection of all sites listed under the Act.

There are no registered sacred sites within the project site. The proponent will obtain an Authority Certificate from the AAPA prior to commencement of works.

7.5 Environmental Offsets

In accordance with the EPBC Act, an offset is required to compensate for any residual adverse impact to a matter of NES. Offsets are likely to be required for Black-footed Tree-rat as it was assessed that after considering the proposed mitigation and avoidance measures, a significant impact on the species is likely (Section 7.4.1.2).

The area of habitat that is likely to require offsetting is estimated to be 23 ha, consisting of one 5.53 ha patch in 2CRU and 17.5 ha across four patches in Muirhead North (see Section 7.2.4.3). In addition, habitat within a 7.5 ha patch along the boundary of the development with the conservation area in 2CRU will be modified to comply with the Biting Insect Management Plan. All other habitat is unlikely to be suitable for Black-footed Tree-rat due to a lack of large trees and food plants, and proliferation of Gamba Grass in the ground-layer (see Section 7.2.4.3).

Offsets would be obtained in a staged manner reflective of the staged development of the project, with offsets sought prior to each stage commencing (see Table 3). Offsets will be sought via a combination of on-site and off-site offsets as described below.

7.5.1 On-site offset

The protection of suitable habitat within the 21.95 ha conservation area would more than suitably offset the loss of habitat within 2CRU in accordance with the EPBC Act offset policy (DSEWPaC 2012). The conservation area supports Monsoon Vine-thicket and eucalypt woodland, and the study by Griffiths *et al.* (2002) not only recorded the species in this area but showed the species had a preference for nesting trees in the area of Monsoon Vine-thicket compared to other habitats in and around 2CRU.

The 21.95 ha conservation area, previously zoned as Commonwealth land was rezoned as 'Conservation' during the rezoning process in late 2015. The conservation area is currently managed by DHA and will be transferred to the NT Government.

The EPBC Act-offset policy (DSEWPaC 2012) was considered when assessing whether the conservation area would be suitable habitat for the loss of habitat for Black-footed Tree-rat at 2CRU (

Table 61). The data used to characterise the offset site is considered to be conservative. Nonetheless, the conservation area achieves more than 100% of the required offset for loss of Black-footed Tree-rat habitat at 2CRU (

Table 61).

As the rezoning of the conservation area was undertaken to facilitate the residential development of the project site, and was done voluntarily by the proponent, it is considered to meet the 'additionality' requirement of an offset site in accordance with the EPBC Act offset policy (DSEWPac 2012). In addition, the rezoning process occurred in December 2015, and therefore conservation benefits have been delivered to Black-footed Tree-rat prior to the proposed impact occurring. As such, early rezoning of the conservation areas has increased the overall benefit of the offset site as outlined in the EPBC Act advanced offset policy (DoE 2016). These additional benefits have not been accounted for in the offset calculations below.

Management actions to be undertaken in the conservation area that will improve the overall quality of the offset site include:

- Rehabilitating informal access tracks
- Addressing erosion issues
- Planting Black-footed Tree-rats' preferred food plants in suitable locations
- Pest animal control
- Improved awareness of values of conservation area as part of broader signage programs for migratory shorebirds and threatened sawfish.

A suitably qualified environmental contractor will be appointed by DHA to implement these actions until the NT Government take responsibility for managing (and funding) the conservation zone. It has yet to be agreed when the NT Government will take ownership of the conservation area.

The management of the conservation area for offsets will be implemented in accordance with an approved offset management plan to be prepared in conjunction with Parks and Wildlife Service.

Table 61. Offset calculations for Black-footed Tree-rat habitat at 2CRU

	Factor	Value	Description
IMPACT CALCULATOR	Area (ha)	9.28	Loss of 5.53 ha patch adjoining Lee Point Road, as well as 50% of the area lost in the 7.5 ha (i.e. 3.75 ha) patch due to habitat modifications to comply with Biting Insect Management Plan.
	Quality (/10)	5	Averaged from components scores of: site condition (7/10), species stocking rate (4/10) and site context (4/10). Stocking rate is considered low given no animals were detected during survey in 2CRU. Site context is low as local population is considered to be isolated in Lee Point area and unlikely to be connected with other populations.
	Total quantum of impact	4.64	As per offset calculator
OFFSET CALCULATOR	Time over which loss is averted (years)	20	Maximum time allowed in accordance with the EPBC Act policy.
	Time until ecological benefit (years)	5	Rezoning, rehabilitation of informal tracks, replanting with food trees, fixing erosion problems, pest animal control are expected to deliver benefits to species within this time frame.
	Start area (ha)	21.95	Area of conservation area.
	Start quality (/10)	4	Conservative estimate for purposes of calculation. Species has previously been recorded in conservation area, and number of large trees present that would provide suitable denning resources. Dense areas of Monsoon Vine-thicket without large eucalypt or pandanus trees only marginal value.
	Future quality without offset (/10)	3	Conservative estimate for purposes of calculation. Illegal site access, ongoing pressure from existing users of Casuarina beach, plus erosion would contribute to decline in quality.
	Future quality with offset (/10)	6	Conservative estimate for purposes of calculation. Revegetation with preferred food plants, addressing erosion problems, formalising access tracks, would improve value of habitat.
	Risk of loss (%) without offset	20	Conservative estimate for purposes of calculation. Ongoing pressures from illegal site access, ongoing pressure from existing users of Casuarina Beach, pest animals and erosion threatens the viability of the proposed offset site.
	Risk of loss (%) with offset	5	Background rate of extinction.
	Confidence in result (%)	80	Conservative estimate for purposes of calculation. Rezoning process, managing impacts from beach users, formalising access tracks and revegetation are considered best-practice in order to achieve intended ecological benefit.

The conservation area represents one of the few remaining, if not the remaining area of freehold land that is suitable habitat for Black-footed Tree-rat and can be used as an offset. An examination of the current land-uses and tenure of known Black-footed Tree-rat sites in the greater Darwin area identified all as either Crown land or Defence land that is therefore either already protected for conservation purposes or could not be realistically managed for conservation purposes (see Stokeld and Gillespie 2015 for further information).

7.5.2 Off-site offset

To offset the loss of Black-footed Tree-rat habitat in Muirhead North, it is proposed that a direct payment on a per hectare basis be made into a fund, or to a conservation group, that will be dedicated to undertaking management on crown land, that will provide direct benefits to Black-footed Tree-rat. Rangers from the Larrakia National Aboriginal Corporation have identified a suitable site at Cox's Peninsula. The area contains suitable habitat for Black-footed Tree-rat; however, is currently not being managed for conservation and is under threat from fire frequency, weeds (Gamba Grass) and pest animals (feral cat and pig). The proposed off-site offset will involve providing rangers from the Larrakia National Aboriginal Corporation with funding to implement a range of management actions to improve Black-footed Tree-rat habitat in accordance with an approved offset management plan. The offset management plan will be implemented over a ten-year period. The offset management plan will be developed prior to offset commencement and will directly address the key threats on site.

The location of the offset has not been finalised but will be approximately 100 hectares in size. The use of the EPBC Act calculator to determine the adequacy of the off-site offset proposal cannot be directly applied in this instance due to the land-tenure of the offset site. This is common for many offset proposals in the Northern Territory as the majority of land is lease-hold (although the project site is owned by DHA). Given the proposed on-site offset, which is 21.95 hectares in size, can address the loss of approximately one third of Black-footed Tree-rat habitat on site (Table 62), a 100 hectare off-site offset would adequately compensate for the loss of the remaining two-thirds of Black-footed Tree-rat habitat.

Using the approval conditions for the Eastern Leases Project at Groote Eyland, Northern Territory (EPBC 2014/7228) as a precedent, a cash payment of \$4,500 (exc GST) is proposed for every hectare of Black-footed Tree-rat habitat removed. Using the Eastern Leases Project as a precedent, a cash payment of \$4,500 (exc GST). While the cash payment for the Eastern Leases Project was for all native vegetation removed (not just identified habitat), it was also to address impacts to two threatened species and the quality of native vegetation was much higher. Furthermore, no detailed habitat mapping for threatened species was undertaken for the Eastern Leases Project, whereas an accurate understanding of habitat for Black-footed Tree-rat has been provided for 2CRU and Muirhead North based on targeted camera trap surveys and detailed habitat assessments.

Payments will be made directly to the Larrakia Nation Aboriginal Corporation prior to each stage commencing, for an amount equivalent to the area of habitat to be removed.

The NT EPA and DoEE will be notified in writing prior to each stage commencing to confirm that payment has been made to the relevant management group.

The offset arrangement of paying compensatory fees will be finalised as part of the offset management plan.

7.5.3 Staging Strategy

Due to the staged nature of development, Black-footed Tree-rat habitat will be cleared progressively in accordance with the staging plan (Table 3). The area of Black-footed Tree-rat habitat that will be impacted by each stage has been calculated below (Table 62). The strategy for offsetting habitat is also shown. Removal of Black-footed Tree-rat will not commence until offsets are secured (i.e. for habitat loss in 2CRU), or

compensatory payments have been made in accordance with approved offset management plan (i.e. for habitat loss in Muirhead North).

Table 62. Alignment of Black-footed Tree-rat offset strategy with staging plan

Stage	Site	Estimated Start Date	Estimated Completion Date	Area of habitat (ha)	Offset Strategy
1A	2CRU	April 2019	November 2019	0.40	Onsite offset
1B	Muirhead North	April 2019	November 2019	5.10	Compensatory payments
2A	2CRU	March 2020	December 2020	0.47 (=0.93 x 0.5)	Onsite offset
2B	Muirhead North	March 2021	November 2021	12.37	Compensatory payments
3	2CRU	March 2022	October 2022	5.13	Onsite offset
4	2CRU	April 2023	November 2023	3.02 (=6.03 x 0.5)	Onsite offset
5	2CRU	March 2024	November 2024	0.26 (=0.52 x 0.5)	Onsite offset
Total				26.75	

8 SOCIAL ECONOMIC

8.1 Introduction

This chapter has been prepared to satisfy the socio-economic requirements of the ToR for the *Lee Point Master-Planned Urban Development* Environmental Impact Statement, and covers the required aspects from Sections 4, 5.6 and 5.7.8 of the ToR. The chapter has been prepared in accordance with the NT EPA's *Guidelines for the Preparation of an Economic and Social Impact Assessment* (NT EPA 2013).

The chapter is structured in the following manner:

- Background information on the relevant legislation, planning provisions, the Lee Point Master-planned Urban Development and key stakeholders that will be involved or impacted (positively or negatively) during the project (Sections 8.2 to 8.4).
- Description of the availability of community services, and workforce to support the project, any stresses the project is likely to project on to existing services, and the commercial and employment opportunities the project is expected to deliver (Section 8.5).
- A summary of the risks to social and economic factors and related mitigation measures, including stakeholder engagement and community strategy (Section 8.6).

Further information is provided in the CEMP about the proposed monitoring methods that will be undertaken to check that performance of the project meets the stated social and economic Key Performance Indicators.

8.2 Legislation

The following legislation and guidelines have been referenced in the preparation of this chapter:

- *Northern Territory Environmental Assessment Act*
- *Northern Territory Planning Act*
- *Northern Territory Environment Protection Authority Guidelines for the preparation of an Economic and Social Impact Assessment (May 2013)*
- *Queensland Department of Infrastructure and Planning Social Impact Assessment: Guideline to preparing a Social Impact Management Plan (September 2010)*
- *International Association for Public Participation Public Participation Spectrum (2014)*
- *Queensland Government Office of Urban Management (Department of Infrastructure) South East Queensland Regional Plan 2005-2026 – Implementation Guideline No. 5: Social Infrastructure Planning (June 2007)*
- *Parks and Wildlife Commission of the Northern Territory Casuarina Coastal Reserve Management Plan (April 2016)*
- *Parks and Wildlife Commission of the Northern Territory Casuarina Coastal Reserve Experience Development Plan (2015)*
- *Northern Territory Planning Scheme*
- *Northern Territory Department of Lands, Planning and the Environment Darwin Regional Land Use Plan 2015*

In addition to the above legislation and policy documents, a number of reports, studies and websites have been reviewed in the preparation of these reports, which are included in the reference list (Section 0).

8.3 Locality

The 2CRU and Muirhead North sites are situated in the area of Lee Point, between the existing and developing suburbs of Lyons and Muirhead (respectively), the Casuarina Coastal Reserve to the west of 2CRU and the Lee Point public recreation area at the northern end of Lee Point Road (comprising the northern extent of the Casuarina Coastal Reserve). Immediately north of Muirhead North is the Lee Point Village Resort, comprising a large caravan park including cabins and camp grounds, along with recently developed motel facilities concentrated in the northern portion of the site (adjacent to Buffalo Creek Road). Buffalo Creek Road, located opposite and slightly north of Muirhead North provides access to the mouth of Buffalo Creek, including boat ramp and trailer parking area.

To the south of the project site, the joint DHA/private residential suburbs of Lyons and Muirhead are located on the western and eastern sides of Lee Point Road respectively. Lyons comprises approximately 690 lots with Muirhead some 1,200 lots once completed. Stages 6 and 7 of Muirhead are currently under construction. A small local centre is identified for future development within Muirhead, located adjacent to the Lee Point Road frontage. Adjacent to the western boundary of Lyons is the Royal Darwin Hospital, Darwin Private Hospital and associated government and private health facilities. Further south are the suburbs of Tiwi, Wanguri and Leanyer.

Zoning within the greater locality comprises a mix of residential, accommodation, public, community and conservation zones. The project site is zoned FD (Future Development) per Clause 5.26 of the Northern Territory Planning Scheme. The FD Zone within the subject land links with the Lee Point Area Plan and Planning Principles within Clause 14.1.5 of the Scheme, which provide a framework for urban residential, commercial, tourism and community development within the project site, along with the protection of significant environmental and heritage qualities.

The Casuarina Coastal Reserve, which extends along the western boundary of 2CRU, is zoned CN (Conservation). To the south of 2CRU is the Royal Darwin Hospital, which is encompassed within Zone CP (Community Purpose). The suburb of Lyons is Zoned SD17 (Specific Use Darwin 17). Muirhead is zoned SD23 (Specific Use Darwin 23), with land adjacent to the eastern boundary zoned PS (Public Open Space). To the north of Muirhead North, land is zoned OR (Organised Recreation), reflective of current/future development as a golf course, with a small strip of PS land extending from Lee Point Road adjacent to part of the site's northern boundary. The Lee Point Village Resort is zoned CV (Caravan Park), with land further north comprising a combination of PS, CP and CN zones.

Commercial and recreation facilities within the broader locality include the Tracey Village Social and Sports Club, Casuarina shopping and commercial precinct, Hibiscus Shopping Centre and various small local shops.

Schools, early learning centres and childcare facilities in the greater locality include the Dripstone Middle School, Tiwi Early Learning Centre, Henbury School, Wanguri Preschool, Leanyer Primary School, St Andrew Lutheran School and the Holy Spirit Catholic Primary School. The majority, if not all, commercial and community facilities are outside of what would ordinarily be considered the immediate locality.

Both Muirhead North and 2CRU present to Lee Point Road as natural bushland with relatively minimal intrusion, and thus the amenity of the locality is moderate-high. The communications tower adjacent to the north-east corner of the project site is a prominent feature, with the southern portion of the Lee Point Village

Resort maintaining vegetation through established landscaping. Further north along Lee Point Road, the Resort is more sparsely vegetated due to the presence of hardstand areas and the recently developed motel facilities. Lee Point Road crests near the intersection with Buffalo Creek Road, and allows ocean views from this point onwards (to vehicles travelling north).

8.4 Lee Point Master Planned Urban Development

In late 2015, the Minister for Lands and Planning approved an amendment to the Northern Territory Planning Scheme to rezone the land to FD (Future Development) and introduce the Lee Point Area Plan into the Scheme. The amendment was proposed to facilitate the regulatory policy framework to allow the development of the area for the purpose of a new suburb, including residential, commercial, tourist accommodation, recreation, community, education and open space uses. Specifically, the amendment sought to:

- Introduce a land use/development zone under the NT Planning Scheme to the project site by zoning the land FD.
- Rezone lot 09370 from SD26 to FD (Future Development).
- Amend Part 8 of the Scheme to include the *Lee Point Area Plan and Planning Principles*, contained in Attachment B, in order to facilitate a master planned urban subdivision on the project site.

The Lee Point Area Plan will ultimately facilitate for the project site:

- Residential development at a range of densities and housing typologies to accommodate a mix of defence and private residents.
- The development of land for necessary and appropriate community services and facilities based on the existing and anticipated population within the subject land and surrounding areas.
- A mixed use 'neighbourhood centre' that will integrate tourism, commercial, community and residential development around a 'main street', whilst integrating with surrounding residential, community and open space development.
- A dedicated tourism precinct, including accommodation and tourism/community activities that integrate with the main street.
- Coastal view corridors and access to the Casuarina Coastal Reserve, whilst protecting the reserve from potential impacts arising from the development of the land.
- Development that responds to the characteristics and constraints of the site and surrounding land, including the coastal reserve, tourism and public space facilities, the Royal Darwin Hospital and existing residential areas.
- Due consideration to historically significant items within the subject land and the historic use and significance of defence operations.
- Integration with the surrounding road network, including safe, functional and efficient connections to Lee Point Road for all necessary forms of transport.
- A high quality open space network, including a high level of accessibility and connectivity for pedestrians and cyclists.
- Staging of development to align with population growth, the demand for housing and other facilities, and the provision of services and infrastructure.

The FD Zoning will enable the Lee Point Urban Development Master Plan to be finalised and an application for subdivision to reflect the final Master Plan to be lodged in accordance with the *Lee Point Area Plan and Planning Principles*. Upon the completion of the various stages of development within the site, the land will be rezoned in accordance with the relevant Planning Scheme Zone, likely to include (but not necessarily limited to):

- TC (Tourist Commercial) and C (Commercial).
- SD (Single Dwelling), MD (Multiple Dwelling), MR (Medium Density Residential) and HR (High Density Residential).
- CP (Community Purpose).
- PS (Public Open Space) and OR (Organised Recreation).
- CN (Conservation).

The draft planning principles seek to ensure the development of a distinctive neighbourhood environment that takes advantage of its coastal location, provides an integrated neighbourhood centre, includes tourism activities and accommodation, requires the appropriate provision of community services and ensures an emphasis on walking and cycling.

8.4.1 Residential Development

The majority of the Area Plan identifies land for residential development within the project site at General Urban and Suburban densities, in addition to residential development within the neighbourhood centre.

Nominal densities are provided based on net developable area (i.e. residential areas exclusive of open space, road infrastructure and community facilities), with the following density rates provided:

- *Urban Centre* – 60-80 dwellings per hectare, reflective of intended future development in the form of medium-high density housing as part of the mixed use neighbourhood centre.
- *General Urban* – 20-40 dwellings per hectare to facilitate a range of housing options including detached housing (single dwellings), duplex housing, units, townhouses, row dwellings and apartments at densities consistent with zones SD, MD and MR.
- *Sub-Urban* – 10-20 dwellings per hectare reflective of a more traditional sub-urban residential area, whilst retaining the ability to provide a range of housing options generally consistent with zones SD and MD. Small-lot housing (less than 400m²), townhouse, unit and walk-up housing development to be concentrated in areas of high amenity and/or in close proximity to public open space.
- *Rural Residential* – Provision of housing development with minimum lot size of 4,000m² in accordance with Zone RR due to the need to retain the 1 kilometre biting insect buffer to urban development. Maximum dwelling densities of 5 dwellings per hectare is reflective of the ability for the development of *independent units* pursuant to Clause 7.10.4.

Based on the above density rates and servicing, it is anticipated that the project site will accommodate between 600 and 1,000 dwellings.

8.4.2 Community Purpose Land

The Area Plan identifies a *Primary School and Community Hub* at Muirhead North, comprising approximately 3.7 ha of land for community development, and an additional 2 ha as an *Active Recreation Reserve*. Fully-served lots to provide for the Primary School and Community Hub will be provided by DHA, while the NT Government will be responsible for construction of the buildings and other facilities.

The Lee Point Urban development is intended to facilitate the future provision of the following community and social infrastructure:

- Affordable housing, particularly for Defence personnel and key workers.
- Medical practitioner and/or allied health services.
- Two child care centres, each with 60 places with room for expansion.
- Integrated school/education facility comprising one primary school, integrated/collocated after school-hours care facilities, pre-school/long day-care/kindergarten.
- Community centre as a shared space with multiple rooms and flexible useability.
- Outdoor sports facilities including AFL/cricket oval, football (soccer) pitch, tennis and netball facilities.
- Local/neighbourhood parks and playgrounds.
- Neighbourhood shops.

The provision of a range of housing options, lot sizes and locations seeks to increase the affordability of housing in the northern suburbs of Darwin. Commercial space within the neighbourhood centre will be appropriately zoned to allow the development of land for convenience shopping needs and recreational retail (such as cafes and restaurants), as well as the development of a medical clinic, including general practice and allied health services.

It is anticipated this service would be provided by the private sector. Additional child care facilities outside of the community precinct could also be accommodated in the neighbourhood centre.

8.4.3 Commercial Development and Neighbourhood Centre

The Lee Point Area Plan proposes a main street neighbourhood centre expanding into the tourist accommodation and higher density residential areas. The main street is anticipated to accommodate a vibrant mix of retail servicing the local (and broader) community, along with occupants of accommodation facilities, with convenience shopping to complement the future Muirhead Centre. Retail areas within 2CRU are provided in close proximity to the community precinct, with appropriate urban design opportunities available to maximise accessibility and pedestrian traffic between the two.

In addition to accommodation, commercial and recreation-based retail development, the centre is expected to take advantage of the ability to combine residential and non-residential opportunities in accordance with Zone C (Commercial), including medium-high density residential uses above ground level. Varied building heights along the main street, from 4, to 8 to 12 storeys, along with the setback requirements for residential buildings within the Planning Scheme, will prevent overbearing built form and ensure the appropriate transition of scale to urban residential areas. Mixed use development incorporating residential areas will

extend the vibrancy and viability of the neighbourhood centre beyond daylight hours and outside of the peak tourist season, and increase opportunities for a range of housing options to be collocated with goods and services.

8.4.4 Street Network and Open Space

The Lee Point Area Plan establishes the intent for a primary road network that enables efficient access to and between all areas of the estate, with connections to Lyons, Muirhead and the primary connection to Lee Point Road. The intention for primary pedestrian and cycling routes are also demonstrated, including along Lee Point Road, and along the Coastal Esplanade. The coastal esplanade is intended to provide a shared route integrated with a lineal open space along the western side, providing a cleared separation between development areas and the coastal reserve. Beyond the esplanade and lineal open space, the existing coastal reserve boundaries will extend into 2CRU to align with the open space and drainage reserve (in the southern portion).

Road connections heading west from Lee Point Road are generally aligned perpendicular to the coast to allow the creation of focal points at the western extent of the site. The main street will provide an efficient connection to Lee Point Road to encourage vehicles into the neighbourhood centre, whilst retaining fluid vehicle movements for those visiting destinations further north, including the Lee Point Village Resort, Lee Point coastal area and the Buffalo Creek boat ramp. An open space area at the Lee Point Road entrance to the neighbourhood centre signifies the desire to establish an entry statement to the site.

Primary street connections into Muirhead North seek to reaffirm the community hub as the focal point east of Lee Point Road by indicating roads to the north and south from Lee Point Road. The importance of safe controlled intersections to Lee Point Road, with a particular emphasis on pedestrian and cycle movement, is identified in the area plan. Vital connections to Lyons and Muirhead have been identified to increase accessibility to existing residential areas, and to increase accessibility to future commercial and community land.

Discussions with the Public Transport Division within the Department of Transport have led to the development of a bus route that connects to the existing Lyons service through Damabila Drive, along the coastal esplanade and back along Lee Point Road, ensuring the provision of public transport services within 400 metres of the majority of residential areas, and direct public transport services to the centre and the community hub.

The majority of open space in the form of local and neighbourhood parks will be provided as part of a master plan/subdivision proposal in accordance with the requirements of the Planning Scheme. The Lee Point Area Plan identifies open space areas critical to the development of Lee Point due to their role:

- In the establishment of view corridors and areas of high amenity.
- As part of a broader community benefit (such as the coastal esplanade and additional coastal reserve area).
- Due to a critical design importance (neighbourhood centre entry statement).
- Broader community purpose role (active recreation space).

OR

- Service/infrastructure role (drainage reserves).

Open space on the eastern side of the proposed coastal reserve boundary within 2CRU would be developed as formal, lineal open space. Land to the west of the boundary line would remain in its natural state, with the possible inclusion of a beach access trail, appropriately located, constructed and limited to preserve the integrity of the expanded coastal reserve.

8.4.5 Stakeholder Overview

8.4.5.1 Key Stakeholders

The project will proceed via an arrangement between the two primary stakeholders, being DHA and the Northern Territory Government, with DHA the landowner of 2CRU, and the Northern Territory Department of Infrastructure, Planning and Logistics (DIPL) the controlling agency of Muirhead North. Defence Housing Australia provide housing and related services to Defence members and families, including the acquisition and development of land, construction and house purchasing.

In addition to the primary stakeholders, there are a number of key agency stakeholders to which the proposal will provide infrastructure that will require ownership and management and/or has the potential to directly impact on land under the control of the relevant agency. These stakeholders include:

- Larrakia Development Corporation and Larrakia National Aboriginal Corporation, representatives of the Larrakia people who are the traditional owners of the project site.
- City of Darwin as the relevant local government body, including the responsible agency for local roads, stormwater systems and public open space.
- Northern Territory Parks and Wildlife Commission as the agency responsible for the Casuarina Coastal Reserve.
- PWC as the agency responsible for the ownership and maintenance of reticulated electricity, potable water and sewerage services within the Northern Territory.

In addition to the above, there are a number of agencies, commercial and community stakeholders who have an approval or regulatory role, may have a non-commercial or direct stakeholder interest in the site or may stand to benefit from additional development and/or population growth within the area, including:

- Larrakia people as traditional owners.
- Northern Territory Department of Health, including the Royal Darwin Hospital.
- Users of the Casuarina Coastal Reserve, including the Buffalo Creek Boat Ramp.
- Existing Darwin residents and landowners, particularly those within Lyons and Muirhead, including those residents in the northern section of Lyons, close to future development.
- Owners, staff and guests of the Lee Point Village Resort and Club Tropical Resorts.
- Northern Territory Department of Land Resource Management.
- Northern Territory Environment Protection Authority.

- Northern Territory Department of Transport.

8.4.6 Consultation

Defence Housing Australia and those engaged by DHA have undertaken a range of consultation activities with stakeholders to inform and seek input into the proposed development. Consultation has included:

- Stakeholder workshop (10 April 2014) with relevant government agencies and service authorities. Inform and involve ensuring input into the development master plan.
- Stakeholder workshop (30 July 2014) with relevant government agencies and service authorities. Presentation of draft concepts, inform and seek feedback as input into the advancement of the development master plan.
- Community workshop at the Lyons Community Centre. Inform and involve to ensure community concerns are adequately understood and considered in the planning process.
- Community infrastructure workshop with identified stakeholders to identify community and social infrastructure requirements (19 June 2014). Inform and involve relevant stakeholders to define required social and community infrastructure based on projected population growth.
- Consultation with representatives of the Larrakia people including the LDC and LNC (13 March 2018).
- Parks and Wildlife Commission (14 March 2018).

In addition to consultation undertaken by and on behalf of DHA, statutory consultation has also occurred as part of the submission to the Minister for Lands and Planning to amend the Northern Territory Planning Scheme, including:

- Public exhibition of proposed Planning Scheme Amendment, including all application documents, in accordance with Part 2 of the Northern Territory Planning Act, between 21 November and 19 December 2014. Exhibition included on-site yellow notification signs, NTNews and online advertisements and direct notification.
- Consideration of all matters raised in submissions received per the above exhibition. Detailed response to all issues raised, further environmental and servicing investigations in response to issues raised, and amendments to master plan, area plans and nature of proposed Planning Scheme Amendment in response to specific issues.
- Reporting Body Hearing, conducted by the Darwin Division of the Development Consent Authority, to obtain feedback, hear the applicant's response and provide a report to the Minister for Lands and Planning.

8.5 Existing Conditions and Project Impact

8.5.1 Community Structures and Vitality

8.5.1.1 Social Demographics and Development Impact

Demographic data was sourced from the Australian Bureau of Statistics (ABS) database, including population, employment and economic data from the 2011 census, as well as 2012, 2013 and 2014 where available.

The project site is located in the ABS division of Lyons, encompassing the residential suburbs of Lyons and Muirhead, the northern portion of the Casuarina Coastal Reserve, Lee Point and immediate surrounds. The greater Darwin Statistical Region is used for comparison. According to the ABS Region Profile, relevant demographic characteristics of the Lyons region include:

- A total population in 2014 of 2,933 persons, comprising 1,417 (48.3%) females and 1,516 (51.7%) males, with a median age of 29.2 years. The ratio of females to males within Lyons is generally consistent with greater Darwin, with 47.5% females and 52.5% males. Lyons accommodates a younger population than Greater Darwin, which has a median age of 33.1 years.
- Based on the population estimates between 2010 and 2014, population growth within the Lyons statistical division is well above the regional average, averaging approximately 12.65% growth per annum compared with 2.34% for Greater Darwin. This increase is likely due to the growth suburbs of Lyons and Muirhead, which comprise a significant portion of the statistical division.
- A population density of 416.6 persons per km² compared to 44.4 persons per km² for Greater Darwin. The lower figure reflects the range of suburb and locality types in Greater Darwin (i.e. non-residential areas, rural areas, etc.).
- In 2011 (limited by the availability of data), household types overwhelmingly consisted of family households, with approximately 12.36% of households consisting of lone person or group households. The average household size in 2011 was 3.1 persons compared to 2.7 persons for the Greater Darwin Region. The larger household size for Lyons is likely due to the predominance of low and medium density housing rather than low, medium and high density housing for Greater Darwin.
- At the 2011 census, Aboriginal and Torres Strait Islander people within Lyons as a proportion of the total population was well below that for Greater Darwin, at 3.2%, compared to 9.2%;

Based on the areas identified within the Lee Point Master Plan, and using the density rates within the Lee Point Area Plan in Clause 14.1.5 of the Northern Territory Planning Scheme, the Lee Point Master-planned Urban Development is likely to be developed with between 600 (low range) and 1,000 (high range) dwellings, comprising a mix of detached and attached housing. For the purpose of determining the likely population, a projected density at the high range is taken.

A range between the average household size for Greater Darwin and the Lyons statistical division is considered appropriate. The higher average household size for Lyons is reflected by the relative lack of apartments and medium-high density living, and is unlikely to accurately reflect population projections for the Lee Point Master-planned Urban Development. Accordingly, the projected development profile for the proposal comprises:

- Approximately 1,000 new dwellings comprising a range of low, medium and medium-high density housing.
- Dwelling typology comprising approximately 700 detached and semi-detached dwellings, 270 apartments and 30 low density rural residential allotments (Muirhead North only).
- A projected residential population between 2,700 and 3,100 persons.
- Projected population cross-section consistent with that existing in the Lyons statistical division, including approximately 16.9% of residents aged between 5 and 14 years (between 456 and 523 persons), with some 3.7% of residents over the age of 65 (between 100 and 115 persons), and a median age of 30.1 years.

8.5.1.2 *Health and Social Well-being*

Lee Point is located in the northern extent of Darwin's northern suburbs, with a range of health care services and facilities easily accessible by private motor vehicle and public transport. The Royal Darwin Hospital and Darwin Private Hospital are located a short distance south of the project site. The hospital campus includes specialty health services such as the Alan Walker Cancer Care Centre, as well as medical research facilities such as the Menzies School of Health Research.

In addition to the hospital campus, there are a number of community and private-sector based health services available to the northern suburbs, including the Casuarina Community Care Centre, health and medical services provided by CDU, and the Casuarina Health Services Centre. Services include general practitioners, community health-care, specialist services, medical imaging and day surgery facilities.

Associated health facilities and services within the locality include:

- Carpentaria disability services
- Somerville Community Services
- Centre for Youth and Community Music (CDU)
- Headspace Darwin
- Healthy Living NT
- Danila Dilba Health Services.

A review of the capacity, normative- and identified need for the Lee Point area identifies a requirement for the provision of a general practice and allied health facilities (such as physiotherapy or dental) to provide an immediate service to new development areas, whilst there's sufficient capacity in existing community health precincts, hubs, centres and hospitals to accommodate the increase in population.

8.5.1.3 *Education and child care*

Approximately 15 child care centres are situated within the broader locality, albeit concentrated within the areas south of Lyons and Muirhead. A future commercial development within the suburb of Muirhead will include a child care facility to alleviate demand from Lyons and Muirhead residents; however, existing centres

are at or near capacity, and the likely high proportion of future residents in the project between the ages of 0 and 4 is likely to demand childcare facilities within the development, in addition to that proposed in Muirhead.

A number of public and private primary, secondary and specialty education facilities are accessible from the Lee Point area within a regional locality (i.e. in Darwin's northern suburbs in the area east of Rapid Creek). Public Pre- and Primary Schools include Wanguri, Leanyer, Malak, Nakara, Wulagi, Jingili, Alawa, Moil and Anula. Public secondary education facilities include the Dripstone and Sanderson Middle Schools, and the Casuarina Senior College. Specialty education facilities include the Namarluk School and Henbury School, adjacent the Dripstone Middle School. Private education facilities include the Holy Spirit Catholic Primary School, St Andrew Lutheran School, Holy Family Catholic Primary School, O'Loughlin Catholic College and Marrara Christian School and College.

The CDU Casuarina Campus provides undergraduate, post-graduate and vocational education including in the faculties of law, business, arts, education, health, science and technology. There are also a number of institutes of advanced studies, including the Menzies School of Health Research, School of Social and Policy Research, the Research School of Environmental Studies, and the Graduate School of Health Practice.

Existing education facilities (particularly Public Pre- and Primary schools) are concentrated in the areas south of Lyons and Muirhead; thus, are poorly situated to accommodate increased demand from further population growth in the Lee Point area, in addition to housing and population increase in Muirhead. Discussions with the Department of Education (GHD 2014) indicates existing pre-school/long day care/ kindergarten facilities are at capacity, and located such that accommodation of increased population in the Lee Point area is unlikely to be feasible or appropriate. There is limited capacity at some local primary schools, with some space at existing sites for expansion; however, the distance to primary schools coupled with additional population in Muirhead is likely to create a shortage of current services. Existing secondary school facilities are currently at or near capacity; however, expansion of existing facilities with space available is likely to accommodate increased demand. Increased mobility of secondary school students indicates a greater ability to rely on an expansion of current services.

8.5.1.4 Conservation Areas and Recreation/Sporting Facilities

The Casuarina Coastal Reserve is located immediately adjacent to the western boundary of 2CRU, with the development including a proposal to increase the size of the coastal reserve to encapsulate and protect the fragile Monsoon Vine-thicket area. The reserve extends along the coastline from Dripstone Cliffs to Buffalo Creek. In addition to conservation areas, the reserve includes visitor facilities, open space/recreation areas, vehicle access and car parking, a boat ramp and the Darwin Surf Club.

The Casuarina Coastal Reserve, managed by the Northern Territory Parks and Wildlife Commission, remains the most popular Northern Territory Conservation/National Park by annual visits (with the exception of the federally-managed Kakadu National Park). The Casuarina Coastal Reserve receives 935,000 annual visits, with the vast majority of users being local to the Greater Darwin Area (Parks and Wildlife Commission of the Northern Territory 2016).

Assuming 80% of visits consist of Greater Darwin locals and an average of 5.33 annual visits per resident (based on 2014 population estimate), an additional 3,100 residents in the Lee Point area as a result of the project is likely to contribute an additional 16,517 annual resident visits, while there is likely to be 1,632 annual tourist

visits from accommodation areas. This combines to a total of an additional 18,149 visits to the Casuarina Coastal Reserve, or an increase in 2%, as a result of the Lee Point Master-planned Urban Development.

Other areas of public open space generally comprise neighbourhood and local parks and reserves, tailored for local and neighbourhood open space and recreation needs. The Tracy Village Sporting Complex includes multi-sport fields, indoor and outdoor function and recreation areas and licensed premises. The Marrara Sports Complex comprises the primary regional sporting facility and includes TIO Stadium, Darwin Football Stadium, Marrara Indoor Stadium, the Darwin Netball Association, as well as smaller ovals and courts for other sports. Gsnell Park is occupied by the Casuarina Public Swimming Pool, including toddler pools and swimming/lifesaving training. The Leanyer Water Park on Trower Road provides a large-scale community recreation water park.

8.5.1.5 Shopping, Commerce and Governance

A range of convenience, weekly and specialty shopping services are accessible from the Lee Point area. Neighbourhood and district-level centres, all including full-line supermarkets, are available at Leanyer (Hibiscus), Karama, Casuarina Village and Casuarina Shopping Centre (Casuarina Square). Casuarina Shopping Centre includes a major internalised shopping facility with discount department stores, specialty shops, eateries and commerce services (banking, insurance and health care).

Neighbourhood and district centres are supplemented by local centres at Tiwi, Wanguri, Wagaman, Wulagi, Moil, Jingili, Alawa and Malak. Lot 11847 (15 Fuhrmann Street, Muirhead) is a 9,760m² site within the latter stages of Muirhead, adjacent to Lee Point Road, which will be developed as a local centre with childcare facilities, improving the availability of commercial and community services to residents of Lyons, Muirhead and the Lee Point area. An application to the Darwin Division of the Development Consent Authority (DCA) has been lodged for the development of a commercial centre comprising a mid-line supermarket, a childcare centre, medical clinics, gymnasium and specialty shops and restaurants.

Government and additional community services are available in the Scaturchio Street locality of Casuarina, including Centrelink, the Northern Territory office of Consumer Affairs, employment services and the Northern Territory Civil and Administrative Tribunal offices and hearing rooms. The Casuarina Library is located on Bradshaw Terrace. Higher order judicial services are available in the Darwin Central Business District, including the Darwin Magistrates Court and Northern Territory Supreme Court.

Given the anticipated development of a neighbourhood centre at Muirhead, commercial development within the main street centre (identified in the Lee Point Area Plan) will comprise a mix of retail servicing the local (and broader) community, along with accommodation facilities. Convenience shopping will be limited so as not to compromise the level of service offered by the Muirhead Centre.

8.5.1.6 Emergency Services

Access to emergency services includes the Casuarina Police Station (approximately 4.4 km by road) within the broader locality, with the Peter McAuley Centre (9.8 km) providing administrative police services. St John Ambulance services are located in Dripstone Road (4.8 km), in close proximity to the Casuarina Shopping Centre. Fire and rescue services are located in Marrara (5 km), Berrimah (13.5 km) and Darwin (16.5 km).

8.5.1.7 Access to Services

Lee Point Road is a City of Darwin-controlled sealed single lane road (each-way) which connects directly with the road network throughout the northern suburbs. Further south of Lee Point, through the suburb of Wanguri, Lee Point Road has been subject to significant upgrades to improve traffic flow and facilities for cyclists and pedestrians. The City of Darwin will require these upgrades to continue north as residential development expands, and have established a Developer Contribution Plan to facilitate developer funding for upgrade works.

Services and facilities throughout the northern suburbs are generally easily accessible from the Lee Point area for private motor vehicles. Informal and 'nature' walking trails are available within the Casuarina Coastal Reserve, with upgrades to Lee Point Road improving formal access arrangements for pedestrians and cyclists.

8.5.1.8 Housing

Residential development within the Darwin's northern suburbs comprises mostly detached dwellings at average densities (lot sizes approximately 800m²), with areas of medium density development at townhouse and apartment densities generally concentrated near commercial areas, community facilities (such as schools), public open space and public transport routes. Housing in the newer suburbs of Lyons and Muirhead is generally at marginally higher densities, with average land size for detached dwellings between 600 and 700m², and a higher concentration of multiple dwellings (15-20% of all dwellings), generally at townhouse densities (i.e. 1 dwelling per 300m²). Built form includes a range of post-cyclone housing types, both ground-level and elevated homes. Development in Lyons and Muirhead is typical of newer estate homes, with strict covenants in both suburbs controlling the layout and appearance of built form.

8.5.2 Community infrastructure needs analysis

GHD were engaged in early 2014 to analyse the Lee Point Area Plan along with the surrounding population, and through a workshop process with relevant stakeholders identify specific demands for the provision of community infrastructure within the Lee Point Area.

Relevant stakeholders include community service agencies such as the Department of Education, Department of Housing, Department of Lands, Planning and the Environment, Department of Health, Department of Sport and Recreation and the City of Darwin (Department names have been changed since the 2016 Northern Territory Elections).

The report identified a need for the following facilities within the Lee Point area:

- Affordable housing, particularly for Defence personnel and key workers.
- Medical practitioner and/or allied health services.
- 1-2 child care centres, each with 60 places with room for expansion.
- Integrated school/education facility comprising one primary school, integrated/collocated after school-hours care facilities, pre-school/long day care/kindergarten.
- Community centre as a shared space with multiple rooms and flexible useability.

- Outdoor sports facilities including AFL/cricket oval, football (soccer) pitch, tennis and netball facilities.
- Local/neighbourhood parks and playgrounds.
- Neighbourhood shops.

Additional community purpose infrastructure was considered and discounted within the project site for the following reasons:

- Aged care/residential aged care/aged housing – service dependant on provision by the private sector.
- Community health precincts, hubs, centres and services – capacity in existing services.
- Hospitals – capacity in existing services/inappropriate location.
- Ambulance, Police and Fire – capacity in existing services/inappropriate location.
- Library – capacity in existing services/inappropriate location.
- Youth Centre – reliance on general community infrastructure.
- Middle school/high school – existing facilities to be expanded as required.
- Aquatic centre and indoor recreation centre – not required for local needs.
- Outdoor youth recreation facility – can be accommodated in local parks.
- District park – not required for local needs.

The outcomes of the Community Infrastructure Requirements are provided in Table 63 below. The facility type is identified, including the number existing within the local and district areas, comparative rate (based on existing population), normative need for the Lee Point Master-planned Urban Development, any identified need and the development approach.

The increased provision of a range of housing options, lot sizes and locations will likely increase the affordability of housing in the northern suburbs. Commercial space within the neighbourhood centre will allow development of land for convenience shopping needs and recreational retail (such as cafes and restaurants), as well as the development of a medical clinic, including general practice and allied health services.

It is anticipated that the medical clinic would be provided by the private sector. Additional child care facilities outside of the community precinct could also be accommodated in the neighbourhood centre.

A community precinct of approximately 5.7 hectares is indicated in the master plan in Muirhead North, and comprises 3.7 hectares of land for combined community and education facilities, and 2 hectares for organised recreation.

The community purpose site at Muirhead North covers an area of 3.5 hectares for combined primary school, after school-hours care facilities, pre-school/long day-care/kindergarten and child care facilities, with the inclusion of school-specific play space and sports facilities (such as a soccer pitch). An additional 2,000m² will allow the development of a community centre. The recreation site provides approximately two hectares of land for the development of larger organised recreation facilities, such as an AFL/cricket oval, tennis and netball courts.

More passive areas of public open space, such as neighbourhood parks and lineal shared paths, will be required at the rate of no less than 10% of the total residential area, and located within 400 metres of the majority of residential development, as per Clause 11.2.2 of the Northern Territory Planning Scheme.

The location of the community site at Muirhead North, whilst somewhat separated from the northern boundary of Lyons and Muirhead, will allow the integration of facilities within close proximity of the neighbourhood village by acting as a natural extension of the 'main street' identified in the Lee Point Area Plan. An appropriate design outcome will need to ensure connectivity in accordance with the Planning Principles within the Area Plan. Given the intended concentration of foot traffic between the centre and the community hub, the integration maximises accessibility and walkability for students, residents and the community. This location also permits the provision of community facilities in close proximity to higher density residential areas, and thus a greater concentration of population.

Table 63. Community Infrastructure Requirements (project site and Muirhead North site)

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
<i>Aged Care</i>					
Aged Care	4 local, 1 district	1:10,000 persons	Low need. Low proportion of incoming residents aged over 65 years. Increasing proportion of older people in district area.	Department of Health indicated that there is a need for local aged care in the northern suburbs with currently several aged patients in Darwin Hospital unable to find suitable housing and care in the community. Potential services could include respite care, personal home care and social support at both home or in a facility.	Provision of land led by demand from public/private sector, but unlikely to be required for local needs.
Residential Aged Care/Aged Housing	1 local	1:54,000 persons	Moderate need. Low proportion of incoming residents aged over 65 years but significant proportion of older people in district catchment.	Some Departments have identified need for aged housing particularly for low income residents. Limited aged housing in Northern suburbs.	Provision of land led by demand from public/private sector, but unlikely to be required for local needs.
<i>Housing</i>					
Affordable housing	Not applicable	Not applicable	High need. Defence households will require access to housing which is affordable. Key workers require access to affordable housing in Northern suburbs.	Rent paid by Defence households in DHA homes are required to be affordable. For non-Defence households, some Departments have identified need for affordable housing particularly for key workers e.g. nurses, teachers, retail workers etc. There was an agreement amongst Departments that a change in the range of housing types to increase density would assist affordability.	Range of housing types and lot sizes within development.
<i>Healthcare</i>					
Medical practice and General Practitioner including allied health services such as physiotherapy or chiropractor	10 local, 3 district	1:4,500 persons	Some need. Due to the high proportion of incoming children aged 0-12 requiring higher frequency medical care and preventative health services.	Department of Health indicated that a General Practitioner would be needed to service this new population.	One medical practice that could include allied health services. This service would be provided by the private sector.

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
Community Health Precincts, Hubs, Centres and Services	3 local	1:18,000 persons	Some need. Due to the high proportion of incoming children aged 0-12 requiring higher frequency medical care.	No need identified given the proximity to existing community health precincts.	Capacity in existing services
Hospital	1 Local	1:54,000 persons	Some need. Due to the high proportion of incoming children aged 0-12 requiring hospital services.	No need identified	Capacity in existing services
<i>Emergency Services</i>					
Ambulance	1 Local/District	1:27,000	Low need. Serviced by facility at Casuarina.	No need identified, however improved access for Ambulances was identified.	Capacity in existing services
Police	1 Local/District	1:27,000	Low need. Serviced by facility at Casuarina.	No need identified	Capacity in existing services
Fire and Rescue	1 Local/District	1:27,000	Low need. Serviced by facility at Casuarina.	No need identified	Capacity in existing services
<i>Childcare</i>					
Child Care Centre	8 local, 13 district	1:3,000	High need due to high proportion of incoming children aged 1-4 years.	Need for additional childcare centres as existing centres are at capacity.	Commercial and community land at Muirhead North will allow the provision of 1-2 child care centres with 60 places with opportunity for expansion.
Out of School Hours Care	10 local, 9 district	1:3,000	High need due to high proportion of incoming children aged 5-12 years.	After school care is an issue as service is at capacity and will be in high demand as more people move into the Muirhead area. Generally attached to schools.	One located on primary school site at Muirhead North.
<i>Community Facilities</i>					
Community Centre	3 local, 1 district	1:18,000 persons	High need. Due to large number of new resident requiring facility for	Need for additional community centre space should be considered as the existing facility at Lyons is well utilised.	One Community

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
			community building and social integration.	Departments agreed that it should be a shared space that included multiple rooms and the provision of affordable office space. It could also have a service attached to it with a lead tenant.	Centre at Muirhead North site.
Library	1 local, 2 district	1:18,000 persons	Moderate need. Due to significant number of children expected but estate will have broadband access	Casuarina library is a district facility which will service new residents.	Capacity in existing services.
Youth Centre	Unknown local, 3 district	1:18,000 persons	Moderate need. Due to the significant number of incoming and future youth aged 13-18 years.	Provision of outdoor space suitable for youth activities/program identified by Council.	Service model is to use general community infrastructure.
<i>Education</i>					
Pre-School, Long Day Care, Kindergarten	4 local, 3 district	1:8,000 persons	High need. Due to the high proportion of incoming children aged 0-4 years and significant need of preschool/kindergarten by Defence families.	Existing services at capacity and need identified for long day care an/preschool focused on early childhood education.	One located on school site at Muirhead North.
Primary School	6 local, 11 district	1:3,500 persons	High need. Due to the high number of incoming children aged 5-12 years.	Limited capacity at local primary schools with some space for expansion on existing sites. Could be part of a 'community hub' which includes long day care/preschool/kindergarten.	One primary School at Muirhead North
Middle School	4 local, 2 district	1:9,000 persons	High need. Due to the significant number of incoming children aged 13-17 years.	Existing school servicing local catchment is at capacity.	Existing middle school to be expanded as required.
High School	3 local, 1 district	1:14,000 persons	High need. Due to the significant number of incoming children aged 13-17 years.	No need identified.	Existing facilities to be expanded as required.
<i>Recreation and Open Space</i>					
Sports Field / Sports Ground	5 local, 3 district	1:7,000 persons	High need. Due to predominance of young children and young parents. Likely to be high sports participation.	Strong demand for sports field with potential for joint use with public school facilities. A football (soccer) field with junior pitch and a shared AFL and cricket oval were identified by Council and could be located on the school site.	One full sized AFL/Cricket oval, one full sized football (soccer) pitch and one junior size football

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
					(soccer) pitch integrated within school and recreation area at Muirhead North
Aquatic Centre	1 local, 1 district	1:27,000 persons	Low need due to existing pool at Casuarina	No need identified at a local level; however, Council is currently assessing the future of Casuarina Pool and this may create demand for a future district leisure centre.	Not required for local needs.
Indoor Recreation Centre	2 district	1:11,000 persons	Low need	No need identified at a local level. Opportunity exists to develop covered playground areas and indoor spaces for recreation at community centre or other indoor spaces.	Not required for local needs.
Outdoor Sports Courts e.g. tennis, netball	1 local, 3 district	1:18:000 persons	High need. Due to predominance of young children and young parents. Likely to be high sports participation.	Opportunity for parks to provide more activities for youth e.g. half basketball court. Tennis and netball courts were identified and could be located on school site with community access.	One or two tennis courts. One or two netball courts.
Playground/Play space	2 local, 1 district	1:18,000 persons	High need. Due to the high proportion of incoming children aged 0-12 years.	Need identified by government agencies for local playgrounds Opportunity exists to develop covered playground areas and indoor spaces for recreation at community centre or other indoor spaces.	Provided in accordance with NT Planning Scheme
Local Park	5 local, 3 district	1:7,000 persons	High need. Due to the high proportion of incoming children aged 0-12 years.	Need identified from government agencies for local parks.	Provided in accordance with NT Planning Scheme
Neighbourhood Park	30 local, 20-30 district	1:2,000 persons	High need Due to predominance of young children and young parents. Likely to be active and require outdoor activities.	Need identified from government agencies for a range of open spaces of varying size.	Provided in accordance with NT Planning Scheme
District Park	5-10 local, 5-10 district	1:5,500 persons	Moderate need. Due to predominance of young children and young parents. Likely to be active and require outdoor activities. However close to other district parks and beach.	No need identified	Not required for local needs
<i>Shopping</i>					

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
Neighbourhood Shops			Moderate need. Large incoming population of 6,000. Residents with need for local shops but Casuarina centre and others located within driving distance.	There is agreement amongst agencies about the need for local shops particularly on major transport routes and within walking distance.	Appropriately zoned and serviced land for local supermarket, café and local speciality shops on the project site.

8.5.3 Economic and workforce considerations

8.5.3.1 Economic demographics

The 2014 release of the NT Population Projections for the Greater Darwin region (comprising Darwin City and the suburbs of Palmerston and Litchfield) identifies that the population of Greater Darwin is expected to increase to 172,271 persons by 2026. In 2011, the Census measured a total population of the Greater Darwin region of 129,106. The 2014 estimates increased this existing population to 140,386. In order to provide for this population, and based on current occupancy rates in the Greater Darwin region in 2011 of 2.7 persons per dwelling, an additional 1,066 dwellings will be required each year. The historic rate of population growth is strong in comparison to other cities and Australia as a whole, and future projections anticipate the rate of growth to average 2.1 percent per annum to 2016, before slowing to 1.8 percent per annum to 2026.

The requirement for an additional 1,066 dwellings per year aligns with the forecast short-term (i.e. 5 year) requirement for 5,700 dwellings per the Darwin Regional Land Use Plan (DRLUP). The difference is likely due to the DRLUP accounting for any existing shortfall as well as housing to accommodate growth. The DRLUP anticipates the location of these dwellings as per Table 64 below. Development of the project site is considered as part of the greenfield development in the Darwin Northern Suburbs.

Table 64. Darwin Regional Land Use Plan (2014)

GREENFIELD	DWELLINGS
Darwin Northern Suburbs	680
Palmerston and Litchfield	2,220
Sub-total	2,900
Infill	Dwellings
Darwin CBD	930
Darwin Inner Suburbs	800
Darwin Northern Suburbs	360
Palmerston and Litchfield	770
Sub-total	2,800
Total	5,700

Greenfield Development in Darwin's Northern Suburbs aligns with the remaining development in Muirhead and the first 3-4 stages of the development at the project site that is likely to occur within the short term. The above confirms the importance of residential development within the Lee Point area, in addition to infill areas (for example Berrimah Farm) and greenfield areas (including Palmerston East) to meet the projected short term housing demands.

The 2013-14 mid-year economic report by the NT Treasury states that in 2012-13, the NT economy grew by 5.6 percent, the highest level of economic growth of all States and Territories and well above the national economic growth rate of 2.6 percent.

The report states:

"The strengthening economy was mainly driven by business investment, reflecting construction work on major projects, robust household consumption growth and improvement in the Territory's goods trade surplus."

The outlook for economic growth to remain buoyant at 5 percent in 2013-14, increasing to 7 percent in 2014-15, driven by higher levels of construction activity and household consumption that will more than offset the forecast contraction of public expenditure.

Economic growth is expected to slow in 2015-16 and 2016-17 as construction activity related to INPEX and Total joint venture Ichthys project passes its peak.

As the Ichthys project moves from the construction to the production phase, the export sector is forecast to underpin Territory economic growth from 2016-17... A strengthening in local economic conditions is expected to flow through to stronger growth in population and employment. The Territory's rising population is expected to be driven by increased direct workforce requirements of major projects and indirectly due to increasing levels of economic activity. From 2015-16 onwards, employment is forecast to moderate reflecting the transition of the Ichthys project to the less labour-intensive production phase.⁷" (Northern Territory Government 2013, P2).

Although both population and economic projections are forecast to somewhat moderate following the completion of the construction periods of major projects in the region, overall population growth and housing demand is expected to continue. The recent focus on *Developing Northern Australia* (Commonwealth of Australia 2015) provides confidence of future investment and focus in utilising the strengths and advantages within the region, particularly the region's proximity to Asia for trade and defence purposes.

Domain (2016) reports that the median house price in Darwin in the 12 months to September 2016 is \$587,000, identifying that despite an easing of property prices in the last 24 months, Darwin remains one of the most expensive cities to buy property. The proposed development of the project site is likely to improve housing affordability both through an increase in supply and the provision of alternative housing options in addition to more traditional options prevalent throughout the northern suburbs. Any improvement in housing availability must occur in a location with an appropriate level of access to existing community health facilities and regional centres, as well as the provision of neighbourhood-level community, commercial and open space facilities equal to the increased demands of the locality.

A search of real estate marketing websites identified 195 detached dwellings (realestate.com.au 2016) available for sale within the northern suburbs west of Rapid Creek, with 58 apartments/townhouses (realestate.com.au 2016) available for sale. Within the same area, a total of 114 detached dwellings were available to rent, with 70 apartments/townhouses available (realestate.com.au 2016). SQM Research (2016) identifies Darwin Vacancy rates at 3.1% in September 2016, slightly up from August 2016 (3.0%) and relatively steady (slight decrease) compared with the vacancy rate in September 2015 (3.3%). The Darwin vacancy rates are slightly higher than the national capital city average of 2.4% for the same period. The same report identifies a price reduction in rental asking prices in the last 12 months to September 2016, with a reduction of 4.8% for houses and 3.5% for units. The report concludes that *"rents remain under pressure in Darwin too as the mining downturn weighs on demand"*. Prior to June 2016, vacancy rates were recorded by SQM Research (2016) around 4%, indicating a tightening of vacancy rates and indicative of a cyclical event over the last three years (Australian Broadcasting Corporation 2016).

Labour force participation in Lyons was notably above that for Greater Darwin, at 76.6% compared with 68.7%. Likewise, full youth engagement in either work or study was well above the regional average, at 83.6% compared with 69.6% for Greater Darwin. Median income is \$64,868 compared with \$87,617 for Greater Darwin.

8.5.3.2 Project Costs and Revenue

Based on the anticipated development outcomes in Section 8.5.1.1, the Lee Point Master-planned Urban Development is anticipated to provide between 740 to 760 residential lots, apartment blocks and lots for community and commercial development. With an average subdivision construction cost equivalent to \$125,000 per eventual dwelling, overall construction cost is likely to be in the region of \$125 million. Of this, 10% (\$12.5 million), is likely to consist of consultant and design fees, with the remainder comprising construction and works. In context, the development of the Zuccoli Aspire estate comprises 408 lots, whilst the Zuccoli Village is 830 lots. The Northcrest residential development at Berrimah Farm has just been granted development approval for stage 1 (144 lots), with 2,000 lots anticipated upon completion. With the exception of Northcrest, which is likely to attract significant headworks upgrades, construction costs for the comparable Palmerston East projects are likely to be comparable to those for the Lee Point Master-planned Urban Development project. The proposed Noonamah Ridge rural residential project anticipates more than 4,000 lots upon completion, albeit at rural densities.

In addition to design and construction costs applicable to the project, there will be costs associated with external infrastructure upgrades, headworks, application fees and capital work (Table 65). With an anticipated average lot sale price equivalent to \$350,000 per eventual dwelling, the Lee Point Urban Development is expected to add approximately \$350 million to the Northern Territory Economy.

Construction is expected to commence mid-2018, with completion in consistent staging over the course of 7-8 years, thus allowing for approximately 140-150 dwellings per year. Accordingly, the project is expected to contribute to the Northern Territory economy and provide employment benefits in the short to medium term.

Table 65. Capital expenditure costs associated with the Lee Point Master-planned Urban Development project

Trunk Water Main	
Environmental	\$10,000
General Requirements	\$125,000
Water main excavation and backfill	\$780,000
Pressure main construction	\$1,365,000
Total	\$2,280,000
Upstream and Downstream Capital Works	
DCP COD cost Lee Point Rd	\$1,543,000
DCP PWC pressure booster	\$1,200,000
DCP PWC Sewer pump station	\$300,000
PWC HV	\$1,400,000
Total	\$4,443,000
Headworks Cost – External	
DCP COD cost Lee Point Road/MHN	\$1,236,175
DCP PWC sewer pump station MHN	\$200,000
Total	\$1,436,175
Local Authority Costs external – project site	
Planning application fees	\$21,868
COD application fees	\$462,915
PWC application fees	\$43,155
Landscape application fees	\$75,000
Total	\$602,938

local authority costs external – muirhead north	
Planning application fees	\$12,408
COD application fees	\$370,852
PWC application fees	\$39,450
Landscape application fees	\$45,000
Total	\$467,710
Other External Contributions	
DHA spend on Casuarina Coastal Reserve (in exchange for Muirhead North)	\$1,250,000

8.5.3.3 Workforce

As a large subdivision project including housing, commercial, accommodation, community services and infrastructure construction, development of the project site is expected to provide significant employment benefits to the Darwin region. The employment benefits will be experienced both directly through the infrastructure and subdivision construction works (external to the developer in the form of building construction and development of on-sold allotments), and indirectly in the form of services and employment opportunities in the community, tourism and commercial areas. In addition, peripheral industries, such as building material and tool suppliers, furniture suppliers, landscaping and plant supplies are also likely to benefit from the project.

The Lee Point Master-planned Urban Development project is expected to provide a direct employment benefit through the creation of full-time positions for approximately 150 persons for the duration of construction works.

In addition, approximately 70 sub-contracts will be required, each of which is likely to require between 1 and 4 persons. In relation to external employment benefits, i.e. housing construction, the Housing Institute of Australia forecasts the commencement of 1,490 dwellings in 2017, 1,520 in 2018 and 1,780 in 2019 (Housing Industry Association 2016). Based on the annual dwelling construction identified in section 8.5.2, construction within the project site is likely to comprise between 8 and 10% of construction activity within the Darwin Region. In February 2016, the construction industry employed approximately 15,300 persons within the Northern Territory. Allocating an appropriate proportion to the Darwin Region (63%), the project is likely to provide a direct employment benefit to the construction industry of between 771 and 964 jobs (of which 60% is assumed to be derived from the project site).

Given the strong civil and building construction industry within the Darwin Region, and the nature of civil and construction development works consistent with other new urban estates within the Darwin Region, it is anticipated that there will be a sufficient skill set available within the Darwin region without the need for external recruitment. The commencement of the project, beyond the Inpex construction period and the completion of Muirhead, will ensure that appropriate resources are available.

Long-term, the Lee Point Urban Master-planned Urban Development project is likely to provide permanent indirect employment benefits to the following sectors:

- Electricity, Gas, Water and Waste Services

- Retail Trade
- Accommodation and Food Services
- Information Media and Telecommunications
- Financial and Insurance Services
- Rental, Hiring and Real Estate Services
- Education and Training
- Health Care and Social Assistance
- Arts and Recreation Services.

The largest indirect employment benefits are likely to be gained by the accommodation and food services sector (due to the proposed accommodation precinct), and the education and training sector (due to the proposed primary school).

The accommodation precinct within the project site will provide 1.3% of available short term accommodation within the Northern Territory, and 5.5% of short term accommodation within the Darwin Region (Tourism NT 2017). Based on the August 2016 accommodation and food services sector employment predictions (ABS 2016), the Lee Point Master-planned Urban Development project will provide 117 full and part time accommodation and food service positions. Education facilities are likely to contribute approximately 40 full and part time positions. In addition, there are expected to be smaller benefits within the project to permanent retail, landscape and maintenance, community service and trade employment.

In addition to direct and indirect employment benefits, both the construction process and establishment of the Lee Point Master-planned Urban Development project is likely to benefit education and training through the provision of additional apprenticeship, certificate and on-the-job training opportunities. Defence Housing Australia actively encourage local industry participation and include local input weighting in tender contracts, with specific requests made for local input and/or local emphasis. The project will also present new small business opportunities in the hospitality and retail sectors.

Defence Housing Australia has provided a number of education, training and employment benefits to Indigenous Australians, including the Breezes Muirhead Aboriginal Landscape Education Program (DHA 2016), along with required indigenous participation and training objectives for DHA tender invitation and expression of interest requests (for example, *Expression of Interest for Upgrades and Minor Works to Defence and DHA Homes* – DHA 2013). These initiatives will continue into the development of the project site, with corresponding benefit to indigenous participation, training, education and employment.

The Breezes Muirhead Aboriginal Landscape Education Program was developed with Greening Australia Northern Territory, and comprises an indigenous training program with a practical component based around the Muirhead development site as well as the Greening Australia Native Nursery. This program provides trainees a rare opportunity to gain hands on experience in a commercial setting, emphasizing the need for quality and efficiency in production and task performance. During the Muirhead development, the program saw over 49 entrants, 70% rate of progress to further employment/education, and 67% of participants achieving a Certificate 1 in Horticulture. The same initiative will be implemented during development of the

project site, with the LDC engaged to assist with seed collection, translocation of Darwin Cycads and revegetation works.

There will also be other employment opportunities for the Larrakia people to assist with implementing the management actions detailed in the biodiversity and heritage section (Chapter 7). Defence Housing Australia has committed to engaging the LDC to undertake heritage monitoring during clearing works and prepare interpretive signage, while rangers from LNAC will implement the off-site offset program.

8.5.3.4 Commercial Development

A retail analysis for the Lee Point Urban Development project and locality prepared by Deepend Services in July 2014, reviewed the likely demand and locational aspects of retail floor space within the new development, particularly in the context of the planned retail space adjacent to Lee Point Road in the Muirhead subdivision.

The report concluded that likely retail demand would be limited to convenience shopping facilities and services in the vicinity of 400m² combined convenience retail floor space, in order to complement the recently approved floor space of the Muirhead Centre. This floor space is in addition to more tourism or recreation-based retail, such as restaurants and cafes to be located within the project site.

Accordingly the main street is anticipated to accommodate a vibrant mix of retail servicing the local (and broader) community, along with occupants of accommodation facilities, with convenience shopping to complement the expanded (once development occurs) Muirhead Centre.

The location of the land set aside for the Muirhead Centre, more central to surrounding Lyons and Muirhead populations, will better facilitate larger convenience shopping facilities. As recommended, retail areas within the project site are provided in close proximity to the community precinct, with appropriate urban design opportunities available to maximise accessibility and pedestrian traffic between the two.

In addition to accommodation, commercial and recreation-based retail development, development of the project site is expected to take advantage of the ability to combine residential and non-residential opportunities in accordance with Zone C (Commercial) of the Northern Territory Planning Scheme, including medium-high density residential uses above ground level. Varied building heights along the main street, from 4, to 8 to 12 storeys, along with the setback requirements for residential buildings within the Northern Territory Planning Scheme, will prevent overbearing built form and ensure the appropriate transition of scale to urban residential areas. Mixed use development incorporating residential areas will extend the vibrancy and viability of the neighbourhood centre beyond daylight hours and outside of the peak tourist season, and increase opportunities for a range of housing options to be collocated with goods and services.

8.5.3.5 Tourism Development

In September 2013 the Northern Territory Government established targets for growth in the tourism sector, and identified a demand for an additional 1,660 accommodation rooms to 2020, with current trends suggesting a demand ratio for additional accommodation rooms in the CBD equal to 75% of total demand (Tourism NT 2013). Accordingly, it is anticipated the tourist commercial area will accommodate 150-200 accommodation rooms initially, increasing to 300 rooms over time. The Tourism NT Profile for the year ending

2015 indicates a total of 766,000 visitors to the Northern Territory during 2015, a small (less than 0.2%) growth from 2014. Visitors equated to a total of 6.693 million visitor nights during 2015.

Tourism NT also reports an average Darwin accommodation occupancy rate of 68% for year ending June 2016, a reduction from previous years due to the combination of a softening tourism market and increased accommodation supply. Adopting a conservative estimate for the purpose of determining likely visitor numbers as part of the social impact assessment, a higher rate approaching 2013 highs of roughly 80% occupancy has been taken in this instance. With up to 200 rooms initially, the tourism precinct within the project site could accommodate some 58,400 visitor nights per year, increasing to 87,600 over time (based on an anticipated provision of up to 300 rooms).

Members of the Larrakia people currently run cultural tours around Darwin including in the Lee Point area. The tourism precinct will provide opportunities for the Larrakia people to further market their tourism businesses and improve demand for their services.

8.5.3.6 *Affordable Housing*

Housing affordability has become a critical issue for Darwin accommodation. Although affordability issues have subsided with the easing of the Darwin housing market and a reduction in property prices and rents, a forecast steadying of the housing market and anticipated growth into 2017 and 2018 suggests that the provision of affordable housing options will continue to be critical in ensuring equitable accommodation levels across all sectors of the community.

The Lee Point Master-planned Urban Development project will provide a mix of 1/3rd Defence Housing rentals with the remaining properties released to the private owner/occupier and rental market. Defence Housing Australia provides significant rent subsidies to Defence personnel, with housing types provided based on intended occupant types (e.g. singles, couples or families).

The range of dwelling density rates identified in the Lee Point Area Plan will ensure a range of dwelling types and lot sizes are available at a range of prices, with apartments, townhouses and smaller residential lots more affordable than the larger SD and rural residential (>4,000m²) lots. The inclusion of single dwelling lots (in accordance with NT Planning Scheme Zone SD), small lot residential development and townhouses (Zone MD), medium and medium-high density apartments (in accordance with Zones MR and HR) will ensure a range of detached, attached and apartment dwellings

8.5.3.7 *Visual and Social Amenity*

In addition to active social and community infrastructure, the project site will provide a number of passive social and amenity features available to residents and workers within the project, as well as benefitting the general public. Part 5 of the Northern Territory Planning Scheme provides minimum requirements for the provision of public open space within residential subdivisions, and includes design criteria regarding the form and useability of open space. The City of Darwin's *Subdivision and Development Guidelines* provide further detail on the internal design, servicing and provision of exercise and play equipment, as well as the provision of shared pedestrian and cycle paths and the achievement of full pedestrian connectivity throughout urban areas. The subdivision and development guidelines also cover the provision of street and open space lighting,

landscaping of verge areas and disabled access. The design of subdivision works in accordance with both the Planning Scheme and the Subdivision and Development Guidelines will ensure the appropriate provision of community infrastructure.

No formal access currently exists from Lee Point Road between the area immediately north of the project site and the walking cycling paths from Rocklands Drive. Whilst there are a number of informal walking and cycling paths to the rear and through the hospital, and from the northern section of Lyons, the development of the project site will include a new access to the Casuarina Coastal Reserve, coinciding with the western end of the main street precinct.

Access will be designed in a manner that minimises disturbance to the escarpment, sand dunes, and migratory shorebirds (see Section 7.3.1) and provides a benefit not only to residents and visitors to the Lee Point area, but also to residents of Lyons and Muirhead, and members of the public whose primary purpose in visiting the area is utilising other facilities (for example Lee Point, the Buffalo Creek Boat Ramp and the caravan park).

Residential development within the subject land will supplement the availability of housing within Darwin's northern suburbs, and increase housing options through innovative and varied dwelling design techniques. The provision of climatically appropriate and distinctive row housing, units, townhouses and apartments, along with alternative infrastructure and street connection opportunities, such as rear-lot vehicle access, will have a corresponding benefit on neighbourhood amenity. Defence Housing Australia's commitment to climate responsive design is evident by the design covenants in the Breezes Muirhead estate, with a focus on small lot housing with a corresponding reduction in energy consumption (Safarova 2016). This innovative approach to environmentally sensitive housing has been recognised by the industry with a number of awards, including:

- 2016 Urban Development Institute of Australia (UDIA) Northern Territory Award for Environmental Excellence
- 2016 UDIA Northern Territory Awards for Innovation in Design
- 2015 UDIA Northern Territory Award for Excellence in Masterplanned Development
- 2015 UDIA Northern Territory Award for Excellence for Environmentally Sustainable Development.

It is expected that a similar approach will be adopted for the Lee Point Master-planned Urban Development project.

Development of the project site comprises a large residential subdivision and urban development over a period of 7-8 years. As such, the existing landform will be altered due to the clearing of vegetation, earthworks and drainage works, construction works comprising the installation of and upgrade to service infrastructure, landscaping and built form construction. Landform alteration to the extent proposed will alter the nature and character of the locality, and has the potential to affect public amenity (i.e. visual, sound and traffic) during construction.

The extent of amenity impacts during the construction period will be subject to the management and phasing of construction activities, and the layout, design and implementation process.

Defence Housing Australia has identified the potential for critical amenity impacts and determined appropriate management responses. Specific measures incorporated into the design and construction process will minimise amenity impacts, both visual and otherwise, including:

- Adherence to the built form requirements of the Northern Territory Planning Scheme, including the Lee Point Area Plan, which seeks to limit densities adjacent to existing residential areas in the north of Lyons and Muirhead, with increasing density and building height towards the centre of the project site. The NT Planning Scheme includes design principles relating to urban and streetscape design, protection of heritage and conservation areas, landscaping and public open space.
- Monetary and land contribution to the Casuarina Coastal Reserve, securing a formal buffer between the existing coastal reserve and the extent of urban development.
- Construction Environment Management Plan to detail construction management, including erosion and sediment control, dust control, noise, hours of operation and construction traffic. The management plan will ensure all construction regulations provided by the Northern Territory EPA are adhered to, and amenity impacts from construction activities are minimised. The preparation, approval and adherence to a detailed CEMP will be required as a condition of the subdivision development permit issued by the Development Consent Authority, and must be approved and implemented prior to the commencement of any works on site.
- The determination of all traffic impacts and the capacity of the road network to accommodate increased vehicle movements through detailed traffic impact analysis. Provision of developer contributions to facilitate road upgrades as required.

8.6 Risk Assessment

8.6.1 Risk assessment summary

The identification of social and economic risks during the site preparation, construction and occupation phases of the project site are identified in the risk assessment (Appendix C). The risk assessment identifies parties responsible for potential risks as well as possible affected parties.

The table below presents a summary of the medium to high level risks that could potentially arise through the proposed development of the project site. It also includes the recommended management responses to ensure the project has no negative impact on the local and regional community either socially or economically. The full results of the risk assessment are provided in Appendix C which includes a list all risks identified, as well as a description of expected positive outcomes from the project.

Table 66. Risk assessment summary for the project site

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
<i>Housing and Accommodation</i>									
Oversupply of housing, impact on housing market	Residential stage completion and commencement of sales and marketing.	DHA Housing market vendors	Negative	Medium	High	Align staging and development with growth rates per Darwin Regional Land Use Plan (or updated policies and projections)	DHA	Duration of construction and initial sales (<10 years)	Maintenance and/or growth of pricing and consistency of sales.
<i>Workforce</i>									
Inadequate suitably trained persons within the Darwin Region to supply skills.	Construction	Construction Industry DHA.	Negative although solutions comprising additional training/education opportunities potentially positive.	Low	Medium	Provision of appropriate training opportunities for local market. Importation of skills as a last resort.	DHA.	Duration of construction.	Minimum local input achievement.
Shortfall of skilled workers elsewhere due to construction	Construction	Construction Industry DHA.	Negative although solutions comprising additional	Low (primarily due to commencement of the project post-	Medium-high	Ensure staging and timing of construction aligns with anticipated	DHA (Responsible for management strategy in	Duration of construction.	No unreasonable effect on access to trades /

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
works at Lee Point			training / education opportunities potentially positive.	Inpex construction)		population and housing growth rates for the Darwin Region	previous column)		construction services.
Shortage of workers to provide services in community, commercial and accommodation facilities	Occupation and ongoing	Northern Territory Government Public and private education sector Private service providers and commercial operators DHA	Negative	Low (range of skilled, unskilled, vocational and training opportunities avoids a concentrated demand for specific skills)	Medium	Development in accordance with projected commercial, accommodation and social infrastructure demand based on population projections, to ensure service provision doesn't exceed demand created by population.	DHA Northern Territory Government	Design and Construction	Establishment and continued operation of non-residential services and facilities.
<i>Social Infrastructure</i>									
Increase use of Buffalo Creek Boat Ramp.	Occupation	Northern Territory Government.	Negative	Low	Medium	Ramp has recently been upgraded and access is limited by tidal movement. Continual monitoring required upon	Northern Territory Government.	Upon occupation of development and ongoing.	Ramp waiting times and congestion are within normal ranges.

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
						occupation to determine impact on use patterns.			
Increase visitation to Casuarina Coastal Reserve	Occupation	Northern Territory Parks and Wildlife DHA	Negative	High	High	Monetary and spatial (land) contributions by DHA to increase size and improve visitor facilities within the reserve.	DHA (contribution) Northern Territory Parks and Wildlife (monitoring)	Completion of Construction.	Achievement of appropriate access to facilities for all users. Achievement of relevant objectives of CCR Management Plan.
Shortfall of social services	Occupation	DHA Residents and general public	Negative	Medium	High	Ensure adequate serviced land is available for community and social infrastructure in accordance with needs analysis.	DHA (land) Northern Territory Government / Private Sector (infrastructure)	Commencement of occupation and ongoing.	Achievement of Lead Practice Principles and Benchmarks per social needs analysis.
Increase traffic impacts – Lee point Road	Construction and occupation	DHA All road users.	Negative	High	Medium	Undertake road upgrades in accordance with Traffic Impact Assessment	DHA City of Darwin	Construction and ongoing	Road operates within capacity

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
<i>Amenity and Safety</i>									
Adverse amenity impacts during construction	Site preparation and construction	DHA Lyons / Muirhead Residents and General public Royal Darwin Hospital	Negative	Medium	High	All construction and development works in accordance with a detailed Construction Environment Management Plan (CEMP). Establishment of a complaints register to monitor and respond to complaints	DHA Subcontractors	Construction	No complaints received. Any complaints are promptly resolved.
Adverse amenity impacts from modified landform / built form	Construction and occupation	DHA Lyons / Muirhead Residents and General public Royal Darwin Hospital	Negative	Low	Medium	Ensure appropriate compliance with design and layout requirements of NT Planning Scheme, including minimum lot sizes, setbacks, building heights, landscaping	DHA. DCA. City of Darwin	Construction and ongoing (maintenance)	Issue of Development Permit. Positive public reception of project.

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
						and open space, to ensure visual amenity is maximised.			
<i>Economic / Business Development</i>									
Low / slow take-up of commercial land by private sector	Marketing and occupation	DHA Retail and hospitality sector.	Negative	Low	Medium	Ensure the appropriate provision of serviced commercial land, designed and located to cater for end use. Provide commercial land in accordance with needs analysis (ie avoid over supply)	DHA	Design, construction and marketing	Consistent take-up of commercial land.
Impact on viability of nearby commercial areas by proposed centre facilities	Occupation	DHA Retail and hospitality sector.	Negative	Low-medium	Medium-high	Provide commercial land in accordance with needs analysis (ie avoid over supply), which considers the	DHA	Design, construction and ongoing	No discernible effect on nearby centres. Consistent take-up of commercial land within Lee Point

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
						current and future provision of commercial and centre-type facilities (including the planned Muirhead centre)			(suggesting strong demand)
Over-supply of commercial land	Occupation	DHA Retail and hospitality sector	Negative	Low-medium	Medium-high	Provide commercial land in accordance with needs analysis. Update needs analysis and consult with retail sector during subdivision design. Provide accommodation in accordance with tourist accommodation demand analysis.	DHA. Northern Territory Government (confirm demand for tourist accommodation land)	Design, construction and marketing	Consistent take-up of commercial land. Progression of development concepts to construction.
Commercial land remains	Completion of construction,	DHA	Negative	Medium	Medium	Contractual provisions regarding	DHA	Sales / Marketing and occupation	Commencement, progression and completion

Impact	Phase	Stakeholder s	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequenc e (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
vacant after sale	occupation and ongoing	Commercial land purchasers				commenceme nt of construction (ie within specified time after settlement)			of lot development

8.6.2 Description of impacts and mitigation

Providing the following considerations are adopted, future residents and visitors will have appropriate access to social infrastructure, and the project will provide an appropriate economic and social benefit at both a local and regional scale:

- Provide a range of lot sizes and housing types to ensure availability of housing across different market sectors.
- Provide public open space which, at a minimum, achieves the minimum requirements of the Northern Territory Planning Scheme.
- Provide land for commercial development, appropriately integrated with recreation and tourism-focussed activities which, at a minimum, facilitates a convenience store and opportunity for the establishment of a general practice medical clinic, with provision to be led by the private sector.
- Ensure commercial development does not compromise the hierarchy of centres in the northern suburbs, and more specifically does not compromise the role and function of the commercial centre in Muirhead.

In addition, the social and economic impacts associated with developing the project site assume the provision of community services in the adjoining Muirhead North site as outlined in the Lee Point Master-planned Urban Development plan, including:

- Approximately 3.5 hectare site for the purpose of an integrated primary school, kindergarten and long day care facility.
- At least one childcare centre for approximately 60 children.
- Community centre (likely to be owned and operated by the City of Darwin).
- Integrated formal recreation complex, collocated with primary school site, comprising sport fields and courts.

The proposed development of the project site is also expected to have a number of positive social and economic impacts including:

- Housing affordability
- Integrated residential, community and commercial uses
- Employment opportunities
- Access to commercial services and facilities
- Access to Casuarina Coastal Reserve and Casuarina Beach
- Increased public open space and recreational facilities.

To ensure the social and economic benefits of the project are realised, and that the proposed mitigation and management strategies meet the community and Government's expectation, a stakeholder engagement

strategy will be implemented (Table 67). There will also be ongoing monitoring of the projects' performance against social and economic Key Performance Indicators (KPIs) as detailed in the CEMP (Appendix D).

Defence Housing Australia will adopt an existing organisational dispute resolution policy to outline an active response to community and stakeholder concerns regarding potential social impacts. As a general rule, all concerns, whether from a community group or member, or from a stakeholder/approval agency, will be addressed promptly and a written response provided thereto. A written record of all relevant complaints/issues, action taken and the response provided will be kept by DHA. Identified responses include (but are not limited to):

- Written response to all written submissions received as part of the statutory exhibition process for the development application.
- Transcription of all verbal/written concerns/complaints raised at community meetings, including contact details where provided, and written response thereto.
- Ensure written agreements follow any verbal agreements in relation to development undertakings, agreements and conditions, and continued engagement with relevant stakeholders regarding agreement conditions.
- Implementation of grievance procedure policy for receiving, actioning and responding to complaints/concerns during construction.

The dispute resolution policy will provide pathways and processes for handling grievances, outline procedural steps, measures for the keeping of grievance logs, data evidence of dialogue and communication processes, substantive outcomes achieved and measures for implementing outcomes into wider policy.

Table 67. Stakeholder Engagement Strategy

Key Stakeholders	Stakeholder Interest	Engagement Actions	Steps to ensure implementation	Review Mechanisms
City of Darwin	Agency responsible for local roads and associated infrastructure, stormwater drainage and associated infrastructure, public open space (at a local level) and some community facilities.	Pre-design and application meetings, including presentation to full Council. Legislative consultation during development application process. Formal application to Council for design approval.	Council to formally approval detail design.	Ongoing review during Council meetings and review of full Council decision.
Development Consent Authority	Consent authority for development approval.	Pre-application meetings and briefing to the DCA. Engagement through development application.	Development approval and conditions.	Adverse development application decision.
Northern Territory Parks and Wildlife Commission	Agency responsible for the administration, management and maintenance of the Casuarina Coastal Reserve.	Ongoing meetings and formal agreement with Parks regarding the provision of part of the site into the CCR. Engagement with Parks regarding CEMP.	Agreement to integrate part of the site into the CCR. Approval of CEMP.	Ongoing review during meetings.
Northern Territory Power and Water Corporation	Agency responsible for the reticulation of power, water and sewerage infrastructure within the Northern Territory.	Pre-design and application meetings. Legislative consultation during development application process. Formal application to PWC for design approval.	Detailed design approval of reticulated infrastructure and services.	Review on advice received in response to development application. Review need for further engagement based on detailed design feedback.
Northern Territory Department of Health	Royal Darwin Hospital and associated facilities. Provide advice regarding development potentially subject to impacts from mosquitoes and biting midges.	Pre-application meetings and advice on progress. Pre-application meetings with medical entomology unit to finalise land use restrictions on land affected by biting insects.	No objection from the Department of Health to Development application.	Ongoing review during design, approval and construction phase.

Key Stakeholders	Stakeholder Interest	Engagement Actions	Steps to ensure implementation	Review Mechanisms
General Public – Adjoining owners / occupants	Development on adjoining / nearby land.	Community consultation sessions pre-lodgement. Provision of design details pre-lodgement (Development application).	Design and construction undertakings in response to feedback to be enforced by way of development permit conditions.	Review based on initial feedback.
General Public – users of Casuarina Coastal Reserve	Development on nearby / adjoining land. Increased size and facilities within Casuarina Coastal Reserve.	Community information provided via general community media. DHA contact provided.	Design and construction undertakings (including agreed DHA upgrades / contributions to CCR) in response to feedback to be enforced by way of development permit conditions.	Review based on initial feedback.
Northern Territory Department of Education	Owner / operator of future education facility within 09370.	Pre-design and application meetings, including addressing design and servicing requirements of school site. Legislative consultation during development application process.		Review on advice received in response to development application. Review need for further engagement based on design feedback.
Northern Territory Department of Environment and Natural Resources	Agency responsible for reviewing erosion and sediment control measures, implementation and onsite management.	Pre-design and application meetings, including design input into erosion and sediment control measures. Legislative consultation during development application process.	No objection from the Department of Education to Development application. Development of school site by the Department of Education.	Review on advice received in response to development application. Review need for further engagement based on comments received on ESCP application.
Northern Territory Environment Protection Authority	Agency responsible for assessment and approval of the Environmental Impact Statement under the NT Environmental Assessment Act.	Ongoing consultation during EIS. Legislative consultation during development application process.	Approval of EIS. Acceptable implementation of EIS conditions.	Engagement to be reviewed subject to EIS feedback, decision and conditions.

Key Stakeholders	Stakeholder Interest	Engagement Actions	Steps to ensure implementation	Review Mechanisms
Commonwealth Department of the Environment and Energy	Department responsible for assessment and approval of the Environment Impact Statement under the Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i>	Ongoing consultation during EIS (pre and post lodgement).	Approval of EIS. Acceptable implementation of EIS conditions.	Engagement to be reviewed subject to EIS feedback, decision and conditions.
General Public - Other	Community groups with a focus on environment and development. Members of the public with an interest in the Lee Point area and/or development generally.	Community information provided via general community media. DHA contact provided.	Design and construction undertakings in response to feedback to be enforced by way of development permit conditions.	Review based on initial feedback.

9 NOISE

9.1 Introduction

This chapter assesses the potential noise and vibration impacts of the project and addresses the following criteria of the EIS ToR:

- The Proponent should address the impact of noise resulting from construction stages of the Project on nearby residents.
- The potential sensitivity of receptors to noise and mitigation measures should be discussed.
- A Noise Management Plan should outline methods for communicating with, and reducing the impact on, residents within the vicinity of the Project who may be adversely affected by the Project.

The chapter is structured in the following manner:

- Description of the methods used to model the magnitude of noise and vibration disturbance emanating from the project site during the construction and operation phase, a description of benchmarks based in industry guidelines for the acceptable level of disturbance, and the likely impacts to sensitive receivers including adjoining residents, future residents and future receivers (i.e. proposed primary school at Muirhead North) (Section 9.2).
- A summary of the Identified risks to sensitive receivers and future residents and a list of practical and appropriate mitigation measures to avoid any unacceptable noise or vibration disturbance that may occur during the construction or operation phase of the project (see Section 9.3).

The full risk assessment is provided in Appendix C, while most of the findings presented in this chapter are based on the Noise Impact Assessment prepared by Cardno (2017a, b), which is provided in Appendix H for 2CRU and Appendix I for Muirhead North .

9.2 Existing conditions and impacts

9.2.1 Method of Assessment

The section describes the methods used to model the disturbance of noise and vibration during the construction and operation phase of the project. Modelling is based on industry and Australian Standards. As the type and number of plant and equipment to be utilised during construction has not been confirmed, assumptions were made based on experience with similar residential projects.

9.2.1.1 Construction Noise

To determine construction noise, a SoundPLAN noise model was prepared and noise levels of typical construction plant were input into the model. The type and number of plant and equipment was assumed based upon experience from similar projects and the plant noise data provided in Australian Standard AS 2436:2010, "Acoustics – "Guide to Noise & Vibration Control on Construction, Demolition & Maintenance Sites".

The different construction phases for the project have been assumed based on similar previous projects. The construction phases and assumed sound power levels are outlined below:

- Clearing of Vegetation & Site Establishment ($L_{Aeq} = 121$ dB(A) & $L_{Amax} = 131$ dB(A))
- Bulk Earthworks ($L_{Aeq} = 123$ dB(A) & $L_{Amax} = 133$ dB(A))
- Drainage Infrastructure ($L_{Aeq} = 115$ dB(A) & $L_{Amax} = 116$ dB(A))
- Road Surfacing Works ($L_{Aeq} = 118$ dB(A) & $L_{Amax} = 130$ dB(A))

9.2.1.2 Construction Vibration

Recommended minimum separation distances between sensitive structures and typical vibration generating plant to minimise the risk of cosmetic damage to structures were identified with reference to standard expected ground vibration curves for various equipment types and are likely construction areas and activities.

9.2.1.3 Operational Noise

Road traffic noise was predicted using the 3D noise modelling software SoundPLAN 7.4. SoundPLAN software applies the algorithm from the Calculation of Road Traffic Noise, UK Department of Transport, Welsh Office 1988 (CoRTN), which is commonly used for road traffic noise assessment throughout Australia. The modelling predicts expected road traffic noise impacts based on the following data inputs.

- Existing 3D topography of the site, surrounds and nearby road alignments.
- Proposed Site topography.
- Road traffic flows.
- Posted road traffic speeds, and % heavy vehicles.
- Pavement surface type

General Modelling Methodology

The traffic noise model was used to predict post-development road traffic noise impacts on the dwellings located within the proposed development in the year 2026. The predicted noise levels were compared to the relevant noise criteria and exceedances determined.

Recommendations relating to feasible and reasonable mitigation measures were then developed.

The CoRTN assessment methodology was adopted for this assessment. The CoRTN modelling methodology sets traffic sources at a height of 0.5 metres above the road.

Noise modelling was conducted with and without noise barriers along Lee Point Road for year 2026.

Application of Correction Factors

The following correction factors were applied to the modelling:

- Pavement surface corrections of 0 dB(A) for dense graded asphalt (DGAC)
- An AustRoads correction factor to convert standard CoRTN outputs to Australian Conditions of -1.7 dB(A) was applied to the modelling results for receivers associated with future buildings.
- The standard conversion (referenced from AS 3671) of $L_{A10,18hr} = L_{Aeq, day} + 3 \text{ dB(A)}$ was also applied.
- A conversion factor of $L_{Aeq, night} = L_{Aeq, day} - 3 \text{ dB(A)}$ was applied to determine night-time traffic noise levels.
- A façade correction factor of + 2.5 dB(A) was applied to modelled receivers to allow for façade correction once the buildings are located on each Lot.

Noise Modelling Inputs and Assumptions

Table 68 below details the modelling input assumptions used for the noise modelling.

Table 68: Modelling Assumptions

Modelling Element	Input/Assumption. Source Reference
Ground Elevation Geometry	Provided by Cardno
Proposed Elevation Geometry	Provided by Cardno
Road Alignment	Provided by Cardno
Site Traffic Flow Data	Provided by SMEC & DHA
Road Traffic Speed	Provided by Cardno
Road pavement surfaces	Assumed to be DGA with no pavement correction factors added.
Ground Absorption	50% over soft ground
Methodology	Calculation of Road Traffic Noise, UK Department of Transport, 1988
Weather conditions	Calm Conditions
Façade Reflection	+2.5 dB(A) – applied to traffic prediction models, for receivers associated with future buildings.
L_{A10} and L_{Aeq} conversions	$L_{Aeq, day} = L_{A10, 18hr} - 3 \text{ dB(A)}$
Day time to night-time conversion	$L_{Aeq, night} = L_{Aeq, day} - 3 \text{ dB(A)}$

Modelling Element	Input/Assumption. Source Reference
AustRoads Correction to CoRTN for Façade Corrected Australian Conditions	-1.7 dB(A) CoRTN correction for Australian conditions (with reference to AustRoads.)
Receiver Height	Assumed to be 1.8 and 4.6 metres above ground level.

Traffic Volumes and Posted Speed

Projected traffic volumes for the year 2026 within the project site were obtained from the traffic impact assessment by SMEC (2015). The traffic impact assessment report projected traffic volumes for year 2025 for the finished development of the green field sites north of Lions and Muirhead Breezes Estate. For this assessment it is assumed that traffic volumes for year 2026 is identical to year 2025 as no further developments are likely to occur and that Lee Point Road is a dead end road north of the project site.

The percentage of heavy vehicles (HV) were stated by SMEC (2015) as 0.0%; however, a 5% HV should be used as a conservative assumption, which is in line with previous noise impact assessments carried out for residential developments. Projected traffic volumes and traffic speeds on Lee Point Road, for the noise modelling is presented in the Table 69 below.

It should be noted that traffic volumes at the southern part of the development are predicted to be significantly higher than at the northern end of the development as Lee Point Road is a dead end road with no significant area north of the development suitable for further development.

Table 69. Modelled Traffic Volumes & Speeds

Road Segment	Projected 18 Hour Traffic Volumes on Lee Point Road Between 6am and Midnight (94% of AADT)	% Heavy Vehicles	Proposed Speed
South	8580	5%	60 Km/h
Mid-South	7851	5%	60 Km/h
Mid	5131	5%	60 Km/h
Mid-North	1628	5%	60 Km/h
North	717	5%	60 Km/h

9.2.2 Adopted Noise & Vibration Criteria

9.2.2.1 Construction Noise

To mitigate the risk of excessive construction noise impacting on nearby existing sensitive receivers, noise management criteria has been adopted for the development referenced from the Northern Territory Environmental Protection Authority's Noise Guidelines for Development Sites in the Northern Territory, May 2014. (EPANGDS).

The EPANGDS outlines acceptable construction times and noise levels that should not be exceeded during those times.

The guideline states that construction activities should be restricted to:

- between the hours of 7am and 7pm Monday to Saturday; and

- b. between the hours of 9am and 6pm on a Sunday or public holiday.

The table below outlines the applicable construction noise limits for the project. Derivation of these noise limits is based on assumed background noise levels in each of these areas, and the methodology outlined in Appendix H and Appendix I.

Table 70. Adopted Construction Noise Limits for the Development

Noise Area	Construction Noise Limit, $L_{Aeq,15min}$		Sleep Disturbance from 10pm to 7am, L_{Amax} Externally
	Monday to Saturday from 7am to 7pm	Sunday and public holidays from 9am to 6pm	
Residential	50	50	65
Casuarina Coastal Reserve	50	50	65
Hospital	55	55	65

9.2.2.2 Construction Vibration

The following vibration criteria for human comfort apply to this project.

Table 71. Adopted Continuous Construction Vibration Limits for the Development – Sensitive Receivers

Building	Work Period	Resultant PPV mm/s	
		Lower Limit	Upper Limit
Dwellings (including hotels and motels)	Standard hours	1	2
	Non-Standard hours - evening	0.3	1
	Non-Standard hours - night-time		
Medical/health buildings (wards, surgeries, operating theatres, consulting rooms)	All	0.3	1
Educational facilities (rooms designated for teaching purposes)	While In Use		
Court of Law (Court rooms)			
Court of Law (Court reporting and transcript areas, Judges’ chambers)			
Community buildings (Libraries, places of worship)	While In Use	1	2
Commercial (offices) and retail areas			

The minimum 'safe limits' for continuous construction vibration at low frequencies for commercial and industrial buildings for the project have been referenced from German Standard DIN 4150.3 as follows Table 72).

Table 72. Adopted Continuous Construction Vibration Limits for the Development – Commercial & Industrial Receivers

Type of Structure	Assessment Criteria, mm/s	Reference
Dwellings (including hotels and motels)	5 (rms) at 1-10Hz 5 to 15 (rms) at 10-50Hz 15 to 20 (rms) at 50-100Hz	German Standard DIN 4150
Sensitive structures (including heritage listed structures)	3 (rms) at 1-10Hz 3 (rms) to 8 at 10-50Hz 8 to 10 (rms) at 50-100Hz	German Standard DIN 4150

'Safe limits' are defined as levels where no visible or cosmetic damage is expected to occur.

The transient construction vibration 'limits' to avoid cosmetic damage at low frequencies for different types of buildings from BS 7385-2, have been adopted for this development as follows (Table 73).

Table 73: Adopted Transient Construction Vibration Limits for the Development – All Receivers

Type of Building	Resultant PPV in Frequency Range of Dominant Pulse, mm/s	
	4 to 15Hz	15Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	-
Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Additional noise management measures with respect to construction noise are detailed in Appendix H and Appendix I

9.2.2.3 Sleep Disturbance

In the absence of NT specific criteria for sleep disturbance, relevant guidelines from the World Health Organisation and the QLD EPA EcoAccess Planning for Noise Control Guideline have been applied.

As a rule in planning for short-term or transient noise events, for good sleep over eight hours, the indoor sound pressure level measured as a maximum instantaneous value should not exceed the noise levels outlined in Table 74 within a bedroom.

Table 74. Adopted Sleep Disturbance Noise Limits

Internal Maximum Noise Level L_{Amax}	Maximum Number of Noise Events at Night
45 dB(A)	10 to 15

Internal Maximum Noise Level L_{Amax}	Maximum Number of Noise Events at Night
50 dB(A)	up to 3
65 dB(A)	1

9.2.2.4 Operational Noise

With regard to operational noise impacts the following risks apply to the development:

- Road traffic noise levels above the recommended noise limit for health and wellbeing.
- Road traffic noise levels above the recommended noise limit for sleep disturbance.
- Annoyance or awakening from siren of an emergency vehicle.

To manage these risks, potential impacts for operational noise sources associated with the development has been assessed against the appropriate NT regulations, and mitigation designed accordingly so that noise emissions and immissions associated with this development can be managed to acceptable levels.

The table below shows the applicable external road traffic noise limits as outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads.

Table 75. Adopted External Traffic Noise Limits for the Development – Sensitive Receivers

Receiver Description	Applicable Road Traffic Noise Limits	
	Noise descriptor	External noise level in dB(A)
Residential, Hotels and Tourist Precincts	$L_{10,18hr}$	63
School, Day Care, Library and Community Building	$L_{10,18hr}$	58
Outdoor Educational and Passive Recreational Areas	$L_{10,18hr}$	58
Hospital, Aged Care Facility and Nursing Home	$L_{10,18hr}$	58

Table 76 below shows the applicable internal noise limits as recommended in AS 2107 Recommended design sound levels and reverberation times for building interiors.

Table 76. Adopted Internal Traffic Noise Limits for the Development – Sensitive Receivers

Area	Recommended Internal Design Sound Objective, $L_{eq, (T)}$, dB(A)
Sleeping Areas (All bedrooms)	30
Living Areas (Lounge rooms within dwellings)	35
Work Areas	35
Apartment common areas	45

9.2.3 Impacts

9.2.3.1 Construction Vibration

The tables below outline the recommended minimum separation distances between sensitive structures and typical vibration generating plant for development at 2CRU (Table 77) and Muirhead North (Table 78), in order

to avoid cosmetic damage to structures. It is based on the expected plant and equipment to be used for construction, as the equipment to be used during construction is yet to be determined. The table indicates that cosmetic damage to buildings can be avoided by correct selection of plant when working near vibration sensitive structures.

Table 77. Recommended minimum separation distances – 2CRU

Receiver	Nearest Potential Construction Area	Distance to Nearest Sensitive Structure, metre	Maximum size of Vibratory Roller	Maximum size of Hydraulic Hammer
Darwin Hospital	Project site	175	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Lee Point Village Resort	Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator
Lyons Estate	Project site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Current dwellings at Muirhead Breezes Estate (June 2016)	Lee Point Road Traffic Corridor	50	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Potential future dwellings at Muirhead Breezes Estate	Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator

Table 78. Recommended minimum separation distance - Muirhead North

Receiver	Nearest Potential Construction Area	Distance to Nearest Sensitive Structure, metre	Maximum size of Vibratory Roller	Maximum size of Hydraulic Hammer
The 2CRU Site	Muirhead North Site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Lee Point Village Resort	Muirhead North Site	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Lyons Estate	Muirhead North Site and Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator
Current dwellings at Muirhead Breezes Estate (June 2016)	Muirhead North Site and Lee Point Road Traffic Corridor	50	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Potential future dwellings at Muirhead Breezes Estate	Muirhead North Site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator

9.2.3.2 Predicted Noise Impacts

Construction Noise

Construction noise levels are unlikely to exceed the design benchmark noise limits except for the worst case scenarios, where work is conducted at the boundary of the development and during upgrade work of Lee Point

Road. The exceedances are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. It is worth noting that work along the boundary of the development will occur for short durations only, as clearing of vegetation and general construction work will move around the development site as work progresses. Furthermore, the model exceedances assume that all the noisiest items of plant will be operating simultaneously which is unlikely to occur.

Sleep Disturbance

The most likely source of potential sleep disturbance from the night construction works will be from the use of pneumatic hammers or saw cutting during services relocation and/ or road pavement works or from truck movements on site, in particular the application of air brakes.

Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. Noise levels have been calculated based on a worst case scenario when plant is located at the closest point to each receiver. On this basis, the predicted results (L_{Amax}) indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason, activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking will be minimised or not operated at locations close to noise sensitive receivers during the night-time period. Furthermore, noise screening using temporary noise barriers will be used for stationary plant at night.

9.2.3.3 Operational Noise

2CRU

Road traffic noise emanating from Lee Point Road is predicted to exceed the 63 dB(A) criteria at 16 (4 ground floor and 12 first floor) of the nearest receivers without any external mitigation installed (such as noise barriers). The results also show that this number is reduced to 9 with the inclusion of 1.8 metre high noise barrier located along the site boundary with Lee Point Road, with all of these exceedances being first floor exceedances.

Based on these results, the location of noise sensitive uses, such as schools, childcare centres, retirement accommodation or hospitals, is not recommended immediately adjacent to Lee Point Road. The noise limit of 58 dB(A) for non-residential noise sensitive use is predicted to be exceeded at 70 receivers without the inclusion of noise barriers. This number is reduced to 29 with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road.

The noise impact from road traffic upon 2CRU is primarily occurring at the southern end of the development, due to the higher traffic volumes at this end of the development.

The results indicate that noise barriers aren't required between Lee Point Road and the northern part of the development to achieve compliance with the $L_{A10, 18hour}$ of 63 dB(A) for residential use.

Most of the lots will require building construction in accordance with either AS 3671 Category 1 or Category 2. Forty-eight receivers (26 lots) will require building construction in accordance with AS 3671 Category 3 without the provision of 1.8 metre high noise barriers. The number of receivers requiring building construction

in accordance with AS 3671 Category 3 reduces to 15 (all at first floor levels) with the provision of 1.8 metre high noise barriers.

Muirhead North

Road traffic noise from Lee Point Road is not predicted to exceed the 58 dB(A) criteria at any of the modelled outdoor receivers whether the noise barriers are included or not. As such the predicted noise levels at the proposed sportsgrounds and playgrounds do not indicate that noise barriers are required for the Muirhead North development.

Road traffic noise is not predicted to exceed the 63 dB(A) criteria at any of the receivers with or without the inclusion of noise barriers. As such the predicted noise levels at the proposed residential lots do not indicate that noise barriers are required for the Muirhead North development.

Road traffic noise at two of the proposed school buildings and the proposed community centre building is predicted to exceed the noise limit of 58 dB(A) for non-residential noise sensitive use. Without the provision of a 1.8 metre noise barrier between the school site and Lee Point Road 5 (2 ground floor and 3 first floor) exceedances are predicted. This number is reduced to 3 (1 ground floor and 2 first floor) with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road.

Noise modelling therefore indicates that the school buildings and the community centre building should be placed further away from Lee Point Road or that noise mitigation options, such as a noise barrier between the proposed school site and Lee Point Road, should be included in the design to allow compliance with the external noise limit of 58 dB(A) for non-residential noise sensitive use.

Noise levels of less than 58 dB(A) are predicted at distances in excess of approximately 50 metres from Lee Point Road without including noise amelioration. The inclusion of 1.8 metre high noise barriers provides a significant amount of noise reduction for ground floor levels. Therefore increased buffer distances between the proposed buildings and the road, or provision of a barrier, or both is recommended at this location.

The results indicate that all of the proposed residential lots will require building construction in accordance with either AS 3671 Category 1 or 2. The community centre building and the nearest school building will require building construction in accordance with AS 3671 Category 3 without the provision of a 1.8 metre high noise barrier. If a 1.8 metre high noise barrier is included along the site boundary, the Category 3 construction requirements are only applicable for the first floor levels of the two buildings.

9.3 Risk Assessment

9.3.1 Purpose

This section summarises the noise and/or vibration sources that may impact upon the nearest sensitive receivers, adopted assessment criteria and proposed mitigation measures where appropriate. Full details of the above are contained in Appendix C.

9.3.2 Description of impacts and mitigation measures

9.3.2.1 Recommended Noise Mitigation Measures

General

A summary of noise and vibration impacts that exceed the adopted assessment criteria details above is summarised in Table 79. Appropriate mitigation measures to reduce impacts to below threshold levels are provided.

Table 79. Summary of Recommended Mitigation Measures - General

Impact	Description	Considered Mitigation Measures
Operational Noise		
Sleep disturbance (operation)	Noise events during the night at levels able to cause awakenings	Noise barriers or receiver façade upgrades
Health and wellbeing (operation)	Extended periods of traffic noise levels above recommended levels	Noise barriers, low noise asphalt, reduced speed limits or façade upgrades
Annoyance (operation)	Unusual or unexpected noise events	Noise barriers or façade upgrades
Construction Noise		
Sleep disturbance	Noise events during the night at levels able to cause awakenings	Avoid construction at night, temporary noise barriers.
Health and wellbeing	Extended periods of construction noise	Temporary noise barriers or provide respite periods
Annoyance	Continued perception of reversing beeping alarm	Temporary noise barriers, provide respite periods, offer gifts (movie tickets for noisy periods)
Noise	Annoyance (construction)	- Mulchers should be located away from noise sensitive receivers - Reduce the number of plant operating at one time where works are required to be carried out outside of standard hours and close to existing sensitive receivers - Preference should be for electric powered plant over combustion engine powered plant

Impact	Description	Considered Mitigation Measures
		• Preference should be for hydraulic or electric powered plant over pneumatic powered plant • Avoid metal to metal contact on equipment to reduce impulsive or scraping noise consultation with residents • Provision of noise attenuating controls at the source, such as mufflers, acoustic screens • Keeping plant and equipment well maintained • Locating static sources of noise such as the generators as remotely as possible from noise sensitive receivers • Developing proposed hours of operation in consultation with the residents/occupants of the affected receivers, and NT EPA with a view to minimising potential impacts as far as is practically feasible • Allowing construction to occur only during approved construction hours, unless otherwise required due to climatic conditions or safety requirements • Conducting noise monitoring during operations for the purposes of assisting in noise mitigation and to verify the findings of this noise assessment, if complaints are received or proposed activities and number of plant exceed those assumed in this assessment
Noise	Annoyance (construction)	• Use of broadband reversing alarms, or “quackers”, on mobile equipment in accordance with the relevant health and safety regulations • Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets • Modification of work activities where noise or vibration is found to cause unacceptable impact • Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately • Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings • Avoid the need for reversing in the construction area by creating a loop road or similar • Avoid dropping materials from height • Workers should avoid shouting, minimise talking loudly, and avoid slamming vehicle doors
Operational Vibration		
Vibration (operation)	Perception of heavy vehicles	• Road design and avoid speed bumps

Impact	Description	Considered Mitigation Measures
Construction Vibration		
Vibration (construction)	Perception of vibration or structural damage due to vibration intensive plant	Select suitable plant when near vibration sensitive receivers
	Annoyance (construction)	- Avoid vibration intensive work at night to minimise the risk of sleep disturbance - Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets - Modification of work activities where noise or vibration is found to cause unacceptable impact - Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately - Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings - Avoid dropping materials from height

Construction Noise

Construction noise is typically a problem outside designated working periods such as would be the case for work scheduled during the night time. However, predicted noise levels have been compared to the night time noise limits to determine if out of hours work can be undertaken while complying with the night-time noise limits and in particular the adopted sleep disturbance noise limit. General construction noise mitigation measures to minimise the impact upon sensitive receivers are outlined in Table 79, and include:

- Avoid night-time works.
- Temporary noise barriers
- Reducing the number of plant operating at anyone time.
- Preference for hydraulic electric powered plant over combustion engine or pneumatic powered plant.
- Noise attenuating controls at the source (e.g. mufflers).
- Keeping plant and equipment well maintained.

Construction Vibration

Vibration generated by large plant during the construction of infrastructure and buildings may be transmitted through the ground to such a degree that vibration can be felt at nearby receivers or in some cases at levels that can cause cosmetic damage. Mitigation of vibration is for most cases undertaken by using smaller plant that generates less vibration, however digging a trench between the source and the receiver is also an option

for mitigation of ground borne vibrations. General construction vibration mitigation measures to minimise the impact upon sensitive receivers are outlined in Table 79, and include:

- Select suitable plant when near vibration sensitive receivers.
- Avoid works at night.
- Notifying potentially affected receivers.

Operational Noise

Traffic noise primarily affects dwellings located close to busy roads. Some of the proposed residential dwellings to be developed in the project site are located adjacent to Lee Point Road. Noise mitigation of traffic noise would normally include provision of screening such as noise barriers, reduction of traffic speed, low noise asphalt or upgrade of building facades. General mitigation measures for operational noise impacts are recommended above in Table 79 and focus on the use of noise barriers and façade upgrades. Specific details on the recommended noise barriers and the required category constructions for dwellings for the development are detailed in Appendix H and Appendix I.

It should be noted that upgrade of building facades provides noise reduction internally in homes, but not externally, such as for parks and outdoor recreation areas.

10 CONCLUSION

This EIS has been prepared to address the assessment requirements under the EPBC Act and NT EA Act as set out in the Terms of Reference in Appendix A. Through undertaking detailed risk assessment, the magnitude of impacts to the following environmental components has been identified:

- Hydrology
- Air Quality
- Utilities and Infrastructure
- Biodiversity and Heritage
- Social Economic
- Noise

The major risks to the environment are considered to be increased disturbance of migratory shorebirds along Casuarina Beach and managing stormwater run-off to avoid impacts to Sandy Creek and contributing breeding habitat for biting insect breeding. Appropriate controls have been proposed that will adequately address these risks, which include:

- Locating access to Casuarina Beach north of Sandy Creek mouth.
- Increased signage and community events to improve knowledge of migratory shorebird habitat and their threats.
- A stormwater management plan that ensures no increase in the volume of water entering Sandy Creek from the site, and removing sediment and pollutants.
- Development of an Erosion and Sediment Control Plan.
- Water Quality Monitoring Program.

These and other control measures that have been proposed to ensure any environmental impacts is within an acceptable limit are provided in detail in a CEMP (Appendix D). In addition to the potential impacts of the project, the EIS also discusses the likely benefits of the project which include:

- Provision of affordable housing.
- Employment opportunities in construction during a down-turn in the mining and resources industry.
- Permanent employment in the retail, accommodation and hospitality industries.
- Reduction in sediment entering Sandy Creek through rehabilitation of erosion gullies.

Post approval of the EIS, the following management plans will be prepared or further developed prior to construction commencing:

- Construction Environmental Management Plan including sub-plans for biodiversity, water, heritage and noise based on the overarching CEMP prepared as part of the EIS (Appendix D).

- Water Quality Monitoring Plan based on the overarching WQMP prepared as part of the EIS (Appendix O).
- Erosion and Sediment Control Plan based on the overarching ESCP prepared as part of the EIS (Appendix D).
- Conservation and Offset Management Plan for the 21.95 ha Conservation Area.
- Offset Management Plan for Black-footed Tree-rat third-party offset site.

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