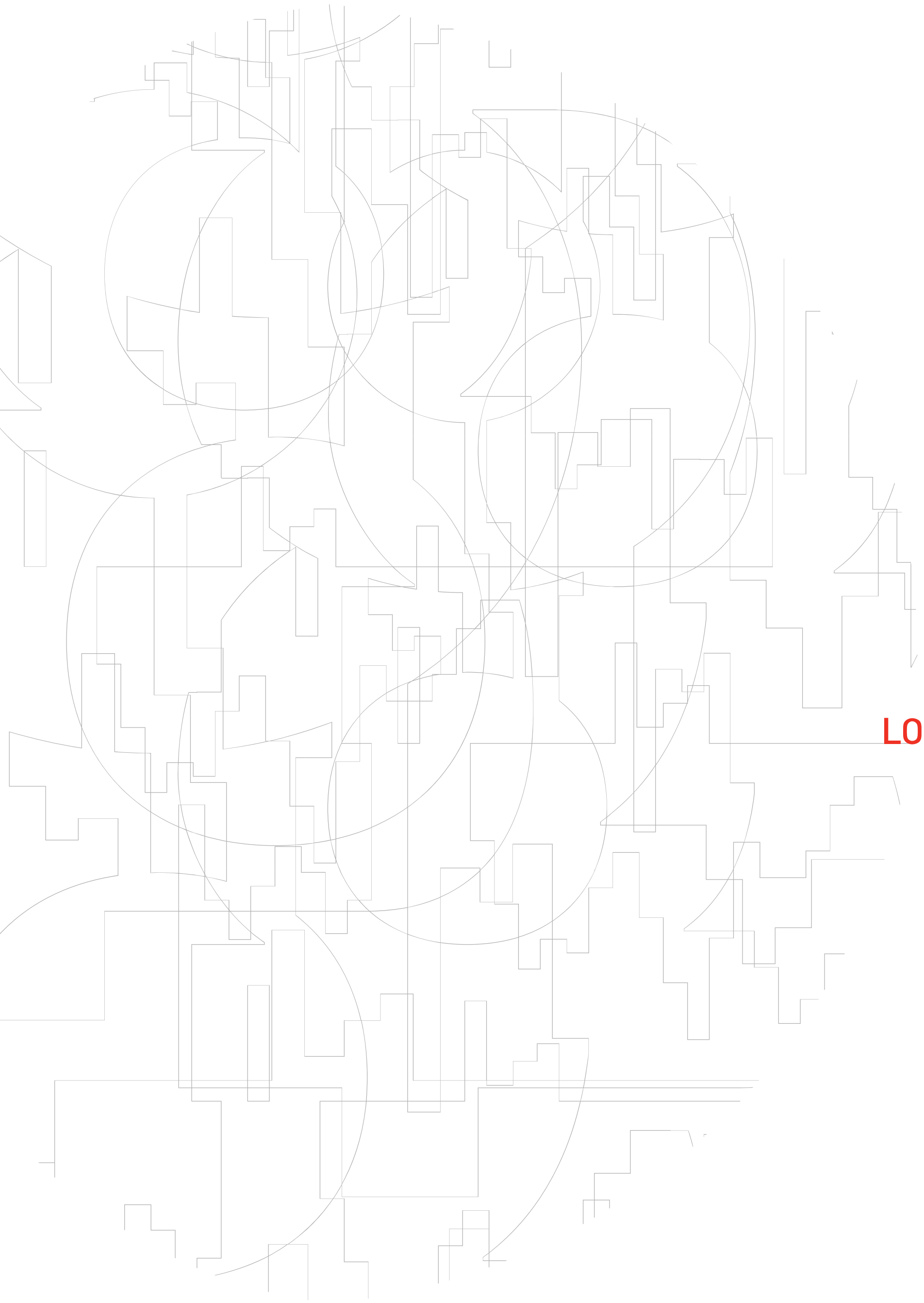
TOWN PLANNING
AND URBAN DESIGN



LOT 500 MADIGAN ROAD, BAYNTON

DEVELOPMENT PLAN

710-200
APRIL 2012

perth
sydney

DOCUMENT CONTROL

Document ID: PLANNING/PG 2010/710-200/Final Documents/Final Report/Amended/Development Plan/Amended Final Madigan Development Plan 23.04.12.indd

Issue	Date	Status	Prepared by		Approved by	
			Name	Initials	Name	Initials
1	26.10.10	Final	Leigh Caddy		David Read	
2	22.12.10	Amended Final	Leigh Caddy		David Read	
3	02.11.11	Amended Final	Leigh Caddy		David Read	
4	26.03.12	Amended Final	Sonny Embleton		David Read	
5	23.04.12	Amended Final	Sonny Embleton		David Read	

This report has been prepared for the exclusive use of the Client, in accordance with the agreement between the Client and TPG ('Agreement').

TPG accepts no liability or responsibility whatsoever in respect of any use of or reliance upon this report by any person who is not a party to the Agreement or an intended recipient.

In particular, it should be noted that this report is a qualitative assessment only, based on the scope and timing of services defined by the Client and is based on information supplied by the Client and its agents.

TPG cannot be held accountable for information supplied by others and relied upon by TPG.

TPG reports are printed on:

Mixed Sources
Product group from well-managed forests and other controlled sources
www.fsc.org
© 1996 Forest Stewardship Council
FSC

EXECUTIVE SUMMARY

The purpose of this report is to enable the Shire of Roebourne and the Western Australian Planning Commission (WAPC) to consider a Development Plan for Lot 500 Madigan Road, Baynton (the 'site'). This Development Plan will facilitate the future development of the site as a residential neighbourhood and will assist in addressing housing demand and land supply issues currently facing Karratha, severely limiting its potential to realise the State Government, the Shire of Roebourne and the local community's vision of Karratha as a 'City of the North'.

This Development Plan will facilitate the potential development of approximately 1440 new dwellings, accommodated within a range of housing types and densities. The Plan will also provide for the staged development of a mixed-use local neighbourhood centre comprising up to 1000m² of new ground floor retail and complementary non-retail commercial uses to provide local employment generation and service local needs. This commercial centre will have the potential to expand as population increases.

The design and development of the Development Plan, which has been prepared in consultation with a range of government stakeholders, represents a site responsive, innovative approach to urban design, responding to the local Karratha context and incorporating a range of design and sustainability initiatives.

This Development Plan provides a new approach to planning and design of residential neighbourhoods in Karratha in contrast to existing older urban areas which lack many of the elements that contribute to the comfort and attractiveness of the public realm. For instance, housing is provided in isolation from day-to-day amenities required by its residents; roads are provided in isolation from a comfortable pedestrian realm; and drainage networks are provided in isolation from functional and attractive parklands.

This Development Plan incorporates a range of design initiatives which seek to create a climate and place responsive urban environment including:

- An urban form designed to facilitate lot orientation that addresses local climatic conditions;
- The provision of housing diversity through a range of housing types and densities;
- A movement network that promotes connectivity and accessibility through the site and with surrounding areas for vehicles, cyclists and pedestrians;
- The provision of an urban form that ensures development focuses on and addresses streets, public open space and drainage areas;
- The provision of multi-functional public open space reflective of the Pilbara context and which integrates drainage requirements;

- Facilitating local employment services and amenities; and
- Facilitating sustainable approach to development.

The design represents the optimal development outcome for the site, and is consistent with the agreed vision for the site identified in the 'Karratha City of the North' Blueprint and 'City Growth Plan' document.

The approval of this Development Plan by the Shire and the WAPC will enable the future subdivision and development of the site to occur.

CONTENTS

CERTIFICATION OF DEVELOPMENT PLAN

IT IS HEREBY CERTIFIED THAT THE DEVELOPMENT PLAN FOR LOT 500 MADIGAN ROAD,

BAYNTON WAS ADOPTED BY RESOLUTION OF THE WESTERN AUSTRALIAN PLANNING COMMISSION

ON

17 May 2012

....

Being an officer of the Commission duly

authorised by the Commission pursuant to

Section 16 of the Planning and Development Act 2005

AND BY

RESOLUTION OF THE COUNCIL OF THE SHIRE OF ROEBOURNE ON

....

AND THE SEAL OF THE MUNICIPALITY WAS PURSUANT TO THE COUNCIL'S RESOLUTION HERETO

AFFIXED IN THE PRESENCE OF:

....

PRESIDENT, SHIRE OF ROEBOURNE

....

CHIEF EXECUTIVE OFFICER, SHIRE OF ROEBOURNE

Expiry Date: 19 October 2030

This page has been left blank intentionally.

PART 1 – STATUTORY PLANNING SECTION

1. STATUTORY PROVISIONS

1.1 TITLE

This Development Plan shall have the formal title of 'Lot 500 Madigan Road Development Plan' (hereafter referred to as the 'Development Plan').

1.2 RELATIONSHIP TO THE SHIRE OF ROEBOURNE TOWN PLANNING SCHEME NO. 8

Unless specified by a specific requirement of this Development Plan, all land uses and development shall occur in accordance with the standards and requirements specified by the Shire of Roebourne Town Planning Scheme No. 8 (TPS8).

1.3 DEVELOPMENT PLAN

The Development Plan is attached as Appendix 1 to this Part and comprises Lot 500 on Deposited Plan 59331 and is 67.7267 hectares in area.

The objective of the Development Plan is to provide a comprehensive master plan to facilitate the orderly and proper subdivision and development of the land. The Development Plan aims to create a sustainable and affordable urban area with a range of lot sizes and diversity of housing types as well as foster a small local neighbourhood centre and set aside land for public open space and drainage purposes.

1.4 LAND USE PRECINCTS AND STANDARDS

The Development Plan identifies several land use precincts that are generally characterised by a predominant use although it is intended that the Development Plan be treated in a flexible manner to allow other compatible uses. The proposed land use precincts include Residential, Mixed Use Commercial/Retail and Public Open Space and Drainage.

1.4.1 Residential Precinct

1.4.1.1 Statement of Intent

The intent of the Residential Precinct is to provide a high quality, environmentally sustainable, residential environment providing a range of living options to cater for a diverse population and sense of community. The provision of Transient Workers Accommodation is permitted within certain locations along Madigan Road.

Development within the Precinct will provide for pedestrian friendly streetscapes with passive surveillance of the public domain. Local employment through viable and suitable home based business is also encouraged within the Precinct.

1.4.1.2 Development Standards

Development standards to be satisfied for the Residential Precinct include:

a) The provisions of the Residential Design Codes of Western Australia (R-Codes) shall apply to residential development in this Precinct unless otherwise specified in this section;

b) A Detailed Area Plan (DAP) is required to be prepared in accordance with section 1.7 for various land areas as identified on the Development Plan. Variations to the provisions of the R-Codes not already permitted by the Codes shall be allowed where prescribed by the DAP;

c) In the case of land subject to a split residential coding, a minimum lot size of 2,500m² or an entire street block is required for development at the higher density code (R60);

d) The subdivision and development of land abutting public open space/drainage areas shall be designed to front onto and address public open space/drainage areas;

e) Multiple dwelling development is not permitted except for areas coded R60 and R-AC2, or areas subject to a split density code where the upper density code (R60) is achieved;

f) The maximum height of development shall not exceed 2 storeys in height, except for areas coded R-AC2 where the maximum height of development shall not exceed 3 storeys in height unless varied by an approved DAP prepared in accordance with section 1.7; and

g) An Acoustic Report is required to be prepared by a suitably qualified Acoustic Consultant as part of a development application demonstrating how the proposed development complies with relevant noise legislation for the following circumtances:

  - Any noise sensitive development proposed within 82 metres of the centreline of Madigan Road;
  - Any noise sensitive development proposed within mixed use development or located near a site(s) in which there is the potential for after hours activity to occur (e.g: café, restaurant); or
  - Any non-residential development in which there is the potential to generate noise that may impact on noise sensitive development.

1.4.1.3 Development Standards - Transient Workers Accommodation

The following additional standards apply to the development of land for Transient Workers Accommodation (TWA):

a) The development of TWA shall be limited to those areas delineated on the Development Plan and developed in a manner which will allow the land to redevelop to a normalised residential area over time;

b) The provision of services and facilities associated with TWA development shall not undermine existing or proposed services and facilities within the community; and

c) The external frontages of TWA development shall be developed to a standard consistent with adjacent residential areas with regards to streetscape, setbacks and landscaping.

1.4.1.4 Land Use Permissibility

Land use permissibility shall be in accordance with the Land Use Permissibility Table in section 1.5.

1.4.2 Mixed Use Commercial/Retail Precinct

1.4.2.1 Statement of Intent

The intent of the Mixed Use Commercial/Retail Precinct is to develop a mixed use area comprising a diversity of retail and non-retail main-street uses which generate day and evening activity, and which are compatible with residential development. A high standard of 'Main Street' built form incorporating environmental sustainable design, active edges and attractive façades is envisaged to provide visual amenity and interaction, pedestrian friendly streetscapes and passive surveillance of the public realm. This centre is to be contained in the Precinct identified on the Development Plan with the intent for retail and restaurant uses to be located abutting the central open space, adjoined by commercial office/consulting room type uses, and then the balance of the street level be residential but with a ceiling height to allow it to transition to ground floor commercial over time.

1.4.2.2 Development Standards

Development standards to be satisfied for the Mixed Use Commercial/Retail Precinct include:

a) The provisions of the Residential Design Codes of Western Australia (R-Codes) shall apply to residential development in this Precinct unless otherwise specified in this section;

b) A Detailed Area Plan (DAP) is required to be prepared in accordance with section 1.7. Variations to the provisions of the R-Codes shall be allowed where outlined on the DAP;

c) Retail uses (including a 'shop' or 'market') and Restaurant/Take away food outlet uses shall only be permitted abutting the central public open space abutting the 'Main Street' unless varied by a DAP prepared in accordance with section 1.7.

d) Commerical uses identified in the permissibility table shall only be permitted in the Mixed Use Commerical/Retail Precinct shown on the Development Plan.

e) The maximum combined NLA of all retail and other non-residential uses abutting the Main Street shall not exceed 1000m^2 unless varried by a DAP prepared in accordance with section 1.7.

f) The maximum retail floorspace for an individual tenancy shall not exceed 500m^2 NLA. A retail tenancy includes a 'shop' and/or 'market'.

g) Non-residential development is only permitted on the ground floor;

h) Multiple dwelling development is encouraged;

i) The maximum height of development shall not exceed 3 storeys in height unless varied by an approved DAP prepared in accordance with section 1.7; and

j) Development abutting the 'Main Street' indentified on the Development Plan shall have a minimum ground floor level to ground floor ceiling level in the room(s) abutting the street of 3.2 metres to enable future conversion to commercial uses;

k) An Acoustic Report is required to be prepared by a suitably qualified Acoustic Consultant as part of a development application demonstrating how the proposed development complies with relevant noise legislation for the following circumtances:

    - Any noise sensitive development proposed within mixed use development or located near a site(s) in which there is the potential for after hours activity to occur (e.g. restaurant); or
    - Any non-residential development in which there is the potential to generate noise that may impact on noise sensitive development.

1.4.2.3 Land Use Permissibility

Land use permissibility shall be in accordance with the Land Use Permissibility Table in section 1.5.

1.4.3 Public Open Space and Drainage

The intent of the Public Open Space and Drainage Precinct is to provide high quality, public open spaces that offer residents and visitors passive and active recreation opportunities whilst facilitating stormwater conveyance particularly in cyclonic events.

1.4.3.1 Development Standards

Development standards to be satisfied for the Public Open Space and Drainage Precinct include:

a) The size and location of public open space shall be in accordance with the Development Plan;

b) The design of public open space areas shall ensure the protection and enhancement of indigenous heritage sites;

c) The design of public open space areas shall ensure appropriate provision for stormwater drainage management; and

d) The landscaping of public open space areas shall be suitable for an arid climate having regard to minimising maintenance and water use whilst providing areas of highly aesthetic and functional amenity.

1.5 LAND USE PERMISSIBILITY

The following table describes the permissible land uses within each Land Use Precinct. The table varies from that in the Scheme, by modifying permissibility for the use classes identified. Where a use is not listed, that use is deemed to be an 'X' use. Council shall have regard to Clause 3.2.2 of the Scheme with regard to the interpretation of the table.

Precinct Land Uses	Residential Precinct	Mixed Use Commericla/ Retail Precinct
RESIDENTIAL		
Aged or Dependent Persons Dwelling	AA	AA
Ancillary Accommodation	AA	X
Grouped Dwelling	P	AA
Home Business	P	P
Home Occupation	P	P
Motel	X*	SA
Multiple Dwelling	P***	P
Residential Building	AA	AA
Short Stay Accommodation	SA	AA
Single House	P	X
Transient Workforce Accommodation	X*	X
INDUSTRY		
Industry – Service	X	SA
COMMERCE		
Display Home	AA	AA
Dry Cleaning Premises	X	P
Market	X	P
Office	X	P
On-site Canteen	IP	X
Reception Centre	X	SA****
Restaurant	X	P****
Shop	X	P****
Take-away Food Outlet	X	P****
HEALTH, WELFARE AND COMMUNITY SERVICES		
Car park	IP	AA
Child Care Service	SA	X
Community Use	SA	AA
Consulting Rooms	X	P
Education Establishment	X	SA
Medical Centre	X	AA
Nursing Home	AA	X
Place of Public Meeting, Assembly or Worship	SA	AA
Minor Utility Installation	AA	AA
Utility Installation	SA	SA
ENTERTAINMENT, RECREATION AND CULTURE		
Entertainment Venue	X	AA
Private Recreation	SA	AA
Public Recreation	AA	AA

* except within the area identified as TWA on the Development Plan

** within areas coded R-AC2

*** multiple dwellings are only permitted within areas coded R60 or R-AC2 or land areas subject to a split coding and the criteria for the higher density (R60) is achieved.

**** only permitted in the Mixed Use Commercial/Retail Precinct when abutting Public Open Space.

1.6 RESIDENTIAL DENSITY CODING

The Development Plan indicates the Residential Density Coding that applies to land zoned 'Residential' pursuant to Clause 6.2.4 of the Scheme and includes the following:

- R17.5;
- R17.5/R60
- R25;
- R25/R60;
- R30;
- R30/R60;
- R60; and
- R-AC2.

Residential development shall be in accordance with the Residential Design Codes of Western Australia (R-Codes) as given effect by Clause 6.2.3 of the Scheme, unless otherwise stated in this Part.

In the case of land subject to a split residential coding, a minimum lot size of 2,500m² or an entire street block is required for development at the higher density (R60).

The built form provisions of the R-Codes may be varied by a local policy applied through Detailed Area Plans (DAP's) adopted at subdivision stage.

1.7 DETAILED AREA PLANS

The Development Plan identifies several land parcels for which a Detailed Area Plan (DAP) is required to be prepared.

An approved DAP shall be prepared (by the developer, an owner of the land or the Shire) and adopted by Council prior to any subdivision and/or substantial development and used as the basis for the determination of all development applications to the Shire of Roebourne.

The DAP will enhance, elaborate and expand the details and provisions contained in this Part as well as supplement the provisions of the Scheme and the R-Codes. DAP's are required to address the following:

a) non-residential land use, size and location (where applicable);
b) building envelopes;
c) setbacks;
d) interfaces with public open space and drainage areas;
e) distribution of land uses within a lot (mixed use lots);
f) vehicular access and parking;
g) loading and unloading areas, storage yards and rubbish collection closures;
h) the location, orientation and design of buildings and the space between buildings; and
i) such other information considered relevant by the Shire of Roebourne.

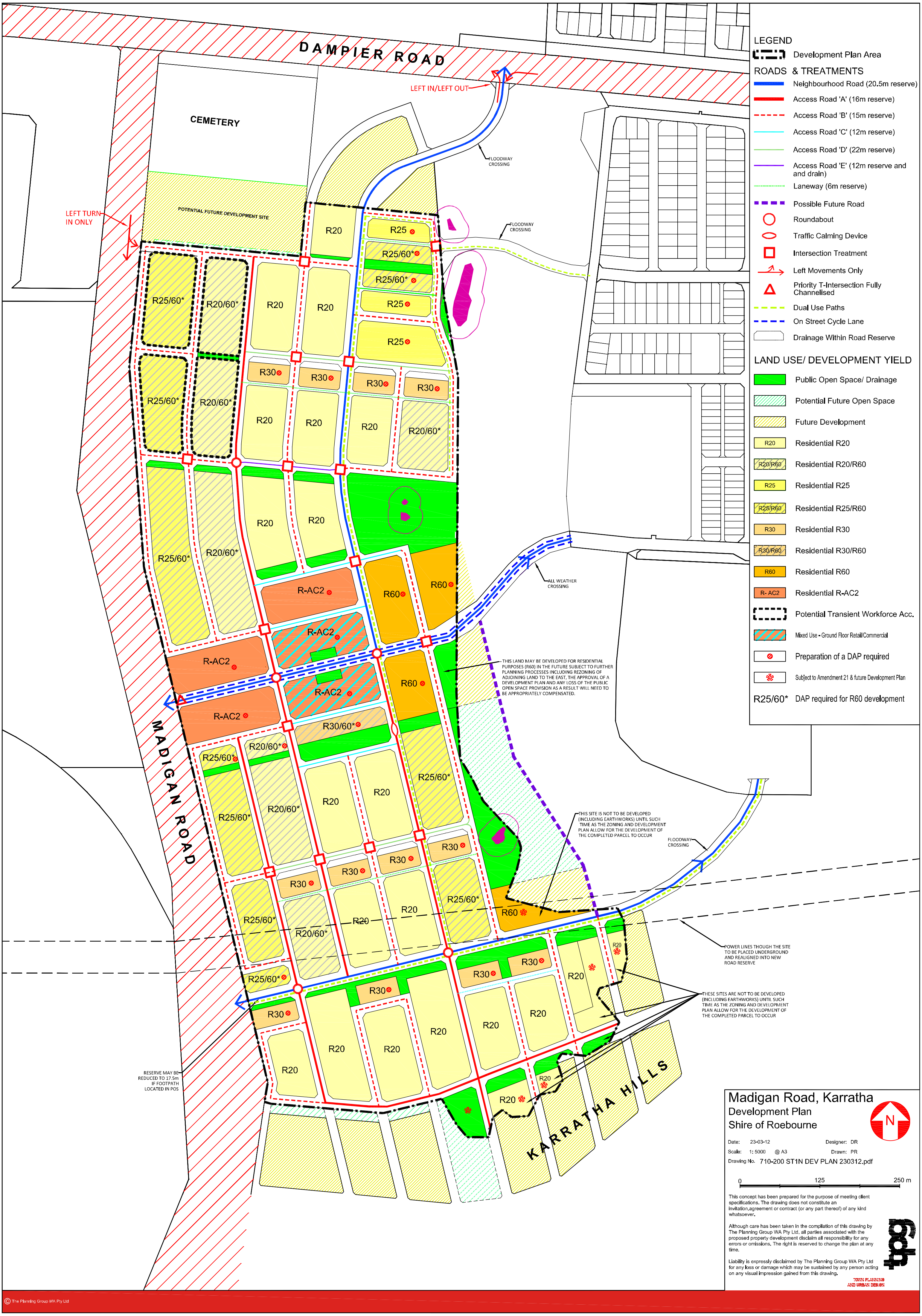
Variations to the provisions of the R-Codes shall be allowed where prescribed on the DAP.

This page has been left blank intentionally.

APPENDIX 1

LOT 500 MADIGAN ROAD DEVELOPMENT PLAN

This page has been left blank intentionally.



THIS LAND MAY BE DEVELOPED FOR RESIDENTIAL PURPOSES (R60) IN THE FUTURE SUBJECT TO FURTHER PLANNING PROCESSES INCLUDING REZONING OF ADJOINING LAND TO THE EAST, THE APPROVAL OF A DEVELOPMENT PLAN AND ANY LOSS OF THE PUBLIC OPEN SPACE PROVISION AS A RESULT WILL NEED TO BE APPROPRIATELY COMPENSATED.

THIS SITE IS NOT TO BE DEVELOPED (INCLUDING EARTHWORKS) UNTIL SUCH TIME AS THE ZONING AND DEVELOPMENT PLAN ALLOW FOR THE DEVELOPMENT OF THE COMPLETED PARCEL TO OCCUR

POWER LINES THOUGH THE SITE TO BE PLACED UNDERGROUND AND REALIGNED INTO NEW ROAD RESERVE

THESE SITES ARE NOT TO BE DEVELOPED (INCLUDING EARTHWORKS) UNTIL SUCH TIME AS THE ZONING AND DEVELOPMENT PLAN ALLOW FOR THE DEVELOPMENT OF THE COMPLETED PARCEL TO OCCUR

RESERVE MAY BE REDUCED TO 17.5m IF FOOTPATH LOCATED IN POS

Madigan Road, Karratha
Development Plan
Shire of Roebourne

Date: 23-03-12
Designer: DR
Scale: 1: 5000 @ A3
Drawn: PR
Drawing No. 710-200 ST1N DEV PLAN 230312.pdf

This concept has been prepared for the purpose of meeting client specifications. The drawing does not constitute an invitation,agreement or contract (or any part thereof) of any kind whatsoever.

Although care has been taken in the compilation of this drawing by The Planning Group WA Pty Ltd, all parties associated with the proposed property development disclaim all responsibility for any errors or omissions. The right is reserved to change the plan at any time.

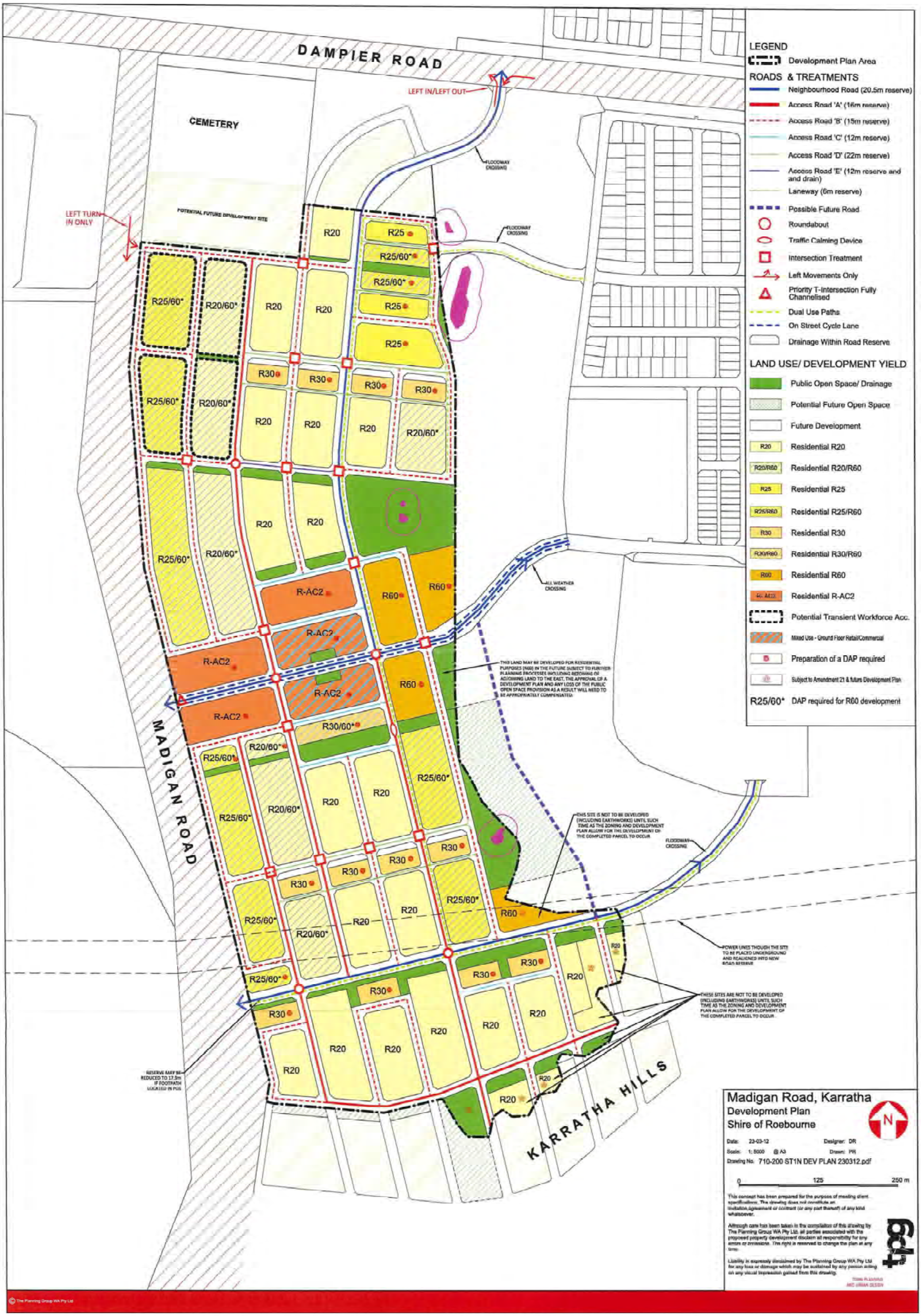
Liability is expressly disclaimed by The Planning Group WA Pty Ltd for any loss or damage which may be sustained by any person acting on any visual impression gained from this drawing.

TOWN PLANNING
AND URBAN DESIGN

APPENDIX 2

DEVELOPMENT PLAN

This page has been left blank intentionally.



Madigan Road, Karratha
Development Plan
Shire of Roebourne

Date: 23-03-12
Designer: DR
Scale: 1: 5000 @ A3
Drawn: PR
Drawing No. 710-200 ST1N DEV PLAN 230312.pdf

This concept has been prepared for the purpose of meeting client specifications. The drawing does not constitute an invitation,agreement or contract (or any part thereof) of any kind whatsoever.

Although care has been taken in the compilation of this drawing by The Planning Group WA Pty Ltd, all parties associated with the proposed property development disclaim all responsibility for any errors or omissions. The right is reserved to change the plan at any time.

Liability is expressly disclaimed by The Planning Group WA Pty Ltd for any loss or damage which may be sustained by any person acting on any visual impression gained from this drawing.

APPENDIX 3

GEOTECHNICAL REPORT

This page has been left blank intentionally.

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GEOTECHNICAL REPORT MADIGAN ROAD DEVELOPMENT SITE

Cossill & Webley Consulting Engineers
Madigan Road, Karratha, WA

GEOTPERT02828AS-AC
25 November 2010

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
89-91 Burswood Road Burswood WA 6100 Australia

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

25 November 2010

Cossill & Webley Consulting Engineers
Level 2, 431 Roberts Road
Subiaco, WA, 6008

Attention: Ray Todd

Dear Sir,

RE: REPORT OF GEOTECHNICAL INVESTIGATION

MADIGAN ROAD DEVELOPMENT SITE

This letter presents our report for the geotechnical investigation carried out on the above project.

If you have any questions or comments related to the report or we can be of further assistance, please do not hesitate to contact the undersigned.

For and on behalf of Coffey Geotechnics Pty Ltd

Stuart Ellis

Associate Geotechnical Engineer

Distribution:	Original held by	Coffey Geotechnics Pty Ltd
	2 Hard copies	Cossill & Webley
	1 Electronic Copy	Cossill & Webley

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
89-91 Burswood Road Burswood WA 6100 Australia
T +61 8 9347 0000 F +61 8 9347 0099
coffey.com

CONTENTS

CONTENTS

ATTACHMENTS

Tables

Figure

Appendices

1 INTRODUCTION

This report presents the results of a geotechnical investigation carried out by Coffey Geotechnics Pty Ltd (Coffey) for Cossill & Webley Consulting Engineers (Cossill & Webley) acting on behalf of Benchmark Projects for the Madigan Road Development Site, Karratha, Western Australia.

This work was commissioned by Mr Jonathan Yelland of Benchmark Projects on 6 October 2010 via a completed "Authorisation to Proceed" form enclosed with the Coffey proposal dated 16 July 2010 (Ref. GEOTPERT02828AS-AA-P).

This report is prepared and is to be read subject to the terms and conditions contained in our proposal referenced above. Our advice is based on the information stated and on the assumptions expressed herein. Should that information or the assumptions be incorrect, then Coffey Geotechnics Pty Ltd shall accept no liability in respect of the advice whether under law of contract, tort or otherwise.

2 PROPOSED DEVELOPMENT

It is understood that the Madigan Road site is about 68ha in area and is proposed for residential development. The residential lots are proposed for R17.5 to R60 zoning.

3 OBJECTIVES

The objectives of the geotechnical investigation were to ascertain the following:

- Soil, rock and groundwater conditions within the significant foundation support zone for the sites in general
- Site classification in accordance with AS2870-1996 and requirements to improve the classification;
- Retaining wall design considerations and design parameters;
- Pavement design parameters and construction requirements; and
- Construction considerations pertinent to the proposed development, including site preparation, excavation conditions, protection of footing excavations, suitability of materials for structural fill, compaction control, groundwater control and the need for subsoil drainage.

4 INFORMATION SUPPLIED BY OTHERS

Cossill & Webley have provided Coffey with the following information:

- Geotechnical Investigation, Lot 500 Madigan Road, Proposed Test Pit Locations (Ref: 14004-00 Rev 0, Dated 15 October 2010);
- Karratha, Regional Hotspot Land Supply Update, Identified Project areas (Ref: GL248-2007-2 Dated 22 October 2010);
- Landcorp Madigan Road Residential (Ref: 11879it4, Dated 9 December 2010); and
- Proposed Test Pit Locations (Ref: Excel Spreadsheet 101015 drill holes, Dated 10 October 2010).

5 FIELDWORK

5.1 General

Fieldwork was carried out on the 19 and 20 October 2010 in the full time presence of personnel from Coffey. Test pit co-ordinates were provided by Cossill & Webley to Coffey and were located onsite using hand held GPS relative to Map Grid of Australia (MGA) to a horizontal accuracy of +/- 5 metres. Several test locations located close to Madigan Road were moved further east to minimise the proximity to buried services. Surveyors from Whelans Pty Ltd completed survey of the test locations after the completion of field work on 3 November 2010. Co-ordinates and elevations are provided on the attached logs.

Access at the site was via Madigan Road. Trafficability at the time of fieldwork was generally good for a four wheel drive vehicle. Some localised areas of dry loose soils at the ground surface (typically indicated by the presence of crabholes) were present in the northern and central regions of the site.

Weather conditions at the time of fieldwork were hot and dry.

Approximate investigation locations are shown on Figure 1.

5.2 Test Pitting

A total of 30 test pits (TP01 to TP30) were excavated by backhoe to depths varying from 0.0m to 3.0m below the existing ground surface.

Disturbed samples considered representative of the soils excavated were collected for laboratory testing.

In-situ testing comprised pocket penetrometer tests carried out in the cohesive soils exposed in the faces of the test pits. The pocket penetrometer test provides an estimate of the unconfined compressive strength of a cohesive soil and approximates its allowable bearing capacity.

The records of the test pit logs showing the major strata that were intersected, the depths at which the samples were taken, in-situ tests carried out, and the results of these tests, together with Explanation Sheets defining the terms used, are presented in Appendix A. Photographs of the test pits and excavated material are also presented in Appendix A.

6 DESCRIPTION OF LABORATORY TESTING

Laboratory testing was carried out in accordance with the general requirements of AS 1289 by the Coffey NATA registered soils laboratory.

The extent of testing carried out to provide the geotechnical parameters required for this study are presented in Table 1.

Table 1 – Extent of Laboratory Testing

Type of Test	Number
Particle Size Distribution tests	11
Atterberg Limits tests	10
Moisture Content tests	5

Laboratory results for the aforementioned tests are attached in Appendix B.

7 SITE CONDITIONS

7.1 Surface Conditions

The site occupies an area of 68 ha and is situated between Dampier Road to the north, Madigan Road to the west, and the Karratha Hills to the South. The topography comprises of relatively flat plains and gentle slopes in the northern and central regions of the site, with steeper slopes as the site approaches the foothills in the south of the site.

Vegetation within the site is dominated by extensive areas of low grass with isolated areas of shrubs and small trees. Scattered shrubs and low trees also define the surface drainage channel along the eastern boundary of the site. It is anticipated that the drainage channel becomes active during significant rainfall events and that significant areas of surface water/sheet wash will occur across the site in response to rainfall events associated with tropical cyclones.

A common feature within the alluvial – colluvial plain throughout the site is the occurrence of "crabholes" indicating Gilgai soils. Gilgai is extremely reactive to changes in soil moisture and shrinks and swells to depths of 1m to 2m in response to seasonal wetting and drying. The resulting terrain, noted throughout the site, consists of small hummocks and hollows with "crabholes" (Figure 2) in the hollows being more concentrated in shallow water courses and lower lying areas where surface water ponds following rainfall events.

Rock outcrops were observed in the central and southern sections of the site (Figure 3), with moderately to highly fractured rock outlays present at the base of the foothills (Figure 4).

Existing site development consists of:

- Several cleared tracks within the site typically running from west to east;
- High voltage power lines running through the site from west to east in the south; and
- Buried services present within the road shoulder of the Madigan Road

7.2 Subsurface Conditions

Based on observations within the test pits, subsurface conditions across the site generally comprise a 1.5m to 2.5m thick layer of high plasticity clay in a friable to stiff condition. The high plasticity clays form highly to extremely reactive soils with large shrink swell potential. The Gilgai soils are considered to have been derived from the weathering of mafic and felsic rocks forming the line of hills to the south of the site. The weathering products from these rocks are renowned for their reactive properties and have been transported by alluvial processes to form the extensive plain towards the current day coastline.

Below the clay is a gravelly clay /clayey gravel layer often incorporating cobble sized fragments of the underlying bedrock and possibly represents a "conglomerate" layer formed at the base of the overlaying alluvial deposits. Test pits typically refused on the underlying bedrock which predominantly consisted of a moderately weathered to residual soil, highly fractured rock.

Based on the field investigation, and in view of the similar engineering characteristics of the two surface materials described above, a generalised subsurface profile covering all sites is shown in Table 2.

Table 2 – Generalised Subsurface Profile

Layer/Unit	Typical Depth to Top of Layer (m)	Typical Layer Thickness (m)	Description/Remarks
1	Surface	0 - 1.2	CLAY/SANDY CLAY (CH) medium to high plasticity, red/brown, friable.
2	Surface – 1.2	0.5 – 2.0	CLAYEY GRAVEL/ GRAVELLY CLAY (GC/CH) medium to course grained, brown/dark brown, friable with medium to high plasticity clayey fines.
3	0.5-2.1	Grading into fresh rock at greater depths	WEATHERED ROCK, material has weathered to soil like material comprising sand/gravel/cobbles in a medium to high plasticity clayey matrix, grey/light grey/brown.

The depth to fresh (unweathered) rock could not be ascertained using the backhoe as refusal of the backhoe was encountered on weathered rock.

7.3 Groundwater Levels

Groundwater was not encountered in any of the test pits during the field investigation. The moisture content of the excavated material was typically low.

It should be noted that groundwater levels are subject to variation due to the influence of rainfall, temperature, local drainage and the seasons. There is potential for development of perched groundwater tables following periods of rainfall.

8 RECOMMENDATIONS

8.1 General

It should be noted that the ground encountered by the testpits represent the ground conditions at the location where the tests have been undertaken and as such are an extremely small proportion of the site to be developed. Accordingly, variations to the ground conditions are likely and allowance should be made for variability in the design and construction budgets.

Whilst, to the best of our knowledge, the information contained in this report is accurate at the date of issue, ground conditions including groundwater levels can change in a limited time or due to seasonal fluctuations. For example fill could be added to a site or surface materials removed from a site that will change the thickness of surface materials and depth to the underlying materials. The potential for change in ground conditions should be recognised particularly if this report is used after a protracted delay.

It is also recommended that any plans and/or specifications prepared which relate to the content of this report or amendments to original plans and specifications be reviewed by Coffey to verify that the intent of the recommendations contained in this report are properly reflected in the design.

8.2 Site Classification

Australian Standard AS2870-1996 provides a system of site classification for residential slabs and footing design as follows:

Table 3 - General Definition of Site Classes

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay site, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include: Soft soils, such as soft clays or silts or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

The standard also notes that in areas where deep soil moisture changes are anticipated the classification shall be further defined with the suffix –D.

Based on the encountered soil sub profile described and the results of the laboratory testing the appropriate site classifications for the site is typically Class H-D. Areas not containing Gilgai soils could be upgraded to Class M by placement of 1.0m of controlled sand fill over the clay. Areas containing Gilgai soils could be upgraded to Class M by placement of 1.2m of controlled sand fill over the clay. Structures should not be founded directly on the expansive Gilgai soils. Sand fill used to improve the site classification should be in accordance with Section 8.5.8.

Creating and maintaining a stable moisture content regime in the reactive clay soils will be necessary for satisfactory footing and structure performance. Section 8.2.1 details the necessary steps that should be undertaken to create a stable moisture regime.

As outlined in Section 8.5.6, cohesive soils not identified as Gilgai soils may be used as fill provided they are placed in accordance with the recommendations of Section 8.5.7. However, the locations containing this cohesive fill material will retain a classification of Class H-D.

8.2.1 Protection of Footings from Moisture Changes

It is recommended that clays supporting shallow footings be protected from significant changes in their moisture content regimes. Otherwise, significant ground movements that are not able to be accommodated by the structure may take place.

It is recommended that no large native trees be planted any closer to the footings than their likely mature height. If trees are to be planted close to footings, (and this practice is not recommended) then regular pruning of the trees will limit their root growth and reduce their water intake. The Water Authority of Western Australia provides advice on suitable species to plant in the vicinity of services and foundations and recommends minimum planting distances from structures.

It is recommended that a moisture barrier is placed to a distance of 1.0m around the boundary walls to prevent water ingress around the footings. This barrier could consist of either a concrete path or buried polythene.

Purchasers should be provided with a copy of the CSIRO Information Sheet on foundation maintenance (see Appendix B).

8.2.2 Perching Of Groundwater on Subsoil Profiles

Perching of groundwater within the subsoil profile is likely to occur above very low permeability horizons such as weathered rock and clayey materials. It is recommended that housing Lot development levels be at least 200mm above the top of kerb level. This will assist the shedding of surface water runoff into the drainage system and away from foundations.

8.2.3 Surface Drainage and Run Off

Runoff from upslope of the sites should be collected and diverted away from building structures. The finished surface level of the site should be graded with falls away from structures and their foundations. This will reduce the incidence of water ponding around the footings. A minimum fall of 2% is recommended.

8.3 Flexible Pavement Design

8.3.1 Sub-grade California Bearing Ratio

Estimates of sub-grade California Bearing Ratio (CBR) have been based on regional experience within the area and relationships between plasticity index, linear shrinkage and particle size distribution.

A design subgrade California Bearing Ratio (CBR) of 1.5 and 3 is recommended for gilgai areas and non gilgai areas respectively, provided the subgrade is prepared in accordance with the recommendations contained in Section 8.3.2 and Section 8.5.3.

8.3.2 Pavement Design

The minimum standard pavement profile (generally based on the Shire of Roebourne requirements – 40 year design life) is deemed suitable for this site. The profile consists of:

- Sub-grade compacted to 95% MMDD to a minimum depth of 150mm below the sub-grade surface.
- Sub-base of a minimum 200mm layer of local crusher dust material compacted to 95% MMDD (400mm minimum in Gilgai soils).
- Base-course of a 200mm layer of proprietary produced crushed rock base compacted to 98% MMDD.
- Prime Coat
- Primerseal.
- 25mm dense grade asphalt.

An alternative to 400mm crusher dust material and 200mm base course layer in Gilgai soil is adding a 200mm layer of lime stabilised Gilgai and reducing the crusher dust thickness to 200mm.

It should be noted that the above pavement is applicable for local traffic access roads for a design life of 20 years with the number of Equivalent Standard Axles in one direction of approximately $1.47x10^6$.

8.3.3 Pavement Materials

Pavement materials should conform to the "Guide to the Selection and Use of Naturally Occurring Materials as Base and Sub Base" jointly published by Main Roads Western Australia and Australian Geomechanics Society (2002).

8.3.4 Requirements for Subsoil Drainage

Subsoil drains should be installed near road drainage outlets to provide a flow path for any water trapped in the base course. It is not expected that subsoil drains would be required in other areas of the project.

It is recommended that depressed road drainage systems, successfully used in other areas of Karratha, be adopted for this project

8.3.5 Drainage Considerations

As the sub-grade material is likely to contain more than 20% by weight of soil fractions finer than 0.075mm there is a risk that permeability inversion (a high contrast in permeability between the pavement base coarse and sub-grade) will develop and adversely affect the pavement. However, since the total pavement thickness recommended in Section 8.3.2 is greater than 200mm, no special precautions other than the subsoil drains noted in Section 8.3.4 are required.

8.4 Retention Systems

Earth retaining structures should be designed in accordance with the requirements of AS 4678-2002.

8.4.1 Design Parameters

The soil parameters recommended for the design of the retaining walls are presented in Table 4.

Table 4 - Soil Parameters Recommended for Design of Retaining Walls

Soil Type	Effective Cohesion (c', kPa)	Friction Angle, (ϕ' degrees)	Unit Weight (γ kN/m^3)	Active Pressure K_a	At Rest K_o	Passive Pressure K_p
Cohesionless Structural Fill	-	35	18	0.27	0.43	3.69
Low Plasticity Structural Fill	2	20	18	0.49	0.66	2.04

Key:

c'	denotes effective cohesion (kPa).
Phi'	denotes effective friction angle (degrees)
K_a	fully mobilised coefficient of active earth pressure
K_p	fully mobilised coefficient of passive earth pressure
K_o	at rest earth pressure coefficient

8.5 Earthworks

8.5.1 General

Earthworks should be carried out in accordance with the principles set out in AS3798-2007.

8.5.2 Removal of Topsoil and Uncontrolled Fill

The surface should be stripped of vegetation and grubbed to a depth of nominally 150mm to remove any root mat material. All organic materials and uncontrolled fill, where encountered should be stripped and stockpiled. The organic material is not suitable for use as structural filling. It is only suitable for landscaping purposes.

The site should then be proof compacted as outlined in Section 8.5.3.

It should be noted that ground conditions and particularly groundwater levels may vary with the seasons. As such, site preparation procedures may differ from the above if development proceeds during wet season.

8.5.3 Proof Compaction

Two proof compaction methods have been suggested as outlined below (large scale and individual lot preparation).

It is recommended that either proof compaction method be monitored by an Engineer experienced in earthworks. If proof compaction is to be performed following recent rainfall, the need for proof compaction should be reviewed by a geotechnical engineer.

Large Scale Compaction

After the site has been stripped to the satisfaction of the Supervising Engineer, the site should be proof compacted using a heavy, self-propelled, smooth drum vibrating roller, capable of operating in variable frequency modes. A Dynapac CA 251D, or equivalent, is recommended (subject to the protection of adjacent buildings from damaging ground vibrations).

The following proof compaction procedure is recommended:

- The entire site should be given a minimum of 4 passes with the roller operating in the low frequency/high amplitude mode. A pass should include a minimum overlap of 20%.
- The site should then be given an additional minimum of 4 passes with the roller operating in the high frequency/low amplitude mode.
- All weak areas, which deform excessively under rolling, should be excavated and replaced with approved fill.

Individual Lot Compaction

After the location of each residential site has been stripped to the satisfaction of the Supervising Engineer, the site should be proof compacted using a heavy, vibrating plate compactor. A Dynapac LG300, or equivalent, is recommended (subject to the protection of adjacent buildings from damaging ground vibrations).

The following proof compaction procedure is recommended:

- The entire site should be given a minimum of 4 passes with the compactor.
- All weak areas, which deform excessively under rolling, should be excavated and replaced with clean sand.

It is recommended that the proof compaction be monitored by an Engineer experienced in earthworks.

8.5.4 Temporary Slopes During Earthworks

Excavated slopes should be constructed in accordance with the WA Code of Practice Excavation (2006) and be not steeper than IV:3H (soil) and IV:1.5H (rock).

Fill slopes should not be steeper than IV:3H.

8.5.5 Excavation Characteristics

Excavation characteristics have been assessed based on site observations during fieldwork and experience in similar materials. It is judged that a nominally 20 tonne excavator would be able to excavate most materials to a depth of nominally 2.0m to 3.0m within a majority of the site and a depth of nominally surface to 2.0m in the at the base of the Karratha Hills.

8.5.6 Suitability of Excavated Materials for Use as Fill

Cohesive soils excavated from site may be used as fill provided it is placed and compacted in layers not exceeding 0.25m thickness and compacted in accordance with the requirement outlined in Section 8.5.7. However, this is not recommended due to the difficulty of obtaining and maintaining adequate moisture content. Surface soils that display Gilgai characteristics (see Figure 2) should not be used as structural fill.

The clayey fill should be moisture conditioned to within 2% of optimum moisture content. Placement of cohesive fill should be relatively continuous. If a break of longer than say 2 hours occurs, the exposed surface should be moisture conditioned prior to the placement of further fill.

Topsoil may be used as fill in landscape areas but should not be used as structural fill

8.5.7 Compaction Requirements

Earthworks should be compacted to achieve the density requirements set out in Table 5.

Table 5 - Compaction Requirements

Item	**Application**	**Compaction Criteria**	
		Minimum density ratio (Cohesive soils) (See Note 1)	**Minimum density index (Cohesionless soils)**
1	Residential – lot fill, house sites	95% std	65%
2	Commercial – fills to support minor loadings, including floor loadings of up to 20 kPa and isolated pad or strip footings to 100 kPa	98% std	70%

Notes

1. Nuclear Density Meter tests and Laboratory Compaction tests should be performed (on a one to one ratio), to ensure cohesive fill is adequately compacted
2. Gilgai soils should not be compacted any more than 95% of the standard MDD. Compaction above 95% may result in increased soil movement due to moisture changes.

8.5.8 Cohesionless Structural Filling

For this study, cohesionless structural fill has been defined as fill satisfying the following criteria:

- Containing less than 5% by weight of soil fractions finer than 0.075mm.
- Having a plasticity index equal to 0%, (i.e. non plastic).
- The sand shall be clean, cohesionless, free draining and free of all silty, organic or any other deleterious inclusions.
- A minimum soaked CBR of 12 if used as pavement subgrade.

It is recommended that a 25 kg representative sample of the proposed structural fill be delivered to a NATA registered soils laboratory for testing at least one week before approval is required.

8.5.9 Low Plasticity Structural Fill

For this study, low plasticity structural fill has been defined as fill satisfying the following criteria:

- Containing less than 20% by weight of soil fraction finer than 0.075mm,
- Having a Liquid Limit of less than 15%,
- The fill shall be clean and free of all organic or any other deleterious inclusions.

8.6 Construction Considerations

8.6.1 General

There are a number of activities that must be undertaken during construction to ensure compliance with design and to ensure the smooth running of the project. The following activities should be carried out during the contract.

8.6.2 Site Drainage and Erosion Control

Runoff from upslope of the site should be collected and diverted away from the structures. The finished surface level of the site should be graded with falls away from the structures and their foundations. This will minimise the incidence of water ponding around the footings.

A minimum fall of 2% is recommended.

Erosion control measures as set out in the "Erosion and Sediment Control Manual for the Darling Range, Perth Western Australia (2002)" should be adopted.

8.6.3 Preparation of Footing Bases in Low Plasticity Structural Fill

For this study, low plasticity sand fill has been defined as fill satisfying the following criteria:

- Containing less than 20% by weight of soil fraction finer than 0.075mm
- Having a Liquid Limit of less than 15%,
- The material shall be clean and free of all organic or any other deleterious inclusions.

All material disturbed in the bases of footing excavations should be compacted. Any uncontrolled fill must be excavated and replaced.

To facilitate compaction, the groundwater should not be any closer than 1m to the base of the footing excavation.

8.6.4 Preparation of Footing Bases in Cohesive Soils

The clayey soils are sensitive to trafficking and will lose a significant proportion of their design strength if they are disturbed and remoulded. Excavation techniques involving minimal trafficking and the use of light equipment for final trimming are recommended for these soil types. Any uncontrolled fill must be excavated and replaced with fill as described in Section 8.5.8 and 8.5.9.

Excavations for footings should be to the neat dimensions of the footing, with footings poured against the sides of the excavation. The use of framework and backfilling around footings is not recommended for structures founded in cohesive soils.

It is recommended that in situ strength testing including pocket penetrometer and shear vane testing be carried out in the cohesive soils exposed in the bases of the footing excavations to check that no disturbed soils are present.

A minimum of 6 tests are recommended for each footing base. The tests should be carried out by a Geotechnical Engineer.

The minimum result from the pocket penetrometer should be 100 kPa.

The bases of footing excavations in cohesive soils should be blinded as soon as practically possible after their testing and approval. A minimum thickness of 50mm of lean mix concrete (min. F'_c = 10 MPa) would suffice. Under no circumstances should the bases of excavations be left exposed overnight.

It is important that the exposure of the clays to climatic drying/wetting be minimised to avoid significant moisture content changes and subsequent foundation movements during moisture equilibration. Otherwise, foundation movements will be greater than allowed for in design.

9 IMPORTANT INFORMATION ABOUT YOUR COFFEY REPORT

The reader's attention is drawn to the important information about this report which follows the main text.

10 REFERENCES

The following standards and references were used in the preparation of this report.

AS 1289 Method of Testing Soils For Engineering Purposes.

AS 1726-1993 SAA Geotechnical Site Investigations.

AS 2870-1996 Residential Slabs and Footings.

AS 3798-2007 Guidelines on Earthworks for Commercial and Residential Developments

AS 4678-2002 Earth Retaining Structures

Institute of Public Works Engineering Australia : Western Australia Division (2006). "Policy Note: Pavement Profiles in Residential Streets".

Kay J N (1990) "Use of the Liquid Limit for Characterisation of Expansive Soil Sites" CE 32 N0 3 IE Aust

Main Roads Western Australia (1998)"Procedure for Thickness Design of Flexible Pavements". Engineering Road Note No. 9 (1988),

Main Roads Western Australia and Australian Geomechanics Society (2002) " A Guide to the Selection and Use of Naturally Occurring Materials as Base and Sub Base in Roads in Western Australia"

NAVFAC (1975) "Soil Mechanics Manual".

WA Code of Practice Excavation (2006)

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Important information about your **Coffey** Report

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.
Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

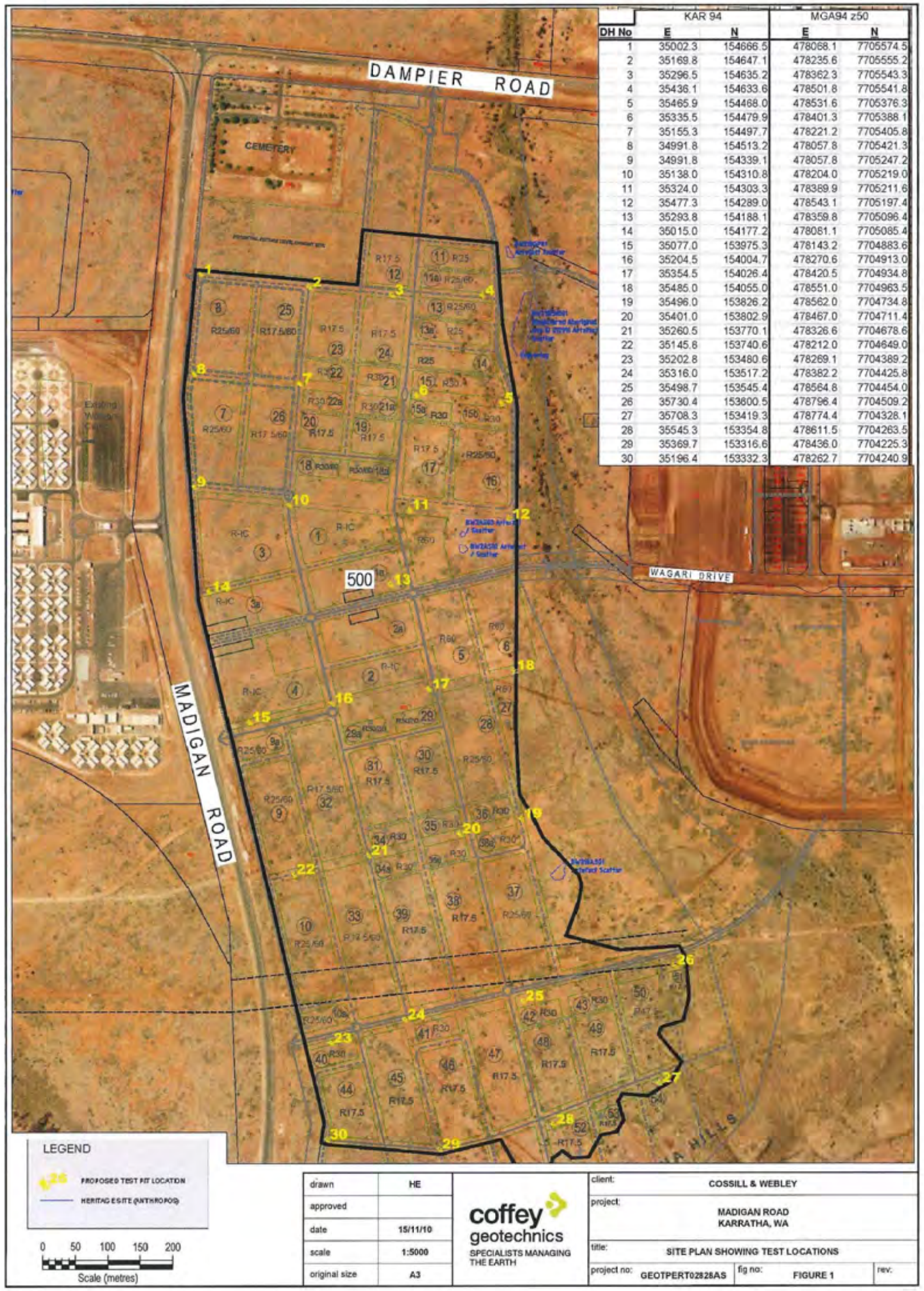
Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

---

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Figures



	KAR 94		MGA94 z50	
DH No	E	N	E	N
1	35002.3	154666.5	478068.1	7705574.5
2	35169.8	154647.1	478235.6	7705555.2
3	35296.5	154635.2	478362.3	7705543.3
4	35436.1	154633.6	478501.8	7705541.8
5	35465.9	154468.0	478531.6	7705376.3
6	35335.5	154479.9	478401.3	7705388.1
7	35155.3	154497.7	478221.2	7705405.8
8	34991.8	154513.2	478057.8	7705421.3
9	34991.8	154339.1	478057.8	7705247.2
10	35138.0	154310.8	478204.0	7705219.0
11	35324.0	154303.3	478389.9	7705211.6
12	35477.3	154289.0	478543.1	7705197.4
13	35293.8	154188.1	478359.8	7705096.4
14	35015.0	154177.2	478081.1	7705085.4
15	35077.0	153975.3	478143.2	7704883.6
16	35204.5	154004.7	478270.6	7704913.0
17	35354.5	154026.4	478420.5	7704934.8
18	35485.0	154055.0	478551.0	7704963.5
19	35496.0	153826.2	478562.0	7704734.8
20	35401.0	153802.9	478467.0	7704711.4
21	35260.5	153770.1	478326.6	7704678.6
22	35145.8	153740.6	478212.0	7704649.0
23	35202.8	153480.6	478269.1	7704389.2
24	35316.0	153517.2	478382.2	7704425.8
25	35498.7	153545.4	478564.8	7704454.0
26	35730.4	153600.5	478796.4	7704509.2
27	35708.3	153419.3	478774.4	7704328.1
28	35545.3	153354.8	478611.5	7704263.5
29	35369.7	153316.6	478436.0	7704225.3
30	35196.4	153332.3	478262.7	7704240.9

drawn	HE
approved	
date	15/11/10
scale	1:5000
original size	A3

coffey
geotechnics
SPECIALISTS MANAGING THE EARTH

client: COSSILL & WEBLEY

project: MADIGAN ROAD
KARRATHA, WA

title: SITE PLAN SHOWING TEST LOCATIONS

project no: GEOTPERT02828AS fig no: FIGURE 1 rev:

EXAMPLE OF GILGAI SOILS

drawn HE
approved
date 15/11/10
scale NOT TO SCALE
original size A4

coffey
geotechnics
SPECIALISTS MANAGING
THE EARTH

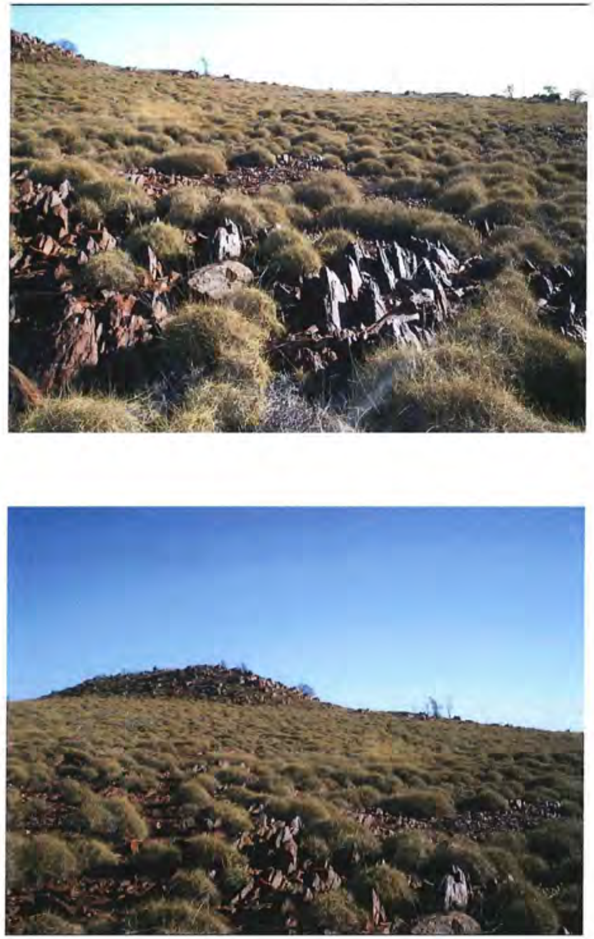
client: **COSSILL & WEBLEY CONSULTING ENGINEERS**
project: **MADIGAN ROAD DEVELOPMENT SITE**
MADIGAN ROAD, KARRATHA
title: **EXAMPLE OF GILGAI SOILS**
project no: **GEOTPERT02828AS** fig no: **FIGURE 2** rev:

DWG: F:\GEOTPERT\[illegible]\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GP02828AS Figure PHOTOS.dwg

LOCALISED ROCK OUTCROPS WITHIN THE SITE

drawn	HE	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	15/11/10			
scale	NOT TO SCALE		title:	LOCALISED ROCK OUTCROPS WITHIN THE SITE
original size	A4		project no:	GEOTPERT02828AS fig no: FIGURE 3 rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GP02828AS Figure PHOTOS.dwg



SURFICIAL ROCK AT THE BASE OF KARRATHA HILLS

drawn	HE	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	15/11/10					
scale	NOT TO SCALE		title:	SURFICIAL ROCK AT THE BASE OF KARRATHA HILLS		
original size	A4		project no:	GEOTPERT02828AS	fig no: FIGURE 4	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GP02828AS Figure PHOTOS.dwg

Appendix A

Results of Field Investigation

Soil Description Explanation Sheet (1 of 2)

DEFINITION:

In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH s_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	-	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: <5% Fine grained soils: <15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 - 12% Fine grained soils: 15 - 30%

SOIL STRUCTURE

ZONING		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

coffey

Soil Description Explanation Sheet (2 of 2)

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

<table>
<tr><th colspan="7">FIELD IDENTIFICATION PROCEDURES
(Excluding particles larger than 60 mm and basing fractions on estimated mass)</th><th>USC</th><th>PRIMARY NAME</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm</td><td rowspan="16">(A 0.075 mm particle is about the smallest particle visible to the naked eye)</td><td rowspan="4">GRAVELS More than half of coarse fraction is larger than 2.0 mm</td><td rowspan="2">CLEAN GRAVELS (Little or no fines)</td><td colspan="3">Wide range in grain size and substantial amounts of all intermediate particle sizes.</td><td>GW</td><td>GRAVEL</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with more intermediate sizes missing.</td><td>GP</td><td>GRAVEL</td></tr>
<tr><td rowspan="2">GRAVELS WITH FINES (Appreciable amount of fines)</td><td colspan="3">Non-plastic fines (for identification procedures see ML below)</td><td>GM</td><td>SILTY GRAVEL</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures see CL below)</td><td>GC</td><td>CLAYEY GRAVEL</td></tr>
<tr><td rowspan="4">SANDS More than half of coarse fraction is smaller than 2.0 mm</td><td rowspan="2">CLEAN SANDS (Little or no fines)</td><td colspan="3">Wide range in grain sizes and substantial amounts of all intermediate sizes</td><td>SW</td><td>SAND</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with some intermediate sizes missing.</td><td>SP</td><td>SAND</td></tr>
<tr><td rowspan="2">SANDS WITH FINES (Appreciable amount of fines)</td><td colspan="3">Non-plastic fines (for identification procedures see ML below).</td><td>SM</td><td>SILTY SAND</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures see CL below).</td><td>SC</td><td>CLAYEY SAND</td></tr>
<tr><td rowspan="8">FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm</td><td colspan="2" rowspan="2"></td><td colspan="3">IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.</td><td></td><td></td></tr>
<tr><td>DRY STRENGTH</td><td>DILATANCY</td><td>TOUGHNESS</td><td></td><td></td></tr>
<tr><td colspan="2" rowspan="3">SILTS & CLAYS Liquid limit less than 50</td><td>None to Low</td><td>Quick to slow</td><td>None</td><td>ML</td><td>SILT</td></tr>
<tr><td>Medium to High</td><td>None</td><td>Medium</td><td>CL</td><td>CLAY</td></tr>
<tr><td>Low to medium</td><td>Slow to very slow</td><td>Low</td><td>OL</td><td>ORGANIC SILT</td></tr>
<tr><td colspan="2" rowspan="3">SILTS & CLAYS Liquid limit greater than 50</td><td>Low to medium</td><td>Slow to very slow</td><td>Low to medium</td><td>MH</td><td>SILT</td></tr>
<tr><td>High</td><td>None</td><td>High</td><td>CH</td><td>CLAY</td></tr>
<tr><td>Medium to High</td><td>None</td><td>Low to medium</td><td>OH</td><td>ORGANIC CLAY</td></tr>
<tr><td colspan="4">HIGHLY ORGANIC SOILS</td><td colspan="3">Readily identified by colour, odour, spongy feel and frequently by fibrous texture.</td><td>Pt</td><td>PEAT</td></tr>
<tr><td colspan="9">• Low plasticity – Liquid Limit W_L less than 35%. • Medium plasticity – W_L between 35% and 50%.</td></tr>
</table>

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	A surface or crack across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	DEFINITION	DIAGRAM
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.	

coffey geotechnics

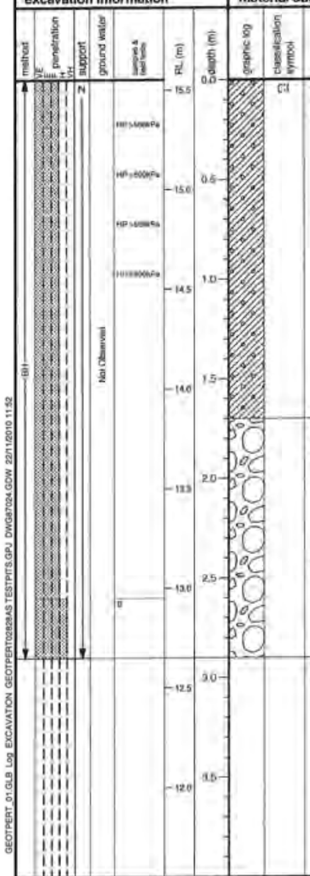
Engineering Log - Excavation

Excavation No. **TP01**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **19/10/10**
Date completed **19/10/10**
Logged by **PCW**
Checked by :

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 476078.1, N: 7705574.5 (50 MGA94)
Surface Elevation : 15.55m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.10m long 2.10m wide

excavation information | **material substance**

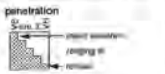


material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
GRAVELLY CLAY, medium plasticity, brown red; gravel, fine to coarse grained, sub-angular, friable; with some sand, coarse grained	D		X X X X	Sub-angular to sub-rounded gravel at ground surface, fine to coarse grained
...0.6m, becoming clayey gravel.				
Grading into				
WEATHERED ROCK, fine grained; residual soil to highly weathered; rock is highly fractured; low to very low strength	D			
...2.3m, rock fragments becoming low to medium strength				
EXCAVATION TP01 TERMINATED AT 2.90 m				

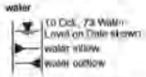
method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration



water



samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP02**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478235.6, N: 7705555.2 (50 MGA94)
Surface Elevation : 15.95m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.20m long 0.70m wide

excavation information

method	support	ground water	samples & field tests	RL (m)	depth (m)
BH (0.0–2.20)	N	Not Observed	HP >600kPa		0.0
			HP >600kPa	15.5	0.5
			B HP >600kPa		
			HP >600kPa	15.0	1.0
				14.5	1.5
				14.0	2.0
				13.5	2.5
				13.0	3.0
				12.5	3.5
				12.0	

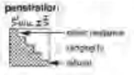
material substance

classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa	structure and other observations
CI	**SANDY CLAY**, medium plasticity, brown; sand, fine to coarse grained; trace of gravel, fine to medium grained	D	H	✕ ✕	Trace rootlets in first 300mm
CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled pale brown; gravel, fine to medium grained Grading into	D	H	✕ ✕	
	WEATHERED ROCK, fine grained; highly weathered; rock is highly fractured; some medium to high strength clasts within layer				
	Refusal on weathered rock EXCAVATION TP02 TERMINATED AT 2.20 m				

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration



water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Excavation No. **TP03**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478362.3, N: 7705543.3 (50 MGA94)
Equipment type : Backhoe
Surface Elevation : 15.44m (AHD)
Method :
Excavation dimensions :

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa	structure and other observations
BH		N	Not Observed	HP>400kPa		0.0	▨	CH	**CLAY**, high plasticity, brown / dark brown; with some sand, medium to coarse grained	D	H	×	
				HP>400kPa	15.0	0.5			....0.5m, trace gravel			×	
				HP>400kPa					....0.8m, gravel content increasing	D		×	
				HP>400kPa B	14.5	1.0		GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, brown; clay, high plasticity	D		×	
					14.0	1.5							
					13.5	2.0			**WEATHERED ROCK**, fine grained; residual soil to moderately weathered, rock is highly fractured, grey/white, recovered as soil/gravel/cobbles	D			
					13.0	2.5			Refusal on weathered rock EXCAVATION TP03 TERMINATED AT 2.50 m				
					12.5	3.0							
					12.0	3.5							
					11.5								

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

no resistance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP04**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**19/10/10**
Date completed	**19/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**

Principal

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478501.8, N: 7705541.8 (50 MGA94)   Surface Elevation : 15.6m (AHD)

Equipment type : Backhoe   Method :   Excavation dimensions : 4.80m long 0.70m wide

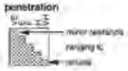
excavation information — method: BH (0.0 to 2.5 m); support: N; ground water: Not Observed

samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE: Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
HP>600kPa HP>600kPa HP>600kPa	15.5 15.0	0.0 0.5	CI	**CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained 0.5m, trace gravel	D	H	× × ×	Trace rootlets in top 300mm
HP>600kPa	14.5	1.0	GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown; gravel, fine to coarse grained Grading into	D - M	H	×	
	14.0 13.5	1.5 2.0		**WEATHERED ROCK**, fine grained; residual soil to highly weathered, dark grey/green; localised pockets of gravelly clay				
	13.0 12.5 12.0	2.5 3.0 3.5		Refusal on weathered rock EXCAVATION TP04 TERMINATED AT 2.50 m				

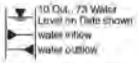
method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration



water



samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	TP05
Sheet No.	1 of 1
Project No.	GEOTPERT02828AS
Date excavated	19/10/10
Date completed	19/10/10
Logged by	PCW
Checked by	

Client : **Cossill & Webley Consulting Engineers**

Principal :

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478531.6, N: 7705376.3 (50 MGA94) Surface Elevation : 16.31m (AHD)

Equipment type : Backhoe Method :

Excavation dimensions : 5.20m long 0.70m wide

method	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	structure and other observations
BH	N	Not Observed			0.0	CI	**CLAY / SANDY CLAY**, medium plasticity, brown; friable; with some sand; trace of gravel, fine grained	D	H	Rootlets/tree roots in top 0.3m
			HP >600kPa	16.0						
			HP >600kPa		0.5		....0.4m, trace of gravel, fine to coarse grained			
			HP >600kPa	15.5		GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown; gravel, fine to coarse grained	D	H	
			HP >600kPa		1.0					
							Grading into			
			B	15.0			**WEATHERED ROCK**, fine grained, grey cream; residual soil to highly weathered; localised areas of gravelly clay/clayey gravel; cobbles typically low to very low strength	D		
					1.5					
				14.5	2.0					
				14.0	2.5					
				13.5						
					3.0		Test depth reached EXCAVATION TP05 TERMINATED AT 2.90 m			
				13.0	3.5					
				12.5						

hand penetrometer kPa: 100 200 300 400

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

no resistance ranging to refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	TP06
Sheet No.	1 of 1
Project No.	GEOTPERT02828AS
Date excavated	19/10/10
Date completed	19/10/10
Logged by :	PCW
Checked by :	

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478401.3, N: 7705388.1 (50 MGA94)
Surface Elevation : 16.27m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.30m long 0.70m wide

method	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	structure and other observations
BH	N	Not Observed			0.0	CI	**CLAY / SANDY CLAY**, medium plasticity, brown; friable, with some sand, fine to coarse grained	D	H	Up to 0.4m trace of roots
			HP >600kPa	16.0						
			HP >600kPa		0.5		0.4m, with some gravel			
			HP >600kPa	15.5		GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled cream grey; gravel, sub-angular, , trace of cobbles	D	H	
			HP >600kPa		1.0					
				15.0						
					1.5					
				14.5						
					2.0		Grading into			
							WEATHERED ROCK, fine grained, grey cream; residual soil to moderately weathered; localised areas of clayey gravel			
			D	14.0						
					2.5		Refusal on weathered rock EXCAVATION TP06 TERMINATED AT 2.50 m			
				13.5						
					3.0					
				13.0						
					3.5					
				12.5						

hand penetrometer kPa: 100 200 300 400

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
no resistance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_p - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Excavation No. **TP07**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478221.2, N: 7705405.8 (50 MGA94)
Surface Elevation : 16.06m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.70m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observation
BH		N	Not Observed		16.0	0.0		CI	**CLAY**, medium plasticity, brown; friable; trace of sand, fine to coarse grained, trace of gravel, fine to medium grained	D	H		Trace of rootlets in top 0.3m
				HP>600kPa								✕	
				HP>600kPa	15.5	0.5						✕	
								GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled grey/off white; gravel, fine to coarse grained, angular; trace of cobbles	D	H		
				HP>600kPa								✕	
				HP>600kPa	15.0	1.0						✕	
									...becoming clayey cobbles				
					14.5	1.5			Refusal weathered rock, hard digging EXCAVATION TP07 TERMINATED AT 1.50 m				
					14.0	2.0							
					13.5	2.5							
					13.0	3.0							
					12.5	3.5							

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:53

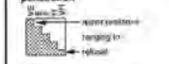
method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration



water

samples & field tests

U50	- Undisturbed Sample 50mm diameter
U63	- Undisturbed Sample 63mm diameter
D	- Disturbed Sample
B	- Bulk Disturbed Sample
ES	- Environmental Sample
MC	- Moisture Content
HP	- Hand Penetrometer (UCS kPa)
VS	- Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT	- Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture

D	- Dry
M	- Moist
W	- Wet
W_P	- Plastic Limit
W_L	- Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Excavation No. **TP08**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478067.8, N: 7705421.3 (50 MGA94)
Surface Elevation : 15.93m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.60m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE: Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structures and other observations
BH		N	Not Observed			0.0		GC	**CLAYEY GRAVEL / CLAYEY COBBLES** fine to coarse grained, brown mottled grey/off white; friable; clay, medium plasticity; cobbles are fine to medium grained; trace rootlets in top 0.3m	D	H	×	
				HP >600kPa								×	
				HP >600kPa	15.5	0.5			....0.5m, cobbles increasing				
				HP >600kPa								×	
				HP >600kPa	15.0	1.0						×	
					14.5	1.5							
				B									
									Refusal on cemented layer EXCAVATION TP08 TERMINATED AT 1.70 m				
					14.0	2.0							
					13.5	2.5							
					13.0	3.0							
					12.5	3.5							
					12.0								

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
VE E M H VH
minor resistance
ranging to
refusal

water
▼ 10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP09**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**19/10/10**
Date completed	**19/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**

Principal :

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478067.8, N: 7705247.2 (50 MGA94)
Surface Elevation : 16.28m (AHD)
Excavation dimensions :

Equipment type : Backhoe
Method :

method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer kPa	structure and other observation
BH		N	Not Observed			0.0	▨	CI	**CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained	D	H		
				HP >600kPa	16.0							×	
				HP>600kPa		0.5			...0.6m, trace gravels increasing with depth			×	
				HP >600kPa	15.5							×	
				HP>600kPa		1.0						×	
					15.0			GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY** fine to coarse grained, clay, medium plasticity	D	H		
						1.5							
					14.5								
						2.0			Refusal on cemented layer, hard digging EXCAVATION TP09 TERMINATED AT 1.88 m				
					14.0								
						2.5							
					13.5								
						3.0							
					13.0								
						3.5							
					12.5								

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
- VE L M H VH
- no resistance
- ranging to
- refusal

water
- 10 Oct. 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP10**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478204, N: 7705219 (50 MGA94)
Surface Elevation : 16.78m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.80m long 0.70m wide

excavation information

method	support	ground water	samples & field tests	RL (m)	depth (m)
BH (0.0–2.4 m)	N	Not Observed			0.0
			HP >600kPa	16.5	
			HP >600kPa		0.5
			HP >600kPa	16.0	
			HP >600kPa		1.0
				15.5	
					1.5
				15.0	
					2.0
			ROCK SAMPLE	14.5	
					2.5
				14.0	
					3.0
				13.5	
					3.5
				13.0	

material substance

classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
CI	**CLAY**, medium plasticity, brown; friable; trace of sand, fine to coarse grained; trace of gravel, fine grained; trace rootlets in top 300mm	D	H	× × × ×	
GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, brown mottled cream/grey: clay, medium to high plasticity Grading info	D	H		
	WEATHERED ROCK, fine grained, grey/green; residual soil to moderately weathered; highly fractured	D			
	Refusal, hard digging EXCAVATION TP10 TERMINATED AT 2.40 m				

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
easy resistance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_p - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP11**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478389.9, N: 7705211.6 (50 MGA94)
Surface Elevation : 16.95m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.60m long 0.70m wide

excavation information / material substance

method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description SOIL TYPE: Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed			0.0	CI	**CLAY**, medium plasticity, brown; friable; trace of gravel; trace of rootlets in top 300mm	D	H		
				[illegible]							×	
				[illegible]	16.5	0.5					×	
				[illegible]			CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled off white; gravel, fine to coarse grained, sub-angular	D	H	×	
				[illegible]	16.0	1.0					×	
					15.5	1.5		Grading into				
					15.0	2.0		**WEATHERED ROCK**, residual soil to highly weathered; rock is extremely low to medium strength, pale grey/dark grey, residual soil is low plasticity clayey sand	D	H		
					14.5	2.5						
					14.0	3.0		Test depth reached EXCAVATION TP11 TERMINATED AT 3.00 m				
					13.5	3.5						
					13.0							

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

no resistance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP12*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

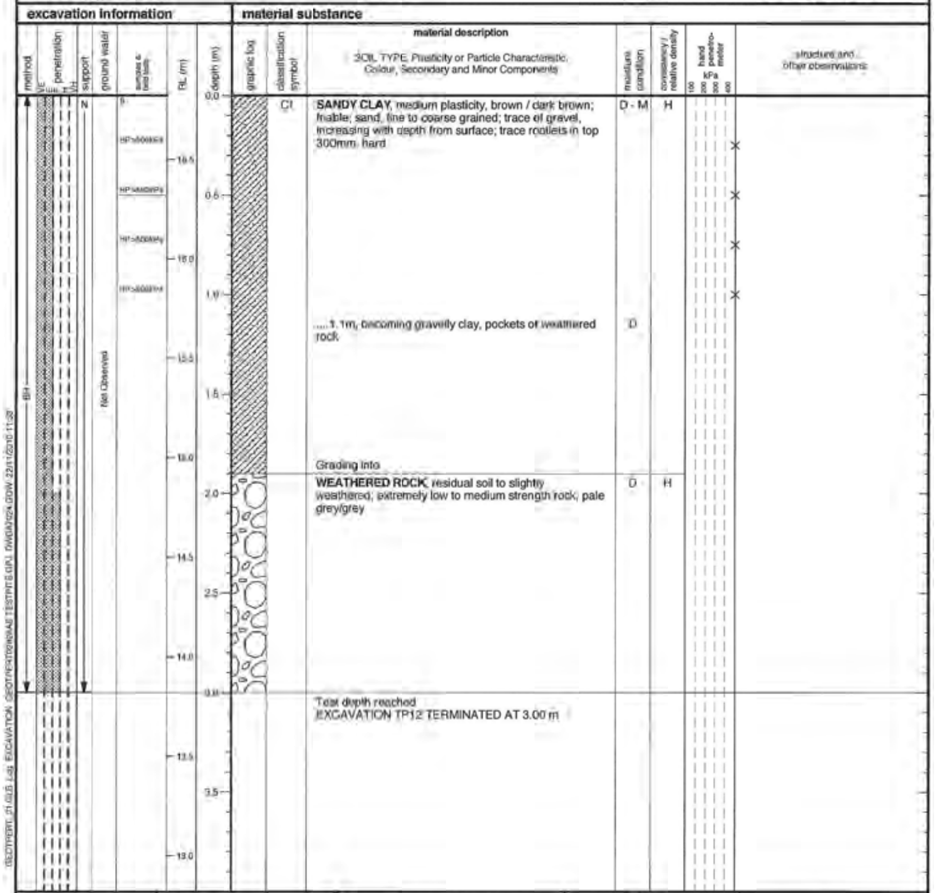
Position : E: 478543.1, N: 7705197.4 (50 MGA94)

Surface Elevation : 16.82m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.20m long 0.70m wide



depth (m)	RL (m)	samples & field tests	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density
0.0		D	CI	**SANDY CLAY**, medium plasticity, brown / dark brown; friable; sand, fine to coarse grained; trace of gravel, increasing with depth from surface; trace rootlets in top 300mm; hard	D - M	H
		HP>600kPa				
	16.5					
0.5		HP>600kPa				
		HP>600kPa				
	16.0					
1.0		HP>600kPa				
				....1.1m, becoming gravelly clay, pockets of weathered rock	D	
	15.5					
1.5						
	15.0			Grading into		
				WEATHERED ROCK, residual soil to slightly weathered; extremely low to medium strength rock; pale grey/grey	D	H
2.0						
	14.5					
2.5						
	14.0					
3.0				Total depth reached EXCAVATION TP12 TERMINATED AT 3.00 m		
	13.5					
3.5						
	13.0					

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

VE E H VH

minor resistance

ranging to

refusal

water

▼ 10 Oct., 73 Water Level on Date shown

► water inflow

◄ water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_p - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No	**TP13**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**20/10/10**
Date completed	**20/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478359.8, N: 7705096.4 (50 MGA94)
Surface Elevation : 17.56m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.60m long 0.70m wide

excavation information / material substance

method	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	structure and other observations
BH	N	Not Observed	B	17.5	0.0	CI	**GRAVEL /CLAYEY GRAVEL**, fine to coarse grained, brown mottled pale yellow white; medium plasticity; friable	D	H	
			HP>600kPa							
			HP>600kPa	17.0	0.5		...0.5m, trace cobbles, becoming clayey gravel			
			HP>600kPa							
			HP>600kPa	16.5	1.0					
							Grading into			
				16.0	1.5		**WEATHERED ROCK**, fine grained; residual soil is slightly weathered, highly fractured, pale grey/green	D	H	
				15.5	2.0					
							Refusal on weathered rock EXCAVATION TP13 TERMINATED AT 2.30 m			
				15.0	2.5					
				14.5	3.0					
				14.0	3.5					

hand penetrometer kPa: 100 200 300 400

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
- no resistance ranging to refusal

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_p - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	***TP14***
Sheet No.	1 of 1
Project No.	***GEOTPERT02828AS***
Date excavated	***20/10/10***
Date completed	***20/10/10***
Logged by :	***PCW***
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Position : E: 478091.1, N: 7705085.4 (50 MGA94)
Surface Elevation : 16.69m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.80m long 0.70m wide

excavation information / **material substance**

method	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH	N	Not Observed			0.0	CI	**CLAY**, medium plasticity, brown / dark brown; friable; with some gravel, fine to medium grained; trace rootlets in top 300mm		H		
			HP >600kPa	16.5						×	
							...0.3m, trace cobbles				
			HP >600kPa		0.5		...0.5m, becoming clayey gravel, medium plasticity; gravel is fine to coarse grained; with some cobbles, brown/dark brown mottled off white			×	
			HP >600kPa	16.0						×	
			HP >600kPa B		1.0	GC	**CLAYEY GRAVEL**, fine to coarse grained, brown mottled off white; clay, medium plasticity; gravel and cobble content increasing with depth	D	H	×	
				15.5							
					1.5						
				15.0			Refusal on cemented gravel layer, hard digging EXCAVATION TP14 TERMINATED AT 1.70 m				
					2.0						
				14.5							
					2.5						
				14.0							
					3.0						
				13.5							
					3.5						
				13.0							

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
1 2 3 4
no resistance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_p - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP15**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478143.2, N: 7704883.6 (50 MGA94)
Surface Elevation : 17.7m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.80m long 0.70m wide

excavation information

method: BH
support: N
ground water: Not Observed

material substance

depth (m)	RL (m)	samples & field tests	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density
0.0			CI	**SANDY CLAY**, medium plasticity, brown / dark brown; trace of gravel, fine grained; trace rootlets in top 300mm	D	H
	17.5	HP>600kPa				
0.5		HP>600kPa				
	17.0	HP>600kPa				
		B	CL-CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, low to medium plasticity, gravel, fine to coarse grained		
		HP>600kPa			D	H
1.0						
	16.5					
1.5						
	16.0					
				1.8m, grading into rock, moderately weathered to residual soil, pale grey		
2.0						
	15.5			**WEATHERED ROCK**, fine grained, pale grey; residual soil to moderately weathered, cobbles up to moderate strength	D	H
2.5						
	15.0					
3.0				Test depth reached EXCAVATION TP15 TERMINATED AT 3.00 m		
	14.5					
3.5						
	14.0					

hand penetrometer kPa: 100 200 300 400

structure and other observations

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
- [illegible]
- ranging to
- refusal

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	TP16
Sheet No.	1 of 1
Project No.	GEOTPERT02828AS
Date excavated	20/10/10
Date completed	20/10/10
Logged by :	PCW
Checked by :	

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478270.6, N: 7704913 (50 MGA94)
Surface Elevation : 18.02m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.60m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed		18.0	0.0		CI	**GRAVELLY CLAY**, medium plasticity, brown mottled off white; gravel, fine to medium grained; friable; trace rootlets and tree roots in top 0.4m, gravel content increasing with depth	D	H		
				HP >600kPa								×	
				HP >600kPa	17.5	0.5						×	
								GC	**CLAYEY GRAVEL**, fine to coarse grained, brown mottled off white, clay, medium plasticity; gravel is typically granite	D	H		
				HP >600kPa								×	
				HP >600kPa	17.0	1.0						×	
									WEATHERED ROCK, fine grained, pale grey green; residual soil to moderately weathered, rock strength is extremely low to medium, recovered as cobbles	D			
					16.5	1.5							
					16.0	2.0			Refusal on weathered rock, hard digging EXCAVATION TP16 TERMINATED AT 2.00 m				
					15.5	2.5							
					15.0	3.0							
					14.5	3.5							

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP17**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**20/10/10**
Date completed	**20/10/10**
Logged by	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**

Principal :

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478420.5, N: 7704934.8 (50 MGA94)

Surface Elevation : 18.29m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.30m long 0.70m wide

excavation information | **material substance**

method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	S	18.29	0.0		CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown / dark brown; gravel, fine to coarse grained; friable; trace of cobbles, fine grained	D	H		
				HP>500kPa	18.0							×	
				HP>500kPa		0.5						×	
				HP>500kPa	17.5							×	
				HP>500kPa		1.0						×	
								GC	**CLAYEY GRAVEL / CLAYEY COBBLES** fine to coarse grained, cobbles are fine to medium grained, brown mottled off white/grey	D	H		
					17.0								
						1.5							
					16.5								
						2.0			Refusal on weathered rock/quartz layer EXCAVATION TP17 TERMINATED AT 2.00 m				
					16.0								
						2.5							
					15.5								
						3.0							
					15.0								
						3.5							
					14.5								

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_p - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

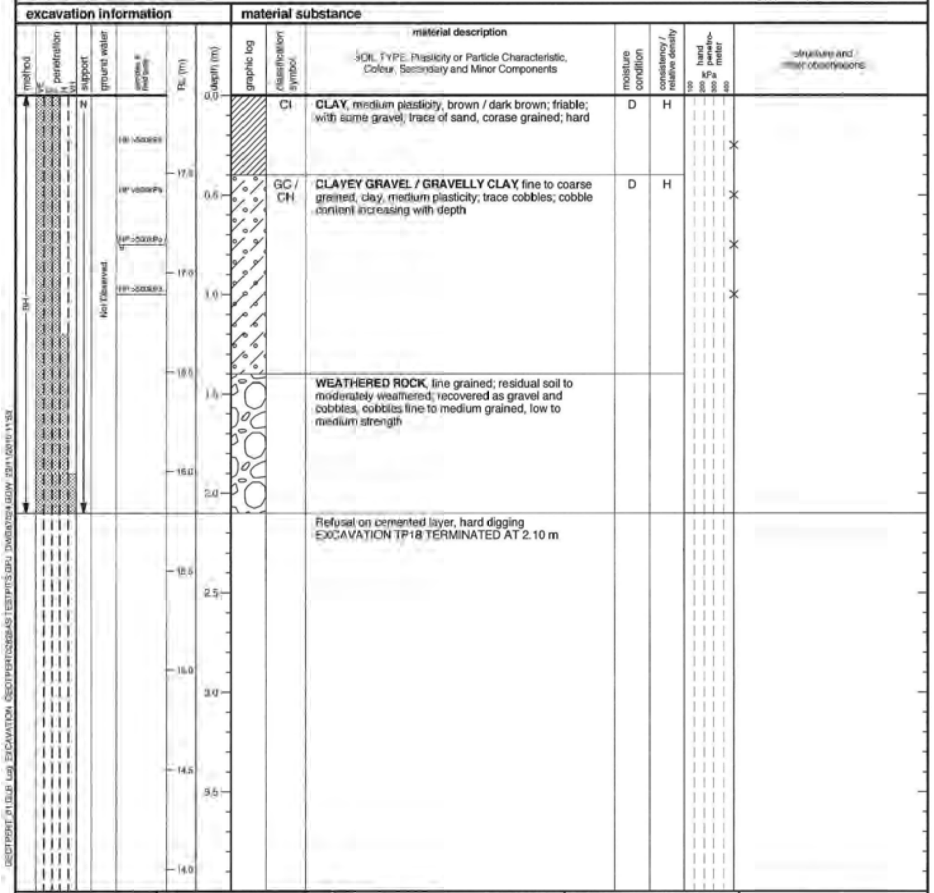
Engineering Log - Excavation

Excavation No. **TP18**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478551, N: 7704963.5 (50 MGA94)
Surface Elevation : 17.89m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.70m long 0.70m wide



classification symbol	material description SOIL TYPE: Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density
CI	**CLAY**, medium plasticity, brown / dark brown; friable; with some gravel; trace of sand, corase grained; hard	D	H
GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, clay, medium plasticity; trace cobbles; cobble content increasing with depth	D	H
	WEATHERED ROCK, fine grained; residual soil to moderately weathered; recovered as gravel and cobbles, cobbles fine to medium grained, low to medium strength		
	Refusal on cemented layer, hard digging EXCAVATION TP18 TERMINATED AT 2.10 m		

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
minor resistance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP19*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478562, N: 7704734.8 (50 MGA94)

Surface Elevation : 19.5m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 5.00m long 0.70m wide

excavation information							material substance						
method	penetration VE E M H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed		19.5	0.0		SC	**CLAYEY SAND**, medium plasticity, brown / dark brown; clay, friable, with some gravel, fine to medium grained	D	H		
				HP >600kPa								×	
				D HP >600kPa	19.0	0.5		GP	**SANDY GRAVEL**, fine to medium grained, pale brown / brown, with some fines, low to medium plasticity; strongly cemented, trace of quartz flakes	D	VD	×	
				HP >600kPa								×	
				HP >600kPa	18.5	1.0						×	
									....1.2m, becoming highly weathered rock, recovered as residual soil/cobbles				
					18.0	1.5							
							Qz		**WEATHERED ROCK**, fine grained; residual soil to slightly weathered, low to high strength, brown/white/grey	D			
					17.5	2.0	Qz						
					17.0	2.5	Qz						
									Refusal on weathered rock, hard digging EXCAVATION TP19 TERMINATED AT 2.60 m				
					16.5	3.0							
					16.0	3.5							

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
minor resistance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP20**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478467, N: 7704711.4 (50 MGA94)
Surface Elevation : 19.76m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 5.00m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE: Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
B		N	Not Observed	HP [illegible] HP [illegible] HP [illegible] HP [illegible]	19.5 19.0	0.0 0.5	▨	CI	**CLAY**, medium plasticity, brown / dark brown; friable; trace of gravel and rootlets in top 0.3m; gravel content increasing with depth	D	H	× × × ×	
					18.5	1.0			**WEATHERED ROCK**, fine grained; residual soil to highly weathered, grey/pale grey/brown; rock is extremely low to medium strength				
					18.0 17.5 17.0 16.5 16.0	1.5 2.0 2.5 3.0 3.5			Refusal on weathered rock layer EXCAVATION TP20 TERMINATED AT 1.40 m				

GEOTPERT_01 GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWGATGW.GDW 23/11/2010 11:56

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
VE E H VH
no resistance
ranging to
refusal

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests

U50	-	Undisturbed Sample 50mm diameter
U63	-	Undisturbed Sample 63mm diameter
D	-	Disturbed Sample
B	-	Bulk Disturbed Sample
ES	-	Environmental Sample
MC	-	Moisture Content
HP	-	Hand Penetrometer (UCS kPa)
VS	-	Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT	-	Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP21**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**20/10/10**
Date completed	**20/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478326.6, N: 7704678.6 (50 MGA94)
Equipment type : Backhoe
Surface Elevation : 19.66m (AHD)
Method :
Excavation dimensions : 4.70m long 0.70m wide

method	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH	N	Not Observed			0.0	CI	**GRAVELLY CLAY**, medium plasticity, brown / dark brown; gravel, fine to coarse grained; friable	D	H		
			HP>500kPa	19.5						×	
			HP>500kPa		0.5		....0.4m, gravel content increasing; trace cobbles and coarse gravel			×	
			HP>500kPa	19.0						×	
			HP>500kPa				Grading to			×	
			B		1.0		**WEATHERED ROCK**, fine grained, grey/pale grey; residual soil to slightly weathered; rock is very low to medium strength	D			
				18.5							
					1.5						
				18.0							
					2.0						
				17.5							
							Refusal, hard digging on weathered rock EXCAVATION TP21 TERMINATED AT 2.30 m				
					2.5						
				17.0							
					3.0						
				16.5							
					3.5						
				16.0							

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

no resistance / ranging to / refusal

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP22*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

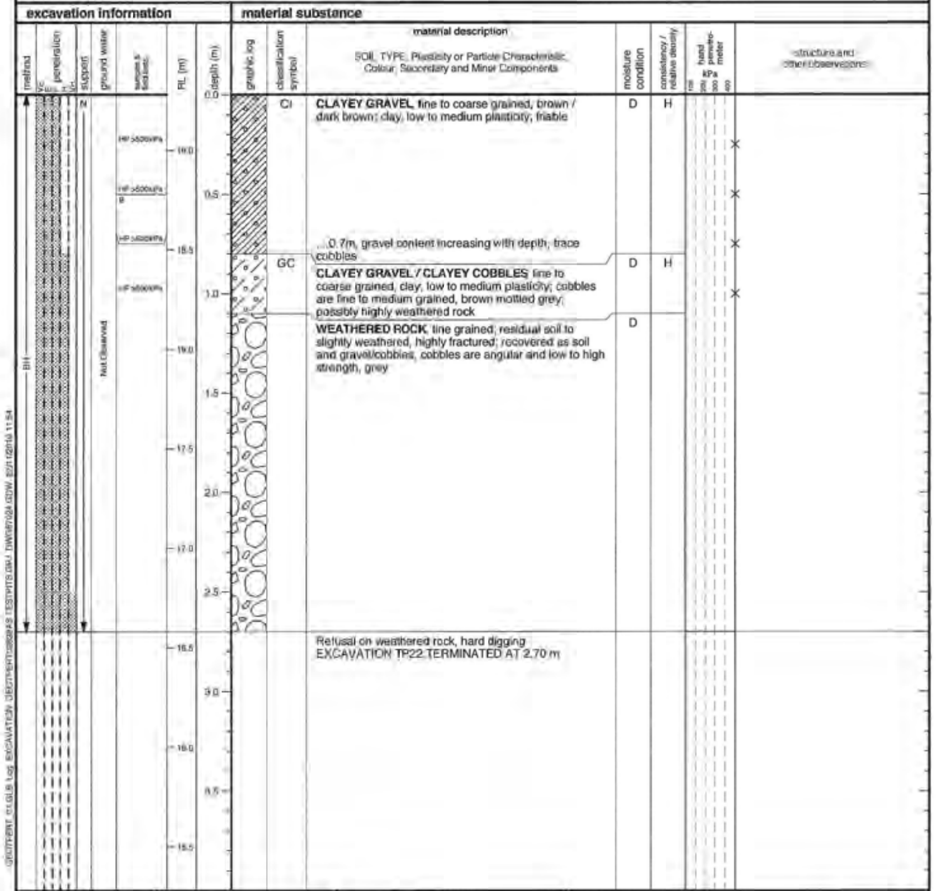
Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478212; N: 7704649 (50 MGA94) Surface Elevation : 19.28m (AHD)

Equipment type : Backhoe Method : Excavation dimensions :



classification symbol	material description	moisture condition	consistency / relative density
CI	**CLAYEY GRAVEL**, fine to coarse grained, brown / dark brown; clay, low to medium plasticity, friable	D	H
	...0.7m, gravel content increasing with depth, trace cobbles		
GC	**CLAYEY GRAVEL / CLAYEY COBBLES**, fine to coarse grained, clay, low to medium plasticity; cobbles are fine to medium grained, brown mottled grey, possibly highly weathered rock	D	H
	WEATHERED ROCK, fine grained, residual soil to slightly weathered, highly fractured; recovered as soil and gravel/cobbles, cobbles are angular and low to high strength, grey	D	
	Refusal on weathered rock, hard digging EXCAVATION TP22 TERMINATED AT 2.70 m		

method
- N - Natural Exposure
- X - Existing Excavation
- BH - Backhoe Bucket
- B - Bulldozer Blade
- R - Ripper
- E - Excavator

support
- N - No Support
- T - Timbering

penetration

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_p - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP23**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **20/10/10**
Date completed **20/10/10**
Logged by **PCW**
Checked by

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478269.1, N: 7704389.2 (50 MGA94)
Surface Elevation : 21.29m (AHD)
Equipment type Backhoe
Method :
Excavation dimensions : 4.90m long 0.70m wide

excavation information / material substance

method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa	structure and other observations
BH		N	Not Observed	HP >600kPa	21.0	0.0	CI	**CLAY**, medium plasticity, brown / dark brown; friable; trace of gravel, fine to medium grained; trace of sand	D	H		
				HP >600kPa HP >600kPa	20.5	0.5	CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled pale grey; fine to coarse grained Grading into	D	H		
				HP >600kPa	20.0 19.5	1.0 1.5		**WEATHERED ROCK**, fine grained; residual soil to moderately weathered, highly fractured; recovered as soil and cobbles, grey/brown; cobbles and gravel are angular, low to high strength	D			
					19.0 18.5 18.0 17.5	2.0 2.5 3.0 3.5		Refusal on weathered rock EXCAVATION TP23 TERMINATED AT 2.00 m				

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
no resistance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_p - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP24**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**
Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Position : E: 478382.2; N: 7704425.8 (50 MGA94)
Surface Elevation : 21.69m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.50m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa	structure and other observations
BH		N	Not Observed	HP >500kPa	21.5	0.0		CI	**CLAY**, medium plasticity, brown / dark brown; friable; trace of sand; trace of gravel, fine grained	D	H	×	
				HP >500kPa				GC	**CLAYEY GRAVEL**, fine to coarse grained, brown; clay, medium plasticity Grading into	D	H	×	
				HP >500kPa B HP >500kPa	21.0 20.5	0.5 1.0			**WEATHERED ROCK**, weathered rock; residual soil to moderately weathere, highly fractured; recovered as soil and cobbles, grey/white; cobbles are angular, low to high strength	D		× × ×	
					20.0 19.5 19.0 18.5 18.0	1.5 2.0 2.5 3.0 3.5			Refusal on weathered rock, hard digging EXCAVATION TP24 TERMINATED AT 1.50 m				

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

no resistance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_p - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP25*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478564.8, N: 7704454 (50 MGA94)

Surface Elevation : 21.8m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.80m long 0.70m wide

excavation information							material substance							
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400		structure and other observations
BH		N	Not Observed	B		0.0		CI	**SANDY CLAY /CLAYEY SAND** low to medium plasticity, brown / dark brown; sand, fine to coarse grained, with some gravel, fine to medium grained, sub-angular; gravel content increasing with depth	D	H	×		
				HP >400kPa	21.5									
				HP >600kPa		0.5		CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL** medium plasticity, gravel, fine to coarse grained	D	H	×		
				HP >500kPa	21.0							×		
				HP >600kPa		1.0			Grading into			×		
					20.5				**WEATHERED ROCK**, fine grained; residual soil to moderately weathered rock; highly fractured; recovered as soil and cobbles, grey/pale grey; cobbles are angular, low to high strength	D				
						1.5								
					20.0									
						2.0			Refusal on weathered rock, hard digging EXCAVATION TP25 TERMINATED AT 1.90 m					
					19.5									
						2.5								
					19.0									
						3.0								
					18.5									
						3.5								
					18.0									

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- EB - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_p - Plastic Limit
- W_l - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP26**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478796.4, N: 7704509.2 (50 MGA94)
Equipment type : Backhoe
Surface Elevation : 22.04m (AHD)
Method :
Excavation dimensions : 4.70m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed		22.0	0.0		CI	**GRAVELLY CLAY**, medium plasticity, brown / dark brown; gravel, fine to medium grained; friable	D			Trace of rootlets in top 300mm
				HP >500kPa								×	
				HP >500kPa	21.5	0.5		GC	**CLAYEY GRAVEL**, fine to coarse grained, angular, grey/brown; clay is medium plasticity	D		×	
				HP 450kPa								×	
				HP 1000kPa	21.0	1.0						×	
					20.5	1.5			Grading into				
					20.0	2.0			**WEATHERED ROCK**, residual soil to moderately weathered, highly fractured; recovered as soil and gravel/cobbles, grey/pale grey, gravel/cobbles are angular				
					19.5	2.5							
					19.0	3.0			Test depth reached EXCAVATION TP26 TERMINATED AT 2.90 m				
					18.5	3.5							

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

water

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- E0 - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP27**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**20/10/10**
Date completed	**20/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**

Principal :

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478774.4, N: 7704328.1 (50 MGA94)   Surface Elevation : 26.32m (AHD)

Equipment type : Backhoe   Method :   Excavation dimensions : 4.00m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed			0.0		GC	**CLAYEY GRAVEL**, fine to coarse grained, brown; clay, medium plasticity	D	H		Granite outcrops noted at surface close to testpit
				HP >500kPa	26.0							×	
				HP >500kPa		0.5						×	
									Refusal on weathered rock EXCAVATION TP27 TERMINATED AT 0.60 m				
					25.5								
						1.0							
					25.0								
						1.5							
					24.5								
						2.0							
					24.0								
						2.5							
					23.5								
						3.0							
					23.0								
						3.5							
					22.5								

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
- minor resistance
- ranging to
- refusal

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. ***TP28***
Sheet No. 1 of 1
Project No. ***GEOTPERT02828AS***
Date excavated ***20/10/10***
Date completed ***20/10/10***
Logged by : ***PCW***
Checked by :

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

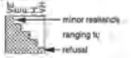
Position : E: 478611.5, N: 7704268.5 (50 MGA94)
Surface Elevation : 24.82m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.20m long 0.70m wide

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed			0.0	▨	CI	**CLAY**, medium plasticity, brown; friable; trace of gravel, trace of rootlets	D	H		
				HP >600kPa								×	
					24.5		▨	GC	**CLAYEY GRAVEL**, fine to coarse grained, clay, medium plasticity; with some boulders and cobbles	D			
				HP >600kPa		0.5						×	
				HP >600kPa	24.0							×	
				HP >600kPa		1.0						×	
									Refusal of weathered rock EXCAVATION TP28 TERMINATED AT 1.10 m				
					23.5	1.5							
					23.0	2.0							
					22.5	2.5							
					22.0	3.0							
					21.5	3.5							
					21.0								

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration



water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP29**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**20/10/10**
Date completed	**20/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**

Principal :

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478436, N: 7704225.3 (50 MGA94)

Surface Elevation : 23.48m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.80m long 0.70m wide

excavation information / material substance

method	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE: Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer kPa	structure and other observations
BH	N	Not Observed	B		0.0	GC	**CLAYEY GRAVEL**, fine to coarse grained, clay, medium plasticity; with some cobbles	D	H		
			HP >500kPa							×	
			HP >500kPa	23.0	0.5					×	
								D			
			HP >500kPa							×	
			HP >500kPa	22.5	1.0					×	
							Grading into				
							WEATHERED ROCK, fine grained; residual soil to moderately weathered, highly fractured; recovered as soil and gravel/cobbles, grey/white, cobbles/gravel are angular				
				22.0	1.5						
				21.5	2.0						
				21.0	2.5						
							Refusal, hard digging EXCAVATION TP29 TERMINATED AT 2.60 m				
				20.5	3.0						
				20.0	3.5						
				19.5							

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

no resistance

ranging to

refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_p - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP30**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**20/10/10**
Date completed	**20/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**

Principal :

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478262.7, N: 7704240.9 (50 MGA94)   Surface Elevation :

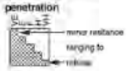
Equipment type : Backhoe   Method :   Excavation dimensions :

excavation information							material substance						
method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
			Not Observed			0.0			Exposed rock at surface in surrounding area. Testpit not undertaken EXCAVATION TP30 TERMINATED AT 0.00 m				
						0.5							
						1.0							
						1.5							
						2.0							
						2.5							
						3.0							
						3.5							

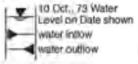
method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration



water

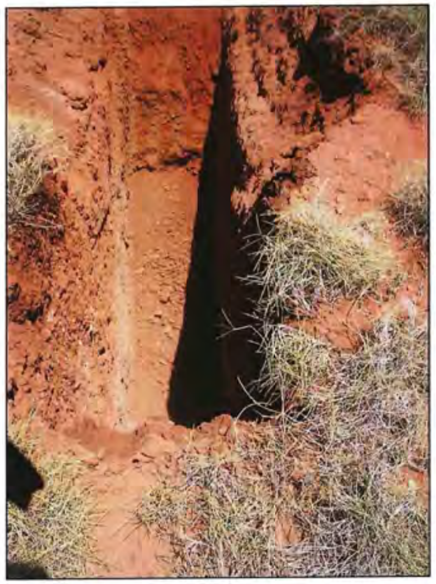

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense



TP01.

TP01 - Stockpile.

drawn	LB
approved	
date	3/11/10
scale	NOT TO SCALE
original size	A4

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

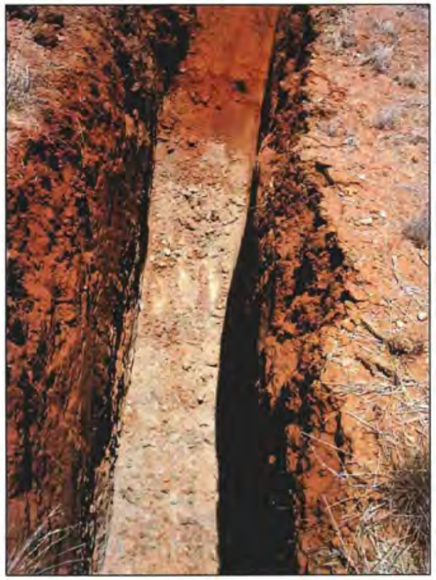
client: **COSSILL & WEBLEY CONSULTING ENGINEERS**

project: **MADIGAN ROAD DEVELOPMENT SITE**
MADIGAN ROAD, KARRATHA

title: **TEST PIT PHOTOGRAPHS - TP01**

project no: **GEOTPERT02828AS** fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg



TP02.

TP02 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP02
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP03.

TP03 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP03
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\CE\OTPERT\[illegible] Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP04.

TP04 - Stockpile.

drawn	LB	coffey geotechnics	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10					
scale	NOT TO SCALE	SPECIALISTS MANAGING THE EARTH	title:	TEST PIT PHOTOGRAPHS - TP04		
original size	A4		project no:	GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP05.

TP05 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP05	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\[illegible] Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP06.

TP06 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP06
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP07.

TP07 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP07	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: P:\GEOTPERT00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP08.

TP08 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP08
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP09.

TP09 - Stockpile.

drawn	LB	**coffey** geotechnics SPECIALISTS MANAGING THE EARTH	client: **COSSILL & WEBLEY CONSULTING ENGINEERS**
approved			project: **MADIGAN ROAD DEVELOPMENT SITE** **MADIGAN ROAD, KARRATHA**
date	3/11/10		
scale	NOT TO SCALE		title: **TEST PIT PHOTOGRAPHS - TP09**
original size	A4		project no: **GEOTPERT02828AS** fig no: rev:

DWG: F:\GEOT\PERTH\00002828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP10.

TP10 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP10
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP11.

TP11 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP11
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\[illegible]AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP12.

TP12 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP12
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madgan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP13.

TP13 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP13	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP14.

TP14 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP14
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP15.

TP15 - Stockpile.

drawn	LB
approved	
date	3/11/10
scale	NOT TO SCALE
original size	A4

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

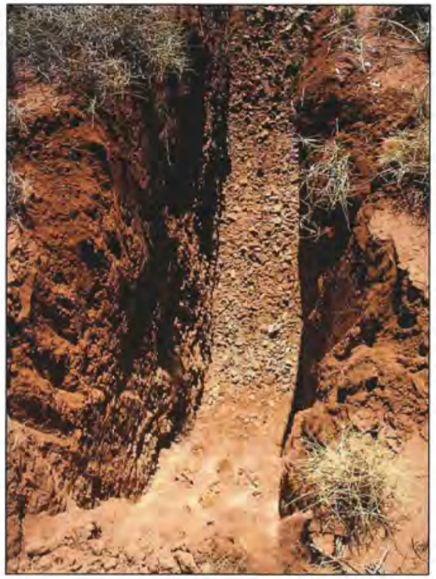
client: COSSILL & WEBLEY CONSULTING ENGINEERS

project: MADIGAN ROAD DEVELOPMENT SITE
MADIGAN ROAD, KARRATHA

title: TEST PIT PHOTOGRAPHS - TP15

project no: GEOTPERT02828AS
fig no:
rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP16.

TP16 - Stockpile.

drawn	LB	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved		project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10				
scale	NOT TO SCALE	title:	TEST PIT PHOTOGRAPHS - TP16		
original size	A4	project no:	GEOTPERT02828AS	fig no:	rev:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP17.

TP17 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP17	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP18.

TP18 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP18
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP19.

TP19 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10		title:	TEST PIT PHOTOGRAPHS - TP19
scale	NOT TO SCALE		project no:	GEOTPERT02828AS
original size	A4		fig no:	rev:

DWG: F:\GEOTPERT\[illegible]02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP20.

TP20 - Stockpile.

drawn	LB
approved	
date	3/11/10
scale	NOT TO SCALE
original size	A4

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client: **COSSILL & WEBLEY CONSULTING ENGINEERS**

project: **MADIGAN ROAD DEVELOPMENT SITE**
MADIGAN ROAD, KARRATHA

title: **TEST PIT PHOTOGRAPHS - TP20**

project no: **GEOTPERT02828AS**
fig no:
rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP21.

TP21 - Stockpile.

drawn	LB
approved	
date	3/11/10
scale	NOT TO SCALE
original size	A4

coffey
geotechnics
SPECIALISTS MANAGING
THE EARTH

client: **COSSILL & WEBLEY CONSULTING ENGINEERS**

project:
MADIGAN ROAD DEVELOPMENT SITE
MADIGAN ROAD, KARRATHA

title: **TEST PIT PHOTOGRAPHS - TP21**

project no: **GEOTPERT02828AS**
fig no:
rev:

DWG: F:\GEOTPERT\00000\02828AS Mulligan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP22.

TP22 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP22
original size	A4		project no:	GEOTPERT02828AS fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP23.

TP23 - Stockpile.

drawn	LB	**coffey geotechnics** SPECIALISTS MANAGING THE EARTH	client:	**COSSILL & WEBLEY CONSULTING ENGINEERS**
approved			project:	**MADIGAN ROAD DEVELOPMENT SITE** **MADIGAN ROAD, KARRATHA**
date	3/11/10			
scale	NOT TO SCALE		title:	**TEST PIT PHOTOGRAPHS - TP23**
original size	A4		project no: **GEOTPERT02828AS**	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP24.

TP24 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP24
original size	A4		project no:	GEOTPERT02828AS fig no: rev:

DWG: F:\GEOTPERT\00000\02828AE Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP25.

TP25 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP25	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828A9 Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg


TP26.


TP26 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP26
original size	A4		project no:	GEOTPERT02828AS fig no: rev:

DWG: F:\GEOTPERT\[illegible]028AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP27.

TP27 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP27
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00WK\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP28.

TP28 - Stockpile.

drawn	LB
approved	
date	3/11/10
scale	NOT TO SCALE
original size	A4

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client: **COSSILL & WEBLEY CONSULTING ENGINEERS**

project: **MADIGAN ROAD DEVELOPMENT SITE**
MADIGAN ROAD, KARRATHA

title: **TEST PIT PHOTOGRAPHS - TP28**

project no: **GEOTPERT02828AS** fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

TP29.

TP29 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP29	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\[illegible]02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley G\DWG\GEOTPERT02828AS PHOTOS.dwg

Appendix B

Results of Laboratory Testing

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Test Report

Report No.: WELS10S- 03811MC

Issue No.: 1

This report replaces all previous issues of report no. WELS10S- 03811MC

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W 10578
Location: Karratha

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS IEC 17025

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below

Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S-03811	TP02 @ 0.60 0.90m	5.9%

Comments:
Sample Supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone +61 8 6466 2400
Facsimile +61 8 6466 2430

Test Report

Report No.: WELS10S- 03813MC

Issue No.: 1

This report replaces all previous issues of report no. WELS10S- 03813MC

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W 10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below

Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03813	TP05 @ 1.30 - 1.60m	9.8%

Comments:
Sample Supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Test Report

Report No.: WELS10S- 03815MC

Issue No.: 1

This report replaces all previous isues of report no. WELS10S- 03815MC

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W 10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accrediation requirements. Accredited for compliance with IOS IEC 17025

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below

Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03815	TP13 @ 0.00 - 0.50m	3.7%

Comments:
Sample Supplied by client

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone +61 8 6466 2400
Facsimile +61 8 6466 2450

Test Report

Report No.: WELS10S- 03818MC

Issue No.: 1

This report replaces all previous issues of report no. WELS10S- 03818MC

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W 10578
Location:	Karratha

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

(This document may not be reproduced except in full.)

WORLD RECOGNISED ACCREDITATION

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.:	see below	**Other Sample Details:**	
Sample ID:	see below	**Date of Test:**	11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03818	TP19 @ 0.40 - 0.70m	3.1%

Comments:
Sample Supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2430

Report No.: WELS10S- 03820MC

Issue No.: 1

This report replaces all previous isues of report no. WELS10S- 03820MC

Test Report

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W 10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below

Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03820	TP25 @ 0.00 - 0.50m	3.3%

Comments:
Sample Supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03811PSD

Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full.)

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03811
Sample ID: TP02 @ 0.60 - 0.90m

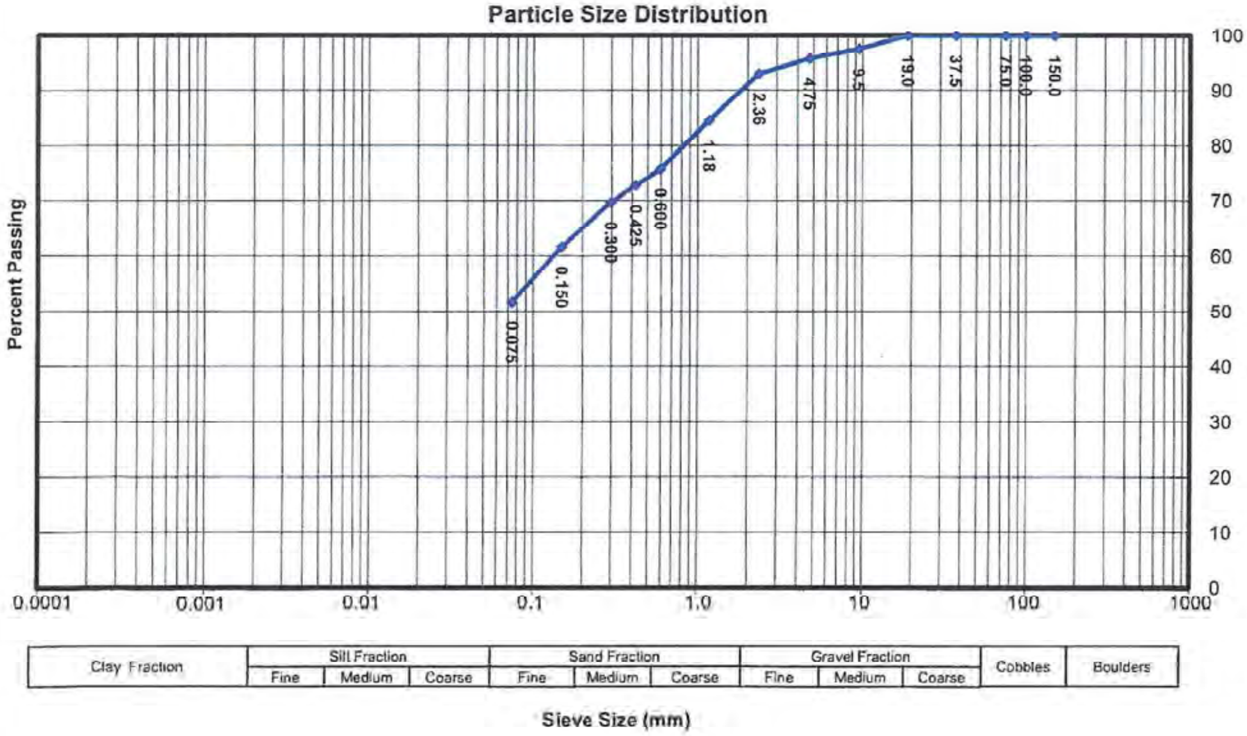
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	93
100.0	100	1.18	85
75.0	100	0.600	76
37.5	100	0.425	73
19.0	100	0.300	70
9.5	98	0.150	62
4.75	96	0.075	52



Comments:
Sample supplied by client

Form Number: R5002, Issue 4, Date 19/03/2010

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03812PSD

Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full)

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03812
Sample ID: TP03 @ 1.00 - 1.20m

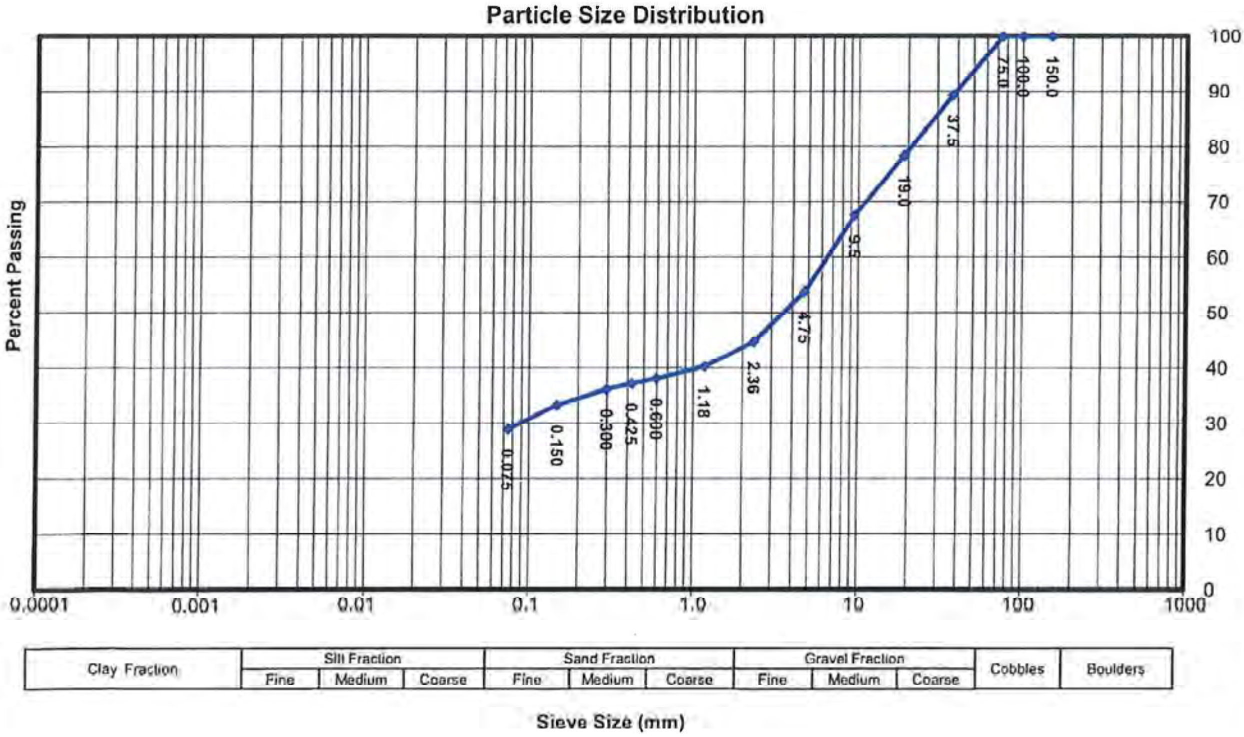
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	45
100.0	100	1.18	40
75.0	100	0.600	38
37.5	89	0.425	37
19.0	78	0.300	36
9.5	68	0.150	33
4.75	54	0.075	29



Comments:
Sample supplied by client
Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

Form Number: R5002, Issue 4, Date 19/03/2010

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6468 2450

Report No.: WELS10S-03813PSD

Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03813
Sample ID: TP05 @ 1.30 - 1.60m

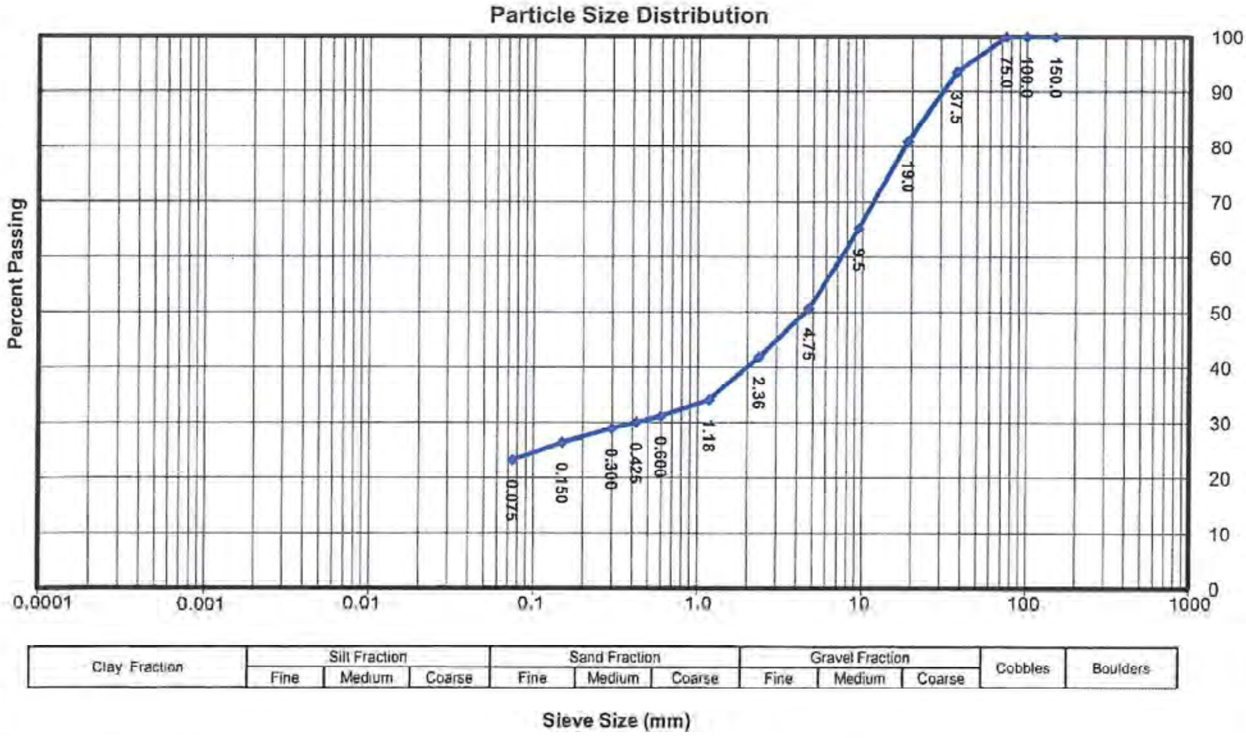
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 9/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	42
100.0	100	1.18	34
75.0	100	0.600	31
37.5	94	0.425	30
19.0	81	0.300	29
9.5	65	0.150	26
4.75	51	0.075	23



Comments:
Sample supplied by client
Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Test Report

Report No.: WELS10S-03814PSD

Issue No.: 1

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03814
Sample ID: TP12 @ 0.00 - 0.50m

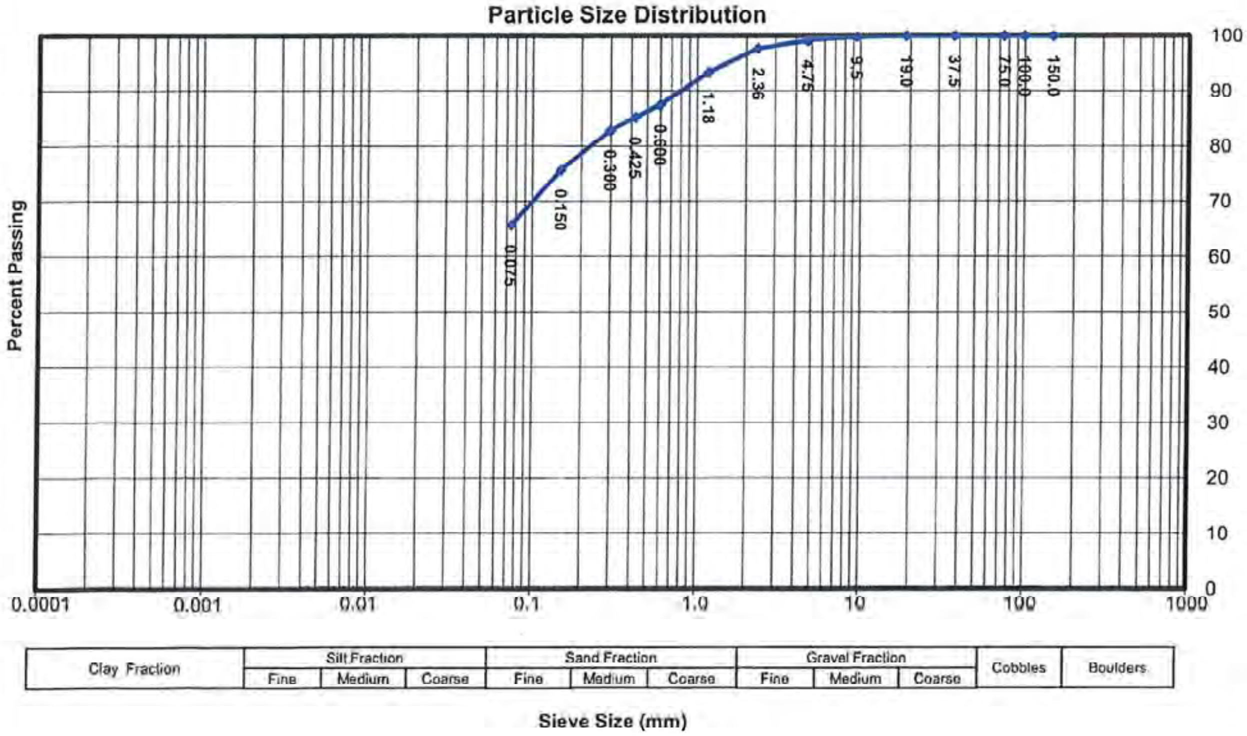
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	98
100.0	100	1.18	93
75.0	100	0.600	88
37.5	100	0.425	85
19.0	100	0.300	83
9.5	100	0.150	76
4.75	99	0.075	66



Comments:
Sample supplied by client

Form Number: R5002, Issue 4, Date 19/03/2010

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Test Report

Report No.: WELS10S-03815PSD

Issue No.: 1

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.:	WELS10S-03815
Sample ID:	TP13 @ 0.00 - 0.50m

Other Sample Details:

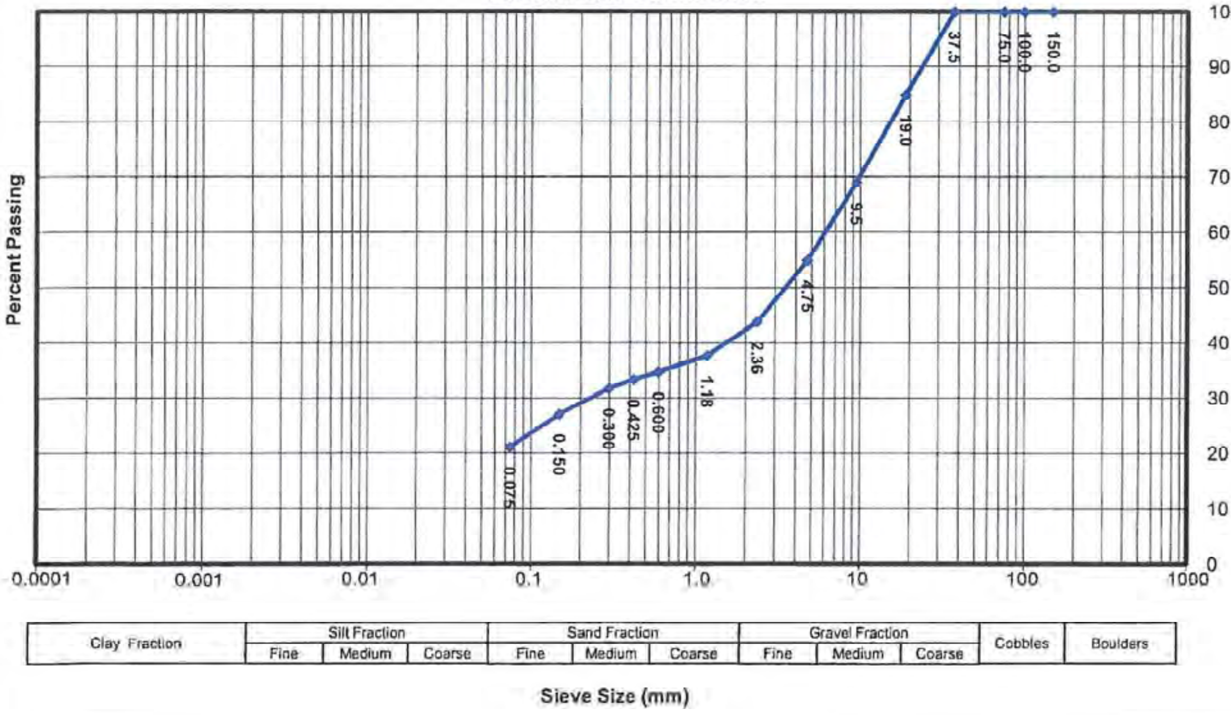
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	44
100.0	100	1.18	38
75.0	100	0.600	35
37.5	100	0.425	33
19.0	85	0.300	32
9.5	69	0.150	27
4.75	55	0.075	21

Particle Size Distribution



Comments:

Sample supplied by client

Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

Form Number: R5002, Issue 4, Date 19/03/2010

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No.: WELS10S-03816PSD

Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.
(This document may not be reproduced except in full.)

B Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03816
Sample ID: TP15 @ 0.80 - 1.00m

Other Sample Details:

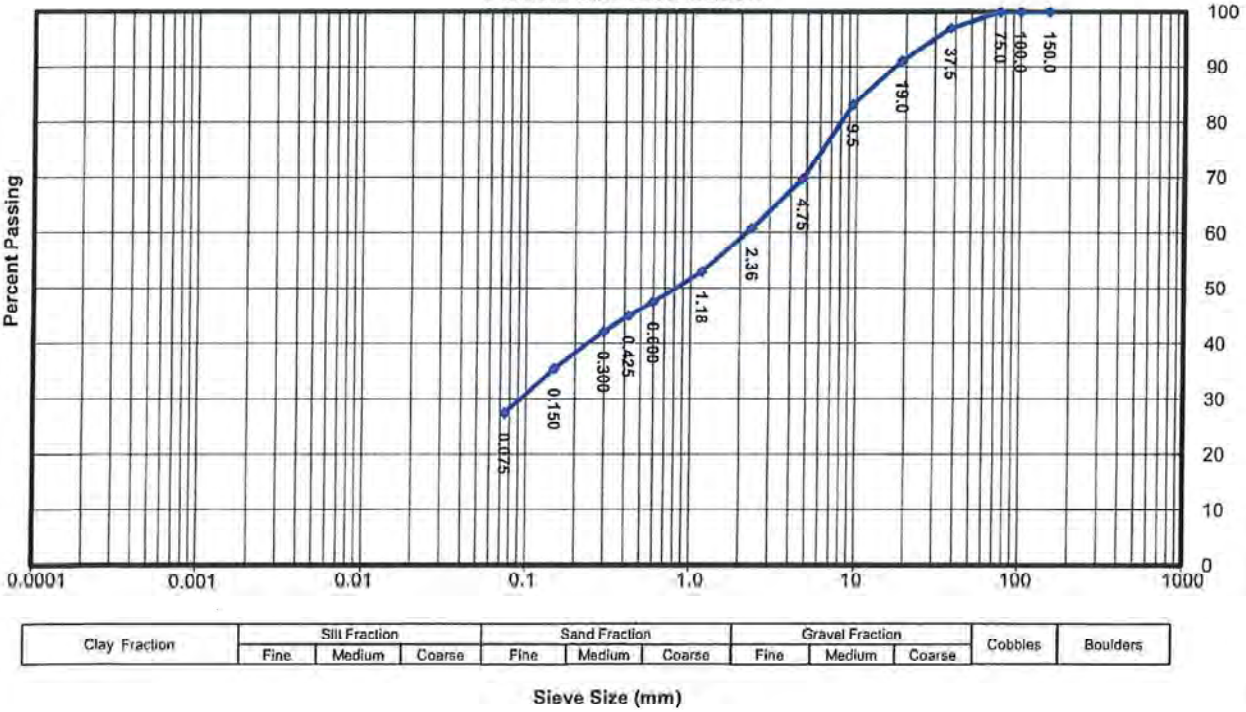
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	61
100.0	100	1.18	53
75.0	100	0.600	47
37.5	97	0.425	45
19.0	91	0.300	42
9.5	83	0.150	35
4.75	70	0.075	27

Particle Size Distribution



Comments:
Sample supplied by client
Deviation from standard method - Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

Form Number: R5002, Issue 4, Date 19/05/2010

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6456 2400
Facsimile: +61 8 6456 2450

Report No.: WELS10S-03817PSD

Issue No.: 1

Test Report

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory: Brad Truslove

NATA Accredited Laboratory Number: 431

Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03817

Sample ID: TP18 @ 0.70 - 1.00m

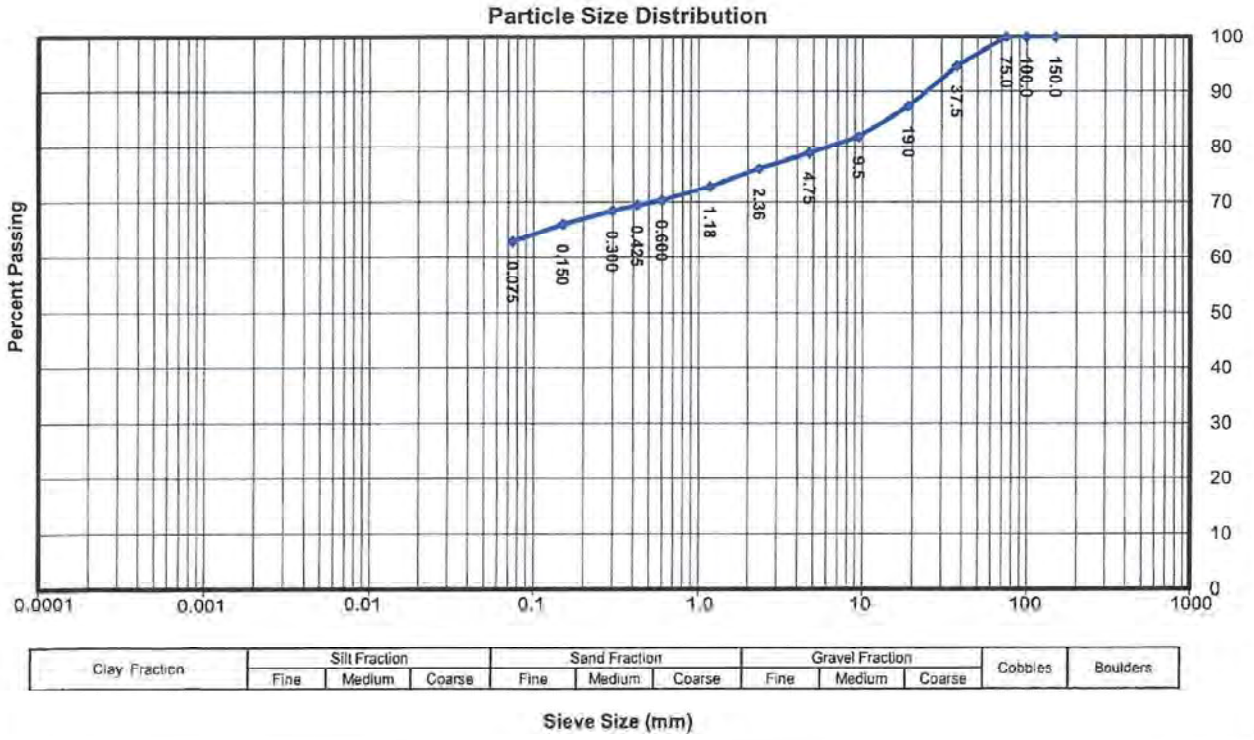
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	76
100.0	100	1.18	73
75.0	100	0.600	70
37.5	95	0.425	69
19.0	87	0.300	68
9.5	82	0.150	66
4.75	79	0.075	63



Comments:

Sample supplied by client

Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No.: WELS10S-03818PSD

Issue No.: 1

Test Report

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03818

Sample ID: TP19 @ 0.40 - 0.70m

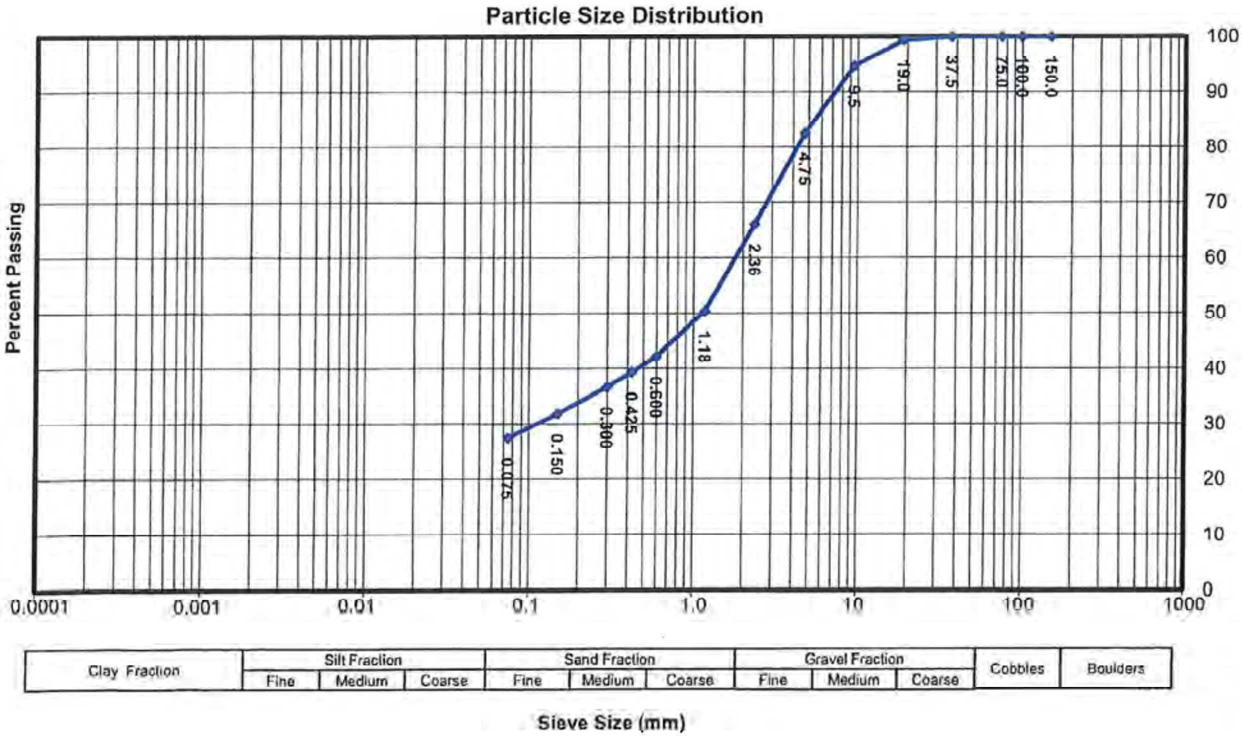
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	66
100.0	100	1.18	50
75.0	100	0.600	42
37.5	100	0.425	39
19.0	99	0.300	37
9.5	95	0.150	32
4.75	83	0.075	27



Comments:

Sample supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03819PSD

Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03819
Sample ID: TP22 @ 0.50 - 0.70m

Other Sample Details:

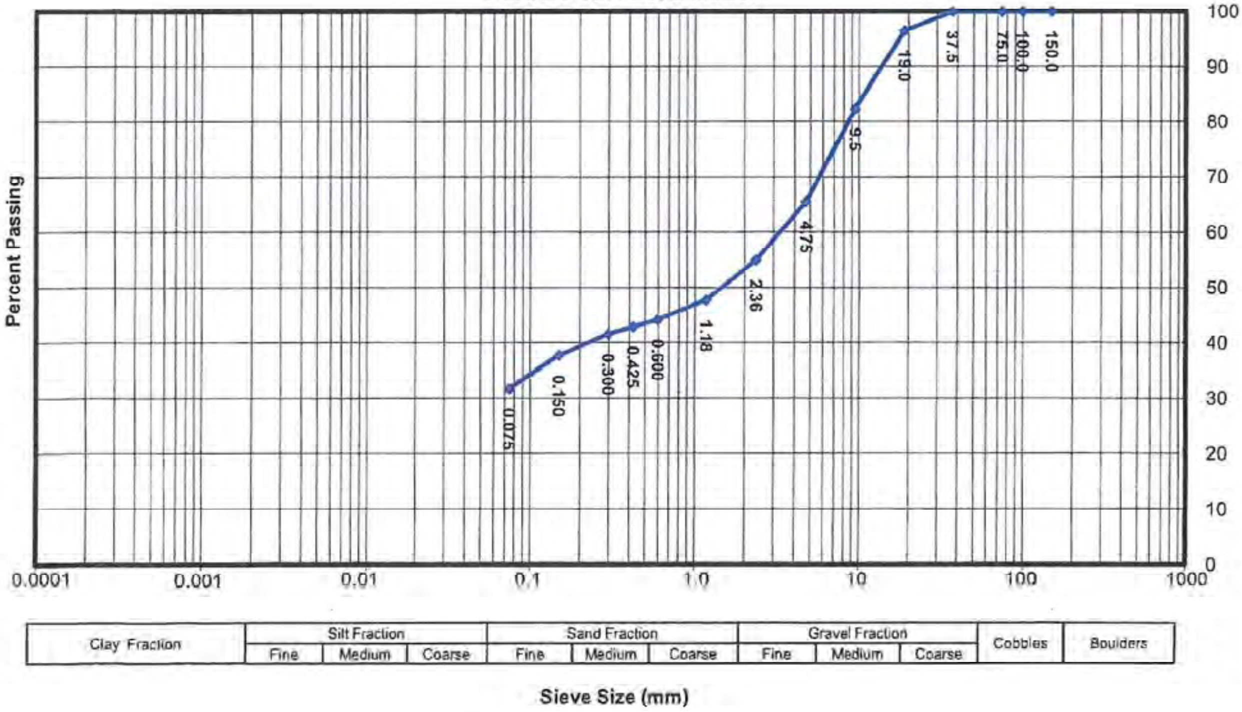
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	55
100.0	100	1.18	48
75.0	100	0.600	44
37.5	100	0.425	43
19.0	97	0.300	42
9.5	82	0.150	38
4.75	66	0.075	32

Particle Size Distribution



Comments:
Sample supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03820PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03820
Sample ID: TP25 @ 0.00 - 0.50m

Other Sample Details:

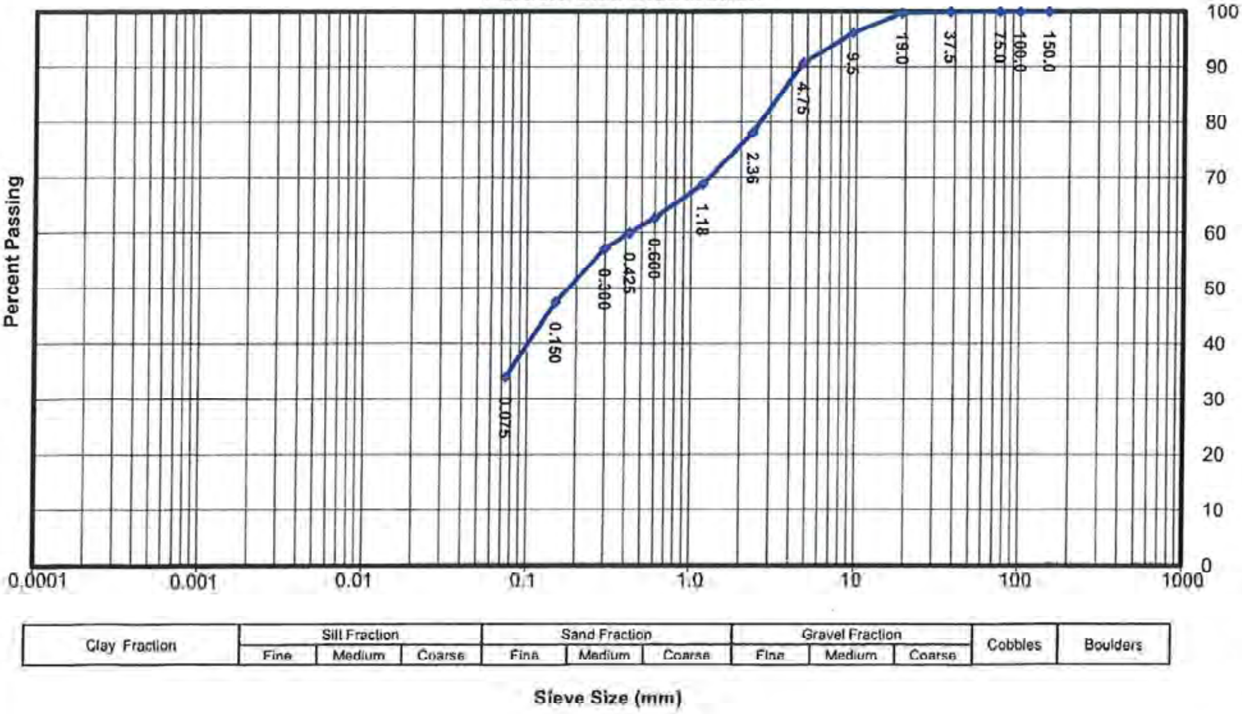
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	78
100.0	100	1.18	69
75.0	100	0.600	63
37.5	100	0.425	60
19.0	100	0.300	57
9.5	96	0.150	47
4.75	91	0.075	34

Particle Size Distribution



Comments:
Sample supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Test Report

Report No.: WELS10S-03821PSD

Issue No.: 1

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.
(This document may not be reproduced except in full.)

B Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03821
Sample ID: TP29 @ 0.00 - 0.40m

Other Sample Details:

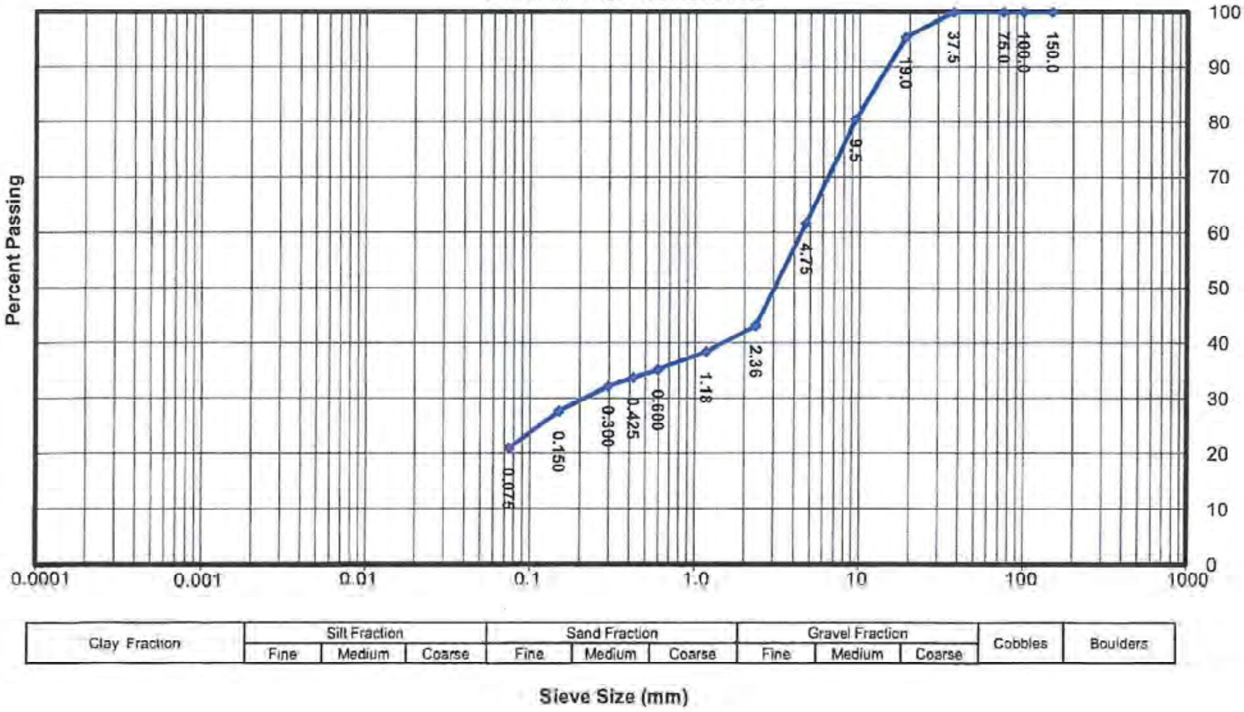
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	43
100.0	100	1.18	38
75.0	100	0.600	35
37.5	100	0.425	34
19.0	95	0.300	32
9.5	80	0.150	28
4.75	62	0.075	21

Particle Size Distribution



Comments:
Sample supplied by client

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03811-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03811
Field Sample: 00001
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP02 @ 0.60 - 0.90m

Test Results

Description	**Method**	**Result**	**Limits**
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	8.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	41	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	18	
Plasticity Index (%)	AS 1289.3.3.1	23	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03812-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

NATA WORLD RECOGNISED ACCREDITATION

B Truslove
Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03812
Field Sample: 00002
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP03 @ 1.00 - 1.20m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	8.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	56	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	23	
Plasticity Index (%)	AS 1289.3.3.1	33	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03814-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.:
TRN:

NATA WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03814
Field Sample: 00004
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP12 @ 0.00 - 0.50m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	13.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	44	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	20	
Plasticity Index (%)	AS 1289.3.3.1	24	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03815-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03815
Field Sample: 00005
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP13 @ 0.00 - 0.50m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	36	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	18	
Plasticity Index (%)	AS 1289.3.3.1	18	

Comments
N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03816-1
Issue No: 1

Material Test Report

Client:	Coffey Geotechnics Pty Ltd (Burswood) Level 1,89-91 Burswood Road Burswood WA 6100
Principal:	Cossill & Webley
Project No.:	INFOWELS00653AA
Project Name:	GEOTPERT02828AS - Madigan Rd Development Site
Lot No.:	**TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID:	WELS10S-03816
Field Sample:	00006
Date Sampled:	
Source:	
Material:	
Specification:	
Sampling Method:	Submitted by client
Project Location:	Maddigan Road, Karratha, WA
Sample Location:	TP15 @ 0.80 - 1.00m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1		
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	6.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	33	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	19	
Plasticity Index (%)	AS 1289.3.3.1	14	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03817-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number 431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03817
Field Sample: 00007
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP18 @ 0.70 - 1.00m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	47	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	20	
Plasticity Index (%)	AS 1289.3.3.1	27	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03818-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03818
Field Sample: 00008
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP19 @ 0.40 - 0.70m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	7.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	33	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	17	
Plasticity Index (%)	AS 1289.3.3.1	16	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03819-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number 431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03819
Field Sample: 00009
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP22 @ 0.50 - 0.70m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	4.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	32	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	19	
Plasticity Index (%)	AS 1289.3.3.1	13	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03820-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03820
Field Sample: 00010
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP25 @ 0.00 - 0.50m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	5.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	30	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	16	
Plasticity Index (%)	AS 1289.3.3.1	14	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03821-1
Issue No: 1

Material Test Report

Client:	Coffey Geotechnics Pty Ltd (Burswood) Level 1,89-91 Burswood Road Burswood WA 6100
Principal:	Cossill & Webley
Project No.:	INFOWELS00653AA
Project Name:	GEOTPERT02828AS - Madigan Rd Development Site
Lot No.:	**TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Bred Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID:	WELS10S-03821
Field Sample:	00011
Date Sampled:	
Source:	
Material:	
Specification:	
Sampling Method:	Submitted by client
Project Location:	Maddigan Road, Karratha, WA
Sample Location:	TP29 @ 0.00 - 0.40m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	7.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	36	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	17	
Plasticity Index (%)	AS 1289.3.3.1	19	

Comments

N/A

Appendix C

CSIRO Information Sheet on Foundation Maintenance

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

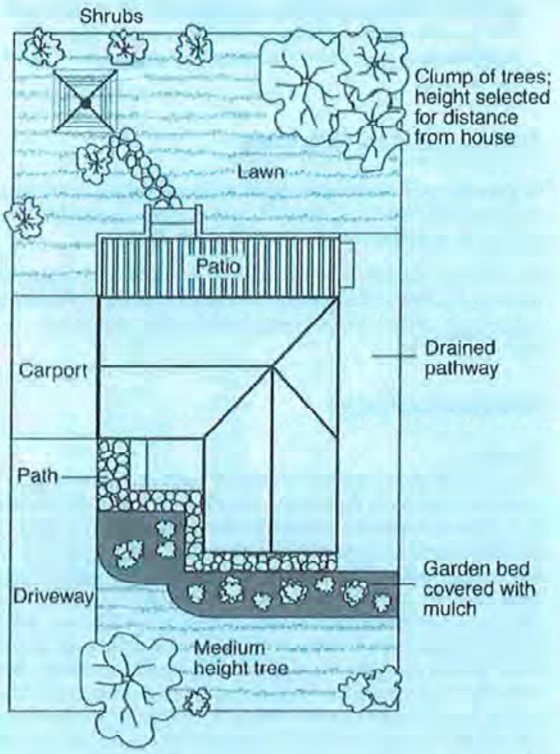
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

Distributed by
CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia
Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au
Email: publishing.sales@csiro.au

APPENDIX 4

INDICATIVE TREE SPECIES

This page has been left blank intentionally.

Species

General planting

Acacia stellaticeps
Cynanchum floribundum
Anigozanthus Bush Sunset
Anigozanthus Bush Tango
Anigozanthus Orange Cross
Acacia ancistrocarpa
Acacia arida
Acacia translucens
Alyogyne hakeifolia
Callistemon "Captain Cook"
Cassia oligophylla
Ipomca costata
Melaleuca glomerata
Azadirachta indica
Tababuia palmeri
Brachychiton gregorii
Eucalyptus terminalis

Trees for mass planting

Acacia aneura	Mulga
Acacia coriacea	Desert oak / Dogwood/ Wirewood
Brachychiton australie	Rock Kurrajong
Brachychiton gregorii	Desert Kurrajong
Eucalyptus aspera	Rough leaf range gum / brittle range gum
Cassia fistula	Golden shower
Eucalyptus coolibah	Coolibah
Eucalyptus dichromophloai	Variable barked bloodwood
Lysiphyllum cunninghamii	Native bauhimia
Melaleuca leucadendron	Cadjeput

Additional Plants for Parks, accent areas etc

Ground Covers & Small Shrubs

Dipteracanthus australasicus	Desert Petunia
Indigoferra georgei	Georges Indigo
Myoporum parvifolium	Creeping Boobialla
Teucrium racemosum	Grey Germanda
Acacia gregorii	Gregorys Wattle
Acacia hilliana	
Ipomoea brasiliensis	Goats Foot/Beach
Myoporum parvifolium	Creeping Boobiala
Grevilliea spp	

Shrubs

Acacia stellaticeps	
Senna artemisiodes ssp. Sturtii	Dense Cassia
Cynanchum fl oribundum	Dumara Bush
Anigozanthus Bush Sunset	Kangaroo Paw
Anigozanthus Bush Tango/Bush Gem	Kangaroo Paw
Anigozanthus Orange Cross Orange	Kangaroo Paw
Acacia ancistrocarpa	Fitzroy Wattle
Acacia arida	Arid White
Acacia translucens	Poverty Bush
Alyogyne hakeifolia	
Callistemon "Captain Cook"	Red Bottlebrush
Callistemon "Kings Park Special"	Red Bottlebrush
Cassia oligophylla	Limestone Cassia/Bloodbush
Ipomca costata	Morning Glory/Native Sweet Potato
Melaleuca glomerata	

Trees

Azadirachta indica	Neem Tree
Tababuia palmeri	Pink Trumpet Tree
Tipuana tipu	Yellow Jacaranda
Brachychiton gregorii	Desert Kurrajong
Eucalyptus terminalis	Bloodwood

This page has been left blank intentionally.

APPENDIX 5

LOCAL WATER MANAGEMENT STRATEGY & FLOOD STUDY

This page has been left blank intentionally.

LandCorp

Madigan Road Urban Development, Karratha
Local Water Management Strategy

March 2011

JDA
Consultant Hydrologists

DISCLAIMER

This document is published in accordance with and subject to an agreement between JDA Consultant Hydrologists ("JDA") and the client for whom it has been prepared ("Client"), and is restricted to those issues that have been raised by the Client in its engagement of JDA. It has been prepared using the skill and care ordinarily exercised by Consultant Hydrologists in the preparation of such documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by JDA and the Client without first obtaining a prior written consent of JDA, does so entirely at their own risk and JDA denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this document for any purpose other than that agreed with the Client.

QUALITY ASSURANCE

JDA provides quality assurance through all aspects of the company operation and is endorsed to AS/NZS ISO 9001:2000 Quality Assurance Accreditation, with third party certification to Bureau Veritas Quality International.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

EXECUTIVE SUMMARY

This Local Water Management Strategy has been prepared to support a Development Plan for the Madigan Road Development Area, Karratha in accordance with Better Urban Water Management (WAPC, 2008). A summary of the water management strategy is provided below.

Principle	Key LWMS Elements
Water Quantity To maintain the total water cycle balance within development areas relative to the pre-development conditions.	• Maintain flow paths for existing catchments • Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area similar to current discharge levels. • No lowering of groundwater levels. • Maximise infiltration opportunities where possible.
Water Quality To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.	• Use of treatment train approach to stormwater management • Application of source controls – including education to reduce nutrient application, use of native plantings and vegetated swales. • Application of structural controls – retention/detention areas, vegetated swales, possible drop structures and sedimentation areas.
Water Conservation To maximise the reuse of stormwater	• Encourage implementation of water efficiency and demand management measures both internal and external of buildings. • Use of native plantings in streetscapes to minimise irrigation requirements.
Ecosystem Health To retain natural drainage systems and protect ecosystem health	• Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area similar current discharge levels to the Madigan Creek.
Economic Viability To implement stormwater systems that are economically viable in the long term	• Use of proven structural WSUD technology. • Use of source control techniques to minimise cost of nutrient management.
Public Health To minimise the public risk, including risk of injury or loss of life to the community	• Design in accordance with relevant design standards, best management practices, council regulations and government agency requirements.
Protection of Property To protect the built environment from flooding	• Identification of 100yr ARI flood levels for Study Area. • Protection of downstream areas by restricting stormwater discharge to existing levels for storm events up to 100yr ARI.
Social Values To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater	• Use of swales within public areas for stormwater conveyance. • Integration of drainage and POS functions.
Development To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability & precautionary principles.	• Urban water management in accordance with Better Urban Water Management (WAPC, 2008). • Development of the LWMS in accordance with government agency guidelines and best management practice recommendations.

1. INTRODUCTION

This document presents a Local Water Management Strategy (LWMS) in support of an urban residential development for approximately 68ha of land located at Madigan Road, Karratha, in the Shire of Roebourne, herein referred to as the Study Area (Figure 1).

1.1 Background

This document has been prepared to support a Structure Plan for the abovementioned property. It presents a recommended approach for total water cycle management within the proposed development area consistent with sustainability principles and the *Better Urban Water Management* (BUWM) (WAPC, 2001) process. The relationship of this document to this BUWM planning process is shown in Table 1.

The LWMS has been developed by JDA Consultant Hydrologists on behalf of LandCorp. The compilation of this document includes a range of expertise and guidelines from leading authorities including the Department of Water (DoW) and the Shire of Roebourne (SoR) to assist in achieving the implementation of best practice in sustainable urban development and urban water management within the Study Area.

Previous advice provided to JDA by the Department of Water for sites in the Pilbara Region of Western Australia indicates that they have not published any guidelines to assist with the preparation of LWMS's specifically for these areas. However, it is acknowledged that flood management and associated issues of erosion and sedimentation are dominant and that peak post development flow rates do not need to be detained to pre-development peak flow, but the velocity of the post development flow should be minimised. A summary of the Department's guidance requirements are presented in Section 1.3.

A copy of the LWMS Checklist has been included as Appendix A to assist the DoW and Shire in review of this document.

TABLE 1: INTEGRATED PLANNING AND URBAN WATER MANAGEMENT PROCESS

Planning Phase	Planning Document	Urban Water Management Document and Status
District	Shire of Roebourne Town Planning Scheme (TPS 8)	N/A
Local	Madigan Rd, Karratha Development Plan (by TPG)	Madigan Road Urban Development Local Water Management Strategy **THIS DOCUMENT**
Subdivision	Subdivision Application	Urban Water Management Plan (required for individual stages of development) **FUTURE PREPARATION**

1.2 Previous Studies

This LWMS uses the following key documents to define its content, principles, and objectives.

1.2.1 State Planning Policy 2.9 - Water Resources

The LWMS has been developed in accordance with regional and local principles and objectives of Integrated Urban Water Management (IUWM).

The Western Australian Planning Commission (2005) defines IUWM (also known as total water cycle management) as promoting

> *'management of the urban water cycle as a single system in which all urban water flows are recognised as a potential resource and where the interconnectedness of water supply, stormwater, wastewater, flooding, water quality, waterways, estuaries and coastal waters is recognised'*.

IUWM promotes water conservation measures, reuse and recycling of water and best practice in stormwater management (Western Australian Planning Commission 2005).

1.2.2 Stormwater Management Manual for WA

The Stormwater Management Manual for Western Australia was first published by the Waters and Rivers Commission in 1998 to define and describe in practical terms Best Management Practices (BMP's) to reduce pollutant and nutrient inputs to stormwater drainage systems as well as guidelines for the incorporation of water sensitive urban design principles. A major review of the Stormwater Management Manual was undertaken by the DoW, with additional input by other State and Local Government Authorities and sectors of the urban development industry. This revised version of the Stormwater Management Manual was officially launched in 2007, though some chapters were published in 2004.

DoW's current position on Urban Stormwater Management in Western Australia is outlined in Chapter 2: Understanding the Context of the Stormwater Management Manual for Western Australia (DoW, 2007), which details the management objectives, principles, and a stormwater delivery approach for WA. Principal objectives for managing urban water in WA are stated as:

- Water Quality: To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.
- Water Quantity: To maintain the total water cycle balance within development areas relative to the pre-development conditions.
- Water Conservation: To maximise the reuse of stormwater.
- Ecosystem Health: To retain natural drainage systems and protect ecosystem health.
- Economic Viability: To implement stormwater systems that are economically viable in the long term.
- Public Health: To minimise the public risk, including risk of injury or loss of life to the community.
- Protection of Property: To protect the built environment from flooding and waterlogging.
- Social Values: To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater.

- Development: To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

The Department of Water released the Decision Process for Stormwater Management in WA in August 2009 to provide a decision framework for the planning and design of stormwater management systems and assist in meeting the objectives specified above.

A copy of the Decision Process is contained as Appendix B with key elements summarised in Table 2.

1.2.3 Better Urban Water Management

This LWMS has been developed to be consistent with the framework and process detailed in the recently released guideline document Better Urban Water Management (WAPC, 2008).

This LWMS has been prepared to an appropriate level of detail to support the proposed Structure Plan for the Study Area. The document includes the principles, objectives and requirements of total water cycle management and a detailed description of the environmental conditions of the site. Constraints and opportunities on the site are well understood and considered in the planning process. The capacity of the site to sustain development, including consideration of ASS, impacts from groundwater and surface water, impacts on ecosystems and biodiversity and impacts on existing infrastructure is also examined.

An Urban Water Management Plan (UWMP) will be required prior to the subdivision of the land.

1.2.4 Karratha City of the North Plan

The Karratha City of the North Plan (KCNP) was adopted by the Shire of Roebourne on 18 May 2010. The plan comprises of a series of documents being:

- The Karratha City Growth Plan
- The Karratha City Growth Plan
- Karratha City Centre Master Plan
- Implementation Blueprint

The KCNP provides a basis for guiding decision makers in assessing rezoning, subdivision and development applications as well as the provision of infrastructure and community facilities over time.

1.3 Key Design Principles and Objectives

A summary of the key principles and objectives applicable to the LWMS for the Study Area based on the above and previous advice provided to JDA by the Department of Water (DoW) for preparation of LWMS's in the Pilbara Region are as follows:

- Towns in the Pilbara have been developed using open drains rather than piped drainage and this is appropriate due to the high rainfall intensities and runoff rates compared with the South West WA.
- Existing creeks and drains are retained as far as possible - working with the existing drainage system, rather than against it.
- Flood risk is the main issue from surface water, however groundwater levels need to be considered.
- Management of erosion and sedimentation is important.
- Other water quality issues such as nutrient concentrations are of lower priority in the Pilbara.
- DoW accepts there will not be 2 years of predevelopment groundwater monitoring data and do not expect any groundwater monitoring data to be supplied.
- DoW will not require any post development surface water or groundwater quantity or quality monitoring.
- The LWMS checklist contained in BUWM (WAPC, 2008) should still be used.

A summary of the key principles and objectives applicable to this LWMS for the Study Area in the Pilbara region based on agreement with DoW is presented in Table 2.

TABLE 2: LWMS KEY PRINCIPLES AND OBJECTIVES

Key WSUD Guiding Principles

- Facilitate implementation of sustainable best practice in water management in the Pilbara region
- Provide integration with planning processes and clarity for agencies involved with implementation
- To minimise public risk, including risk of injury or loss of life
- Protection of infrastructure from flooding and waterlogging
- Encourage environmentally responsible development

Category	Principles	Design Objectives
Water Supply and Conservation	• Consider all potential water sources in water supply planning. • Integration of water and land use planning • Sustainable and equitable use of all water sources having consideration of the needs of all users, including community, industry and environment • Maximise the reuse of stormwater	• Minimise the use of potable water where drinking water quality is not essential, particularly ex-building use. • Apply waterwise landscaping measures to swales in road reserve to reduce/avoid irrigation.
Surface Water Flows and velocity	• Protect development from flooding. • Implement economically viable stormwater systems • Retain natural drainage systems and protect and/or improve ecosystem health – For the Pilbara, reduce the stormwater velocity to prevent export of sediments. • Ensure that stormwater management recognises and maintains social, aesthetic, and cultural values	• For flood management, manage up to the 100yr ARI event within the development. • Use swales through the development to disperse flow throughout the development with the aim to minimise velocity. Swales sized to minimum 5yr ARI, with larger events flowing along road reserve. • Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles consistent with DoW's requirements.
Groundwater Levels	• Protect development from waterlogging	• Protect development from waterlogging
Water Quality	• Where development is associated with an ecosystem dependent upon a particular hydrologic regime, minimise discharge or pollutants to shallow groundwater and receiving waterway and maintain water quality in specified environment	• No sensitive ecosystems in immediate vicinity. The receiving environment is Seven Mile Creek which discharges to the intertidal zone prior to discharging to the ocean. • Nutrients not considered a priority in the Pilbara.

2. PRE-DEVELOPMENT ENVIRONMENT

The environmental conditions of the pre-development Study Area provide an important context for planning future water management strategies. This section describes the pre-development condition.

2.1 Location and Topography

The Study Area is approximately 68ha in size and is located about 6km west of the Karratha town site within the Shire of Roebourne (Figure 1). The Study Area is on the south side of Dampier Road, directly to the east of Madigan Road. The Baynton West residential development is located adjacent to the east of the Study Area.

The site is relatively flat, sloping gently from the Karratha Hills to the south towards Dampier Road. Elevation ranges from approximately 27 mAHD at the southern boundary of the Study Area to approximately 14 mAHD at the north (Figure 2).

2.2 Existing Land Use

The Study Area is currently under native vegetation consisting of low tussock and spinifex grass with no evidence of existing infrastructure.

Surrounding land use consists of the Karratha Hills to the south, Woodside Petroleum's Pluto Worker Camp to the west of Madigan Rd (on land identified for future urban development), Banyton West residential development to the east (currently under development) and Dampier Road to the north.

Also abutting the north of the site is the Karratha Cemetery. The entire east boundary and part of the north boundary is adjacent to land reserved for Public Open Space (POS) and drainage purposes.

2.3 Climate

Karratha has an arid climate characterised by hot summers with periodic heavy rain and mild winters with occasional rainfall.

The Pilbara coast experiences more cyclones than any other part of Australia. Since 1910 there have been 48 cyclones that have caused damaging wind gusts in excess of 90 km/h in the Karratha, Dampier and Roebourne region. On average this equates to about one every two years. About half of these cyclones have an impact equivalent to a category one cyclone. Ten of these: 1925, 1939, 1945, 1954, Shirley 1966, Sheila-Sophie 1971, Trixie 1975, Chloe 1984, Orson 1989 and John 1999 have caused very destructive wind gusts in excess of 170 km/h (BoM 2010).

The average annual rainfall for Karratha is 280 mm per year, with a maximum recorded annual rainfall of 855mm from records taken between 1974-2009 at Karratha Airport (BoM 2010). Most of the recorded precipitation is received during the wet season, as a result of tropical cyclones and local thunderstorms

Along the central Pilbara coast the cyclone season runs from mid December to April peaking in February. Figure 3 presents graphed rainfall data for Karratha Airport (BoM site 4083).

The average annual pan evaporation is approximately 3,590mm (Luke et al, 1988).

2.4 Geology and Soils

The entire Study Area is covered by floodplain deposits of red-brown silty sand, which has been partially reworked by wind action over much of the site. The sand may contain nodules or lenses of calcrete approximately 1m below the surface, and scattered pebbles throughout. The sand is underlain by Archaean bedrock, probably mafic volcanics at an expected depth ranging from 10-20m below surface. The upper few metres of the bedrock are weathered and fractured. Surface Geology is presented in Figure 2.

It is likely that perching of groundwater within the subsoil profile may occur above very low permeability horizons such as weathered bedrock and clayey materials. Consequently, opportunities for infiltration of stormwater are also limited.

2.5 Groundwater Hydrology

Groundwater occurs within a single aquifer known as the Pilbara Fractured Rock Aquifer.

Although there are no long term groundwater monitoring bores known to exist within the Karratha Area, the watertable is expected to be 5-10m below surface and may vary seasonally in depth by 2-3m in response to heavy rainfall. The groundwater is expected to be slightly brackish to saline, in the range 2,500 – 10,000 mg/L Total Dissolved Solids, but there may be more saline groundwater in localized areas of low permeability.

A site visit of September 8th 2010 also noted that there was no evidence of groundwater in any of the surface drainage system of Madigan Creek.

2.6 Surface Water Hydrology

2.6.1 Existing Surface Drainage

No drainage channels or permanent surface water features exist within the Study Area, however immediately adjacent to the east is Madigan Creek as described in Section 2.6.2 (Figure 4).

The Study Area is subject to runoff from the hills located to the south. Due to the generally flat nature of the topography within the Study Area, runoff predominantly sheds naturally towards the north with minor runoff flowing west towards Seven Mile Creek.

However since construction of Madigan Rd, the minor flow to the west is now detained behind Madigan Rd at three locations by single 300mm diameter culverts. These culverts also convey localised surface runoff from the east side of Madigan Road back towards Seven Mile Creek.

During large rainfall events, this runoff detained behind Madigan Rd flows north through the cemetery area and back towards Madigan Creek.

2.6.2 Madigan Creek

A major drainage line occurs immediately east of the Study Area. This feature is a non-perennial natural creek which conveys storm runoff from a catchment formed within the Karratha Hills to the south of the

Study Area. The creek flows northwards towards the coast through 4 x 1500m culverts located under Dampier Road (Figure 4) and is referred to as Madigan Creek. Stormwater drainage from the Baynton West development discharges directly into Madigan Creek.

A Flood Study was recently prepared for Madigan Creek by JDA (2010). The Flood Study assessed existing 20yr, 50yr and 100yr ARI flood levels along Madigan Creek from the southern limit of development downstream to north of Dampier Rd (Figure 5). The impact of three proposed adjacent development areas (including this Study Area) were also assessed and results described in Section 4.2.5.

Main Roads Western Australia (MRWA) and the Shire of Roebourne have advised that Dampier Road has never been overtopped during any storm event. However no anecdotal evidence is available to support this.

No previous measurements for flow or water quality data is available for Madigan Creek.

2.7 Water Resources

Karratha is located within the Rights in Water and Irrigation Act 1914 Pilbara Surface Water and Groundwater Area.

There is no immediate infrastructure situated on local surface water courses (Seven Mile Creek or Madigan Creek) to provide a surface water resource. Similarly, the Pilbara Fractured Rock Aquifer is not considered to be a suitable groundwater resource in terms of quality or yield for potable or non-potable requirements. However, water could potentially be sourced from existing Karratha supplies including the Harding Dam (surface water resource) and/or the Millstream Borefield (groundwater resource).

2.8 Acid Sulphate Soils

The Department of Environment and Conservation (DEC) Acid Sulphate Soil (ASS) mapping identifies a narrow margin on the eastern boundary of the Study Area as "Moderate to Low Risk" of acid sulphate soils occurring within 3m of natural soil surface (or deeper)" (DEC 2008), this is likely to be associated with the proximity of the adjacent creekline. The remainder of the site is mapped as "No Known Risk" (Figure 2).

2.9 Vegetation

Environmental Assessment performed by Coffey Environmental (2010) indicates the vegetation is not considered significant at the local, state or national level and there are no Threatened Ecological Communities (TEC) within the Study Area.

2.10 Aboriginal Heritage

Three Aboriginal archaeological sites have been identified within the Study Area as a result of an Aboriginal heritage survey (March 2010).

TPG (2010) advise that it is likely that a Section 18 clearance under the Aboriginal Heritage Act 1972 will be required for the development along with a comprehensive management plan where sites are to be retained.

3. PROPOSED DEVELOPMENT

The proposed Structure Plan (TPG, 2010) for the Study Area is shown in Figure 6. It shows that land use in the proposed development will consist of a mixture of varying densities of residential (R17.5 to R60), mixed use commercial and various pockets of public open space (POS) areas integrated with drainage.

The POS areas will have a dual function of provision of active and passive recreational form integrated with drainage swales to convey stormwater runoff to Madigan Creek. The drainage swales will vary in base width being smaller upstream and larger downstream all within the allocated POS area. They will have a shallow profile 0.575m and in some locations may form a special feature with an elevated footbridge etc.

The alignment with Madigan Creek will be retained as existing and the interface with the development to be integrated with potential future open space.

4. LOCAL WATER MANAGEMENT STRATEGY

The proposed Local Water Management Strategy for the Study Area is outlined in this section. It includes discussions regarding water use and conservation, and details key elements of groundwater and surface water with respect to demonstrated best management practice in water sensitive urban design.

Issues related to implementation are discussed in Section 5.

4.1 Water Use & Sustainability Initiatives

The supply and sustainable use of water within the proposed development are key components of the management strategy.

4.1.1 Water Sources

A development scale water reuse scheme is not planned for the Study Area.

Potable water supply to the Study Area is proposed from the scheme water serviced via an extension of the Water Corporation's existing infrastructure for the Karratha town. It is envisaged that potable water supply will be used for in and ex house uses.

The use of groundwater as a non-potable water supply source, particularly for POS irrigation purposes, is considered unlikely due to poor yields from the nature of the fractured rock aquifer. POS areas will be landscaped appropriately for the climatic conditions and any area requiring irrigation will be minimal. Irrigation water source will be from the scheme water supply.

4.1.2 Water Conservation

Development of the Study Area will lead to an increased demand for water for domestic supply as well as irrigation of public open space. Water conservation measures will be promoted to reduce scheme water consumption within the development and will be consistent with Water Corporation's "Waterwise" land development criteria which could include:

- Promotion of use of waterwise practices including water efficient fixtures and fitting (taps, toilets and appliances, waterwise landscaping, plumbing for grey water reuse).
- Use of native vegetation requiring less irrigation in proposed drainage swales and public areas.
- Rainwater tanks as one method of collecting roof stormwater for possible reuse. However given the low rainfall pattern of the region, viability will need to be assessed prior to implementation.
- Opportunities for localised capturing and storing of rainfall runoff within the drainage swales and Madigan Creek will also be investigated during landscape design to assist in enhancing the creek ecosystem and support vegetation growth.

Specific measures to achieve water conservation will be detailed in the UWMP.

4.1.3 Non Potable Water Supply & Water Balance

A water balance at the LWMS stage is generally requested to support the identification of excess water generated by the development for potential use as a non-potable water supply scheme.

Based on geotechnical investigations (Section 2.3) opportunities for infiltration (pre and post development) and storage of stormwater for reuse in the Study Area are limited. Furthermore, recharge and abstraction from the superficial aquifer for non potable use is considered unlikely due to the presence of subsurface clay.

Whilst development generally leads to an increase in the post development peak flow and volume of surface water discharge to the receiving environment, the limited infiltration and high runoff rates are similar for both pre and post development condition. Consequently, change in landuse to post development generates limited excess water from a water balance perspective.

4.2 Surface Water Management

Management of surface water in the Study Area following development involves mitigating the impacts from flooding and designing a suitable stormwater system to convey and improve water quality.

4.2.1 Flood Management Concepts

Local stormwater management is proposed to be undertaken consistent with water sensitive design practices and meet key objectives and criteria as detailed in Table 2. The main emphasis of the drainage design is to overcome the need for the traditional deep drainage gullies that currently exist throughout the town site and to integrate them into the POS (Figure 6).

The local stormwater management system will consist of a series of shallow drainage swales with the aim of safely conveying stormwater from the Study Area to Madigan Creek. The drainage swales will also attenuate peak surface water flows, and provide water quality treatment for the proposed development prior to discharge from the Study Area. Due to the large rainfall intensity and volumes experienced in the Pilbara region, conveyance of stormwater is via open drainage systems rather than underground pipe systems.

The stormwater drainage system will be designed using a major/minor approach. The minor drainage system is defined as the system of swales, kerbs, gutters etc. designed to carry runoff generated by low frequency ARI storms, typically less than 5 year ARI. The major drainage system is defined as the arrangement of roads, drainage swales and open space areas planned to provide safe passage of stormwater runoff from extreme events which exceeds the capacity of the minor system.

As the Shire of Roebourne do not have a standard rainfall event (ARI) criterion for design of stormwater drainage systems, a design criteria of 20yr ARI has been adopted for the drainage swale sizing. This design criteria is consistent with that generally adopted by Main Roads WA.

4.2.2 Minor Road Design

Minor roads are all roads other than those that are located adjacent to the drainage swales. The minor roads will convey stormwater runoff generated by impervious areas from both the lots and the road reserve via the road gutter system into the main drainage swales.

These roads will be crowned at the centre with stormwater runoff contained within the depth of the kerb for rainfall events up to the critical 5yr ARI. For rainfall events greater, stormwater runoff may exceed the depth of the kerb and utilise part of the road reserve as the overland flow path prior to discharge into the drainage swale.

Locations where flow from these minor roads discharge into the drainage swale will be sufficiently protected by rock armour or engineering structures such as drop structures to assist in minimising or preventing scouring and erosion.

4.2.3 Drainage Swale Design

Drainage swales are arranged in an east-west orientation and form part of the POS. In some instances they are located adjacent to a road designed with a one way crossfall for runoff to flow directly into the drainage swale. They convey stormwater runoff from both the adjacent road and the minor roads to Madigan Creek by the shortest route.

The drainage swales are located within POS areas and have varying base widths being smaller upstream to wider downstream as the contributing flow areas increase. The base width may also vary due to landscaping treatments and erosion control measures to be detailed during detailed design. The swales will have a nominal depth of 0.575m to maintain a shallow profile for urban form and allow integration of drainage function with passive POS.

The drainage swales flow under cross roads via culverts and over cross roads as a spillway for events greater than 20yr ARI. The culverts have varying widths and a maximum height of 375mm to assist in maintaining the low profile of the swale. The spillway level of the cross road is nominally 200mm above the culvert resulting in swale depth of 575mm prior to overflow. Attenuation of flow is achieved within the drainage swale by the culverts.

Note that the use of culverts have been proposed to pass flow under the cross roads to minimise the occurrence of stormwater runoff and associated silt flowing over the cross roads during storm events. However during further detail design, there maybe opportunities to avoid the use of culverts and use the cross roads spillways for all conveyance where:

- Some dust/minor silt conveyance is acceptable to the Shire given its likely infrequency and low level of impact;
- A design solution to silting is developed;
- Topography or landscape design intent make a small bridge a more appropriate or attractive option to shallow culverts.

At some locations, the drainage swale junction at cross roads maybe designed as a feature with elevated footpaths or pedestrian bridges over spillways. Similarly, cross road junctions along the eastern boundary road with Madigan Creek maybe designed into feature bridges with speed bumps for safety. Further detail of these designs will be investigated during detail design and presented in the subsequent Urban Water Management Plan (UWMP).

The swales will be landscaped with native vegetation to assist in improving water quality and contain strategically placed boulders to minimise scouring and erosion. French (1985) recommends a maximum design velocity of 1.1m/s to protect against erosion and scouring for alluvial silts and ordinary firm loam which are considered representative of the Study Area.

For safety purposes, the product of depth and velocity shall not exceed $0.4m^2/s$ (IEAust, 2000).

The swales will not contain any permanent open water bodies, an approach consistent with the DoW's current policy on the use of constructed lakes for stormwater management.

Minimum building floor levels will be 0.5m above the estimated 100yr ARI flood level, consistent with Australian Rainfall & Runoff (AR&R) (Institution of Engineers, Australia 2000).

4.2.4 Pre-development Discharge Modelling

Pre-development modelling has been performed to determine discharge rates for post development comparison.

A simple method of analysis is using the Rational Method for the North West Region as outlined in AR&R (IEAust 2000). However, in this instance the size of the Study Area catchment is $0.68km^2$, notably less than the minimum size of the range of catchments used (40.5 to $7980km^2$) to derive the Rational Method formula for the North West. Consequently peak flow estimates from the Rational Method are not reliable.

An alternative method for estimating pre-development flow rates is using the rainfall runoff routing model RORB, which was used to prepare the Madigan Creek Flood Study (JDA, 2010). Based on topographic contours, the Study Area falls within a sub-catchment of Madigan Creek from which pre-development flow estimates have been calculated as part of catchment modelling using RORB.

The loss model adopted in the Madigan Creek Flood Study assumed a 100% runoff coefficient with a 5mm initial loss and a 2mm/hr continuing loss. This loss model was similar to that adopted by GHD (2010) for the neighbouring Seven Mile Creek catchment. The Flood Study found that the 30min to 1hr rainfall event was the critical duration for all ARI's.

Modelling results from RORB from the Flood Study based on a pro-rata assessment of flows estimated for the Madigan Creek catchment ($[Area_1/Area_2]^{0.7}$) indicate flows for the Study Area as follows:

- 5yr ARI: 12 m^3/s
- 20yr ARI: 19 m^3/s
- 100yr ARI: 30 m^3/s

Note that for the minor surface runoff that flows westwards towards Seven Mile Creek through the existing single 300mm diameter culverts at two locations along Madigan Rd, the culverts have not been installed to convey a specific design flow. Consequently, maximum flow through these culverts have been estimated to be equivalent to pipe full capacity of $0.34m^3/s$ for the two culverts combined. For the surface runoff that overflows north through the cemetery to Madigan Creek during large rainfall events, the flow estimate is included in the above assessment for the Study Area.

4.2.5 Post Development Stormwater System Design

Conceptual stormwater modelling was performed for the Study Area using the model XP-STORM to determine post development flood storage requirements and assess whether sufficient area has been provided within the POS in the Development Plan for drainage purposes. Modelling was based on the proposed land use plan shown in Figure 6.

The design storms modelled by XP-STORM for pre-development were calculated internally by the model with reference to the methodology in Australian Rainfall & Runoff (AR&R) (Institution of Engineers, Australia 2000). The rainfall temporal pattern was assumed to be spatially uniform across the catchment. Storm durations modelled ranged from 10 minutes to 72 hours for the 5yr, 20yr and 100yr ARI storm events.

Eight drainage swales are proposed with the post development catchments shown on Figure 7. Catchment boundaries are based on each drainage swale having a connecting minor road with a maximum length of 200m. This is the maximum length the minor road can be to convey the critical 5yr ARI 1hr rainfall event without flow exceeding the road gutter depth.

The loss model adopted for the modelling assumed a 5mm initial loss from both the Lot and Road Reserve areas. A conservative runoff rate of 100% was also applied to both these areas for the 5yr, 20yr and 100yr ARI rainfall events.

For Catchments 1 to 7, the drainage swales will have a minimum longitudinal grade of 1 in 500 with the downstream invert set at the current existing natural surface at the boundary of the Study Area. The elevations at these locations are approximately 0.5m above the adjacent invert of Madigan Creek. A free outfall condition into Madigan Creek was adopted for this modelling as these inverts are above the modelled post development flood levels of Madigan Creek (Figure 8).

The drainage outlets into Madigan Creek are to be appropriately designed during detail design with sufficient protection such as rock armouring, drop structures or concrete spillways to prevent or minimise scouring and erosion.

For Catchment 8, a drainage swale will be naturally formed along the east side of Madigan Rd in the road reserve between the raised Madigan Rd and the Development area. All stormwater runoff discharges through the existing 300mm diameter culverts at two locations with no overflow north through the cemetery and back towards Madigan Creek.

Culvert inverts and widths at cross roads have been modelled with the same invert and width of the upstream drainage swale.

The drainage swales have been designed to contain the critical 20yr ARI rainfall event within the designated POS area with a maximum flood depth of 0.575m. This is the maximum swale depth prior to overflow onto the adjacent road and over the cross road spillway. Base widths varied in size from upstream to downstream and modelling has been performed to determine absolute minimum widths prior to incorporation of any erosion and velocity reducing measures, sedimentation areas and landscaping treatments that may require wider swale widths.

4.2.6 Post Development Stormwater System Modelling Results

Stormwater modelling results for the drainage swale in each catchment for the critical rainfall duration (ranging between 30min and 1hr) for the 5yr, 20yr and 100yr ARI are presented in Figures 9 to 16. These figures show flood level and flows as longitudinal sections together with the modelled minimum swale widths. Recommended swale widths have also been presented on these figures to ensure erosion and velocity reducing measures, sedimentation areas and any landscaping treatments can be accommodated during detailed design.

Modelling results indicate that the POS areas allocated within each drainage catchment can sufficiently accommodate stormwater runoff for up to the critical 20yr ARI rainfall event within the swale design depth of 0.575m, and without flow over the cross road spillway. For events greater up to the critical 100yr ARI rainfall event, flow occurs over the cross road spillway with a maximum depth of approximately 0.2m and all flow is contained within the road reserve.

Total combined flows from the drainage swale outlets (Catchment 1 to 7) to Madigan Creek for the 5yr, 20yr and 100yr ARI are approximately 13m^3/s, 21m^3/s and 38m^3/s respectively. These are similar to the pre-development flows calculated in RORB for the 5yr and 20yr ARI as shown below. The 100yr is slightly larger however this increase of approximately 8m^3/s is considered negligible compared to estimated 100yr flow in Madigan Creek at Dampier Highway of approximately 99m^3/s.

- 5yr ARI: 13 m^3/s (pre-development 12 m^3/s)
- 20yr ARI: 21 m^3/s (pre-development 19 m^3/s)
- 100yr ARI: 38 m^3/s (pre-development 30 m^3/s)

For Catchment 8, the swale modelled in the Madigan Road reserve with the existing single 300mm diameter culverts at two locations under Madigan Rd can contain up to the 100yr ARI with a maximum flood depth of 1m. Combined post development discharge from the two culverts for the 5yr, 20yr and 100yr ARI are approximately 0.26m^3/s, 0.30m^3/s and 0.34m^3/s respectively, similar to the pre-development maximum culvert capacity of 0.34m^3/s.

Maximum velocity modelled within one section of a drainage swale is 1.8m/s, exceeding the recommended maximum design velocity of 1.1m/s to protect against scouring and erosion of in-situ material. However it is considered that refinement of the drainage swale dimensions (widening base width), modelling parameters and inclusion of engineering structures (where appropriate) during detail design will reduce velocity within the recommended design limit and be presented in the UWMP.

From a safety perspective, the product of velocity and flood depth should not exceed 0.4m^2/s. Although this applies to stormwater flow on the road system, it has also been conservatively applied to the drainage swales within the POS. A maximum of 0.6m^2/s has been modelled within a section of a drainage swale. As described above, refinement of the drainage swale during detailed design will reduce this factor to within recommended design limits.

A sensitivity analysis was also performed assuming a backwater condition of a 100yr ARI flood level in Madigan Creek being 0.5m above its existing invert. This results in a negligible impact on the 100yr ARI flood levels within the drainage swales.

Figure 17 presents a snapshot of the event plans for the 5yr, 20yr and 100yr ARI rainfall events.

Overall, the modelling results indicate that there is sufficient area within the allocated POS area to contain the required drainage swale for the post development catchments for up to the critical 100yr ARI event.

The final drainage swale configuration (area, side slopes etc) and location will be documented in the UWMP and will be dependent on final earthworks, drainage and road design levels for the development. Minor changes (refinements) in catchment areas shown in this report are therefore considered likely to occur as detailed design proceeds.

Discussion regarding the system compliance with DoW requirements is contained in Section 4.7.

Landscaping design for POS areas will be undertaken in conjunction with detailed design and preparation of the UWMP for agency approval during subdivision.

4.3 Groundwater Management

A groundwater management strategy is required to ensure the required separation between building floor levels for development and groundwater level is achieved.

As discussed in Section 2.5, the watertable is approximately 5-10m below the surface and may vary seasonally in depth by 2-3m in response to heavy rainfall. Consequently, as there is at least 2m of clearance to groundwater from the natural surface level, groundwater management such as subsoil drainage is currently not required.

Note that fill required to satisfy flood levels and geotechnical requirements are considered to be the critical factor in determining fill requirements rather than groundwater levels.

However, while this LWMS establishes criteria and the general approach for setting development levels, finished lot levels and fill requirements are a detailed design issue and will addressed during preparation of Urban Water Management Plans (UWMP's).

4.4 Vegetation Management

Native and endemic vegetation species are proposed to be incorporated into POS areas for landscaping treatments. Landscape plans and management details including planting locations and species will be prepared during detail design by a landscape consultant and summarised in the UWMP.

4.5 Water Quality Management

With respect to water quality management the LWMS proposes that the use of swales is appropriate treatment for minor events in the Pilbara region.

- **Non Structural Controls**
  Planning practices (wide road reserves to accommodate dedicated drainage swales)
  Construction practices (construction management, use of appropriate native plantings)
  Maintenance practices (of the swale systems)

- **Structural Controls**
  Infiltration of frequent events where possible (swales)
  Creation of ephemeral retention/detention areas
  Use of vegetated swales

Other water quality parameters such as oils, grease and hydrocarbons are considered to be treated by structural controls as specified by the Shire of Roebourne.

4.5.1 Assessment of Proposed Structural BMP's to Design Criteria

Table 3 details a summary from DoW's Stormwater Management Manual for Western Australia (2007) of expected pollutant removal efficiencies for vegetated swales and detention/retention systems in relation to the water quality design criteria previously discussed in Section 1.2. Expected nutrient input reductions via non structural measures calculated in Section 4.5.1 are also reported in Table 3.

While DoW (2007) does not provide expected pollutant removal efficiencies for all BMP's, application of a treatment train approach using a combination of non structural and structural measures detailed in Section 4.5 will therefore clearly achieve the design objectives for water quality.

Specific details on the location, scale of application, and responsibilities for individual BMP's will be addressed during development of the Urban Water Management Plan (UWMP).

TABLE 3: BMP WATER QUALITY PERFORMANCE IN RELATION TO DESIGN CRITERIA

Parameter	**Design Criteria via PDC(2006)** (required removal as compared to a development with no WSUD)	**Non Structural Controls** (refer Section 4.5.1) Nutrient Input Reduction	**Structural Controls** Nutrient Output Reduction [1]	
			Vegetated Swales	**Detention/ Retention Measures**
Total Suspended Solids	80%	-	60-80%	65-99%
Total Phosphorus	60%	45%	30-50%	40-80%
Total Nitrogen	45%	39%	25-40%	50-70%
Gross Pollutants	70%	-	-	>90%

1. Typical Performance Efficiencies via DoW (2007)

4.6 Construction Management

The potential presence of groundwater and acid sulphate soils may require management during construction of the proposed development.

4.6.1 Dewatering

Dewatering may be required for some elements of subdivision construction. Given the depth of construction, dewatering will only be in the superficial aquifer. As the volume of dewatering is generally minor and of a temporary nature, the overall impact on the aquifer will be minimal, although some drawdown will occur at the dewatering site.

Prior to the commencement of any dewatering, the construction contractor will prepare a Dewatering Management Plan consistent with the DoW's Water Quality Protection Note (WQPN 13, 2006) and apply for and obtain from DoW a "Licence to Take Water". All dewatering will be carried out in accordance with the conditions of this licence and the Dewatering Management Plan.

Where possible, construction will be timed to minimise groundwater impacts and dewatering requirement.

4.6.2 Acid Sulphate Soils

As previously discussed in Section 2.8, a narrow margin on the eastern boundary of the Study Area as "Moderate to Low Risk" of acid sulphate soils occurring within 3m of natural soil surface (or deeper)" (DEC 2008) (Figure 2).

During detail design, assessment and management of ASS is to be conducted in accordance with the Acid Sulphate Soil Guideline Series Identification and Investigation of Acid Sulphate Soils (DoE, 2004), including a Preliminary Site Assessment (PSA) involving a targeted soil and groundwater sampling and analysis program, detailed site assessment, and ultimately an ASS Management Plan if ASS occurs.

Should further investigations indicate the presence of ASS, during construction, appropriate handling methods will need to be employed by the construction contractor to manage any potential acid sulphate soils. Handling should be in accordance with the Acid Sulphate Soils Guidelines Series Treatment and Management of Disturbed Acid Sulphate Soils (DoE, 2004). These guidelines specify holding times and specific methods for treatment of such soils.

To confirm the status of soils, the site engineer/scientist will regularly inspect excavations and spoil, and ensure such soils where encountered are appropriately tested and managed before reuse or disposal.

4.7 Water Management Strategy Summary

Table 4 provides an overall summary of key elements of the proposed water management strategy for the Study Area, with an assessment of the strategy in relation to DoW (2007) principle objectives for stormwater management in Western Australia (Section 1.2.4).

TABLE 4: SUMMARY OF PROPOSED LOCAL WATER MANAGEMENT STRATEGY

Principle	Key LWMS Elements
Water Quantity To maintain the total water cycle balance within development areas relative to the pre-development conditions.	• Maintain flow paths for existing catchments • Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels. • No lowering of groundwater levels. • Maximise infiltration opportunities where possible.
Water Quality To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.	• Use of treatment train approach to stormwater management • Application of source controls – including education to reduce nutrient application, use of native plantings and vegetated swales. • Application of structural controls – retention/detention areas and vegetated swales.
Water Conservation To maximise the reuse of stormwater	• Encourage implementation of water efficiency and demand management measures both internal and external of buildings. • Use of native plantings to minimise irrigation requirements.
Ecosystem Health To retain natural drainage systems and protect ecosystem health	• Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels to the Madigan Creek.
Economic Viability To implement stormwater systems that are economically viable in the long term	• Use of proven structural WSUD technology. • Use of source control techniques to minimise cost of nutrient management.
Public Health To minimise the public risk, including risk of injury or loss of life to the community	• Design in accordance with relevant design standards, best management practices, council regulations and government agency requirements.
Protection of Property To protect the built environment from flooding	• Identification of 100yr ARI flood levels for Study Area. • Protection of downstream areas by restricting stormwater discharge to existing levels for storm events up to 100yr ARI.
Social Values To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater	• Use of swales within public areas for stormwater conveyance. • Integration of drainage and POS functions.
Development To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability & precautionary principles.	• Urban water management in accordance with Better Urban Water Management (WAPC, 2008). • Development of the LWMS in accordance with government agency guidelines and best management practice recommendations.

5. IMPLEMENTATION

Implementation of the Local Water Management Strategy involves defining the roles and responsibilities of the developer and local authority, outlining further documentation required to support the development and defining operation, monitoring and maintenance of the stormwater system.

5.1 Roles and Responsibilities

Table 5 details the roles and responsibilities to undertake the implementation plan.

The operation and maintenance of the stormwater management system will initially be the responsibility of the developer within the Study Area. Responsibility for all areas will ultimately be reverted to the local authority. Preparation of the UWMP will be the responsibility of the developer.

TABLE 5: IMPLEMENTATION RESPONSIBILITIES

IMPLEMENTATION		RESPONSIBILITY	
LWMS Section	**Action**	**Developer**	**Shire of Roebourne**
5.2	Preparation of an Urban Water Management Plan to support subdivision	✓	
5.3	Construction of stormwater system	✓	
5.3	Stormwater system operation and maintenance		✓

5.2 Subdivision Process

A UWMP for the Study Area will be submitted by the developer to the Department of Water and the Shire of Roebourne as required under relevant conditions of subdivision. The UWMP will address:

- Detailed stormwater management design including the size, location and design of swales, integrating major and minor flood management capability, landscape plants for the swales as related to stormwater function, specific details of local geotechnical investigations and their impact on stormwater design;
- Detail measures to reduce velocity of stormwater discharge to prevent erosion and sediment transportation.
- Management of groundwater levels, and if any proposed dewatering is necessary;
- Agreed/approved measures to achieve water conservation and efficiencies of use including sources of water for non-potable uses and detailed designs, controls, management and operation of any proposed system;
- Management of sub-divisional works (management of soil/sediment including dust)
- Implementation plan including monitoring program, roles, responsibilities, funding and maintenance arrangements. Contingency plans should also be indicated where necessary

5.3 Stormwater System Operation and Maintenance

Ongoing operation and maintenance of the drainage system will be the responsibility of the Shire of Roebourne. The surface drainage system will require routine maintenance to ensure its efficient operation. It is considered the following operating and maintenance practices will be implemented periodically:

- removal of debris to prevent blockages
- cleaning of sediment build up and litter layer on the bottom of drainage swales

A summary of the proposed maintenance schedule is presented in Table 6 below.

TABLE 6: MAINTENANCE SCHEDULE FOR DRAINAGE INFRASTRUCTURE

Item	Maintenance Interval		
	Quarterly	Biannually	As required
Drainage Swales			
Removal of debris to prevent blockages	✓		
Inspect for erosion + sediment accumulation		✓	
Assess health of vegetation. Remove dead plants and replace where necessary.	✓		
Removal of sediment and leaf litter layer build up.			✓

5.4 Monitoring Program

The stormwater management system outlined in this LWMS focuses on implementation of current known best management practice without the requirement of a post development monitoring program.

6. REFERENCES

Department of Environment (2004), Treatment and Management of Disturbed Acid Sulphate Soils, Acid Sulphate Soils Guideline Series, October 2004.

Department of Environment and Conservation (2008), Acid Sulphate Soil Mapping.

Department of Indigenous Affairs (2009), Aboriginal Heritage Enquiry System.

Department of Water (2006) Dewatering of Soils at Construction Sites

Department of Water (2007), Stormwater Management Manual for Western Australia, August 2007.

French, Richard.H. (1985), Open Channel Hydraulics.

JDA Consultant Hydrologists (2010), Madigan Creek Flood Study, December 2010 for LandCorp.

Institution of Engineers, Australia (2000), Australian Rainfall & Runoff

Institution of Engineers Australia (2006), Australian Runoff Quality.

Luke, G.L., Burke, K.L. & O'Brien, T.M. (1988). Evaporation Data for Western Australia – Technical Report 65. Perth: W.A. Department of Agriculture, Division of Resource Management.

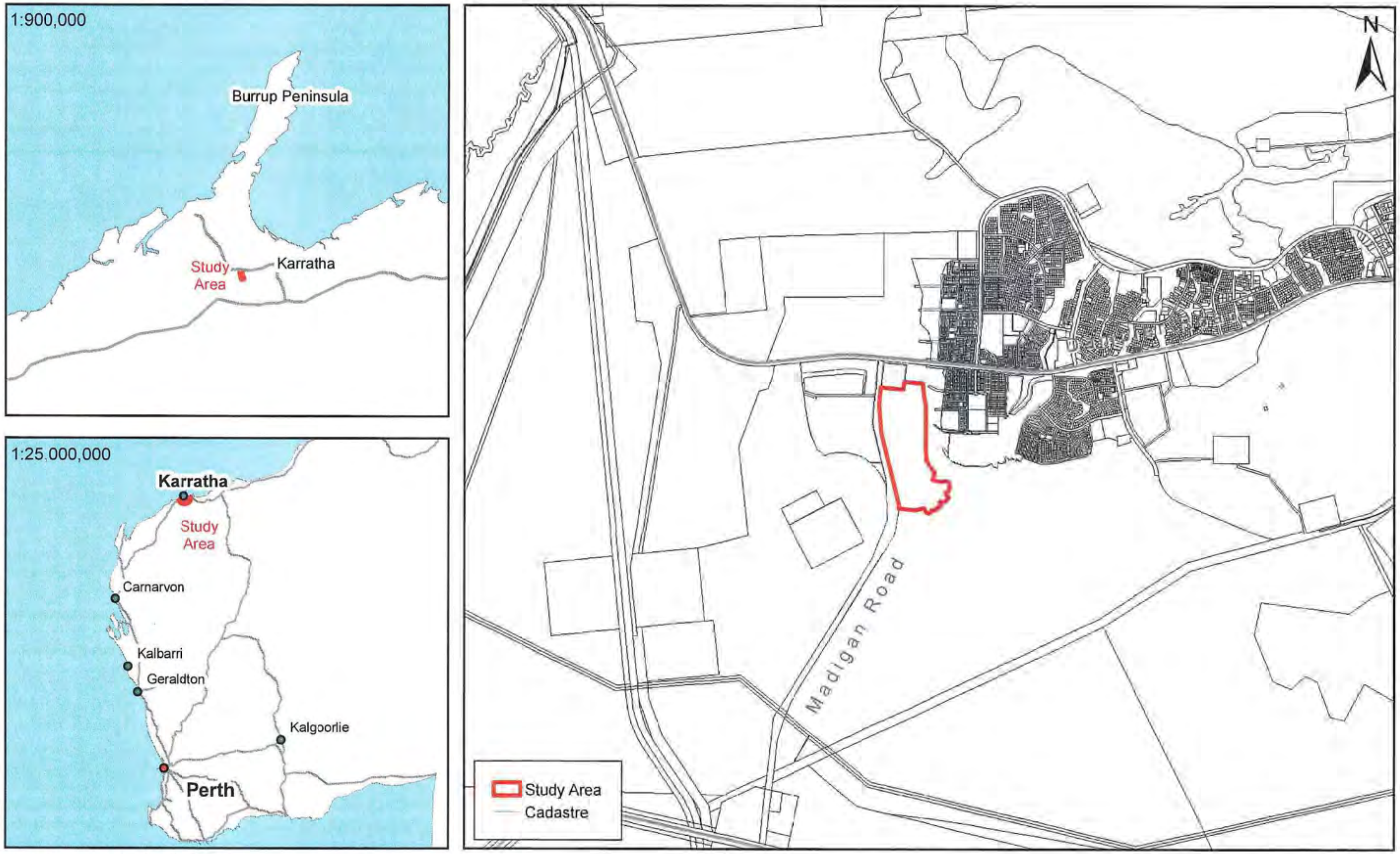
Western Australian Planning Commission (2003), WAPC Planning Bulletin 64, Acid Sulphate Soils, November 2003.

Western Australian Planning Commission (2005), Water Resources State Planning Policy 2.9.

Western Australian Planning Commission (2007), Liveable Neighbourhoods, A Western Australian Government Sustainable Cities Initiatives

Western Australian Planning Commission. (2008), Better Urban Water Management, October 2008

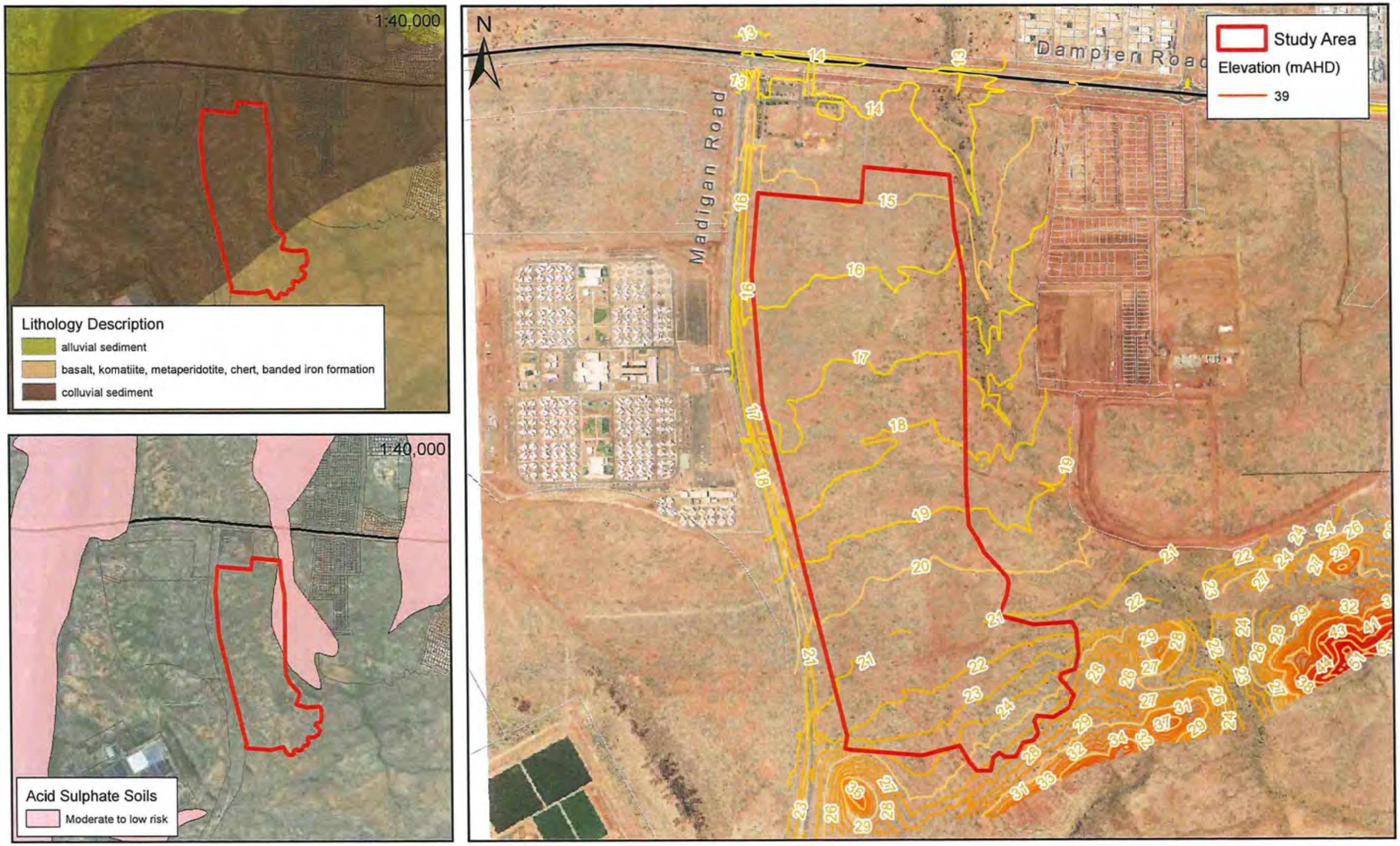
FIGURES



Data Source: WA Atlas (2010)

Job No. J4755
Scale: 1:60,000

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 1: Location Plan



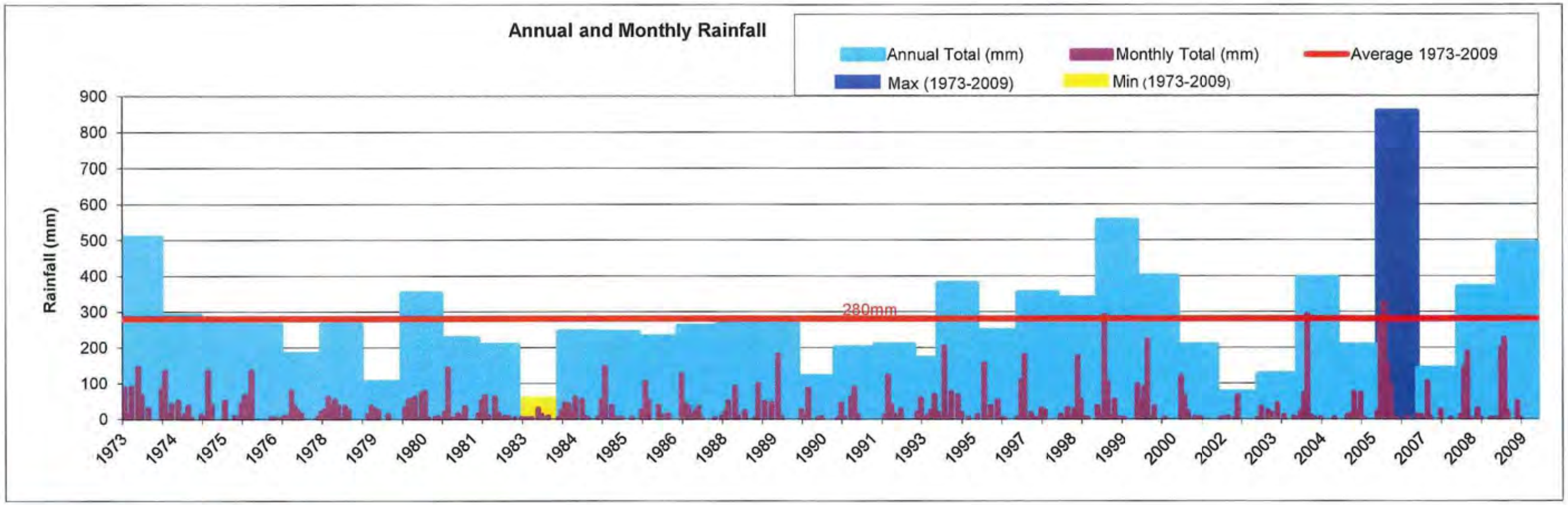
Data Source: DEC (2008), WA Surface Geology (2010), Landgate (2010)

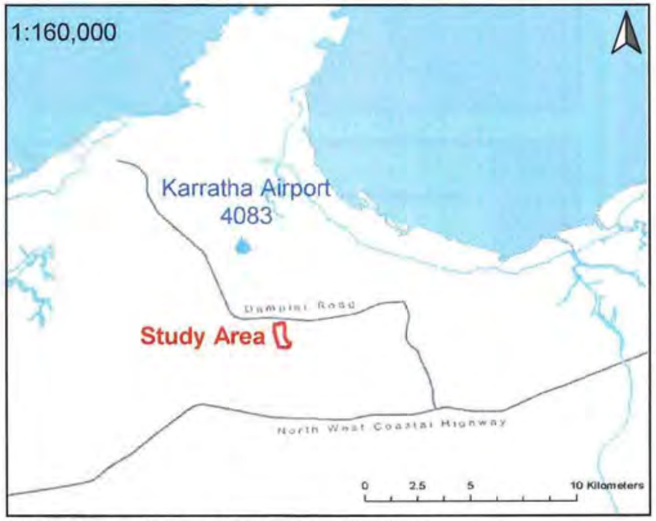
JDA

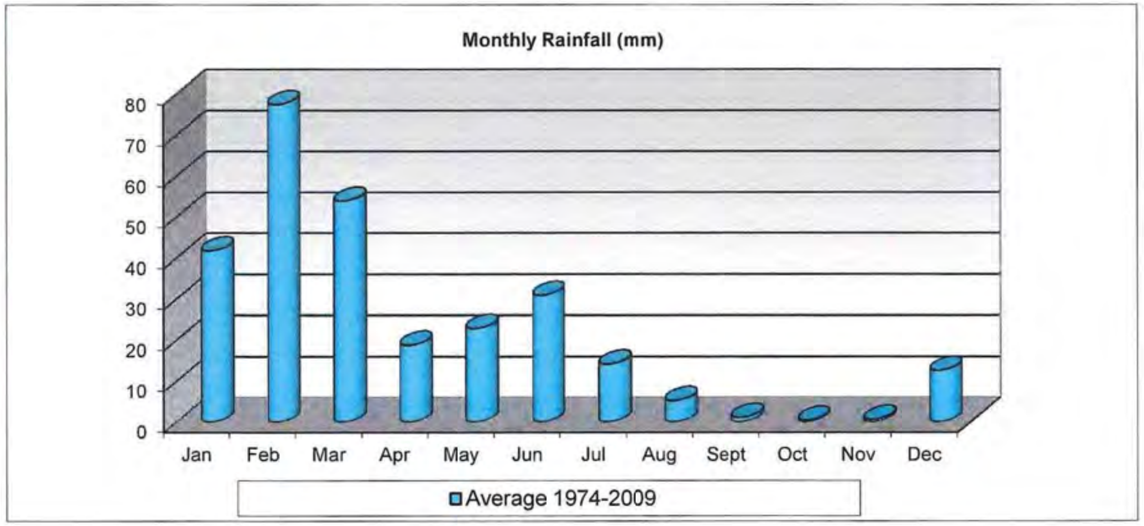
Job No. J4755
Scale:1:13,000
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS

Figure 2: Environmental Setting







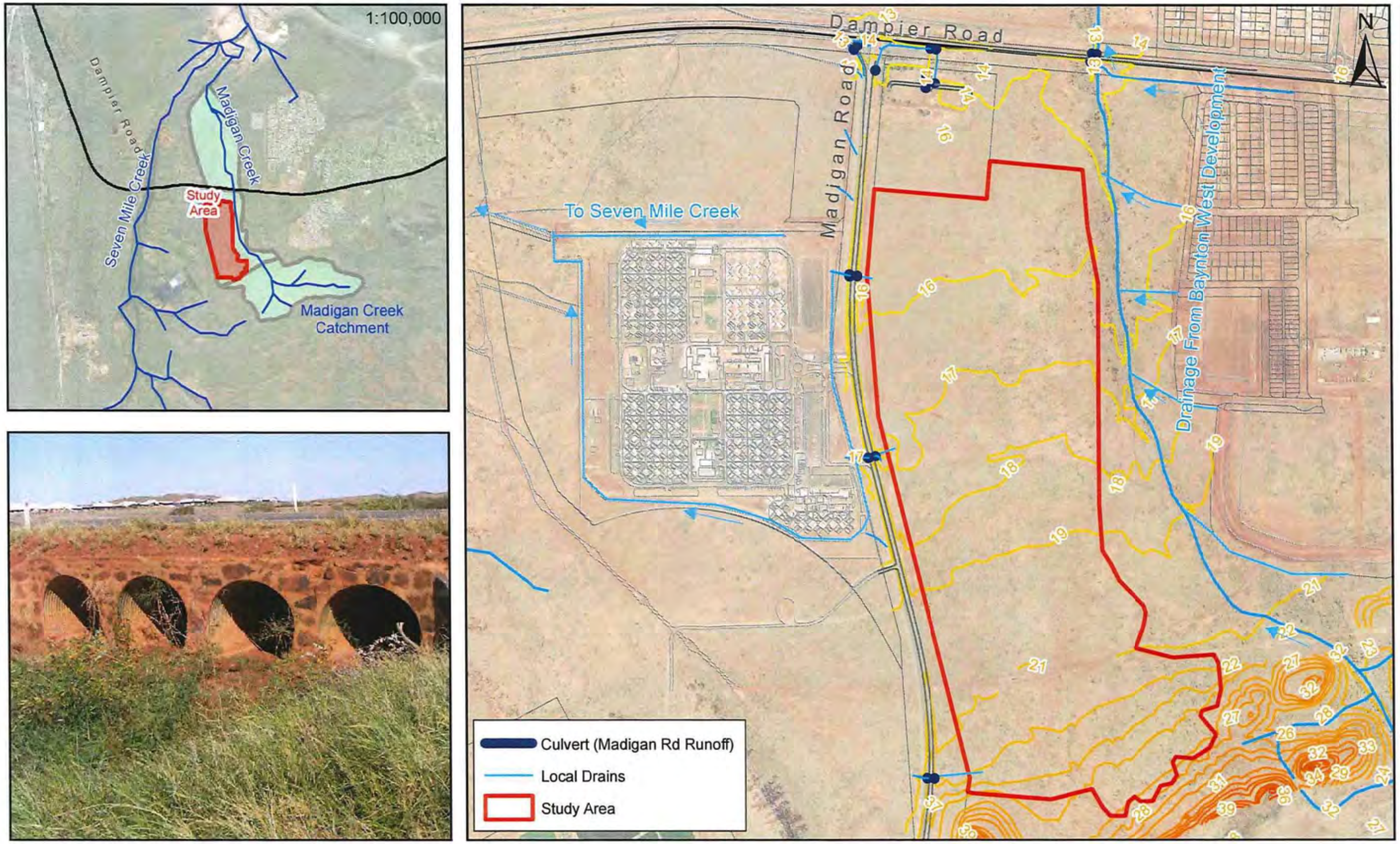
Data Source: Bureau of Metereology (2010)

Job No. J4755

LandCorp

Madigan Road Urban Development, Karratha - LWMS

Figure 3: Karratha Airport Annual and Monthly Rainfall

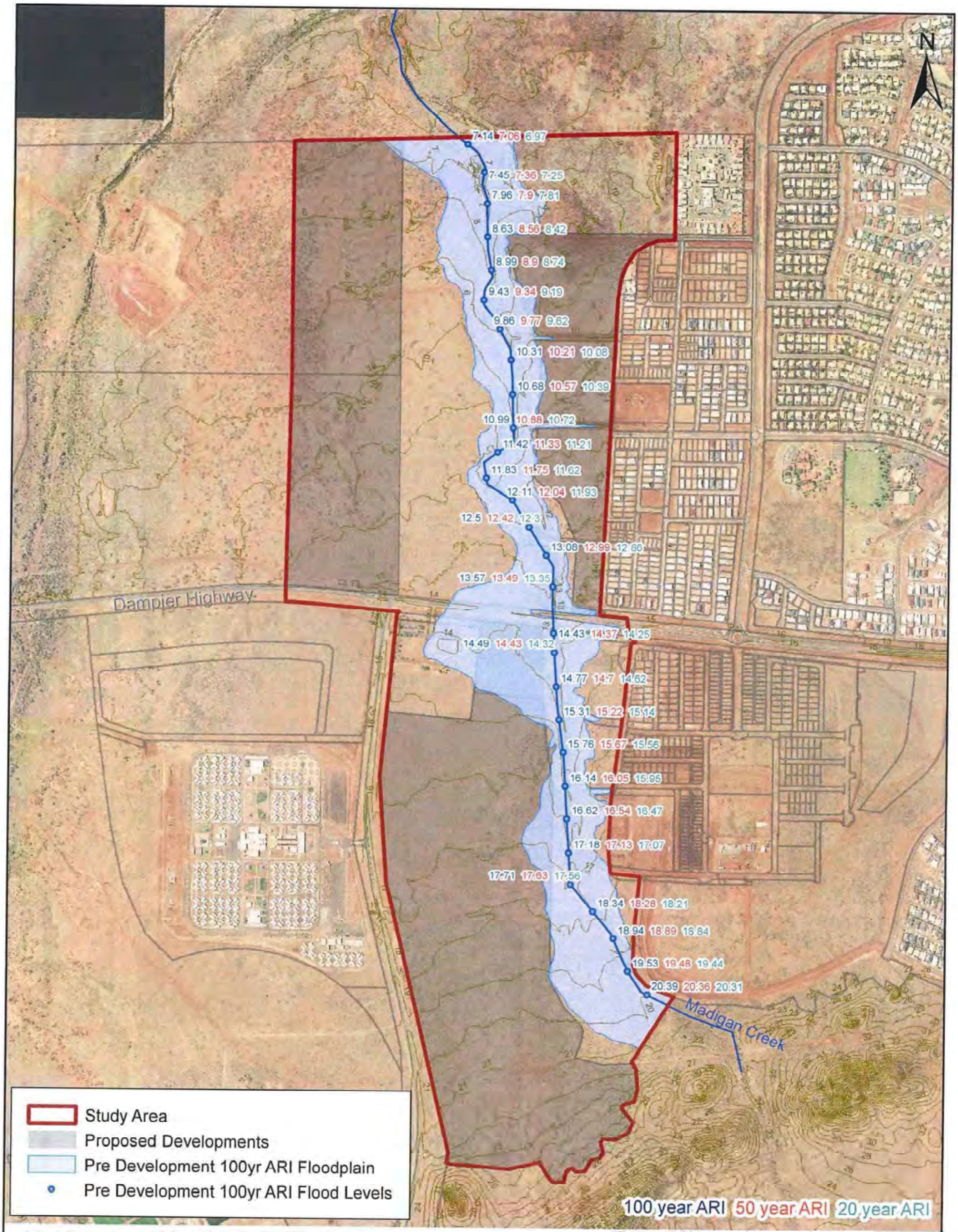


Data Source: DoW (2010)

Job No. J4755
Scale:1:12,000
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS

Figure 4: Surface Hydrology



Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA

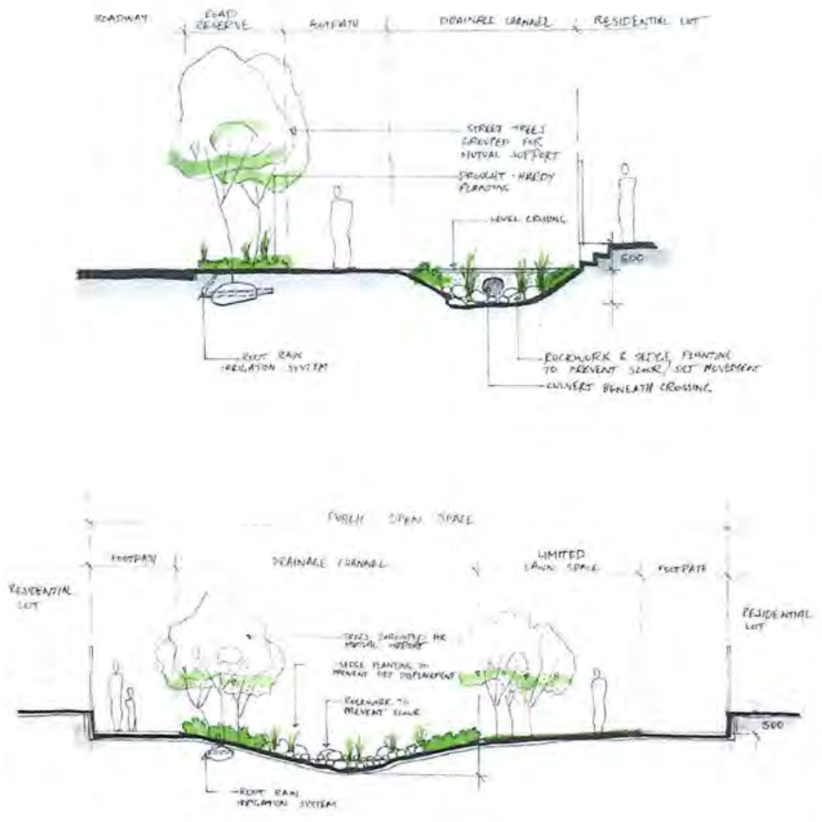
Job No. J4755
Scale 1:15,000

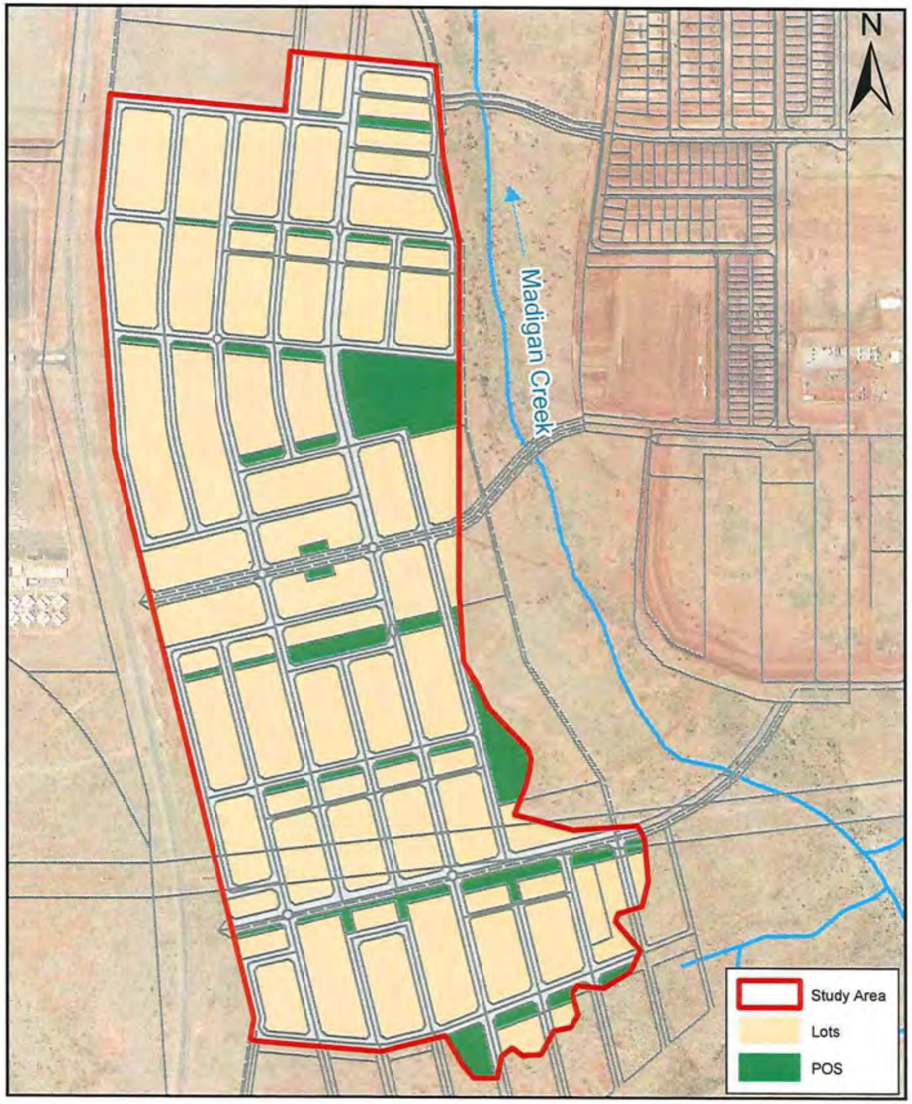
© COPYRIGHT JIM DAVIES & ASSOCIATES PTY. LTD. 2011

LandCorp
Madigan Road Urban Developmen. Karratha - LWMS

Figure 5: Madigan Creek Flood Study, Pre-Development Flood Levels

Concept Drainage Swale Cross Sections





Data Source: TPG (2011), EPCAD (2010)

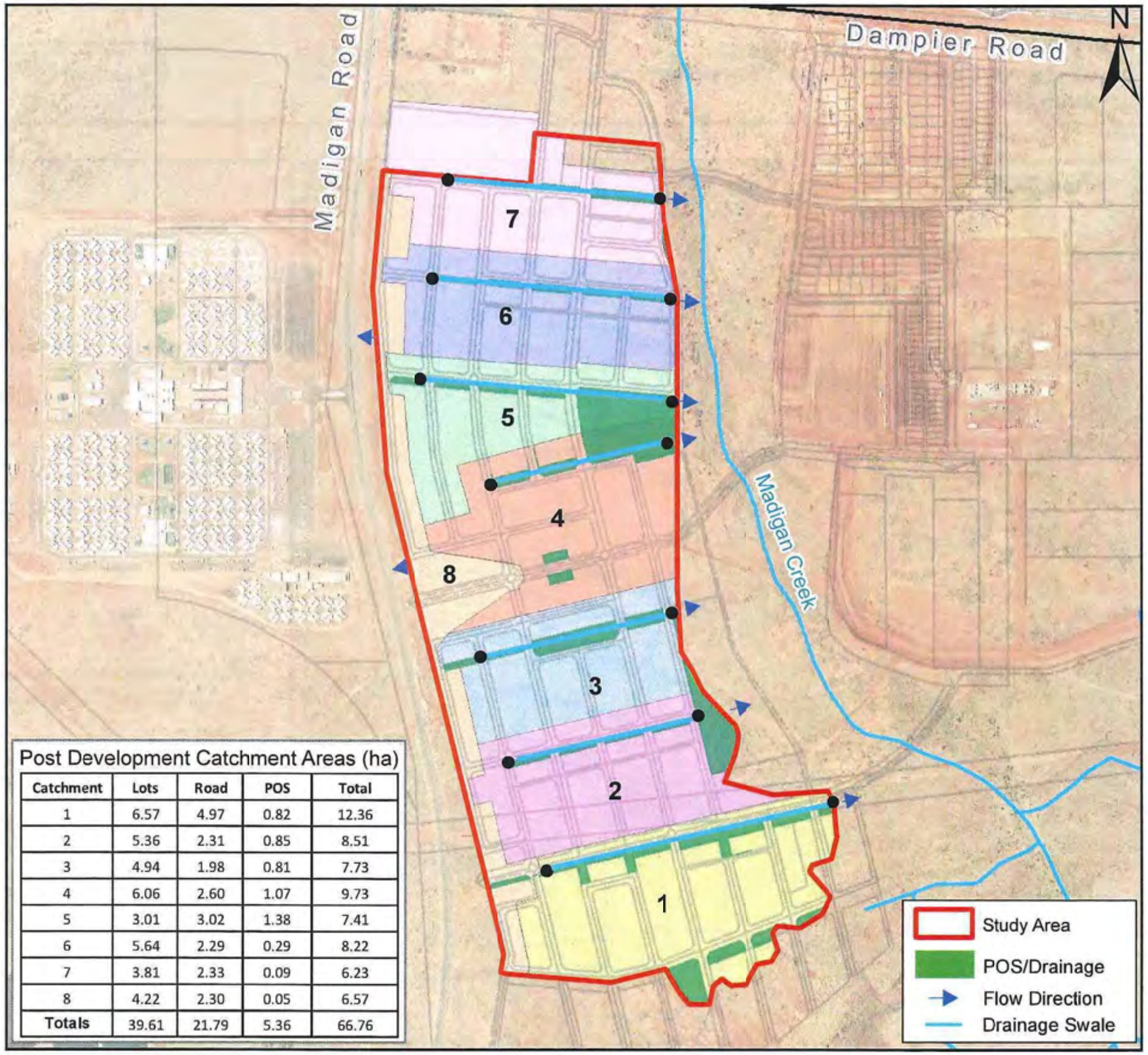
Job No. J4755
Scale: 1:10,000
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 6: Local Structure Plan

Stormwater Management Assumptions

- Drainage swales contained within POS areas
- Drainage swales have a shallow profile with 575mm depth
- Drainage swales flow under cross roads via culverts and over cross roads via spillways for events greater than 20yr ARI
- Culverts have varying widths and a maximum height of 375mm
- Downstream outlet invert set to existing natural surface (0.5m above existing Madigan Creek invert)
- Longitudinal gradient of swale 1:500
- Swales will be landscaped with native vegetation to assist in improving water quality and contain strategically placed vegetation and boulders to minimise scouring and erosion

Swale Design Concept



Post Development Catchment Areas (ha)

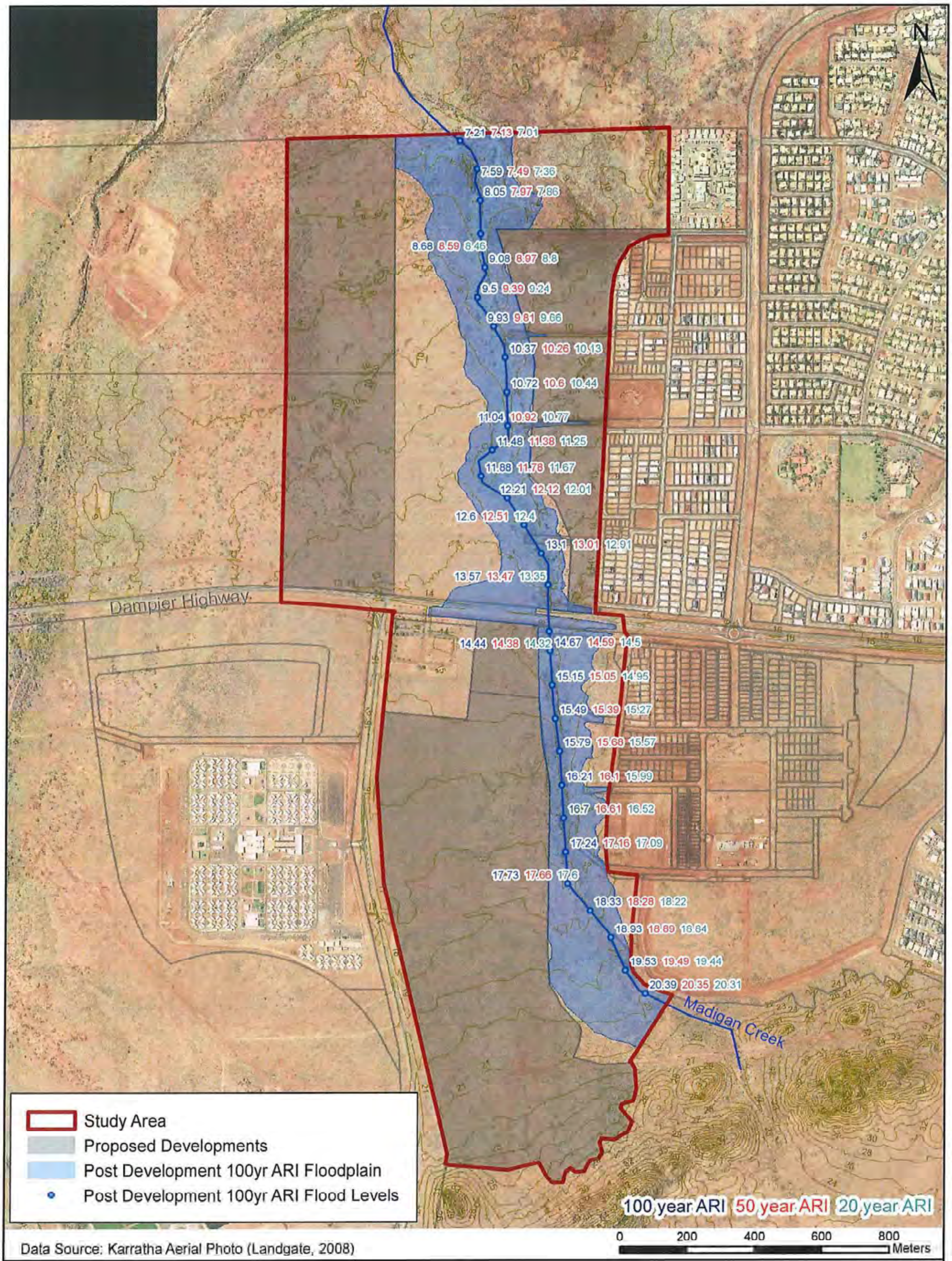
Catchment	Lots	Road	POS	Total
1	6.57	4.97	0.82	12.36
2	5.36	2.31	0.85	8.51
3	4.94	1.98	0.81	7.73
4	6.06	2.60	1.07	9.73
5	3.01	3.02	1.38	7.41
6	5.64	2.29	0.29	8.22
7	3.81	2.33	0.09	6.23
8	4.22	2.30	0.05	6.57
Totals	39.61	21.79	5.36	66.76

Data Source: TPG (2010), EPCAD (2011)

JDA

Job No. J4755
Scale: 1:11,000
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 7: Stormwater Management Plan



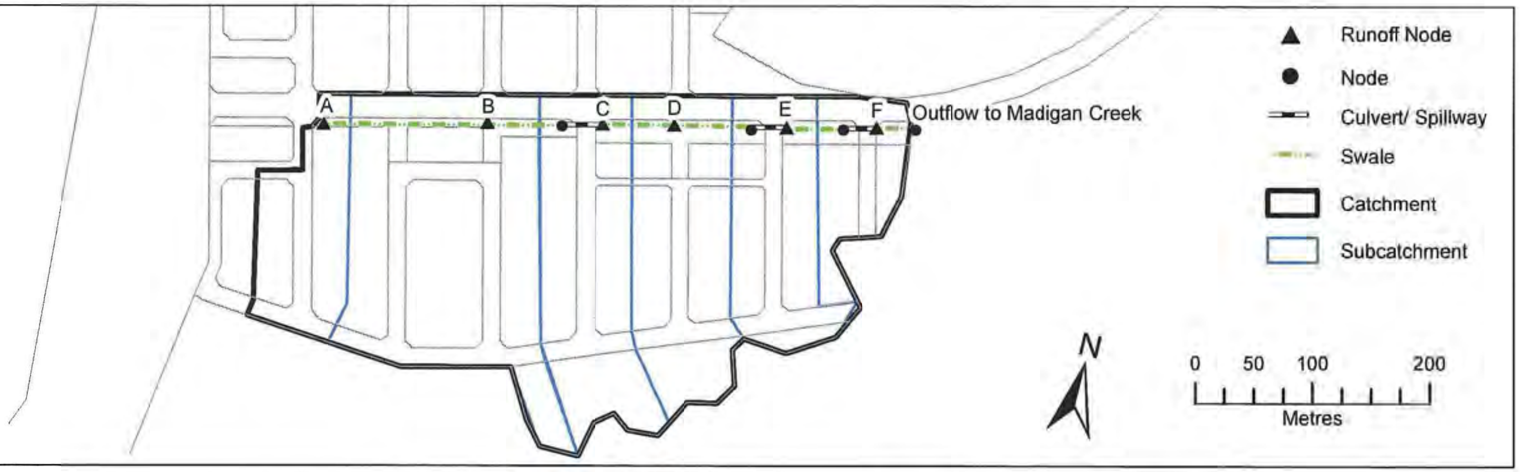
Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA

Job No. J4755
Scale 1:15,000

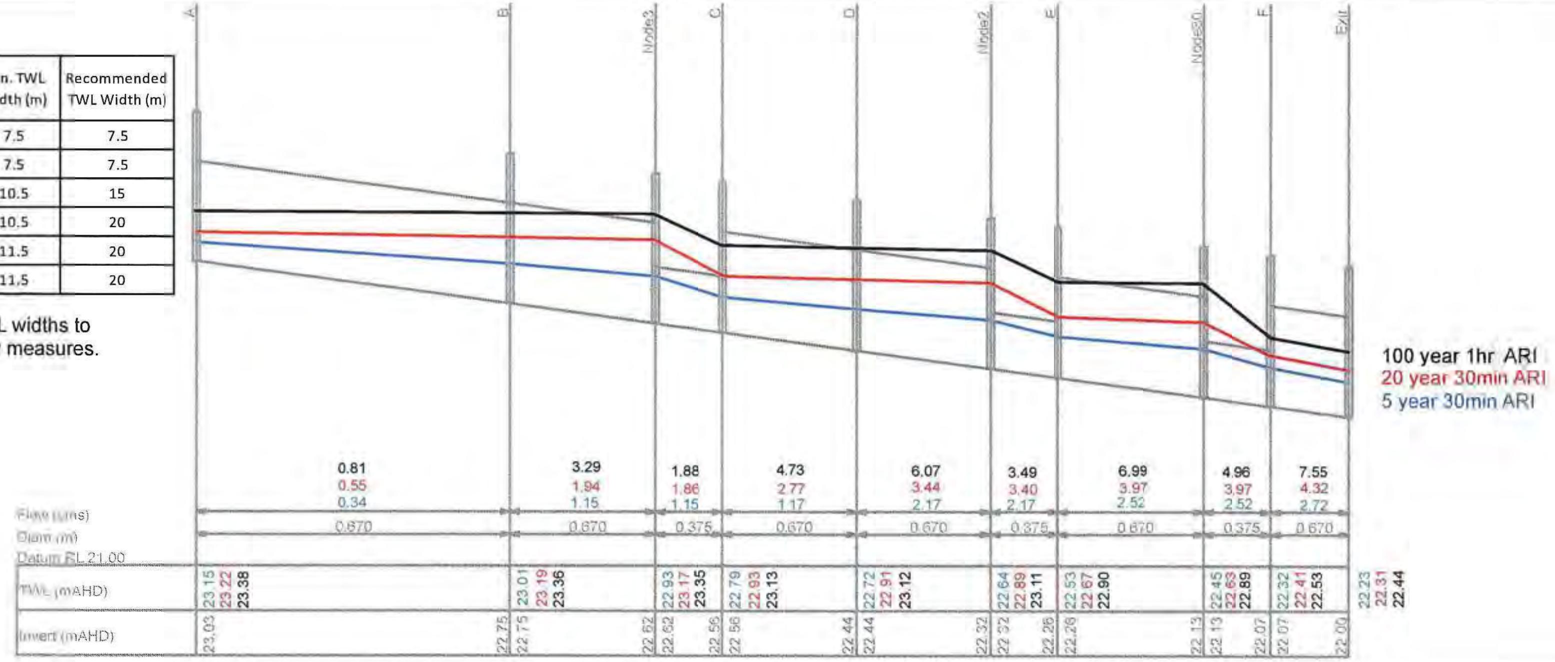
LandCorp
Madigan Road Urban Developmen. Karratha - LWMS

Figure 8: Madigan Creek Flood Study, Post-Development Flood Levels



Swale (m)	Min. Base Width (m)	Min. TWL Width (m)	Recommended TWL Width (m)
A	3.5	7.5	7.5
B	3.5	7.5	7.5
C	6.5	10.5	15
D	6.5	10.5	20
E	7.5	11.5	20
F	7.5	11.5	20

NOTE: Recommended TWL widths to allow for erosion and safety measures. (Section 4.2.6)



JDA

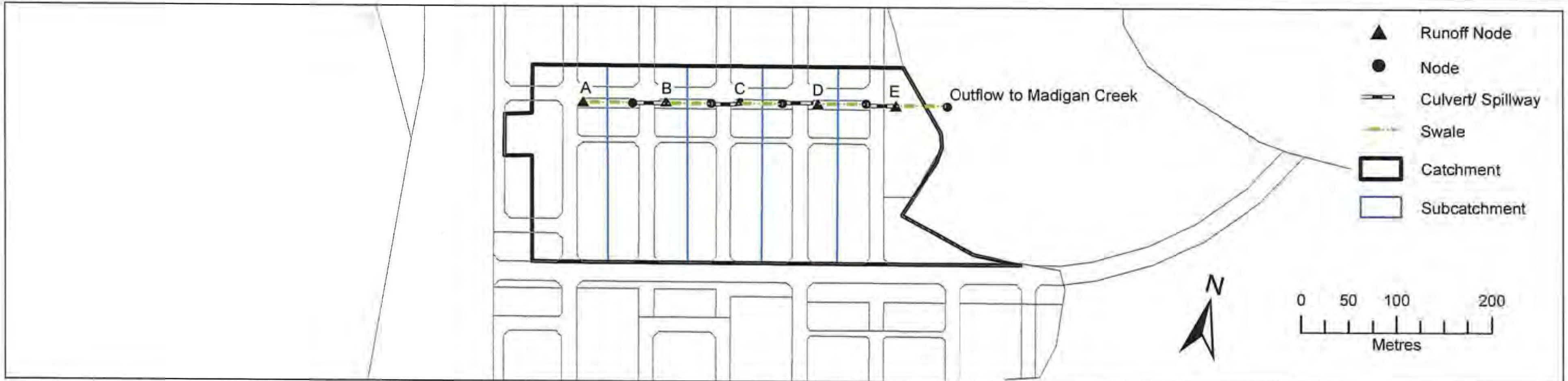
Job No. J4755

1:6,000

LandCorp

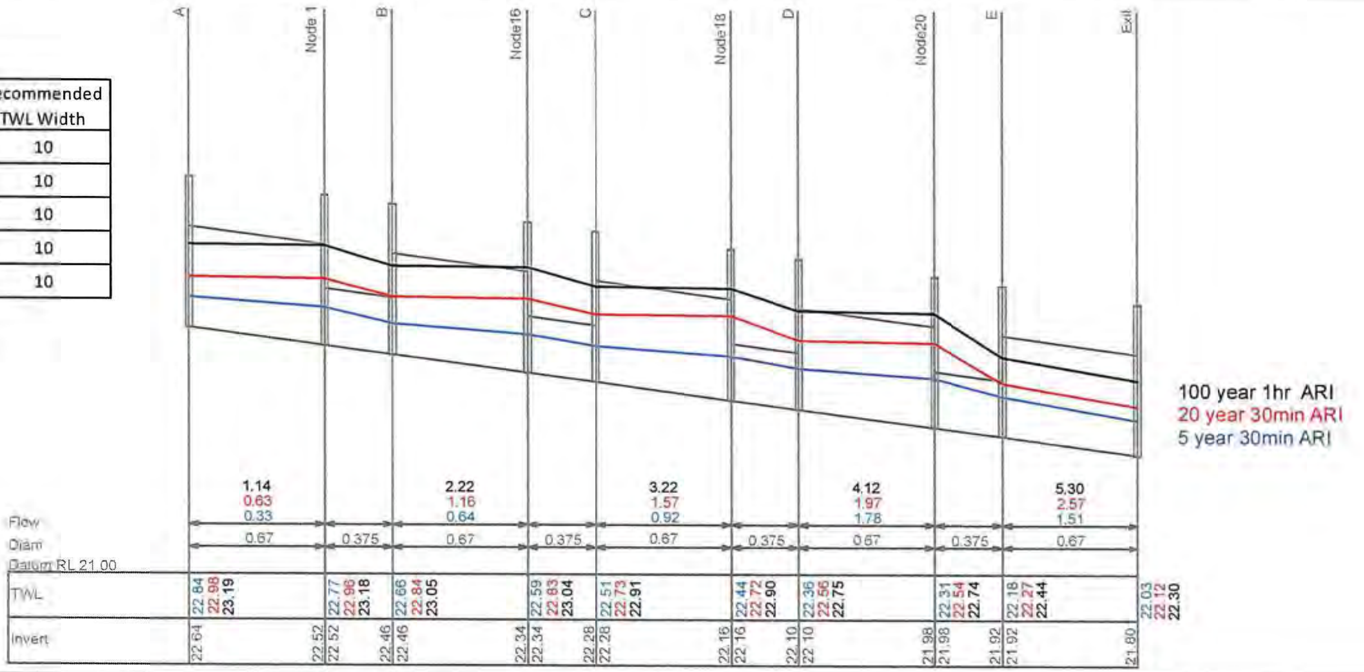
Madigan Road Urban Development, Karratha - LWMS

Figure 9: Catchment 1 Profile Plot for 5yr, 20yr & 100yr ARI



Swale	Min. Base Width	Min. TWL Width	Recommended TWL Width
A	1.5	5.5	10
B	3	7	10
C	3.5	7.5	10
D	3.5	7.5	10
E	4	8	10

NOTE: Recommended TWL widths to allow for erosion and safety measures. (Section 4.2.6)



JDA

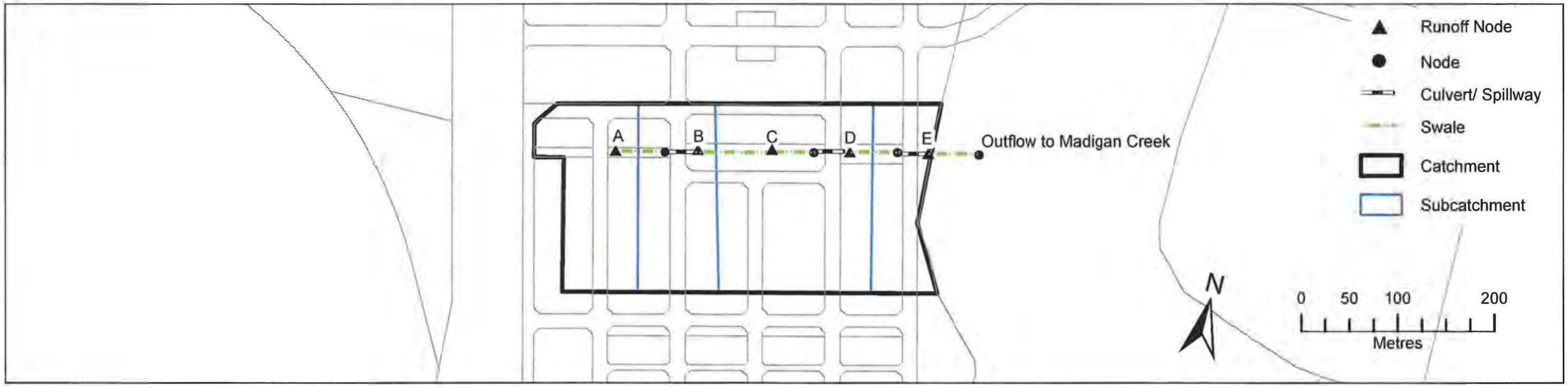
Job No. J4755

1:6,000

LandCorp

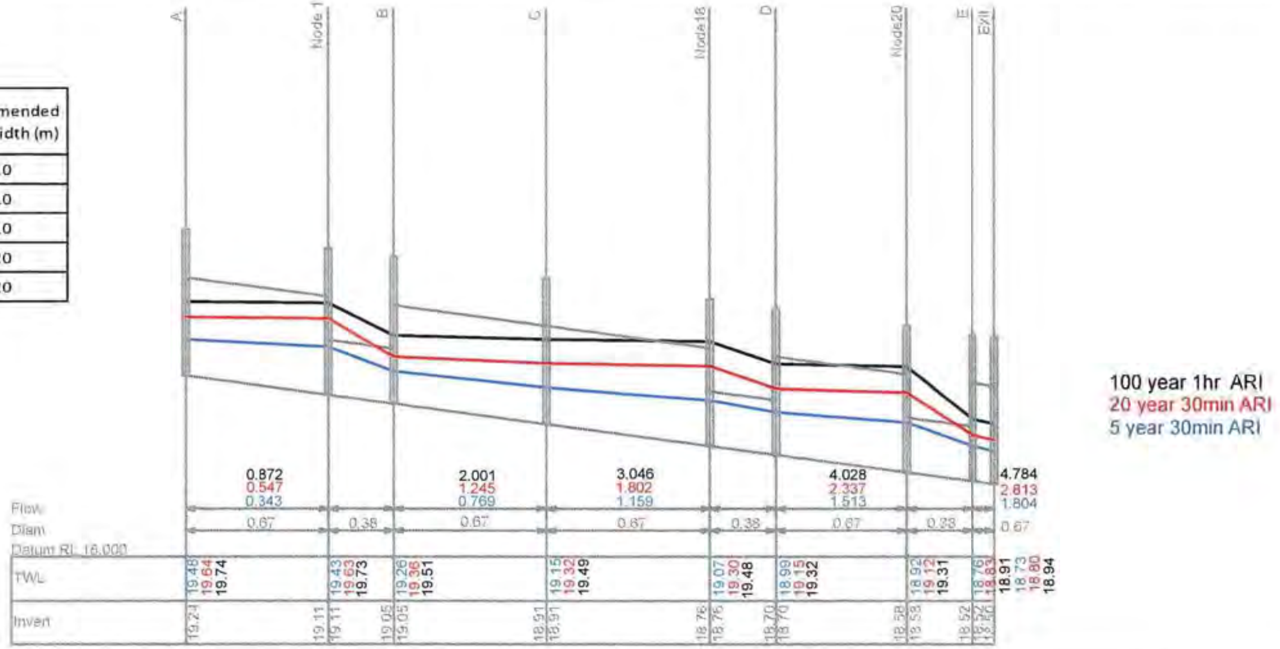
Madigan Road Urban Development, Karratha - LWMS

Figure 10: Catchment 2 Profile Plot for 5yr, 20yr & 100yr ARI



Swale (m)	Min. Base Width (m)	Min. TWL Width (m)	Recommended TWL Width (m)
A	1	5	10
B	3	7	10
C	4	8	10
D	4	8	20
E	5	9	20

NOTE: Recommended TWL widths to allow for erosion and saftey measures. (Section 4.2.6)



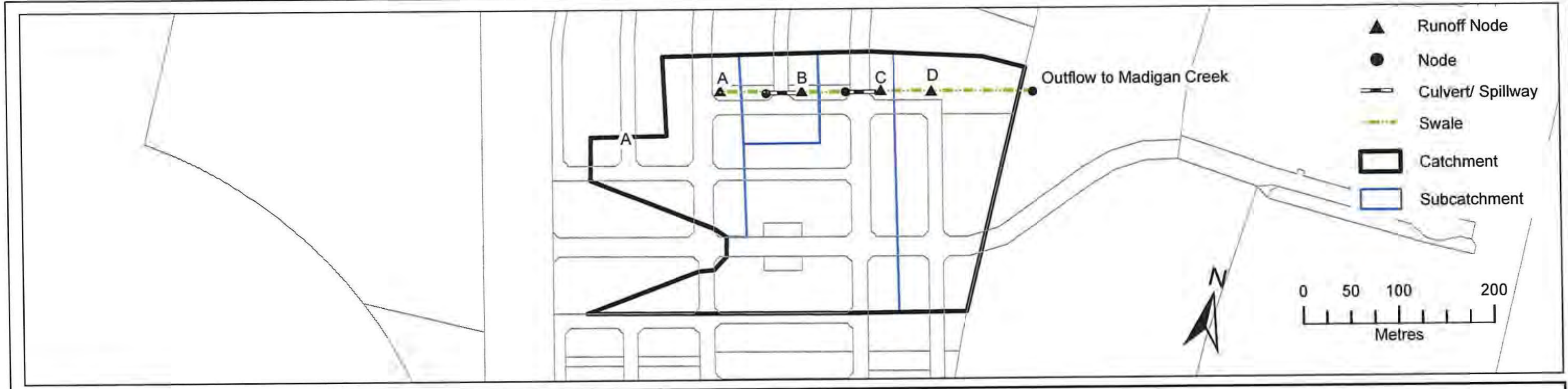
Job No. J4755

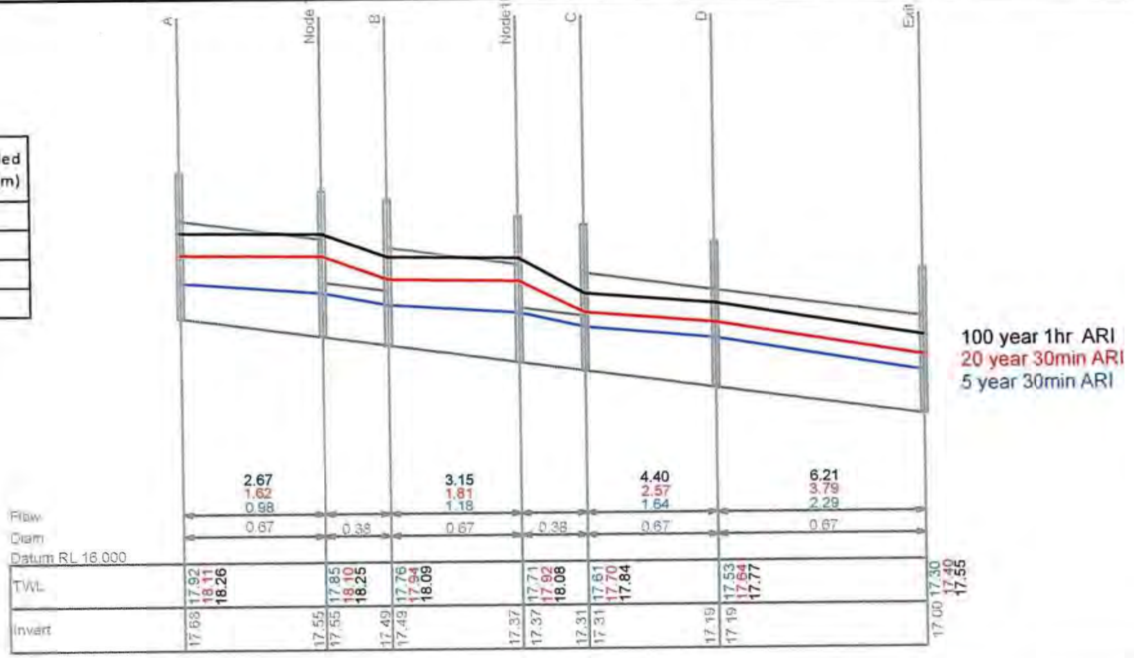
1:6,000

LandCorp

Madigan Road Urban Development, Karratha: LWMS

Figure 11: Catchment 3 Profile Plot for 5yr, 20yr & 100yr ARI





Swale (m)	Min. Base Width (m)	Min. TWL Width (m)	Recommended TWL Width (m)
A	3.5	7.5	16
B	3.5	7.5	16
C	4	8	16
D	4	8	16

NOTE: Recommended base widths to allow for erosion and saftey measures. (Section 4.2.6)

JDA

Job No. J4755

1:6,000

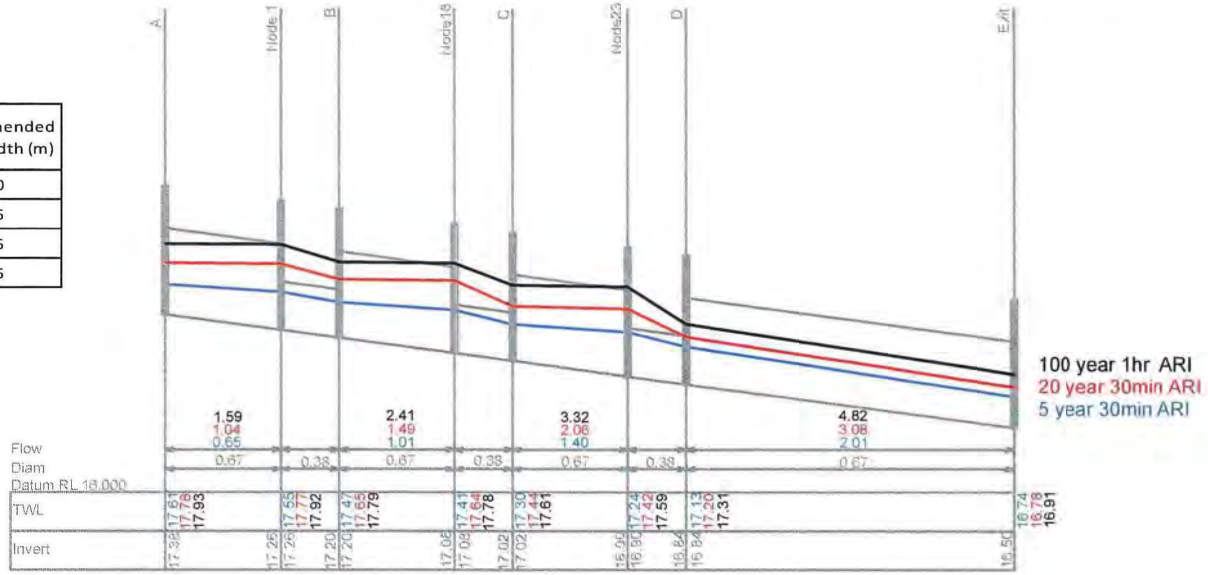
LandCorp

Madigan Road Urban Development, Karratha - LWMS

Figure 12: Catchment 4 Profile Plot for 5yr, 20yr & 100yr ARI

Swale (m)	Min. Base Width (m)	Min. TWL Width (m)	Recommended TWL Width (m)
A	2.5	6.5	10
B	3	7	15
C	4	8	15
D	5	9	15

NOTE: Recommended TWL widths to allow for erosion and saftey measures. (Section 4.2.6)



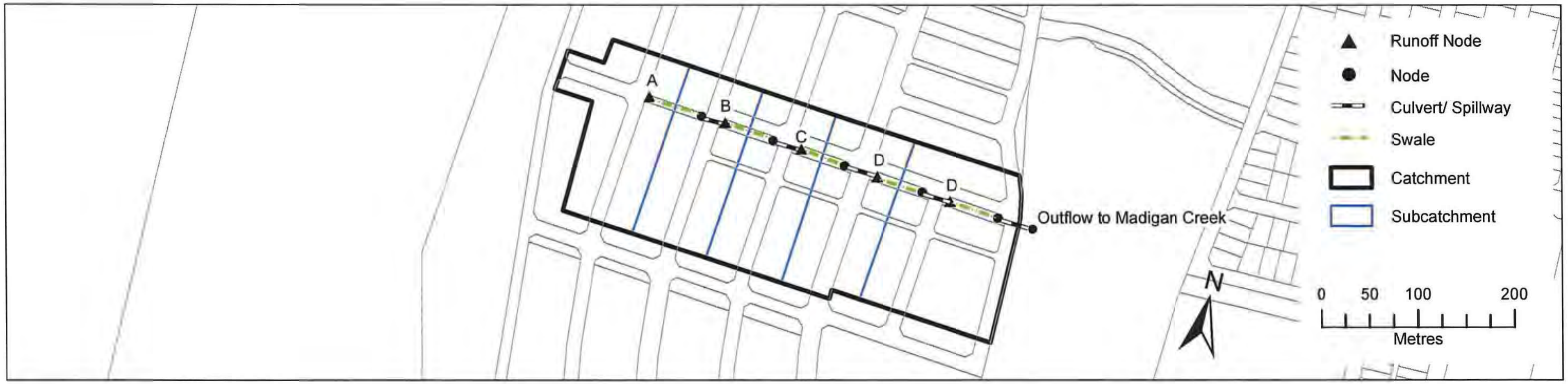
Job No. J4755

1:6,000

LandCorp

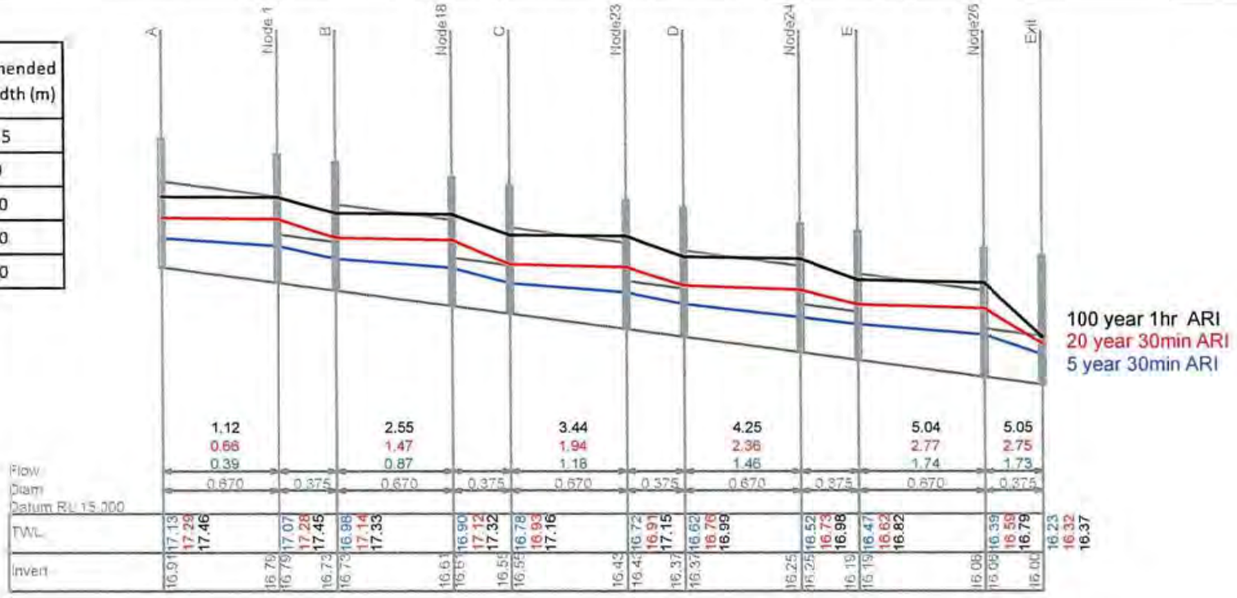
Madigan Road Urban Development, Karratha - LWMS

Figure 13: Catchment 5 Profile Plot for 5yr, 20yr & 100yr ARI



Swale (m)	Min. Base Width (m)	Min. TWL Width (m)	Recommended TWL Width (m)
A	1.5	5.5	7.5
B	3	7	9
C	4.5	8.5	10
D	4.5	8.5	10
E	5	9	10

NOTE: Recommended TWL widths to allow for erosion and saftey measures. (Section 4.2.6)



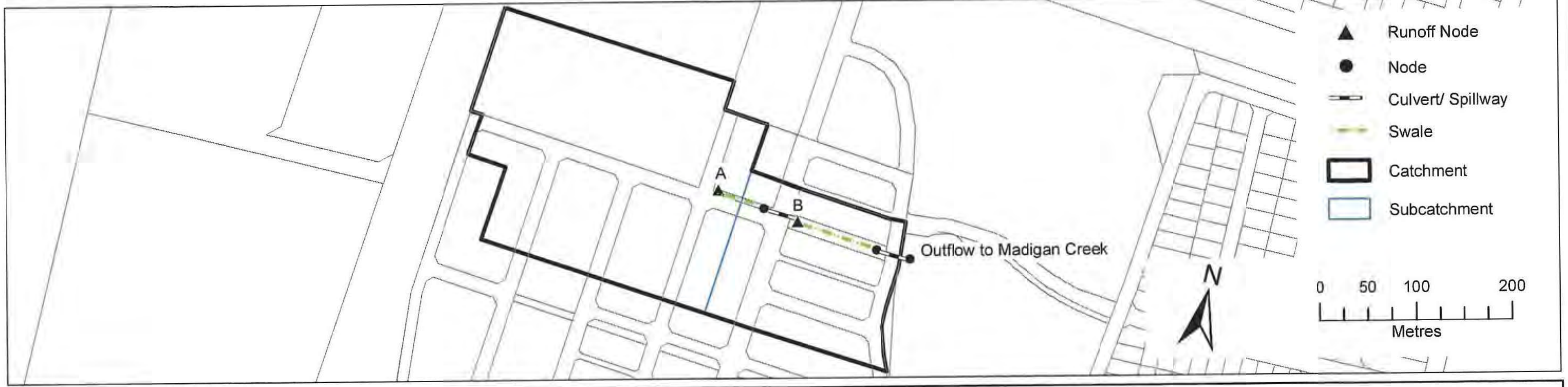
Job No. J4755

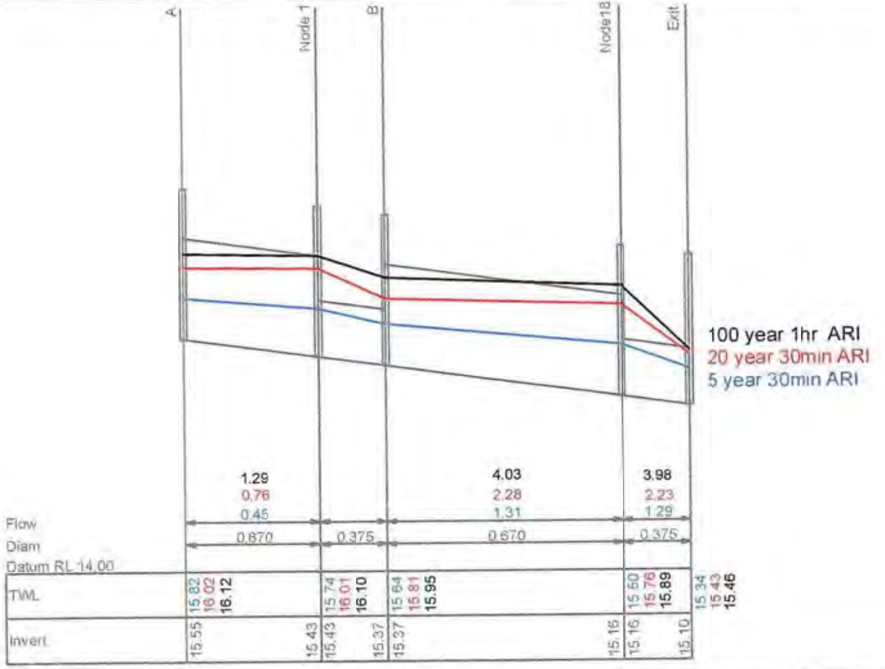
1:6,000

LandCorp

Madigan Road Urban Development, Karratha: LWMS

Figure 14: Catchment 6 Profile Plot for 5yr, 20yr & 100yr ARI





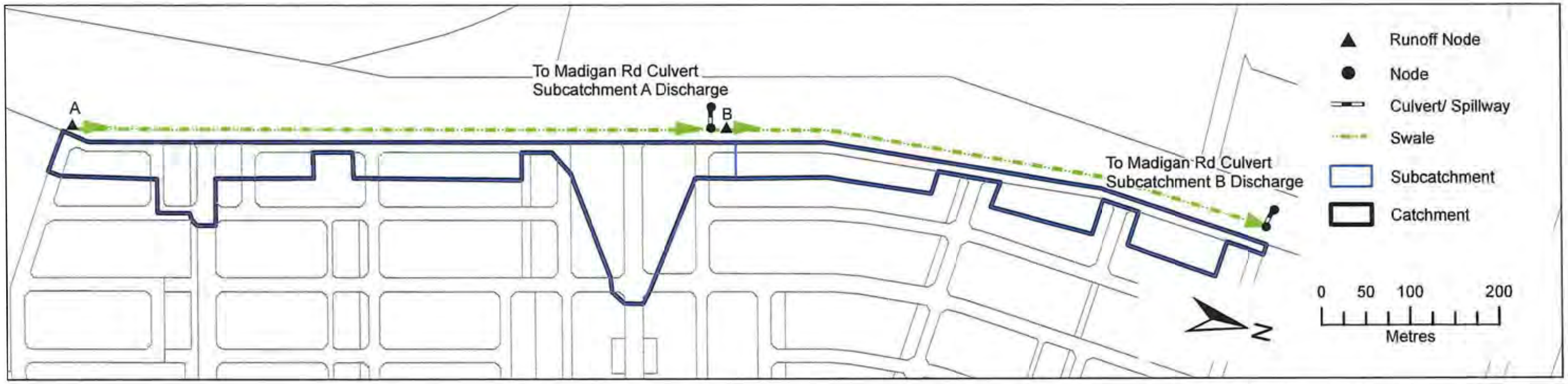
Swale (m)	Min. Base Width (m)	Min. TWL Width (m)	Recommended TWL Width (m)
A	1.5	5.5	5.5
B	4	8	15

NOTE: Recommended TWL widths to allow for erosion and safety measures. (Section 4.2.6)

JDA

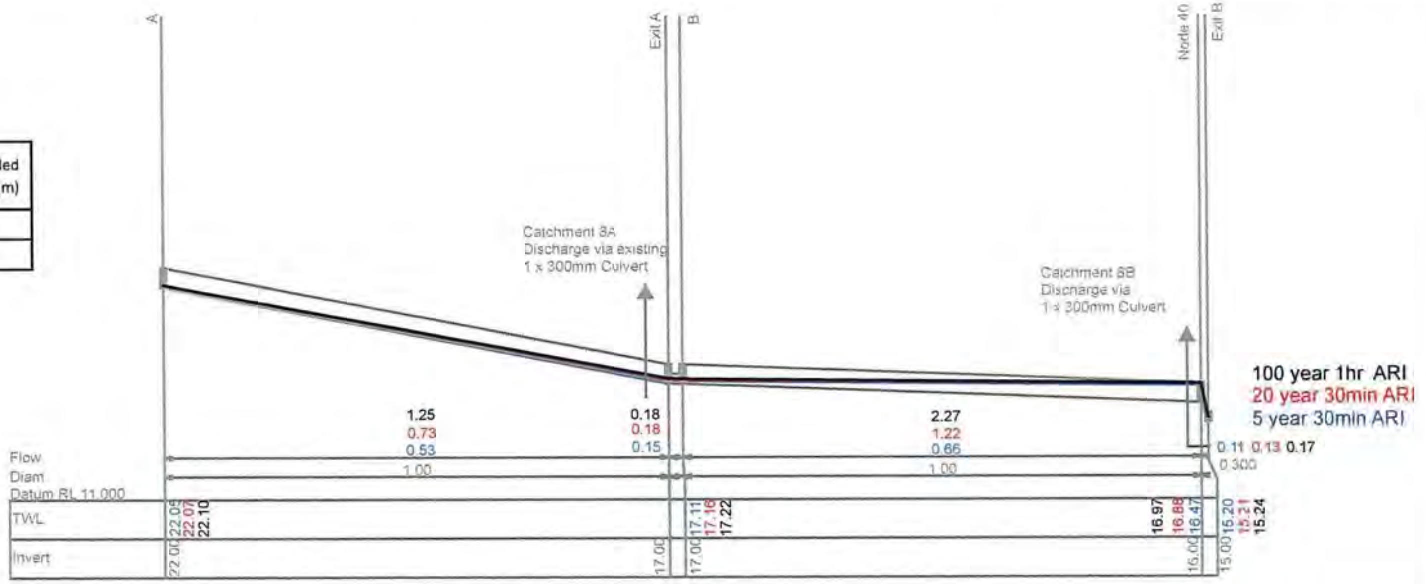
Job No. J4755
1:6,000

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 15: Catchment 7 Profile Plot for 5yr, 20yr & 100yr ARI



Swale (m)	Min. Base Width (m)	Min. TWL Width (m)	Recommended TWL Width (m)
A	10.5	25	25
B	10.5	25	25

NOTE: Recommended TWL widths to allow for erosion and safety measures. (Section 4.2.6)



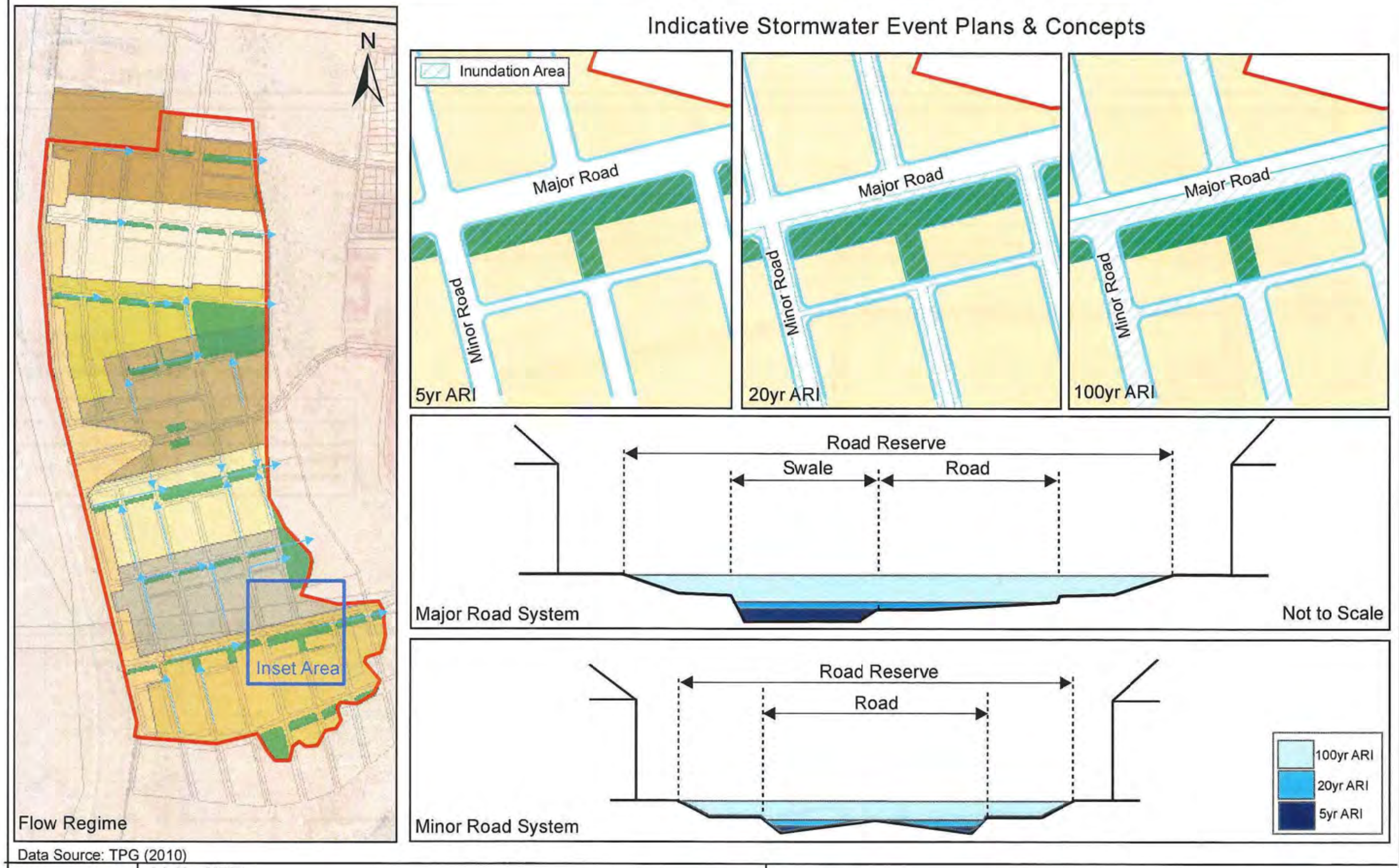
Job No. J4755

1:6,500

LandCorp

Madigan Road Urban Development, Karratha - LWMS

Figure 16: Catchment 8 Profile Plot for 5yr, 20yr & 100yr ARI



Data Source: TPG (2010)

JDA

Job No. J4755
Scale:1:12,000
0 200 400 600 800 Meters

Landcorp
Madigan Road Urban Development, Karratha - LWMS

Figure 17: 5yr, 20yr and 100yr ARI Event Plan Snapshot

APPENDIX A

Local Water Management Strategy Checklist for Developers

LOCAL WATER MANAGEMENT STRATEGY: CHECKLIST (WAPC, 2008)

The following checklist provides a guide to items which should be addressed by developers in the preparation of Local Water Management Strategies for assessment by the local authority when an application for a structure plan is lodged.

1. Tick the status column for items for which information is provided
2. Enter N/A in the status column if the item is not appropriate and enter the reason in the comments column
3. Provide brief comments on any relevant issues
4. Provide brief descriptions of any proposed best management practices, e.g. multi-use corridors, community based-social marketing, water re-use proposals

Applicant: LandCorp Name of Plan: Madigan Road, Karratha	**Date:** March 2011
Contact: Matthew Yan, JDA Consultant Hydrologists	
Address: Suite 1, 27 York St Subiaco WA 6008	
Telephone: 9388 2436	**Email:** matt@jdahydro.com.au

Local Water Management Strategy Item	Required Deliverable	Deliverable LWMS Reference	☐	Comment
Executive Summary				
Summary of the development design strategy, outlining how the design objectives are proposed to be met	Design elements and requirements for BMPs and critical control points	Executive Summary	✓	
Introduction				
Total water cycle management – principles & objectives Planning background Previous studies		Section 1.3 Section 1.1 Section 1.2	✓	
Proposed Development				
Structure plan, zoning and land use. Key landscape features Previous land use	Site context plan Structure plan	Sections 2, 3 Figs 1 & 2	✓	
Landscape - proposed POS areas, POS credits, water source, bore(s), lake details (if applicable), irrigation areas	Landscape Plan	Sections 3.0, 4.1 Figs 6	✓	

Local Water Management Strategy Item	Required Deliverable	Deliverable LWMS Reference	☐	Comment
Design Criteria				
Agreed design objectives and source of objective		Sections 1.3	✓	
Pre-development Environment				
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?	Existing Site Charicteristics	Section 2, Fig 2, 4, 5	✓	
Site Conditions - existing topography / contours, aerial photo underlay, major physical features	Site Condition Plan	Section 2.1, Fig 1 &Fig 2	✓	
Geotechnical - topography, soils including acid sulfate soils and infiltration capacity, test pit locations	Geology Description	Sections 2.4, 2.8 Fig 2	✓	
Environmental - areas of significant flora and fauna, wetlands and buffers, waterways and buffers, contaminated sites	Environmental Plan plus supporting datasets where appropriate	Section 2.6, 2.9	✓	
Surface Water – topography, 100 year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)	Surface Water Plan	Section 2.6. Fig 4	✓	
Groundwater – topography, pre development groundwater levels and water quality, test bore locations	Groundwater Plan	Section 2.5	✓	
Water Use Sustainability Initiatives				
Water efficiency measures – private and public open spaces including method of enforcement		Section 4.1, Fig 6	✓	
Water supply (fit-for-purpose strategy), agreed actions and implementation. If non-potable supply, support with water balance		Section 4.1	✓	
Wastewater management		Section 4.1	✓	
Stormwater Management Strategy				
Flood protection - peak flow rates, volumes and top water levels at control points,100 year flow paths and 100 year detentions storage areas	100yr event Plan	Section 4.2, Figs 7-17	✓	
Manage serviceability - storage and retention required for the critical 5 year ARI storm events Minor roads should be passable in the 5 year ARI event	5yr event Plan	Section 4.2, Figs 7-17	✓	

Local Water Management Strategy Item	Required Deliverable	Deliverable LWMS Reference	☐	Comment
Protect ecology – detention areas for the 1 yr 1 hr ARI event, areas for water quality treatment and types of (including indicative locations for) agreed structural and non-structural best management practices and treatment trains. Protection of waterways, wetlands (and their buffers), remnant vegetation and ecological linkages	1yr event plan	Section 4.2	✓	
Groundwater Management Strategy				
Post development groundwater levels, fill requirements (including existing and likely final surface levels), outlet controls, and subsoils areas/exclusion zones	Groundwater Plan	Section 4.3	✓	
Actions to address acid sulfate soils or contamination		Section 4.6.2, Fig 2	✓	
The Next Stage - Subdivision and Urban Water Management Plans				
Content and coverage of future urban water management plans to be completed at subdivision. Include areas where further investigations are required prior to detailed design.		Section 5.2	✓	
Monitoring				
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		Sections 5.4	✓	
Implementation				
Developer commitments		Section 5.1	✓	
Roles, responsibilities, funding for implementation		Section 5.1	✓	
Review		Section 5.1	✓	

Western Australian Planning Commission (2008), Better Urban Water Management, Perth,

APPENDIX B

WA Stormwater Management Objectives, Principles and Delivery Approach & Decision Process for Stormwater Management in WA (DoW, 2009)

Government of **Western Australia**
Department of **Water**

Decision process for stormwater management in WA

A component of Chapter 4: Integrating stormwater management approaches, Stormwater management manual for Western Australia (Department of Water 2004–07)

Looking after all our water needs

Department of Water
August 2009

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
www.water.wa.gov.au

August 2009

ISBN 978-1-921637-99-5 (online)

For more information about this report, contact
Emma Monk, Environmental Officer, Drainage and Waterways Branch.

Introduction

The *Decision process for stormwater management in WA* provides a decision framework for the planning and design of stormwater management systems. The desired outcome of the decision process methodology is to minimise potential changes in the volume of surface water flows and peak flows resulting from the urbanisation of an area (i.e. residential, rural-residential, commercial and industrial development). If these changes are not managed, they can lead to adverse impacts on the water regime, water quality, habitat diversity and biodiversity in receiving water bodies[1] and affect public health and amenity.

The decision process also addresses the management of flood events to protect properties. It sits within the objectives, principles and delivery approach outlined in the *Stormwater management manual for Western Australia* (Department of Water 2004–07). These objectives include:

- minimising risk to public health and amenity
- implementing systems that are economically viable in the long term
- retaining natural drainage systems and protecting ecosystem health
- ensuring that social, aesthetic and cultural values are maintained.

The stormwater management design for a site should be consistent with the approved urban water management plan and/or the district or local water management strategy for the area, which should be prepared in accordance with *Better urban water management* (Western Australian Planning Commission 2008), *Urban water management plans – guidelines for preparation and compliance with subdivision conditions* (Department of Water 2008a) and/or *Interim: Developing a local water management strategy* (Department of Water 2008b). These planning documents have been developed to assist the land development industry to demonstrate compliance with the policies and principles of *State planning policy no. 2.9: water resources* (Western Australian Planning Commission 2006).

A significant stormwater management measure is to minimise the 'effective imperviousness' of a development area. Effective imperviousness is defined as the combined effect of the proportion of constructed impervious surfaces in the catchment, and the connectivity of these impervious surfaces to receiving water bodies. The purpose of minimising effective imperviousness is to reduce the transportation of pollutants to receiving water bodies and for post development hydrology to mimic pre-development hydrology as closely as possible. This is achieved by disconnecting constructed impervious areas from receiving water bodies (preventing direct discharge) and by reducing the amount of constructed impervious areas.

To retain the pre-development hydrology of a site, the order of management priorities is:

- the magnitude of peak flows
- the volume of catchment runoff
- the seasonality of catchment runoff.

---

[1] Water bodies are defined as waterways, wetlands, coastal marine areas and shallow groundwater aquifers.

Rainfall, for the majority of events occurring each year, should be retained[2] or detained[3] on-site (i.e. as high in the catchment and as close to the source as possible, subject to adequate site conditions). Runoff from constructed impervious areas (e.g. roofs and paved areas) should be retained or detained through the use of devices such as soakwells, pervious paving, vegetated swales, gardens or rainwater tanks. For detention systems, the pre-development critical 1-year average recurrence interval (ARI[4]) peak flow rate and discharge volume from constructed impervious areas should be preserved. Events larger than 1-year ARI can overflow off-site via an appropriate flowpath.

For larger rainfall events (i.e. greater than 1-year ARI events), runoff from constructed impervious areas should be retained or detained to the required design storm event in landscaped retention or detention areas in road reserves, public open space or linear multiple use corridors. Any overflow of runoff towards waterways and wetlands should be by overland flow paths across vegetated surfaces. Further detention may be required to ensure that the pre-development hydrologic regime of the receiving water bodies is largely unaltered, particularly in relation to peak flow rates and, where practical, discharge volume.

Urban pollutants, whether in particulate or soluble forms, are conveyed by stormwater almost every time a storm event occurs. Studies in urban areas have shown that there is no general trend of increased concentrations of contaminants such as nutrients and metals with increasing storm sizes. Wong *et al.* (1999) found that most hydraulic structures can be expected to treat over 99 per cent of the expected annual runoff volume when designed for a 1-year ARI peak discharge. Unlike flood mitigation measures, stormwater quality treatment devices do not need to be designed for rainfall events of high ARI to achieve high hydrologic effectiveness (i.e. the percentage of mean annual runoff volume subjected to treatment).

The design of stormwater management systems should be based on adequate field investigations to determine the conditions of the site. Prior to design, developers should consult with the Department of Water, local government authorities and other relevant stakeholders. Please refer to the flow chart for more detailed guidance.

---

[2] Retention is defined as the process of preventing rainfall runoff from being discharged into receiving water bodies by holding it in a storage area. The water may then infiltrate into groundwater, evaporate or be removed by evapotranspiration of vegetation. Retention systems are designed to prevent off-site discharges of surface water runoff, up to the design ARI event. It is the difference between total precipitation and total runoff.

[3] Detention is defined as the process of reducing the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design ARI event) and then releasing it slowly, to reduce the impact on downstream water bodies and to attenuate urban runoff peaks for flood protection of downstream areas.

[4] Average recurrence interval (ARI) is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. For further information, refer to *Australian rainfall and runoff* (Engineers Australia 2001) and the Bureau of Meteorology website via <www.bom.gov.au/hydro/has/ari_aep.shtml>.

References and further reading

Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and Australian and New Zealand Environment and Conservation Council (ANZECC) 2000, National Water Quality Management Strategy No. 10, *Australian guidelines for urban stormwater management*, ARMCANZ and ANZECC, Canberra, Australian Capital Territory.

Bureau of Meteorology (undated), *ARI and AEP*. Retrieved 27 January 2005 from <www.bom.gov.au/hydro/has/ari_aep.shtml>.

Center for Watershed Protection (undated), Chapter 2: 'The importance of imperviousness', *Site planning for urban stream protection*, Center for Watershed Protection, United States of America.

Cottingham, P 2004, 'World experience focuses on streams suffering urban syndrome', *WaterShed*, October 2004, pp. 4–5.

Cottingham, P, Walsh, C, Rooney, G & Fletcher, T 2004, *Urbanization impacts on stream ecology – from syndrome to cure?*

Department of Environment and Conservation 2007, *Policy position – acid sulfate soils and the Contaminated Sites Act 2003*, Department of Environment and Conservation, Perth, Western Australia. Available via <www.dec.wa.gov.au> or by telephoning (08) 6364 6500.

Department of Environment and Conservation (in preparation), *A guide to managing and restoring wetlands in Western Australia*, Department of Environment and Conservation, Perth, Western Australia.

Department of Water 2004–07, *Stormwater management manual for Western Australia*, Department of Water, Perth, Western Australia. Available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Department of Water 2007, *Interim position statement: constructed lakes*, Department of Water, Perth, Western Australia. Available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Department of Water 2008a, *Urban water management plans – guidelines for preparation and compliance with subdivision conditions*, Department of Water, Perth, Western Australia. Available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Department of Water 2008b, *Interim: Developing a local water management strategy*, Department of Water, Perth, Western Australia. Available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Department of Water (in preparation), *Guidelines for ecological water requirements for urban water management*, Department of Water, Perth, Western Australia. Will be available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Engineers Australia 2001, *Australian rainfall and runoff – a guide to flood estimation*, Pilgrim, DH (Editor-in-Chief), Institution of Engineers Australia, Barton, Australian Capital Territory.

Engineers Australia 2006, *Australian runoff quality – a guide to water sensitive urban design*, Wong, THF (Editor-in-Chief), Engineers Media, Crows Nest, New South Wales. Available via <www.arq.org.au>.

Environmental Protection Authority 1992, *Environmental protection (Peel Inlet–Harvey Estuary) policy*, Environmental Protection Authority, Perth, Western Australia. Available via <www.epa.wa.gov.au> or by telephoning (08) 6364 6500.

Environmental Protection Authority 2004, *Environmental protection of wetlands position statement no. 4*, Environmental Protection Authority, Perth, Western Australia. Available via <www.epa.wa.gov.au> or by telephoning (08) 6364 6500.

Environmental Protection Authority 2008, *Environmental guidance for planning and development – guidance statement no. 33*, Perth, Western Australia. Available via <www.epa.wa.gov.au> or by telephoning (08) 6364 6500.

Government of Western Australia 1997, *Wetlands conservation policy for Western Australia*. Copies may be viewed at the Department of Environment and Conservation library, telephone (08) 6364 6500.

Government of Western Australia 2004, *Riverplan – an environmental management framework for the Swan and Canning Rivers: a comprehensive management plan and implementation strategy for the Environmental protection (Swan and Canning Rivers) policy 1998*. Available via <www.swanrivertrust.wa.gov.au> or by telephoning (08) 9278 0900.

Ladson, T, Walsh, C, Fletcher, T & Cornish, S 2003, 'Beyond the 10% rule: improving streams by retro-fitting in suburbs to decrease the connections between impervious surfaces and waterways', *Catchword – Newsletter of the Cooperative Research Centre for Catchment Hydrology*, No. 123, December 2003, pp 9–10.

Ladson, T, Walsh, C & Fletcher, T 2004, 'Is reducing runoff frequency the key to restoring urban streams?', *Catchword – Newsletter of the Cooperative Research Centre for Catchment Hydrology*, No. 129, July 2004, pp 9–10.

Pyper, W 2004, 'Stormwater drainage is reducing stream biodiversity', *ECOS*, Vol. 120, p. 35.

Swan River Trust 2008, *Healthy rivers action plan*, Swan River Trust, Perth, Western Australia. Available via <www.swanrivertrust.wa.gov.au> or by telephoning (08) 9278 0900.

Swan River Trust (in publication), *Best management practices for shoreline stabilisation*, Swan River Trust, Perth, Western Australia.

Swan River Trust (in preparation), *River protection strategy*, Swan River Trust, Perth, Western Australia.

Walsh, CJ 2004, *Protection of in-stream biota from urban impacts: minimise catchment imperviousness or improve drainage design?* Cooperative Research Centre for Freshwater Ecology, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.

Water and Rivers Commission/Department of Environment 1999–2003, *River restoration – a guide to the nature, protection, rehabilitation and long-term management of waterways in Western Australia*, Water and Rivers Commission/Department of Environment, Perth, Western Australia. Available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Water and Rivers Commission 2000, *Environmental water provisions policy for Western Australia*, Water and Rivers Commission, Perth, Western Australia. Available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Water and Rivers Commission 2001, *Position statement: wetlands*, Water and Rivers Commission, Perth, Western Australia. Available via <www.dec.wa.gov.au> or by telephoning (08) 9334 0333.

Water and Rivers Commission 2002, *Foreshore policy 1 – identifying the foreshore area*, Water and Rivers Commission, Perth, Western Australia. Available via <www.water.wa.gov.au> or by telephoning (08) 6364 7600.

Western Australian Planning Commission 2006, *State planning policy no. 2.9: water resources*, Western Australian Planning Commission, Perth, Western Australia. Available via <www.wapc.wa.gov.au> or by telephoning (08) 9264 7777.

Western Australian Planning Commission 2008, *Better urban water management*, Western Australian Planning Commission, Perth, Western Australia. Available via <www.wapc.wa.gov.au> or by telephoning (08) 9264 7777.

Wong, THF, Wootton, RM, Argue, J & Pezzaniti, D 1999, 'Bringing order to the pollution control industry – issues in assessing the performance of gross pollutant traps', *Proceedings of the International Congress on Local Government Engineering and Public Works*, Sydney, 22-26 August 1999.

Decision Process for stormwater management in WA (Department of Water 2009)

A component of Chapter 4: Integrating stormwater management approaches, Stormwater management manual for Western Australia (Department of Water 2004-07)

The following process should be used to guide all stages of planning and designing stormwater management systems

1. Prior to and throughout the design process (including during structure planning), proponents shall consult with the Department of Water, Department of Environment and Conservation, local government authorities, the Swan River Trust (where applicable) and other relevant stakeholders.
2. Development should be planned in accordance with *Better urban water management* (Western Australian Planning Commission 2008) and applicable land and water planning guidance documents.
3. Stormwater management systems shall be designed in accordance with the objectives, principles and delivery approach outlined in the *Stormwater management manual for Western Australia* (Department of Water 2004–07). The objectives include: minimising risk to public health and amenity; protecting the built environment from flooding and waterlogging; retaining natural drainage systems and protecting ecosystem health; implementing systems that are economically viable in the long term; ensuring that social, aesthetic and cultural values are maintained; maximising the reuse of stormwater; maintaining or improving surface and ground water quality; and maintaining the total water cycle balance.
4. Adequate field investigations shall be undertaken to determine the appropriate hydrologic regime for the site and potential site constraints, such as contaminated sites, acid sulfate soils or highly elevated nutrient levels in groundwater. Baseline and/or ongoing monitoring of groundwater and surface water quality and quantity may be required.
5. Stormwater management systems may be subject to additional design and performance criteria if they have the potential to impact on sensitive receiving environments. Sensitive receiving environments include the following environments, as defined in *Environmental guidance for planning and development – guidance statement no. 33* (Environmental Protection Authority 2008): natural areas of high conservation significance (chapter B1.2.1); native vegetation and flora of high conservation significance (chapter B2.2.2); areas of high conservation significance for native fauna (chapter B3.2.2); wetlands of high conservation significance (chapter B4.2.2); waterways of high conservation significance (chapter B5.2.2); waterways management areas (attachment B5-5); Swan and Canning Rivers Development Control Area (attachment B5-5); public drinking water source area wellhead protection zones and reservoir protection zones (chapter B6-1); landscapes and landforms of high conservation significance (chapter B8.2.1); and karst areas of high conservation significance (chapter B9.2.2).

Water quantity management

1. Is the proposal completely or partly within a known contaminated site (i.e. a contaminated site listed on the contaminated sites register, or identified through adequate field investigations) or a high acid sulfate soil risk area?
2. Does the soil or groundwater contain highly elevated nutrient levels? A definition for highly elevated nutrient levels has not been provided, as nutrient breakthrough is highly variable and is dependent on the soil type (e.g. organic, clay and iron oxyhydroxide content) and local wetting and drying cycles.

Yes (to either question)

Avoid mobilisation or disturbance of the in-situ contaminants

If yes to question 1 – seek further advice from the Department of Environment and Conservation.

If yes to question 2 – consult with the Department of Water about best management practices to minimise nutrient leaching through the soil profile (i.e. structural and non-structural controls suitable to the site conditions) and the Swan River Trust where the waters in the Trust Development Control Area are likely to be affected.

No (most situations)

1. Maintain the pre-development annual discharge volume and peak flow, unless otherwise established through determination of ecological water requirements for sensitive receiving environments. For more information, see the *Guidelines for ecological water requirements for urban water management* (Department of Water, in preparation).
2. Hydrologic and hydraulic analyses, modelling and design shall incorporate the recommendations and methodology of *Australian rainfall and runoff – a guide to flood estimation* (Engineers Australia 2001).
3. The effective imperviousness of a development shall be minimised. The process for achieving this is outlined below:

Less than and equal to 1-year ARI events:

Retain or detain stormwater runoff from constructed impervious surfaces generated by up to 1-year, 1-hour average recurrence interval (ARI) events on-site (i.e. as high in the catchment and as close to the source as possible).

Generally, detention systems should preserve the pre-development critical 1-year ARI peak flow rate and discharge volume for the catchment.

Greater than 1-year and up to 100-year ARI events:

Manage runoff from constructed impervious areas for greater than 1-year, 1-hour ARI events in landscaped retention or detention areas in road reserves, public open space or linear multiple use corridors. Runoff into waterways and wetlands shall be by overland flow paths across vegetated surfaces.

Design for greater than 1-year and less than/equal to 5-year (residential/rural-residential) or 10-year (commercial/industrial) ARI events

Minor system conveyance
(e.g. via swales and overflow pipes)

Design for greater than 5/10-year and up to 100-year ARI events

Major system conveyance
(i.e. via overland flow paths)

Water quality management

1. On-site field investigations are required to determine the appropriate water quality management measures for the site, including consideration of potential pathways of pollutants toward receiving water bodies. Receiving water bodies are defined as waterways, wetlands, coastal marine areas and shallow groundwater aquifers.
2. The components of the water quality treatment train must be designed so that their combined effect contributes to meeting the water quality management objectives of the catchment. The objectives may be defined in a water quality improvement plan, regional water plan, drainage and water management plan, district or local water management strategy, urban water management plan, local government stormwater management plan, regional natural resource management strategy, the *Healthy rivers action plan* (Swan River Trust 2008), or the *Environmental protection (Peel Inlet–Harvey Estuary) policy 1992* (Environmental Protection Authority 1992). The requirements for demonstration of compliance shall depend upon the scale of the proposed land development. Demonstration of compliance may be achieved by the use of appropriate assessment methods, to the satisfaction of the Department of Water.
3. Practices to achieve water quality management objectives should be a combination of structural and non-structural controls.

Protect waterways and wetlands

1. Retain and restore waterways and wetlands. For waterways, the approach to protection and management should be consistent with the *River restoration manual* (Water and Rivers Commission/Department of Environment 1999–2003), *Foreshore policy 1 – identifying the foreshore area* (Water and Rivers Commission 2002), *Environmental guidance for planning and development – guidance statement no. 33* (Environmental Protection Authority 2008) and, in the Swan and Canning catchments, *Riverplan* (Government of Western Australia 2004) as a guideline until completion of the *River protection strategy* (Swan River Trust, in preparation) and *Best management practices for shoreline stabilisation* (Swan River Trust, in publication). For wetlands, the approach to protection and management should be consistent with *A guide to managing and restoring wetlands in Western Australia* (Department of Environment and Conservation, in preparation), *Environmental protection of wetlands position statement no. 4* (Environmental Protection Authority 2004), *Wetlands conservation policy for Western Australia* (Government of Western Australia 1997), *Environmental guidance for planning and development – guidance statement no. 33* (Environmental Protection Authority 2008), *Position statement: wetlands* (Water and Rivers Commission 2001) and relevant environmental protection policies.
2. There shall be no new constructed stormwater infrastructure (e.g. no pipes or constructed channels) within conservation category wetlands and their buffers, or other wetlands of high conservation significance and their buffers (as defined in Environmental Protection Authority 2008), or resource enhancement category wetlands and their buffers, unless authorised by the Department of Environment and Conservation or the Environmental Protection Authority. For multiple use category wetlands, stormwater management shall be consistent with *Environmental guidance for planning and development – guidance statement no. 33* (Environmental Protection Authority 2008). There shall be no new constructed stormwater infrastructure within a waterway foreshore area, unless authorised by the Department of Water or the Environmental Protection Authority or, where applicable, the Swan River Trust.
3. The creation of artificial lakes or permanent open water bodies generally will not be supported when they involve the artificial exposure of groundwater (e.g. through excavation, or lined lakes that require groundwater to maintain water levels in summer), or the modification of wetland type (e.g. converting a dampland into a lake). Where water conservation (e.g. summer water supply) and environmental and health concerns (e.g. hydrology, water quality, mosquitoes, midges, algal blooms, acid sulfate soils and iron monosulfide minerals) can be shown to be addressed adequately through design and maintenance, consideration may be given to the creation of artificial lakes/ponds. Ephemeral detention or infiltration areas, or approved constructed waterways (i.e. ephemeral living streams) are preferred options. For further guidance, refer to the *Interim position statement: constructed lakes* (Department of Water 2007).

Management of groundwater levels

1. Any proposals to control the seasonal or long-term maximum groundwater levels through controlled groundwater levels (CGL) shall demonstrate (through adequate field investigation and to the satisfaction of the Department of Water) that local and regional environmental impacts are managed adequately.
2. The CGL is defined as the controlled (i.e. modified) groundwater level (measured in metres Australian height datum) at which the Department of Water will permit drainage inverts to be set. The CGL must be based on local and regional ecological water requirements determined in accordance with the *Environmental water provisions policy for Western Australia* (Water and Rivers Commission 2000) and the *Guidelines for ecological water requirements for urban water management* (Department of Water, in preparation). If groundwater levels are proposed to be controlled using a subsoil drainage system, the proposal to determine and implement a CGL is to be described in a district water management strategy and the estimated CGL level may be proposed at this stage. The CGL calculation will then need to be refined in a local water management strategy and further refined in an urban water management plan. The Department of Water is preparing guidelines on determining groundwater drainage levels.
3. Where appropriate, field investigations must be undertaken to identify acid sulfate soils (ASS). Any reduction in groundwater levels via drainage should not expose ASS to the air, as this may cause groundwater contamination. Refer to the Department of Environment and Conservation ASS guideline series, including *Policy position - acid sulfate soils and the Contaminated Sites Act 2003* (Department of Environment and Conservation 2007) and the Western Australian Planning Commission ASS planning guidelines. If field investigations identify ASS, seek further advice from the Department of Environment and Conservation.

Western Australian Stormwater Management Objectives

Water Quality
To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

Water Quantity
To maintain the total water cycle balance within development areas relative to the pre development conditions.

Water Conservation
To maximise the reuse of stormwater.

Ecosystem Health
To retain natural drainage systems and protect ecosystem health.

Economic Viability
To implement stormwater management systems that are economically viable in the long term.

Public Health
To minimise the public risk, including risk of injury or loss of life, to the community.

Protection of Property
To protect the built environment from flooding and waterlogging.

Social Values
To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

Development
To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

Stormwater Delivery Approach for WA

Protect water quality
Stormwater remains clean and retains its high value

Implement best management practice on-site.
Implement non-structural controls, including education and awareness programs.
Install structural controls at source or near source.
Use in-system management measures.
Undertake regular and timely maintenance of infrastructure and streetscapes.

Protect infrastructure from flooding and inundation
Stormwater runoff from infrequent high intensity rainfall events is safely stored and conveyed

Safe passage of excess runoff from large rainfall events towards watercourses and wetlands.
Store and detain excess runoff from large rainfall events in parks and multiple use corridors.
Safely convey excessive groundwater to the nearest watercourse.

Minimise runoff
Slow the migration of rainwater from the catchment and reduce peak flows

Retain and infiltrate rainfall within property boundaries.
Use rainfall on-site or as high in the catchment as possible.
Maximise the amount of permeable surfaces in the catchment.
Use non-kerbed roads and carparks.
Plant trees with large canopies over sealed surfaces such as roads and carparks.

Maximise local infiltration
Fewer water quality and flooding problems

Minimise impervious areas.
Use vegetated swales.
Use soakwells and minimise use of piped drainage systems.
Create vegetated buffer and filter strips.
Recharge the groundwater table for local bore water use.

Make the most of nature's drainage
Cost effective, safe and attractive alternatives to pipes and drains

Retain natural channels and incorporate into public open space.
Retain and restore riparian vegetation to improve water quality through bio-filtration.
Create riffles and pools to improve water quality and provide refuge for local flora and fauna.
Protect valuable natural ecosystems.
Minimise the use of artificial drainage systems.

Minimise changes to the natural water balance
Avoid summer algal blooms and midge problems and protect our groundwater resources

Retain seasonal wetlands and vegetation.
Maintain the natural water balance of wetlands.
No direct drainage to Conservation Category Wetlands or their buffers, or to other conservation value wetlands or their buffers, where appropriate.
Recharge groundwater by stormwater infiltration.

Integrate stormwater treatment into the landscape
Add value while minimising development costs

Public open space systems incorporating natural drainage systems.
Water sensitive urban design approach to road layout, lot layout and streetscape.
Maximise environmental, cultural and recreational opportunities.

Convert drains into natural streams
Lower flow velocities, benefit from natural flood water storage and improve waterway ecology

Create stable streams, with a channel size suitable for 1 in 1 year ARI rainfall events, equivalent to a bankfull flow.
Accommodate large and infrequent storm events within the floodplain.
Create habitat diversity to support a healthy, ecologically functioning waterway.

Note: Selection of appropriate methods should be determined by site conditions.

Suite 1, 27 York St, Subiaco WA 6008
PO Box 117, Subiaco WA 6904
Ph: +61 8 9388 2436
Fx: +61 8 9381 9279

www.jdahydro.com.au

info@jdahydro.com.au

LandCorp

Madigan Creek Flood Study

Karratha

December 2010

JDA Consultant Hydrologists

DISCLAIMER

This document is published in accordance with and subject to an agreement between JDA Consultant Hydrologists ("JDA") and the client for whom it has been prepared ("Client"), and is restricted to those issues that have been raised by the Client in its engagement of JDA. It has been prepared using the skill and care ordinarily exercised by Consultant Hydrologists in the preparation of such documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by JDA and the Client without first obtaining a prior written consent of JDA, does so entirely at their own risk and JDA denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this document for any purpose other than that agreed with the Client.

QUALITY ASSURANCE

JDA provides quality assurance through all aspects of the company operation and is endorsed to AS/NZS ISO 9001:2000 Quality Assurance Accreditation, with third party certification to Bureau Veritas Quality International.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

JDA were appointed by LandCorp, to conduct a Flood Study on Madigan Creek on the western edge of the Karratha townsite.

1.1 Background

Madigan Creek is shown in Figure 1 attached. The creek flows north from the Karratha Hills to the confluence with Seven Mile Creek. The Dampier Highway bisects the creek approximately halfway between the Hills and downstream confluence.

This Flood Study has been prepared to identify flooding impacts on the proposed Madigan Development of approximately 68ha of urban residential development. Madigan Creek flows along the eastern boundary of the development and the extent of flooding into the proposed development area is currently unknown.

Other proposed developments, Gap Ridge North and Nickol West, are located north of Dampier Highway and may also be influenced by the flooding regime of Madigan Creek. This report evaluates the extent of flooding within all of the proposed development areas.

The objectives of the study are to determine the extent of the 100 year Average Recurrence Interval (ARI) flood extent for Madigan Creek. Flood levels for the 20 and 50 year ARI events are also determined. The impacts of the proposed Madigan, Gap Ridge North and Nickol West developments on flood levels will be assessed. An upgrade and duplication of the Dampier Highway by Main Roads WA has also been proposed in future and implications of possible designs mentioned.

1.2 Existing Flood Information

There have been many tropical cyclones in the Pilbara region of Western Australia. These tropical storms are responsible for flooding and storm surges that threaten towns and infrastructure. Karratha is not located on or adjacent to a major river system which reduces the risk of severe flooding, however, localised flooding in low lying areas and along creeks does occur.

The most severe cyclone of the past decade was Tropical Cyclone Monty that crossed the Dampier coastline on March 1st 2004. Records from the Bureau of Meteorology show that 323mm of rainfall were recorded for Roebourne with severe flooding throughout the Pilbara. Sections of the Northwest Coastal Highway were washed away at the bridge over the Maitland River (BoM, 2010). Anecdotal evidence provided by staff from the Shire of Roebourne indicates that the Dampier Highway near Madigan Creek was overtopped during Tropical Cyclone Monty.

Seven Mile Creek flows to the west and north of Madigan Creek and is shown in Figure 1. A flood study for this creek was undertaken south of the Dampier Highway in support of a proposed development adjacent to Seven Mile Creek (GHD, 2009). The catchment for Seven Mile Creek ($60km^2$) is significantly larger than for Madigan Creek ($5.46km^2$), and the main channel is larger and more defined. Reference to the Seven Mile Creek flood study is made throughout this report.

2. CATCHMENT DESCRIPTION

The Madigan Creek catchment is located in the Pilbara region of Western Australia and has a number of environmental conditions that influence flooding response. This section describes the environmental context of the catchment and includes details of the site visit by JDA Consultant Hydrologists on the 8 September 2010.

2.1 Location

The Madigan Creek catchment is located approximately 6km west of the Karratha Townsite and is approximately 546ha in area. The catchment is within the Shire of Roebourne and includes the proposed Madigan Development. Residential developments Baynton West and Nickol form the eastern section of the catchment. Seven Mile Creek is located to the west (Figure 1).

2.2 Topography

The topography of the Madigan Creek catchment varies, with steep hills in the upper catchment and relatively flat, gently sloping topography in the remainder of the catchment. The Karratha Hills to the south of Study Area feature elevations as high as 74mAHD to 14mAHD near Dampier Highway and approximately 7mAHD at the northern boundary of the Study Area (Figure 2).

2.3 Climate

Karratha has an arid climate characterised by hot summers with periodic heavy rain and mild winters with occasional rainfall.

The Pilbara coast experiences more cyclones than any other part of Australia. Since 1910 there have been 48 cyclones that have caused damaging wind gusts in excess of 90km/h in the Karratha, Dampier and Roebourne region. This equates to about one cyclone every two years, on average. About half of these cyclones have an impact equivalent to a category one cyclone.

The average annual rainfall for Karratha is 280mm per year, with a maximum recorded annual rainfall of 855mm from records taken between 1974-2009 at Karratha Airport (BoM 2010). Most of the recorded precipitation is received during the wet season, as a result of tropical cyclones and local thunderstorms.

Along the central Pilbara coast the cyclone season runs from December to April peaking in February. Figure 3 presents graphed rainfall data for Karratha Airport (BoM site 4083).

The average annual pan evaporation is approximately 3,590mm (Luke et al, 1988).

2.4 Soils and Vegetation

The Madigan Creek catchment is entirely covered by floodplain deposits of red-brown silty sand, which has been partially reworked by wind action over much of the catchment. The sand may contain nodules or lenses of calcrete approximately one metre below the surface, and scattered pebbles throughout. The sand is underlain by Archaean bedrock, probably mafic volcanics at an expected depth ranging from 10-20m below surface. The upper few metres of the bedrock are weathered and fractured.

Undeveloped regions of the catchment feature low tussock and spinifex grass vegetation (Figure 2). An Environmental Assessment performed by Coffey Environmental (2010) indicates the vegetation is not considered significant at the local, state or national level and there is no Threatened Ecological Community (TEC) within the catchment.

2.5 Existing Drainage

The Study Area features only one significant surface water feature, Madigan Creek, that flows through the site from the Karratha Hills (south) to Seven Mile Creek (north) (Figure 4).

Madigan Creek is a non-perennially flowing natural channel that is not well defined and less than 1m in depth south of the Dampier Highway. The creek is restricted underneath the highway by four 1500m circular culverts (Figure 4). Flow also occurs over the highway via a floodway to the west of the culverts.

Along three locations on Madigan Road there are single 300mm culverts which are located even distance apart. Due to the limited size, these culverts are not considered to be sized for conveying flow from the Study Area. Instead they have been designed to convey surface runoff from the east side of the crowned Madigan Road back towards Seven Mile Creek.

No previous measurements for flow or water quality data are available for Madigan Creek.

2.6 Groundwater

Groundwater occurs within a single aquifer known as the Pilbara Fractured Rock Aquifer.

Although there are no long term groundwater monitoring bores known to exist within the Karratha Area, the watertable is expected to be 5-10m below surface and may vary seasonally in depth by 2-3m in response to heavy rainfall. The groundwater is expected to be slightly brackish to saline, in the range 2,500 – 10,000 mg/L Total Dissolved Solids, but there may be more saline groundwater in localized areas of low permeability.

A site visit of September 8th 2010 also noted that there was no evidence of groundwater in any of the surface drainage systems (Madigan Creek).

2.7 Land Use

Land use within the Study Area is a mixture of developed and undeveloped areas. The majority of the Study Area features sparse native vegetation consisting of low tussock and spinifex grass. Significant infrastructure includes the Dampier Highway that bisects the Study Area and Madigan Road on the western boundary (Figure 2). Near the corner of Madigan Road and Dampier Highway is the Karratha Cemetery.

The future Madigan and Gap Ridge North developments will be located within the western section of the Study Area. The proposed Nickol West residential development will be to the east of the creek.

Surrounding land use in the wider catchment consists of the Karratha Hills to the south and Banyton West and Nickol residential development to the east. Woodside Petroleum's Pluto Worker Camp is to the west of Madigan Road, but not within the Madigan Creek catchment.

3. HYDROLOGY

Hydrologic analysis of the Madigan Creek catchment was performed to calculate flood hydrographs for the study area for various design ARI storm events.

For this study, the hydrologic analysis involved modelling of flood hydrographs using RORB and validation of peak flows against estimates from Rational and Index Flood Methods.

The calculated flood hydrographs from sub catchment areas of the study area are used as input for hydraulic modelling. Details of the catchment hydrologic analysis are presented below.

3.1 Hydrologic Model

Hydrologic modelling for the Madigan Creek catchment was performed using the runoff routing model RORB. This model is a general runoff and stream flow routing program used to calculate flood hydrographs from rainfall. It calculates runoff as rainfall excess by subtracting losses from rainfall.

The model is areally distributed, nonlinear, and applicable to both rural and urban catchments. It has the capacity to model temporal and spatial variability in rainfall, as well as storage reservoirs and culverts. Reach storage is the main way in which RORB represents hydrologic processes. Reach storages are assumed to have storage-discharge relations of the form:

$$S = 3600kQ^{m}$$

where S is the storage (m^3), Q is the outflow discharge (m^3/s), m is a dimensionless exponent, and k is a dimensional empirical coefficient that is comprised of the product of k_r and k_c, where k_r is a dimensionless ratio called the relative delay time, and k_c is an empirical coefficient characterising the entire catchment and stream network. It is important to note that k_c can only be generally compared between models that have the same catchment sub-divisions and stream network, though some rough comparison can be made if the catchment is sub-divided differently.

Calibration of storm event runoff hydrographs (where available) in RORB is predominantly achieved by adjusting the m and k_c values to achieve the best fit, as well as the runoff coefficient R_c which is the runoff volume as a proportion of rainfall volume.

3.1.1 Catchment Data

The Madigan Creek catchment has a catchment area of 5.46 km^2. For modelling purposes, the catchment was divided into 6 sub-catchments based on topographic contours and aerial photography (Figure 6).

The sub-catchment areas and mainstream lengths for four of the six were calculated using ArcGIS and have been modelled in RORB as connected nodes. Two catchments representing the existing developments within the catchment have been estimated from previous drainage studies.

3.1.2 Rainfall

Rainfall input for the modelling of design storms was calculated internally by RORB, based on procedures from Australian Rainfall and Runoff (AR&R) (IEAust, 1997). This includes rainfall intensities and temporal patterns for all design storm durations (5min to 72hrs) and ARI's (20, 50 and 100 year) for Karratha.

The rainfall pattern was assumed to be spatially uniform across the catchment.

3.1.3 Parameters k_c and m

RORB parameters k_c and m are either estimated by best fit of estimated and/or observed stream flow hydrographs or based on existing published data.

As there is no hydrograph data available for the Madigan Creek catchment, k_c value was calculated from the regional relationship as the recommended procedure by AR&R (IEAust, 1997). The relationship applicable to the study area is for the North West as follows:

$$k_c = 1.06\, L^{0.87} S^{-0.46}$$

where L is the mainstream channel length (km), S slope (m/Km). With the mainstream channel length for the Madigan Creek catchment being 5.0km and slope 4.5m/km, the k_c value adopted for modelling is 2.15.

For the dimensionless exponent m, a value of 0.85 was adopted consistent with other similar studies, considered appropriate for Western Australian conditions (IEAust, 1997).

3.1.4 Loss Model

The loss model adopted in RORB model were used based on AR&R (IEAust, 1997) procedure. AR&R indicated for Pilbara with an initial loss of 40mm and continuing loss of 5mm/h. JDA used 5mm initial loss for 100yr, 50yr and 20yr ARI and 2mm continuing loss of all the storm events, consistent with other studies in Pilbara. The Seven Mile Creek study (GHD, 2009) used an initial loss of 5mm for 100yr ARI event and 15mm for the 10yr ARI event and a continuing loss of 2mm/h for both storm events.

3.1.5 Peak Flows

The RORB model was run based on the above parameters for the Madigan Creek catchment (sub-catchments 1 to 4) to generate peak flows for the 20, 50 and 100 year ARI rainfall events. These estimated peak flows are presented in Table 2 below.

TABLE 2: MADIGAN CREEK SUB CATCHMENT PEAK FLOW ESTIMATES

Location	Area (ha)*	Peak Flow Estimate (m^3/s)		
		20 year ARI	50 year ARI	100 year ARI
Madigan Creek Catchment	432	85	103	125

*Excludes catchments 5 and 6.

3.2 Model Calibration

Calibration of hydrographs and peak flow estimates generated from the RORB model could not be performed due to the absence of gauging station data within the Madigan Creek catchment. Validation of the RORB peak flows based on comparison with alternative flood estimation methods was performed instead.

3.2.1 Rational and Index Flood Methods

The Rational and Index Flood Methods use regionalisation techniques for estimating peak flows in catchments where there are ungauged sites or sites with limited streamflow data (Water & Rivers Commission, 1999). Equations adopted for validation of the Madigan Creek catchment for both methods are from relationships derived from gauged catchments in the North West region of Western Australia (IEAust, 1997).

Note that the Rational and Index Flood Methods only provide peak flow estimates up to the 50 year ARI event. The results were therefore extrapolated to estimate the 100 year ARI event peak flows.

Peak flow estimates from the two methods compared with the RORB model for the Madigan catchment are presented in Table 3 below. Peak flows estimated using Rational Method for 20, 50 & 100 year ARI range between 2% to 14% compared to the flows modelled in RORB.

TABLE 3: COMPARISON OF RORB PEAK FLOWS WITH RATIONAL & INDEX FLOOD METHODS

Flow Estimation Method	100yr ARI Peak Flows (m^3/s)			Difference Compared to RORB		
	20 yr ARI	50 yr ARI	100 yr ARI	20 yr ARI	50 yr ARI	100 yr ARI
RORB	85	102	125	-	-	-
Rational Method	73	104	137	14 %	2 %	9 %
Index Flood Method	24	39	40	70 %	39 %	68 %

3.3 Design Flood Estimation

3.3.1 Design Hydrographs

Based on the RORB model parameters described above, a series of RORB runs were performed to generate design hydrographs for the 20, 50 and 100 year ARI rainfall events with durations ranging from 1hr to 72hr. The critical duration was selected based on the highest peak of the flow hydrographs generated. The loss models and rainfall parameters used for the design hydrographs are as stated in Section 3.1.

Hydrographs were extracted from RORB at four locations as follows:

- Madigan Creek: sub-catchment 1 at location A.
- Madigan Creek: sub-catchment 2 at location B.
- Madigan Creek: sub-catchment 3 at location C.
- Madigan Creek: sub-catchment 4 at location D.

The hydrographs for sub-catchment 5 was generated from peak flow estimates from the Baynton West Development modelling (Wood & Grieve, 2008). The stormwater system in this development was designed for minimum flow attenuation. This hydrograph was adapted for sub-catchment 6 by scaling the area in the two catchments (Catchment 5: 64.8ha and Catchment 6: 46.5ha).

The RORB design hydrographs for the critical duration 20, 50 and 100 year ARI rainfall events are shown in Figures 7 to 10 with the peak flows presented in Table 4. The critical storm duration for all rainfall events was 1hr.

TABLE 4: RORB SUBCATCHMENTS DESIGN HYDROGRAPH PEAK FLOWS

Sub Catchments	Area (ha)	Peak Flow Estimate (m^3/s)		
		20 year ARI	50 year ARI	100 year ARI
1	178	32	41	50
2	55	38	46	54
3	55	38	46	54
4	144	82	99	116
5	69	21	25	30
6	47	14	17	20

4. FLOOD MODELLING PARAMETERS

Hydraulic modelling of Madigan Creek was undertaken to determine the 20, 50 and 100 year ARI flood levels which are then used to delineate the 100yr ARI floodplain. The software package used for this analysis was MIKE 11 (version 2009) developed by the Danish Hydraulic Institute (DHI).

4.1 MIKE 11 Preparation

MIKE11 is a 1D hydrodynamic modelling tool for simulating unsteady flows in river channels. In conjunction with MIKE-GIS, the model utilises the digital elevation model, inflow hydrographs determined from the catchment hydrology analysis (Section 3) and roughness parameters (Manning's n) to determine the flood levels and extent of the floodplain.

The model extent for Madigan Creek south of the Dampier Highway is east of Madigan Road to the Bayton West development. North of the Dampier Highway the model extends to Seven Mile Creek and is bounded by the Nickol West development and the catchment boundary to the east.

These areas are shown in Figure 5. The future Madigan Development and the proposed Gap Ridge North development are also shown.

4.2 Survey and DEM Inputs

Topographic information for the site was obtained through existing Landgate contours (and spot heights) and previous surveys conducted by Whelans. Both datasets are as recent as 2007. An additional survey was conducted by Whelans in September 2010 to provide greater resolution of the Madigan Creek channel and floodplain. The survey focused on the longitudinal profile of the creek and cross sections extending 200m left and right of the channel.

A digital elevation model (DEM) was then produced from the survey data for the Study Area. The Survey points were converted into a 10m resolution grid of elevations data points. Using the generated grid, the river network including the main Madigan Creek channel and smaller channels were extracted for the model. Similarly cross sections of the river network were extracted every 100m along the channel, extending 500m from the centre of the channel.

4.3 Infrastructure

The major infrastructure features that affect the channel are four culverts and a floodway on the Dampier Highway (Figure 4). These structures were incorporated into the MIKE 11 model with parameters as shown in Table 5. The culverts were surveyed as part of the additional Madigan Creek survey conducted by Whelans. The dimensions of this floodway were provided by Cossill & Webley (Drawing No. 6055-00-SK03). Although the floodway invert is located approximately 150m west of the culverts, it is below the obvert of the culverts. Information from the survey and engineering drawings of these features was incorporated into the hydraulic model (MIKE 11).

The hydraulic performance of the culverts was assessed to determine their ability to convey the flows in Madigan Creek prior to flow over the existing floodway. The culverts were found to be able to convey approximately 15m^3/s when the water level was just below the obvert of the culverts (ie. invert of the floodway). This capacity is insufficient to convey any of the critical 1hr duration storm events from 5yr ($35m^3/s$) to 100yr without flow over the Dampier Highway floodway.

TABLE 5: EXISTING DRAINAGE INFRASTRUCTURE

Culvert Parameters			
Type	Circular	Upstream Invert Level	12.50 m AHD
Diameter	1.5 m	Downstream Invert Level	12.40 m AHD
No. of Culverts	4	Length	15 m
Manning's n	0.020		
Floodway Parameters			
Floodway Invert	13.84 mAHD	Adjacent Road Elevation	14.54 mAHD
Type	Sloped	Width	240m

4.4 Roughness Parameters

The roughness parameter for the channel and floodplain adopted for this model is the Manning's Roughness Coefficient; *n*. The selection of parameter values is based on criteria outline by Chow (1981), aerial photography of the study area and JDA's site visit. Madigan Creek is a relatively shallow and minor channel a single value of roughness, Manning's $n = 0.05$ was adopted across the entire Study Area. This is consistent with the resistance value adopted in the Seven Mile Creek study (GHD, 2009).

4.5 Baseflow

The intermittent rainfall of Karratha (Section 2.2) means that the site is predominantly dry prior to major rainfall events. The site only averages 25 days of rainfall per year. Therefore the creek was considered to be dry and no baseflow was added to the hydrographs or initial conditions.

4.6 Boundary Conditions

A downstream boundary condition was defined for the MIKE11 model as the water level at the confluence with Seven Mile Creek. The 20 year, 50 year and 100 year ARI levels were determined by extrapolating the flood levels from the Seven Mile Creek Flood Study (GHD, 2009) 100yr ARI flood levels. The downstream condition adopted for Madigan Creek was a conservative water level of 5.1m AHD, plus an 0.8m increase to account for increase in water levels from climate change (unpublished). The resulting downstream condition was a level of 5.9m AHD and in shown in Table 6. Although these estimates are imprecise, the model results within the Study Area were generally insensitive to the value selected as the boundary condition.

TABLE 6: BOUNDARY CONDITIONS

Boundary Location	Type	Boundary Condition
Upstream	Inflow Hydrograph	Hydrograph A (Figures 7 to 9)
Downstream	Water Level	5.9mAHD

Inflow hydrographs for each sub-catchment, as outlined in Section 3 and Figures 7 to 9.

4.7 Validation

Validating the hydraulic modelling for Madigan Creek is difficult owing to the lack of data available. Anecdotal evidence from the Shire of Roebourne indicates that Dampier Highway was over-topped during Cyclone Monty in 2004. Bureau of Meteorology (BoM) records indicate that Roebourne (10km west of Karratha) experienced their highest two-day rainfall total since 1945. However, the BOM records are available for 24hr periods which do not allow for analysis of 1hr storm events which is critical for the Madigan catchment. Therefore it cannot be determined which 1hr ARI storm event Cyclone Monty was without further detailed investigation.

No anecdotal information is available about the frequency of the Dampier Highway being over-topped. The short duration of these storm events mean it is unlikely that many people would have seen this road being over-topped.

5. FLOOD MODELLING RESULTS

The validated model was used to determine the existing flood levels and the impacts from the proposed developments adjacent to Madigan Creek.

5.1 Scenarios

The model was used to determine the floodplain extent for the 100 year ARI design hydrograph and flood levels for the 5, 20 and 50 year ARI design hydrographs. The floodplain is defined as areas adjacent to rivers, stream and creeks that are subject to inundation from large flows caused by heavy rain (SCARM, 2000). The current pre-development conditions were modelled as a baseline scenario.

The proposed Madigan and Gap Ridge North developments have the potential to impact the floodplain and increase flood levels upstream. A post-development scenario was modelled featuring land within the developments that was prevented from being flooded. This replicated the importation of fill into the developments. A post-development floodplain was generated for the 100 year ARI design hydrographs and flood levels for the 20 and 50 year ARI design hydrographs were calculated.

5.2 Model Outputs

The floodplains for 100 year ARI events (pre and post-development) are determined by the extent of inundated areas. The maximum flood extent, determined by MIKE 11 modelling, is shown in Figure 10. The water level at the upstream extent of the Study Area is 20.39mAHD and 7.14mAHD at the downstream end (Figure 11). The depth of flow for the 100 year ARI event is shown in Figure 12, with the deepest flow reaching 1.93m, upstream of the Dampier Highway.

Figures 11 and 12 also show the maximum water levels during the 20 and 50 year ARI events respectively. Pre and post-development water levels are shown along with the maximum depth of flow along Madigan Creek.

5.3 100 year ARI Results

The 100yr ARI flood event is significant for floodplain management and the protection of infrastructure in the proposed developments. For the pre-development 100 year ARI flood event, the floodplain is generally restricted to within 200m either side of Madigan Creek. The shallow topography of the catchment allows for a wide floodplain despite depths are generally less than 1.5m. The largest inundated area is immediately upstream of Dampier Highway owing to restriction of flow through the culverts.

South of Dampier Highway the depth of flow in the creek is generally less than 1.2m in the pre-development scenario. Within the proposed Madigan Development area is there are two small areas that are flooded along the eastern boundary. Immediately upstream of the Dampier Highway there is a significant area that is flooded during the 100yr ARI event. Water flowing in the creek is backed up behind the highway embankment as it discharges through the culverts and over the floodway. The modelling indicates that the water depth is 1.93m immediately upstream of the highway (0.59m depth over the floodway) and flooding extends into the Karratha cemetery area.

Downstream of the highway, flood depths were generally around 1.3m. The floodplain generally follows the morphology of the creek although it widens significantly near the confluence with Seven Mile Creek. There is only a minor area of the proposed Gap Ridge North development that is inundated during the 100yr ARI event. There is some flooding along the western boundary of the proposed Nickol West development as shown in Figure 10.

Throughout the catchment, there is also some flooding of the adjacent stormwater drains that discharge from Baynton West and Nickol West. Note that modelling with the downstream boundary condition of 5.9mAHD and varying up to 7.0mAHD has negligible impact on water levels within the Study Area.

5.3.1 Infrastructure Performance

The large inundated area immediately upstream of the Dampier highway is caused by the design of the culverts and floodway for Dampier Highway. Based on advice from Main Roads WA, drainage infrastructure is designed based on the 50 year ARI flood event, so a large backwater and flow over the floodway is not unexpected. As discussed in Section 4.3, the culverts are able to convey approximately 15m^3/s prior to flow over the Dampier Highway floodway.

During the 100yr ARI pre-development scenario there is a discharge of approximately 99m^3/s through the culverts and over the floodway, causing a maximum flooding depth of 0.59m over the lowest point of the floodway. The post development discharge and depth are approximately 104m^3/s and 0.60m respectively.

The afflux across the highway is approximately 0.87m between the immediate upstream and downstream water levels during peak flow which is as expected over a floodway.

Further detail on the infrastructure performance and design is presented in Section 5.4.1.

5.3.2 Proposed Development Impacts

The importation of fill for the three proposed residential developments has an impact on the floodplain extent and flood levels as shown in Figures 13 to 15. A comparison of the pre and post-development floodplains is shown in Figure 16. Downstream of the Dampier Highway, the Proposed Gap Ridge North Development has a minimal impact on the flood levels as only a small portion floodplain is within the proposed development area. The Nickol West development, however, causes an increase in flood levels of approximately 0.10m in adjacent areas along the creek.

Upstream of the Dampier Highway there is considerable change to the floodplain extent. Fill in the proposed Madigan Development area restricts the available 100yr ARI floodplain area and therefore water levels increase up to 0.38m in the vicinity immediately upstream of Dampier Highway. Note that should fill for the Madigan Development extend up to Dampier Highway, an overland flow path must be maintained between the creek centreline and the floodway approximately 150m west.

5.4 Other ARI Results

Flood levels and depths for the 20 and 50 year ARI flood events are presented in Figures 11 and 12 respectively. The pre-development scenario for each event is consistent; however, the water levels for the 20 and 50 year ARI events are generally 0.19m and 0.08m less than the 100yr ARI results.

5.4.1 Infrastructure Performance

As mentioned above, the 50 year ARI storm event is used by Main Roads WA for the design of drainage infrastructure. Details of the discharge and flood depth for the pre-development scenario over the Dampier Highway are shown in Table 7. During the 50 year ARI event, there is a maximum flooding depth of 0.54m over the floodway and 21.4m^3/s discharging through the culverts.

TABLE 7: PRE-DEVELOPMENT DAMPIER HIGHWAY FLOOD INFORMATION

Storm Event	Max Discharge (m^3/s)	Max Flooding Depth[1] (m)	Peak Stage (mAHD)	Back water (m)	Upstream Stage[2] (mAHD)	Down-stream Stage[3] (mAHD)	Peak Discharge Culverts (m^3/s)	Peak Discharge Floodway (m^3/s)
20yr ARI	53	0.41	14.25	0.07	14.32	13.35	20	33
50yr ARI	78	0.53	14.37	0.06	14.43	13.49	21	57
100yr ARI	99	0.59	14.43	0.06	14.49	13.57	21	78

1. Maximum flooding depth from invert of floodway at 13.84mAHD.
2. Location is approximately 100m upstream from Dampier Highway.
3. Location is approximately 100m downstream from Dampier Highway.

The post-development results for the Dampier Highway are shown in Table 8. During the 50 year ARI storm event there is a slight increase in discharge across the floodway.

TABLE 8: POST-DEVELOPMENT DAMPIER HIGHWAY FLOOD INFORMATION

Storm Event	Max Discharge (m^3/s)	Max Flooding Depth[1] (m)	Peak Stage (mAHD)	Back water (m)	Upstream Stage[2] (mAHD)	Down-stream Stage[3] (mAHD)	Peak Discharge Culverts (m^3/s)	Peak Discharge Floodway (m^3/s)
20yr ARI	60	0.48	14.32	0.18	14.50	13.35	20	40
50yr ARI	82	0.54	14.38	0.21	14.59	13.47	21	61
100yr ARI	105	0.60	14.44	0.23	14.67	13.57	21	84

1. Maximum flooding depth from invert of floodway at 13.84mAHD.
2. Location is approximately 100m upstream from Dampier Highway.
3. Location is approximately 100m downstream from Dampier Highway.

5.4.2 Proposed Development Impacts

The impact from the proposed developments results in a similar increase in water levels as occurred in the 100yr ARI flood event. For both the 20 and 50yr ARI events, there is an average increase of 0.06m along the creek from the infilling of the floodplains within the proposed development areas (Figures 14 and 15). The largest increase is upstream of the Dampier Highway where the development will lead to an increase in flood levels of 0.33m (20 year ARI) and 0.36m (50 year ARI).

5.5 Dampier Highway Duplication

JDA have been advised by Jerome Goh (Main Roads Western Australia (MRWA)) that MRWA are currently designing a lane duplication for the Dampier Highway at the Madigan Creek crossing location.

Results from this flood study indicates that Dampier Highway is overtopped as frequently as during the 1hr 5yr ARI storm event. Consequently the design of the culverts and floodway are not sufficient to prevent a significant backwater upstream of the highway during the larger flood events (20, 50 and 100 year ARI events).

Recent discussion with Jerome Goh (MRWA) indicates that the post-development design of the highway upgrade will include the following design criteria:

- The serviceability and survivability for the 1 in 50 year ARI flood event.
- Preventing the backwater from exceeding 150mm

The post-development modelling performed in this report has assumed that the existing culverts and floodway will be retained. Consequently, should the capacity of the culverts be reduced, or the floodway removed, there may be detrimental impacts for floodplain management and potentially damage to infrastructure within the proposed residential developments.

6. FLOODPLAIN MANAGEMENT

The main objective of effective floodplain management is to provide protection to people, infrastructure and the environment by preventing damage to infrastructure from flooding, limiting the effect of flooding on individuals and communities, and preserving ecological and amenity values. This Section is based on best management practices outlined by SCARM (2000) and Waters and River Commission (2001).

Floodplain management in Western Australia is guided by the Department of Water (DoW) through the provision of advice and recommendation of guidelines for proposed development on floodplains with the object of minimising flood risk and damage. DoW uses the following guiding principles to ensure proposed development in floodprone areas is acceptable with regard to major flooding:

- Proposed development has adequate flood protection from a 100 year ARI flood event.
- Proposed development does not detrimentally impact on the existing 100 year ARI flooding regime of the general area.

Further details of the Strategy for existing development and proposed future developed are described below in the following sections.

6.1 Existing Development

The presence of the highway drainage structures on the floodplain can alter the flow and hence influence the flooding regime of the general area. Existing structures identified on 100 year ARI floodplain of the Madigan Creek are the Dampier Highway culverts and floodway.

As discussed in Section 5.5, the culverts do not convey the flow for Madigan Creek and the floodway is overtopped. These structures are may adversely affect major flooding following duplication of the highway without sufficient design.

6.2 Proposed Development

Future development on the floodplain has the potential to adversely impact on the natural flooding regime of the river. Similarly development can threaten the environmental factors that influence the waterway function.

To ensure adequate flood protection is provided to future development the recommended floodplain management strategy is (Figure 17):

- For proposed development located outside of the 100 year ARI floodplain, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level is recommended.
- For proposed development located within the 100 year ARI floodplain, the Department of Water will provide advice on each proposal based on its merits. Factors that will be examined are depth of flow, velocity of flow and potential flood damage. If development is considered acceptable, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level will be recommended.

A failure to properly adhere to these recommendations will result in a greater exposure to risks of flood damage. It should be noted that this information is related to major flooding only and other planning issues, such as environmental and ecological considerations, may also need to be addressed.

Structural flood mitigation measures, such as levees, bypass floodways, channel alignment and dams are not considered appropriate to mitigate flooding in Madigan Creek. Current development within the Study Area is not threatened and future development can be protected through appropriate land use planning. Future river crossings however should be designed to allow appropriate flow conveyance dependent upon the importance as an escape route during a major flood.

The type of fence on a property should also be approved by the Shire to ensure it does not adversely affect flood flow. For example, fences that allow the free flow of floodwaters (ie, post and rail type) are acceptable. However, solid or mesh fences aligned perpendicular to the flow are not acceptable as they may increase flood levels and are more prone to flood damage.

Structures related to stormwater management, such as detention basins or swales, may be required, but these should be determined through appropriate planning as the development progresses. It is recommended that stormwater management techniques follow the water sensitive urban design approach consistent with Stormwater Management Manual of Western Australia (DoE 2004) with critical infrastructure being located outside of the 100 year ARI floodplain.

In addition, any other proposed development within the 100 year ARI floodplain area including lot boundaries, firebreaks, clearing, roads and stormwater infrastructure are generally considered inappropriate and should be avoided if practical.

6.3 Emergency Response Procedures

Flood emergency response measures are required when flooding occurs above the design flood level, in this case, the 100 year ARI design flood. Emergency measures may include flood forecasting and warning, plans for the evacuation of the development and plans for the recovery of an area once the flood subsides (SCARM 2000).

It is recommended that the Shire of Roebourne in conjunction with the local emergency services prepare a Flood Emergency Plan for Madigan Creek once the final development structure plan has been approved. Included with this Emergency Plan should be some community education for new and existing residents. Education should involve community awareness of their role in the foreshore management and procedures for the defence and evacuation of the town during a flood event (SCARM 2000). Any emergency procedure should be consistent with the Shire of Roebourne's Emergency Evacuation Plan (2009).

7. REFERENCES

Bureau of Meteorology Website (2010), Tropical Cyclones Affecting the Karratha/Dampier/Roebourne Region

Coffey Environmental (2010), 'Geotechnical Investigation for Karratha Townsite - Baynton West'

Department of Environment (DoE) (2004), *Stormwater Management Manual for Western Australia,* Perth, Western Australia.

GHD (2009) 'Seven Mile Creek Flood Study'

Institution of Engineers, Australia (1997), Australian Rainfall & Runoff Volume 1: A Guide to Flood Estimation.

Luke, G.L., Burke, K.L. & O'Brien, T.M. (1988). 'Evaporation Data for Western Australia – Technical Report 65', Perth: W.A. Department of Agriculture, Division of Resource Management

Shire of Roebourne (2009) Shire of Roebourne Local Community Emergency Management Arrangements

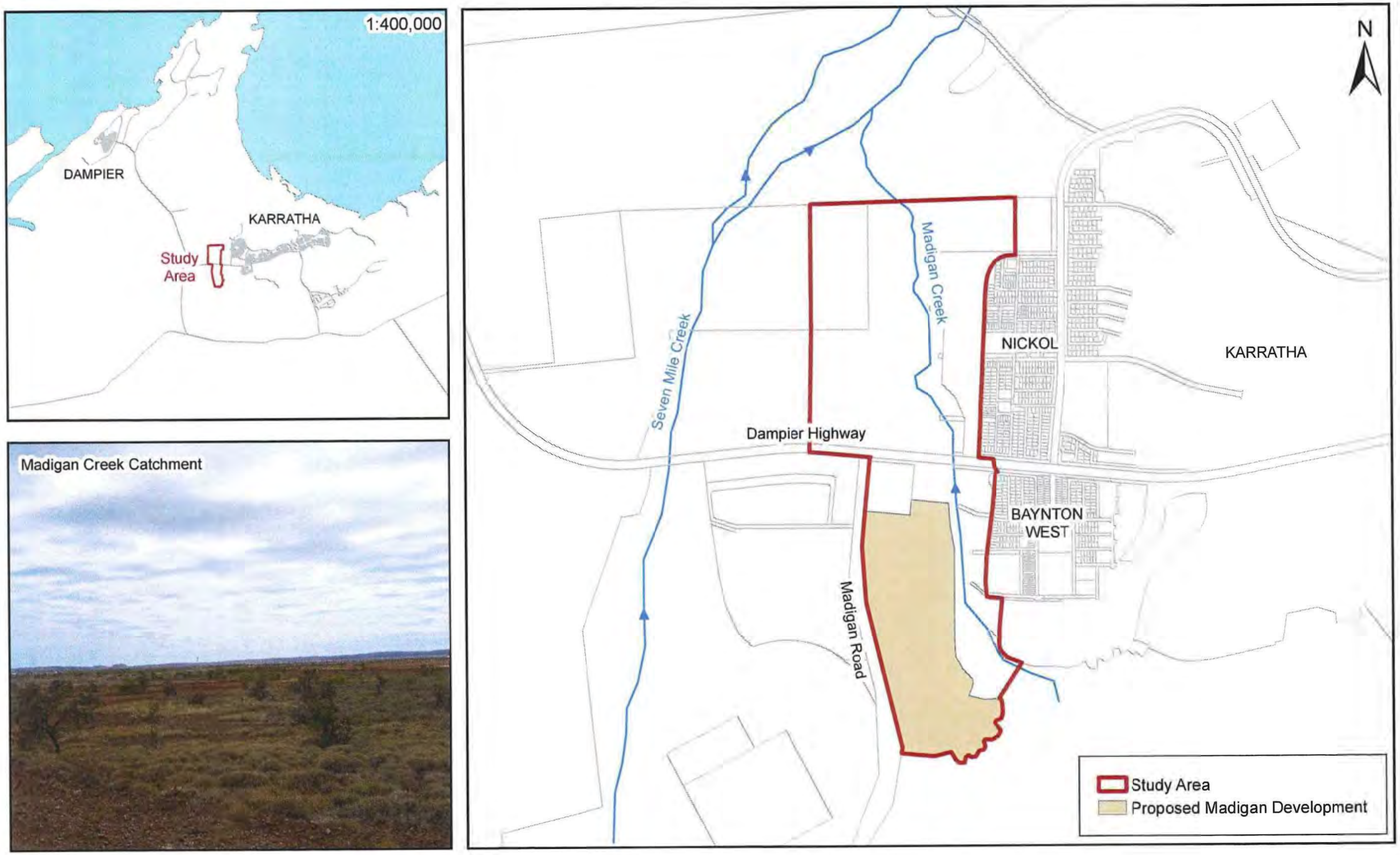
Standing Committee on Agriculture and Resource Management (SCARM) (2000), CSIRO, 'Floodplain management in Australia: best practice principles and guidelines' SCARM Report 73

Water & Rivers Commission (1999) Surface Water Hydrology, An Introduction, Surface Water Hydrology Series Unpublished Report SWH 26.

Water & Rivers Commission (WRC) (2001) *Determining foreshore reserves* Report No. RR 16.

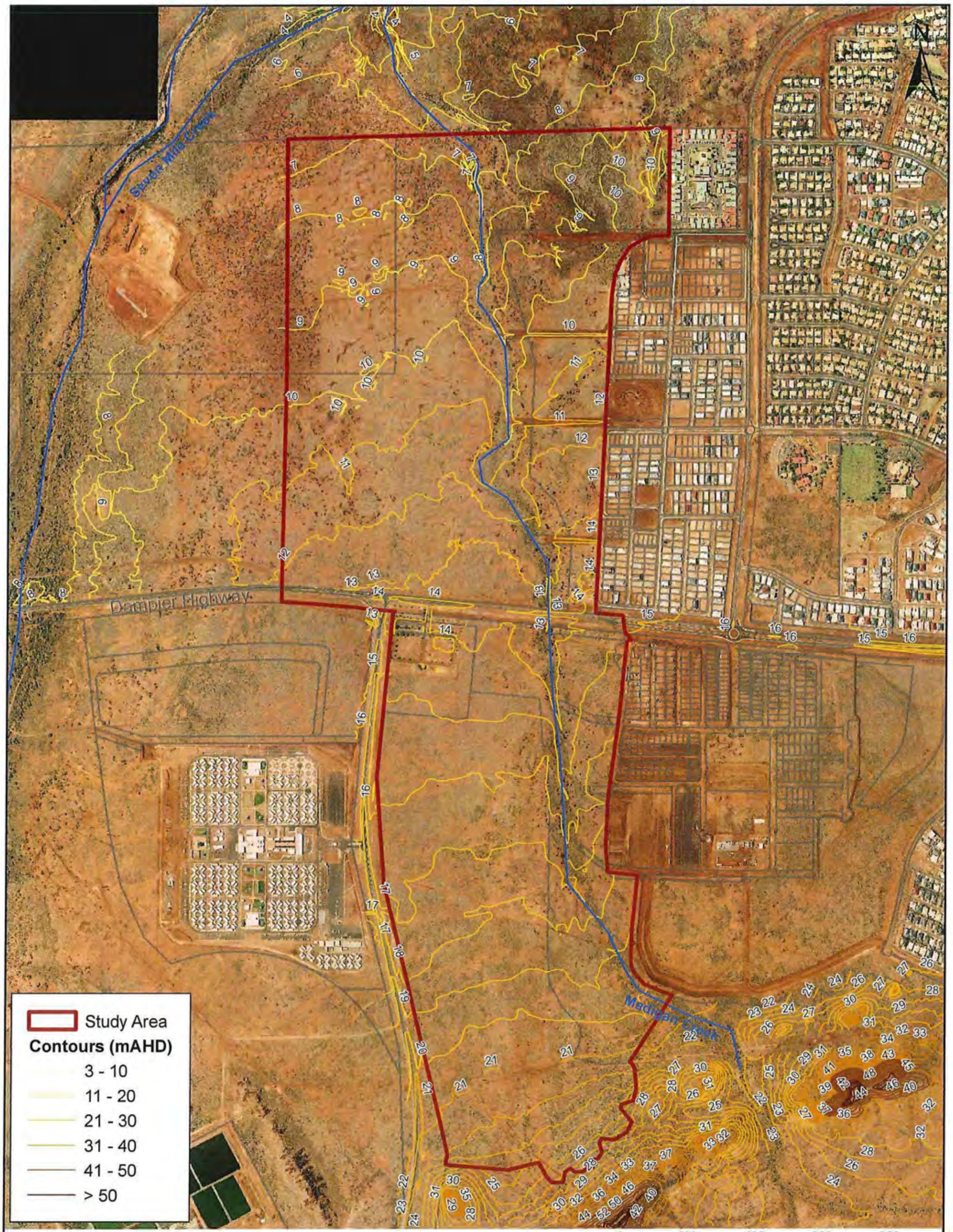
Wood & Grieve (2008), Baynton West Karratha Stages 1 to 4 Drainage Report.

FIGURES



Job No. J4755
Scale: 1:30,000
0 200 400 600 800 Meters

LandCorp
Madigan Creek Flood Study
Figure 1: Location Plan

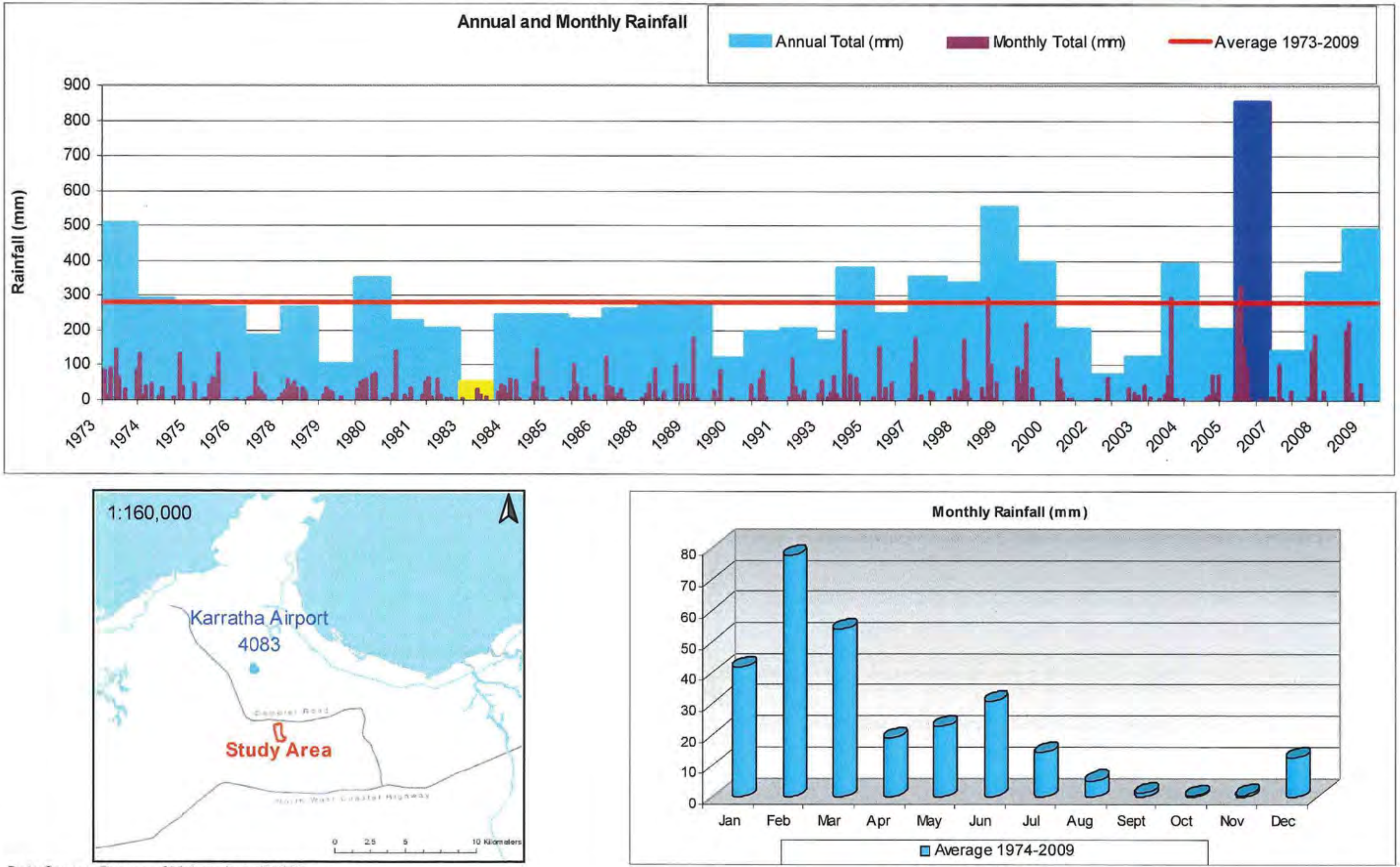


Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 2: Aerial Photograph and Topography

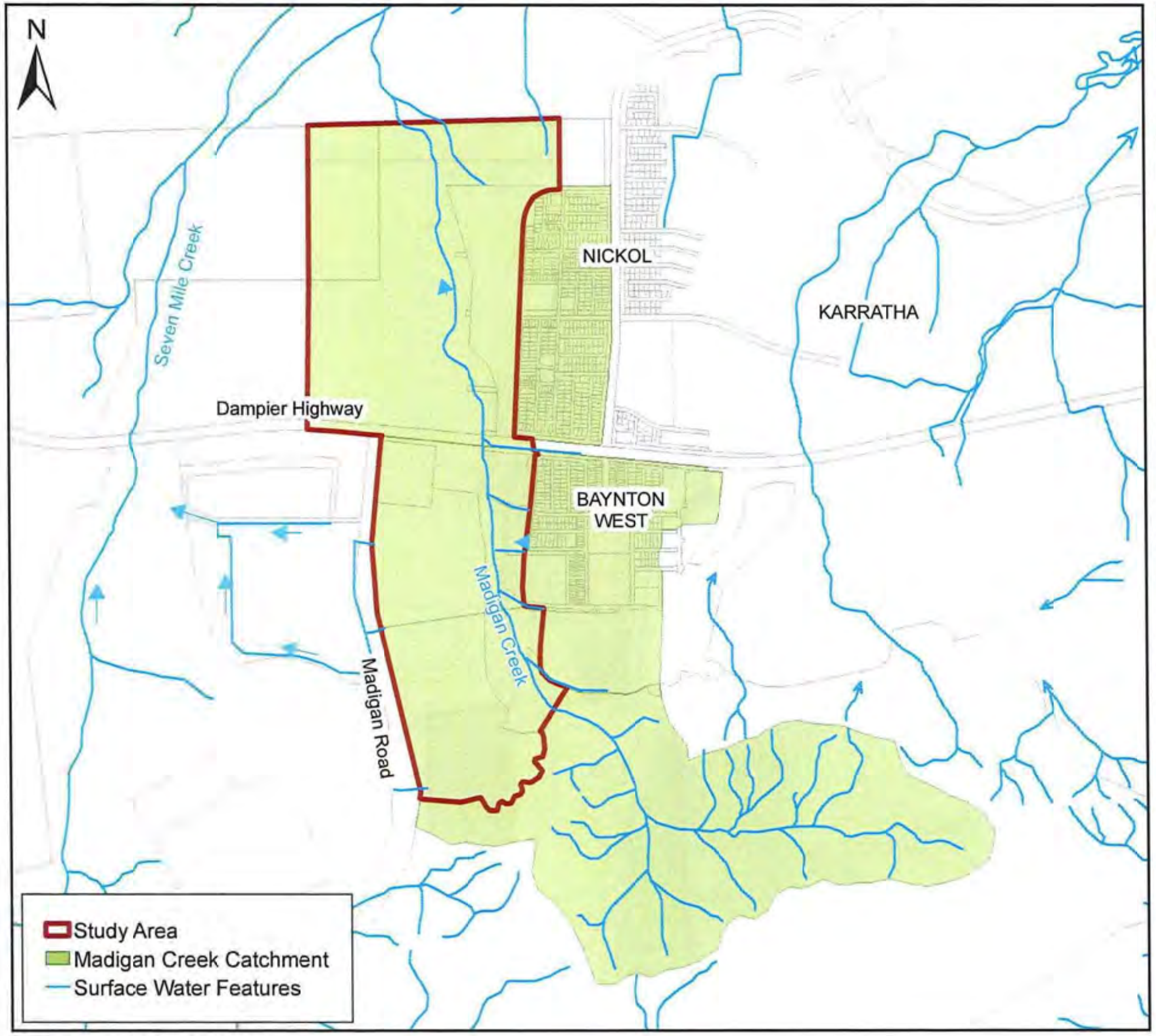


Data Source: Bureau of Metereology (2010)

Job No. J4755

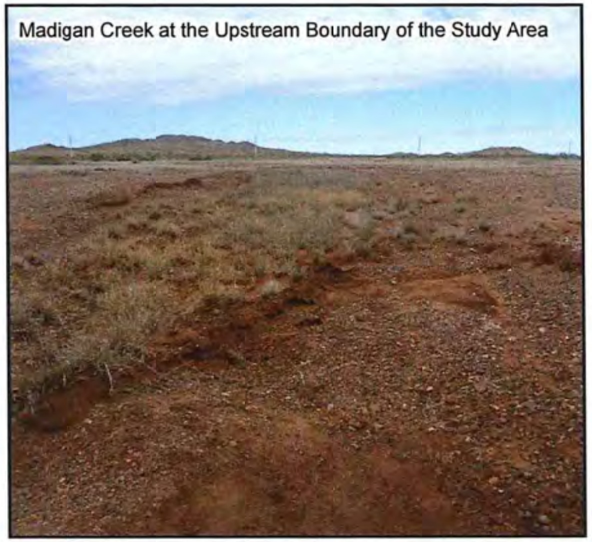
LandCorp
Madigan Creek Flood Study

Figure 3: Karratha Airport Annual and Monthly Rainfall



Data Source: Whelans (2010)

Local Drain Adjacent to Dampier Highway (Baynton West)



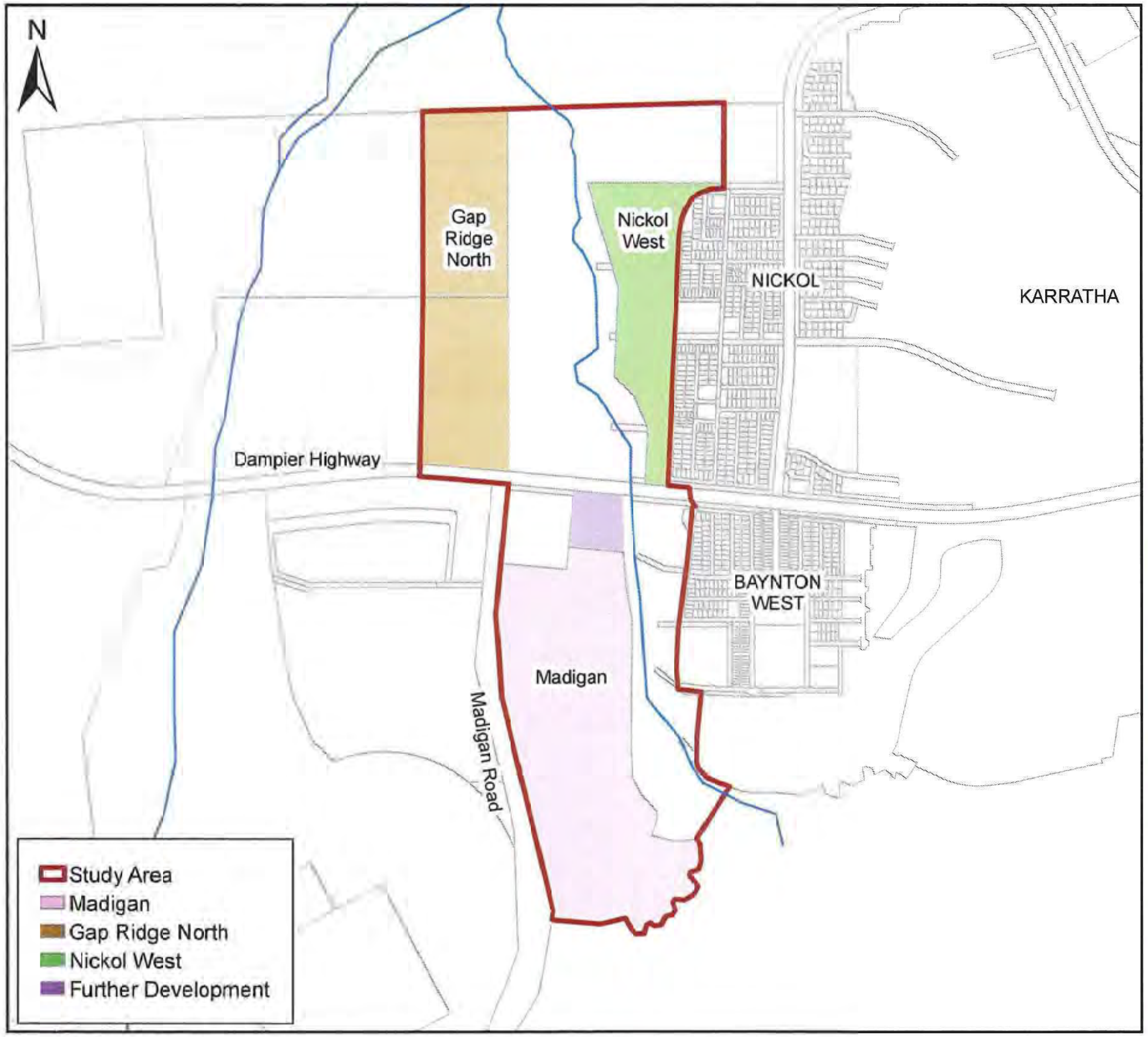
Madigan Creek at the Upstream Boundary of the Study Area

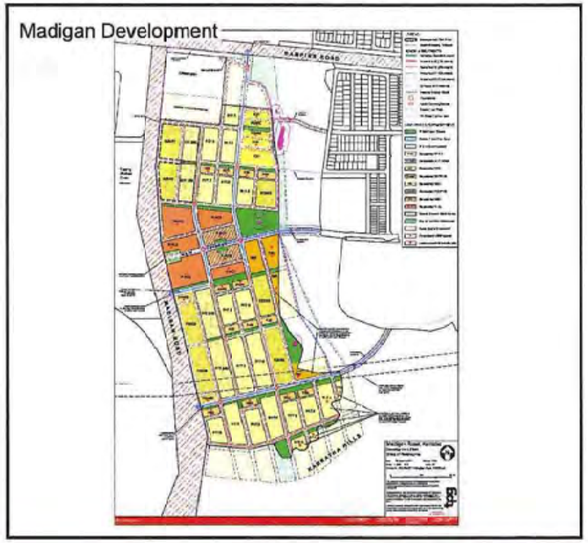
JDA

Job No. J4755
Scale: 1:30,000
0 200 400 600 800 Meters

LandCorp
Madigan Creek Flood Study

Figure 4: Existing Surface Drainage

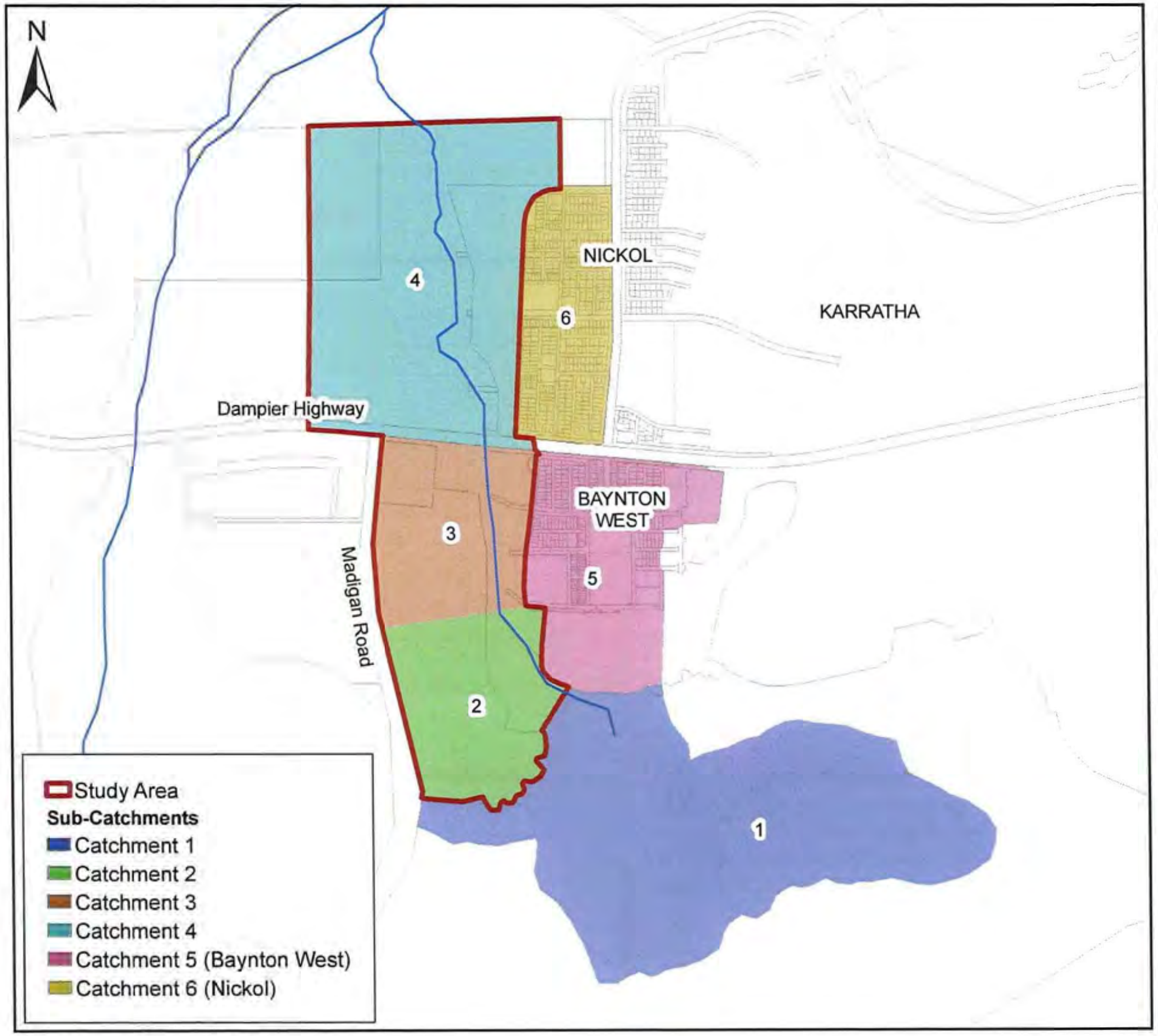




Data Source: TPG (2010)

Job No. J4755
Scale: 1:25,000
0 200 400 600 800 Meters

LandCorp
Madigan Creek Flood Study
Figure 5: Proposed Developments



Sub - Catchment Areas:

Catchment 1: 178.0ha
Catchment 2: 54.5ha
Catchment 3: 54.5ha
Catchment 4: 143.6ha
Catchment 5 (Baynton West): 68.7ha
Catchment 6 (Nickol): 46.5ha

TOTAL: 545.8ha

Roughness Coefficient:
Manning's n = 0.05

Culverts under Karratha-Dampier Road

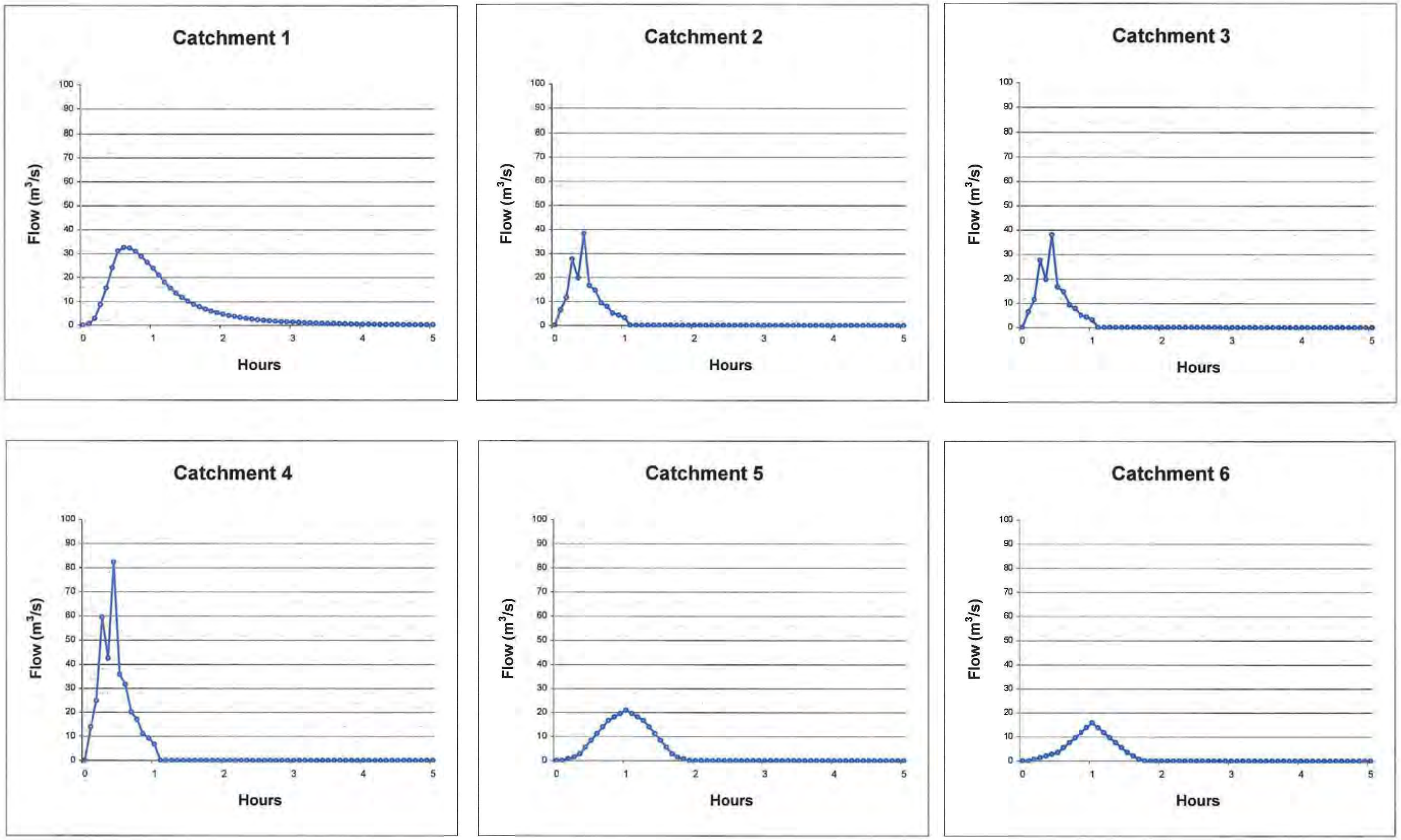
Data Source: Whelans (2010)

JDA

Job No. J4755
Scale: 1:30,000
0 200 400 600 800 Meters

LandCorp
Madigan Creek Flood Study

Figure 6: Madigan Creek Sub-Catchments



Catchment 1

Catchment 2

Catchment 3

Catchment 4

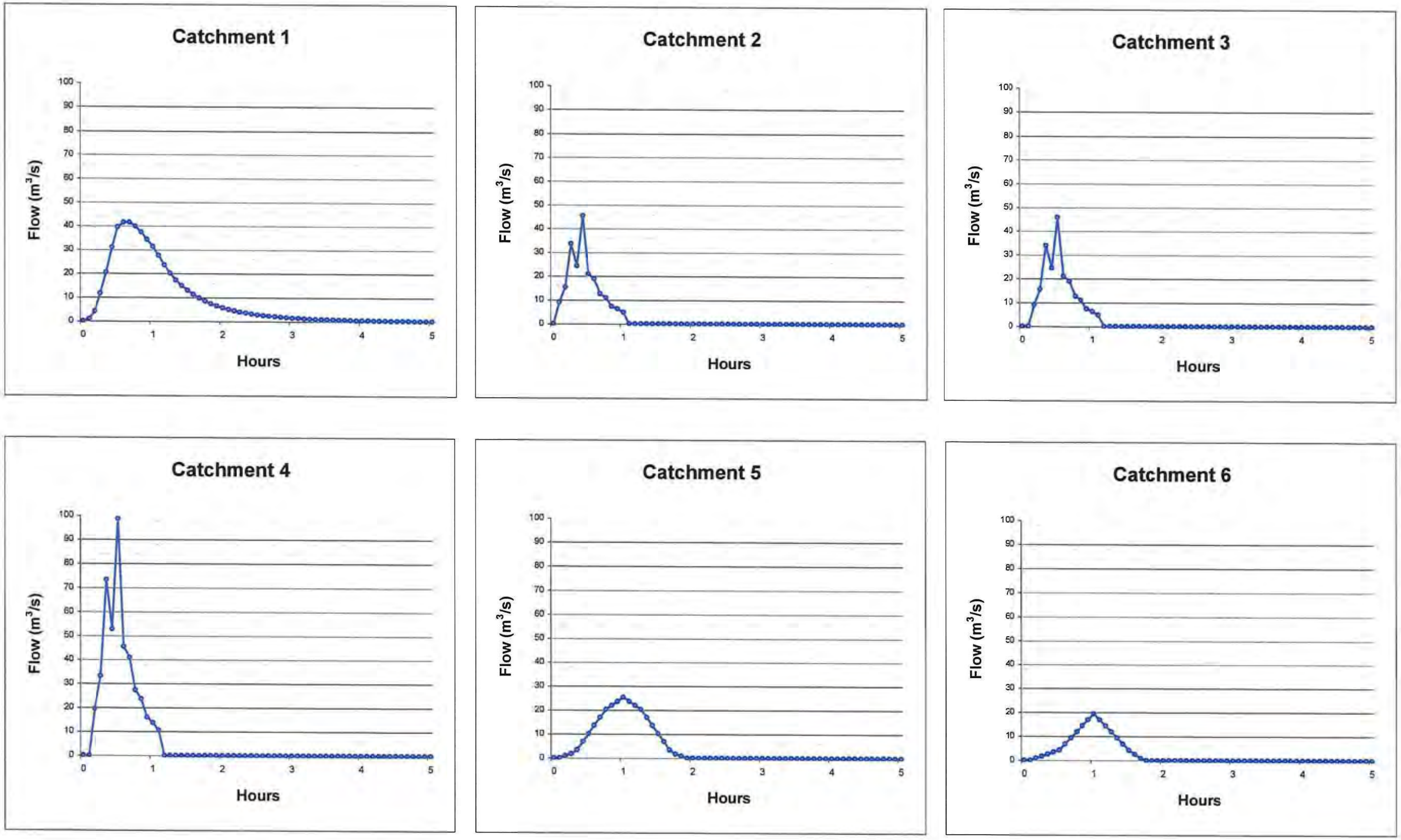
Catchment 5

Catchment 6

Job No. J4755

LandCorp
Madigan Creek Flood Study

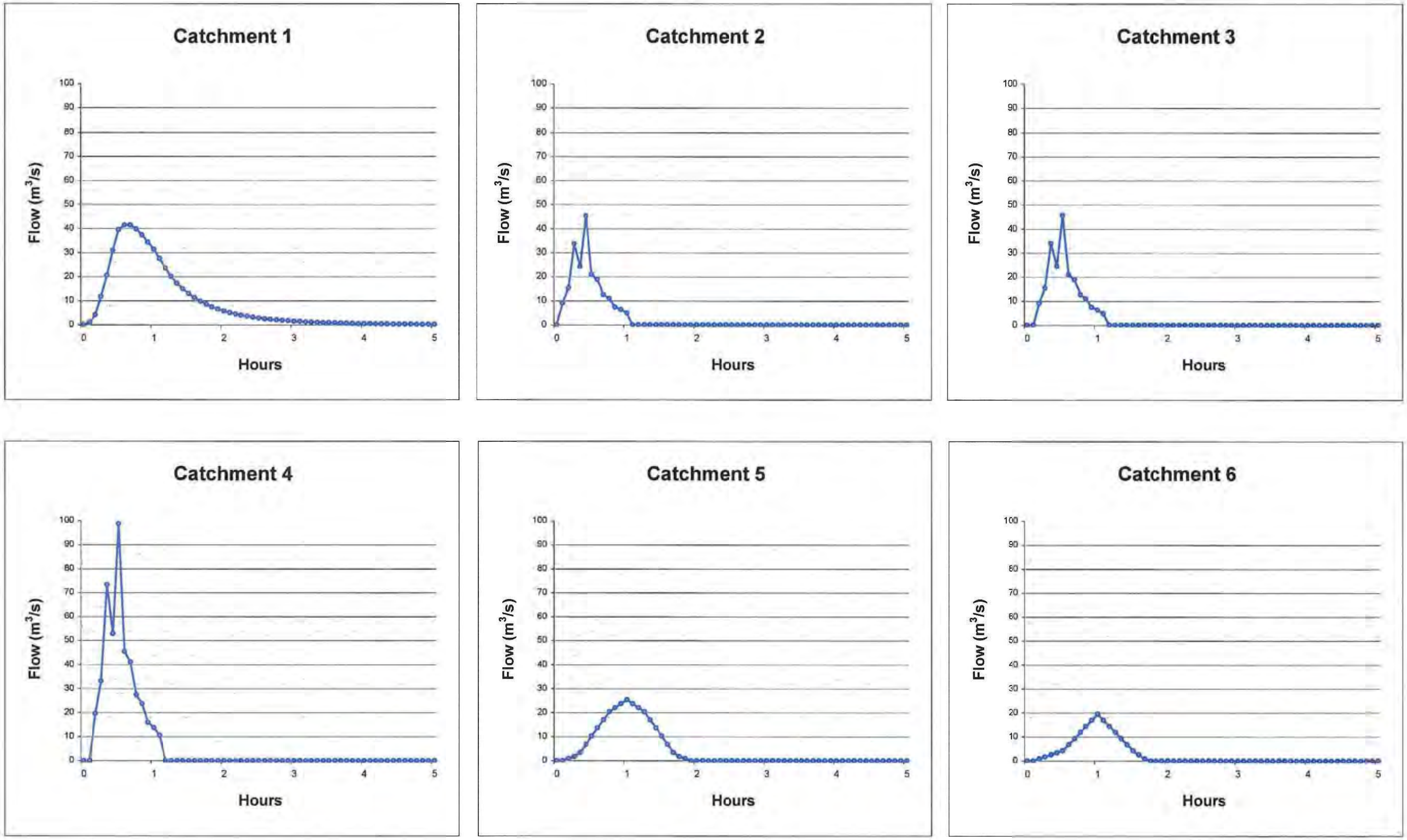
Figure 7: Design Hydrographs - 20 Year ARI



Job No. J4755

LandCorp
Madigan Creek Flood Study

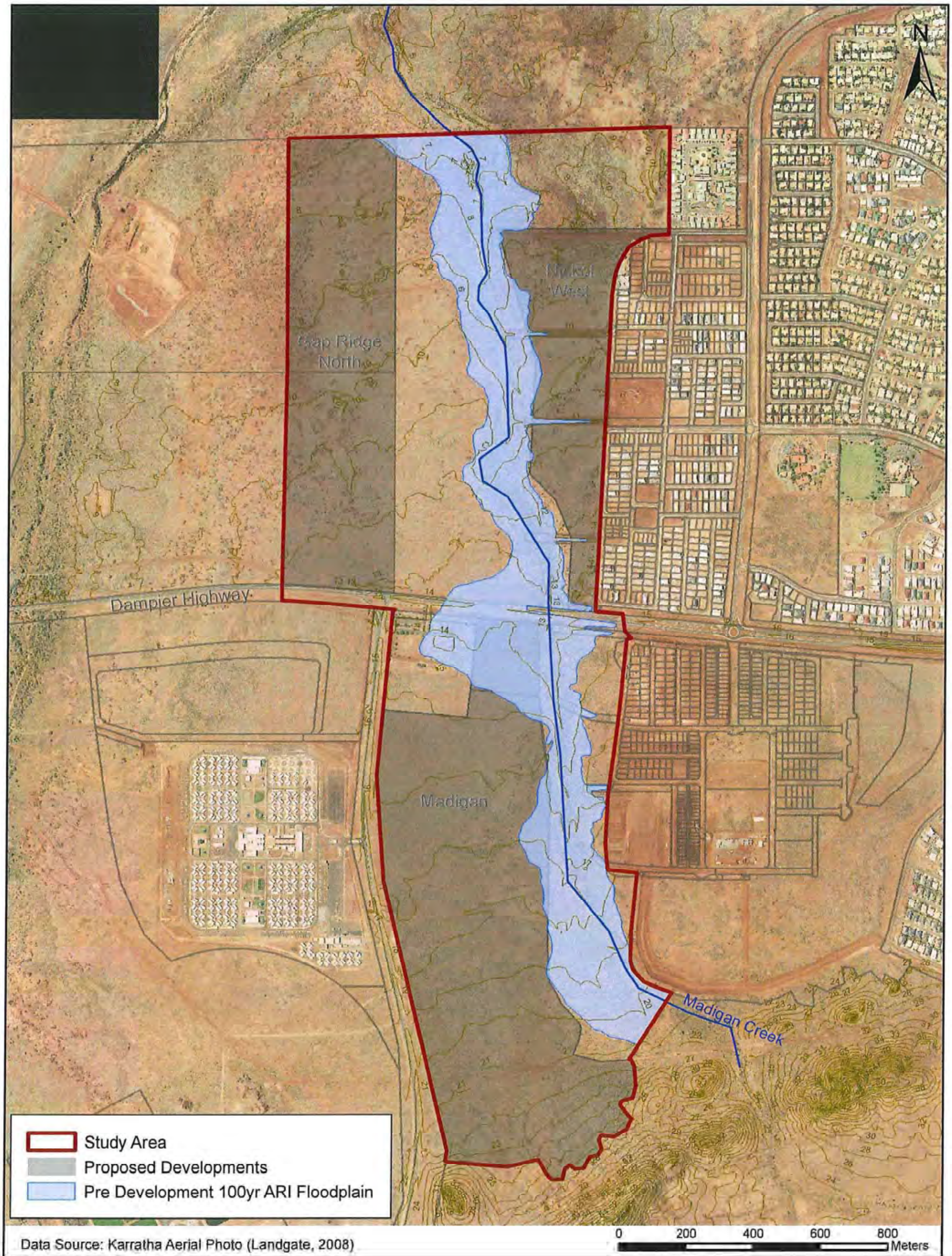
Figure 8: Design Hydrographs - 50 Year ARI



Job No. J4755

LandCorp
Madigan Creek Flood Study

Figure 9: Design Hydrographs - 100 Year ARI

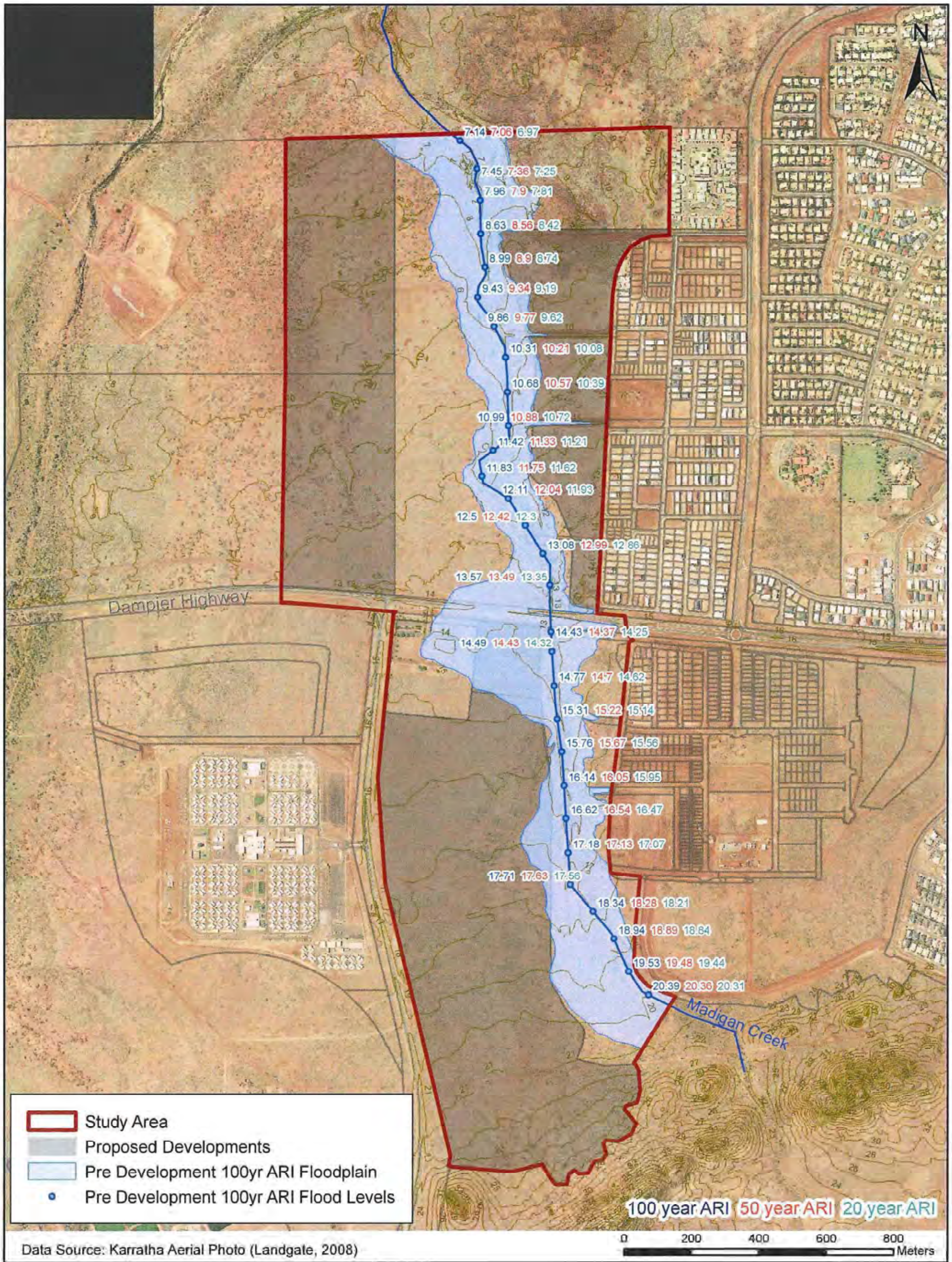


Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 10: 100 year ARI Pre-Development Floodplain

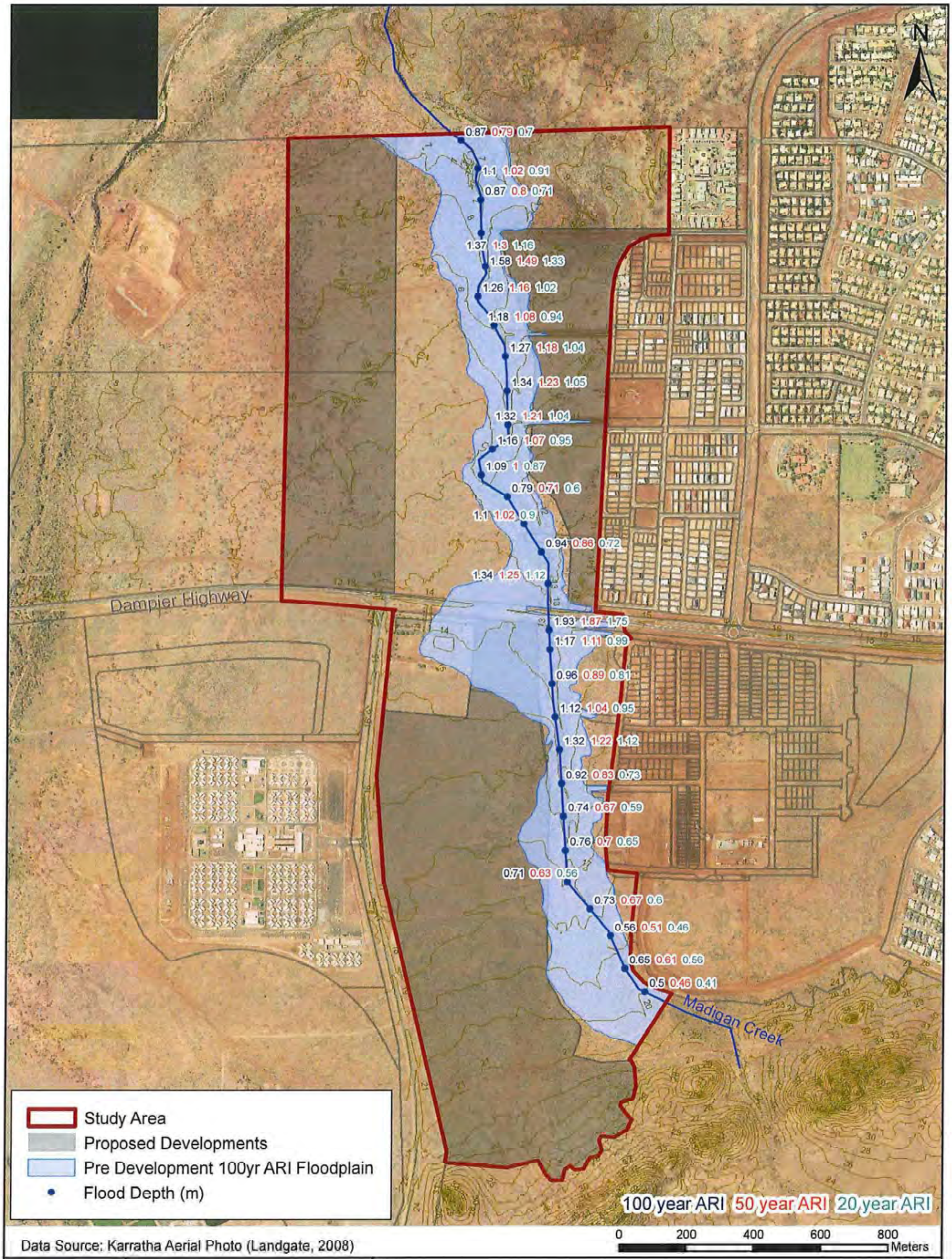


Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 11: 20, 50 & 100 year ARI Pre-Development Flood Levels



Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA

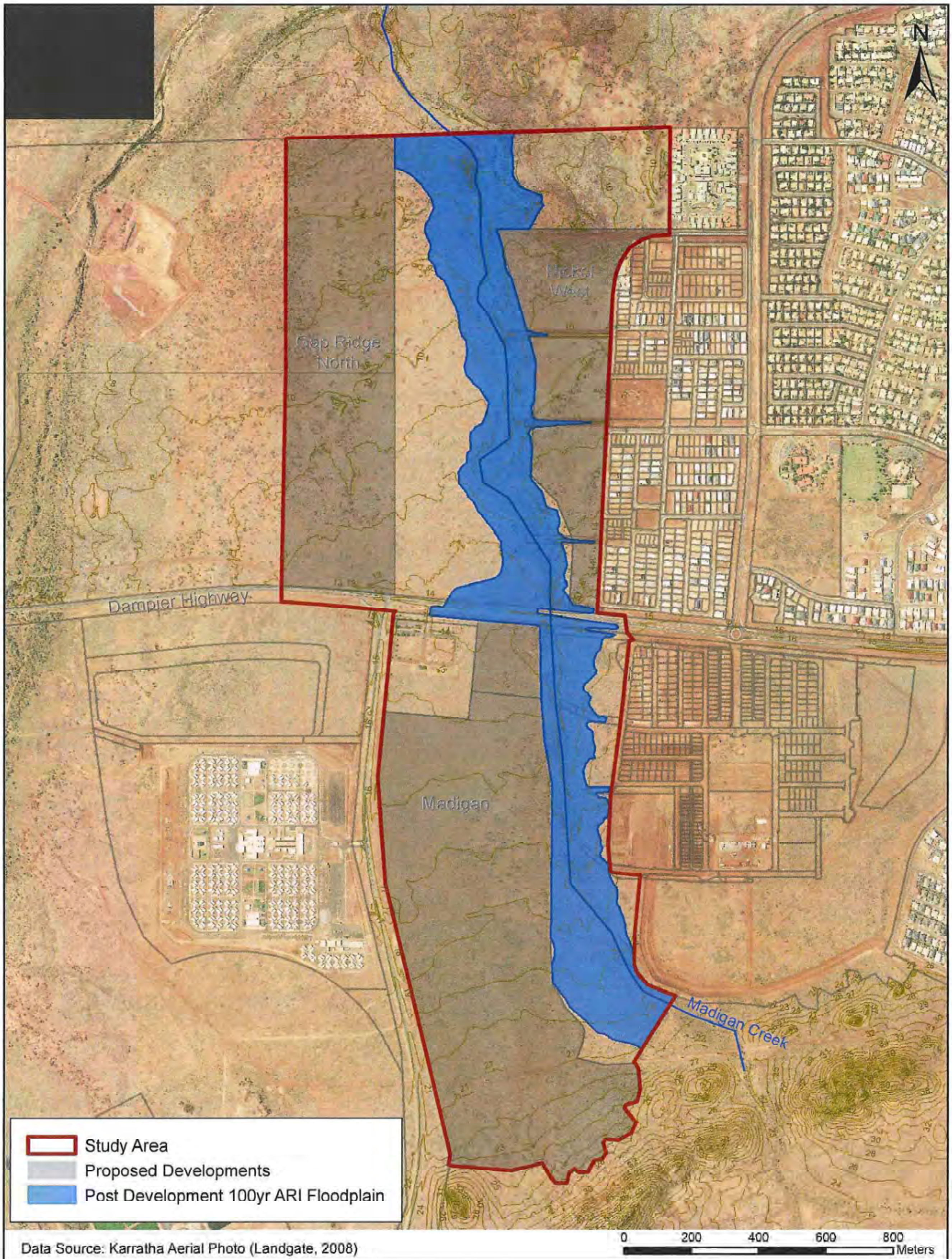
Job No. J4755

Scale 1:15,000

LandCorp

Madigan Creek Flood Study

Figure 12: 20, 50 & 100 year ARI Pre-Development Flood Depths



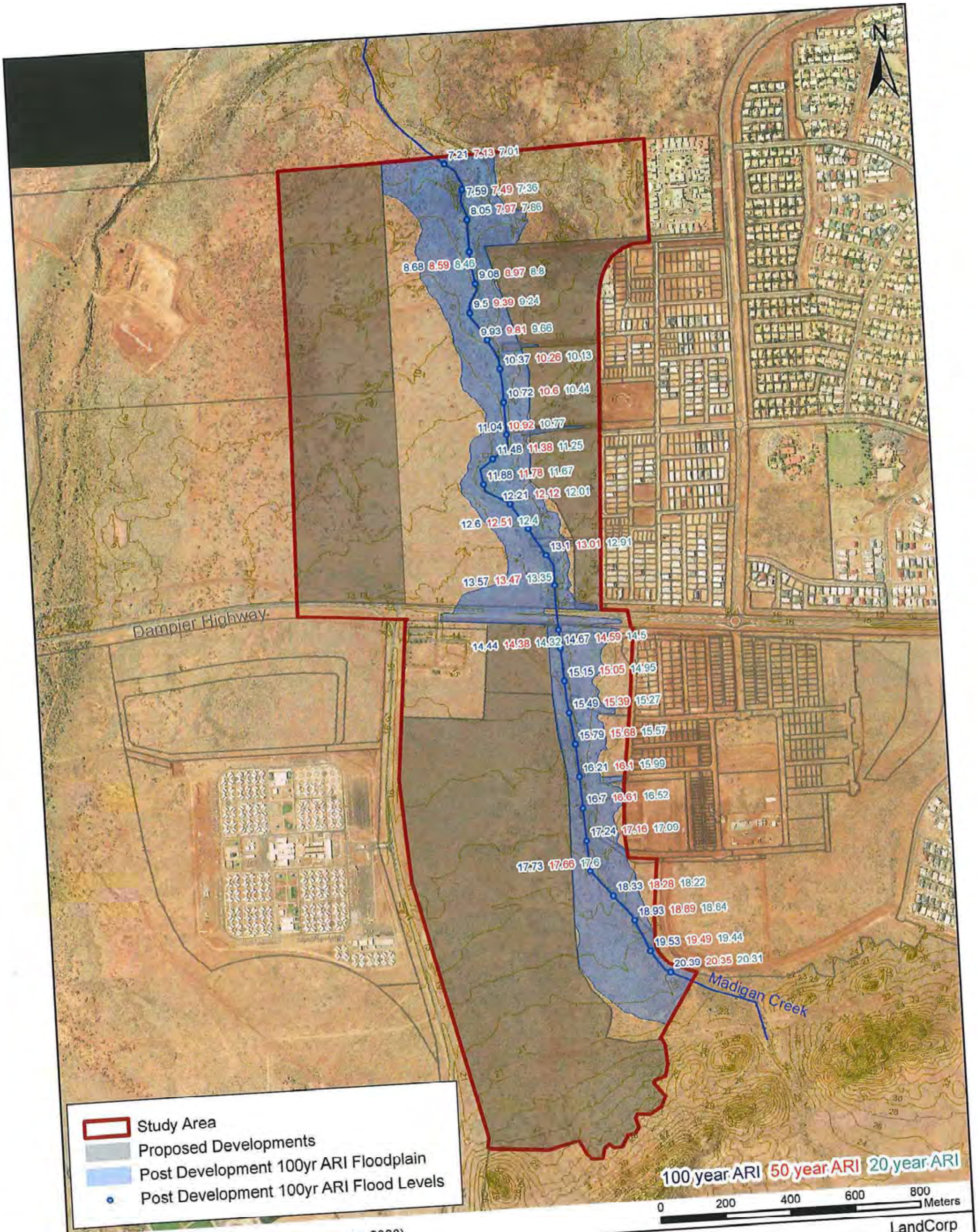
Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 13: 100 year ARI Post-Development Floodplain



Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA

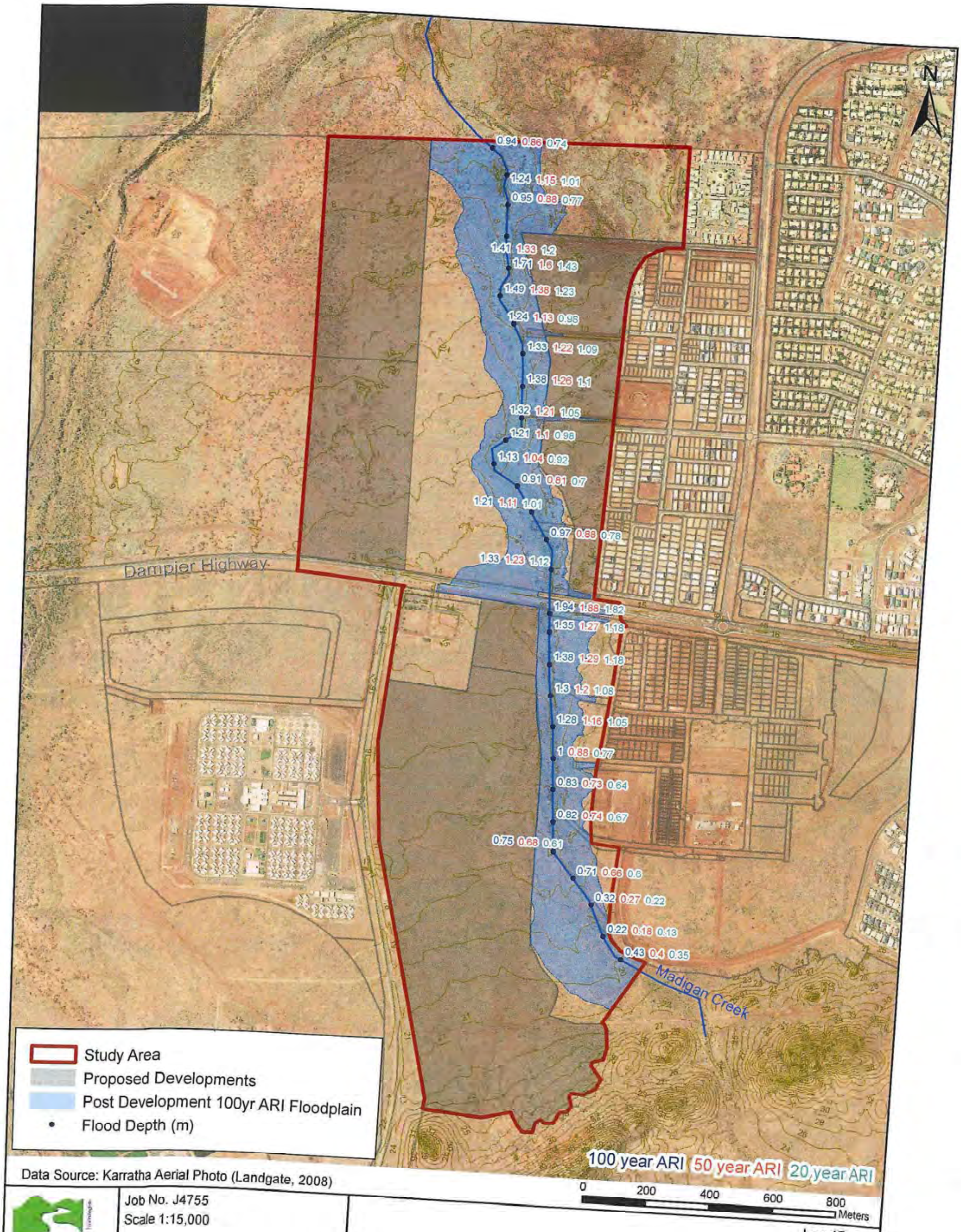
Job No. J4755

Scale 1:15,000

LandCorp

Madigan Creek Flood Study

Figure 14: 20, 50 & 100 year ARI Post-Development Flood Levels



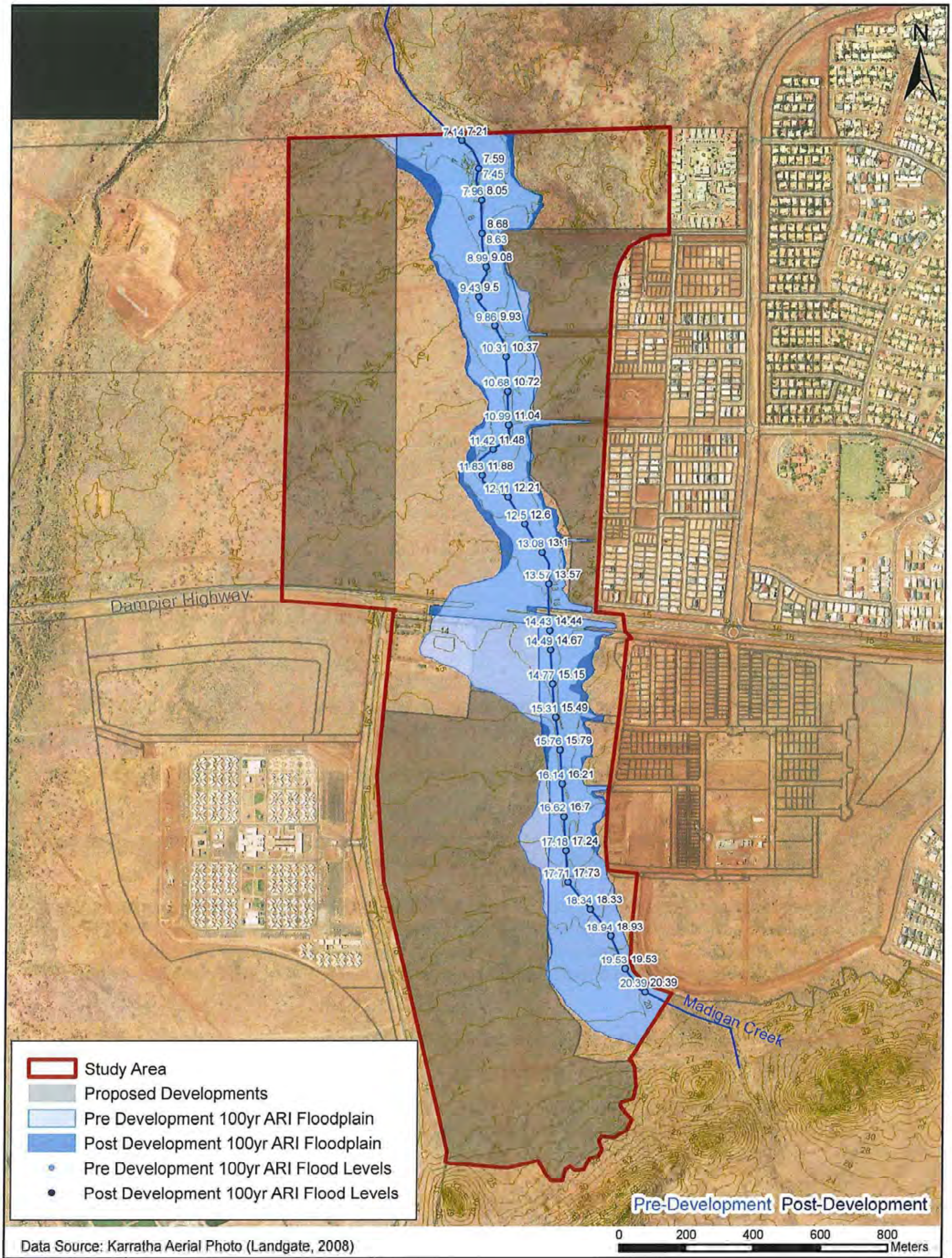
Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 15: 20, 50 & 100 year ARI Post-Development Flood Depth



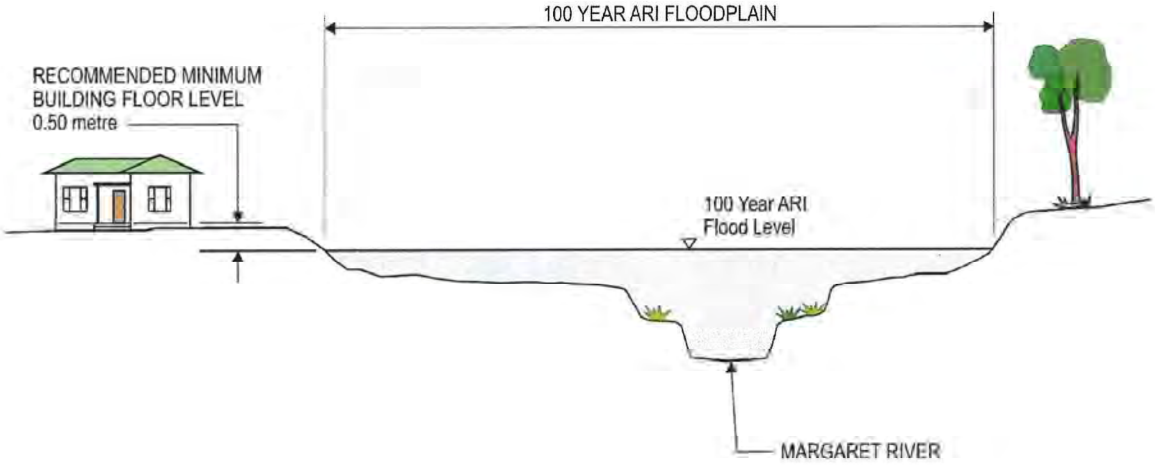
Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 16: Pre and Post-Development 100 year ARI Floodplains

RECOMMENDED FLOODPLAIN MANAGEMENT STRATEGY



(SCALE: DIAGRAMMATIC)

GENERAL NOTES

1. The 100 year ARI flood level is expected to occur, on average, once every 100 years. Floods higher than this level will occur but, on average, will be less frequent.

2. To ensure adequate flood protection is provided to future development the recommended floodplain management strategy is:

   2.1 For proposed development located outside of the 100 year ARI floodplain, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level is recommended.

   2.2 For proposed development located within the 100 year ARI floodplain, the Department of Water will provide advice on each proposal based on its merits. Factors that will be examined are depth of flow, velocity of flow and potential flood damage. If development is considered acceptable, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level will be recommended.

3. A failure to properly adhere to these recommendations will result in a greater exposure to risks of flood damage.

4. It should be noted that this information is related to major flooding only and other planning issues, such as environmental and ecological considerations, may also need to be addressed.

Data Source: Floodplain Management Strategy (DoW, 2010)

JDA

Job No. J4755

LandCorp
Madigan Creek Flood Study
Figure 17: Floodplain Strategy

Suite 1, 27 York St, Subiaco WA 6008
PO Box 117, Subiaco WA 6904
Ph: +61 8 9388 2436
Fx: +61 8 9381 9279

www.jdahydro.com.au

info@jdahydro.com.au

APPENDIX 6

ACOUSTIC REPORT

This page has been left blank intentionally.

EReport Number:	**10010105**
Revision Number:	**1.1**

ACOUSTIC ASSESSMENT

of a

PROPOSED RESIDENTIAL SUBDIVISION
MADIGAN ROAD KARRATHA WA 6714

for

THE PLANNING GROUP WA
LEVEL 7, 182 ST GEORGES TERRACE
PERTH WA 6000

on behalf of

LANDCORP

PO Box 2124, Malaga WA 6944
ndengine@bigpond.net.au
T: (08) 9249 9619
F: (08) 9249 9622
M: 0412 679 431

ND Engineering
Consulting Engineers

Index:

Revisions

Revisions to the report compared to the previous report, if any, are contained in italics for the paper copy and in red italics text for the PDF copy of the report.

Revision N°:	Date:	Comment	Status
1	18 October 2010	Issued for Approval	Superseded
1.1	**20 October 2010**	**Minor revisions**	**Current**

Author

Nick DELLA GATTA, BE (Mechanical) CPEng MIEAust

N. M. Della Gatta
MIEAust CPEng
Chartered Professional Engineer
Membership No. 1184788

References:

A. State Planning Policy 5.4 '*ROAD AND RAIL TRANSPORT NOISE AND FREIGHT CONSIDERATIONS IN LAND USE PLANNING*', gazetted 22 SEP 2009 Gazette No 169 Special.

B. Attachment 2 *IMPLEMENTATION GUIDELINES* May 2009
for SPP 5.4 'Road and Rail Transport Noise and Freight Considerations in Land Use Planning'.

C. Australian Standard 2107-2000
'Acoustics - Recommended design sound levels and reverberation times for building interiors'.

D. tpg Drawing No 710-200 ST1C Madigan Plans 051010, dated 11 OCT 10

SUMMARY

0.1 ND Engineering's opinion is that traffic noise impact on the proposed development can meet the requirements of Reference A, SPP 5.4, by:

a. Deferring the sale of land on the Western half of blocks 8, 7, 3, 4, 9a, 9, 10, 10a, 40 and 44 (See Figure 0 below) nominally within 82 metres from the centre line of Madigan Road until such time as the Ridge Gap Village construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route; and

b. Adjusting the shape of the block facing Dampier Road so that there will not be any residences North of the roundabout. See Figure 0 – BUFFER; and

c. Reassessing the noise levels prior to the sale of the deferred land once the construction camp ceases operation and if necessary once Madigan Road is no longer used as a heavy haulage route.

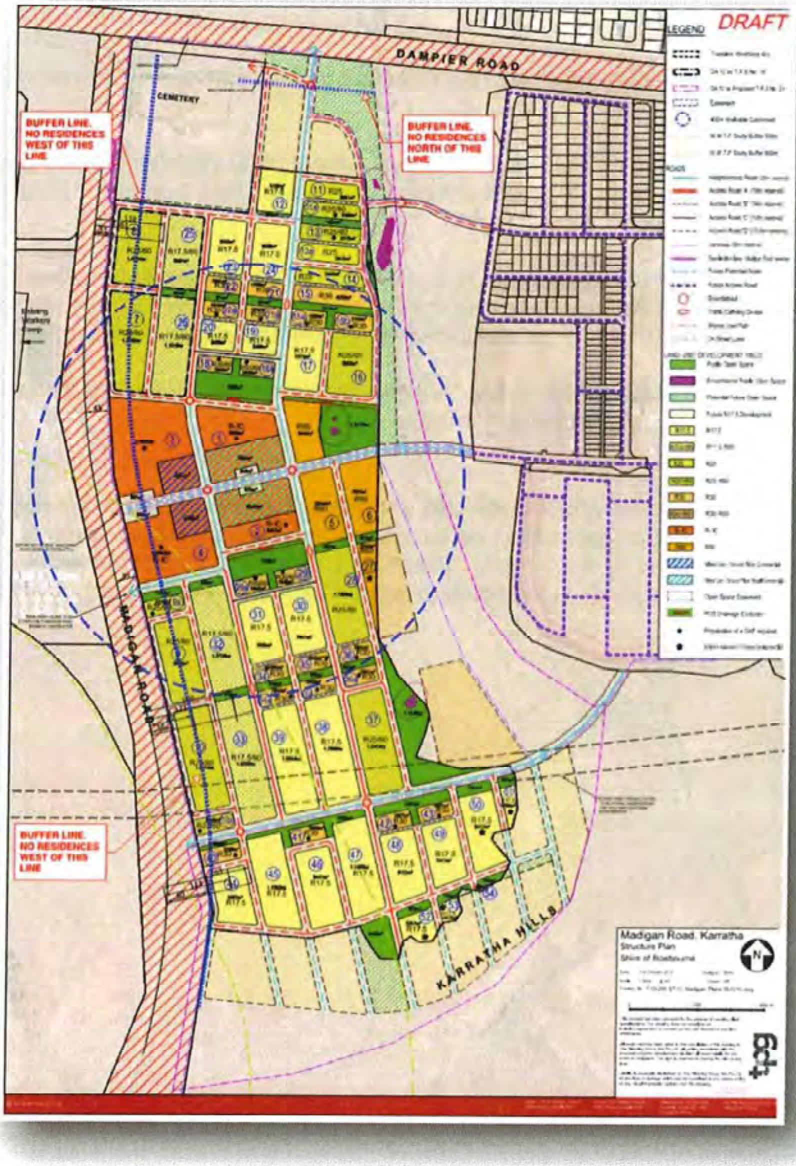


FIGURE 0 – BUFFER LINES

INTRODUCTION

1.1 ND Engineering was commissioned to conduct an acoustic assessment of the proposed development to determine the requirements for compliance with Reference A, SPP 5.4, noting that the construction of a barrier wall along Madigan Road and restrictions on the construction of dwellings was not desirable given anticipation that there would be reductions in traffic volumes in the next 5 to 10 years.

1.2 Compliance with Reference A, while negating a barrier wall along Madigan Road and restrictions on the construction of dwellings, was envisaged as being achievable by the creation of a buffer of land to be withheld from development until such time as closure of the construction camp and relocation of the heavy haulage route from Madigan Road, anticipated to be in the next 5 to 10 years respectively.

SITE DESCRIPTION

2.1 The site is located near the corner of Madigan Road and Dampier Road. See Annex A for details.

2.2 The Madigan Road average week day traffic count is about 3000 vehicles per day South of Dampier Road of which comprises about 80% light vehicles (Ausroads Class 1 and 2). Observations on site show that the traffic movement between:

a. 0500 to 0800 hours and 1600 to 2000 hours is predominantly light vehicles and buses associated with movement between Dampier Road and the Gap Ridge Village entry/exit producing hourly average noise levels of about LAeq 60 to 65 dB(A) at the measurement location; and

b. 0800 to 1600 hours is predominantly heavy vehicles producing hourly average noise levels of about LAeq 55 to 60 dB(A) at the measurement location.

2.3 The traffic volumes are currently 3000 vehicles per day and is expected to decrease significantly once the Ridge Gap Village construction camp ceases operation and again when Madigan Road is not longer used as a heavy haulage route. The reduction in traffic volume associated with the closure of the Ridge Gap Village is expected to reduce the noise levels by about 5 dB(A).

ASSESSMENT

The following subsections form the assessment:

- 3.0 Assumptions & Limitations.
- 3.1 Outdoor Noise Criteria.
- 3.2 Measurements.
- 3.3 Outdoor Noise Assessment.
- 3.4 Indoor Noise Assessment.

Assumptions & Limitations - Assessment

3.0 The following assumptions and limitations are made:

a. The noise measurements are based 'on the day' and cannot take into account any future mixes of traffic which may result in variations from the predicted noise levels.

b. The proposed development is as shown in Annex A;

c. The residences will be single storey residences in blocks 8, 7, Western half of 3 and 4, 9a, 9, 10, 10a, 40 and 44;

d. That the Gap Ridge Village located on the Western side of Madigan Road is anticipated to be closed and removed, without any future replacement, in approximately 5 years from now in 2015;

e. That the heavy haulage route currently on Madigan Road will be relocated approximately 10 years from now in 2020.

Outdoor Noise Criteria

3.1.1 Table 1 of Reference A, SPP 5.4, gives the following outdoor noise criteria.

Table 3.1 - Outdoor noise Criteria (Reference A's Table 1)

Time of Day	Noise Target	Noise Limit
DAY - 6am to 10 pm	$L_{Aeq(Day)}$ = 55 dB(A)	$L_{Aeq(Day)}$ = 60 dB(A)
Night - 10 pm to 6 am	$L_{Aeq(Night)}$ = 50 dB(A)	$L_{Aeq(Night)}$ = 55 dB(A)

3.1.2 The guidelines (see Reference B) associated with SPP 5.4 (see Reference A) provide two deemed to comply noise insulation packages for residential developments.

These two deemed to comply packages, Reference B's Package A Table 8 and Package B Table 9, are designed to ensure that the indoor noise standards in the policy are achieved for residential developments in areas where the outdoor noise levels are likely to be higher than the target noise levels by up to 8 dB(A).

3.1.3 Part of this noise assessment is to determine a demarcation point beyond which the application of the deemed to satisfy packages is not required as the noise levels will be below noise target.

Measurements

3.2.1 Measurements on site indicated at the development's Western site boundary parallel to Madigan Road, at the junction between blocks 7 and 8,outdoor noise levels were $L_{Aeq(Day)}$ = 61 dB(A) and $L_{Aeq(Night)}$ = 52 dB(A) prior to any adjustments.

3.2.2 Calculations indicate that at a distance 80 metes the outdoor noise levels reduce to $L_{Aeq(Day)}$ = 54 dB(A) and $L_{Aeq(Night)}$ = 46 dB(A) prior to any adjustments. These two noise levels are below the noise target.

Outdoor Noise Assessment

3.3 The outdoor noise levels, $L_{Aeq(Day)}$ = 54 dB(A) and $L_{Aeq(Night)}$ = 46 dB(A), are below the noise target therefore no further assessment is required with respect to Reference A and B.

Indoor Noise Assessment

3.4 The outdoor noise measurements, $L_{Aeq(Day)}$ = 54 dB(A) and $L_{Aeq(Night)}$ = 46 dB(A), are below the noise target therefore no further assessment is required with respect to Reference C, AS/ 2107:2000

CONCLUSIONS

4. ND Engineering's opinion is that traffic noise impact on the proposed development can be reduced to meet the requirements of Reference A, SPP 5.4, by:

a. Deferring the sale of land on the Western half of blocks 8, 7, 3, 4, 9a, 9, 10, 10a, 40 and 44 (See Figure 0 below) nominally within 82 metres from the centre line of Madigan Road until such time as the Ridge Gap Village construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route; and

b. Adjusting the shape of the block facing Dampier Road so that there will not be any residences North of the roundabout. See Figure 0 – BUFFER LINES; and

c. Reassessing the noise levels prior to the sale of the deferred land once the construction camp ceases operation and then later if necessary once Madigan Road is not longer used as a heavy haulage route.

RECOMMENDATIONS

5. The following recommendation are made:

a. Deferring the sale of land on the Western half of blocks 8, 7, 3, 4, 9a, 9, 10, 10a, 40 and 44 (See Figure 5 – BUFFER LINES below) nominally within 82 metres from the centre line of Madigan Road until such time as the construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route; and

b. Adjusting the shape of the block facing Dampier Road so that there will not be any residences North of the roundabout. See Figure 5 – BUFFER LINES; and

c. Reassessing the noise levels prior to the sale of the deferred land once the construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route.

FIGURE 5 – BUFFER LINES

End of Report

Annexes:

A. Site Location.

B. Site Measurement Data.

C. Ancillary Data.

ANNEX A - Site Description

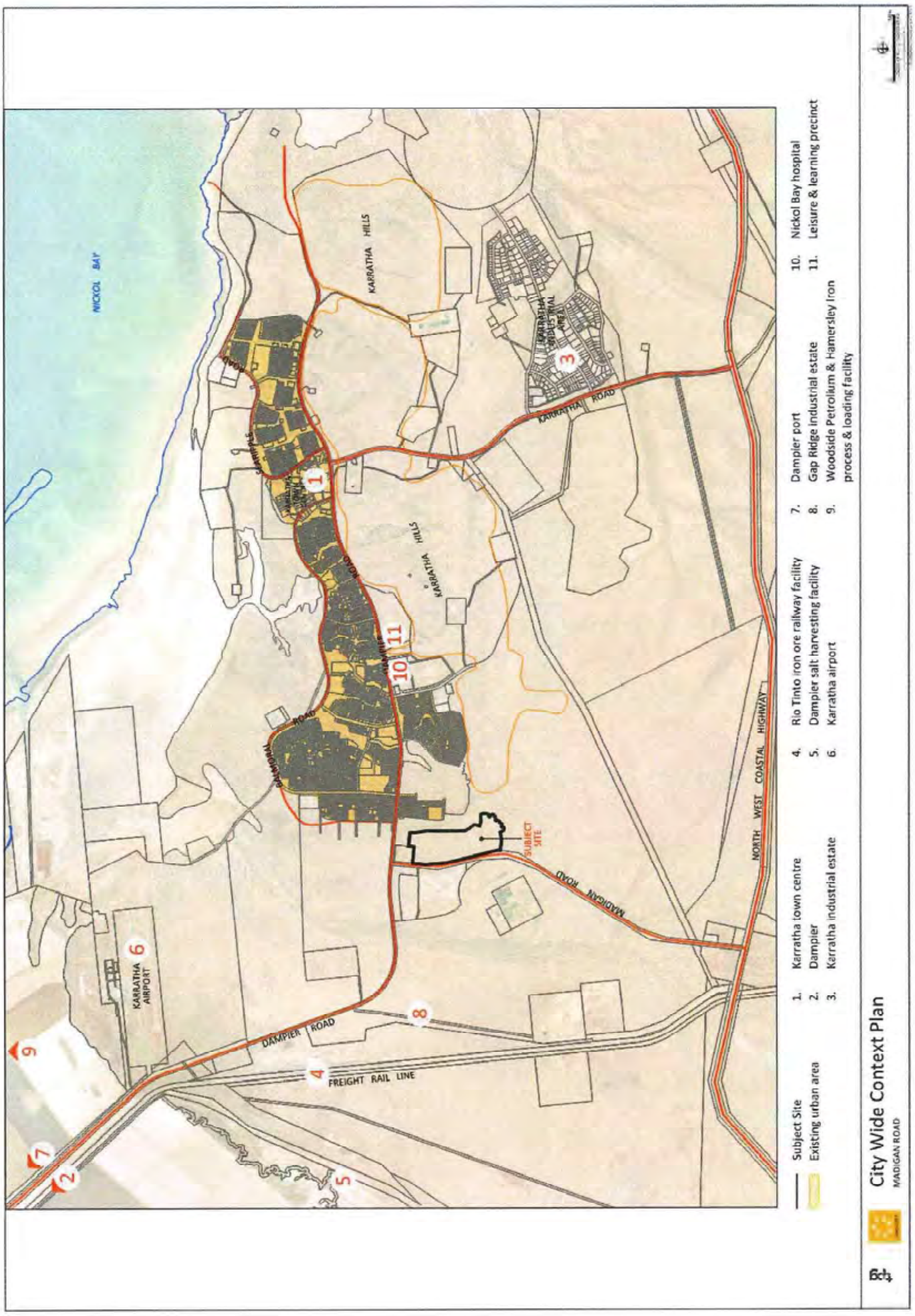


Figure A.1 – SITE LOCATION

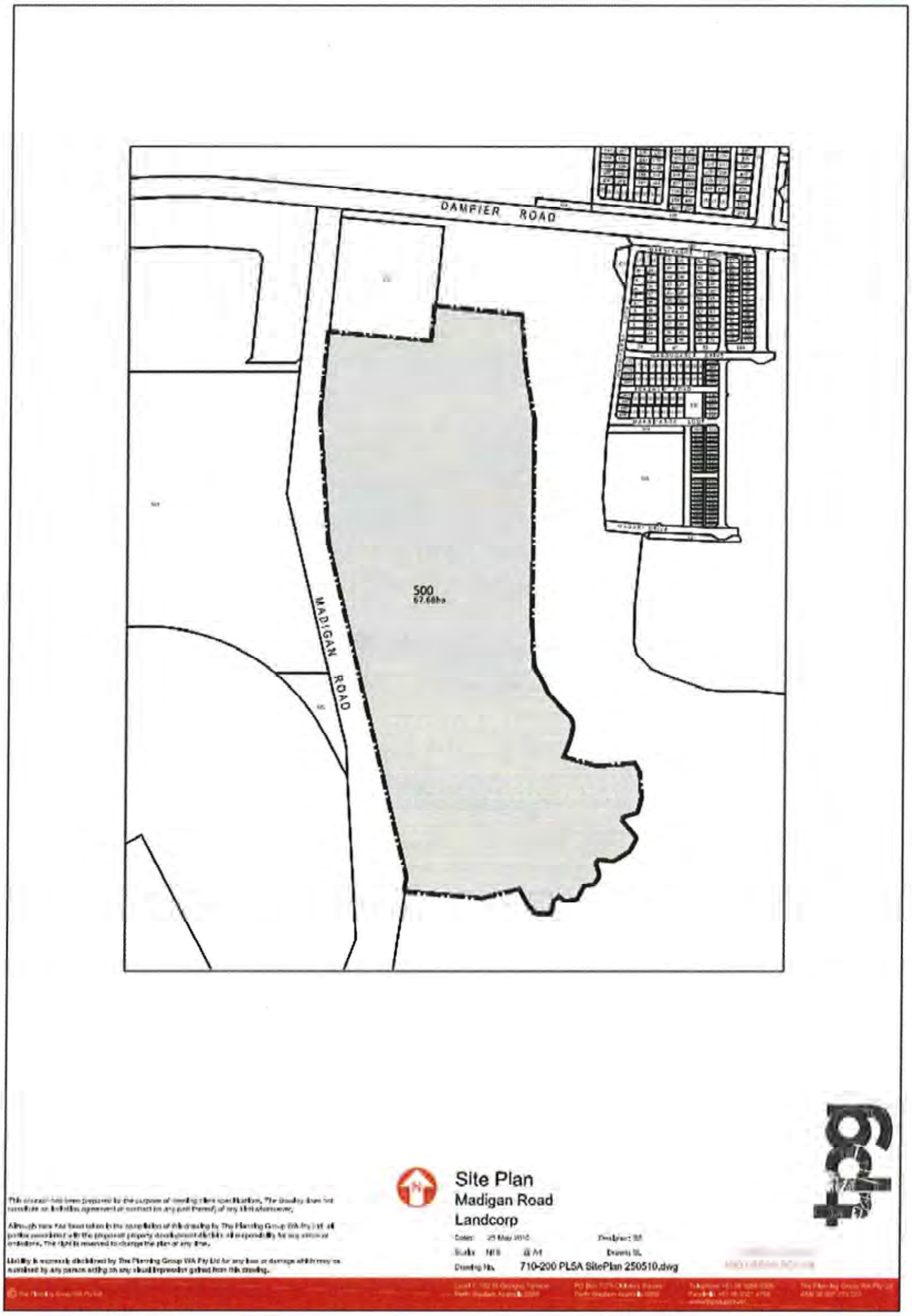


Figure A.2 – SITE PLAN

Figure A.2 – DETAILED SITE PLAN

End of Annex A

ANNEX B - Site Measurement Data

B1 This appendix summarises the measurement details:

a. Measurements were taken by a HP3569A Type 1 Integrating Sound Level Meter with a ACO calibrator both having current NATA calibration certificates from NVMS Leederville WA.

b. Duration of measurements 24 hours;

c. Sampling time 30 minutes;

d. Measurement days Thursday 14th and Friday 15th October 2010.

e. Weather conditions at the time of measurements was warm nominally 25 to 35 oC, no cloud, no rain and generally no wind however the wind on the late afternoon of the 14th and early morning of the 15th caused measurements to be corrupted by wind and vegetation noise.

f. Speed limit 80 kph.

g. The Madigan Road average week day traffic count is about 3000 vehicles per day South of Dampier Road of which comprises about 80% light vehicles (Ausroads Class 1 and 2). Observations on site show that the traffic movement between:

(1) 0500 to 0800 hours and 1600 to 2000 hours is predominantly light vehicles and buses associated with movement between Dampier Road and the Gap Ridge Village entry/exit producing hourly average noise levels of about LAeq 60 to 65 dB(A) at the measurement location; and

(2) 0800 to 1600 hours is predominantly heavy vehicles producing hourly average noise levels of about LAeq 55 to 60 dB(A) at the measurement location.

h. The following table contains the measurement results:

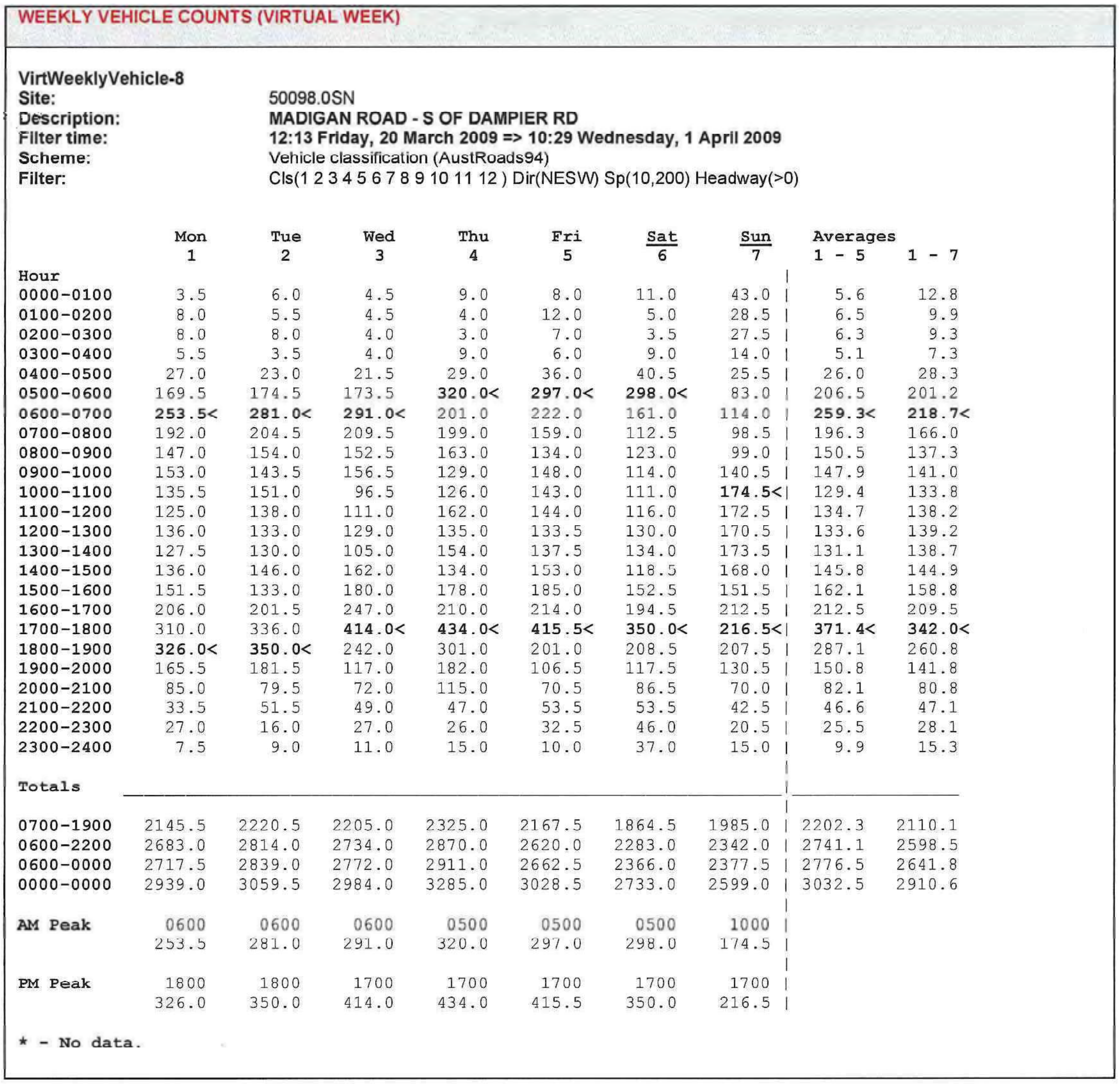
MEASUREMENT RESULTS

TIME		Average Week Day Traffic count	Sound Levels LAeq dB(A)			
From	To		Measured	Normalised (to Traffic Count)	Day	Night
6.00	7.00	259.3	wind	64.0	60.9	
7.00	8.00	196.3	wind	60.8		
8.00	9.00	150.5	wind	57.7		
9.00	10.00	147.5	57.5	57.5		
10.00	11.00	129.4	55.5	56.0		
11.00	12.00	134.7	57.4	56.5		
12.00	13.00	133.6	57.8	56.4		
13.00	14.00	131.1	57.4	56.1		
14.00	15.00	145.8	59.5	57.4		
15.00	16.00	162.1	61.6	58.6		
16.00	17.00	212.5	62.5	61.7		
17.00	18.00	371.4	63.8	68.1		
18.00	19.00	287.1	62	65.2		
19.00	20.00	150.8	wind	57.8		
20.00	21.00	82.1	wind	50.8		
21.00	22.00	46.6	wind	44.2		
22.00	23.00	25.5	wind	37.3		52.4
23.00	0.00	9.9	wind	26.4		
0.00	1.00	5.6	wind	19.8		
1.00	2.00	6.5	wind	21.6		
2.00	3.00	6.3	wind	21.2		
3.00	4.00	5.1	45.7	18.8		
4.00	5.00	26	wind	37.5		
5.00	6.00	206.5	56.2	61.4		

End of Annex B

ANNEX C - Ancillary Data

C1. The information provided in this annex has been supplied to ND Engineering by *tpgwa* and has been included in the report, in order to preserve the information, for future reference during subsequent assessments.



WEEKLY VEHICLE COUNTS (VIRTUAL WEEK)

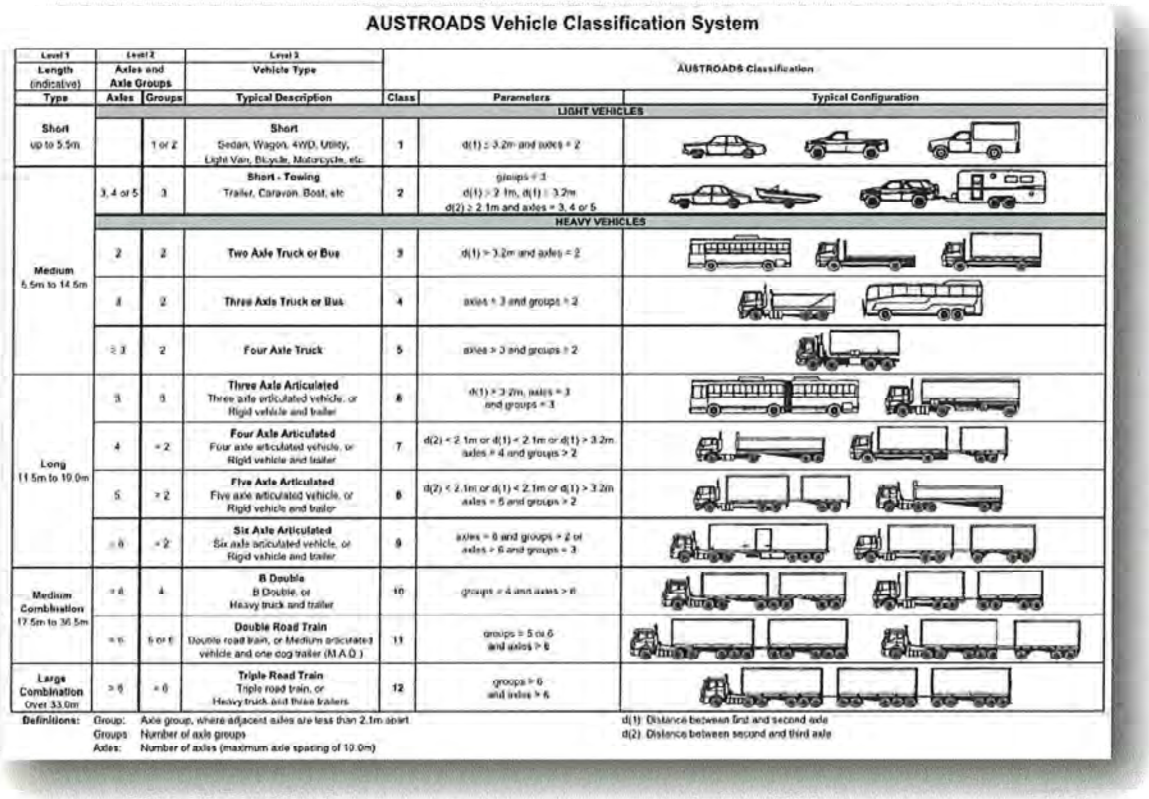
VirtWeeklyVehicle-8
Site: 50098.0SN
Description: **MADIGAN ROAD - S OF DAMPIER RD**
Filter time: **12:13 Friday, 20 March 2009 => 10:29 Wednesday, 1 April 2009**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,200) Headway(>0)

```
                 Mon      Tue      Wed      Thu      Fri      Sat      Sun    Averages
                  1        2        3        4        5        6        7     1 - 5    1 - 7
Hour                                                                     |
0000-0100        3.5      6.0      4.5      9.0      8.0     11.0     43.0 |   5.6     12.8
0100-0200        8.0      5.5      4.5      4.0     12.0      5.0     28.5 |   6.5      9.9
0200-0300        8.0      8.0      4.0      3.0      7.0      3.5     27.5 |   6.3      9.3
0300-0400        5.5      3.5      4.0      9.0      6.0      9.0     14.0 |   5.1      7.3
0400-0500       27.0     23.0     21.5     29.0     36.0     40.5     25.5 |  26.0     28.3
0500-0600      169.5    174.5    173.5    320.0<   297.0<   298.0<    83.0 | 206.5    201.2
0600-0700      253.5<   281.0<   291.0<   201.0    222.0    161.0    114.0 | 259.3<   218.7<
0700-0800      192.0    204.5    209.5    199.0    159.0    112.5     98.5 | 196.3    166.0
0800-0900      147.0    154.0    152.5    163.0    134.0    123.0     99.0 | 150.5    137.3
0900-1000      153.0    143.5    156.5    129.0    148.0    114.0    140.5 | 147.9    141.0
1000-1100      135.5    151.0     96.5    126.0    143.0    111.0    174.5<| 129.4    133.8
1100-1200      125.0    138.0    111.0    162.0    144.0    116.0    172.5 | 134.7    138.2
1200-1300      136.0    133.0    129.0    135.0    133.5    130.0    170.5 | 133.6    139.2
1300-1400      127.5    130.0    105.0    154.0    137.5    134.0    173.5 | 131.1    138.7
1400-1500      136.0    146.0    162.0    134.0    153.0    118.5    168.0 | 145.8    144.9
1500-1600      151.5    133.0    180.0    178.0    185.0    152.5    151.5 | 162.1    158.8
1600-1700      206.0    201.5    247.0    210.0    214.0    194.5    212.5 | 212.5    209.5
1700-1800      310.0    336.0    414.0<   434.0<   415.5<   350.0<   216.5<| 371.4<   342.0<
1800-1900      326.0<   350.0<   242.0    301.0    201.0    208.5    207.5 | 287.1    260.8
1900-2000      165.5    181.5    117.0    182.0    106.5    117.5    130.5 | 150.8    141.8
2000-2100       85.0     79.5     72.0    115.0     70.5     86.5     70.0 |  82.1     80.8
2100-2200       33.5     51.5     49.0     47.0     53.5     53.5     42.5 |  46.6     47.1
2200-2300       27.0     16.0     27.0     26.0     32.5     46.0     20.5 |  25.5     28.1
2300-2400        7.5      9.0     11.0     15.0     10.0     37.0     15.0 |   9.9     15.3
                                                                          |
Totals     _______________________________________________________________|________________
                                                                          |
0700-1900     2145.5   2220.5   2205.0   2325.0   2167.5   1864.5   1985.0 | 2202.3   2110.1
0600-2200     2683.0   2814.0   2734.0   2870.0   2620.0   2283.0   2342.0 | 2741.1   2598.5
0600-0000     2717.5   2839.0   2772.0   2911.0   2662.5   2366.0   2377.5 | 2776.5   2641.8
0000-0000     2939.0   3059.5   2984.0   3285.0   3028.5   2733.0   2599.0 | 3032.5   2910.6
                                                                          |
AM Peak         0600     0600     0600     0500     0500     0500     1000 |
               253.5    281.0    291.0    320.0    297.0    298.0    174.5 |
                                                                          |
PM Peak         1800     1800     1700     1700     1700     1700     1700 |
               326.0    350.0    414.0    434.0    415.5    350.0    216.5 |

* - No data.
```

CLASS SPEED MATRIX

ClassMatrix-10
Site: 50098.0SN
Description: **MADIGAN ROAD - S OF DAMPIER RD**
Filter time: **12:13 Friday, 20 March 2009 => 10:29 Wednesday, 1 April 2009**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,200) Headway(>0)

```
Speed (km/h)                                                                    Speed Totals
                                                                              |
         ---------------------------------------------------------------------|
                                         Class                                |
              1     2     3     4     5     6     7     8     9    10    11    12 |
  10-20 |    21     .     1     1     1     .     .     .     1     1     1     . |    27   0.1%
  20-30 |    73     .     2     1     2     .     .     .     2     1     3     1 |    85   0.2%
  30-40 |    81     2     8    10     1     .     1     .     5     1    19    51 |   179   0.5%
  40-50 |   405     7    82    32    25     2     2     7    73    12   190    74 |   911   2.6%
  50-60 |  2291    42   464   109    52     5    11    14   371    22   402   216 |  3999  11.5%
  60-70 |  7583   147   930   335    66    16    17    60   666    62   553   102 | 10537  30.3%
  70-80 | 10049   170   795   322    55    17    17    47   483    23   159    52 | 12189  35.0%
  80-90 |  4597    77   216   133     9     3     4     5    82     4    17     5 |  5152   4.8%
 90-100 |  1252    14    43    19     2     .     .     .    13     1     .     . |  1344   3.9%
100-110 |   270     1     9     .     .     .     .     .     .     .     .     . |   280   0.8%
110-120 |    63     .     3     .     .     .     .     .     1     .     .     . |    67   0.2%
120-130 |    12     .     1     .     .     .     .     .     .     .     .     . |    13   0.0%
130-140 |     4     .     .     .     .     .     .     .     .     .     .     . |     4   0.0%
140-150 |     1     .     .     .     .     .     .     .     .     .     .     . |     1   0.0%
150-160 |     1     .     .     .     .     .     .     .     .     .     .     . |     1   0.0%

|_____________________________________________________________________________|____________
        | 26703   460  2554   962   213    43    52   133  1697   127  1344   501| 34789
        | 76.8%  1.3%  7.3%  2.8%  0.6%  0.1%  0.1%  0.4%  4.9%  0.4%  3.9%  1.4%|
                                     Class Totals
```



AUSTROADS Vehicle Classification System

Level 1 Length (indicative) Type	Level 2 Axles and Axle Groups Axles	 Groups	Level 3 Vehicle Type Typical Description	AUSTROADS Classification Class	 Parameters	 Typical Configuration
LIGHT VEHICLES						
Short up to 5.5m		1 or 2	**Short** Sedan, Wagon, 4WD, Utility, Light Van, Bicycle, Motorcycle, etc	1	d(1) ≤ 3.2m and axles = 2	
Medium 5.5m to 14.5m	3, 4 or 5	3	**Short - Towing** Trailer, Caravan, Boat, etc	2	groups = 3 d(1) ≥ 2.1m, d(1) ≤ 3.2m d(2) ≥ 2.1m and axles = 3, 4 or 5	
HEAVY VEHICLES						
	2	2	**Two Axle Truck or Bus**	3	d(1) > 3.2m and axles = 2	
	3	2	**Three Axle Truck or Bus**	4	axles = 3 and groups = 2	
	≥ 3	2	**Four Axle Truck**	5	axles > 3 and groups = 2	
Long 11.5m to 19.0m	3	3	**Three Axle Articulated** Three axle articulated vehicle, or Rigid vehicle and trailer	6	d(1) > 3.2m, axles = 3 and groups = 3	
	4	≥ 2	**Four Axle Articulated** Four axle articulated vehicle, or Rigid vehicle and trailer	7	d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 4 and groups > 2	
	5	≥ 2	**Five Axle Articulated** Five axle articulated vehicle, or Rigid vehicle and trailer	8	d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 5 and groups > 2	
	≥ 6	≥ 2	**Six Axle Articulated** Six axle articulated vehicle, or Rigid vehicle and trailer	9	axles = 6 and groups > 2 or axles > 6 and groups = 3	
Medium Combination 17.5m to 36.5m	> 6	4	**B Double** B Double, or Heavy truck and trailer	10	groups = 4 and axles > 6	
	> 6	5 or 6	**Double Road Train** Double road train, or Medium articulated vehicle and one dog trailer (M.A.D.)	11	groups = 5 or 6 and axles > 6	
Large Combination Over 33.0m	> 6	> 6	**Triple Road Train** Triple road train, or Heavy truck and three trailers	12	groups > 6 and axles > 6	

Definitions:
Group: Axle group, where adjacent axles are less than 2.1m apart
Groups: Number of axle groups
Axles: Number of axles (maximum axle spacing of 10.0m)
d(1): Distance between first and second axle
d(2): Distance between second and third axle

End of Annex C

TOWN PLANNING
AND URBAN DESIGN

LOT 500 MADIGAN ROAD, BAYNTON

DEVELOPMENT PLAN

710-200
MARCH 2011

perth
sydney

DOCUMENT CONTROL

Document ID: PLANNING/PG 2010/710-200/Final Documents/Amended/Development Plan/ Amended Final Madigan Development Plan 16.03.11.indd						
Issue	Date	Status	Prepared by		Approved by	
			Name	Initials	Name	Initials
1	26.10.10	Final	Leigh Caddy		David Read	
2	22.12.10	Amended Final	Leigh Caddy		David Read	
3	16.03.11	Amended -2 Final	Leigh Caddy		David Read	

This report has been prepared for the exclusive use of the Client, in accordance with the agreement between the Client and TPG ('Agreement').

TPG accepts no liability or responsibility whatsoever in respect of any use of or reliance upon this report by any person who is not a party to the Agreement or an intended recipient.

In particular, it should be noted that this report is a qualitative assessment only, based on the scope and timing of services defined by the Client and is based on information supplied by the Client and its agents.

TPG cannot be held accountable for information supplied by others and relied upon by TPG.

TPG reports are printed on:

FSC Mixed Sources
Product group from well-managed forests and other controlled sources
www.fsc.org
© 1996 Forest Stewardship Council

EXECUTIVE SUMMARY

The purpose of this report is to enable the Shire of Roebourne and the Western Australian Planning Commission (WAPC) to consider a Development Plan for Lot 500 Madigan Road, Baynton (the 'site'). This Development Plan will facilitate the future development of the site as a residential neighbourhood and will assist in addressing housing demand and land supply issues currently facing Karratha, severely limiting its potential to realise the State Government, the Shire of Roebourne and the local community's vision of Karratha as a 'City of the North'.

This Development Plan will facilitate the potential development of approximately 1250 new dwellings, accommodated within a range of housing types and densities. The Plan will also provide for the staged development of a mixed-use local neighbourhood centre comprising up to 1000m² of new ground floor retail and complementary non-retail commercial uses to provide local employment generation and service local needs. This commercial centre will have the potential to expand as population increases.

The design and development of the Development Plan, which has been prepared in consultation with a range of government stakeholders, represents a site responsive, innovative approach to urban design, responding to the local Karratha context and incorporating a range of design and sustainability initiatives.

This Development Plan provides a new approach to planning and design of residential neighbourhoods in Karratha in contrast to existing older urban areas which lack many of the elements that contribute to the comfort and attractiveness of the public realm. For instance, housing is provided in isolation from day-to-day amenities required by its residents; roads are provided in isolation from a comfortable pedestrian realm; and drainage networks are provided in isolation from functional and attractive parklands.

This Development Plan incorporates a range of design initiatives which seek to create a climate and place responsive urban environment including:

- An urban form designed to facilitate lot orientation that addresses local climatic conditions;
- The provision of housing diversity through a range of housing types and densities;
- A movement network that promotes connectivity and accessibility through the site and with surrounding areas for vehicles, cyclists and pedestrians;
- The provision of an urban form that ensures development focuses on and addresses streets, public open space and drainage areas;
- The provision of multi-functional public open space reflective of the Pilbara context and which integrates drainage requirements;

- Facilitating local employment services and amenities; and
- Facilitating sustainable approach to development.

The design represents the optimal development outcome for the site, and is consistent with the agreed vision for the site identified in the 'Karratha City of the North' Blueprint and 'City Growth Plan' document.

The approval of this Development Plan by the Shire and the WAPC will enable the future subdivision and development of the site to occur.

CONTENTS

CERTIFICATION OF DEVELOPMENT PLAN

IT IS HEREBY CERTIFIED THAT THE DEVELOPMENT PLAN FOR LOT 500 MADIGAN ROAD,

BAYNTON WAS ADOPTED BY RESOLUTION OF THE WESTERN AUSTRALIAN PLANNING COMMISSION

ON

....

....

Being an officer of the Commission duly

authorised by the Commission pursuant to

Section 16 of the Planning and Development Act 2005

AND BY

RESOLUTION OF THE COUNCIL OF THE SHIRE OF ROEBOURNE ON

....

AND THE SEAL OF THE MUNICIPALITY WAS PURSUANT TO THE COUNCIL'S RESOLUTION HERETO

AFFIXED IN THE PRESENCE OF:

....

PRESIDENT, SHIRE OF ROEBOURNE

....

CHIEF EXECUTIVE OFFICER, SHIRE OF ROEBOURNE

This page has been left blank intentionally.

PART 1 – STATUTORY PLANNING SECTION

1. STATUTORY PROVISIONS

1.1 TITLE

This Development Plan shall have the formal title of 'Lot 500 Madigan Road Development Plan' (hereafter referred to as the 'Development Plan').

1.2 RELATIONSHIP TO THE SHIRE OF ROEBOURNE TOWN PLANNING SCHEME NO. 8

Unless specified by a specific requirement of this Development Plan, all land uses and development shall occur in accordance with the standards and requirements specified by the Shire of Roebourne Town Planning Scheme No. 8 (TPS8).

1.3 DEVELOPMENT PLAN

The Development Plan is attached as Appendix 1 to this Part and comprises Lot 500 on Deposited Plan 59331 and is 67.7267 hectares in area.

The objective of the Development Plan is to provide a comprehensive master plan to facilitate the orderly and proper subdivision and development of the land. The Development Plan aims to create a sustainable and affordable urban area with a range of lot sizes and diversity of housing types as well as foster a small local neighbourhood centre and set aside land for public open space and drainage purposes.

1.4 LAND USE PRECINCTS AND STANDARDS

The Development Plan identifies several land use precincts that are generally characterised by a predominant use although it is intended that the Development Plan be treated in a flexible manner to allow other compatible uses. The proposed land use precincts include Residential, Mixed Use Commercial/Retail and Public Open Space and Drainage.

1.4.1 Residential Precinct

1.4.1.1 Statement of Intent

The intent of the Residential Precinct is to provide a high quality, environmentally sustainable, residential environment providing a range of living options to cater for a diverse population and sense of community. The provision of Transient Workers Accommodation is permitted within certain locations along Madigan Road.

Development within the Precinct will provide for pedestrian friendly streetscapes with passive surveillance of the public domain. Local employment through viable and suitable home based business is also encouraged within the Precinct.

1.4.1.2 Development Standards

Development standards to be satisfied for the Residential Precinct include:

a) The provisions of the Residential Design Codes of Western Australia (R-Codes) shall apply to residential development in this Precinct unless otherwise specified in this section;

b) A Detailed Area Plan (DAP) is required to be prepared in accordance with section 1.7 for various land areas as identified on the Development Plan. Variations to the provisions of the R-Codes not already permitted by the Codes shall be allowed where prescribed by the DAP;

c) In the case of land subject to a split residential coding, a minimum lot size of 2,500m² or an entire street block is required for development at the higher density code (R60);

d) The subdivision and development of land abutting public open space/drainage areas shall be designed to front onto and address public open space/drainage areas;

e) Multiple dwelling development is not permitted except for areas coded R60 and R-AC2, or areas subject to a split density code where the upper density code (R60) is achieved;

f) The maximum height of development shall not exceed 2 storeys in height, except for areas coded R-AC2 where the maximum height of development shall not exceed 3 storeys in height unless varied by an approved DAP prepared in accordance with section 1.7; and

g) An Acoustic Report is required to be prepared by a suitably qualified Acoustic Consultant as part of a development application demonstrating how the proposed development complies with relevant noise legislation for the following circumtances:

  - Any noise sensitive development proposed within 82 metres of the centreline of Madigan Road;
  - Any noise sensitive development proposed within mixed use development or located near a site(s) in which there is the potential for after hours activity to occur (e.g: café, restaurant); or
  - Any non-residential development in which there is the potential to generate noise that may impact on noise sensitive development.

1.4.1.3 Development Standards - Transient Workers Accommodation

The following additional standards apply to the development of land for Transient Workers Accommodation (TWA):

a) The development of TWA shall be limited to those areas delineated on the Development Plan and developed in a manner which will allow the land to redevelop to a normalised residential area over time;

b) The provision of services and facilities associated with TWA development shall not undermine existing or proposed services and facilities within the community; and

c) The external frontages of TWA development shall be developed to a standard consistent with adjacent residential areas with regards to streetscape, setbacks and landscaping.

1.4.1.4 Land Use Permissibility

Land use permissibility shall be in accordance with the Land Use Permissibility Table in section 1.5.

1.4.2 Mixed Use Commercial/Retail Precinct

1.4.2.1 Statement of Intent

The intent of the Mixed Use Commercial/Retail Precinct is to develop a mixed use area comprising a diversity of retail and non-retail main-street uses which generate day and evening activity, and which are compatible with residential development. A high standard of 'Main Street' built form incorporating environmental sustainable design, active edges and attractive façades is envisaged to provide visual amenity and interaction, pedestrian friendly streetscapes and passive surveillance of the public realm. This centre is to be contained in the Precinct identified on the Development Plan with the intent for retail and restaurant uses to be located abutting the central open space, adjoined by commercial office/consulting room type uses, and then the balance of the street level be residential but with a ceiling height to allow it to transition to ground floor commercial over time.

1.4.2.2 Development Standards

Development standards to be satisfied for the Mixed Use Commercial/Retail Precinct include:

a) The provisions of the Residential Design Codes of Western Australia (R-Codes) shall apply to residential development in this Precinct unless otherwise specified in this section;

b) A Detailed Area Plan (DAP) is required to be prepared in accordance with section 1.7. Variations to the provisions of the R-Codes shall be allowed where outlined on the DAP;

c) Retail uses (including a 'shop' or 'market') and Restaurant/Take away food outlet uses shall only be permitted abutting the central public open space abutting the 'Main Street' unless varied by a DAP prepared in accordance with section 1.7.

d) Commerical uses identified in the permissibility table shall only be permitted in the Mixed Use Commerical/Retail Precinct shown on the Development Plan.

e) The maximum combined NLA of all retail and other non-residential uses abutting the Main Street shall not exceed 1000m^2 unless varried by a DAP prepared in accordance with section 1.7.

f) The maximum retail floorspace for an individual tenancy shall not exceed 500m^2 NLA. A retail tenancy includes a 'shop' and/or 'market'.

g) Non-residential development is only permitted on the ground floor;

h) Multiple dwelling development is encouraged;

i) The maximum height of development shall not exceed 3 storeys in height unless varied by an approved DAP prepared in accordance with section 1.7; and

j) Development abutting the 'Main Street' indentified on the Development Plan shall have a minimum ground floor level to ground floor ceiling level in the room(s) abutting the street of 3.2 metres to enable future conversion to commercial uses;

k) An Acoustic Report is required to be prepared by a suitably qualified Acoustic Consultant as part of a development application demonstrating how the proposed development complies with relevant noise legislation for the following circumtances:

- Any noise sensitive development proposed within mixed use development or located near a site(s) in which there is the potential for after hours activity to occur (e.g. restaurant); or
- Any non-residential development in which there is the potential to generate noise that may impact on noise sensitive development.

1.4.2.3 Land Use Permissibility

Land use permissibility shall be in accordance with the Land Use Permissibility Table in section 1.5.

1.4.3 Public Open Space and Drainage

The intent of the Public Open Space and Drainage Precinct is to provide high quality, public open spaces that offer residents and visitors passive and active recreation opportunities whilst facilitating stormwater conveyance particularly in cyclonic events.

1.4.3.1 Development Standards

Development standards to be satisfied for the Public Open Space and Drainage Precinct include:

a) The size and location of public open space shall be in accordance with the Development Plan;

b) The design of public open space areas shall ensure the protection and enhancement of indigenous heritage sites;

c) The design of public open space areas shall ensure appropriate provision for stormwater drainage management; and

d) The landscaping of public open space areas shall be suitable for an arid climate having regard to minimising maintenance and water use whilst providing areas of highly aesthetic and functional amenity.

1.5 LAND USE PERMISSIBILITY

The following table describes the permissible land uses within each Land Use Precinct. The table varies from that in the Scheme, by modifying permissibility for the use classes identified. Where a use is not listed, that use is deemed to be an 'X' use. Council shall have regard to Clause 3.2.2 of the Scheme with regard to the interpretation of the table.

Precinct Land Uses	Residential Precinct	Mixed Use Commericla/ Retail Precinct
RESIDENTIAL		
Aged or Dependent Persons Dwelling	AA	AA
Ancillary Accommodation	AA	X
Grouped Dwelling	P	AA
Home Business	P	P
Home Occupation	P	P
Motel	X*	SA
Multiple Dwelling	P***	P
Residential Building	AA	AA
Short Stay Accommodation	SA	AA
Single House	P	X
Transient Workforce Accommodation	X*	X
INDUSTRY		
Industry – Service	X	SA
COMMERCE		
Display Home	AA	AA
Dry Cleaning Premises	X	P
Market	X	P****
Office	X	P
On-site Canteen	IP	X
Reception Centre	X	SA****
Restaurant	X	P****
Shop	X	P****
Take-away Food Outlet	X	P****
HEALTH, WELFARE AND COMMUNITY SERVICES		
Car park	IP	AA
Child Care Service	SA	X
Community Use	SA	AA
Consulting Rooms	X	P
Education Establishment	X	SA
Medical Centre	X	AA
Nursing Home	AA	X
Place of Public Meeting, Assembly or Worship	SA	AA
Minor Utility Installation	AA	AA
Utility Installation	SA	SA
ENTERTAINMENT, RECREATION AND CULTURE		
Entertainment Venue	X	AA
Private Recreation	SA	AA
Public Recreation	AA	AA

* except within the area identified as TWA on the Development Plan where it is then a 'P' use.

** within areas coded R-AC2

*** multiple dwellings are only permitted within areas coded R60 or R-AC2 or land areas subject to a split coding and the criteria for the higher density (R60) is achieved.

**** only permitted in the Mixed Use Commercial/Retail Precinct when abutting Public Open Space.

1.6 RESIDENTIAL DENSITY CODING

The Development Plan indicates the Residential Density Coding that applies to land zoned 'Residential' pursuant to Clause 6.2.4 of the Scheme and includes the following:

- R20;
- R20/R60
- R25;
- R25/R60;
- R30;
- R30/R60;
- R60; and
- R-AC2.

Residential development shall be in accordance with the Residential Design Codes of Western Australia (R-Codes) as given effect by Clause 6.2.3 of the Scheme, unless otherwise stated in this Part.

In the case of land subject to a split residential coding, a minimum lot size of 2,500m² or an entire street block is required for development at the higher density (R60).

The built form provisions of the R-Codes may be varied by a local policy applied through Detailed Area Plans (DAP's) adopted at subdivision stage.

1.7 DETAILED AREA PLANS

The Development Plan identifies several land parcels for which a Detailed Area Plan (DAP) is required to be prepared.

An approved DAP shall be prepared (by the developer, an owner of the land or the Shire) and adopted by Council prior to any subdivision and/or substantial development and used as the basis for the determination of all development applications to the Shire of Roebourne.

The DAP will enhance, elaborate and expand the details and provisions contained in this Part as well as supplement the provisions of the Scheme and the R-Codes. DAP's are required to address the following:

a) non-residential land use, size and location (where applicable);

b) building envelopes;

c) setbacks;

d) interfaces with public open space and drainage areas;

e) distribution of land uses within a lot (mixed use lots);

f) vehicular access and parking;

g) loading and unloading areas, storage yards and rubbish collection enclosures;

h) the location, orientation and design of buildings and the space between buildings; and

i) such other information considered relevant by the Shire of Roebourne.

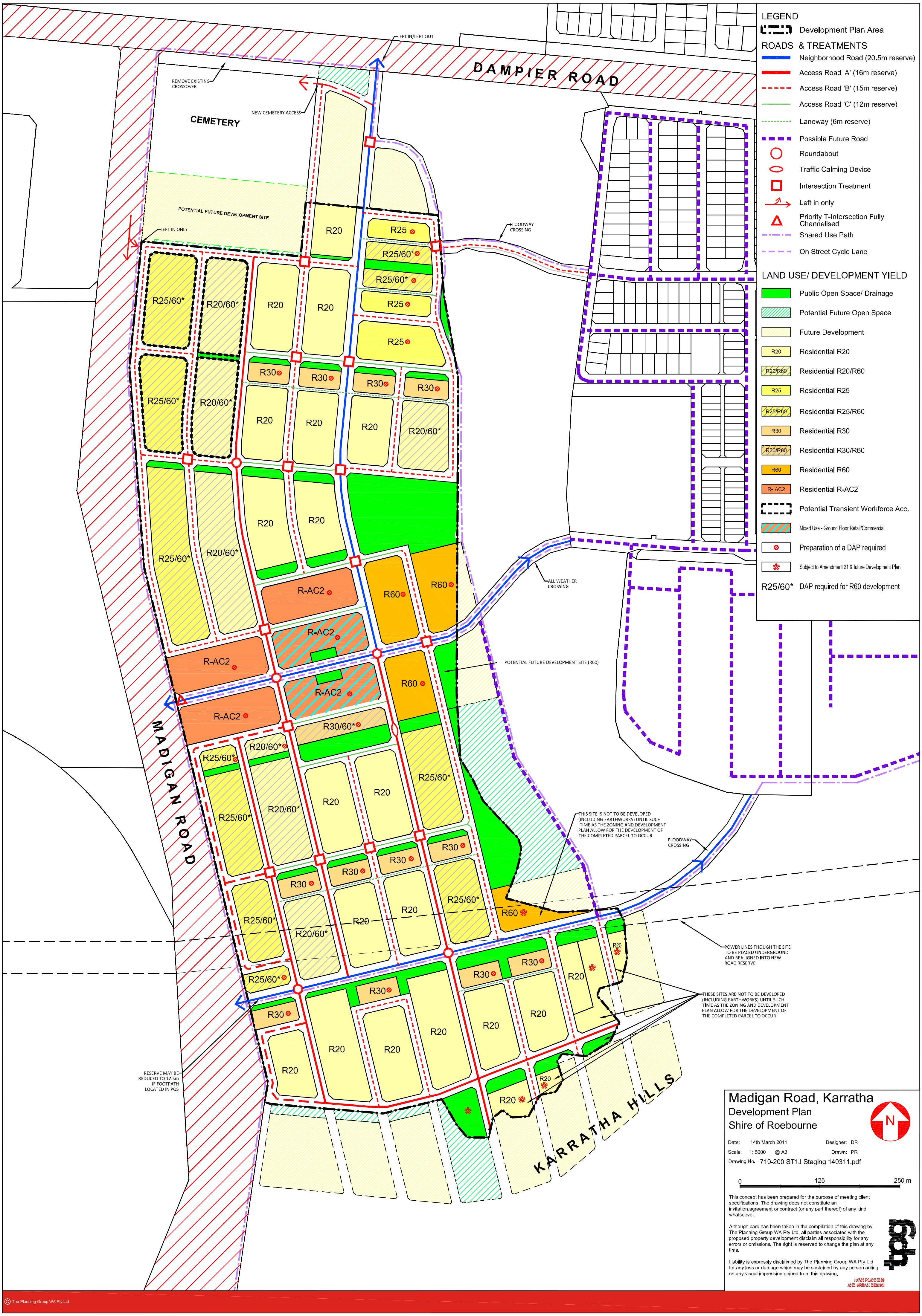
Variations to the provisions of the R-Codes shall be allowed where prescribed on the DAP.

This page has been left blank intentionally.

APPENDIX 1

LOT 500 MADIGAN ROAD DEVELOPMENT PLAN

This page has been left blank intentionally.



LEGEND

- ▭ Development Plan Area

ROADS & TREATMENTS

- Neighborhood Road (20.5m reserve)
- Access Road 'A' (16m reserve)
- Access Road 'B' (15m reserve)
- Access Road 'C' (12m reserve)
- Laneway (6m reserve)
- Possible Future Road
- ○ Roundabout
- ⬭ Traffic Calming Device
- □ Intersection Treatment
- ↗ Left in only
- △ Priority T-Intersection Fully Channelised
- Shared Use Path
- On Street Cycle Lane

LAND USE/ DEVELOPMENT YIELD

- 🟩 Public Open Space/ Drainage
- ▨ Potential Future Open Space
- ▨ Future Development
- R20 Residential R20
- R20/R60 Residential R20/R60
- R25 Residential R25
- R25/R60 Residential R25/R60
- R30 Residential R30
- R30/R60 Residential R30/R60
- R60 Residential R60
- R- AC2 Residential R-AC2
- ▭ Potential Transient Workforce Acc.
- ▨ Mixed Use - Ground Floor Retail/Commercial
- ⊘ Preparation of a DAP required
- ❋ Subject to Amendment 21 & future Development Plan
- R25/60* DAP required for R60 development

Madigan Road, Karratha
Development Plan
Shire of Roebourne

Date: 14th March 2011 Designer: DR
Scale: 1: 5000 @ A3 Drawn: PR
Drawing No. 710-200 ST1J Staging 140311.pdf

0 125 250 m

TOWN PLANNING
AND URBAN DESIGN

PART 2 – EXPLANATORY REPORT

INTRODUCTION

This Development Plan has been prepared on behalf of LandCorp to facilitate the future urban development Lot 500 on Deposited Plan 59331, located at the corner of Dampier Road and Madigan Road, Baynton as a residential neighbourhood including a local centre and open space reserves.

Lot 500 is currently zoned "Urban Development" under the Shire of Roebourne's Town Planning Scheme No. 8 (the 'Scheme') for which a Development Plan is required to be prepared prior to the subdivision and development of the land.

This Development Plan has been prepared in accordance with the strategic and statutory planning framework applicable to the land including Shire of Roebourne Town Planning Scheme No. 8, (as amended by Amendment No. 18) and having regard to Amendment No. 21 to the Scheme, which has been prepared to implement the Karratha City of the North Blueprint and City Growth Plan.

This report addresses relevant planning requirements, traffic, acoustic, environmental, and engineering matters. This Development Plan has been prepared with input from the following:

- Benchmark Projects - Project Management
- TPG Town Planning and Urban Design – Town Planning and Urban Design
- Cossill and Webley – Engineering
- Coffey Environments – Environmental
- Coffey Geotechnics - Geotechnical
- JDA Consultant Hydrologists – Urban Water Management
- Transcore – Traffic and Transport
- Epcad – Landscape Architecture
- Whelans - Surveying
- ND Engineering – Acoustic Consultant
- Anthropos Australis - Heritage Consultant

SUBJECT SITE

SITE DETAILS

The site subject of this report comprises Lot 500 Madigan Road, Baynton (the 'Site'). The site is 67.7267 hectares in area and is bound by Madigan Road to the west, the Karratha Cemetery and a drainage reserve fronting Dampier Road to the north, a drainage reserve to the east and the Karratha Hills to the south.

The site is located at the western end of the Karratha townsite and represents the continuation of the current residential development front.

LAND OWNERSHIP & ENCUMBRANCES

The Certificate of Crown Land Title identifies the site as Unallocated Crown Land (UCL) and is registered as Lot 500 on Deposited Plan 59331.

The State of Western Australia is listed as the primary interest holder with the responsible agency being the Department of Regional Development and Lands (DRDL). No limitations, interest, encumbrances or notifications are identified on the Title. Table 1 summarises the Title details:

Table 1: Certificate of Title details

Lot	Street	Deposited Plan	Volume/Folio	Status Order/ Interest	Registered Owner
500	None Available	59331	LR3153/ 612	Unallocated Crown Land	State of Western Australia

A copy of the Title is attached as Appendix 1.

Native Title

Karratha has Native Title rights held by the Ngarluma Aboriginal Corporation which is the registered native title prescribed body corporate.

The lot is also subject to the Burrup Maitland Industrial Estate Agreement (BMIEA) governed by the State and the Murujuga Aboriginal Corporation as detailed further in the Heritage Survey for this Lot by Anthropos Australis Pty Ltd & Context Anthropology Pty Ltd.

Mining Tenements (Department of Mineral and Petroleum Resources)

Mining Tenements (Exploration Licenses - EL's) are granted partially over Lot 500. As the site is within the boundary of the Karratha Townsite, written consent is required from the Minister for State Development before any mining activity may occur. The land Mining Tenement holders are generally only interested in exploration outside of the Townsite.

Local Orders over the Land: EPA, Heritage, Local Authority

A Heritage Survey for the site by Anthropos Australis Pty Ltd & Context Anthropology Pty Ltd has identified three Aboriginal Sites within Lot 500 and two additional sites outside the site but in close proximity to the northeast corner of Lot 500. Further details related to the Aboriginal heritage significance of the site are provided in Section 5.1.4 of this report.

Contaminated Sites Register

A search of the Department of Environment and Conservation's Contaminated Sites Register shows that there are no registered sites comprising the site or located within proximity to the site.

LOCATION & ACCESS

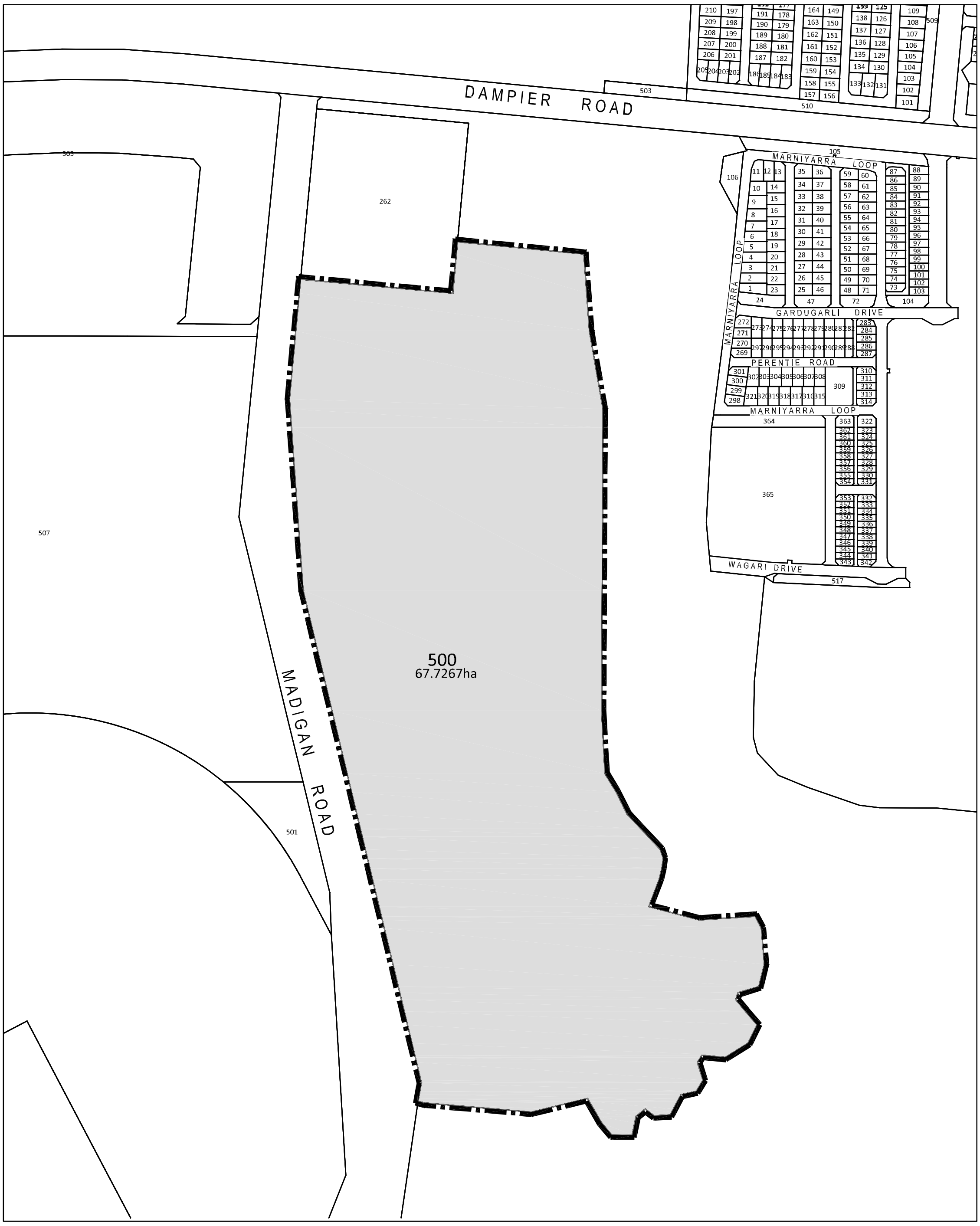
The Karratha townsite is situated in the Shire of Roebourne in the Pilbara region of Western Australia. The site is located in the western portion of the existing Karratha townsite, south of Dampier Road and directly east of Madigan Road. The site is 6 kilometres to the west of the Karratha Town Centre and situated west of the suburb of Baynton and north of the Karratha Hills.

The site is currently accessed from the Madigan Road, although there are no formal connections into the site. Madigan Road forms the western boundary of the site and presently accommodates heavy haulage traffic for between North West Coastal Highway and Dampier Road.

The Baynton West residential development, located to the east of the site, is separated from the site by a natural drainage creekline stemming from the Karratha Hills. The Karratha Cemetery is located at the northwest corner, abutting the intersection of Dampier and Madigan Roads.

Refer to Figure 1 - Location Plan.

Figure 1 - Location Plan



PHYSICAL CHARACTERISTICS

The site is relatively flat, sloping gently from the Karratha Hills situated to the south down toward Dampier Road. The site levels range from a height of approximately 25-26 metres AHD at the foot of the Hills to 15 metres AHD abutting Dampier Road. A natural drainage line forms the site's eastern edge.

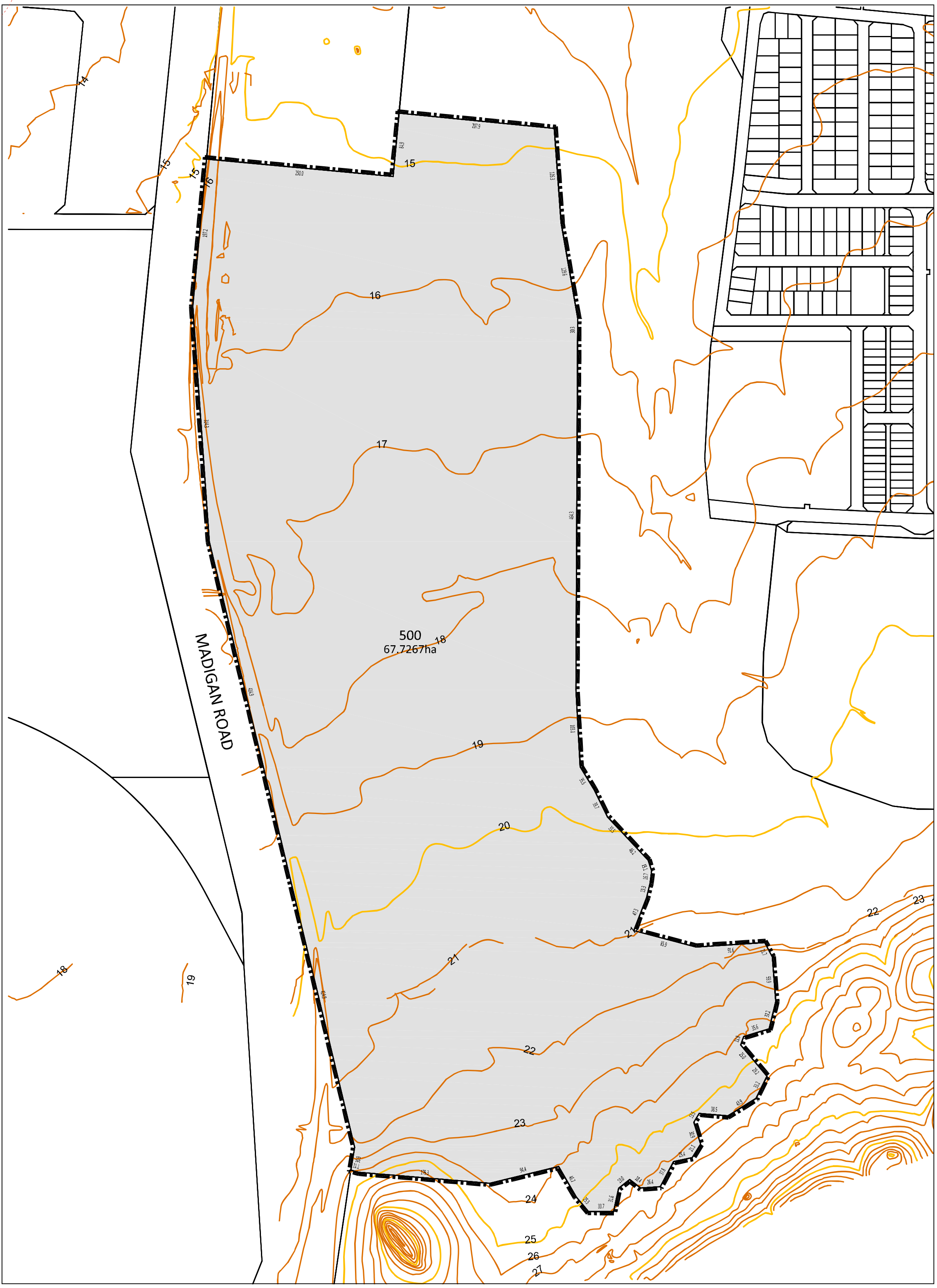
There are no improvements contained within the site except for a high voltage above-ground powerline which extends in an east-west direction across the southern portion of the site.

Refer to Figure 2 - Site Plan.

SITE HISTORY AND CURRENT LAND USE

There is no evidence that suggests that the site has been the subject of any formal land use or activity in the past.

Figure 2 - Site Plan



SITE CONTEXT

CITY WIDE CONTEXT

The site is largely situated within the locality of Baynton at the south-western extent of the existing urban areas of the Karratha Townsite and approximately 6 kilometres to the west of the Karratha Town Centre and 12 kilometres to the south-east of the Dampier Townsite.

Major local industrial and commercial employment generators in the area include the Karratha Industrial Estate (KIE) (situated approximately 8 kilometres to the south-east), the Rio Tinto Iron Ore railway facility (situated approximately 3 kilometres to the north-west), Dampier Salt's salt harvesting facility, the Karratha Airport (situated approximately 4 kilometres to the north), the maritime/port facility (at Dampier) and the major industrial and port facilities located at the Burrup Peninsula.

A future industrial area (Gap Ridge Industrial Estate) is approved to the west of the site accessed from Dampier Road and situated adjacent to the Rio Tinto Iron Ore railway facility. Development plans prepared for the estate identify approximately 37 general industrial lots and 76 light industrial lots.

Situated on the Burrup Peninsula are several major industrial areas comprising Woodside Petroleum and Hamersley Iron's petroleum and mining processing and loading facilities. These facilities represent major generators of employment in the region.

Situated approximately 2.5 kilometres to the east of the site on Dampier Road is the Nickol Bay Hospital, which provides medical and related services to the region.

Adjacent to the Hospital to the east is the proposed 'Leisure and Learning Precinct'. A plan for the development of the Precinct was recently approved by Council, which will provide for a range of facilities including the existing TAFE and Walkington Theatre, a new high school and recreational sporting facilities to cater for Karratha and the regional areas.

Dampier Road is an important regional road and represents a key element of the Karratha road network, serving as the primary distributor of east-west traffic movements connecting the Dampier and Karratha townsites as well as providing access to the Burrup Peninsula via Burrup Road (3 kilometres southeast of the Dampier townsite).

Madigan Road, which connects Dampier Road at its northern end (approximately 200 metres to the north of the site) and the North West Coastal Highway (NWCH) at its southern end (approximately 4 kilometres to the south of the site), is another important element of the Karratha road network, facilitating heavy vehicle movements to the Burrup Peninsula from NWCH bypassing Karratha townsite. A proposal to create an alternative heavy haulage vehicle route to the west of Madigan Road to provide a more direct connection between Dampier Road and the NWCH is being considered by Main Roads WA.

Refer to Figure 3 - City Wide Context Plan.

LOCAL CONTEXT

Land uses surrounding the site predominantly comprise existing and future residential areas to the east and north, Woodside Petroleum's 'Pluto' Workers Camp to the west (situated on land identified for future urban purposes), undeveloped land situated within a 500 metre buffer associated with a wastewater treatment plant (WWTP) to the south-west and the natural landscape comprising the western extents of the Karratha Hills to the south.

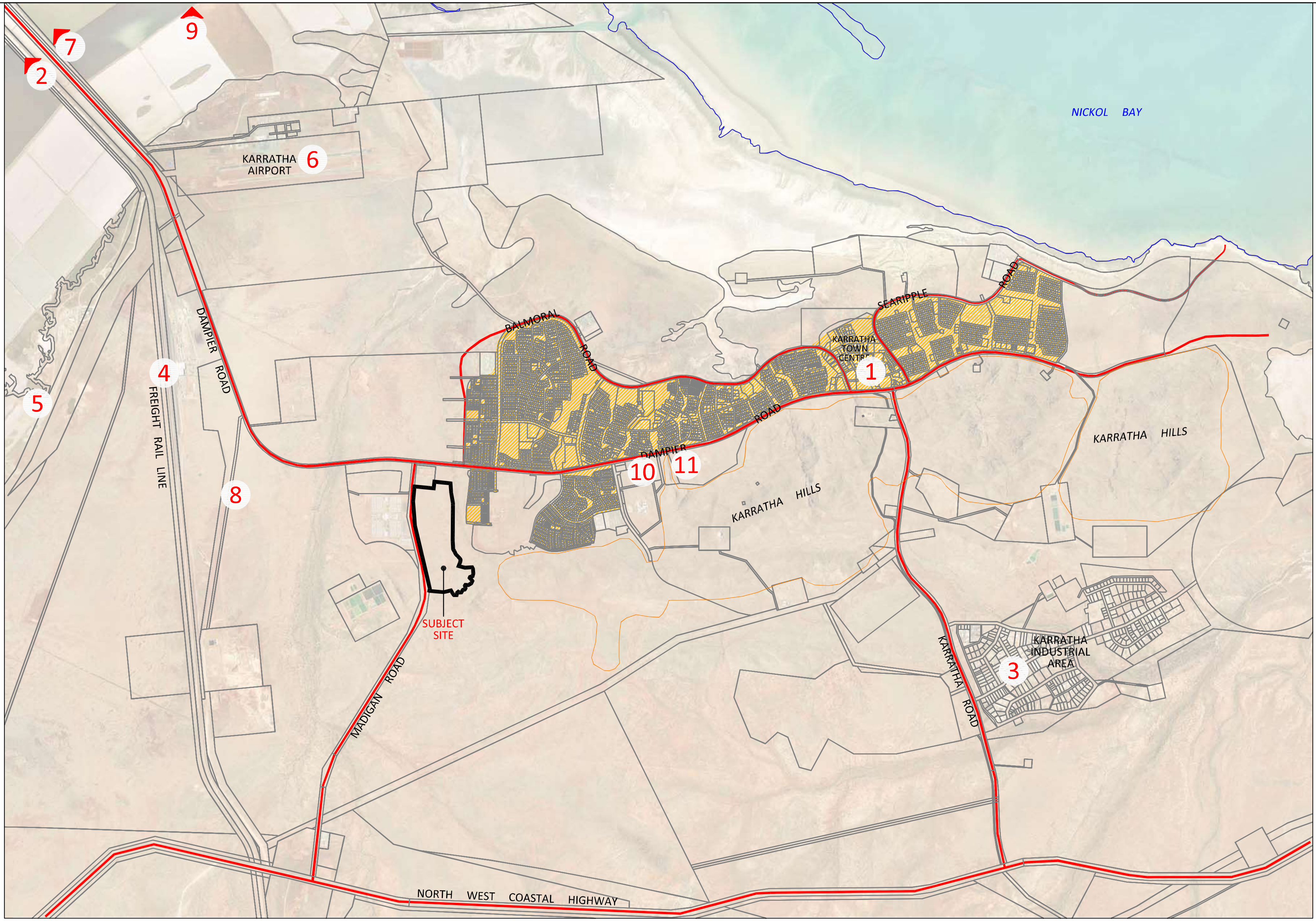
The Pluto Workers Camp currently accommodates 2133 single rooms over an area of 37.7ha and is currently leased for a period of 10 years with an option to extend for an additional 10 years. The existing Pluto Workers Camp may be redeveloped in the future, and potentially expanded over an 11 ha area to provide an additional 181 dwellings at a density of R40.

Abutting the entire eastern boundary is land reserved for parks and recreation and drainage purposes. To the east of this reserve is the Baynton West residential area which is currently being developed in accordance with an approved Development Plan. The Development Plan identifies predominantly 'Residential R17.5' development over most of the Development Plan area with a pocket of low density development ('Residential R10') along the southern extent adjacent to the Karratha Hills and several areas of higher density development adjacent to areas of open space and community facilities (ranging from 'Residential R30' to 'Residential R80').

Abutting the site to the north and fronting Dampier Road is the Karratha Cemetery and land reserved public open space and drainage purposes. To the north of Dampier Road, there are several residential areas which are currently being developed in accordance with approved Development Plans (being Nickol West and Tambrey). Development Plans for these areas generally identify predominantly 'Residential R17.5' with areas of higher density development adjacent to areas of open space (generally up to a density of R30) and several group housing sites (up to a density of R40).

A future bulky goods/showroom (Large Format Retail) precinct is proposed to the west of the site, at the south western corner of Dampier and Madigan Roads. The site is approximately 17.91ha and is presently UCL owned by the State. The site, which requires a Scheme Amendment and subdivision approvals, is currently proposed to be developed into approximately 13 lots ranging in size between 2,500m² - 25,000m².

The MAC Services temporary workers accommodation site is proposed to the south of the bulky goods/showroom site. This site covers an area of 18.8ha, is envisaged to have an average density of R60 and provide for an estimated 370 dwellings.



—	Subject Site
▨	Existing urban area

1. Karratha town centre
2. Dampier
3. Karratha industrial estate
4. Rio Tinto iron ore railway facility
5. Dampier salt harvesting facility
6. Karratha airport
7. Dampier port
8. Gap Ridge industrial estate
9. Woodside Petroleum & Hamersley Iron process & loading facility
10. Nickol Bay hospital
11. Leisure & learning precinct

City Wide Context Plan

MADIGAN ROAD

N

0 200m

1 : 25,000 @ A1 - 1 : 50,000 @ A3

Base mapping data supplied by Whelans

710-200 PL8A CityWideContext 260510

Existing community facilities within proximity to the site include the Tambrey Primary School (situated on Balmoral Road approximately 1 kilometre to the north-east of the site) as well as a proposed primary school and community purpose site (family/child care centre) within Baynton West.

The Tambrey Tavern and Cultural Centre is situated on Tambrey Drive approximately 1.5 kilometres to the north-east of the site whilst a future district retail centre at the intersection of Tambrey Drive and Bathgate Road (approximately 2 kilometres to the north-east) has been identified within strategic planning documents comprising up to around 8,500m² of retail floorspace (refer below).

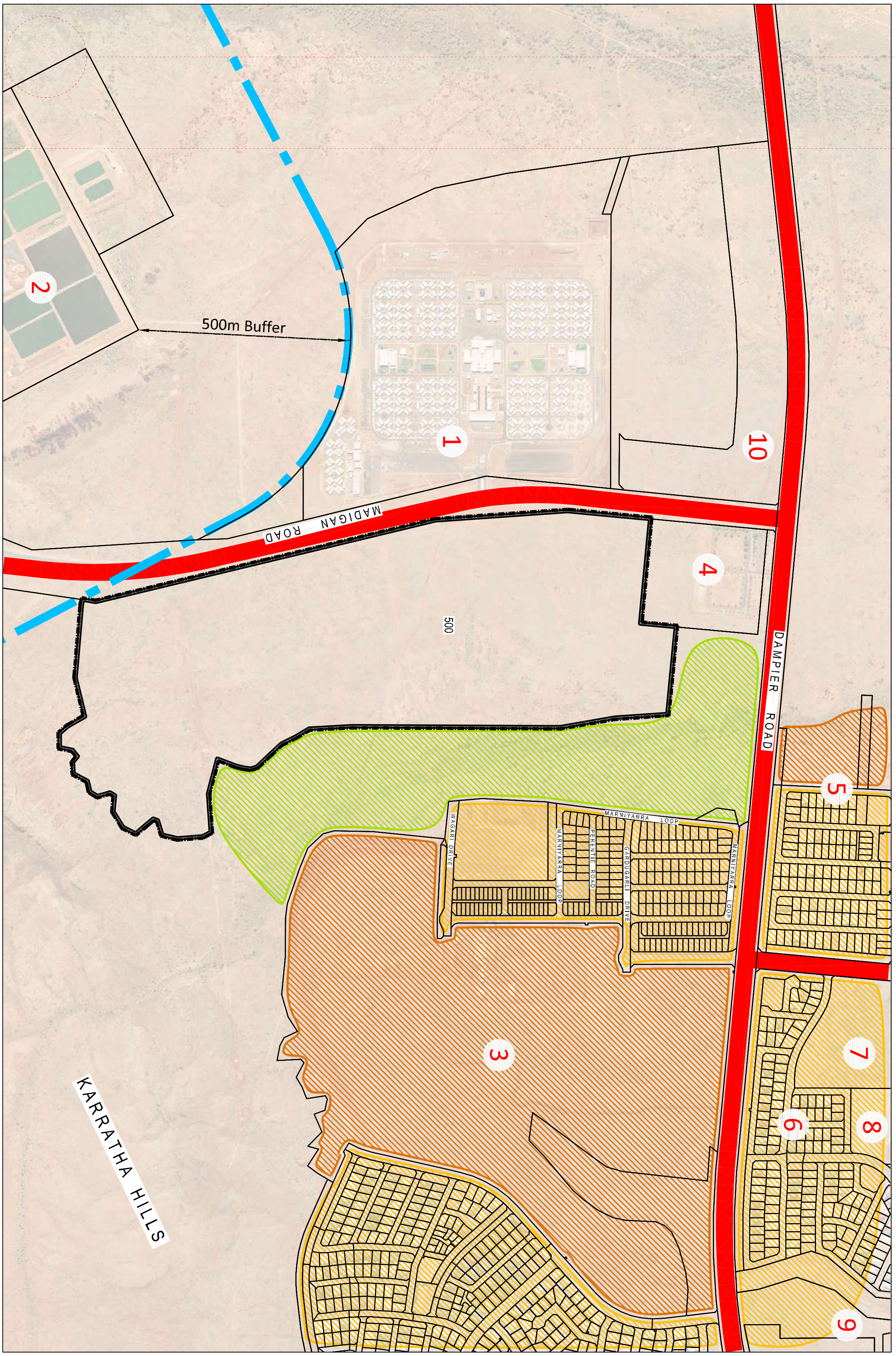
Refer to Figure 4 – Local Context Plan.

FIGURE 4 – LOCAL CONTEXT PLAN.

Legend:

-·-·-	Structure Plan Boundary
▬	State & Regional roads
▨	Existing residential area
▨	Future residential area
▨	Public open space/Drainage

1. Pluto workers camp
2. Waste water treatment plant
3. Baynton West residential estate
4. Cemetery
5. Nickol West residential estate
6. Tambrey residential estate
7. Tambrey primary school
8. Tambrey tavern & cultural centre
9. Proposed district centre
10. Proposed bulky goods/showroom precinct



STRATEGIC AND STATUTORY PLANNING FRAMEWORK

STRATEGIC DOCUMENTS

There are a number of strategic documents that are relevant to the planning and development of the subject site. An overview of the documents is provided below.

State Planning Strategy (1997)

The State Planning Strategy provides the basis for long-term State and regional land use planning and coordinates a whole-of government approach to planning.

The vision for the Pilbara Region as identified in the State Planning Strategy is as follows:

"In the next three decades, the Pilbara Region will be a world leading resource development area focusing on mineral extraction, petroleum exploration and production and the primary stages of downstream processing. The region's population will grow in the future, fuelled by specific resource development projects, the sustainable development of Karratha and Port Hedland and a more diverse economy. A growing tourism industry will have developed based on the region's unique natural environment."

The document identifies a series of strategies to achieve the above vision, which are based on the environment and resources, community, economic and infrastructure principles. These strategies include:

- Protect sensitive environmental and heritage areas;
- Address the need for the provision of social facilities;
- Improve town amenity;
- Give greater emphasis to local recruitment and training of the work-force;
- Promote opportunities for economic development;
- Minimise the detrimental impact of fly-in, fly-out resource development projects;
- Provide coordination of government agencies to minimise the obstructing/delaying of resource developments and associated infrastructure needs;
- Provide strategic transport linkages within and to the Pilbara Region;
- Improve access to water supplies for domestic and industrial usage; and
- Ensure infrastructure provision is the focus of government agencies.

The detailed planning and development of the site will be guided by the above strategies.

Pilbara Infrastructure and Planning Framework (draft)

The Western Australia Planning Commission (WAPC) is currently preparing the 'Pilbara Planning and Infrastructure Framework' for the Pilbara region. The document, which will set out a settlement-focused regional development structure for the region, will provide a framework for public and private sector investment, as well as context for the preparation of local planning strategies and local planning schemes by local authorities.

The framework is built on detailed profiles of the region's major settlements in which Karratha is designated as a regional centre providing facilities and services not only to the 5 nearby satellite settlements of Dampier, Roebourne, Wickham, Point Samson and Cossack, but also to Pannawonica, Onslow and Cape Preston.

The framework also incorporates findings from a range of existing Pilbara-wide studies and strategies including the Pilbara Plan document.

The plan for the development of the site will add to the threshold population and assist in achieving the recommendations contained within the document.

Karratha City of the North Plan (2010)

The Karratha City of the North Plan (KCNP), adopted by the Shire of Roebourne on 18 May 2010, comprises a series of documents being the Karratha City Growth Plan, the Karratha City Centre Master Plan and the Implementation Blueprint. Together, these documents identify a range of spatial and non-spatial requirements to guide the future growth of Karratha into a regional city of 50,000 residents

The KCNP will provide a basis for guiding decision makers in assessing rezoning, subdivision and development applications as well as the provision of infrastructure and community facilities over time.

The document(s) have been endorsed by the WAPC and issued to the Pilbara Cities Office for implementation.

Karratha City Growth Plan (2010)

The Karratha City Growth Plan (CGP) is a city–wide strategy to guide the future development of Karratha into a city of 50,000 residents. Specifically the CGP will guide the future spatial and non-spatial development requirements for the growth of Karratha, identifying the need for land supply, housing diversity, open spaces, commercial nodes, entertainment and retail areas, as well as the provision of community and servicing infrastructure.

The CGP identifies Karratha as a series of neighbourhood precincts. Each precinct is described in terms of its desired urban character, land use and urban structure as well as identifying key assumptions and planning considerations requiring further resolution.

Under the CGP, the site is situated within the 'Gap Ridge/Seven Mile Precinct' as a 'New Residential Neighbourhoods' (refer to Figure 5 – City Growth Plan).

The general design intent of the Precinct is for the development of a site responsive, walkable and connected residential neighbourhood that provides good pedestrian and vehicular connectivity within and to and from existing residential areas.

The CGP envisages residential development on the site to be consistent with an average density of R40 with some areas of R60 around centres of activity.

A new east-west road incorporating a future bus route linking Madigan Road with new residential development to the east is identified through the centre of the site. A local activity centre, situated on Madigan Road just to the north of this link road, is also identified with the potential to comprise a delicatessen and local community facilities.

Dampier Road and Madigan Road are identified as key gateway roads, which should be designed to provide those entering the town with a sense of arrival and place. The existing cemetery is proposed to be retained within the Precinct however is to be limited to its current size.

With regard to land adjacent to the site, land to the west of Madigan Road incorporating the Pluto Workers Camp is identified as 'Light Industry/Administration/Accommodation' whilst land within the wastewater treatment plant buffer is identified as 'New District Open Space'. Land to the north and east (beyond the drainage reserve) are identified for residential purposes.

The CGP states several existing planning assumptions (or factors which were considered as unknown or requiring resolution at the time) are identified. These include buffer requirements to the wastewater treatment plant, noise contours from the airport, existing mining leases, indigenous and non-indigenous heritage issues and Native Title. It should be noted that these planning assumptions apply generally to the Precinct and may not directly impact to the site. Additionally several infrastructure considerations are identified for the future planning of the Precinct including:

- 2D stormwater modelling required confirming extent of residential development adjacent to natural drainage lines;
- Extension of water distribution mains;

- New sewer pumping stations north and south of Dampier Road;
- Extension of underground power from upgraded existing network;
- New Telstra infrastructure to include high speed optic fibre connection;
- Potential for connection to a 3rd pipe recycled water network;
- Provision of reserve or easement about existing power transmission line; and
- Additional land area and buffer for Wastewater Treatment Plant No 2.

The document identified several planning actions to be undertaken to facilitate future development within the Precinct. Those actions that apply to the site include the preparation of a structure plan, subdivision applications, and design guidelines.

Refer to Figure 5 – City Growth Plan

Karratha Area Development Strategy (1998)

The Karratha Area Development Strategy (KADS) is a sub-regional land and water use strategy that was intended to guide the future development of Karratha, its hinterland and the marine waters and islands over 25 years.

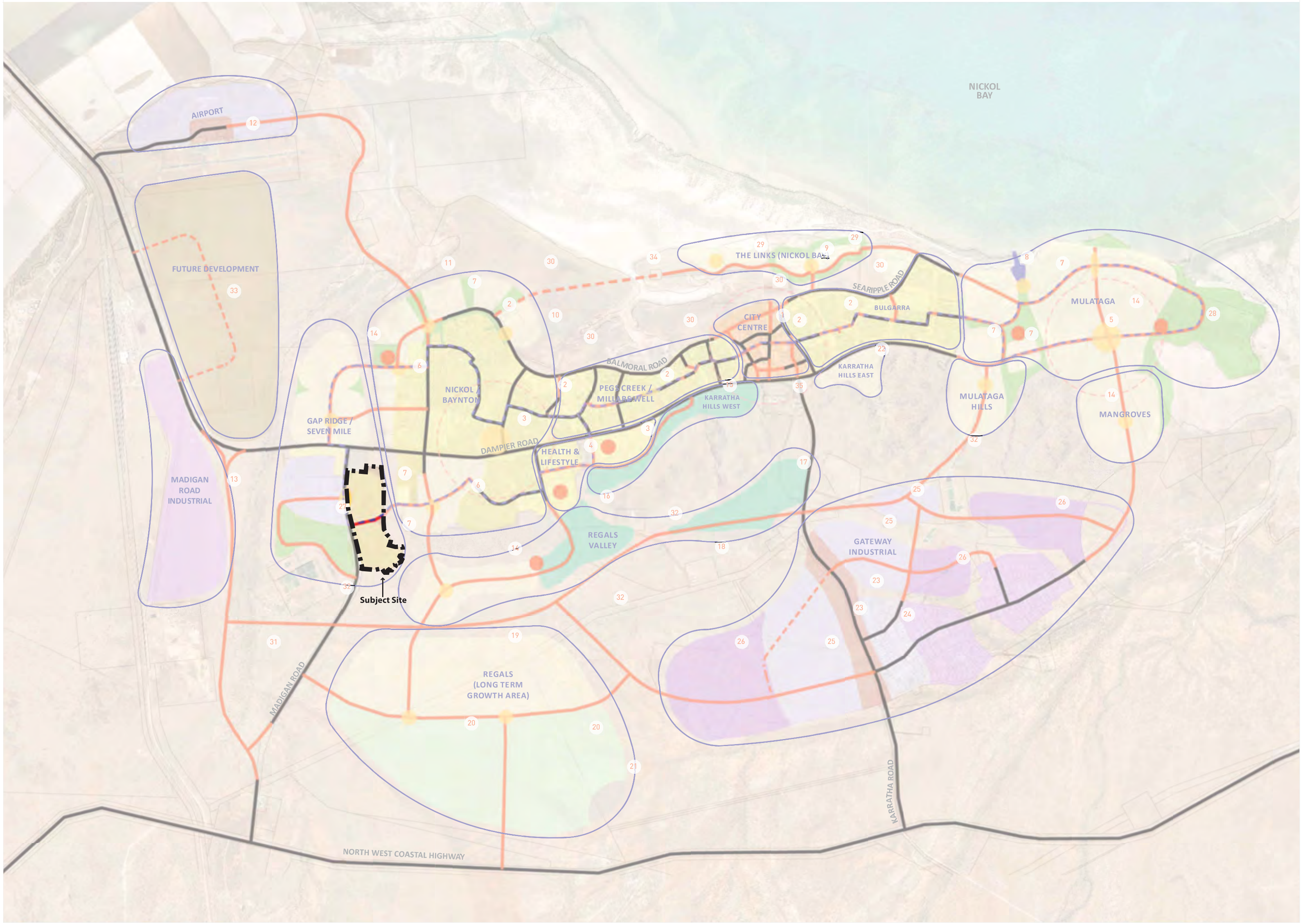
The Strategy identified Karratha as the focus of major urban expansion with a need to enhance its regional role through the promotion of higher level services and facilities, such as secondary and tertiary education, employment training and health amenities. The Strategy also identified a need to strengthen the identity and improve the visual attractiveness of Karratha and its surrounding areas for both residents and tourists.

The Strategy also incorporated a structure plan for Karratha which facilitates the expansion of the townsite to accommodate up to 37,000 people, of which 20,000 people were able to be accommodated in the existing and future areas to the north of the Hills with the balance in a second settlement south of the Hills.

The site is identified in the structure plan as a future residential area.

This document provided the strategic direction for the development of Karratha and planning at the local level for the past 12 years however it is intended that it will be superseded by the KCNP upon its endorsement by the WAPC.

Refer to Figure 6 - Karratha Area Development Strategy



1. Town Centre revitalised and expanded with new links to include link from Balmoral Road to Searipple Road.
2. Existing communities linked with bus and cycle route. Traffic calming to limit traffic volumes and speed.
3. Leisure and Learning Centre to consolidate and integrate major new facilities.
4. Health and wellbeing centre campus.
5. New local retail and commercial centre to service daily needs and eastern and western neighbourhoods.
6. Expansion of existing neighbourhoods.
7. Proposed neighbourhoods to address immediate population demands.
8. Waterfront development with potential for swimming lagoon focus.
9. New country club and international hotel.
10. Expanded caravan park and resort.
11. New link to airport and Karratha gateway feature and developments.
12. Airport hotels and commercial with surrounding logistic services area.
13. New heavy industrial area (in progress).
14. City growth neighbourhoods.
15. Hillside research and development facility, apartments and villa development integrated into landscape.
16. Education related playfields, health and education, staff accommodation, retirement development and short stay accommodation compatible with power station.
17. Tourism uses, adventure tour buses and short stay accommodation compatible with power station.
18. Power station.
19. Long term future residential neighbourhoods.
20. Rural living lots.
21. Potential cemetery use.
22. Hillside apartments and villa development integrated into landscape.
23. Urbanised industrial area lining gateway boulevard.
24. Industrial area converted to light industrial with workers camps and short stay accommodation.
25. Future light industrial area.
26. Future heavy industrial area.
27. New playfield potentially using water treated waste.
28. Future playfield area with potential for second public golf course and mangrove estuary enhancement.
29. Elevated course estate with reconfigured international quality golf course.
30. Ecological and landscape enhancement zone as foreground to view of Nickol Bay and Bumps.
31. Western bypass road.
32. New south of Karratha Hills bypass.
33. Land for future non urban city uses.
34. Possible northern bypass link and causeway. Possible inclusion of a lock to create link.
35. Nickol Bay lookout and cultural centre incorporating water tanks and indigenous heritage trails.

LEGEND

🟧 City Centre
🟨 Enhanced Existing Residential (Potential for increased density).
▨ New Residential Neighbourhoods
🟩 New District Open Space
🟩 Institutional
🟪 Industry
▨ Light Industry/Administration/Accommodation
▨ Logistics / Short Stay Accommodation with Airport
▨ Rural (future urban growth beyond 50,000.
▨ New Important Connection
🟨 Activity Centre
● High School
▨ Bus Route
▨ Future Investigation Area

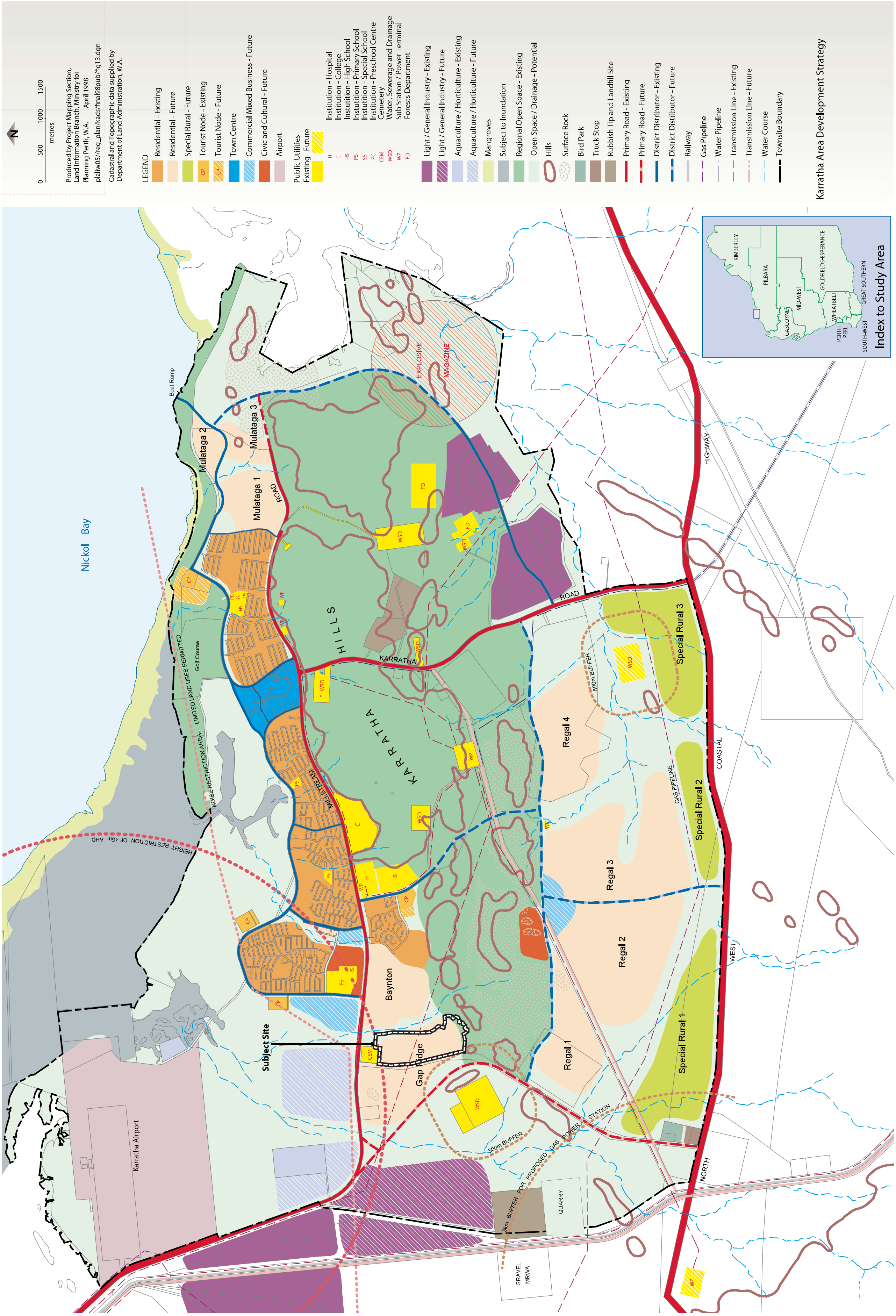
N

0 2000m

1 : 500,000 @ A3

Base mapping data supplied by Whelans

Figure 6 - Karratha Area Development Strategy



Karratha Primary Trade Area Retail & Commercial Strategy (2009)

The Karratha Primary Trade Area Retail & Commercial Strategy prepared by the Department for Planning and Infrastructure analysed existing retail and commercial floorspace provision for the principle towns within the Shire of Roebourne and identified future floorspace demand by the year 2020.

With regard to Karratha, the Strategy projected a resident population of only 14,000 with 1000 FIFO workers (based on Pilbara Industry Community Council population projections).

Retail floorspace was projected to expand by 20,150m² from 36,473m² and office floorspace by 16,200m² from 26,581m². Of these total figures, only 6,550m² of the retail floorspace (which included a 2,500m² Department Store) and all of the office floorspace was envisaged to be accommodated within the Karratha Town Centre with other retail centres to be established in Nickol (8,100m² of retail floorspace in Tambrey) and the Gap Ridge Bulky Goods Centre (5,500m²).

With regard to the site, the document identified that there is "little if no retail and commercial provision within the suburbs of Baynton and Nickol".

Karratha Regional HotSpots Land Supply Update (2010)

The Karratha Regional HotSpots Land Supply Update prepared by the WAPC in 2010, provided an overview of land supply within Karratha based on the status of major projects, current and anticipated lot creation activity and the recommendation of the City of the North City Growth Plan.

The Update identified that land release and housing supply within Karratha was subject to several key challenges including:

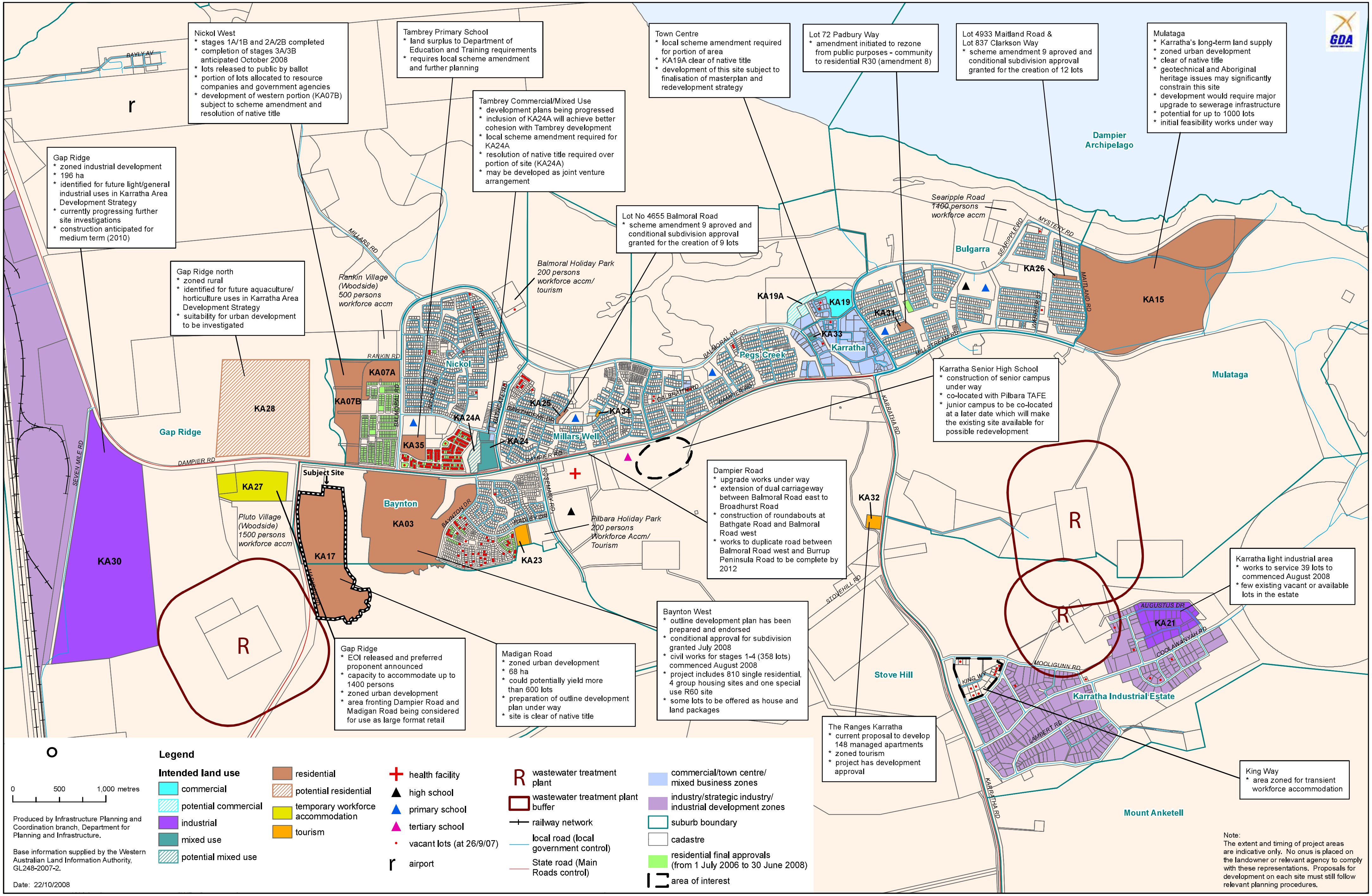
- Population growth, serviced land, housing scarcity and constrained infrastructure are among Karratha's greatest current challenges; and
- The limited capacity of Karratha's infrastructure is imposing critical constraints on residential, industrial and business growth, although major upgrades are in progress or planned.

The document identified a total of 1160ha of land zoned for urban development, including the site.

With regard to the site, the document identifies the site as having the potential to yield at least 600 lots (with an ultimate yield of 1100 dwellings) over the short term (0-5 years). The document states that the site is clear of native title and that further traffic analysis and upgrades to power, water and wastewater infrastructure as part of future planning.

The document is relevant to the planning of the site as it guides infrastructure agencies in the planning of future servicing requirements.

Refer to Figure 7 - Karratha Regional HotSpots Land Supply Update.



Nickol West
- stages 1A/1B and 2A/2B completed
- completion of stages 3A/3B anticipated October 2008
- lots released to public by ballot
- portion of lots allocated to resource companies and government agencies
- development of western portion (KA07B) subject to scheme amendment and resolution of native title

Tambrey Primary School
- land surplus to Department of Education and Training requirements
- requires local scheme amendment and further planning

Tambrey Commercial/Mixed Use
- development plans being progressed
- inclusion of KA24A will achieve better cohesion with Tambrey development
- local scheme amendment required for KA24A
- resolution of native title required over portion of site (KA24A)
- may be developed as joint venture arrangement

Town Centre
- local scheme amendment required for portion of area
- KA19A clear of native title
- development of this site subject to finalisation of masterplan and redevelopment strategy

Lot 72 Padbury Way
- amendment initiated to rezone from public purposes - community to residential R30 (amendment 8)

Lot 4933 Maitland Road &
Lot 837 Clarkson Way
- scheme amendment 9 aproved and conditional subdivision approval granted for the creation of 12 lots

Mulataga
- Karratha's long-term land supply
- zoned urban development
- clear of native title
- geotechnical and Aboriginal heritage issues may significantly constrain this site
- development would require major upgrade to sewerage infrastructure
- potential for up to 1000 lots
- initial feasibility works under way

Gap Ridge
- zoned industrial development
- 196 ha
- identified for future light/general industrial uses in Karratha Area Development Strategy
- currently progressing further site investigations
- construction anticipated for medium term (2010)

Gap Ridge north
- zoned rural
- identified for future aquaculture/ horticulture uses in Karratha Area Development Strategy
- suitability for urban development to be investigated

Lot No 4655 Balmoral Road
- scheme amendment 9 aproved and conditional subdivision approval granted for the creation of 9 lots

Searipple Road
1400 persons
workforce accm

Rankin Village
(Woodside)
500 persons
workforce accm

Balmoral Holiday Park
200 persons
workforce accm/
tourism

Karratha Senior High School
- construction of senior campus under way
- co-located with Pilbara TAFE
- junior campus to be co-located at a later date which will make the existing site available for possible redevelopment

Pluto Village
(Woodside)
1500 persons
workforce accm

Pilbara Holiday Park
200 persons
Workforce Accm/
Tourism

Dampier Road
- upgrade works under way
- extension of dual carriageway between Balmoral Road east to Broadhurst Road
- construction of roundabouts at Bathgate Road and Balmoral Road west
- works to duplicate road between Balmoral Road west and Burrup Peninsula Road to be complete by 2012

Karratha light industrial area
- works to service 39 lots to commenced August 2008
- few existing vacant or available lots in the estate

Baynton West
- outline development plan has been prepared and endorsed
- conditional approval for subdivision granted July 2008
- civil works for stages 1-4 (358 lots) commenced August 2008
- project includes 810 single residential, 4 group housing sites and one special use R60 site
- some lots to be offered as house and land packages

Gap Ridge
- EOI released and preferred proponent announced
- capacity to accommodate up to 1400 persons
- zoned urban development
- area fronting Dampier Road and Madigan Road being considered for use as large format retail

Madigan Road
- zoned urban development
- 68 ha
- could potentially yield more than 600 lots
- preparation of outline development plan under way
- site is clear of native title

The Ranges Karratha
- current proposal to develop 148 managed apartments
- zoned tourism
- project has development approval

King Way
- area zoned for transient workforce accommodation

Produced by Infrastructure Planning and Coordination branch, Department for Planning and Infrastructure.

Base information supplied by the Western Australian Land Information Authority, GL248-2007-2.

Date: 22/10/2008

Note:
The extent and timing of project areas are indicative only. No onus is placed on the landowner or relevant agency to comply with these representations. Proposals for development on each site must still follow relevant planning procedures.

Karratha 2020

The Karratha 2020 Vision and Community Plan ('K2020'), prepared by the Shire in partnership with the State Government and industry, assesses Karratha's infrastructure and service needs in response to anticipated future population growth.

The document aspirationally identifies transforming Karratha from a principally resource driven settlement to a sustainable, economically diverse regional city of some 30-50,000 people by 2020.

The document categorises these needs around six themes for which a number of initiatives are identified to address the needs requirements for a growing population. The six themes comprise:

- Business, Entrepreneurialism and Economic Development;
- Infrastructure Investment and Transport;
- Leadership and Capacity;
- Liveability and Lifestyle;
- Natural Capital; and
- Community Health and Wellbeing.

In addition, a number of specific major projects to enhance the town's liveability, diversify the economy and assist with meeting the needs of major industry are identified.

The document identifies several community facilities within the Baynton area which include a new primary school, district playing fields and a community family centre. These facilities have been incorporated into the Development Plan prepared for the Baynton West development east of the site.

Karratha Open Space Strategy

The Karratha Open Space Strategy, prepared by the Shire, provides a framework for the provision of public open space within Karratha and assists Council to rationalise its open space system within the context of overall need, function and operation.

The Strategy outlined that several considerations influence the provision of open space in Karratha relating to climate, drainage and maintenance. The provision of adequate drainage to accommodate major storm events is an important issue in planning for open space areas. The high temperatures experienced in the town generally discourage daytime walking/cycling although these activities do occur in the evenings and cooler months. As a result of these extreme climatic conditions, maintaining public open space areas is a significant cost impost on Council.

In terms of factors influencing the usage of open space, the document recognised that Karratha serves as a regional recreation hub for a lot of formalised recreational pursuits. There is a demand for a greater diversity of activities with an emphasis on cultural, non-competitive and passive sport and recreation opportunities to cater for a significant proportion of the population who are working shift hours and who are unable to engage in active recreational pursuits on a regular basis.

The Strategy identified opportunities for the excision of approximately 19.82 ha of land from the open space system across Karratha whilst maintaining the 10% open space requirement.

This document identifies potential infill development opportunities within existing urban areas and highlighted the meed to limit the amount of open space to only the minimum that is required for drainage and recreational purposes.

Liveable Neighbourhoods

Liveable Neighbourhoods is an operational policy, adopted by the WAPC, for the design and assessment of structure plans and subdivision, for new urban (predominantly residential) in the metropolitan area and country centres, on greenfield and large urban infill sites.

The policy is a performance-based code which advocates the structure of new urban areas be formed by the clustering of compact, walkable neighbourhoods, each incorporating a centre that comprises a range of compatible uses, including retail that provides for a variety of daily needs as well as act as a community focus. A range of residential densities and a variety of housing types that increase towards the centre, and an interconnected street network that focuses on the centre and provides good access for vehicles, cyclists and pedestrians in a pleasant, efficient and safe manner is also advocated.

Additionally the policy states the WAPC may accept a minimum of five per cent of the gross subdivisible area for public open space for new development in regional areas (excluding drainage and restricted open space) subject to the support of the local government, the open space being developed to a minimum standard and for the widest possible use of the community and public open space being readily available in the community.

Planning for the site will need to have due regard to the Policy although care needs to be taken to ensure it is adapted to the local arid environment.

STATUTORY DOCUMENTS

Shire of Roebourne District Planning Scheme No. 8

The Shire of Roebourne District Planning Scheme No. 8 (the Scheme) is a land use based statutory Scheme, which was prepared, based on the KADS and associated Townsite Structure Plan, and gazetted in 2000. The principal functions of the Scheme are to reserve and zone land, and control development on reserved and zoned land. The Scheme prescribes zonings and a 'Use/Class' table which permits, prohibits and provides Council discretion to approve certain land uses in certain zones depending on the purpose, intent and objective of the zone.

The Scheme also stipulates several objectives to guide the future development of Karratha including the following statements that are considered relevant to the development of the site:

(i) Facilitate the continued growth of Karratha as the regional centre of the West Pilbara in accordance with the Karratha Townsite Structure Plan (as amended);

(ii) Preserve the key recreational, landscape and heritage values of the Karratha Hills;

(iii) Develop local commercial centres so as to provide convenience goods and services to the local community;

(iv) Enhance the high level of residential amenity within Karratha in both existing suburbs and the residential expansion areas; and

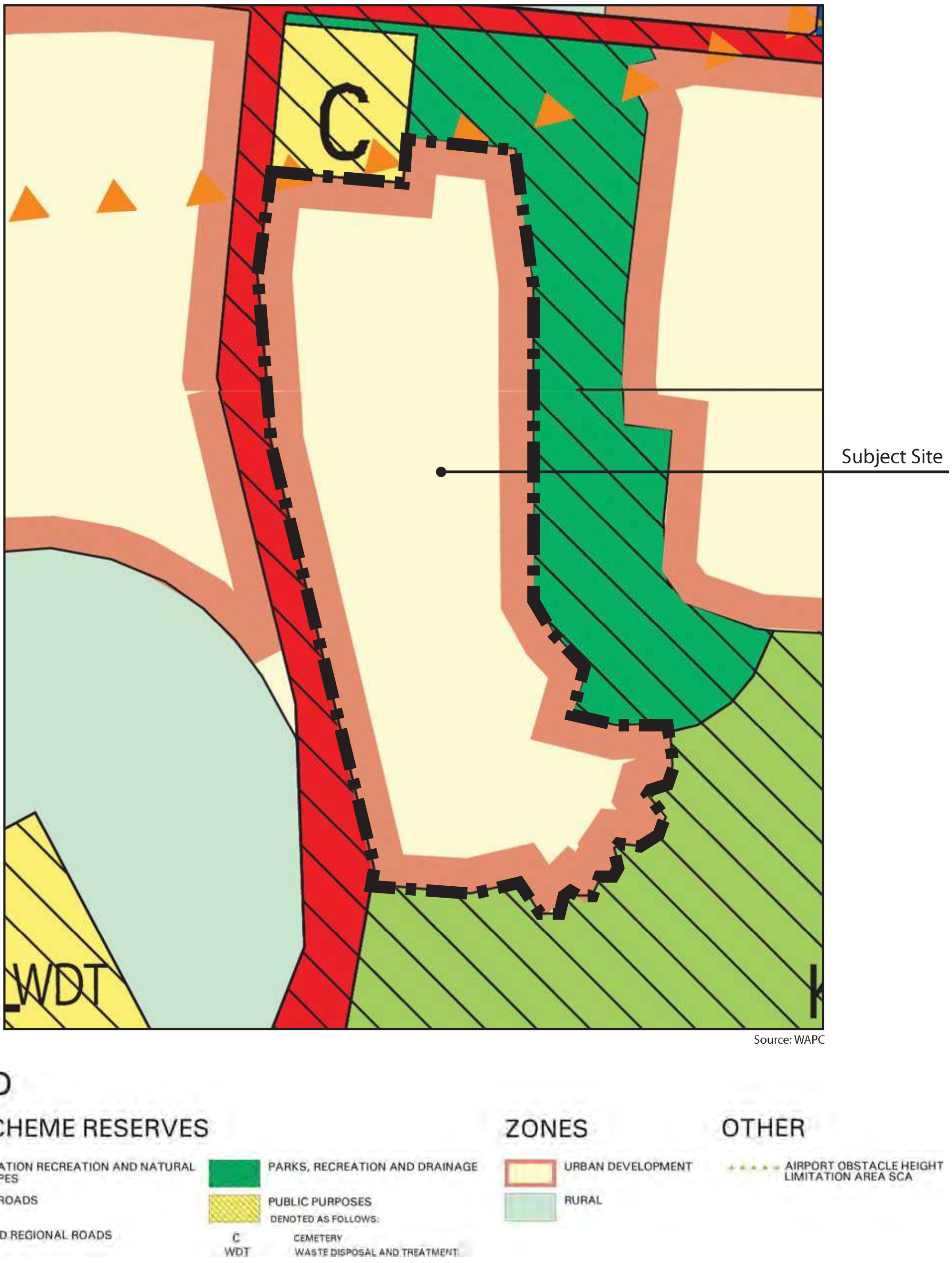
(v) Encourage residential development that will accommodate a greater range of lifestyles and needs to reflect the broadening population base.

The Scheme is technically past the 5 year review date stipulated by the Planning and Development Act (2005) and significant amendments are now being undertaken in response to the recent Karratha City of the North initiative.

This document is relevant to the development of the site as it represents the Shire of Roebourne's statutory instrument for land use and development control and includes land already identified for urban development.

Refer to Figure 8 - Shire of Roebourne District Planning Scheme No. 8

Figure 8 - Shire of Roebourne District Planning Scheme No. 8



Source: WAPC

Specific Planning Scheme Provisions*

Under the Scheme, the site is zoned 'Urban Development'. Section 6.4 of the Scheme provides standards for the development of land in the 'Urban Development' zone. Section 6.4.1 states that:

"Before considering any proposal for subdivision or development of land within the Urban Development Zone, the Council may require the preparation of a Development Plan for the entire development area or any part or parts as is considered appropriate by Council."

Section 6.4.2 outlines details that should be contained within a Development Plan which include:

(i) landform, topography, landscape, vegetation and soils of the area;

(ii) location, existing roads, land uses and surrounding land uses and features;

(iii) ownership, title description, area, encumbrances and any legal considerations;

(iv) existing and proposed services including water, sewerage, energy, communications, drainage and catchment considerations;

(v) existing places and features of heritage and/or cultural significance, including natural landscapes, flora and fauna in addition to built structures and other modified environments;

(vi) location and density of housing areas, including lot and dwelling yield, estimated population outcomes, net residential density and detailed subdivision standards relating to solar access, efficient use of water resources, design features and density rationale;

(vii) road layout and traffic assessment, communal and incidental parking areas, pedestrian/cycle network/underpasses;

(viii) public open space and recreation provision and relationship to natural features;

(ix) comprehensive drainage systems for stormwater runoff and natural drainage lines;

(x) commercial and community centres and facilities including schools;

(xi) lot layout, major buildings and landscaping proposals;

(xii) the method of carrying out the development including the projected times of completion of each stage; and

(xiii) other information as may be required by the Council.

**This section reflects the Scheme prior to Amendment 18 being gazetted on 8 March, which was prior to writing this report.*

Accordingly a Development Plan is required to be prepared for the site in accordance with the above and is required to be adopted by the WAPC as the basis for approval of subdivision applications within the area covered by the plan. Whilst part 6.4 of the Scheme refers to a process for the consideration of Development Plans, the process does not require advertising of the plan as a mandatory requirement (although advertising is undertaken by officers as a standard procedure) and does not stipulate a timeframe by the which the Development Plan needs to be assessed, or provide a deemed right of refusal. These anomalies are proposed to be rectified as part of Scheme Amendment No. 18 (refer below).

With regard to the reservation and zoning of land surrounding the site, land immediately to the east is reserved 'Parks, Recreation and Drainage' whilst further beyond land is zoned 'Urban Development' currently being developed by Landcorp as part of Baynton West. Land to the south is reserved 'Conservation, Recreation and Natural Landscapes', whilst to the west, Madigan Road is reserved 'State and Regional Road' with land further beyond zoned 'Urban Development' and 'Rural'. The cemetery abutting the north-western corner of the site is reserved 'Public Purpose Cemetery' whilst the north-eastern corner abuts a portion of land reserved 'Parks, Recreation and Drainage'. Further the north, Dampier Road is reserved 'State and Regional Road' with land further beyond zoned 'Rural'.

Whilst there is no impediment to a Development Plan being adopted outside the Urban Development zone, subdivision and development of such land should not be permitted under an orderly and proper planning process until such time as the base zoning is appropriate. It is envisaged though that the subdivision application will occur concurrent with the assessment of the Development Plan to ensure approvals are achieved in a timely manner.

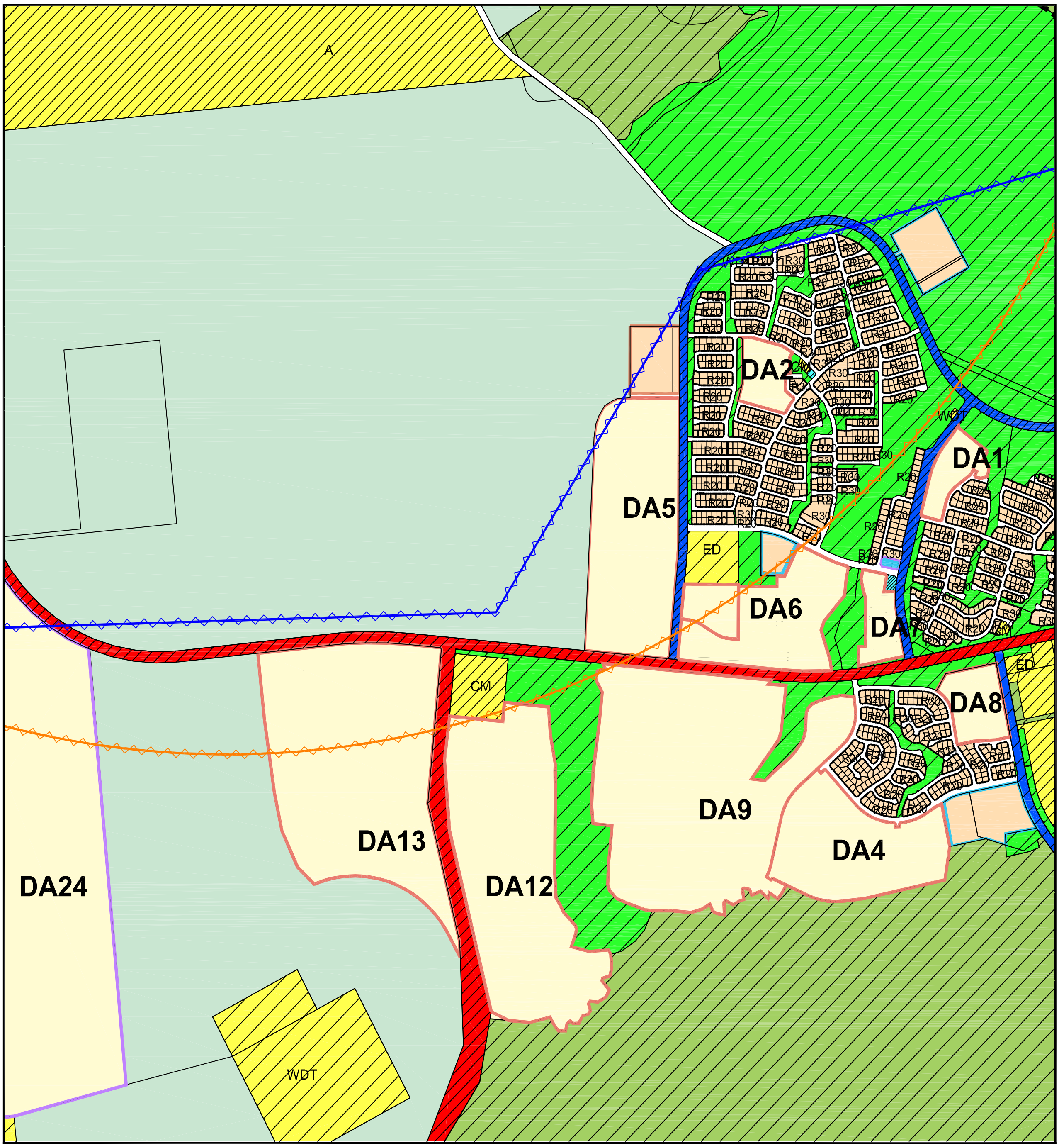
Scheme Amendment No. 18

The first Scheme Amendment relevant to the site that has just been gazetted is Scheme Amendment No. 18. Whilst the initial intent of the Amendment was to address the planning framework for the Karratha Town Centre (to amongst other matters create a 'City Centre'), the opportunity was taken by the Shire to also implement a series of consequential textual amendments that relate to a number of matters and areas outside the Town Centre.

Specific to the site, the Scheme Amendment proposes to insert a series of provisions in relation to Development Plans, to include all areas zoned 'Urban Development' within a Special Control Area and have regard to the Special Conditions inserted into Appendix 7 of the Scheme. The Amendment also inserted a new appendix, Appendix 8, into the Scheme which outlines all matters to be considered as part of a Development Plan.

Refer to Figure 9 - Scheme Amendment 18 Plan

Figure 9 - Scheme Amendment 18 Plan



For the site, the area is inserted as 'Special Control Area DA 12' where the Special Conditions are:

1. An approved Development Plan together with all approved amendments shall apply to the land in order to guide subdivision and development.
2. To provide for residential, commercial, community, recreation and drainage.
3. Retail floor space shall be commensurate with a Local Centre.
4. Provision shall be made for a public bus transport linkage as per the City of North Growth Plan.
5. Land uses classified on the Development Plan apply in accordance with clause 7.2.11.4.

In terms of the other requirements that need to be addressed by the Development Plan, Appendix 8 states all Development Plans shall address the following matters:

(i) landform, topography, landscape, vegetation and soils of the area;

(ii) location, existing roads, land uses an surrounding land uses and features;

(iii) legal considerations, ownership, title description, area and encumbrances;

(iv) existing and proposed services and infrastructure including reticulated or other potable water supply, sewerage, energy, communications, drainage and catchment considerations;

(v) existing places and features of Aboriginal and non-Aboriginal heritage and/or cultural significance, including natural landscapes, flora and fauna in addition to built structures and other modified environments;

(vi) road layouts and traffic assessments, communal and incidental parking areas, pedestrian/cycle network/ underpasses, including impacts on the surrounding movement network;

(vii) public open space and recreation provision, environmental protection areas, and relationships to natural features;

(viii) assessment of the impact of the proposal on the natural environment, including management of potential effluent, emissions and other forms of pollution;

(ix) comprehensive drainage systems for stormwater runoff and natural drainage lines;

(x) indicate the design of the proposal including lot layout, major buildings, roads and landscaping proposals;

(xi) the demand for the development in relation to the overall market for similar developments;

(xii) the method of carrying out the development including the projected times of completion of each stage;

(xiii) provide provisions, as may be considered appropriate by local government, for inclusion in the Policy Manual; and

(xiv) any other information as may be required by local government.

Development Plans in the 'Urban Development' zone should also address the following matters:

(i) location and density of housing areas, including lot and dwelling yield, population outcomes, net residential density and detailed subdivision standards relating to solar access, efficient use of water resources, design features and density rational; and

(ii) indicate demand for commercial and community facilities, including schools, generated by the proposal and implications for the provision of these within the development area or elsewhere.

In summary the provisions for Development Areas prescribed by Clause 7.2 address matters such as:

- Ensure the Shire does not consider development in a Development Area unless a Development Plan is prepared or it is confident that such development will not prejudice the future development of the Area;
- Prescribe the level of detail to be addressed in a Development Plan and accompanying report;
- Require a Development Plan to be submitted to the WAPC within 7 days of receipt and provides the WAPC with 30 days in which to advise whether it is prepared to endorse the Development Plan for advertising;
- Require the Shire to advertise the Development Plan within 60 days of receipt of an application compliant with Section 7.2.5 of the Scheme for a period of not less than 21 days;
- Provide the Shire with a further 60 days in which to determine the Development Plan and forward its determination within 7 days to the WAPC for the WAPC's determination;
- Prescribe the operation of the Development Plan once adopted and how such Development Plan can be amended;
- Establish a process for the preparation, adoption and operation of Detailed Area Plans which can provide additional details in relation to particular lots or areas with a Development Plan area; and
- Prescribe the appeal rights in relation to Development Plans and Detailed Area Plans.

City Growth Amendment

A second Scheme Amendment, Scheme Amendment No. 21, has been prepared to implement the Karratha City of the North Blueprint and Growth Plan. Council at its meeting of the 19 July 2010, resolved:

1. Should, if no substantive objections in the opinion of the Chief Executive Officer are received from landowners affected by the proposed changes to the amendment and legal advice be received that the potential financial risk to Council from claims for injurious affection are acceptable:
2. Initiate the proposed Shire of Roebourne Town Planning Scheme No.8 Omnibus Amendment No. 21 to introduce various Development Areas and associated Special Conditions, and changes to the proposed City Centre zone in order to reflect the proposals within the Karratha City Growth Plan and the Karratha City Centre Master Plan.
3. Advertise the Amendment in accordance with the requirements of the Town Planning Regulations 1967 for a period of 42 days, subject to the advice from the Environmental Protection Authority that under s.48A of the Environmental Protection Act 1986 that Amendment 21 is not subject to formal environment assessment.

Preliminary advertising has been undertaken by the Shire and is currently being considered by the EPA.

The focus of this Amendment is to re-zone much of Karratha and its surrounds to facilitate the implementation of the City Growth Plan by including all potential development areas within a Special Control Development Area in the Scheme and inserting Special Conditions in Appendix 7 for each Development Area.

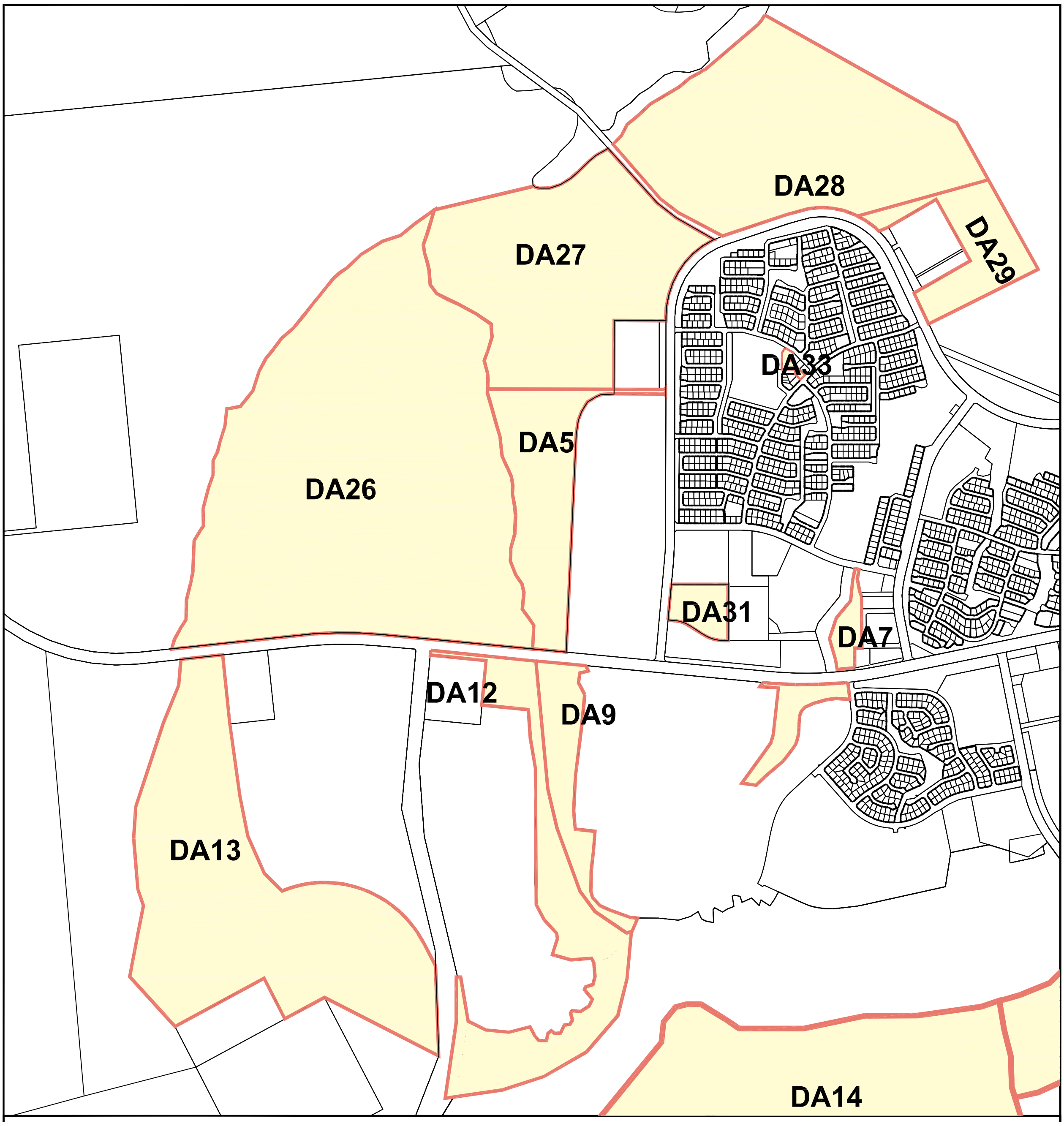
For the site, the Amendment proposes to extend the 'Urban Development' zone Development Area to the east into the adjoining drainage area and also extend the area south further into the adjoining hillside. It also proposes to extend the 'Urban Development' zone and Development Area for Baynton West to abut the Development Zone for Madigan Road. Whilst the majority of this area will still need to be set aside for drainage purposes, the zoning will enable the boundary of the developable area to be determined by actual drainage modelling and allow greater connection to be provided between the two Development Areas. It is hoped that by doing this, that the optimal development of the land can be achieved without land being set aside for drainage unnecessarily which ultimately would be maintained by the Shire.

For the southern extension to the Madigan Road area, an analysis will need to be undertaken to determine exactly how far the developable area extends into the Hills having regard for matters such visual amenity, services, heritage issues.

It should also be noted that these extension areas are still subject to Native Title restrictions which will need to involve the Ngarluma people (Ngarluma Aboriginal Corporation) as the registered native title holders.

Refer to Figure 10 – Proposed Scheme Amendment No. 21.

FIGURE 10 – PROPOSED SCHEME AMENDMENT NO. 21



State Planning Policy 5.4: Road and Rail Transport Noise and Freight Considerations in Land Use Planning (2009)

This Policy is primarily concerned with how the planning system can be used to minimise the adverse impact of transport noise on noise-sensitive development without placing unreasonable restrictions on development or adding unduly to the cost of road and rail infrastructure.

The Policy is applicable in the case where noise-sensitive development is proposed in proximity to major roads and/or railways. In this regard, the Policy identifies Madigan Road as a 'State Freight Road' for which transport noise may affect sensitive land uses.

The policy sets out the outdoor noise criteria that apply for new noise-sensitive development. The noise levels are measured at a distance of 1 metre from the most exposed, habitable façade of the proposed building, at each floor level, and within at least one outdoor living area on each residential lot. The outdoor noise criteria requirements are as follows:

Time of day	Noise Target	Noise Limit
Day (6 am–10 pm)	LAeq(Day) = 55dB(A)	LAeq(Day) = 60dB(A)
Night (10 pm–6 am)	LAeq(Night) = 50dB(A)	LAeq(Night) = 55dB(A)

Generally where the noise target is likely to be exceeded for outdoor areas, a detailed noise assessment and/or the implementation of mitigation measures may be required by the developer to achieving the target levels.

For residential buildings, acceptable indoor noise levels are LAeq(Day) of 40dB(A) in living and work areas and LAeq(Night) of 35dB(A) in bedrooms.

CONTEXT ANALYSIS

NATURAL AND CULTURAL HERITAGE ANALYSIS

Heritage Council of Western Australia

A search of the HCWA database showed no state listed properties (buildings or places) on either the interim or permanent register.

National Trust

A search of the National Trust database showed no listed properties (buildings or places) on the Trust register.

Municipal Inventory

There are no significant sites of European heritage located within the site and listed on the local Municipal Inventory.

Ethnographic and Archaeological Site Register

Table 2: Registered Aboriginal sites within the Survey Area (Source: Preliminary Advice of an Aboriginal Heritage Survey – March 2010)

Site ID	Status	Access	Site Name	Site Type	Coordinates (MGA Zone 50)
8959	S	O	Karratha West Access Road / Madigan Road 01	Artefacts / Scatter	478039mE, 7705655mN
8960	S	O	Karratha West Access Road / Madigan Road 02	Artefacts / Scatter	DIA Register: 477900mE, 770500mN Site File: 477900mE, 7705000mN
8961	S	O	Karratha West Access Road / Madigan Road 03	Hidden / Scatter	DIA Register: 477939mE, 7704955mN Site File: 477800mE, 7704800mN

Archaeological Survey Results

Five Aboriginal archaeological sites have been identified within and adjacent to the Baynton West Stage 2 Survey Area (Refer to Figure 8). These sites consist of three artefact scatters, one grinding patch site and one engraving site which have been given field ID's BW210AS01, BW210AS02, BW2AS03, BW210GP01 and BW210ENG01. All of these sites have been recorded to Site Identification standard.

BW210GP01 and BW210ENG01 are immediately adjacent to the eastern extent of the Survey Area and as such may potentially be impacted by development and will need to be addressed in the proposed Cultural Heritage Management Plan.

One newly identified Aboriginal archaeological site has been identified adjacent to the Baynton West Stage 2 Survey Area and recorded to Site Identification standard. This site has been given field ID BW210ENG01 and corresponds to registered Aboriginal site ID 21299.

Registered Aboriginal sites ID 8959, 8960 and 8961 were not relocated within the Baynton West Stage 2 Survey Area.

Three sites are located within the site itself whilst the balance of the identified Aboriginal heritage sites are located in the adjacent Parks, Recreation and Drainage reservation.

These sites have been identified on site and located within public open space areas to be protected. The management and protection of these sites both during construction and once the estate is complete will be addressed via the a management plan prepared in consultation with the Ngarluma Aboriginal Corporation and where necessary the Department of Indigenous Affairs.

These sites are proposed to be retained and protected within open space areas.

ENVIRONMENTAL ANALYSIS

Climate

The climate of the Pilbara region in WA is characterised by arid tropical with summer rain (Beard, 1990). Cyclone season extends from 1 November to 30 April. Mean maximum daily temperatures recorded at Karratha vary from 36.1°C in January and 26.1°C in July, and mean minimum daily temperatures vary from 26.8°C in January and February to 13.6°C in July (Karratha airport weather station, BoM, 2010).

The site is characterised by dominant easterly winds in winter and westerlies in summer. Average wind speeds in both seasons vary from 10-20km/hr and sustained periods of winds to 35km/hr can occur, particularly in winter. Stronger winds, in excess of 300km/hr, occur in association with tropical cyclones between November and April (GHD, 2009). Prevailing westerly winds occur early in the day in spring and summer and become north to north westerly in the afternoons. During winter and autumn, morning winds are east to south easterly becoming north to north easterly in the afternoon. Wind speeds average between 14.4 and 18.8km/hr in the mornings (0900 hours) and between 20.1 and 29.2km/hr in the afternoons (1500 hours) (GHD, 2009).

Annual rainfall is approximately 277mm with an average of 20 rain days per year. Most of the rainfall occurs during January and June (BoM, 2010) and the average annual evaporation rate exceeds rainfall by as much as 2,500mm (GHD, 2009).

Geology and Landforms

The site is situated over the Pilbara Craton Formation which comprises a mid- Archaean granite-greenstone terrane and an overlying late-Archaean volcano sedimentary sequence called the Hamersley Basin. The site is mapped as Unit Ayx, which is described as 'Granophyric dyke' (GSWA, 2001).

Topography at the site slopes gently to the north with elevations of 26m Australian Height Datum (AHD) in the south to 15m AHD at the northern boundary.

Hydrology

Surface Water

One drainage line occurs to the east of the site. Retention of this feature in its natural condition is recommended with the minimal amount of engineering works to accommodate increased storm water from surrounding development. Another smaller drainage line occurs west of the site along the existing Madigan Road. No wetlands are present on the site.

Groundwater

The Department of Water's (DoWs) Hydrogeological Atlas (DoW, 2010a) describes the hydrogeology of the site as volcanic and sedimentary rock in greenstone belts, and shows there is a single aquifer beneath the site.

The Pilbara Fractured Rock aquifer consists of Precambrian granite-greenstone terrain overlain by surficial sediments in the river valleys. The water table is generally within 5m to 10m below the surface in the granitic areas. There are not considered to be any major regional groundwater resources in the Pilbara fractured rock (DoW, 2010a).

The groundwater beneath the site is considered brackish having total dissolved solids (TDS) of 1000-3000 mg/L (DoW, 2010a). A search of the DoW WIN database revealed that there are two DoW bores 1km west of the site, however neither of these bores have had sufficient monitoring events to establish any trends in groundwater levels.

The DoW Geographic Data Atlas (DoW, 2010b) indicates there is no Public Drinking Water Source Area beneath or near the site. As groundwater beneath the site is brackish to saline and there are no major rivers located in close proximity to the site where fresh water could be sourced, potable water could potentially be sourced from current Karratha sources; the Hardling Dam and the Millstream borefield.

Vegetation and Flora

Vegetation

Coffey Environments undertook a site inspection on 4 May 2010 and a targeted search for conservation significant flora on 14 October 2010.

The vegetation on the Madigan site is uniform and consisted of a shrub steppe community of Acacia and Triodia wiseana. Dominant Acacia species were included A. pyrifolia and A. bivenosa. Other native grasses were also present including Eragrostis xerophila.

The drainage channel to the east of the site contained similar species to the plains, although several different Acacia species including A. coriacea were also identified. The condition of the vegetation ranged from Degraded in the northern section where Buffel Grass (Cenchrus ciliaris) was prevalent and the density of Acacias was low. The majority of the vegetation in the southern two-thirds of the site was generally in Very Good condition with some evidence of human disturbance in the form of tracks, and little to no weed invasion.

Conservation Significance of Vegetation

A search of the Department of Environment and Conservation's (DEC's) Threatened Ecological Communities (TEC) database was undertaken by Coffey Environments. One Priority Ecological Community (PEC) was listed as occurring in the vicinity of the site, this being the 'Stony Chenopod association of the Roebourne Plains area' (Priority 1). The vegetation present on the site is not considered to represent any known TECs or PECs, and therefore the vegetation present is not regarded to be of local, state or national significance.

Flora

Database Searches

A search of the following databases was undertaken to ascertain the potential presence of conservation significant flora on the site:

- The DEC 'Threatened Flora' database;
- The DEC 'Declared Rare and Priority Flora List' which contains species that are Declared Rare (Conservation code R or X for those presumed to be extinct), poorly known (Conservation codes 1, 2 or 3) or require monitoring (Conservation code 4); and
- The Western Australian Herbarium specimen database.

No records of any conservation significant species within the site were identified. However, a total of 19 species were identified as potentially occurring within the vicinity of the site, these are presented in the table below:

Species	Conservation Category	Preferred Site Characteristics	Flowering Period
Acacia NLAucocaesia	P3	Red loam, sandy loam, clay. Floodplains	Jul–Sep
Atriplex lindleyi subsp. conduplicata	P3	Crabhole plains	-
Eragrostis lanicaulis	P3	Red sandy clay. Flats	Mar–May/Aug–Oct
Eriachne semiciliata	P3	Shallow soils over rock, red sand, sandy clay. Ridges, sand dunes	Mar–Apr
Eriochloa fatmensis	P3	-	-
Gomphrena cucullata	P2	Red sandy loam, clayey sand. Open floodplains	Feb/May
Gomphrena leptophylla	P3	Sand, sandy to clayey loam, granite, quartzite. Open flats, sandy creek beds, edges salt pans & marshes, stony hillsides	Mar–Sep
Gomphrena pusilla	P2	Fine beach sand. Behind foredune, on limestone	Mar–Jun
Goodenia pallida	P1	Red soils	Aug
Gymnanthera cunninghamii	P3	Sandy soils	Jan-Dec
Helichrysum oligochaetum	P1	Red clay. Alluvial plains	Aug–Nov
Ipomoea sp. A Kimberley Flora (L.J. Penn 84)	P1	Shallow soils on sandstone	Jun
Rhynchosia bungarensis	P4	Pebbly, shingly coarse sand amongst boulders. Banks of flow line in the mouth of a gully in a valley wall	-
Schoenus punctatus	P3	Watercourses	Aug
Stackhousia clementii	P3	Skeletal soils. Sandstone hills	-
Tephrosia bidwillii	P3	-	May/Aug
Terminalia supranitifolia	P3	Sand. Among basalt rocks	May–Jul/Dec. Sand
Themeda sp. Hamersley Station (M.E. Trudgen 11431)	P3	Red clay. Clay pan, grass plain	Aug
Vigna sp. Rock Piles (R. Butcher et al. RB 1400)	P3	-	-

Of the 19 species of flora, many are highly unlikely to be present on the site due to the absence of specific habitat requirements. To confirm the presence/absence of conservation significant flora, Coffey Environments undertook a targeted survey of the site. Although the timing of the targeted survey was not optimal, the conservation significant species that were most likely to be found on the site would have been readily identifiable at the time of the survey. No conservation significant species or Priority Flora were present on the site at the time of the targeted survey. A clearing permit has been lodged for approval prior to any clearing or earthworks taking place.

Fauna

A search of the DEC's Threatened and Priority Fauna database and the Western Australian Museum database was undertaken to identify potential scheduled and threatened species in the region. A search of the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* database was also undertaken to identify species of national environmental significance.

Habitats Present

The site is dominated by a single habitat type, this being:

- Spinifex and low sparse shrubs over a gravelly and rocky substrate.

Conservation Significant Fauna Species Predicted to Occur on Site

The results of the database searches are presented as Appendices A and B in the Preliminary Environmental Assessment Report prepared by Coffey Environments (2010).

Species	Status under Wildlife Conservation Act	Status under Cwth EPBC Act	Potential to be found in the project area
Northern Quoll (Dasyurus hallucatus)	Schedule 1	Endangered	Occasionally found in the region, though generally prefers rocky outcrops containing dens which were not identified during the site visit.
Pilbara Olive Python (Liasis olivaceus barroni)	Schedule 1	Vulnerable	Occasionally found in the region and potentially could utilise the site, though unlikely to rely on the site for its survival due to the degraded condition of the habitat on the site.
Peregrine Falcon (Falco peregrinus)	Schedule 4		Occasionally may overfly the site, though unlikely to rely on the site for its survival because of its ability to forage over a large area.
Little North-Western Mastiff Bat (Mormopterus loriae cobourgiana)	Priority 1		Highly unlikely to be present on the site due to an absence of the species preferred habitat (mangroves).
Australian Bustard (Ardeotis australis)	Priority 4		Occasionally found in the region and potentially could utilise the site, though unlikely to rely on the site for its survival as it is a highly mobile species that would move to adjoining areas if disturbed.
Bush Stone-curlew (Burhinus grallarius)	Priority 4		Unlikely to be present on the site.
Pebble-mound Mouse (Pseudomys chapmani)	Priority 4		Potentially present in the Karratha hills area, though the Pebble-mound Mouse occurred on the Burrup Peninsula in the past, but has not been recorded recently.
Lakeland Downs Mouse (Leggadina lakedownensis)	Priority 4		Highly unlikely to be present on the site owing to the degraded habitat present on the site.
Ghost Bat (Macroderma gigas)	Priority 4		May infrequently visit the site, though unlikely to reside on the site due to the absence of caves.
Eastern Curlew (Numernius madagasca-eriensis)	Priority 4		Unlikely to be present due to an absence of the species preferred habitat.
Flock Bronzewing (Phaps histrionica)	Priority 4		Highly unlikely to be present as this species relies on mature native grasslands. The habitat present on the site is degraded, and if present, the species would move to adjoining areas if disturbed.

Based on the habitat present on the site it is unlikely that many of the species listed in the table above would be significantly impacted by development of the Madigan Road site due to the following reasons:

- Habitat condition is degraded in comparison to other nearby areas;
- Some species habitat preferences are absent from the site;
- If disturbed by site activity, some species would move to adjoining areas;
- Some species may visit the site but are unlikely to rely on the site for their survival as they are able to forage over a wide area.

Acid Sulphate Soils

Acid sulphate soils (ASS) typically comprise wetland soils and unconsolidated sediments that contain iron sulphides which, when exposed to atmospheric oxygen in the presence of water, form sulphuric acid. When disturbed by excavation or dewatering, these soils are prone to produce sulphuric acid and thereby mobilise arsenic, aluminium, iron, manganese and other heavy metals from the soil profile into groundwater. The release of these reaction products can be detrimental to biota, human health and built infrastructure. The release of acid and metals can cause deterioration of water quality, and can result in fish kills in downgradient waterways. Acid released by oxidation of ASS also has the potential to corrode concrete and steel infrastructure, reducing their functional lifespan.

DEC maps the majority of the Madigan Road site as "no known risk" of ASS occurring generally at depths less than 3m. A strip along the eastern boundary of the site is mapped as "moderate risk" of ASS occurring generally at depths less than 3m. This increased risk is associated with the proximity of the sites eastern boundary to the adjacent creekline.

Contamination

A contaminated site is defined in the WA *Contaminated Sites Act 2003* as "land or water [surface and groundwater] containing a substance above background concentrations that presents or has the potential to present a risk of harm to human health or the environment". In other words, the contaminated site has the potential to cause risk to human health, the environmental value or to the environment.

A search of the Contaminated Sites Register shows that there are no registered sites located within or near the site.

Geotechnical

Cossill & Webley arranged for Coffey Geosciences to carry out a desk top study of likely ground conditions at the site. The study is based upon Coffey's experience working in close proximity to the site, the 1:50,000 Urban Geology Series map (Karratha & Nickol Bay) and satellite imagery from Google Earth.

Coffey has advised they expect that the subsurface profile over the majority of the site is most likely to comprise varying thicknesses of high plasticity clayey sands/ sandy clays overlying highly weathered Basalt and Granite at depth of about 2m. The 1:50,000 Urban Geology Series map (Karratha) shows the northwest corner of the site to be covered by Aeolian sand and the southeast corner of the site is shown to be bordering a ridge of Archaen aged Chert and clastic sediments.

Based on AS2870-1996 (Residential Slabs and Footings), the site would be classified as Class H-D and should be designed to resist cyclones in a cyclone designated area. It should be noted that the classification of the site may be improved if appropriate remedial actions are being taken. On balance it is considered Class M-D can be achieved.

It is noted that the ground conditions at the site are inferior to the Baynton West site (the soils interface is close to the alignment of the watercourse to the east of the site) and most of the Karratha town site but are nevertheless suitable for land development so long as dwellings are provided with an appropriate footing system.

A Geotechnical Report has been completed by Coffey Geotechnics Pty Ltd and can be seen in Appendix 3. The report confirms that the site is currently typically classed H (Highly reactive clay) with the potential for deep soil mositure changes, but can be upgraded to a Class M (Moderately reactive clay) by the placement of between 1-1.2m of controlled fill over the clay

Refer to Appendix 3 Geotechnical Report.

Waste Water Treatment Plant Buffer

On the western side of Madigan Road is the Water Corporations Waste Water Treatment Plant No. 2. The Plant has a 500 metre radius around the Plant which is reflected by the Plant's cadastral boundary. No residential development is proposed within this buffer zone.

TRANSPORT AND TRAFFIC

Existing Road Network

Dampier Road is classified as a Primary Distributor road and is under the care and control of Main Roads WA. It is an important regional road connecting Dampier and Karratha town sites to North West Coastal Highway. It also provides direct or indirect access to major local industrial, transport and tourism nodes including Burrup Industrial Area, Burrup Peninsula, Karratha Industrial Estate, Dampier Salts, Rio Tinto Railway Terminal and Karratha Airport.

The section of Dampier Road traversing Karratha town site has recently been upgraded to dual carriageway standard with a typical cross-section comprising of two 3.5m traffic lanes in each direction with up to 2m wide shoulders and a 7m wide central median. It has dual lane roundabouts or turn pockets at major intersections. The speed limit on the section of Dampier Road in this vicinity is 80 km/h. The remainder of Dampier Road and in the vicinity of Madigan Road is still a two-lane, single carriageway rural road.

According to traffic counts sourced from Main Roads WA for Dampier Road (between Madigan Road and Balmoral Road West) it carried approximately 10,650vpd in March 2008 with a 9% heavy vehicle traffic component.

As is evident from the latest traffic count data, the current standard of this two-lane section of Dampier Road is reaching its practical capacity. As a result, Main Roads WA are in the process of upgrading this road to dual carriageway standard west of Balmoral Road West intersection to Burrup Road intersection to ensure an efficient and safe level of service and enable sustainable future traffic growth.

Based on the current information, the entire 12.3km section of Dampier Road between Balmoral Road West and Burrup Road intersection will be constructed as one contract and would include 8-12 intersections depending on control of access provisions with the airport and rail access roads. The duplication of Seven Mile Creek Bridge is also part of this project. The construction works of this stage is planned for late 2011.

Madigan Road connects North West Coastal Highway (NWCH) with Dampier Road and at present provides a freight route for traffic travelling from NWCH to Burrup Peninsula and Dampier bypassing the Karratha town site. It is constructed to 7m wide, single carriageway standard with 1m sealed shoulders and wide gravel shoulders. It entails an 80km/h sign-posted speed limit. Madigan Road is classified as a Primary Distributor road and is under care and control of Main Roads WA.

The latest traffic volumes obtained from Main Road WA indicate that Madigan Road (south of Dampier Road intersection) carried approximately 3,050vpd (April 2009).

The Dampier Road / Madigan Road intersection is an un-signalised and channelised 'Give Way' controlled T-intersection with left turn slip lanes on Madigan Road and Dampier Road (westbound direction) and a right-turn pocket on Dampier Road (eastbound direction). There are no sightline issues at the intersection as the terrain and geometry at this location is flat and relatively straight. The duplication of Dampier Road will modify the intersection layout thereby providing additional capacity and improving safety.

During the traffic modelling, analysis and assessments undertaken by Transcore for Gap Ridge Industrial and Karratha Revitalisation projects for Landcorp, it was established that signalisation of this intersection would be required once the Dampier Road duplication is complete. This requirement has been discussed with Main Roads WA and it is Transcore's understanding that the signalisation of this intersection is being incorporated into the Dampier Road duplication project.

Madigan Road Bypass Project

Madigan Road Bypass is planned as a heavy vehicle route in the Karratha Town Structure Plan (KTSP) document and incorporated in Main Roads WA long-term planning. The proposed alignment of this road in KTSP is proposed to connect NWCH (west of the existing NWCH / Madigan Road intersection) and Dampier Road (west of Seven Mile Creek Bridge). At present there is no timeframe for the construction of the Bypass. Main Roads WA is currently reviewing the final alignment and Dampier Road / Madigan Road Bypass intersection / interchange location and design options. The construction of the bypass will result in downgrading of Madigan Road as the total traffic and, in particular, heavy vehicle traffic will be reduced on this road.

This page has been left blank intentionally.

THE DEVELOPMENT PLAN

The following section of this report provides a description of the Development Plan, its design rationale and objectives land uses, estimated population and residential densities, movement networks, servicing considerations built form design considerations.

PROJECT OBJECTIVES

The Karratha CGP provides an overall framework for the future development of Karratha and its evolution into a City. It aims to co-ordinate the work of local and state government and other key stakeholders in a coherent plan to improve the quality of life for all the people living in the area. Preparation of the CGP has taken into account the existing social, economic and environmental conditions, challenges and the implications these have for development.

Aspirational Goals for Karratha's evolution were developed as part of the CGP plan by adopting a Driving Force-Pressure-State-Impact-Response (DPSIR) framework to assist with contextual understanding as well as developing project objectives. These formed the basis for spatial and non-spatial responses and finally the CGP recommendations.

The CGP objectives have been adopted for establishing project objectives for the site. By extending the CGP project objectives there is inherent legitimacy built into the next layer of planning and design.

The project objectives that have guided the design and development of the Development Plan include:

- Provide residential development in accordance with the CGP;
- Facilitate housing diversity;
- Provide for an urban form that focuses on the public realm;
- Facilitate local employment services and amenities;
- Optimise land use; and
- Facilitate climate responsive and sustainable approach to development.

DEVELOPMENT PLAN DESIGN RATIONALE

The design of the Development Plan is based around the provision of an interconnected street grid network that provides good permeability and connections with the site's surrounding natural assets and the existing urban fabric, whilst facilitating opportunities for good climate responsive development.

REFER TO APPENDIX 2 - DEVELOPMENT PLAN

The design and orientation of the street network maximises east-west lot orientations ensuring new development capitalises on the prevailing breezes to assist with natural cooling in winter months and maximises shading by ensuring only the narrow frontages face lower morning and summer sun. The orientation of the street network also facilitates views towards the Karratha Hills from within the development as well as vistas to new internal public open space areas and the public open space area abutting the site to the east, thereby providing significant amenity and a strong sense of place.

The design and location of open space has been based around catering for the site's drainage requirements yet also providing opportunities to facilitate pedestrian movement between residential areas and the public open space areas within and to the east of the site. Indigenous cultural and heritage sites have been integrated within open space areas, thereby ensuring the protection and conservation of these elements.

Optimal integration with the Baynton West development will be achieved through the establishment of new at-grade and grade-separated roads across the adjacent open space area.

A local mixed use ('Main Street') centre is proposed to provide local convenience and service needs and serve as a community focal point for the development. The local centre is centrally located within the development on the main link road between Baynton West and Madigan Road ensuring a significant proportion of new residences are within a short walking distance of the centre.

The centre is proposed to comprise ground floor active uses with upper floor residential apartments within high quality development framing a central open space area. The design of the central open space will facilitate passive recreational opportunities as well as serve as a gathering space for community events.

The design of the Development Plan appropriately integrates the cemetery site through new road frontages to the southern and eastern boundaries of the cemetery. These new roads can facilitate new access points into the cemetery or allow for residential development to extend into the cemetery site should it be considered suitable in the future.

Community Design

The Development Plan will facilitate the provision of a sustainable, coherent and attractive neighbourhood offering a wide choice of housing, local identity and sense of place, a range of recreational opportunities, and promote local self-containment.

The Plan will also facilitate sustainable urban development through the north-south orientation of street blocks, maximising the potential for climate responsive lot design and local employment opportunities through the provision of a local centre which will provide for some local convenience and business needs. Climate responsive design principles will also be incorporated into detailed area plans developed in the future and which will promote energy efficient built form.

The Plan provides for a range of accommodation and living options through the provision of a diverse mix of residential densities and housing types. Areas of higher density residential development potentially incorporating apartments within low rise development have been located around high amenity areas including the local centre and parklands.

The Plan will provide for a sense of place and local identity by responding to the site's context and characteristics, protecting key natural and cultural assets. The urban form facilitates views towards the Karratha Hills as well as towards the Burrup Peninsula with public open space areas located to act as focal points within the development.

Legibility and sense of place is also provided via an integrated movement network comprising a clear street hierarchy and shared path network which will facilitate safe and efficient movement for pedestrians, cyclists and vehicles. The design of the movement network ensures good internal connectivity and external linkages to the surrounding area.

The design effectively integrates the neighbouring residential neighbourhood of Baynton West through a movement network and urban form which promotes a coherent and integrated urban structure.

POPULATION AND RESIDENTIAL DENSITIES

The Development Plan provides for a diversity of residential living options within residential development ranging in density from R20 to R-AC2. The distribution of residential density has been based on the provision of higher densities around the local centre and overlooking high amenity public open space areas.

The range of residential densities will assist with meeting current and future market demand for residential housing. Approximately 24% and potentially up to 33% of the Development Plan is identified for development at the R20 density code which is generally consistent with existing residential densities within Karratha. A further 19% of the Plan is identified for development at low to medium densities (R25, R30) with up to 11% of the plan identified for higher densities (R60, R-AC2). Lots identified for low and medium densities (R20, R25 and R30) are envisaged to be developed as single residential dwellings, facilitating a range of lot sizes to cater for large family homes and smaller more compact homes. Land subject to the higher density codings (R60 and R-AC2) are envisaged to comprise predominantly multiple dwelling developments facilitating apartment style residential living for single persons or couple households.

To provide flexibility in the provision of housing to respond to market demand, several areas within the Development Plan have a split residential coding in which a higher residential density (R60) may be permitted. The Development Plan incorporates provisions in which development at the higher density is only permitted on land which is a minimum of 2,500m² in area or comprises an entire street block. Notwithstanding this, any development at the higher density will still be limited to 2 storeys, ensuring it is consistent with that of adjacent development developed at a lower density.

The Development Plan also allows for the possible development of a Transient Workers Accommodation (TWA) to the north-west portion of the site abutting Madigan Road adjacent to the existing Pluto worker's camp. The Development Plan includes provisions which require the design and development of TWA's such that internal lot layout, road networks and housing are developed to typical residential standards to ensure consistency and integration with surrounding residential development as well as to enable the land to adapt to residential use over time should the need for a TWA cease.

Tables 3 and 4 below summarise the estimated development yields and population generated under the Development Plan.

Table 3: Development Areas Summary

Land Use	Land Area (hectares)	Percentage of Development Plan
Residential		
Residential R20	16.1446ha	23.8%
Residential R20/R60	6.3004	9.3%
Residential R25	1.4054	2.1%
Residential R25/R60	8.1305	12%
Residential R30	2.3646	3.5%
Residential R30/R60	0.4097	0.6%
Residential R60	2.6184	3.9%
Residential R-AC2	2.6854	4.0%
Mixed Use Commercial Retail	1.6056	2.4%
Public Open Space	3.4742	5.1%
Drainage	3.2349	4.8%
Road	19.353	28.5%
TOTAL	**67.7267**	**100%**

Table 4: Estimated Dwelling Yield and Population

Residential Type	Estimated No. Dwellings (based on the lower density for the split density code)	Estimated Population[1] (based on the lower density for the split density code)
Residential R20	448 dwellings	1120 persons
Residential R25	238 dwellings	595 persons
Residential R30*	83 dwellings	207 persons
Residential R60**	157 dwellings	392 persons
Residential R-AC2***	343 dwellings	857 persons
TOTAL	**1269 dwellings**	**3171 persons**

1 *Based on an average household size for a normalised Australian city of "2.5 persons" (KCNP Summary, p34).*

* *Assuming an average density of 333m² per dwelling - [R30]*

** *Assuming an average density of 167m² per dwelling - [R60]*

*** *Assuming an average density of 125m² per dwelling - [R80]*

MOVEMENT NETWORK

Proposed Street Network

The Development Plan provides for an interconnected street network that facilitates safe and efficient internal connectivity and access to the surrounding area for vehicles, cyclists and pedestrians. The design of the street network provides clear physical distinctions between neighbourhood roads and local roads, ensuring a high level of legibility and robustness.

The street network is characterised by three neighbourhood roads which form the backbone to the design and serve as the main access points to the proposed development. A north-south neighbourhood road is proposed through the site and which connects with Dampier Road. Two east-west neighbourhood roads are proposed through the site providing connections with Madigan Road and the Baynton West residential area, facilitating access and connectivity to the Baynton West primary school and community facilities, as well as promoting community cohesiveness. An additional access road is proposed to the Baynton West residential area at the northern end of the development.

Several local access roads connect to these neighbourhood roads servicing the proposed development with laneways providing access to smaller lots fronting open space areas. The layout of the road system ensures that development will front all streets and public open space areas.

The design of streets incorporates a number of principles that facilitate pedestrian safety, efficiency of vehicular/cycle/pedestrian movement and sustainable urban stormwater management in an attractive environment.

Specifically, the proposed street network hierarchy comprises the following:

- Neighbourhood Road (Local Centre) – 20.5m reserve designed as a low speed pedestrian oriented environment comprising of a 7.0m wide pavement (no central median), and a 1.5m cycle lane, 2.3m embayed parking and a 2.95m hard landscaped verge (and incorporating servicing) to either side;
- Neighbourhood Road (Non-Local Centre) – 20.5m reserve incorporating a 2.0m central landscaped median, and a 3.75m wide pavement, 2.5m embayed parking and 3.0m verge (comprising a pedestrian path and servicing) to either side. Where this road type abuts open space/drainage areas, the reserve width can be reduced to 17.5m where the pedestrian path is located within the open space;
- Access Road 'A' – 16.0m reserve incorporating a 6.0m pavement, and a 5.0m verge to either side comprising 2.3m embayed parking, and 2.7m for a pedestrian path and servicing;
- Access Road 'B' – 15.0m reserve incorporating a 6.0m pavement, and a 4.5m verge to either side comprising 2.3m embayed parking, and 2.2m for a pedestrian path and servicing. Where this road type abuts open space/drainage areas, the verge adjacent to the open space can be reduced by 1.2m (comprising the pedestrian path) with the path located within the open space;
- Access Road 'C' – 12.0m reserve incorporating a 2.7m hard landscaped verge abutting the rear of park-fronted lots (incorporating servicing), a 6.0m pavement, 2.3m embayed parking and a 1.0m pedestrian path to the opposite side;
- Laneway – 6.0m reserve incorporating a 6.0m pavement. The rear of lots will be truncated as required to incorporate electrical servicing domes.

The proposed street hierarchy is described in Figure 11.

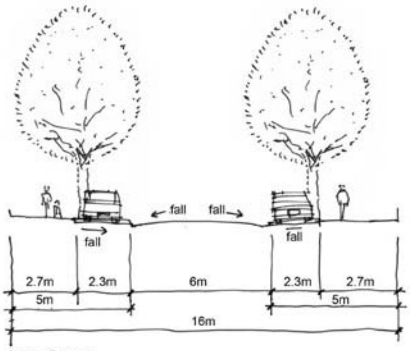
REFER TO FIGURE 11 - PROPOSED ROAD HIERARCHY PLAN

Indicative street cross sections for the above road types have been provided in Figure 12.

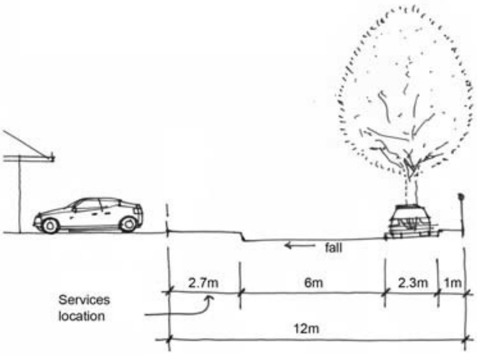
REFER TO FIGURE 12 - INDICATIVE STREET CROSS SECTIONS.

Figure 11 - Proposed Road Hierarchy Plan

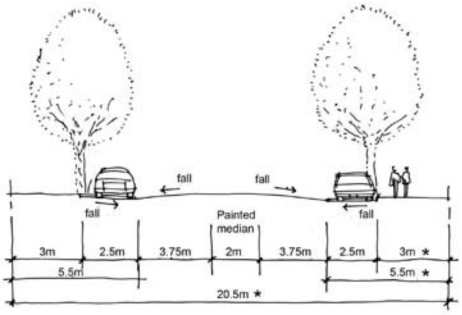
Figure 12 – Indicative Street Cross Sections



16m Street

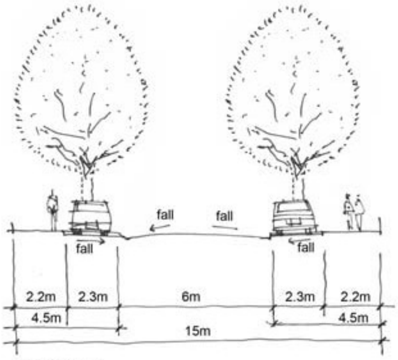


12m Access Lane Street

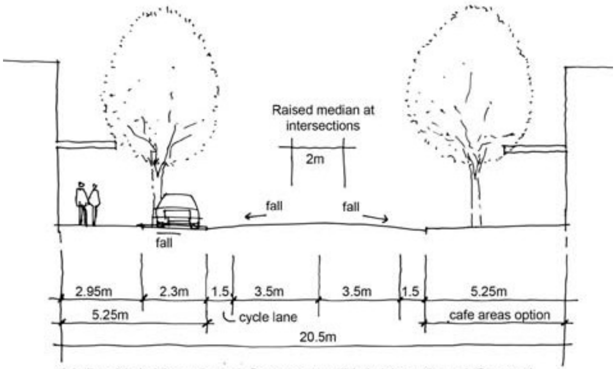


20.5m Neighbourhood Connector (Non Centre)
Painted median becomes raised median at intersections
On-street parking removed at intersections

* Verge may be removed, road reserve reduced to 17.5m and fall redirected where street is against a linier park.



15m Street



20.5m Neighbourhood Connector (Neighbourhood Centre)
On-street parking removed at intersections

Access and Preliminary Traffic Modelling

The provision of safe and equitable access for all users has been a key consideration in the development of the movement network. The interconnected grid movement network promotes clarity, permeability and ease of access to enable intuitive movement for all users throughout the Development Plan area. Integration of drainage corridors with the movement network and public open space provide high amenity landscape links with opportunities to strengthen pedestrian and cycling networks.

In order to investigate access options for the Madigan Road site Development Plan Transcore's EMME3 traffic model developed for the Gap Ridge Industrial project and further developed and expanded for the Karratha Revitalisation Project were sourced. Also, additional preliminary desktop modelling and analysis were undertaken for each stage of the Development Plan development.

The LSP access system and internal road network coded in the EMME3 model are described as following:

The main access point of the Development Plan is proposed to be on Madigan Road. According to the information obtained from Main Roads WA the minimum required distance for the intersection spacing between the main access intersection on Madigan Road and Pluto site access intersection should be about 300m in the interim scenario (Before the construction of the Madigan Road Bypass). In the ultimate scenario, when Madigan Road bypass is constructed the intersection spacing can be reduced to approximately 110m. On this basis the main access intersection on Madigan Road is planned at approximately 300m south of Pluto access intersection on Madigan Road.

Along Madigan Road, in addition to the main access point intersection another access intersection is proposed towards the southern section of the Development Plan. It is also proposed that a service road will be constructed parallel to Madigan Road to serve the western lots of the Development Plan fronting Madigan Road. This service road will be constructed from the southern boundary of the cemetery via a left turn slip lane to immediately north of the local centre without connecting back to Madigan Road. Main Roads does not currently support a service road within the Madigan Road reserve or an exit from the service road to Madigan Road. Once the Madigan Road by-pass is in place this option could be revisited.

In order to ensure good permeability of the Development Plan area and to reduce traffic impacts onto Baynton West subdivision and the intersection of Dampier Road/Madigan Road a restricted (left in/ left out) access intersection is also proposed on Dampier Road. This restricted access point is proposed to be located approximately 300m east of the intersection of Madigan Road/ Dampier Road.

The access system for the Development Plan area has been discussed with Main Roads WA, which has approved the access system "in principle".

In addition to the external access system, the Development Plan also makes provisions for three link roads connecting to Baynton West subdivision to improve connectivity and permeability.

Figure 13 illustrates the projected daily traffic volumes on the internal and external roads in accordance with the modelling of the ultimate development of the Development Plan (average 1,100 residential lots with a retail area of approximately 500m2 NLA and commercial area of about 500m2 GFA). It should be noted that the boundary road traffic projection shown in Figure 13 are the ultimate traffic projections including full development of the Karratha Revitalisation project.

Refer to Figure 13 - Projected Daily Traffic Volumes for the Ultimate Scenario

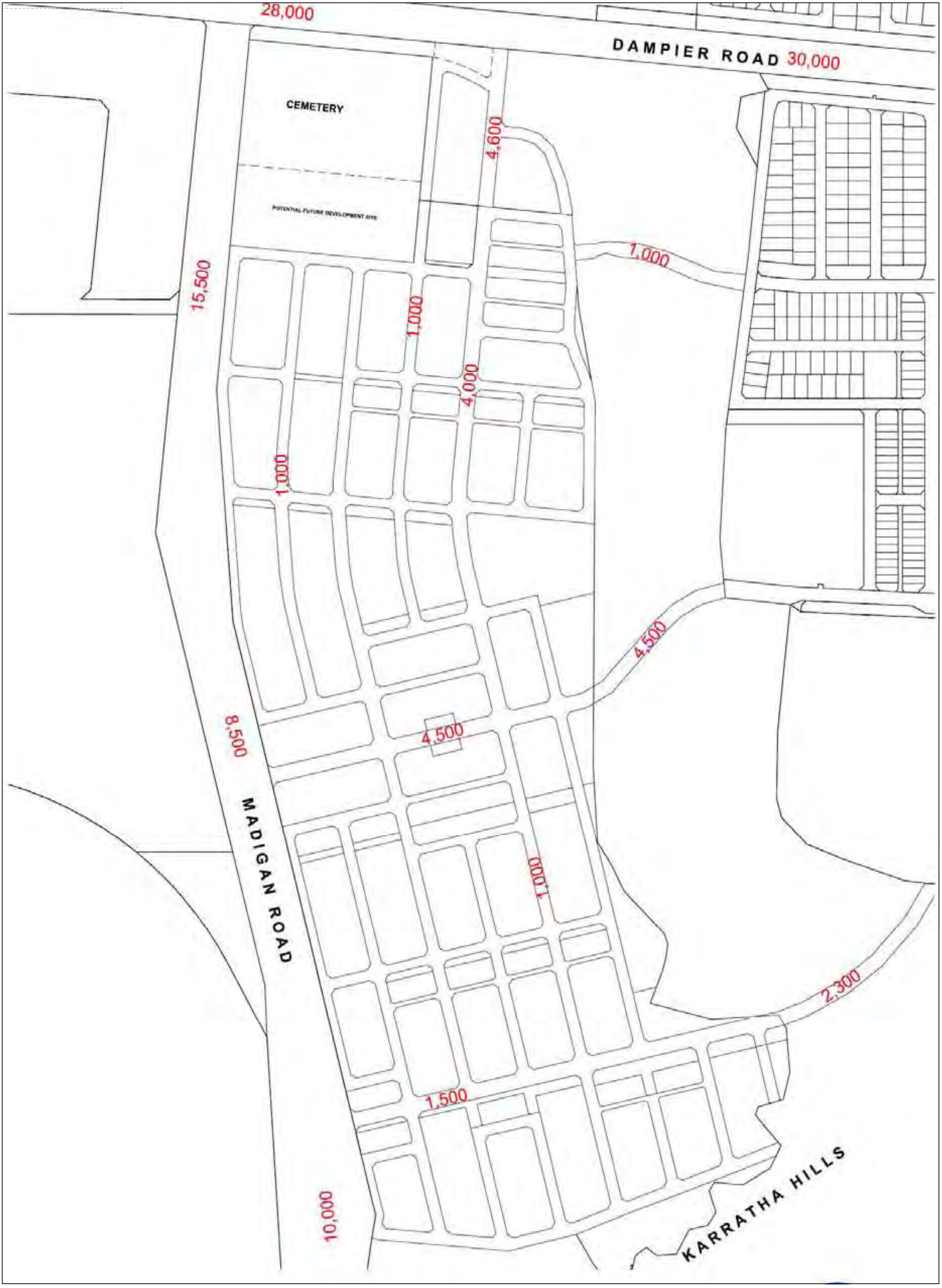
Intersection Analysis

SIDRA intersection analysis was undertaken to assess the performance of the main access intersection on Madigan Road during the interim and ultimate stages of the development. Intersection analysis indicate that the main access intersection will work satisfactorily and within capacity during the interim and ultimate stages of the development, with level of service C for the right turn traffic out of the development into Madigan Road (critical movement). This analysis assumes left and right turn pockets on Madigan Road and separate left and right turn lanes on the Development Plan access road at this intersection for both interim and ultimate scenarios.

The provision of right and left turn pockets on Madigan Road (approximately 100m including taper) is to maximise safety and satisfy Austroads requirements based on the current speed and environment. These could be reviewed at a later date, particularly after the construction of the bypass.

The southern access intersection on Madigan Road would carry less traffic volume and therefore it is expected that with the same treatment as the main access intersection (with left and right turn pockets on Madigan Road) it would operate satisfactorily and within capacity.

Figure 13 - Projected Daily Traffic Volumes for the Ultimate Scenario



Intersection Treatments

Based on the projected traffic volumes and the proposed road hierarchy, the suggested intersection treatments for the Development Plan are shown on Figure 14.

Roundabouts are recommended for the intersections adjacent to the local centre and also major intersections within the Development Plan area. These roundabouts will provide for effective circulation and the control of speed along the major roads.

There are several 4-way intersections within the Development Plan area that don't warrant the provision of the roundabouts. For these intersections suitable threshold treatments (such as raised red asphalt) are recommended on the minor roads as shown in Figure 14. Other traffic calming devices are also proposed to control speed along reasonably long stretches of roads.

The access point intersections on Madigan Road are proposed to operate as priority T-Intersections with left and right turn pockets on Madigan Road for the interim and ultimate scenarios.

The Dampier Road left out/left in intersection is proposed to entail a left turn pocket to improve safety and minimise impact on the traffic flow on Dampier Road.

REFER TO FIGURE 14 - PROPOSED INTERSECTION TREATMENTS

Pedestrian and Cyclist Network

The Shire of Roebourne has an objective to improve pedestrian and cyclist facilities within Karratha and as part of new subdivisions and developments. The Madigan Road site Development Plan aims to integrate its internal pedestrian and cycle network system with the neighbouring Baynton West subdivision to form a comprehensive path network. Also, shared paths are proposed along the boundary roads to complete the integration process.

Figure 15 illustrates the proposed cycle and footpath network for the Development Plan. Footpaths are proposed on all roads with shared paths and at least on one side of all other roads.

Streets have been designed to formalise and maximise on street parking and allow for tree planting. The formalisation of parking should limit any parking across footpaths and on street parking and tree planting should assist with traffic calming and improved comfort for pedestrians.

REFER TO FIGURE 15 - PROPOSED DEVELOPMENT PLAN PEDESTRIAN AND CYCLIST NETWORK

FIGURE 14 - PROPOSED INTERSECTION TREATMENTS

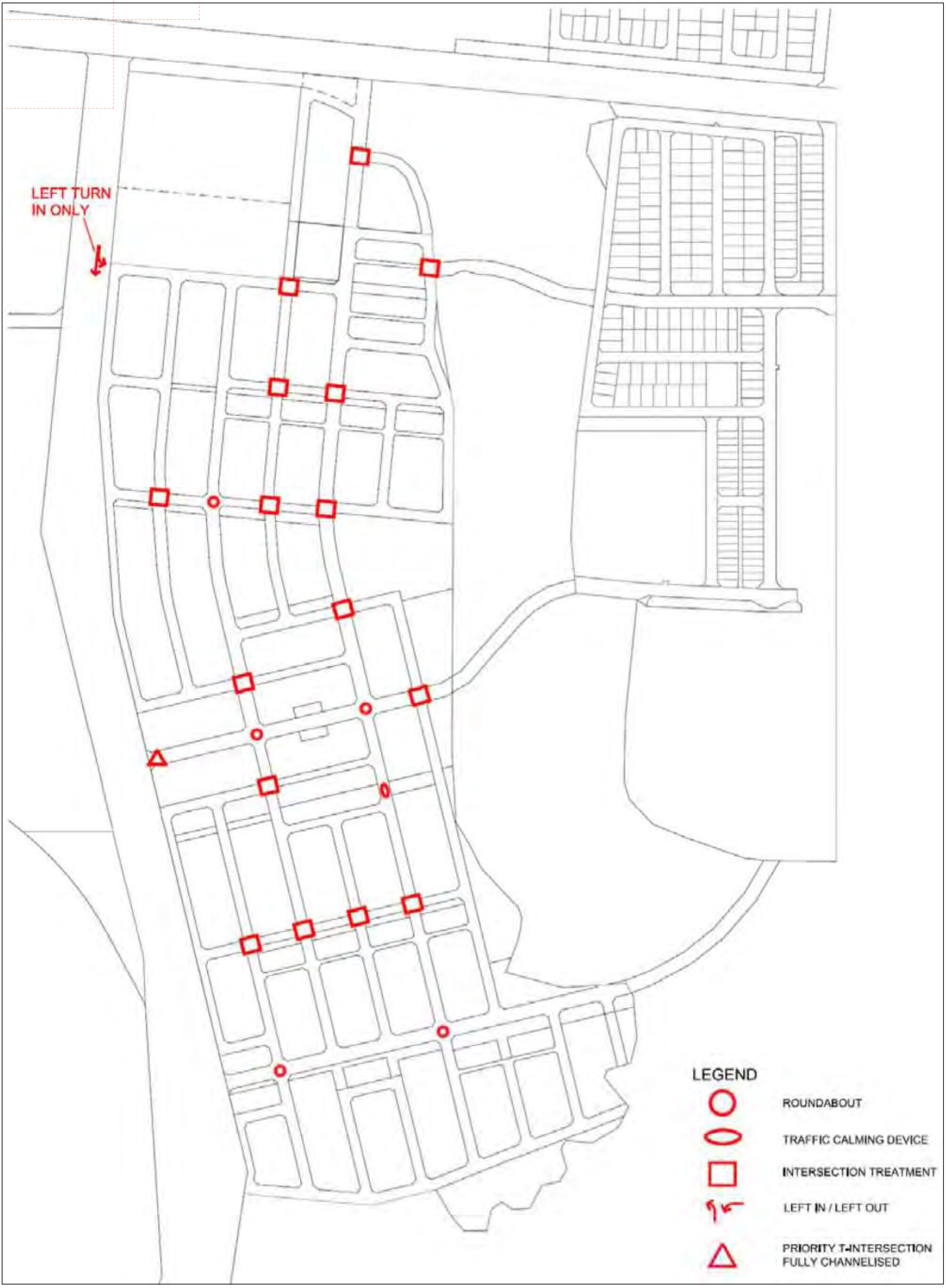


Figure 15 - Proposed Development Plan Pedestrian and Cyclist Network

Public Transport

The CGP document identifies a public transport route through the site, connecting Madigan Road with Baynton West. Whilst a public transport is a medium to long-term vision for Karratha, the design of the 'Main Street' road link, which connects Baynton West with Madigan Road, will facilitate opportunities for the provision of a public transport service when such services become available in the future.

LOT LAYOUT & TYPOLOGY

The Development Plan provides diverse residential lot types and sizes to cater for a range of household types and lifestyles. Generally lot types have been distributed based on providing higher densities around the local centre and high amenity public open space areas.

The design of the Development Plan ensures lots will front onto and overlook public realm areas facilitating a high level of passive surveillance and assist in creating a safe and attractive pedestrian oriented urban environment. Lots fronting open space and drainage areas are generally serviced via rear laneways, however where rear access is not provided for park fronted lots, it is envisaged that the overlooking of open space areas shall be achieved through the creation of battleaxe lots accessed from side roads.

Generally each street block is provided with a minimum depth of 65 metres to provide a minimum lot depth of 32.5 metres. The lower density single residential lots then vary on the allocated density to provide diverse residential lot types and sizes to cater for a range of household types and lifestyles. The following table identifies the lot configurations envisaged under each density code for single residential lot development.

Table 5: Proposed Single Residential Lot Configurations

Density	Lot Width	Area
R20	15-18m	485m²-585m²
R25	13m	422m²
R30	11m	325m²

The lot depth and width configurations described above have been identified so as to ensure the development of single residential housing will adequately cater for house designs with due consideration for the provision of garaging and access (including visitor parking on driveways) and boat storage.

The following table summarises the potential lot yield that may be generated under the Development Plan. In the case of split coded sites, the potential lot yield has been calculated based on development at the lower density (as development at the higher density (R60) is presumed to be multiple dwelling development contained on a single strata titled lot). Land parcels coded R60 and R-AC2 have been assumed as individual lots.

Table 6: Proposed Single Residential Lot Configurations

Density	Lot Type	Potential Number of Lots
R20	Single dwelling	448 Lots
R25	Single dwelling	272 Lots
R30	Single dwelling	92 Lots
R60	Multiple dwelling	4 Lots
R-AC2	Multiple dwelling	5 Lots
Total Lot Yield		821 Lots

Climate Responsive Design

The design and development of the Development Plan has been significantly influenced by the findings contained within LandCorp's Draft Climate Responsive Design Policy for the North-West of Western Australia. The Draft Policy aims to:

- Reduce the need for mechanised, energy dependent air-conditioning devices;
- Sustain and increase thermal comfort for occupants;
- Maximise liveability through access to natural light, natural ventilation and natural climate control; and
- Preserve and enhance the relationship between internal and external living areas.

Several principles contained within the document have been incorporated into the design and development of the plan with particular consideration given to ensure a good site responsive lot orientation is achieved.

The north-south orientation of the street network allows for predominantly east-west oriented lots which can facilitate house designs that capture Karratha's cooling breezes from the west, north-west in the summer evenings and the east, north-east winter breezes.

In addition to good lot orientation, several other climate responsive design principles are envisaged to be incorporated within design guidelines and detailed area plans to guide new development. These include the provision of appropriate setbacks and the location of outdoor spaces to assist with capturing breezes and cross ventilation of dwellings and the provision of adequate shading through elements such as eaves and landscaping treatments.

The range of residential densities and housing types will facilitate a diverse mix of accommodation and living options. Indicative housing types are presented in Figure 16 demonstrating key design principles envisaged for the various lot types under the Development Plan.

Refer To Figure 16 - Indicative Housing Types

PUBLIC PARKLAND

The provision of parkland within the development has been informed by the CGP and driven by the principles within the CGP and Liveable Neighbourhoods. The design of the plan recognises the floodway to the east and the Karratha Hills to the south will be protected as regional open space whilst district play fields are proposed to the west under the CGP. The amenity afforded by these areas has been captured and integrated into the development through the creation of a street and open space network that link directly to these spaces.

The public open space within the development is arranged to complement these areas of open space whilst providing easy pedestrian access to open space across the community. The park and drainage open space corridors form a linear park system that will create a network of paths linking areas of activity. These paths will also provide an outlook for a wide variety of development types and lifestyles.

The public open space areas within the development will be landscaped to provide for an appropriate mix of active and passive recreational opportunities within easy reach of residents and available for day and night use. Drainage swales through these will be landscaped to provide visual interest whilst conveying water during storm events.

The landscape approach to development of parks will be to provide a low water use, low maintenance and management environment that will accommodate passive and more formalised active recreation within a self sustaining vegetation structure.

Open Space and Public Open Space Contribution

The Development Plan proposes a range of multi-functional open space areas, comprising 6.7076ha of the site, representing 10.1% of the site. The open space areas comprise a combination of landscaped parklands and open space corridors, which together provide for a connected network of open space through the development.

Parklands

The parklands have been designed and located to act as focal points within the development, enhancing local identity and sense of place. These areas (some of which include a small drainage function which once then deducted from the POS calculations) comprise:

- A parkland of approximately 750m² situated to the north-east of the development abutting the open space reservation to the east to act as a buffer to an archeological site;
- A large parkland of approximately 1.6ha situated to the east of the local centre and abutting the open space corridor to the east of the site;
- A centrally located parkland of approximately 4015m² situated to the south of the local centre;
- A parkland of approximately 1.4338ha situated to the south-east of the development and abutting the open space corridor to the east of the site; and
- A centrally located parkland of approximately 3328m² situated at the foot of the Karratha Hills.

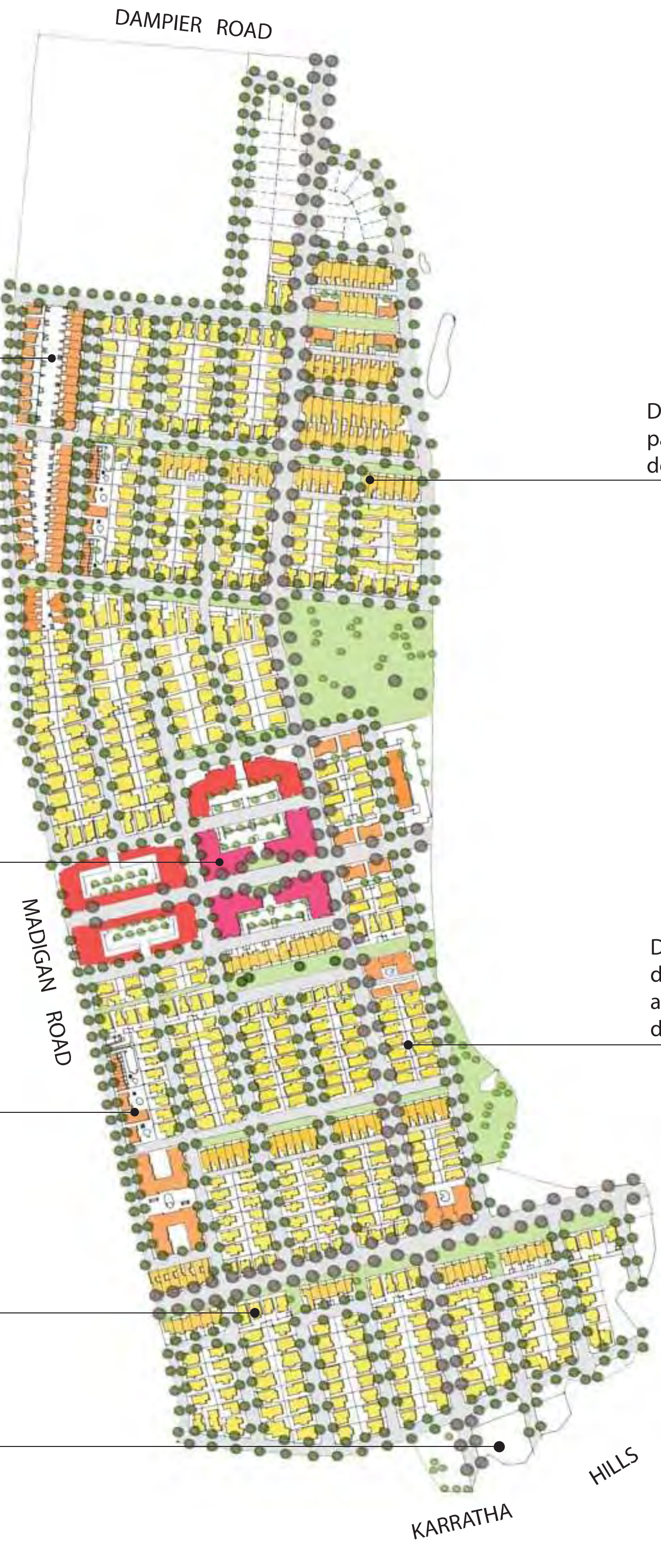
The parklands represent a total of 6.7076ha or 10.1% of the gross subdivisible area. Allowing for 3.2349ha of land for overland drainage paths, the amount of public open space within these parklands comprises 3.4727ha or 5.4% of the gross subdivisible area. Thus the development complies with requirements of Liveable Neighbourhoods in terms of the permitted regional variation of a minimum of 5% unconstrained open space.

It is noted that these parklands include the archeological sites and their associated buffers, however as the actual land area of these sites is relatively small, they will not reduce the total unencumbered space below 5% of the gross subdivisible area.

Open Space Corridors

The various open space corridors throughout the development have been strategically located to provide visual connections to the parklands. These areas will be landscaped and facilitate pedestrian movement through the area in addition to facilitating the conveyance of stormwater through the site. These open space corridors will incorporate best practice urban water management principles in accordance with Liveable Neighbourhoods.

The open space corridors, together with land specifically set aside for overland drainage paths purposes within them, comprise a total of 3.2349ha, or 4.8% of the gross subdivisible area. Given the shallow depth (500mm) of these drainage areas it is anticipated that they will provide a passive recreational purpose for the majority of the year when they will be dry.



DAPs will ensure a good outcome if special forms of development are proposed (e.g: shared central access and storage areas)

DAPs will ensure frontage to parkland corridor in medium density areas

DAPs will ensure good street frontage in R-AC2 areas

DAPs will ensure split code development is not developed as survey strata with villas down shared driveways

DAPs will require noise attenuation or non noise sensitive uses if Madigan Road is not quietened

DAPs will ensure frontage to parkland corridor in low density areas

DAPs will ensure sensitive design in future development at the base of the Karratha Hills

LEGEND

- 🟥 Multi storey mixed use pedestrian oriented 'Main Street' development
- 🟥 Multi storey mixed use development
- 🟧 Multi storey residential apartments / attached housing
- 🟨 Rear lane serviced townhouses
- 🟨 Single detached housing

* Location and type of development may vary within parameters set by zoning and built form regulations

N

INDICATIVE LOT TYPOLOGY PLAN
LOT 500 MADIGAN ROAD, BAYNTON
LANDCORP

Date: 10 March 2011
Designer: DR
Scale: NTS @ A3
Drawn: PR
Drawing No. 710-200 PL11C IDP 100311.pdf

TOWN PLANNING
AND URBAN DESIGN

Level 7, 182 St Georges Terrace
Perth Western Australia 6000

PO Box 7375 Cloisters Square
Perth Western Australia 6850

Telephone +61 08 9289 8300
Facsimile +61 08 9321 4786
www.tpgwa.com.au

The Planning Group WA Pty Ltd
ABN 36 097 273 222

Public Open Space Provision

The total open space provided under the Development Plan (i.e: land set aside as parklands and open space corridors) comprises 10.1% of the developable area of which, the actual Public Open Space contribution (as per the requirements of Element 4, R34 of Liveable Neighbourhoods) comprises 5.4%. The following table summarises the open space contribution for the site.

Table 7: Schedule of Public Open Space Contributions

Public Open Space Schedule	Ha	Ha
Site Area		67.7267
Deductions		
Drainage	3.2349	
Total		64.4918
Gross Subdivision Area		64.4918
Public Open Space @ 5% (as per Element 4, R34)		3.2246
Total Public Open Space Provided		3.4727
Percentage of Gross Subdivisional Area		5.4%

Public open space within the Development Plan is in accordance with Element 4, R34 of Liveable Neighbourhoods which allows for a minimum public open space contribution of 5% of the gross subdivisible area for regional areas subject to:

- The public open space being designed, developed and located for the widest possible use of the community, readily available for day and night use and developed to a minimum standard (full earthworks, reticulation etc) in accordance with a landscaping plan;
- Adequate areas provided elsewhere for drainage and flooding; and
- The public open space does not contain any restricted uses.

The public open space contribution provided under the Development Plan meets these requirements for the following reasons:

- The total public open space contribution comprises 5.4% of the gross subdivisible area;
- At least 5.0% of the public open space contribution is unencumbered by drainage and/or areas of land for flooding, which have been provided elsewhere as additional open space areas within the development; and
- The public open space contains archeological sites which restrict uses but still greater than 5% unencumbered POS area is provided. The POS will be designed and developed to a high standard for the widest possible use of the community.

Whilst the Development Plan provides other 5.0% of unencumbered public open space, it is noted that portions of public open space adjacent to (or within) future stages may be expanded upon as part of future detailed planning following consideration and determination of Scheme Amendment No. 21 which will dramatically increase this percentage.

Landscaping Strategy

The landscape approach to the development of parklands will be to provide a low water use and a low maintenance and management environment that will accommodate passive and more formalised active recreation within a self sustaining vegetation structure.

Objectives for the new landscape:

- Create a liveable place;
- Create a sustainable lasting landscape (principal issues - water and management);
- Create new diverse urban landscapes that reinforce sub neighbourhood characteristics;
- Retain vegetation wherever practical; and
- Promote the use of native, low water demanding plants.
- Strategies for the new landscape:
- Establish landscape corridors, links and greenways;
- Establish primary landscape character areas;
- Establish primary infrastructure and development levels that maximise the potential retention of vegetation;
- Pursue water harvesting, passive irrigation and integrated urban irrigation;
- Use of natives as a dominant species in Public Open Space and public realm infrastructure; and
- Minimise and discourage irrigated lawns and thirsty exotics.

The Landscape Approach

The development of the site will be a community living within a potentially harsh natural setting. The planning and design approach to landscaping will be to create an "enhanced natural" character of the site providing shade and "softening" vegetation throughout the area. The area will have distinctive landscape character sub-precincts created by street tree planting and the parks. The linear park system that incorporates the drainage links will be designed as an extension of the natural ephemeral flood route to the east of the site.

The approach to landscaping falls into two broad categories, "Open space" and "Streetscapes". The open spaces will form the dominant feature of the community with parks designed to provide recreational space and facilities within a strong vegetation structure. The streetscapes will present a different character and will include some drought tolerant non local tree planting in key locations as a highlight. The street planting will consist of individual plantings combined with groups of trees with shrub vegetation to side of end lots for wind reduction and aesthetics.

Public Open Space – the Parks

The public open spaces are arranged to ensure all of the community has easy and direct access to parks. The linear park system accommodates a series of walks and cycle routes that link to provide diverse recreational routes and circuit walks throughout the community by providing paths along the drainage routes and streets connecting to parks.

The landscape design for the open spaces will adopt a landscape strategy of "Strings, Beads and Settings" to the provision of public open space (refer to Figure 17).

REFER TO FIGURE 17 – "STRINGS, BEADS, SETTING"

- Strings being maintained movement routes;
- Beads, the intensively developed sites; and
- Setting, the native vegetation providing overall structuring element.

This approach limits maintenance and management while providing an achievable aesthetic that will provide attractive spaces throughout the community.

This strategy will deliver a maintainable, manageable, quality landscape that focuses maintenance and water requirements to key areas, creating an environmentally responsible landscape.

Strings:

The maintained corridors will be paths and trails that ensure that residents have a safe series of recreational and destination routes. The linking of natural parkland will be well observed from adjacent housing that will afford a high level of natural surveillance. The strings will create "cool corridors" – shade walks with NLAdes around the community. The character of these linear spaces will draw on the native bush but will be presented with contemporary detailing of incidental seating areas and structures and the presentation of native vegetation in a bold and dramatic way. Linear features such as ephemeral streams will lead linear park users from one area to the next. Such features accept and celebrate the seasonal landscape changes. The plan provides a series of linking linear spaces that will be developed as extensions of the existing floodway, creating shady corridors that carry informal walking and cycling routes around the community, linking other park activity spaces.

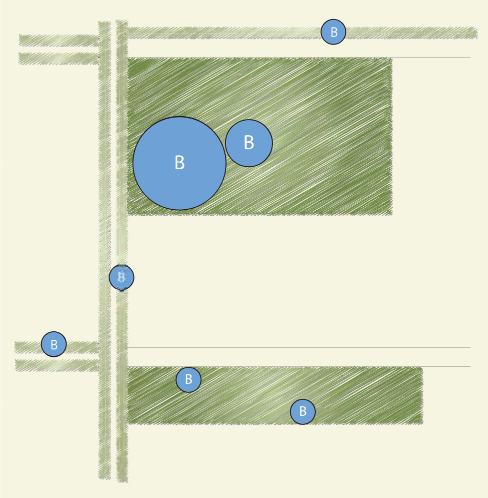


FIGURE 17 – "STRINGS, BEADS, SETTING"

Beads:

The beads are nodes of maintained and developed parkland providing destinations and local facilities. The specific facilities will be determined with the local authority but they will range from local play areas and activity areas to more active open kick-a-bout areas and will incorporate furniture such as seating and shade structures. The parklands may incorporate limited areas of usable managed lawns and introduced species that accept the conditions but are not locally native.

Setting:

The major component of the open space network will be the setting, which will create the dominant landscape of the community. The setting will comprise new areas of recreated native landscapes that are planned and designed to provide a quality aesthetic. The setting will be low maintenance, with the more intensive maintenance and irrigation being focused only on the strings and beads. The landscape will create a strong visual and physical indigenous landscape that uses native plants and local materials counterbalanced with contemporary design and a bold use of colours drawn from the inherent colour palette of the local environment. Wherever practical, drainage will be integrated within the landscape to provide passive irrigation.

The landscape approach recognises the importance of the native vegetation and the value that a strong "enhanced natural" landscape structure creates as a recreational, aesthetic and functional local environment. It is anticipated that the design of these areas will incorporate a natural approach to the ground and utilise stones and gravels as mulches and finished surfacing.

Streetscapes

In addition to the structuring open space landscape, the streetscape of the development areas will play a critical role in defining the neighbourhood identity. The structuring streetscape will also utilise native species augmented in selected locations with Australian natives and in some areas selected exotics.

The plant range will be drawn from species that are tolerant of the local site conditions, and which are low water users.

A diverse streetscape hierarchy is proposed that creates distinctive places ranging from informal street planting to formal avenues of large trees with monocultures of native ground covers. The need to facilitate solar access to selected streets and spaces will dictate species selection. It is intended that each sub neighbourhood within the development has a distinctive character that is created from the relationship to open space and street tree planting.

The landscape treatment of the streets will reinforce the hierarchy of roads. Species, planting types and verge treatments will create a diverse range of experiences and integrate drainage within the landscape.

REFER TO FIGURE 18 – POS LANDSCAPING PLAN

AND

FIGURE 19 AND 19A - INDICATIVE DRAINAGE LANDSCAPING CONCEPTS

Water Harvesting, Passive Irrigation and Integrated Urban Irrigation

A water supply strategy for the new landscape is considered essential as without having a strategy for the delivery of water to the area for landscape purposes, the development will be bound into a non-sustainable approach to the production of the new public realm environment.

All public realm landscapes require water. To ensure that adequate water is available for the establishment and ongoing health of the new urban landscape, two strategic responses are being considered:

- water harvesting and passive irrigation; and
- integrated urban irrigation.

These two engineering approaches will complement the use of native and low water demanding species as the dominant landscape trees in the urban landscape.

Water Harvesting and Passive Irrigation

Within the site, the planning of surface water drainage at the local development plan level incorporates drainage management techniques that facilitate the passive seasonal irrigation of public open space and verges. The management of drainage and infiltration measures should be designed to allow for the passive irrigation of general amenity grass areas and structural landscape planting.

Integrated Urban Irrigation

The development of a coordinated urban irrigation strategy using water that is produced by the urban community is considered essential for this location. The opportunity may exist to reuse waste water on a district level and to plan this in from the beginning. District level urban irrigation utilising a reticulated recycled water supply to public landscapes will be pursued as a strategy. Interim provision of water may be required until an integrated system is achieved.

Figure 18 – POS Landscaping Plan

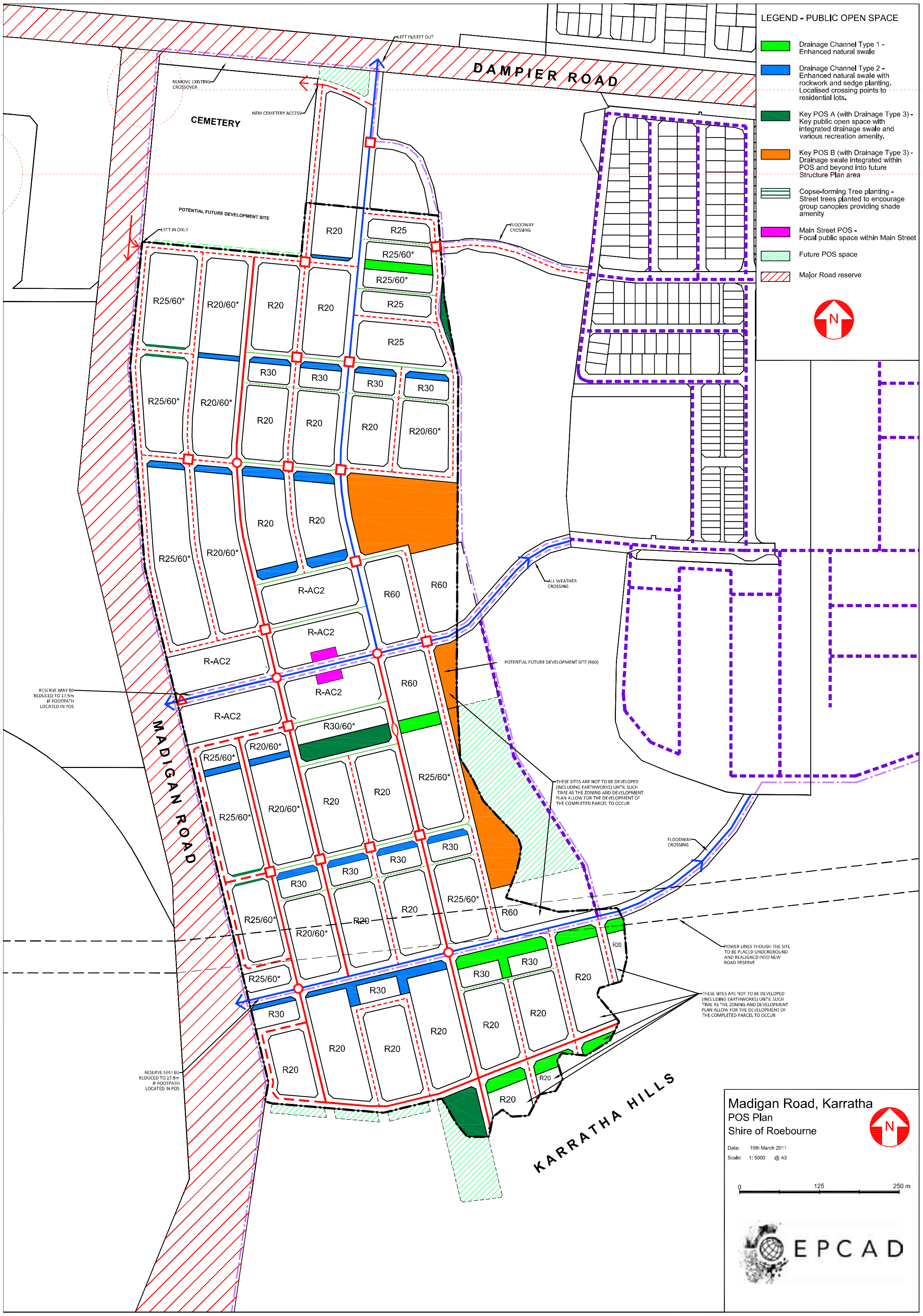
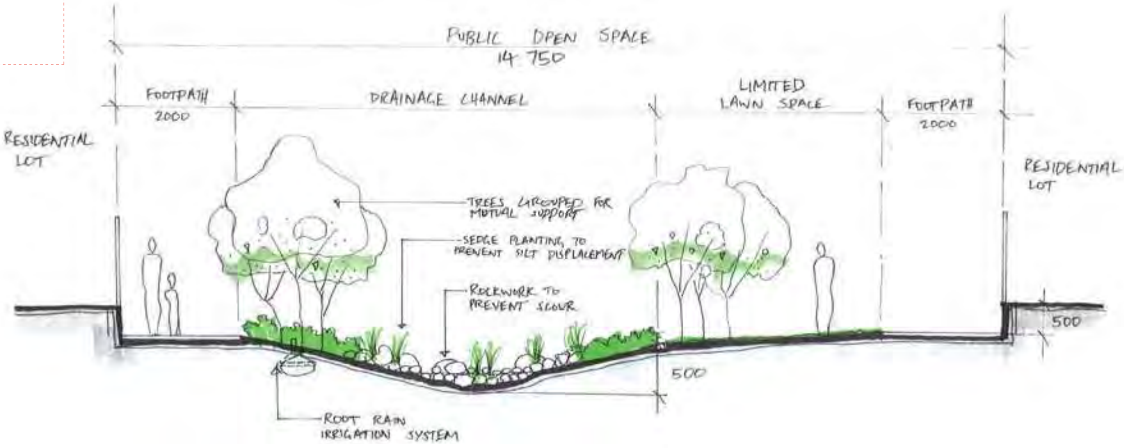


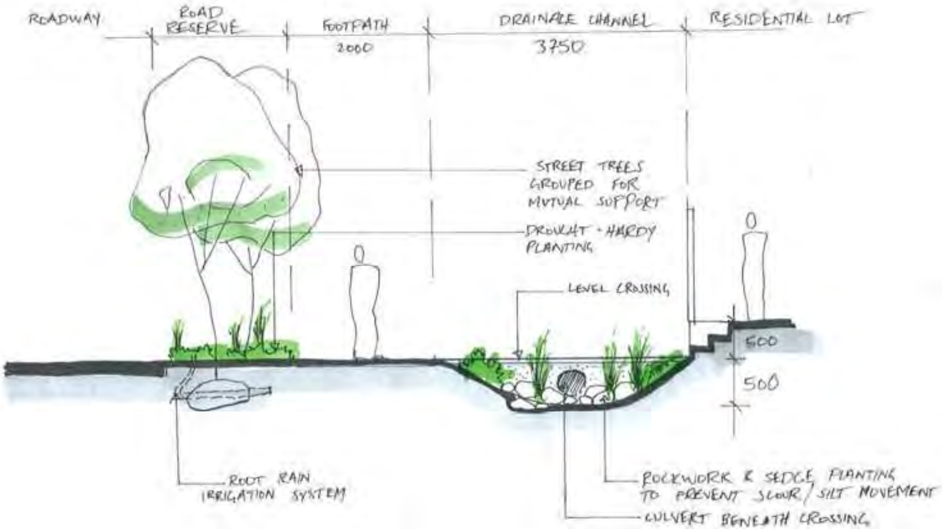
FIGURE 19 - INDICATIVE DRAINAGE LANDSCAPING CONCEPTS



Drainage Channel Type 1
Section AA
Madigan Road, Karratha

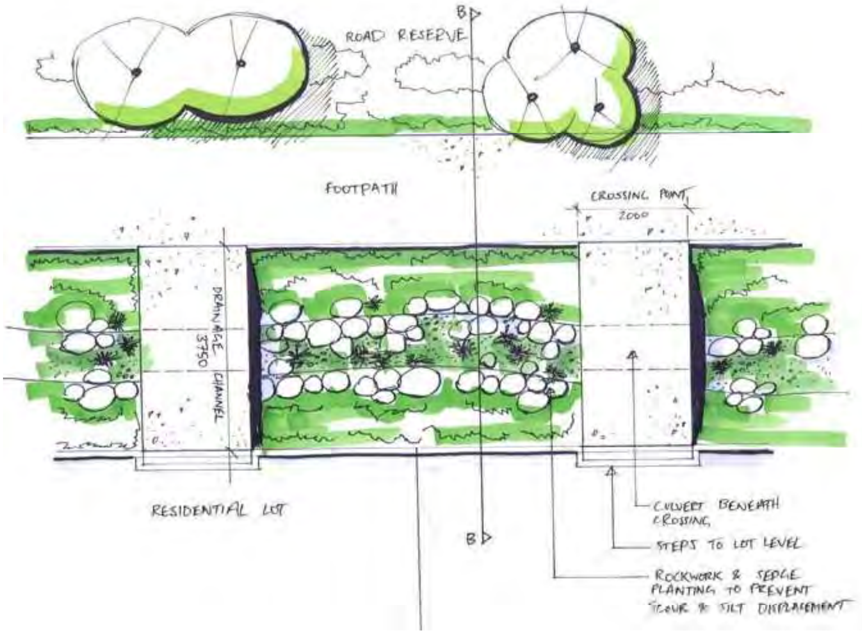
October 2010

EPCAD

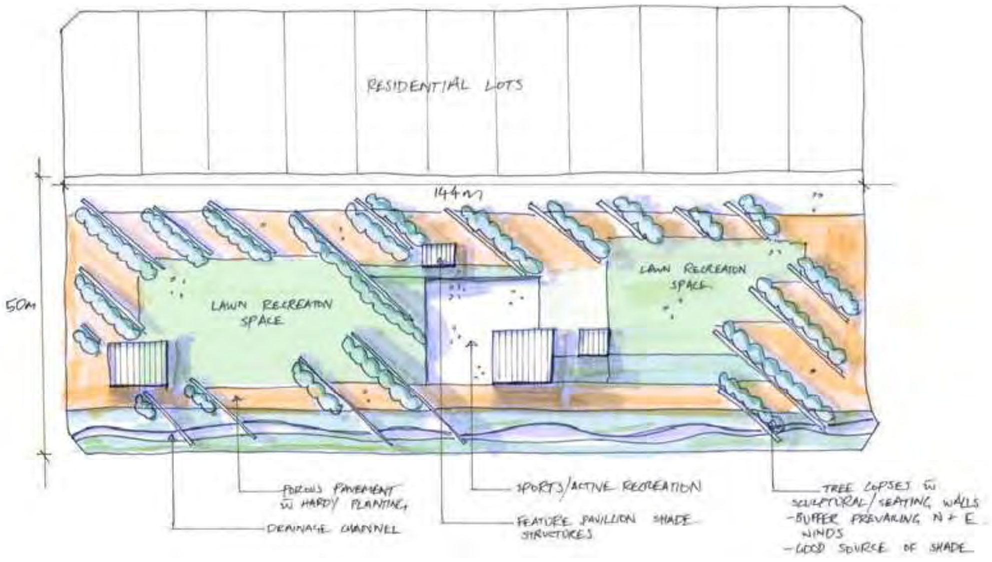


Drainage Channel Type 2

Figure 19A - Indicative Drainage Landscaping Concepts



Drainage Channel Type 2



Drainage Channel Type 3

Natives as a Dominant Species in Public Open Space and Public Realm Infrastructure

It is proposed that low water use native vegetation will form the dominant species in all public realm landscape. Species will not generally be local provenance types as the existing species on site may not be appropriate for the urban situation where shade and stature are characteristics that are sought. Other native but not local species, appropriate to the modified urban environment are capable of creating a sustainable vegetative structure across the site. The dominant native structuring landscape will be contrasted around activity nodes and on key streets with species that are aesthetically contrasting but still capable of establishing in the prevailing environment.

The harsh environment limits the landscaping approach quite significantly. Plants will need to be largely native in order to survive the conditions of the area, and to reduce the need for irrigation.

An Indicative Tree Species List Is Provided In Appendix 4.

Refer to Appendix 4 - Indicative Tree Species

URBAN WATER MANAGEMENT

A detailed Local Water Management Strategy (LWMS) has been prepared by JDA Consultant Hydrologists and attached as Appendix 5.

Refer To Appendix 5 - Local Water Management Strategy & Flood Study.

The LWMS has been developed consistent with the framework and process detailed in the WAPC's Better Urban Water Management guidelines (2008).

The document includes the principles, objectives and requirements of total water cycle management and a detailed description of the environmental conditions of the site. The capacity of the site to sustain development, including consideration of acid sulphate soils, impacts from groundwater and surface water, impacts on ecosystems and biodiversity and impacts on existing infrastructure is also examined.

The following table provides a summary of key elements of the proposed water management strategy for the site, with an assessment of the strategy in relation to DoW (2007) principle objectives for stormwater management in Western Australia (Section 1.2.4).

Table 8: LWMS Key Principles and Elements

Principle	Key LWMS Elements
Water Quantity To maintain the total water cycle balance within development areas relative to the pre-development conditions.	Maintain flow paths for existing catchments. Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels. No lowering of groundwater levels. Maximise infiltration opportunities where possible.
Water Quality To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.	Use of treatment train approach to stormwater management. Application of source controls – including education to reduce nutrient application, use of native plantings and vegetated swales. Application of structural controls – retention/detention areas and vegetated swales.
Water Conservation To maximise the reuse of stormwater.	Encourage implementation of water efficiency and demand management measures both internal and external of buildings. Use of native plantings to minimise irrigation requirements.
Ecosystem Health To retain natural drainage systems and protect ecosystem health.	Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels to the Madigan Creek east of the site.
Economic Viability To implement stormwater systems that are economically viable in the long term.	Use of proven structural Water Sensitive Urban Design (WSUD) technology. Use of source control techniques to minimise cost of nutrient management.
Public Health To minimise the public risk, including risk of injury or loss of life to the community.	Design in accordance with relevant design standards, best management practices, council regulations and government agency requirements.
Protection of Property To protect the built environment from flooding.	Identification of 100yr ARI flood levels for Study Area and ensuring lot levels are above this level. Protection of downstream areas by restricting stormwater discharge to existing levels for storm events up to 100yr ARI.
Social Values To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater.	Use of swales within public areas for stormwater conveyance. Integration of drainage and POS functions.
Development To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability & precautionary principles.	Urban water management in accordance with Better Urban Water Management (WAPC, 2008). Development of the LWMS in accordance with government agency guidelines and best management practice recommendations.

Implementation of the LWMS will be undertaken through the preparation of a detailed Urban Water Management Plan (UWMP) under relevant conditions of subdivision. The UWMP will be submitted by the developer to the Department of Water and the Shire of Roebourne as required and will address:

- Detailed stormwater management design including the size, location and design of swales, integrating major and minor flood management capability, landscape plants for the swales as related to stormwater function, specific details of local geotechnical investigations and their impact on stormwater design;
- Detail measures to reduce velocity of stormwater discharge to prevent erosion and sediment transportation;
- Management of groundwater levels, and if any proposed dewatering is necessary;
- Agreed/approved measures to achieve water conservation and efficiencies of use including sources of water for non-potable uses and detailed designs, controls, management and operation of any proposed system;
- Management of sub-divisional works (management of soil/sediment including dust); and
- Implementation plan including monitoring program, roles, responsibilities, funding and maintenance arrangements. Contingency plans should also be indicated where necessary.

UTILITIES

Water Supply

The Water Corporation provided the following emailed response on 12 May 2010 (and updated 12 October 2010) to Cossill & Webley's enquiry regarding the availability of potable water to facilitate development of the Madigan Road site over say a 5 year period, commencing May 2011.

"Water source and wastewater treatment capacity issues are serious and will need significant funding to address.

The town's water system is rapidly approaching its maximum capacity. There is a limited number of new water services available. The Harding Dam and Millstream water sources are at their limit and the ability to meet projected growth demands in Karratha will depend on a commitment by the state government to fund the investigation and establishment of a new water source/s, which might include a seawater desalination plant.

The Water Corporation has completed a high-level review of water source, storage and trunk network integration.

Previous water distribution planning exists for the town, but this is now outdated and is subject to review. The previous planning indicated the need to extend a DN375 water distribution main westwards along the main highway from Baynton West to serve the Madigan Road site. A review of the detailed water network planning has just recently commenced and is scheduled for completion by March 2011. Among other things this review will decide the size of distribution main to the Madigan Rd site, which is likely to be 375 or possibly larger.

The Corporation is currently making arrangements to bring two existing, disused 9,000m^3 storage tanks back on line (Karratha Tanks No. 1 and No.2 – on the hill to SW of intersection of Karratha Rd and Millstream Rd) and install an associated filling main. This will allow the town to be split into two gravity zones, east and west, and will provide additional storage capacity to meet short term growth demands."

Given the Water Corporation's advice, it is probable that there may be sufficient capacity within the existing water supply system to cope with initial stages of the Madigan Road Project. Furthermore, subject to State Government intervention, it is likely the entire site can be supplied with water if development proceeds in an orderly manner.

Though water supply source is a significant constraint, it is not considered to be a 'fatal flaw' at this point in time. However, the situation clearly needs to be monitored and reviewed again once the Water Corporation's review is released.

Wastewater

The Water Corporation provided the following emailed response on 12 May 2010 (and updated 12 October 2010) to Cossill & Webley's enquiry regarding the capacity of sewer infrastructure in relation to the development of the Madigan Road site over say a 5 year period.

"Water source and wastewater treatment capacity issues are serious and will need significant funding to address.

The site is situated within the catchment of Karratha WWTP No. 2, which is operated by the Water Corporation. This plant has reached its maximum capacity and is not able to accept additional flows. The Water Corporation is currently undertaking a review of wastewater infrastructure planning for Karratha, which includes wastewater treatment and conveyance planning. The high-level wastewater treatment and re-use strategy is soon to be finalised and is likely to be adopted in late November 2010. The wastewater conveyance planning review is still underway and is scheduled to be completed by about the end of this year (mid-December 2010).

This planning will provide clearer direction on conveyance and the timing and funding of major WWTP upgrades.

If the Madigan Road site is to be developed within the next 5 years as indicated, it may require a separate package treatment plant (MBR) to be built on/near the site to deal with wastewater in the short term. The location of the plant and conveyance have not yet been determined. An odour buffer may also be required around the package plant. The plant will need to be funded by the developer. More detailed planning for the Madigan Road site should therefore also address local domestic re-use within the development area."

Whilst the wastewater system in Karratha is clearly at capacity, the Water Corporation's response should be seen as positive in as much as they are willing to entertain the interim use of package treatment plants, which is a departure from standard practice.

However, the Water Corporation's support for such an approach would likely be based upon medium term strategy being put in place to upgrade wastewater infrastructure. This strategy would likely require the State Government to commit funds to facilitate the design and construction of the necessary facilities.

The use and cost of package treatment plants should be further investigated. It may be that LandCorp might receive similar advice in relation to the short term development of other sites in Karratha in which case it may be appropriate to examine the feasibility of establishing a single package treatment plant in a centrally located suitable site. Wastewater from various sites could potentially be collected and conveyed by 'tanker' to a single site.

It is also noteworthy that wastewater was collected by tanker from the Ellenbrook project for several years before more permanent conveyance was put in place. As such, with Water Corporation support, it would likely be practical to collect wastewater and tanker it to a central location for several years.

Though wastewater capacity is a significant constraint, it is not considered to be a 'fatal flaw' at this point in time. However the situation clearly needs to be monitored and reviewed again once advice from the Water Corporation has been received.

The Water Corporation's preliminary catchment planning makes provision for the construction of a wastewater pumping station (WWPS) in the north-west corner of the large format retail / MAC services site east of Madigan Road. It is intended the WWPS pump directly into an existing pressure main in Madigan Road.

In the event the large format retail / MAC Services development proceeds before the Madigan Road project it is anticipated that the pumping station will be built and deep sewerage extended to Madigan Road as a condition of subdivision.

In the event the Madigan Road Project occurs in advance of the large format retail / MAC Services development and arrangements can not be reached with that development to locate sewer infrastructure within it, then it is likely the Madigan Road project would require a temporary, developer funded WWPS to be built in the north-west corner of the Madigan Road project.

It is recommended discussions be held between the proponents of all three projects to cost effectively and fairly deal with sewer infrastructure. Whilst it is possible to service some parts of the Madigan Road site by gravity into the sewer outlet from Baynton West (which head in a northerly direction after crossing Dampier Road), there are downstream sewer capacity issues which would be expensive to overcome.

Electricity Supply

The existing high voltage (HV) power infrastructure throughout Karratha utilises 11kV distribution network, which is currently being upgraded to 22kV power network. It is anticipated the 22kV network will be available prior to the subdivision being constructed. The proposed subdivision is located in an area where several new developments are being proposed or are already under construction.

The anticipated power requirement for the proposed residential subdivision is in the order of 6 MVA based on 600 lots and After Diversity Maximum Demand (ADMD) power allowance of 10kVA/lot. Based on the ADMD of 10kVA/lot in general one 630kVA transformer substation will be required to provide power services to 45 – 50 lots.

Substation finish ground level must be 1m above the 100-year flood level. This requirement may necessitate the substation area to be increased to incorporate batters or retaining walls around some substations to achieve the required level.

New underground power distribution, both high voltage (HV) and low voltage (LV), will need to be installed throughout the subdivision to service each lot in the subdivision.

It is envisaged that based on a total electrical load in the order of 6 MVA this will require a minimum of two new dedicated HV feeders to be extended to the subdivision area from the Horizon Power zone substation.

The nearest zone substation – Pegs Creek Substation – is located adjacent Karratha Hospital about 4 kilometres from the proposed subdivision site.

There are also existing 132 kV transmission lines and poles that traverse the proposed development site. These existing transmission lines are likely to require relocation to suit the subdivision. Irrespective of whether the 132kV lines are to be relocated or not an appropriate easement will need to be established through the subdivision for the lines. An approximately 40 metre wide easement is required for the 132kV transmission lines.

The 132kV transmission line could be placed underground for a cost of about $3 million. As well as improving the visual amenity, this would significantly reduce the land take for easement purposes.

SITEWORKS, EARTHWORKS AND DRAINAGE

Flooding

The site naturally sits about a metre below Baynton West to the east. The watercourse that separates the two sites floods from time to time and in significant events it inundates parts of the site.

The areas subject to inundation can be filled such that they are above flood level but such filling may affect the dynamics of the currently projected flood mapping and may have an impact on the Baynton West site.

Significant flooding takes place east of the cemetery and part of this land would need to be filled if a road connection is made to Dampier Road. This filling may have a negative effect on available flood storage and could also impact on the Baynton West and flood levels in the Madigan Road site.

A comprehensive flood modelling study has been undertaken to determine likely flood and fill levels and to ensure the project does not impact on any existing developments. The flood modelling study includes a review of the benefits of providing additional culverts under Dampier Road to reduce the amount of flooding upstream of Dampier Road. The study reviews the impact of providing additional culverts on land downstream of Dampier Road. The Flood Study can be seen in Appendix 5.

Refer to Appendix 5 - Local Water Management Strategy & Flood Study

Some of the benefits of providing additional culverts under Dampier Road could be:

i) Reduced fill levels in the Madigan Road site and a reduction in the cost of imported fill.

ii) Land east of the cemetery being less flood-prone and therefore more suitable to possible future residential development.

Conveyance of Stormwater

The current approach in Karratha to dealing with the conveyance of stormwater essentially involves the utilisation of the road carriageway to convey stormwater from lots and road reserves to large open drains which in turn convey water to Nickol Bay. Whilst the current system is functional and cost effective, it is not generally aesthetically appealing.

As part of the development of the site it is recommended the following be undertaken.

i) A drainage system be developed that will collect and convey stormwater with minimal nuisance, danger or damage which meets LandCorp's objectives of being financially, socially and environmentally acceptable to the community as a whole. The system should also limit flooding of property, both within the catchment and downstream to acceptable levels.

ii) The retention of the natural watercourse east of the site in its existing state.

iii) The establishment of a range of road cross-sections and verge treatments throughout the project which are safe, aesthetically pleasing and have the capability of conveying stormwater with the overall objective of minimising the length of wide, 'engineered', open channels.

Some wide open channels will inevitably be required but the objective should be to minimise the prevalence of these. It is considered this could potentially be achieved by increasing the distance over which stormwater must travel, prior to arriving at more substantial drainage infrastructure, by increasing the capacity of the road system to carry water through the use of landscaped, shallow swale drains and the like.

The current approach to drainage is very cost effective and any alternative is likely to be more expensive and potentially require more land to be set aside for road reserves. However, the additional cost should be weighed up against the benefits it will bring to the community as a whole.

Considerable design inputs will be required to develop revised drainage treatments which take into consideration erosion, scouring, siltation, maintenance, cost, landscape, hydraulic and safety matters.

It should also be recognised that there are drainage guidelines which are intended to limit the depth and rate of flow of stormwater and road reserves for the convenience and safety for pedestrians and vehicles. As a guide the product of the average velocity and average flow depth for the design flow rates should be less than 0.4m^2/sec.

ROAD NOISE

In light of Madigan Road's classification under *State Planning Policy 5.4: Road and Rail Transport Noise and Freight Considerations in Land Use Planning* as a 'State Freight Road' and its potential as a source of road noise which may impact on future residential development, ND Engineering were commissioned to undertake an acoustic assessment of the site. An Acoustic Report detailing the findings of the assessment is attached as Appendix 6.

REFER TO APPENDIX 6 - ACOUSTIC REPORT.

The assessment revealed outdoor noise levels were LAeq(Day) = 61 dB(A) and LAeq(Night) = 52 dB(A), prior to any adjustments, along the western site boundary parallel to Madigan Road.

The report states that traffic noise impact on the proposed development can be reduced to meet the requirements of the Policy, by:

1. Deferring the sale of land on the western half of the street blocks adjacent to Madigan Road, nominally within 82 metres from the centre line of Madigan Road, until such time as the Ridge Gap Village construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route; and
2. Adjusting the shape of the block facing Dampier Road so that there will not be any residences north of the roundabout; and
3. Reassessing the noise levels prior to the sale of the deferred land once the construction camp ceases operation and then later if necessary once Madigan Road is not longer used as a heavy haulage route.

ACTIVITY CENTRES AND EMPLOYMENT

Type of Centre

The Development Plan proposes a small local centre, consistent with that identified under the City Growth Plan, serving as a central community focal point for the development. The centre will ultimately provide local retail and other services to serve some of the requirements of local community and facilitate local employment generation.

The local centre maintains a number of features important to ensuring the success of a local commercial centre as identified under Liveable Neighbourhoods being:

- a central location within a 400-500m walkable catchment;
- a location on an intersection of relatively busy streets with good through traffic levels;
- a location generally along the key traffic artery in the Development Plan area;
- a location in close proximity to residential land uses and home-based business opportunities; and
- good on street parking opportunities.

The centre has been strategically located around the intersection of the primary north-south and east-west neighbourhood roads, ensuring high visibility and good access.

The centre is envisaged to comprise a high standard of 'Main Street' built form incorporating environmental sustainable design, active edges and attractive façades to provide visual amenity and interaction, pedestrian friendly streetscapes and passive surveillance of the public realm. Short term customer parking is envisaged to occur on the street with longer term customer and employee parking envisaged to be located to the rear of development with shared access arrangements.

Land Use Distribution

The types of commercial uses located in the proposed local centre will be lower order uses which are typically located outside of a District Centre and will not compromise development of the Tambrey District Centre or the efficient distribution of commercial services within the district.

The distribution of land uses within the centre has been structured around the creation of a Mixed Use Commercial/Retail Precinct. This Precinct is envisaged as an active focus for the community that may contain a diversity of local retail, consulting rooms, entertainment and main-street commercial office uses that generate day and evening activity. To assist with maximising local vitality, upper floors of development will incorporate residential dwellings. Non-residential floorspace within the Precinct is proposed to be limited to 1000m² NLA with retail tenancies limited to a maximum floorspace of 500m² NLA.

The basis for determining a 1000m² retail/commercial floorspace limit within the local centre is premised on allowing for limited fine-grained retail uses such as a small deli/supermarket, cafes and restaurants to serve residents and local businesses within the Development Plan area without competing with the Karratha City Centre or the Tambrey Neighbourhood Centre.

In the longer term, once these two other areas are establish it is envisaged that a slightly greater amount of commercial/retail floorspace will be permitted abutting the Main Street but contained within the Mixed Use Commercial/Retail Precinct. To this end it is proposed that all buildings fronting the Main Street will be required to have a minimum ground floor level to ground floor ceiling level of the ground level of 3.2m to enable transition to commercial uses over time. The mechanism to control this timing is proposed to be via a DAP approved by the Shire of Roebourne.

Employment Rates and Opportunities

The local centre will ultimately provide opportunities to facilitate local employment generation to assist in achieving a level of employment self sufficiency within the development as well as contributing to diversifying Karratha's economy and employment base. Employment rates within the local centre are expected to be low primarily consisting of local business owners and employees.

In addition, the development will provide an additional population base which will support existing services and facilities within Karratha, as well as ensuring the continued economic growth of Karratha's primary commercial and retail centres.

SCHOOLS

The CGP document states that the existing or proposed education facilities in the nearby suburbs of Baynton and Nickol are sufficient to cater for future subdivisions within the area.

Additionally the DET have advised via correspondence to LandCorp that the Baynton West Primary School, which comprises a site area of 4.5ha, has provision to be developed in the future to a facility approximately 1.5 times the size of a typical primary school to enable it to specifically cater for new residents within the Development Plan area as well as the Baynton community.

Accordingly no schools are proposed within the Development Plan area.

This page has been left blank intentionally.

ORDERLY AND PROPER PLANNING

The proposed Development Plan represents the logical, orderly and proper development of the land that is consistent with both the current strategic vision prescribed by the Karratha City of the North Blueprint and also the statutory objectives highlighted by the Scheme as amended by Scheme Amendment No. 18. The Development Plan is also consistent with the strategic planning vision identified under the KCN documents.

At the strategic level, the proposed Development Plan will facilitate achieving the objectives of the recently endorsed KCN Blueprint City Growth Plan which highlights the site as being developed for residential purposes with opportunities for increased density. The site is also a logical extension of the existing Baynton West neighbourhood and provides housing diversity and density within the established urban fabric to reduce pressure to develop on the fringe and in the Regals south of Karratha Hills. The design is also responsive to the site providing a neighbourhood that is walkable with a high level of pedestrian and vehicle connectivity, including to the adjoining residential and open space areas.

The intent for the site to be developed for residential purposes is also reflected in both the WAPC Pilbara Framework: Regional Profile (2009) and the Karratha Regional Hotspots Land Supply Update 2010 which both identify the site to be developed for residential purposes.

The Shire of Roebourne Karratha 2020 Vision and Community Plan (2009) also notes the high cost of housing and the situation of employee accommodation being provided by certain employment sectors. The result being that there is an established need for additional housing in Karratha to address the high cost of housing. Providing additional and diverse housing opportunities on the site will also help address this issue raised by the 2020 Plan.

From a statutory viewpoint, the Development Plan assists in achieving the objectives of the Scheme as per clause 5.8 of TPS 8 in that it represents the continued growth of Karratha and will:

(i) *Facilitate the continued growth of Karratha as the regional centre of the West Pilbara, in accordance with the Karratha Townsite Structure Plan (as amended);*

(iii) *Preserve the key landscape and heritage values of the Karratha Hills;*

(viii) *Develop local commercial centres so as to provide convenience goods and services to the local community;*

(ix) *Enhance the high level of residential amenity within Karratha in both existing suburbs and the residential expansion areas; and*

(x) *Encourage residential development that will accommodate a greater range of lifestyles and needs to reflect the broadening population base.*

In addition the Development Plan ensures that future stages of the development can be integrated with the development and developed in an orderly and proper manner in accordance with proposed Scheme Amendment No. 21.

SITE SUITABILITY AND RELATIONSHIP TO ADJOINING DEVELOPMENT

The current planning framework identifies the site for urban purposes and generally as a future urban development area. The proposed Development Plan is consistent with TPS8, the vision and objectives of the CGP and the associated Scheme Amendments No. 18 and 21.

The Development Plan is consistent with surrounding land uses and represents the most efficient use of land. The site is surrounded by and within proximity to a range of services and facilities including regional open space, educational facilities (primary, secondary and tertiary), recreational sporting facilities, and commercial and employment centres.

The Development Plan will provide an increased resident base which will support these surrounding services and facilities and contribute to the continued economic growth of Karratha.

The provision of a residential neighbourhood is consistent with existing development to the north and east of the site. The gradation of density residential development around areas of high amenity and local neighbourhood centres ensures appropriate interfaces to surrounding areas is achieved.

The provision of east-west road links through to Baynton West will facilitate the effective integration of new development with the existing Baynton West residential neighbourhood.

Aside from the road network and provision of compatible land uses and residential densities, integration with surrounding land is somewhat challenged by the shape of the Development Plan Area, and physical barriers in the form of Dampier Road, Madigan Road, and the Karratha Hills.

ACCESS TO EXISTING SERVICES AND COMMUNITY INFRASTRUCTURE

All standard essential residential services and infrastructure exist within proximity to the site (within Nickol and Baynton West residential areas) and are able to be extended into the development.

As identified previously, the site is within proximity and easy access to several existing community facilities which will cater for the local needs of future residents. These include the Tambrey Primary School as well as the proposed primary school and family/child care centre in Baynton West. A future district open space is identified under the CGP to the west of the site and in the area subject of the WWTP buffer.

Higher order retail and commercial service needs will be available through the future Tambrey district retail centre as well as the Karratha City Centre.

SUSTAINABLE DEVELOPMENT ASSESSMENT

LandCorp is committed to demonstrating high quality design and sustainability initiatives in land and building development to promote resource efficiency and encourage lifestyle opportunities that integrate with their surrounding community and the natural environment.

These values have been woven through the development of the CGP for Karratha and extended into the detailed planning and design for the site.

Accordingly, a set of draft project objectives for these sites have been developed based heavily upon the CGP objectives, LandCorp's sustainability assessment tool and contextual knowledge of the site.

Refer To Table 9 - Project Objectives And Performance Measures.

Table 9: Project Objectives and Performance Measures.

Project Objectives	Performance Measures	
Community cohesion, vitality and involvement	– Provision of communication and information networks for the community (intranet, newsletter, welcome packs, information events etc) – Provision of effective Information Communication Technology (ICT) infrastructure	
Acknowledgement of cultural heritage through built form, public art, community art and community activities	– Analyse and document the place character, inclusive of community beliefs and understanding of the place identity – Demonstrate that the place identity is integrated into the proposed plan, programs and events	
Community participation in goal setting and decision-making processes	– Communication and Engagement Plan completed and implemented – Representation of community and stakeholders in decision making from initiation to delivery	
Integration of workforce with local community	– Provision of a range of housing types to meet resident and short stay needs	
To plan for safe communities, reducing the potential for crime and vandalism.	– Develop crime prevention programs and partnerships including program, community and built form initiatives	
Protection of significant natural landform & biodiversity	– Development of a management plan agreed with Local Government (LG) or DEC	
Protection of significant native vegetation and habitat	– % of site with endemic vegetation retained – Development of a management plan agreed with Local Government (LG) or DEC	
Retention of predevelopment water balance and quality	– Development of Urban Water Management Strategy/Plan agreed with DoW	
Reduced net per capita carbon emissions and energy efficient built form	– Incorporations of climatic responsive design of road networks, through road systems with cardinal orientation (this will facilitate the achievement of climatic responsive design lot layout) Climatic responsive design of lot layout that supports climatic responsive design. – Climatic responsive design of buildings (including solar access, natural breezes, and shade considerations) Incorporation of energy efficiency design for residential and commercial buildings through design, fittings and fixtures (including; eves, appliances, lighting, hot water system etc) – Consideration of alternative energy sources (e.g. solar, wind, biomass, gas, hydro) for all, or a portion of the developments energy requirements	
To decrease volume of waste output to landfill	– % reduction of waste output (by mass) to landfill as outlined in site waste management plan – Demonstrate provision for recycling storage in design	
Best practice per capita water consumption	– Maximise water efficiency and reuse in public areas (e.g. xeriscaping, water wise landscapes, and efficient irrigation systems, centralised/ decentralised wastewater reuse, stormwater harvesting) – Maximise water efficiency and reuse in commercial and residential buildings and private space through design, fittings and fixtures, xeriscaping, water wise landscapes, efficient irrigation systems, wastewater and rainwater harvesting to toilet, laundry hot water or landscape	

Project Objectives	Performance Measures	
Energy efficient built form	– 100% of all residential buildings with minimum BCA performance accreditation	
Effective and well utilised public transport	– Early delivery of public transport – Percentage use of alternative transport to private car use	
A place based response that reflects the climate, context and site	– Context and site analysis investigations completed.	
Management strategies for climate change and natural disasters	– Buildings and landscape design demonstrates appropriate indoor and outdoor room response for the climate zone and climate change implications	
An integration of uses that achieves functionality, efficiency, diversity and compatibility	– Convenient access to a range and mix of retail, community and local services are provided – A variety of stimulating spaces and activities that support social interaction are integrated into the design	
Connectivity at local, district and regional scale	– Evidence of overall regional, district and local connectivity based on a dispersed movement model	
A network and hierarchy of streets and public spaces that provides permeability and legibility	– Proposed plan demonstrates a coherent, connected, permeable and legible network of streets, squares and open spaces – Open spaces, urban elements, and structures are provided to aid way-finding and enhance sense of place	
A integrated movement network that ensures the safe movement of pedestrians, cyclists and vehicles	– Within development area sight lines, views and visual connections are incorporated into the overall design – Proposed plan demonstrates safe road design and traffic management with clearly defined access routes and pedestrian/cycle priority where applicable	
A diverse mix of uses, buildings and housing types	– Diverse range and mix of housing is incorporated to cater for a variety of occupants, ages and lifestyles	
High quality well designed buildings that reflect the site context	– Buildings of appropriate scale, height and quality are incorporated Building and landscape design incorporates materials, textures and details that reinforce local identity – Building design that takes advantage of contextual opportunities.	
A variety of well defined open spaces	– Public spaces to cater for a range of users, age groups and activities is incorporated in the design – Integrated art, water features, natural features and urban elements are incorporated into the design – Proposed plan demonstrates active street frontages with surveillance of streets, open spaces and parking areas	
Accessible and legible activity centres	– A variety of connections to activity centres to cater for pedestrian, cycling and vehicle based transport	

This page has been left blank intentionally.

IMPLEMENTATION AND STAGING

INDICATIVE STAGING AND TIMING

A staged approach to development is envisaged for the Madigan Road site based on linkages into the Baynton West development, access arrangements on Madigan Road and Dampier Road, the downgrading of Madigan Road to a main-street format once heavy haulage traffic is diverted to the Madigan Road Bypass, and consideration and determination of Scheme Amendment No. 21.

Figure 19 depicts an indicative approach to staging that may be implemented with the development of site. The approach to staging is based on facilitating the release of land that is able to serviced immediately and developed as a logical extension to existing services and infrastructure (generally Stages 1 to 3).

Land identified within future stages (Stage 4) however is generally subject to several outstanding matters requiring resolution which include:

- Consideration and determination of Scheme Amendment No. 21;
- Issues regarding road noise associated with the use of Madigan Road; and
- Detailed drainage modelling and Native Title issues associated with land to the north, east and south.

The timing of development is largely dependent on the availability and extension of services into the site as well as seeking necessary approvals relating to the following:

- The extension of roads through Crown land reserves;
- Clearing permits and earthworks approvals;
- Subdivision applications; and
- Possible Section 18 clearances.

A shortage of housing as well as housing affordability are significant issues facing Karratha, severely limiting its potential to realise the vision of Karratha as a 'City of the North'. The State Government has issued a target of delivering 1000 dwellings per annum in Karratha to address housing demand and provide more affordable housing. The provision of residential land in a timely manner is critical to achieving this target.

LandCorp is largely responsible for the delivery of land for residential development in Karratha and is committed to obtaining the above approvals as soon as possible to enable development of the site to progress expeditiously. Notwithstanding, it is envisaged that earthworks for the land can be commenced early in 2011 with the provision of the initial stages of the development to the market towards the middle of 2011.

Refer to Figure 20 – Indicative Staging Plan

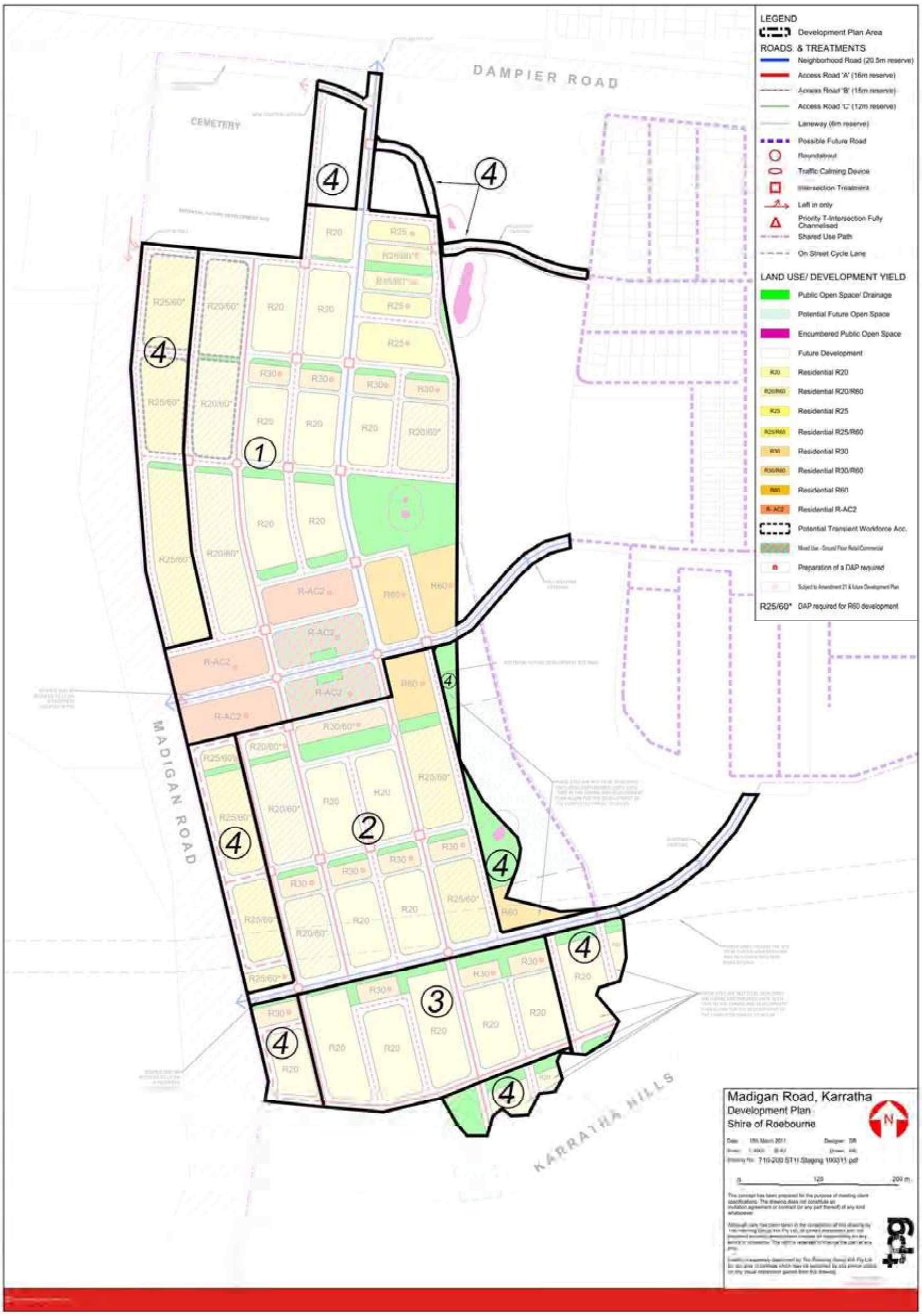


Figure 20 – Indicative Staging Plan

APPLICATION FOR SUBDIVISION

Given lead times associated with the Shire's and the Commission's consideration of the Development Plan as well as the preparation, consideration and approval of detailed subdivision plans, normally the initial stages of development within a Development Plan area would not proceed within 6-12 months following lodgement of a Development Plan.

Due to the demand for the provision of development ready residential land within Karratha, applications for the initial stages of subdivision will be lodged with the Commission as soon as possible in order to achieve the necessary approvals and ensure that lots are available for sale in a timely manner.

DESIGN GUIDELINES

To assist in creating a sustainable, visually interesting and attractive place, detailed design guidelines will be prepared at a future date to control the detailed design of built form within the Development Plan area.

It is envisaged that design guidelines will build upon the planning and urban design principles identified in this report and incorporate the use of climate responsive design principles and architectural design elements that are culturally and locally relevant so as to ensure new development exhibits a unique local style or Karratha vernacular.

Design guidelines will incorporate a range of provisions relating to elements including climate responsive design principles, building design and materials, orientation and surveillance, setbacks, garaging and access (including boat parking), design and location of screening/fencing, signage, landscaping, and noise attenuation (for development that may be subject to road noise associated with Madigan Road and Dampier Road).

Design guidelines will also guide new development within the local centre to ensure an activated and vibrant urban environment is created. New development within the local centre will be required to exhibit articulated facades and strong legible ground level relationships to create a human scale village feel with sustained visual interest. Unity in landscape and urban design elements will be utilised to bolster the creation of an effective sense of place and connectivity.

DETAILED AREA PLANS

The Development Plan identifies certain land parcels for which the preparation of Detailed Area Plans (DAP's) are required to control the detailed design of the built form to achieve a desired standard and/or address interface considerations. Generally these include lots which are rear serviced, lots abutting and fronting open space/drainage areas, and areas coded R-AC2.

Generally it is envisaged that DAP's will include provisions and standards relating to non-residential uses, building envelopes, setbacks, interface with public open space and drainage areas, protection of sites of heritage significance and parking/access considerations. In the case of land coded R-AC2, additional provisions relating to site coverage, distribution of land uses within a lot (mixed use lots), the location of height and loading and storage areas are also envisaged to ensure new development effectively achieve the desired vision and objectives of the Development Plan.

It is envisaged that the DAP's would be adopted by Council pursuant to the Scheme and administered by the Shire. For matters not covered by the R-Codes, Council's Scheme or Policies, then these will be addressed by Covenants on the Title and enforced by the developer.

CONCLUSIONS

This Development Plan has been prepared in order to facilitate the orderly future subdivision, land use and development of the southern portion of Lot 500 Madigan Road, Baynton. The Development Plan and this supporting report demonstrate how the proposed development is in accordance with State and Local Government vision for the site, in particular the Karratha City of the North Blueprint, City Growth Plan and the objectives of the Shire of Roebourne Town Planning Scheme No. 8 and proposed Amendment No. 21.

The proposed residential land use with a variety of densities and housing types represents the highest and best use for the property and the design and layout is based on sound design intent. Following adoption of the Development Plan, it is envisaged that further discussions will be held with the servicing authorities to ascertain the timing of providing appropriate services to the land and for a subdivision application to be lodged with the WAPC for consideration and determination.

Based on the consistency of the Development Plan with the agreed vision for the site and that the design represents the optimal development outcome for the site, it is requested that the Shire and WAPC approve the Development Plan at its earliest convenience to enable subdivision and development to occur.

This page has been left blank intentionally.

APPENDIX 1

CERTIFICATE OF TITLE

This page has been left blank intentionally.

REGISTER NUMBER	
500/DP59331	
DUPLICATE EDITION	DATE DUPLICATE ISSUED
N/A	N/A

WESTERN AUSTRALIA

VOLUME	FOLIO
LR3153	612

RECORD OF CERTIFICATE
OF
CROWN LAND TITLE

UNDER THE TRANSFER OF LAND ACT 1893
AND THE LAND ADMINISTRATION ACT 1997

NO DUPLICATE CREATED

The undermentioned land is Crown land in the name of the STATE of WESTERN AUSTRALIA, subject to the interests and Status Orders shown in the first schedule which are in turn subject to the limitations, interests, encumbrances and notifications shown in the second schedule.

BG Roberts
REGISTRAR OF TITLES

LAND DESCRIPTION:

LOT 500 ON DEPOSITED PLAN 59331

STATUS ORDER AND PRIMARY INTEREST HOLDER:
(FIRST SCHEDULE)

STATUS ORDER/INTEREST: UNALLOCATED CROWN LAND

PRIMARY INTEREST HOLDER: STATE OF WESTERN AUSTRALIA

LIMITATIONS, INTERESTS, ENCUMBRANCES AND NOTIFICATIONS:
(SECOND SCHEDULE)

Warning: A current search of the sketch of the land should be obtained where detail of position, dimensions or area of the lot is required. Lot as described in the land description may be a lot or location.

---------------------------------------END OF CERTIFICATE OF CROWN LAND TITLE---------------------------------------

STATEMENTS:

The statements set out below are not intended to be nor should they be relied on as substitutes for inspection of the land and the relevant documents or for local government, legal, surveying or other professional advice.

SKETCH OF LAND:	DP59331 [SHEET 1,2].
PREVIOUS TITLE:	LR3135-735.
PROPERTY STREET ADDRESS:	NO STREET ADDRESS INFORMATION AVAILABLE.
LOCAL GOVERNMENT AREA:	SHIRE OF ROEBOURNE.
RESPONSIBLE AGENCY:	DEPARTMENT OF REGIONAL DEVELOPMENT AND LANDS (SLSD).

NOTE 1: K598882 CORRESPONDENCE FILE 50851-2007-01RO

VER	AMENDMENT	AUTHORISED BY	DATE

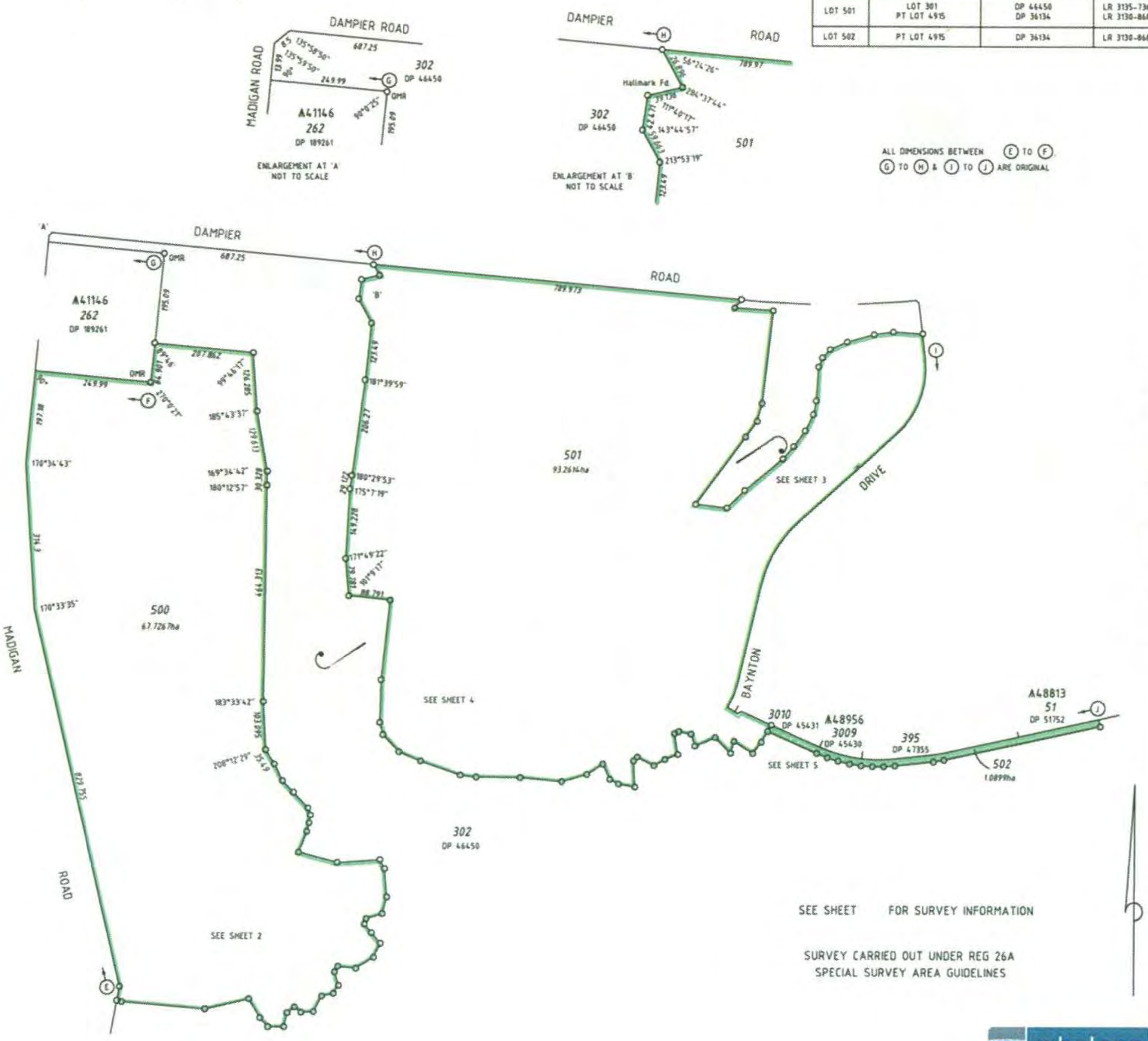
LOT	FORMER P/TENURE	ON PLAN\DIAGRAM	TITLE
LOT 500	LOT 300	DP 44450	LR 3135-735
LOT 501	LOT 301 PT LOT 4915	DP 44450 DP 36134	LR 3135-736 LR 3130-868
LOT 502	PT LOT 4915	DP 36134	LR 3130-868

TYPE CROWN

PURPOSE SUBDIVISION

PLAN OF

LOTS 500, 501 & 502



SEE SHEET FOR SURVEY INFORMATION

SURVEY CARRIED OUT UNDER REG 26A
SPECIAL SURVEY AREA GUIDELINES

DISTRICT	DE WITT	SSA YES/~~NO~~	
TOWNSITE	KARRATHA	FORMER TENURE	SEE TABLE ABOVE
DPI FILE	50851-2007		
LOCAL AUTHORITY	SHIRE OF ROEBOURNE		
LOCALITY	BAYNTON		
INDEX	ON BH65 (2) 28.26, 27.26 (10) 6.5, 6.6	FIELD BOOK	106654

SCALE 1:6000
AT A2 SIZE
ALL DISTANCES ARE IN METRES

SURVEYOR'S CERTIFICATE - Reg 54

I, IAN KEITH GARDINER

hereby certify that this is accurate and is a correct representation of the
(a) survey and /or
(b) calculations from measurements
(delete if inapplicable)
undertaken for the purposes of this plan and that it complies with the relevant written law(s) in relation to which it is lodged

Licensed Surveyor Date

SURVEYOR'S CERTIFICATE - Compiled

I,
hereby certify that this compiled plan
(a) is a correct and accurate representation of the survey(s) of subject land ; and
(b) is in accordance with the relevant law in relation to which it is lodged.

Licensed Surveyor Date

SURVEYING & DRAFTING BY

WHELANS (WA) PTY LTD

LODGED	TYPE OF VALIDATION	APPROVED BY WESTERN AUSTRALIAN PLANNING COMMISSION
DATE	FULL AUDIT	
	LEGAL COMPONENT	FILE EXEMPT FROM WAPC APPROVAL
FEE PAID	DOCKET PLANS/DIAG	
	CERTIFIED CORRECT	Delegated Under S.16 P & D ACT 2005
ASSESS No	I.S.C.	
	F.S.C.	DATE

IN ORDER FOR DEALINGS

SUBJECT TO

FOR INSPECTOR OF PLANS & SURVEYS / AUTHORIZED LAND OFFICER DATE

APPROVED REG 26A (4)

INSPECTOR OF PLANS & SURVEYS / AUTHORIZED LAND OFFICER DATE

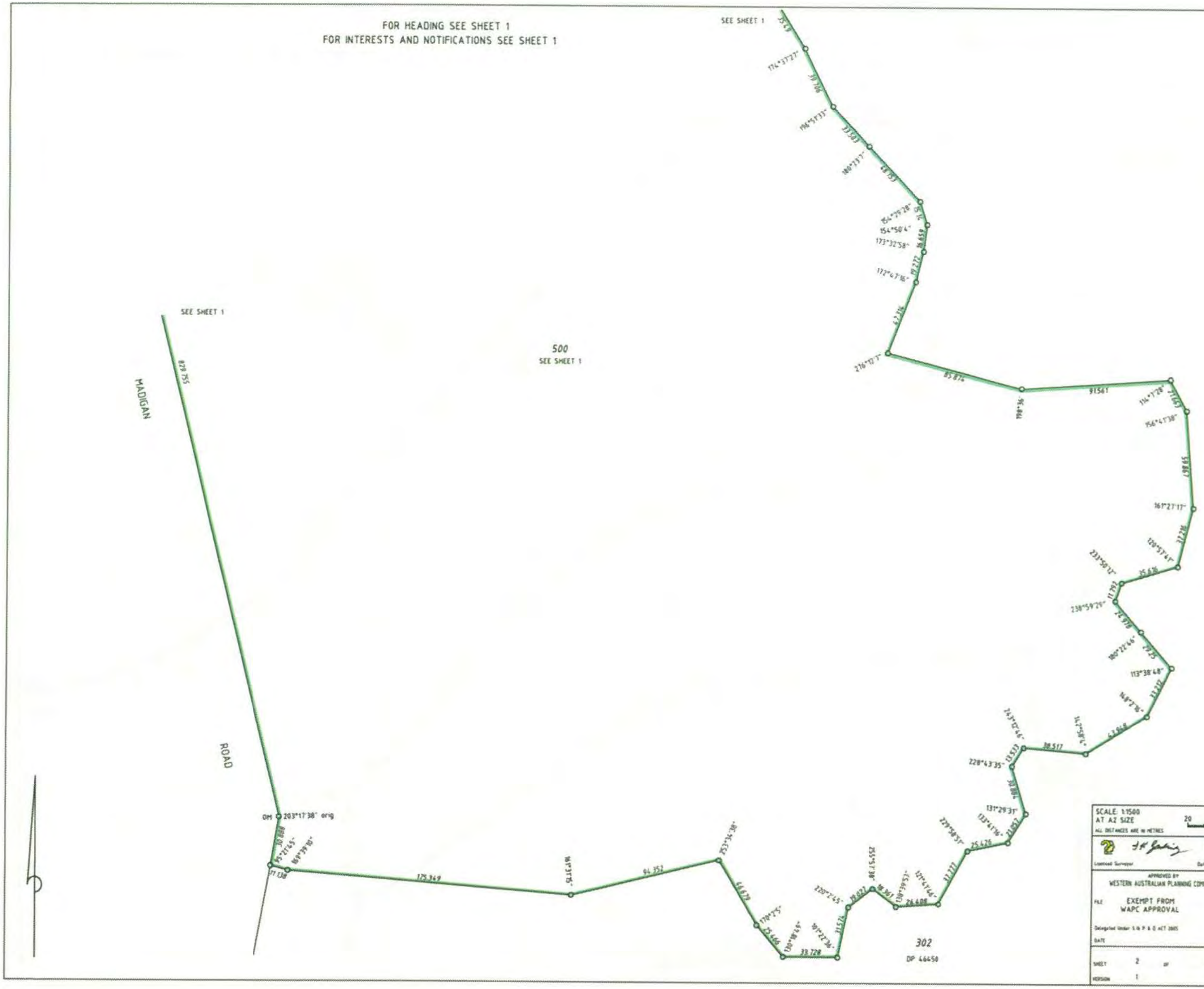
Landgate
Western Australian Land Information Authority

DEPOSITED PLAN

59331

SHEET 1 of 5
VERSION 1

FOR HEADING SEE SHEET 1
FOR INTERESTS AND NOTIFICATIONS SEE SHEET 1



whelans

PP-3879-895-VER 1.0

SCALE: 1:1500
AT A2 SIZE
ALL DISTANCES ARE IN METRES

20 0 20 40 60 80 100

Ian Keith Gardiner
2008.04.07
11:07:07 +08'00'

Licensed Surveyor
Date

APPROVED BY
WESTERN AUSTRALIAN PLANNING COMMISSION

FILE
EXEMPT FROM
WAPC APPROVAL

Delegated Under S.16 P & D ACT 2005
DATE

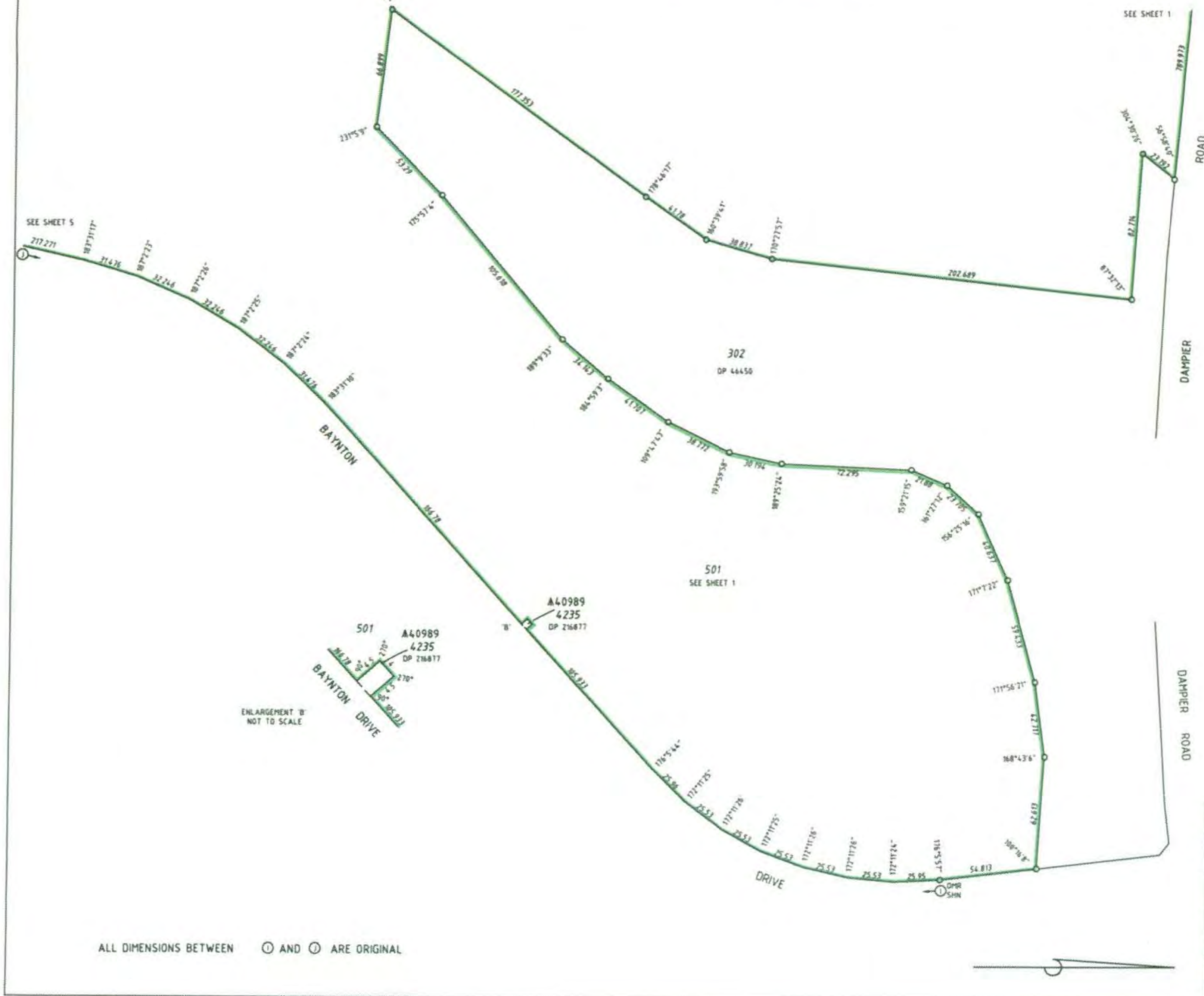
SHEET 2 of 5
VERSION 1

Landgate
Western Australian Land Information Authority

DEPOSITED PLAN

59331

FOR HEADING SEE SHEET 1
FOR INTERESTS AND NOTIFICATIONS SEE SHEET 1



ALL DIMENSIONS BETWEEN ① AND ② ARE ORIGINAL

whelans

1187hop/Sch13.dgn FP 01879 005 VER 1.0

SCALE 1:1500
AT A2 SIZE
ALL DISTANCES ARE IN METRES

20 0 20 40 60 80 100

Licensed Surveyor
Date

APPROVED BY
WESTERN AUSTRALIAN PLANNING COMMISSION

FILE
EXEMPT FROM
WAPC APPROVAL

Delegated Under S.16 P & D ACT 2005

DATE

SHEET 3 OF 5
VERSION 1

Landgate
Western Australian Land Information Authority

DEPOSITED PLAN

59331

FOR HEADING SEE SHEET 1
FOR INTERESTS AND NOTIFICATIONS SEE SHEET 1

whelans

SCALE: 1:1500
AT A2 SIZE
ALL DISTANCES ARE IN METRES

20 0 20 40 60 80 100

Licensed Surveyor
Date

APPROVED BY
WESTERN AUSTRALIAN PLANNING COMMISSION

FILE

EXEMPT FROM
WAPC APPROVAL

Delegated Under S16 P & D ACT 2005

DATE

SHEET 4 OF 5
VERSION 1

Landgate
Western Australian Land Information Authority

DEPOSITED PLAN

59931

FOR HEADING SEE SHEET 1
FOR INTERESTS AND NOTIFICATIONS SEE SHEET 1
ALL DIMENSIONS BETWEEN ① TO ② ARE ORIGINAL

whelans
1187Map/Sub/Sl.dgn
PP 1879-005 VER 1.0

SCALE 1:1500
AT A2 SIZE
ALL DISTANCES ARE IN METRES
20 0 20 40 60 80 100

J K Garding
Ian Keith Gardner
2006.04.01
11:07:07 +08'00'
Licensed Surveyor
Date

APPROVED BY
WESTERN AUSTRALIAN PLANNING COMMISSION
FILE
EXEMPT FROM
WAPC APPROVAL
Delegated Under S.16 P & D ACT 2005
DATE

SHEET 5 OF 5
VERSION 1

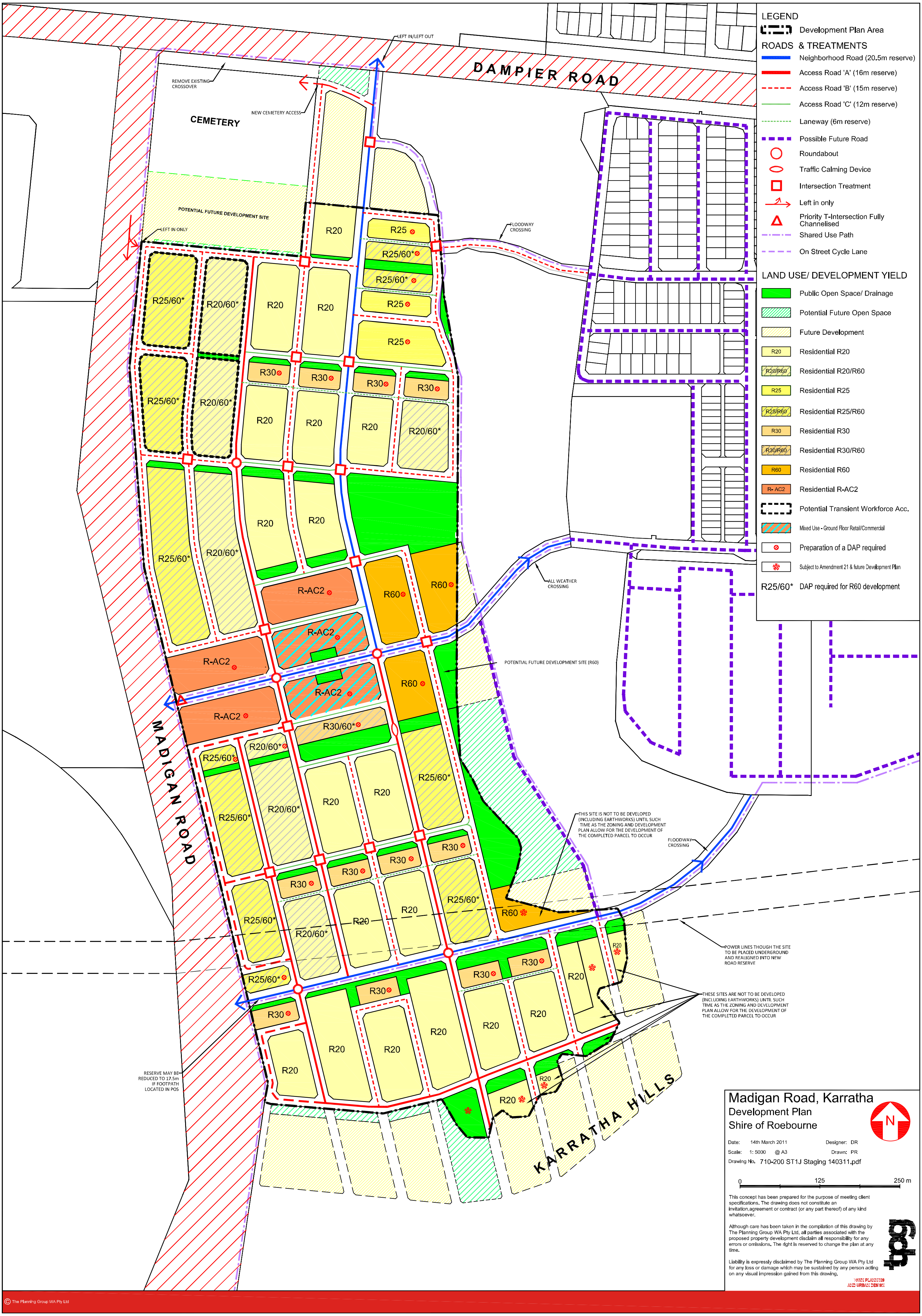
Landgate
Western Australian Land Information Authority

DEPOSITED PLAN
59331

APPENDIX 2

DEVELOPMENT PLAN

This page has been left blank intentionally.



LEGEND

Development Plan Area

ROADS & TREATMENTS

- Neighborhood Road (20.5m reserve)
- Access Road 'A' (16m reserve)
- Access Road 'B' (15m reserve)
- Access Road 'C' (12m reserve)
- Laneway (6m reserve)
- Possible Future Road
- ○ Roundabout
- Traffic Calming Device
- □ Intersection Treatment
- Left in only
- △ Priority T-Intersection Fully Channelised
- Shared Use Path
- On Street Cycle Lane

LAND USE/ DEVELOPMENT YIELD

- 🟩 Public Open Space/ Drainage
- ▨ Potential Future Open Space
- Future Development
- R20 Residential R20
- R20/R60 Residential R20/R60
- R25 Residential R25
- R25/R60 Residential R25/R60
- R30 Residential R30
- R30/R60 Residential R30/R60
- R60 Residential R60
- R- AC2 Residential R-AC2
- Potential Transient Workforce Acc.
- Mixed Use - Ground Floor Retail/Commercial
- Preparation of a DAP required
- Subject to Amendment 21 & future Development Plan
- R25/60* DAP required for R60 development

Madigan Road, Karratha
Development Plan
Shire of Roebourne

Date: 14th March 2011
Designer: DR
Scale: 1: 5000 @ A3
Drawn: PR
Drawing No. 710-200 ST1J Staging 140311.pdf

0 125 250 m

This concept has been prepared for the purpose of meeting client specifications. The drawing does not constitute an invitation,agreement or contract (or any part thereof) of any kind whatsoever.

Although care has been taken in the compilation of this drawing by The Planning Group WA Pty Ltd, all parties associated with the proposed property development disclaim all responsibility for any errors or omissions. The right is reserved to change the plan at any time.

Liability is expressly disclaimed by The Planning Group WA Pty Ltd for any loss or damage which may be sustained by any person acting on any visual impression gained from this drawing.

TOWN PLANNING
AND URBAN DESIGN

APENDIX 3

GEOTECHNICAL REPORT

This page has been left blank intentionally.

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GEOTECHNICAL REPORT MADIGAN ROAD DEVELOPMENT SITE

Cossill & Webley Consulting Engineers
Madigan Road, Karratha, WA

GEOTPERT02828AS-AC
25 November 2010

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
89-91 Burswood Road Burswood WA 6100 Australia

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

25 November 2010

Cossill & Webley Consulting Engineers
Level 2, 431 Roberts Road
Subiaco, WA, 6008

Attention: Ray Todd

Dear Sir,

RE: REPORT OF GEOTECHNICAL INVESTIGATION

MADIGAN ROAD DEVELOPMENT SITE

This letter presents our report for the geotechnical investigation carried out on the above project.

If you have any questions or comments related to the report or we can be of further assistance, please do not hesitate to contact the undersigned.

For and on behalf of Coffey Geotechnics Pty Ltd

Stuart Ellis

Associate Geotechnical Engineer

Distribution:	Original held by	Coffey Geotechnics Pty Ltd
	2 Hard copies	Cossill & Webley
	1 Electronic Copy	Cossill & Webley

CONTENTS

CONTENTS

ATTACHMENTS

Tables

Figure

Appendices

1 INTRODUCTION

This report presents the results of a geotechnical investigation carried out by Coffey Geotechnics Pty Ltd (Coffey) for Cossill & Webley Consulting Engineers (Cossill & Webley) acting on behalf of Benchmark Projects for the Madigan Road Development Site, Karratha, Western Australia.

This work was commissioned by Mr Jonathan Yelland of Benchmark Projects on 6 October 2010 via a completed “Authorisation to Proceed” form enclosed with the Coffey proposal dated 16 July 2010 (Ref. GEOTPERT02828AS-AA-P).

This report is prepared and is to be read subject to the terms and conditions contained in our proposal referenced above. Our advice is based on the information stated and on the assumptions expressed herein. Should that information or the assumptions be incorrect, then Coffey Geotechnics Pty Ltd shall accept no liability in respect of the advice whether under law of contract, tort or otherwise.

2 PROPOSED DEVELOPMENT

It is understood that the Madigan Road site is about 68ha in area and is proposed for residential development. The residential lots are proposed for R17.5 to R60 zoning.

3 OBJECTIVES

The objectives of the geotechnical investigation were to ascertain the following:

- Soil, rock and groundwater conditions within the significant foundation support zone for the sites in general;
- Site classification in accordance with AS2870-1996 and requirements to improve the classification;
- Retaining wall design considerations and design parameters;
- Pavement design parameters and construction requirements; and
- Construction considerations pertinent to the proposed development, including site preparation, excavation conditions, protection of footing excavations, suitability of materials for structural fill, compaction control, groundwater control and the need for subsoil drainage.

4 INFORMATION SUPPLIED BY OTHERS

Cossill & Webley have provided Coffey with the following information:

- Geotechnical Investigation, Lot 500 Madigan Road, Proposed Test Pit Locations (Ref: 14004-00 Rev 0, Dated 15 October 2010);
- Karratha, Regional Hotspot Land Supply Update, Identified Project areas (Ref: GL248-2007-2 Dated 22 October 2010);
- Landcorp Madigan Road Residential (Ref: 11879it4, Dated 9 December 2010); and
- Proposed Test Pit Locations (Ref: Excel Spreadsheet 101015 drill holes, Dated 10 October 2010).

5 FIELDWORK

5.1 General

Fieldwork was carried out on the 19 and 20 October 2010 in the full time presence of personnel from Coffey. Test pit co-ordinates were provided by Cossill & Webley to Coffey and were located onsite using hand held GPS relative to Map Grid of Australia (MGA) to a horizontal accuracy of +/- 5 metres. Several test locations located close to Madigan Road were moved further east to minimise the proximity to buried services. Surveyors from Whelans Pty Ltd completed survey of the test locations after the completion of field work on 3 November 2010. Co-ordinates and elevations are provided on the attached logs.

Access at the site was via Madigan Road. Trafficability at the time of fieldwork was generally good for a four wheel drive vehicle. Some localised areas of dry loose soils at the ground surface (typically indicated by the presence of crabholes) were present in the northern and central regions of the site.

Weather conditions at the time of fieldwork were hot and dry.

Approximate investigation locations are shown on Figure 1.

5.2 Test Pitting

A total of 30 test pits (TP01 to TP30) were excavated by backhoe to depths varying from 0.0m to 3.0m below the existing ground surface.

Disturbed samples considered representative of the soils excavated were collected for laboratory testing.

In-situ testing comprised pocket penetrometer tests carried out in the cohesive soils exposed in the faces of the test pits. The pocket penetrometer test provides an estimate of the unconfined compressive strength of a cohesive soil and approximates its allowable bearing capacity.

The records of the test pit logs showing the major strata that were intersected, the depths at which the samples were taken, in-situ tests carried out, and the results of these tests, together with Explanation Sheets defining the terms used, are presented in Appendix A. Photographs of the test pits and excavated material are also presented in Appendix A.

6 DESCRIPTION OF LABORATORY TESTING

Laboratory testing was carried out in accordance with the general requirements of AS 1289 by the Coffey NATA registered soils laboratory.

The extent of testing carried out to provide the geotechnical parameters required for this study are presented in Table 1.

Table 1 – Extent of Laboratory Testing

Type of Test	Number
Particle Size Distribution tests	11
Atterberg Limits tests	10
Moisture Content tests	5

Laboratory results for the aforementioned tests are attached in Appendix B.

7 SITE CONDITIONS

7.1 Surface Conditions

The site occupies an area of 68 ha and is situated between Dampier Road to the north, Madigan Road to the west, and the Karratha Hills to the South. The topography comprises of relatively flat plains and gentle slopes in the northern and central regions of the site, with steeper slopes as the site approaches the foothills in the south of the site.

Vegetation within the site is dominated by extensive areas of low grass with isolated areas of shrubs and small trees. Scattered shrubs and low trees also define the surface drainage channel along the eastern boundary of the site. It is anticipated that the drainage channel becomes active during significant rainfall events and that significant areas of surface water/sheet wash will occur across the site in response to rainfall events associated with tropical cyclones.

A common feature within the alluvial – colluvial plain throughout the site is the occurrence of “crabholes” indicating Gilgai soils. Gilgai is extremely reactive to changes in soil moisture and shrinks and swells to depths of 1m to 2m in response to seasonal wetting and drying. The resulting terrain, noted throughout the site, consists of small hummocks and hollows with “crabholes” (Figure 2) in the hollows being more concentrated in shallow water courses and lower lying areas where surface water ponds following rainfall events.

Rock outcrops were observed in the central and southern sections of the site (Figure 3), with moderately to highly fractured rock outlays present at the base of the foothills (Figure 4).

Existing site development consists of:

- Several cleared tracks within the site typically running from west to east;
- High voltage power lines running through the site from west to east in the south; and
- Buried services present within the road shoulder of the Madigan Road.

7.2 Subsurface Conditions

Based on observations within the test pits, subsurface conditions across the site generally comprise a 1.5m to 2.5m thick layer of high plasticity clay in a friable to stiff condition. The high plasticity clays form highly to extremely reactive soils with large shrink swell potential. The Gilgai soils are considered to have been derived from the weathering of mafic and felsic rocks forming the line of hills to the south of the site. The weathering products from these rocks are renowned for their reactive properties and have been transported by alluvial processes to form the extensive plain towards the current day coastline.

Below the clay is a gravelly clay /clayey gravel layer often incorporating cobble sized fragments of the underlying bedrock and possibly represents a “conglomerate” layer formed at the base of the overlaying alluvial deposits. Test pits typically refused on the underlying bedrock which predominantly consisted of a moderately weathered to residual soil, highly fractured rock.

Based on the field investigation, and in view of the similar engineering characteristics of the two surface materials described above, a generalised subsurface profile covering all sites is shown in Table 2.

Table 2 – Generalised Subsurface Profile

Layer/Unit	Typical Depth to Top of Layer (m)	Typical Layer Thickness (m)	Description/Remarks
1	Surface	0 - 1.2	CLAY/SANDY CLAY (CH) medium to high plasticity, red/brown, friable.
2	Surface – 1.2	0.5 – 2.0	CLAYEY GRAVEL/ GRAVELLY CLAY (GC/CH) medium to course grained, brown/dark brown, friable with medium to high plasticity clayey fines.
3	0.5-2.1	Grading into fresh rock at greater depths	WEATHERED ROCK, material has weathered to soil like material comprising sand/gravel/cobbles in a medium to high plasticity clayey matrix, grey/light grey/brown.

The depth to fresh (unweathered) rock could not be ascertained using the backhoe as refusal of the backhoe was encountered on weathered rock.

7.3 Groundwater Levels

Groundwater was not encountered in any of the test pits during the field investigation. The moisture content of the excavated material was typically low.

It should be noted that groundwater levels are subject to variation due to the influence of rainfall, temperature, local drainage and the seasons. There is potential for development of perched groundwater tables following periods of rainfall.

8 RECOMMENDATIONS

8.1 General

It should be noted that the ground encountered by the testpits represent the ground conditions at the location where the tests have been undertaken and as such are an extremely small proportion of the site to be developed. Accordingly, variations to the ground conditions are likely and allowance should be made for variability in the design and construction budgets.

Whilst, to the best of our knowledge, the information contained in this report is accurate at the date of issue, ground conditions including groundwater levels can change in a limited time or due to seasonal fluctuations. For example fill could be added to a site or surface materials removed from a site that will change the thickness of surface materials and depth to the underlying materials. The potential for change in ground conditions should be recognised particularly if this report is used after a protracted delay.

It is also recommended that any plans and/or specifications prepared which relate to the content of this report or amendments to original plans and specifications be reviewed by Coffey to verify that the intent of the recommendations contained in this report are properly reflected in the design.

8.2 Site Classification

Australian Standard AS2870-1996 provides a system of site classification for residential slabs and footing design as follows:

Table 3 - General Definition of Site Classes

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay site, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include: Soft soils, such as soft clays or silts or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

The standard also notes that in areas where deep soil moisture changes are anticipated the classification shall be further defined with the suffix –D.

Based on the encountered soil sub profile described and the results of the laboratory testing the appropriate site classifications for the site is typically Class H-D. Areas not containing Gilgai soils could be upgraded to Class M by placement of 1.0m of controlled sand fill over the clay. Areas containing Gilgai soils could be upgraded to Class M by placement of 1.2m of controlled sand fill over the clay. Structures should not be founded directly on the expansive Gilgai soils. Sand fill used to improve the site classification should be in accordance with Section 8.5.8.

Creating and maintaining a stable moisture content regime in the reactive clay soils will be necessary for satisfactory footing and structure performance. Section 8.2.1 details the necessary steps that should be undertaken to create a stable moisture regime.

As outlined in Section 8.5.6, cohesive soils not identified as Gilgai soils may be used as fill provided they are placed in accordance with the recommendations of Section 8.5.7. However, the locations containing this cohesive fill material will retain a classification of Class H-D.

8.2.1 Protection of Footings from Moisture Changes

It is recommended that clays supporting shallow footings be protected from significant changes in their moisture content regimes. Otherwise, significant ground movements that are not able to be accommodated by the structure may take place.

It is recommended that no large native trees be planted any closer to the footings than their likely mature height. If trees are to be planted close to footings, (and this practice is not recommended) then regular pruning of the trees will limit their root growth and reduce their water intake. The Water Authority of Western Australia provides advice on suitable species to plant in the vicinity of services and foundations and recommends minimum planting distances from structures.

It is recommended that a moisture barrier is placed to a distance of 1.0m around the boundary walls to prevent water ingress around the footings. This barrier could consist of either a concrete path or buried polythene.

Purchasers should be provided with a copy of the CSIRO Information Sheet on foundation maintenance (see Appendix B).

8.2.2 Perching Of Groundwater on Subsoil Profiles

Perching of groundwater within the subsoil profile is likely to occur above very low permeability horizons such as weathered rock and clayey materials. It is recommended that housing Lot development levels be at least 200mm above the top of kerb level. This will assist the shedding of surface water runoff into the drainage system and away from foundations.

8.2.3 Surface Drainage and Run Off

Runoff from upslope of the sites should be collected and diverted away from building structures. The finished surface level of the site should be graded with falls away from structures and their foundations. This will reduce the incidence of water ponding around the footings. A minimum fall of 2% is recommended.

8.3 Flexible Pavement Design

8.3.1 Sub-grade California Bearing Ratio

Estimates of sub-grade California Bearing Ratio (CBR) have been based on regional experience within the area and relationships between plasticity index, linear shrinkage and particle size distribution.

A design subgrade California Bearing Ratio (CBR) of 1.5 and 3 is recommended for gilgai areas and non gilgai areas respectively, provided the subgrade is prepared in accordance with the recommendations contained in Section 8.3.2 and Section 8.5.3.

8.3.2 Pavement Design

The minimum standard pavement profile (generally based on the Shire of Roebourne requirements – 40 year design life) is deemed suitable for this site. The profile consists of:

- Sub-grade compacted to 95% MMDD to a minimum depth of 150mm below the sub-grade surface.
- Sub-base of a minimum 200mm layer of local crusher dust material compacted to 95% MMDD (400mm minimum in Gilgai soils).
- Base-course of a 200mm layer of proprietary produced crushed rock base compacted to 98% MMDD.
- Prime Coat.
- Primerseal.
- 25mm dense grade asphalt.

An alternative to 400mm crusher dust material and 200mm base course layer in Gilgai soil is adding a 200mm layer of lime stabilised Gilgai and reducing the crusher dust thickness to 200mm.

It should be noted that the above pavement is applicable for local traffic access roads for a design life of 20 years with the number of Equivalent Standard Axles in one direction of approximately $1.47x10^6$.

8.3.3 Pavement Materials

Pavement materials should conform to the “Guide to the Selection and Use of Naturally Occurring Materials as Base and Sub Base” jointly published by Main Roads Western Australia and Australian Geomechanics Society (2002).

8.3.4 Requirements for Subsoil Drainage

Subsoil drains should be installed near road drainage outlets to provide a flow path for any water trapped in the base course. It is not expected that subsoil drains would be required in other areas of the project.

It is recommended that depressed road drainage systems, successfully used in other areas of Karratha, be adopted for this project.

8.3.5 Drainage Considerations

As the sub-grade material is likely to contain more than 20% by weight of soil fractions finer than 0.075mm there is a risk that permeability inversion (a high contrast in permeability between the pavement base coarse and sub-grade) will develop and adversely affect the pavement. However, since the total pavement thickness recommended in Section 8.3.2 is greater than 200mm, no special precautions other than the subsoil drains noted in Section 8.3.4 are required.

8.4 Retention Systems

Earth retaining structures should be designed in accordance with the requirements of AS 4678-2002.

8.4.1 Design Parameters

The soil parameters recommended for the design of the retaining walls are presented in Table 4.

Table 4 - Soil Parameters Recommended for Design of Retaining Walls

Soil Type	**Effective Cohesion (c', kPa)**	**Friction Angle, (ϕ' degrees)**	**Unit Weight (γ kN/m^3)**	**Active Pressure K_a**	**At Rest K_o**	**Passive Pressure K_p**
Cohesionless Structural Fill	-	35	18	0.27	0.43	3.69
Low Plasticity Structural Fill	2	20	18	0.49	0.66	2.04

Key:
c' denotes effective cohesion (kPa).
Phi' denotes effective friction angle (degrees)
K_a fully mobilised coefficient of active earth pressure
K_p fully mobilised coefficient of passive earth pressure
K_o at rest earth pressure coefficient

8.5 Earthworks

8.5.1 General

Earthworks should be carried out in accordance with the principles set out in AS3798-2007.

8.5.2 Removal of Topsoil and Uncontrolled Fill

The surface should be stripped of vegetation and grubbed to a depth of nominally 150mm to remove any root mat material. All organic materials and uncontrolled fill, where encountered should be stripped and stockpiled. The organic material is not suitable for use as structural filling. It is only suitable for landscaping purposes.

The site should then be proof compacted as outlined in Section 8.5.3.

It should be noted that ground conditions and particularly groundwater levels may vary with the seasons. As such, site preparation procedures may differ from the above if development proceeds during wet season.

8.5.3 Proof Compaction

Two proof compaction methods have been suggested as outlined below (large scale and individual lot preparation).

It is recommended that either proof compaction method be monitored by an Engineer experienced in earthworks. If proof compaction is to be performed following recent rainfall, the need for proof compaction should be reviewed by a geotechnical engineer.

Large Scale Compaction

After the site has been stripped to the satisfaction of the Supervising Engineer, the site should be proof compacted using a heavy, self-propelled, smooth drum vibrating roller, capable of operating in variable frequency modes. A Dynapac CA 251D, or equivalent, is recommended (subject to the protection of adjacent buildings from damaging ground vibrations).

The following proof compaction procedure is recommended:

- The entire site should be given a minimum of 4 passes with the roller operating in the low frequency/high amplitude mode. A pass should include a minimum overlap of 20%.
- The site should then be given an additional minimum of 4 passes with the roller operating in the high frequency/low amplitude mode.
- All weak areas, which deform excessively under rolling, should be excavated and replaced with approved fill.

Individual Lot Compaction

After the location of each residential site has been stripped to the satisfaction of the Supervising Engineer, the site should be proof compacted using a heavy, vibrating plate compactor. A Dynapac LG300, or equivalent, is recommended (subject to the protection of adjacent buildings from damaging ground vibrations).

The following proof compaction procedure is recommended:

- The entire site should be given a minimum of 4 passes with the compactor.
- All weak areas, which deform excessively under rolling, should be excavated and replaced with clean sand.

It is recommended that the proof compaction be monitored by an Engineer experienced in earthworks.

8.5.4 Temporary Slopes During Earthworks

Excavated slopes should be constructed in accordance with the WA Code of Practice Excavation (2006) and be not steeper than IV:3H (soil) and IV:1.5H (rock).

Fill slopes should not be steeper than IV:3H.

8.5.5 Excavation Characteristics

Excavation characteristics have been assessed based on site observations during fieldwork and experience in similar materials. It is judged that a nominally 20 tonne excavator would be able to excavate most materials to a depth of nominally 2.0m to 3.0m within a majority of the site and a depth of nominally surface to 2.0m in the at the base of the Karratha Hills.

8.5.6 Suitability of Excavated Materials for Use as Fill

Cohesive soils excavated from site may be used as fill provided it is placed and compacted in layers not exceeding 0.25m thickness and compacted in accordance with the requirement outlined in Section 8.5.7. However, this is not recommended due to the difficulty of obtaining and maintaining adequate moisture content. Surface soils that display Gilgai characteristics (see Figure 2) should not be used as structural fill.

The clayey fill should be moisture conditioned to within 2% of optimum moisture content. Placement of cohesive fill should be relatively continuous. If a break of longer than say 2 hours occurs, the exposed surface should be moisture conditioned prior to the placement of further fill.

Topsoil may be used as fill in landscape areas but should not be used as structural fill

8.5.7 Compaction Requirements

Earthworks should be compacted to achieve the density requirements set out in Table 5.

Table 5 - Compaction Requirements

Item	Application	Compaction Criteria	
		Minimum density ratio (Cohesive soils) (See Note 1)	Minimum density index (Cohesionless soils)
1	Residential – lot fill, house sites	95% std	65%
2	Commercial – fills to support minor loadings, including floor loadings of up to 20 kPa and isolated pad or strip footings to 100 kPa	98% std	70%

Notes

1. Nuclear Density Meter tests and Laboratory Compaction tests should be performed (on a one to one ratio), to ensure cohesive fill is adequately compacted
2. Gilgai soils should not be compacted any more than 95% of the standard MDD. Compaction above 95% may result in increased soil movement due to moisture changes.

8.5.8 Cohesionless Structural Filling

For this study, cohesionless structural fill has been defined as fill satisfying the following criteria:

- Containing less than 5% by weight of soil fractions finer than 0.075mm.
- Having a plasticity index equal to 0%, (i.e. non plastic).
- The sand shall be clean, cohesionless, free draining and free of all silty, organic or any other deleterious inclusions.
- A minimum soaked CBR of 12 if used as pavement subgrade.

It is recommended that a 25 kg representative sample of the proposed structural fill be delivered to a NATA registered soils laboratory for testing at least one week before approval is required.

8.5.9 Low Plasticity Structural Fill

For this study, low plasticity structural fill has been defined as fill satisfying the following criteria:

- Containing less than 20% by weight of soil fraction finer than 0.075mm.
- Having a Liquid Limit of less than 15%,
- The fill shall be clean and free of all organic or any other deleterious inclusions.

8.6 Construction Considerations

8.6.1 General

There are a number of activities that must be undertaken during construction to ensure compliance with design and to ensure the smooth running of the project. The following activities should be carried out during the contract.

8.6.2 Site Drainage and Erosion Control

Runoff from upslope of the site should be collected and diverted away from the structures. The finished surface level of the site should be graded with falls away from the structures and their foundations. This will minimise the incidence of water ponding around the footings.

A minimum fall of 2% is recommended.

Erosion control measures as set out in the “Erosion and Sediment Control Manual for the Darling Range, Perth Western Australia (2002)” should be adopted.

8.6.3 Preparation of Footing Bases in Low Plasticity Structural Fill

For this study, low plasticity sand fill has been defined as fill satisfying the following criteria:

- Containing less than 20% by weight of soil fraction finer than 0.075mm.
- Having a Liquid Limit of less than 15%,
- The material shall be clean and free of all organic or any other deleterious inclusions.

All material disturbed in the bases of footing excavations should be compacted. Any uncontrolled fill must be excavated and replaced.

To facilitate compaction, the groundwater should not be any closer than 1m to the base of the footing excavation.

8.6.4 Preparation of Footing Bases in Cohesive Soils

The clayey soils are sensitive to trafficking and will lose a significant proportion of their design strength if they are disturbed and remoulded. Excavation techniques involving minimal trafficking and the use of light equipment for final trimming are recommended for these soil types. Any uncontrolled fill must be excavated and replaced with fill as described in Section 8.5.8 and 8.5.9.

Excavations for footings should be to the neat dimensions of the footing, with footings poured against the sides of the excavation. The use of framework and backfilling around footings is not recommended for structures founded in cohesive soils.

It is recommended that in situ strength testing including pocket penetrometer and shear vane testing be carried out in the cohesive soils exposed in the bases of the footing excavations to check that no disturbed soils are present.

A minimum of 6 tests are recommended for each footing base. The tests should be carried out by a Geotechnical Engineer.

The minimum result from the pocket penetrometer should be 100 kPa.

The bases of footing excavations in cohesive soils should be blinded as soon as practically possible after their testing and approval. A minimum thickness of 50mm of lean mix concrete (min. $F'_c = 10$ MPa) would suffice. Under no circumstances should the bases of excavations be left exposed overnight.

It is important that the exposure of the clays to climatic drying/wetting be minimised to avoid significant moisture content changes and subsequent foundation movements during moisture equilibration. Otherwise, foundation movements will be greater than allowed for in design.

9 IMPORTANT INFORMATION ABOUT YOUR COFFEY REPORT

The reader’s attention is drawn to the important information about this report which follows the main text.

10 REFERENCES

The following standards and references were used in the preparation of this report.

AS 1289 Method of Testing Soils For Engineering Purposes.

AS 1726-1993 SAA Geotechnical Site Investigations.

AS 2870-1996 Residential Slabs and Footings.

AS 3798-2007 Guidelines on Earthworks for Commercial and Residential Developments

AS 4678-2002 Earth Retaining Structures

Institute of Public Works Engineering Australia : Western Australia Division (2006). "Policy Note: Pavement Profiles in Residential Streets".

Kay J N (1990) "Use of the Liquid Limit for Characterisation of Expansive Soil Sites" CE 32 N0 3 IE Aust

Main Roads Western Australia (1998)"Procedure for Thickness Design of Flexible Pavements". Engineering Road Note No. 9 (1988),

Main Roads Western Australia and Australian Geomechanics Society (2002) " A Guide to the Selection and Use of Naturally Occurring Materials as Base and Sub Base in Roads in Western Australia"

NAVFAC (1975) "Soil Mechanics Manual".

WA Code of Practice Excavation (2006)

Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Important information about your **Coffey** Report

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.
Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

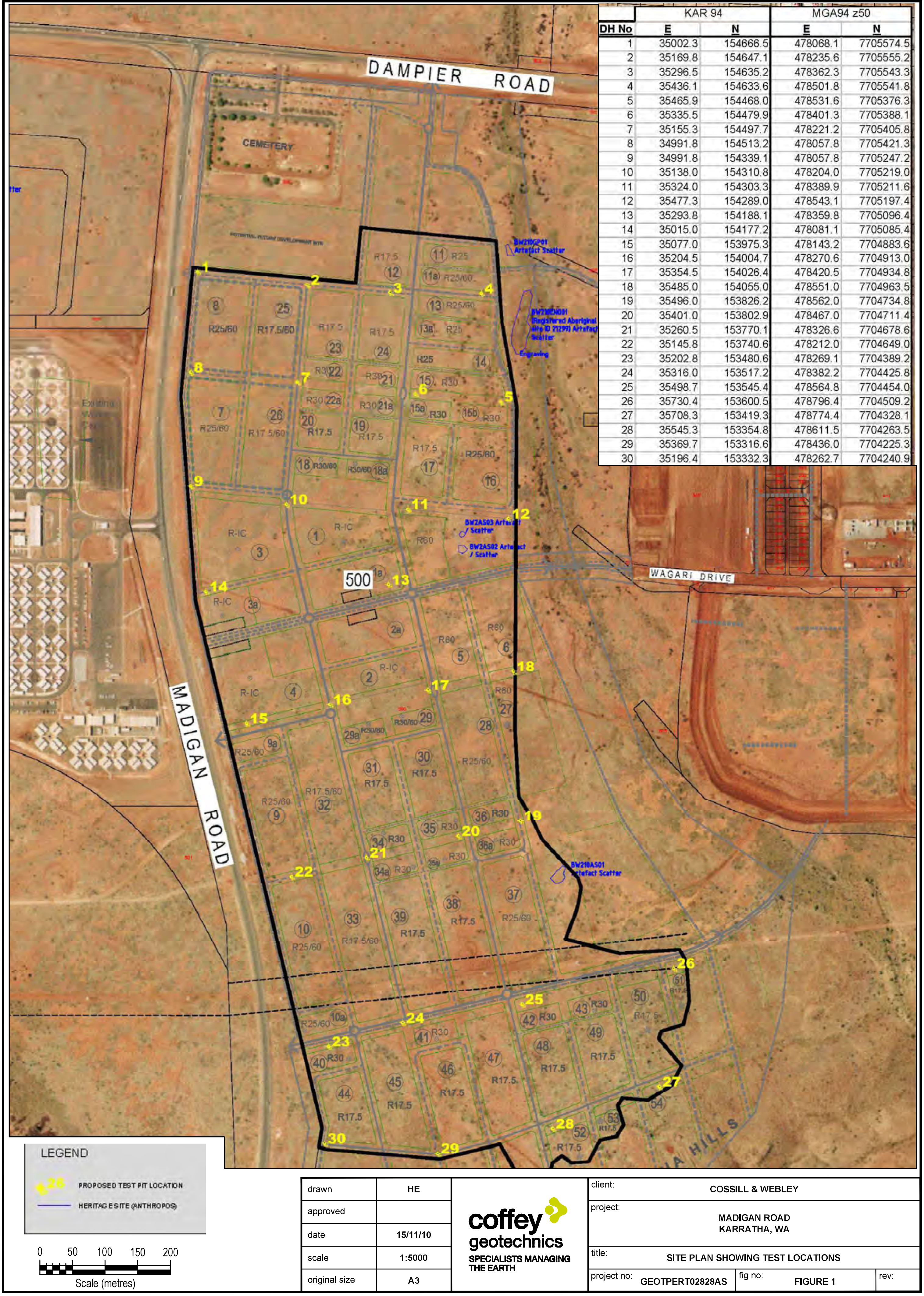
Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

---

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Figures



	KAR 94		MGA94 z50	
DH No	E	N	E	N
1	35002.3	154666.5	478068.1	7705574.5
2	35169.8	154647.1	478235.6	7705555.2
3	35296.5	154635.2	478362.3	7705543.3
4	35436.1	154633.6	478501.8	7705541.8
5	35465.9	154468.0	478531.6	7705376.3
6	35335.5	154479.9	478401.3	7705388.1
7	35155.3	154497.7	478221.2	7705405.8
8	34991.8	154513.2	478057.8	7705421.3
9	34991.8	154339.1	478057.8	7705247.2
10	35138.0	154310.8	478204.0	7705219.0
11	35324.0	154303.3	478389.9	7705211.6
12	35477.3	154289.0	478543.1	7705197.4
13	35293.8	154188.1	478359.8	7705096.4
14	35015.0	154177.2	478081.1	7705085.4
15	35077.0	153975.3	478143.2	7704883.6
16	35204.5	154004.7	478270.6	7704913.0
17	35354.5	154026.4	478420.5	7704934.8
18	35485.0	154055.0	478551.0	7704963.5
19	35496.0	153826.2	478562.0	7704734.8
20	35401.0	153802.9	478467.0	7704711.4
21	35260.5	153770.1	478326.6	7704678.6
22	35145.8	153740.6	478212.0	7704649.0
23	35202.8	153480.6	478269.1	7704389.2
24	35316.0	153517.2	478382.2	7704425.8
25	35498.7	153545.4	478564.8	7704454.0
26	35730.4	153600.5	478796.4	7704509.2
27	35708.3	153419.3	478774.4	7704328.1
28	35545.3	153354.8	478611.5	7704263.5
29	35369.7	153316.6	478436.0	7704225.3
30	35196.4	153332.3	478262.7	7704240.9

drawn	HE
approved	
date	15/11/10
scale	1:5000
original size	A3

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client: COSSILL & WEBLEY

project: MADIGAN ROAD
KARRATHA, WA

title: SITE PLAN SHOWING TEST LOCATIONS

project no: GEOTPERT02828AS
fig no: FIGURE 1
rev:

EXAMPLE OF GILGAI SOILS

drawn	HE	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	15/11/10					
scale	NOT TO SCALE		title:	EXAMPLE OF GILGAI SOILS		
original size	A4		project no:	GEOTPERT02828AS	fig no: FIGURE 2	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GP02828AS Figure PHOTOS.dwg

LOCALISED ROCK OUTCROPS WITHIN THE SITE

drawn	HE	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	15/11/10				
scale	NOT TO SCALE		title:	LOCALISED ROCK OUTCROPS WITHIN THE SITE	
original size	A4		project no: GEOTPERT02828AS	fig no: FIGURE 3	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GP02828AS Figure PHOTOS.dwg

SURFICIAL ROCK AT THE BASE OF KARRATHA HILLS

drawn	HE	**coffey geotechnics** SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	15/11/10			
scale	NOT TO SCALE		title:	SURFICIAL ROCK AT THE BASE OF KARRATHA HILLS
original size	A4		project no: GEOTPERT02828AS	fig no: FIGURE 4 rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GP02828AS Figure PHOTOS.dwg

Appendix A

Results of Field Investigation

Soil Description Explanation Sheet (1 of 2)

DEFINITION:

In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH s_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	–	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: <5% Fine grained soils: <15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 - 12% Fine grained soils: 15 - 30%

SOIL STRUCTURE

ZONING		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

Soil Description Explanation Sheet (2 of 2)

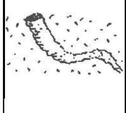
SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)						**USC**	**PRIMARY NAME**
COARSE GRAINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.		GW	GRAVEL
				Predominantly one size or a range of sizes with more intermediate sizes missing.		GP	GRAVEL
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)		GM	SILTY GRAVEL
				Plastic fines (for identification procedures see CL below)		GC	CLAYEY GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes		SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing.		SP	SAND
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).		SM	SILTY SAND
				Plastic fines (for identification procedures see CL below).		SC	CLAYEY SAND
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm			IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.				
			DRY STRENGTH	**DILATANCY**	**TOUGHNESS**		
		SILTS & CLAYS Liquid limit less than 50	None to Low	Quick to slow	None	ML	SILT
			Medium to High	None	Medium	CL	CLAY
			Low to medium	Slow to very slow	Low	OL	ORGANIC SILT
		SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium	MH	SILT
			High	None	High	CH	CLAY
			Medium to High	None	Low to medium	OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS			Readily identified by colour, odour, spongy feel and frequently by fibrous texture.			Pt	PEAT

- Low plasticity – Liquid Limit W_L less than 35%.
- Medium plasticity – W_L between 35% and 50%.

COMMON DEFECTS IN SOIL

TERM	**DEFINITION**	**DIAGRAM**
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	A surface or crack across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	**DEFINITION**	**DIAGRAM**
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.	

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP01**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478078.1, N: 7705574.5 (50 MGA94)
Surface Elevation : 15.55m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.10m long 2.10m wide

excavation information / material substance

depth (m)	RL (m)	method	support	ground water	samples & field tests	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	structure and other observations
0.0	15.5	BH	N	Not Observed		CI	**GRAVELLY CLAY**, medium plasticity, brown red; gravel, fine to coarse grained, sub-angular, friable; with some sand, coarse grained	D		Sub-angular to sub-rounded gravel at ground surface, fine to coarse grained
					HP >500kPa					
0.5	15.0				HP >500kPa					
							....0.6m, becoming clayey gravel			
					HP >500kPa					
1.0	14.5				HP >500kPa					
1.5	14.0						Grading into			
							WEATHERED ROCK, fine grained; residual soil to highly weathered; rock is highly fractured; low to very low strength	D		
2.0	13.5									
							....2.3m, rock fragments becoming low to medium strength			
2.5	13.0				B					
2.90							EXCAVATION TP01 TERMINATED AT 2.90 m			
3.0	12.5									
3.5	12.0									

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
VE E F H VH
minor resitance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP02*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*19/10/10*
Date completed	*19/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*

Principal :

Project : *Madigan Road*

Location : *Karratha*

Position : E: 478235.6, N: 7705555.2 (50 MGA94)

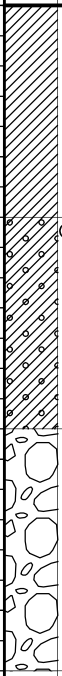
Surface Elevation : 15.95m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.20m long 0.70m wide

excavation information / material substance



depth (m)	RL (m)	method	support	ground water	samples & field tests	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	structure and other observations
0.0 – 0.7	15.95 – 15.25	BH	N	Not Observed	HP >500kPa HP >500kPa	CI	**SANDY CLAY**, medium plasticity, brown; sand, fine to coarse grained; trace of gravel, fine to medium grained	D	H	Trace rootlets in top 300mm
0.7 – 1.4	15.25 – 14.55				B HP >500kPa HP =500kPa	CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled pale brown; gravel, fine to medium grained Grading into	D	H	
1.4 – 2.2	14.55 – 13.75						**WEATHERED ROCK**, fine grained; highly weathered; rock is highly fractured; some medium to high strength clasts within layer			
2.20							Refusal on weathered rock EXCAVATION TP02 TERMINATED AT 2.20 m			

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:53

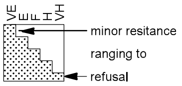
method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration



water

10 Oct., 73 Water Level on Date shown

▶ water inflow

◀ water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**TP03**
Sheet No.	1 of 1
Project No.	**GEOTPERT02828AS**
Date excavated	**19/10/10**
Date completed	**19/10/10**
Logged by :	**PCW**
Checked by :	

Client : **Cossill & Webley Consulting Engineers**

Principal :

Project : **Madigan Road**

Location : **Karratha**

Position : E: 478362.3, N: 7705543.3 (50 MGA94)

Surface Elevation : 15.44m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions :

excavation information / material substance

Method: BH (0.0 – 2.5 m); penetration: VE E F H VH; support: N; ground water: Not Observed

depth (m)	RL (m)	samples & field tests	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
0.0			▨	CH	**CLAY**, high plasticity, brown / dark brown; with some sand, medium to coarse grained	D	H		
		HP >500kPa						×	
	15.0	HP >500kPa						×	
0.5					....0.5m, trace gravel				
		HP >500kPa						×	
					....0.8m, gravel content increasing	D			
	14.5	HP >500kPa						×	
1.0		B		GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, brown; clay, high plasticity				
						D			
	14.0								
1.5									
	13.5								
2.0					**WEATHERED ROCK**, fine grained; residual soil to moderately weathered, rock is highly fractured, grey/white, recovered as soil/gravel/cobbles	D			
	13.0								
2.5					Refusal on weathered rock EXCAVATION TP03 TERMINATED AT 2.50 m				
	12.5								
3.0									
	12.0								
3.5									
	11.5								

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH — minor resitance, ranging to, refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP04**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478501.8, N: 7705541.8 (50 MGA94)
Surface Elevation : 15.6m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.80m long 0.70m wide

excavation information / **material substance**

method	penetration VE E F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed		15.6	0.0	CI	**CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained	D	H		Trace rootlets in top 300mm
				HP >500kPa								
				HP >500kPa	15.0	0.5		....0.5m, trace gravel				
				HP >500kPa								
				HP >500kPa	14.5	1.0	GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown; gravel, fine to coarse grained Grading into	D - M	H		
					14.0	1.5		**WEATHERED ROCK**, fine grained; residual soil to highly weathered, dark grey/green; localised pockets of gravelly clay				
					13.5	2.0						
					13.0	2.5		Refusal on weathered rock EXCAVATION TP04 TERMINATED AT 2.50 m				
					12.5	3.0						
					12.0	3.5						

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH
minor resitance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP05*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*19/10/10*
Date completed	*19/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*

Principal :

Project : *Madigan Road*

Location : *Karratha*

Position : E: 478531.6, N: 7705376.3 (50 MGA94)

Surface Elevation : 16.31m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 5.20m long 0.70m wide

excavation information / material substance

method	penetration	support	ground water	samples & field tests	depth (m)	RL (m)	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and other observations
BH (0.0–2.90 m)		N (0.0–2.90 m)	Not Observed	HP >500kPa	0.0	16.31	CI	**CLAY / SANDY CLAY**, medium plasticity, brown; friable; with some sand; trace of gravel, fine grained	D	H	>400	Rootlets/tree roots in top 0.3m
				HP >500kPa				....0.4m, trace of gravel, fine to coarse grained			>400	
				HP >500kPa			GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown; gravel, fine to coarse grained	D	H	>400	
				HP >500kPa				Grading into			>400	
				B		15.0		**WEATHERED ROCK**, fine grained, grey cream; residual soil to highly weathered; localised areas of gravelly clay/clayey gravel, cobbles typically low to very low strength	D			
					2.90			Test depth reached EXCAVATION TP05 TERMINATED AT 2.90 m				

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

RL scale (m): 16.0, 15.5, 15.0, 14.5, 14.0, 13.5, 13.0, 12.5

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH

minor resitance

ranging to

refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50 -	Undisturbed Sample 50mm diameter
U63 -	Undisturbed Sample 63mm diameter
D -	Disturbed Sample
B -	Bulk Disturbed Sample
ES -	Environmental Sample
MC -	Moisture Content
HP -	Hand Penetrometer (UCS kPa)
VS -	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT -	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D -	Dry
M -	Moist
W -	Wet
W_P -	Plastic Limit
W_L -	Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

Engineering Log - Excavation

Excavation No.	*TP06*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*19/10/10*
Date completed	*19/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478401.3, N: 7705388.1 (50 MGA94)

Surface Elevation : 16.27m (AHD)

Equipment type : Backhoe

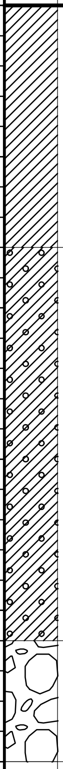
Method :

Excavation dimensions : 4.30m long 0.70m wide

excavation information

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)
BH (0.0–2.5 m)		N	Not Observed			0.0
				HP >500kPa	16.0	
				HP >500kPa		0.5
				HP >500kPa	15.5	
				HP >500kPa		1.0
					15.0	
						1.5
					14.5	
						2.0
				B	14.0	
						2.5
					13.5	
						3.0
					13.0	
						3.5
					12.5	

material substance



classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
CI	**CLAY / SANDY CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained ....0.4m, with some gravel	D	H	✕ ✕ ✕ ✕	Up to 0.4m trace of roots
GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled cream grey; gravel, sub-angular,; trace of cobbles Grading into	D	H		
	WEATHERED ROCK, fine grained, grey cream; residual soil to moderately weathered; localised areas of clayey gravel				
	Refusal on weathered rock EXCAVATION TP06 TERMINATED AT 2.50 m				

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH — minor resitance ranging to refusal

water

- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP07**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478221.2, N: 7705405.8 (50 MGA94)
Surface Elevation : 16.06m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.70m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed		16.0	0.0		CI	**CLAY**, medium plasticity, brown; friable; trace of sand, fine to coarse grained; trace of gravel, fine to medium grained	D	H		Trace of rootlets in top 0.3m
				HP >500kPa								×	
				HP >500kPa	15.5	0.5						×	
								GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled grey/off white; gravel, fine to coarse grained, angular; trace of cobbles	D	H		
				HP >500kPa								×	
				HP >500kPa	15.0	1.0						×	
									....becoming clayey cobbles				
					14.5	1.5			Refusal weathered rock, hard digging EXCAVATION TP07 TERMINATED AT 1.50 m				
					14.0	2.0							
					13.5	2.5							
					13.0	3.0							
					12.5	3.5							

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH
minor resitance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP08**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478067.8, N: 7705421.3 (50 MGA94)
Surface Elevation : 15.93m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.60m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed			0.0		GC	**CLAYEY GRAVEL / CLAYEY COBBLES**, fine to coarse grained, brown mottled grey/off white; friable; clay, medium plasticity; cobbles are fine to medium grained; trace rootlets in top 0.3m	D	H		
				HP >500kPa								×	
				HP >500kPa	15.5	0.5			....0.5m, cobbles increasing			×	
				HP >500kPa								×	
				HP >500kPa	15.0	1.0						×	
					14.5	1.5							
				B									
						1.70			Refusal on cemented layer EXCAVATION TP08 TERMINATED AT 1.70 m				
					14.0	2.0							
					13.5	2.5							
					13.0	3.0							
					12.5	3.5							
					12.0								

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH
minor resitance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. *TP09*
Sheet No. 1 of 1
Project No. *GEOTPERT02828AS*

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Date excavated *19/10/10*
Date completed *19/10/10*
Logged by : *PCW*
Checked by :

Position : E: 478067.8, N: 7705247.2 (50 MGA94)
Surface Elevation : 16.28m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions :

excavation information							material substance						
method	penetration VE E F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed			0.0		CI	**CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained	D	H		
				HP >500kPa	16.0								
				HP >500kPa		0.5							
									....0.6m, trace gravels increasing with depth				
				HP >500kPa	15.5								
				HP >500kPa		1.0							
					15.0			GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, clay, medium plasticity	D	H		
						1.5							
					14.5								
									Refusal on cemented layer, hard digging EXCAVATION TP09 TERMINATED AT 1.90 m				
						2.0							
					14.0								
						2.5							
					13.5								
						3.0							
					13.0								
						3.5							
					12.5								

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
VE E F H VH
minor resitance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP10**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Date excavated **19/10/10**
Date completed **19/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478204, N: 7705219 (50 MGA94)
Surface Elevation : 16.78m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.80m long 0.70m wide

excavation information / material substance

method	penetration VE E F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed	HP >500kPa HP >500kPa HP >500kPa HP >500kPa	16.5 16.0	0.0 0.5 1.0	▨	CI	**CLAY**, medium plasticity, brown; friable; trace of sand, fine to coarse grained; trace of gravel, fine grained; trace rootlets in top 300mm	D	H	× × × ×	
					15.5 15.0	1.5		GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, brown mottled cream/grey: clay, medium to high plasticity Grading into	D	H		
				ROCK SAMPLE	14.5	2.0			**WEATHERED ROCK**, fine grained, grey/green; residual soil to moderately weathered; highly fractured	D			
					14.0 13.5 13.0	2.5 3.0 3.5			Refusal, hard digging EXCAVATION TP10 TERMINATED AT 2.40 m				

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
VE E F H VH
minor resitance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Engineering Log - Excavation

Excavation No.	*TP11*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*

Principal :

Project : *Madigan Road*

Location : *Karratha*

Position : E: 478389.9, N: 7705211.6 (50 MGA94)

Surface Elevation : 16.95m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.60m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	HP >500kPa HP >500kPa HP >500kPa HP >500kPa	16.5 16.0	0.0 0.5 1.0		CI	**CLAY**, medium plasticity, brown; friable; trace of gravel; trace of rootlets in top 300mm	D	H	×	
					15.5	1.5		CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled off white; gravel, fine to coarse grained, sub-angular Grading into	D	H	×	
					15.0 14.5 14.0	2.0 2.5			**WEATHERED ROCK**, residual soil to highly weathered; rock is extremely low to medium strength, pale grey/dark grey, residual soil is low plasticity clayey sand	D	H		
					13.5 13.0	3.0 3.5			Test depth reached EXCAVATION TP11 TERMINATED AT 3.00 m				

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:53

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH

minor resitance

ranging to

refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP12**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Date excavated ***20/10/10***
Date completed ***20/10/10***
Logged by : ***PCW***
Checked by :

Position : E: 478543.1, N: 7705197.4 (50 MGA94)
Surface Elevation : 16.82m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.20m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	B		0.0	CI	**SANDY CLAY**, medium plasticity, brown / dark brown; friable; sand, fine to coarse grained; trace of gravel, increasing with depth from surface; trace rootlets in top 300mm; hard	D - M	H		
				HP >500kPa							×	
					16.5							
				HP >500kPa		0.5					×	
				HP >500kPa							×	
					16.0							
				HP >500kPa		1.0					×	
								....1.1m, becoming gravelly clay, pockets of weathered rock	D			
					15.5							
						1.5						
					15.0			Grading into				
								WEATHERED ROCK, residual soil to slightly weathered; extremely low to medium strength rock, pale grey/grey	D	H		
						2.0						
					14.5							
						2.5						
					14.0							
						3.0		Test depth reached EXCAVATION TP12 TERMINATED AT 3.00 m				
					13.5							
						3.5						
					13.0							

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:53

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH
minor resitance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP13*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478359.8, N: 7705096.4 (50 MGA94)   Surface Elevation : 17.56m (AHD)

Equipment type : Backhoe   Method :   Excavation dimensions : 4.60m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	B	17.5	0.0		CI	**GRAVEL /CLAYEY GRAVEL**, fine to coarse grained, brown mottled pale yellow white; medium plasticity; friable	D	H		
				HP >500kPa								×	
				HP >500kPa	17.0	0.5			....0.5m, trace cobbles, becoming clayey gravel			×	
				HP >500kPa								×	
				HP >500kPa	16.5	1.0						×	
									Grading into				
					16.0	1.5			**WEATHERED ROCK**, fine grained; residual soil is slightly weathered, highly fractured, pale grey/green	D	H		
					15.5	2.0							
									Refusal on weathered rock EXCAVATION TP13 TERMINATED AT 2.30 m				
					15.0	2.5							
					14.5	3.0							
					14.0	3.5							

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:53

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH

minor resitance
ranging to
refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP14**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478091.1, N: 7705085.4 (50 MGA94)
Surface Elevation : 16.69m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.80m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	HP >500kPa HP >500kPa HP >500kPa HP >500kPa	16.69	0.0	▨	CI	**CLAY**, medium plasticity, brown / dark brown; friable; with some gravel, fine to medium grained; trace rootlets in top 300mm ....0.3m, trace cobbles ....0.5m, becoming clayey gravel, medium plasticity; gravel is fine to coarse grained; with some cobbles, brown/dark brown mottled off white	D	H	× × × ×	
				B		1.0	⊘	GC	**CLAYEY GRAVEL**, fine to coarse grained, brown mottled off white; clay, medium plasticity; gravel and cobble content increasing with depth	D	H		
						1.70			Refusal on cemented gravel layer, hard digging EXCAVATION TP14 TERMINATED AT 1.70 m				

RL (m) scale: 16.5, 16.0, 15.5, 15.0, 14.5, 14.0, 13.5, 13.0
depth (m) scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration
VE E F H VH
minor resitance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	***TP15***
Sheet No.	1 of 1
Project No.	***GEOTPERT02828AS***
Date excavated	***20/10/10***
Date completed	***20/10/10***
Logged by :	***PCW***
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478143.2, N: 7704883.6 (50 MGA94)

Surface Elevation : 17.7m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.80m long 0.70m wide

excavation information

method	penetration	support	ground water	samples & field tests	RL (m)	depth (m)
BH	VE F / H (0.0–1.0), VE F H (1.0–3.0)	N	Not Observed	HP >500kPa	17.5	0.0
				HP >500kPa		0.5
				HP >500kPa	17.0	
				B		
				HP >500kPa		1.0
					16.5	
						1.5
					16.0	
						2.0
					15.5	
						2.5
					15.0	
						3.0
					14.5	
						3.5
					14.0	

material substance

depth (m)	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
0.0	CI	**SANDY CLAY**, medium plasticity, brown / dark brown; trace of gravel, fine grained; trace rootlets in top 300mm	D	H	×, ×, ×	
0.8	CL-CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, low to medium plasticity, gravel, fine to coarse grained			×	
1.0		....1.8m, grading into rock, moderately weathered to residual soil, pale grey	D	H		
2.1		**WEATHERED ROCK**, fine grained, pale grey; residual soil to moderately weathered, cobbles up to moderate strength	D	H		
3.0		Test depth reached EXCAVATION TP15 TERMINATED AT 3.00 m				

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH — minor resitance ranging to refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

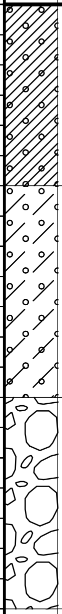
Excavation No. **TP16**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478270.6, N: 7704913 (50 MGA94)
Surface Elevation : 18.02m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.60m long 0.70m wide

excavation information / material substance



method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	HP >500kPa	18.0	0.0	CI	**GRAVELLY CLAY**, medium plasticity, brown mottled off white; gravel, fine to medium grained; friable; trace rootlets and tree roots in top 0.4m, gravel content increasing with depth	D	H	×	
				HP >500kPa	17.5	0.5					×	
				HP >500kPa HP >500kPa			GC	**CLAYEY GRAVEL**, fine to coarse grained, brown mottled off white; clay, medium plasticity; gravel is typically granite	D	H	× ×	
					17.0	1.0						
								WEATHERED ROCK, fine grained, pale grey green; residual soil to moderately weathered, rock strength is extremely low to medium, recovered as cobbles	D			
					16.5	1.5						
					16.0	2.0		Refusal on weathered rock, hard digging EXCAVATION TP16 TERMINATED AT 2.00 m				
					15.5	2.5						
					15.0	3.0						
					14.5	3.5						

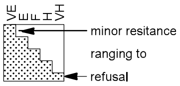
method

N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support

N No Support
T Timbering

penetration



water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests

U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP17*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*

Principal :

Project : *Madigan Road*

Location : *Karratha*

Position : E: 478420.5, N: 7704934.8 (50 MGA94)

Surface Elevation : 18.29m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.30m long 0.70m wide

excavation information							material substance						
method	penetration VE E F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetro-meter kPa 100 200 300 400	structure and other observations
BH		N	Not Observed	B HP >500kPa HP >500kPa HP >500kPa HP >500kPa	18.0 17.5	0.0 0.5 1.0		CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown / dark brown; gravel, fine to coarse grained; friable; trace of cobbles, fine grained	D	H	× × × ×	
					17.0 16.5	1.5		GC	**CLAYEY GRAVEL / CLAYEY COBBLES**, fine to coarse grained, cobbles are fine to medium grained, brown mottled off white/grey	D	H		
					16.0 15.5 15.0 14.5	2.0 2.5 3.0 3.5			Refusal on weathered rock/quartz layer EXCAVATION TP17 TERMINATED AT 2.00 m				

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH

minor resitance

ranging to

refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP18**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

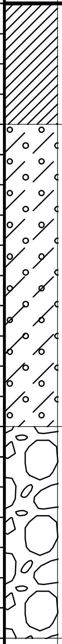
Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478551, N: 7704963.5 (50 MGA94) Surface Elevation : 17.89m (AHD)
Equipment type : Backhoe Method : Excavation dimensions : 4.70m long 0.70m wide

excavation information / material substance

Method: BH (0.0 – 2.10 m); Support: N; Ground water: Not Observed

depth (m)	RL (m)	samples & field tests	classification symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)
0.0 – 0.4	17.89 – 17.5	HP >500kPa	CI	**CLAY**, medium plasticity, brown / dark brown; friable; with some gravel; trace of sand, corase grained; hard	D	H	×
0.4 – 1.4	17.5 – 16.5	HP >500kPa HP >500kPa B HP >500kPa	GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, clay, medium plasticity; trace cobbles; cobble content increasing with depth	D	H	× × ×
1.4 – 2.1	16.5 – 15.79			**WEATHERED ROCK**, fine grained; residual soil to moderately weathered; recovered as gravel and cobbles, cobbles fine to medium grained, low to medium strength			
2.1				Refusal on cemented layer, hard digging EXCAVATION TP18 TERMINATED AT 2.10 m			



structure and other observations

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
VE E F H VH
minor resitance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	***TP19***
Sheet No.	1 of 1
Project No.	***GEOTPERT02828AS***
Date excavated	***20/10/10***
Date completed	***20/10/10***
Logged by :	***PCW***
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478562, N: 7704734.8 (50 MGA94)   Surface Elevation : 19.5m (AHD)

Equipment type : Backhoe   Method :   Excavation dimensions : 5.00m long 0.70m wide

excavation information							material substance						
method	penetration VE E F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed		19.5	0.0		SC	**CLAYEY SAND**, medium plasticity, brown / dark brown; clay, friable; with some gravel, fine to medium grained	D	H		
				HP >500kPa								×	
				B HP >500kPa	19.0	0.5		GP	**SANDY GRAVEL**, fine to medium grained, pale brown / brown; with some fines, low to medium plasticity; strongly cemented; trace of quartz flakes	D	VD	×	
				HP >500kPa								×	
				HP >500kPa	18.5	1.0						×	
									....1.2m, becoming highly weathered rock, recovered as residual soil/cobbles				
					18.0	1.5							
							Qz		**WEATHERED ROCK**, fine grained; residual soil to slightly weathered, low to high strength, brown/white/grey	D			
					17.5	2.0	Qz						
					17.0	2.5	Qz						
									Refusal on weathered rock, hard digging EXCAVATION TP19 TERMINATED AT 2.60 m				
					16.5	3.0							
					16.0	3.5							

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

VE E F H VH
- minor resitance
- ranging to
- refusal

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP20*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*

Principal :

Project : *Madigan Road*

Location : *Karratha*

Position : E: 478467, N: 7704711.4 (50 MGA94)

Surface Elevation : 19.76m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 5.00m long 0.70m wide

excavation information / material substance

method	penetration VE E F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
B		N	Not Observed	HP >500kPa HP >500kPa HP >500kPa	19.5 19.0	0.0 0.5	▨	CI	**CLAY**, medium plasticity, brown / dark brown; friable; trace of gravel and rootlets in top 0.3m; gravel content increasing with depth	D	H	× × ×	
				HP >500kPa	18.5	1.0			**WEATHERED ROCK**, fine grained; residual soil to highly weathered, grey/pale grey/brown; rock is extremely low to medium strength			×	
					18.0 17.5 17.0 16.5 16.0	1.5 2.0 2.5 3.0 3.5			Refusal on weathered rock layer EXCAVATION TP20 TERMINATED AT 1.40 m				

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH

minor resitance

ranging to

refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP21*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*

Principal :

Project : *Madigan Road*

Location : *Karratha*

Position : E: 478326.6, N: 7704678.6 (50 MGA94)

Surface Elevation : 19.66m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.70m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	HP >500kPa HP >500kPa HP >500kPa HP >500kPa	19.5 19.0	0.0 0.5	CI	**GRAVELLY CLAY**, medium plasticity, brown / dark brown; gravel, fine to coarse grained; friable ....0.4m, gravel content increasing; trace cobbles and coarse gravel Grading to	D	H	× × × ×	
				B	18.5 18.0 17.5	1.0 1.5 2.0		**WEATHERED ROCK**, fine grained, grey/pale grey; residual soil to slightly weathered; rock is very low to medium strength	D			
					17.0 16.5 16.0	2.5 3.0 3.5		Refusal, hard digging on weathered rock EXCAVATION TP21 TERMINATED AT 2.30 m				

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH

minor resitance

ranging to

refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	- Undisturbed Sample 50mm diameter
U63	- Undisturbed Sample 63mm diameter
D	- Disturbed Sample
B	- Bulk Disturbed Sample
ES	- Environmental Sample
MC	- Moisture Content
HP	- Hand Penetrometer (UCS kPa)
VS	- Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	- Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	- Dry
M	- Moist
W	- Wet
W_P	- Plastic Limit
W_L	- Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP22*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

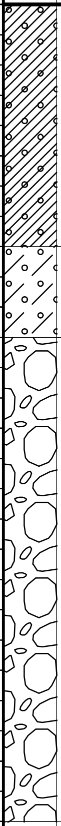
Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478212, N: 7704649 (50 MGA94)   Surface Elevation : 19.28m (AHD)

Equipment type : Backhoe   Method :   Excavation dimensions :

excavation information | **material substance**

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	HP >500kPa HP >500kPa B HP >500kPa	19.0 18.5	0.0 0.5		CI	**CLAYEY GRAVEL**, fine to coarse grained, brown / dark brown; clay, low to medium plasticity; friable ....0.7m, gravel content increasing with depth, trace cobbles	D	H	✕ ✕ ✕	
				HP >500kPa		1.0		GC	**CLAYEY GRAVEL / CLAYEY COBBLES**, fine to coarse grained, clay, low to medium plasticity; cobbles are fine to medium grained, brown mottled grey; possibly highly weathered rock	D	H	✕	
					18.0 17.5 17.0	1.5 2.0 2.5			**WEATHERED ROCK**, fine grained; residual soil to slightly weathered, highly fractured; recovered as soil and gravel/cobbles, cobbles are angular and low to high strength, grey	D			
					16.5 16.0 15.5	3.0 3.5			Refusal on weathered rock, hard digging EXCAVATION TP22 TERMINATED AT 2.70 m				

method
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support
- N No Support
- T Timbering

penetration

VE E F H VH
- minor resitance
- ranging to
- refusal

water
- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests
- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture
- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP23*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478269.1, N: 7704389.2 (50 MGA94)

Surface Elevation : 21.29m (AHD)

Equipment type : Backhoe

Method :

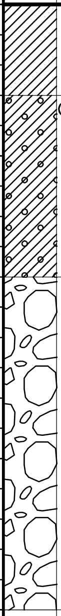
Excavation dimensions : 4.90m long 0.70m wide

excavation information / material substance

Method: BH (0.0–2.0 m). Penetration: VE E F H VH. Support: N (0.0–2.0 m). Ground water: Not Observed.

samples & field tests	RL (m)	depth (m)	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	structure and other observations
HP >500kPa HP >500kPa	21.0	0.0	CI	**CLAY**, medium plasticity, brown / dark brown; friable; trace of gravel, fine to medium grained; trace of sand	D	H	
HP >500kPa HP >500kPa	20.5	0.5	CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled pale grey; fine to coarse grained Grading into	D	H	
	20.0 19.5	1.0 1.5		**WEATHERED ROCK**, fine grained; residual soil to moderately weathered, highly fractured; recovered as soil and cobbles, grey/brown; cobbles and gravel are angular, low to high strength	D		
	19.0 18.5 18.0 17.5	2.0 2.5 3.0 3.5		Refusal on weathered rock EXCAVATION TP23 TERMINATED AT 2.00 m			

hand penetrometer kPa: 100 200 300 400



method

- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper
- E Excavator

support

- N No Support
- T Timbering

penetration

VE E F H VH — minor resitance ranging to refusal

water

- 10 Oct., 73 Water Level on Date shown
- water inflow
- water outflow

samples & field tests

- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density

- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP24*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478382.2, N: 7704425.8 (50 MGA94)

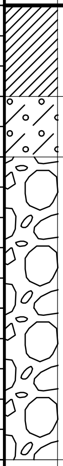
Surface Elevation : 21.69m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.50m long 0.70m wide

excavation information | **material substance**

method	penetration VE E F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
BH		N	Not Observed	HP >500kPa	21.5	0.0		CI	**CLAY**, medium plasticity, brown / dark brown; friable; trace of sand; trace of gravel, fine grained	D	H	×	
				HP >500kPa				GC	**CLAYEY GRAVEL**, fine to coarse grained, brown; clay, medium plasticity Grading into	D	H	×	
				HP >500kPa B HP >500kPa	21.0 20.5	0.5 1.0			**WEATHERED ROCK**, weathered rock; residual soil to moderately weathere, highly fractured; recovered as soil and cobbles, grey/white; cobbles are angular, low to high strength	D		× ×	
					20.0 19.5 19.0 18.5 18.0	1.5 2.0 2.5 3.0 3.5			Refusal on weathered rock, hard digging EXCAVATION TP24 TERMINATED AT 1.50 m				

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:54

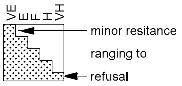
method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration



water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

- U50 - Undisturbed Sample 50mm diameter
- U63 - Undisturbed Sample 63mm diameter
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- ES - Environmental Sample
- MC - Moisture Content
- HP - Hand Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

- D - Dry
- M - Moist
- W - Wet
- W_P - Plastic Limit
- W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP25*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*

Principal :

Project : *Madigan Road*

Location : *Karratha*

Position : E: 478564.8, N: 7704454 (50 MGA94)

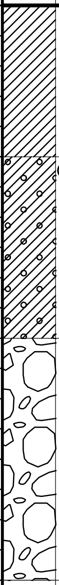
Surface Elevation : 21.8m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.80m long 0.70m wide

excavation information / material substance



method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	B HP >500kPa HP >500kPa	21.5	0.0	CI	**SANDY CLAY /CLAYEY SAND**, low to medium plasticity, brown / dark brown; sand, fine to coarse grained; with some gravel, fine to medium grained, sub-angular; gravel content increasing with depth	D	H	× ×	
				HP >500kPa HP >500kPa	21.0	0.5	CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, gravel, fine to coarse grained Grading into	D	H	× ×	
					20.5 20.0	1.0 1.5		**WEATHERED ROCK**, fine grained; residual soil to moderately weathered rock; highly fractured; recovered as soil and cobbles, grey/pale grey; cobbles are angular, low to high strength	D			
					19.5 19.0 18.5 18.0	2.0 2.5 3.0 3.5		Refusal on weathered rock, hard digging EXCAVATION TP25 TERMINATED AT 1.90 m				

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH — minor resitance ranging to refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP26*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : ***Cossill & Webley Consulting Engineers***

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

Position : E: 478796.4, N: 7704509.2 (50 MGA94)

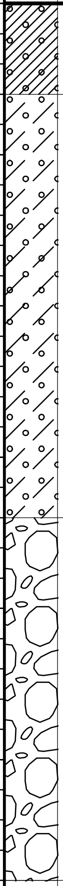
Surface Elevation : 22.04m (AHD)

Equipment type : Backhoe

Method :

Excavation dimensions : 4.70m long 0.70m wide

excavation information / material substance



method	support	ground water	samples & field tests	classification symbol	material description (SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components)	moisture condition	consistency / relative density	structure and other observations
BH	N	Not Observed	HP >500kPa HP >500kPa HP >500kPa HP >500kPa	CI	**GRAVELLY CLAY**, medium plasticity, brown / dark brown; gravel, fine to medium grained; friable	D		Trace of rootlets in top 300mm
				GC	**CLAYEY GRAVEL**, fine to coarse grained, angular, grey/brown; clay is medium plasticity Grading into	D		
					WEATHERED ROCK, redisual soil to moderately weathered, highly fractured; recovered as soil and gravel/cobbles, grey/pale grey, gravel/cobbles are angular			
					Test depth reached EXCAVATION TP26 TERMINATED AT 2.90 m			

depth (m)	RL (m)
0.0	22.0
0.5	21.5
1.0	21.0
1.5	20.5
2.0	20.0
2.5	19.5
3.0	19.0
3.5	18.5

penetration: VE F H VH

hand penetrometer kPa: 100 200 300 400

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE F H VH

minor resitance

ranging to

refusal

water

10 Oct., 73 Water Level on Date shown

water inflow

water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP27**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : **Cossill & Webley Consulting Engineers**
Principal :
Project : **Madigan Road**
Location : **Karratha**

Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478774.4, N: 7704328.1 (50 MGA94)
Surface Elevation : 26.32m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.00m long 0.70m wide

excavation information / material substance

method	penetration (VE E F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH		N	Not Observed	HP >500kPa HP >500kPa	26.0	0.0–0.6		GC	**CLAYEY GRAVEL**, fine to coarse grained, brown; clay, medium plasticity	D	H		Granite outcrops noted at surface close to testpit
						0.60			Refusal on weathered rock EXCAVATION TP27 TERMINATED AT 0.60 m				

RL (m) scale: 26.0, 25.5, 25.0, 24.5, 24.0, 23.5, 23.0, 22.5
Depth (m) scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
VE E F H VH
minor resitance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP28**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : ***Cossill & Webley Consulting Engineers***
Principal :
Project : ***Madigan Road***
Location : ***Karratha***

Date excavated **20/10/10**
Date completed **20/10/10**
Logged by : **PCW**
Checked by :

Position : E: 478611.5, N: 7704268.5 (50 MGA94)
Surface Elevation : 24.82m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.20m long 0.70m wide

excavation information / material substance

method	penetration (VE F H VH)	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description: SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa (100 200 300 400)	structure and other observations
BH	minor resistance ranging to refusal	N	Not Observed			0.0	▨	CI	**CLAY**, medium plasticity, brown; friable; trace of gravel; trace of rootlets	D	H		
				HP >500kPa								×	
					24.5			GC	**CLAYEY GRAVEL**, fine to coarse grained, clay, medium plasticity; with some boulders and cobbles	D			
				HP >500kPa		0.5						×	
				HP >500kPa								×	
					24.0								
				HP >500kPa		1.0						×	
									Refusal of weathered rock EXCAVATION TP28 TERMINATED AT 1.10 m				
					23.5								
						1.5							
					23.0								
						2.0							
					22.5								
						2.5							
					22.0								
						3.0							
					21.5								
						3.5							
					21.0								

method
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper
E Excavator

support
N No Support
T Timbering

penetration
VE F H VH
minor resitance
ranging to
refusal

water
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests
U50 - Undisturbed Sample 50mm diameter
U63 - Undisturbed Sample 63mm diameter
D - Disturbed Sample
B - Bulk Disturbed Sample
ES - Environmental Sample
MC - Moisture Content
HP - Hand Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture
D - Dry
M - Moist
W - Wet
W_P - Plastic Limit
W_L - Liquid Limit

consistency / relative density

VS	- Very Soft
S	- Soft
F	- Firm
St	- Stiff
VSt	- Very Stiff
H	- Hard
VL	- Very Loose
L	- Loose
MD	- Medium Dense
D	- Dense
VD	- Very Dense

coffey geotechnics

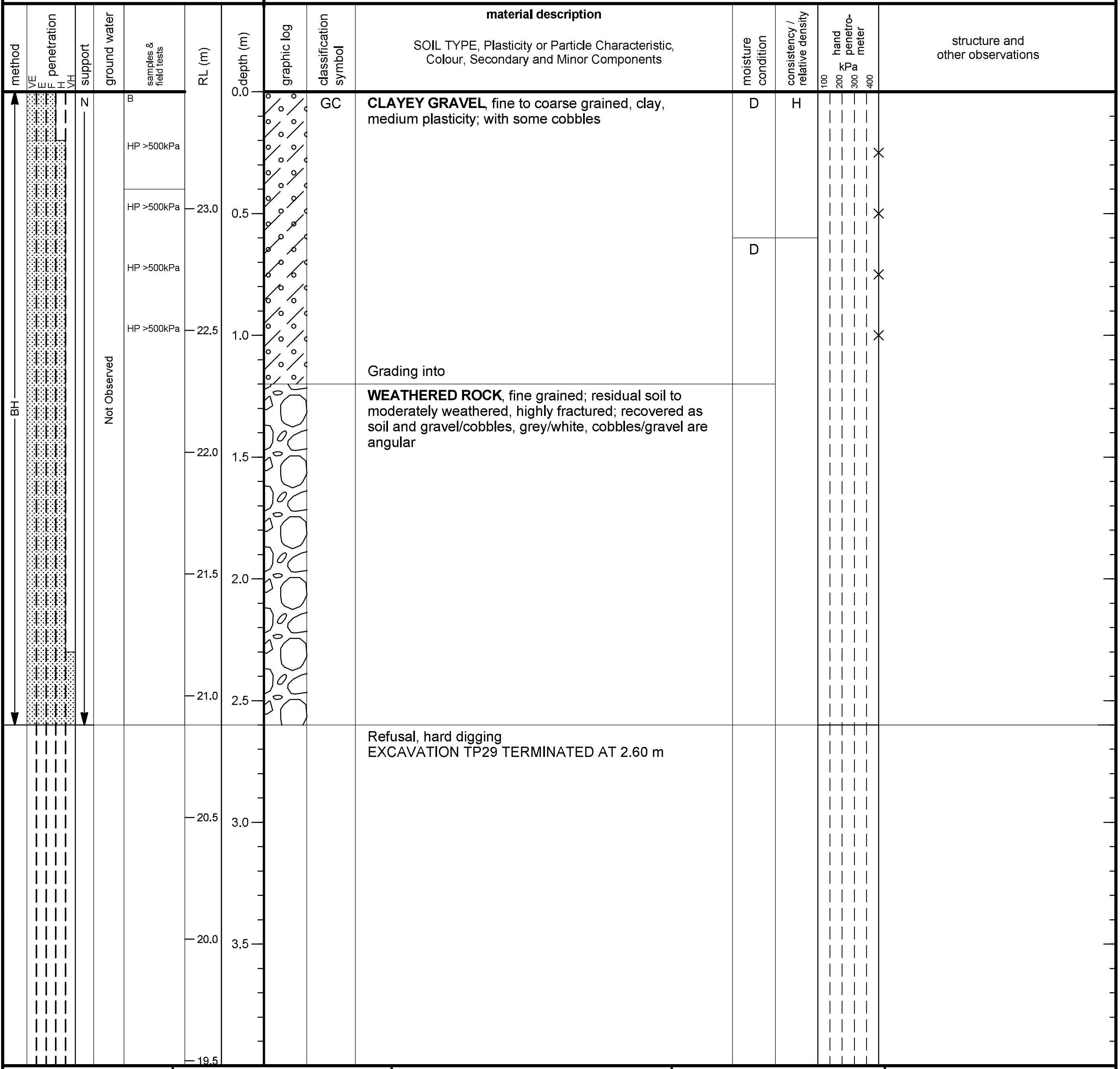
Engineering Log - Excavation

Excavation No. *TP29*
Sheet No. 1 of 1
Project No. *GEOTPERT02828AS*

Client : *Cossill & Webley Consulting Engineers*
Principal :
Project : *Madigan Road*
Location : *Karratha*

Date excavated *20/10/10*
Date completed *20/10/10*
Logged by : *PCW*
Checked by :

Position : E: 478436, N: 7704225.3 (50 MGA94)
Surface Elevation : 23.48m (AHD)
Equipment type : Backhoe
Method :
Excavation dimensions : 4.80m long 0.70m wide



method	support	ground water	samples & field tests	RL (m)	depth (m)	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	structure and other observations
BH	N	Not Observed	B		0.0	GC	**CLAYEY GRAVEL**, fine to coarse grained, clay, medium plasticity; with some cobbles	D	H	
			HP >500kPa							
			HP >500kPa	23.0	0.5					
			HP >500kPa					D		
			HP >500kPa	22.5	1.0		Grading into			
							WEATHERED ROCK, fine grained; residual soil to moderately weathered, highly fractured; recovered as soil and gravel/cobbles, grey/white, cobbles/gravel are angular			
				22.0	1.5					
				21.5	2.0					
				21.0	2.5					
							Refusal, hard digging EXCAVATION TP29 TERMINATED AT 2.60 m			
				20.5	3.0					
				20.0	3.5					
				19.5						

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:54

method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration

VE E F H VH — minor resitance ranging to refusal

water

10 Oct., 73 Water Level on Date shown
water inflow
water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description
Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*TP30*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*
Date excavated	*20/10/10*
Date completed	*20/10/10*
Logged by :	*PCW*
Checked by :	

Client : *Cossill & Webley Consulting Engineers*
Principal :
Project : *Madigan Road*
Location : *Karratha*

Position : E: 478262.7, N: 7704240.9 (50 MGA94)
Surface Elevation :
Equipment type : Backhoe
Method :
Excavation dimensions :

excavation information							material substance						
method	penetration VE F H VH	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description SOIL TYPE, Plasticity or Particle Characteristic, Colour, Secondary and Minor Components	moisture condition	consistency / relative density	hand penetrometer kPa 100 200 300 400	structure and other observations
			Not Observed			0.0			Exposed rock at surface in surrounding area. Testpit not undertaken EXCAVATION TP30 TERMINATED AT 0.00 m				
						0.5							
						1.0							
						1.5							
						2.0							
						2.5							
						3.0							
						3.5							

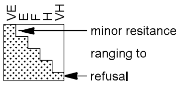
method

N	Natural Exposure
X	Existing Excavation
BH	Backhoe Bucket
B	Bulldozer Blade
R	Ripper
E	Excavator

support

N	No Support
T	Timbering

penetration



water

- 10 Oct., 73 Water Level on Date shown
- ► water inflow
- ◄ water outflow

samples & field tests

U50	Undisturbed Sample 50mm diameter
U63	Undisturbed Sample 63mm diameter
D	Disturbed Sample
B	Bulk Disturbed Sample
ES	Environmental Sample
MC	Moisture Content
HP	Hand Penetrometer (UCS kPa)
VS	Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT	Plate Bearing Test

classification symbols & soil description

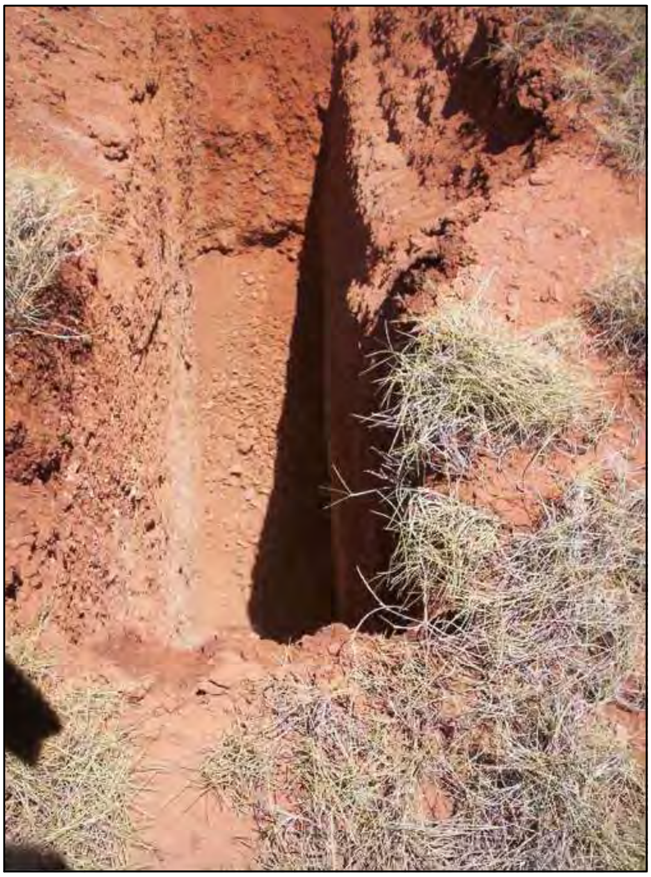
Based on Unified Classification System

moisture

D	Dry
M	Moist
W	Wet
W_P	Plastic Limit
W_L	Liquid Limit

consistency / relative density

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense



TP01.

TP01 - Stockpile.

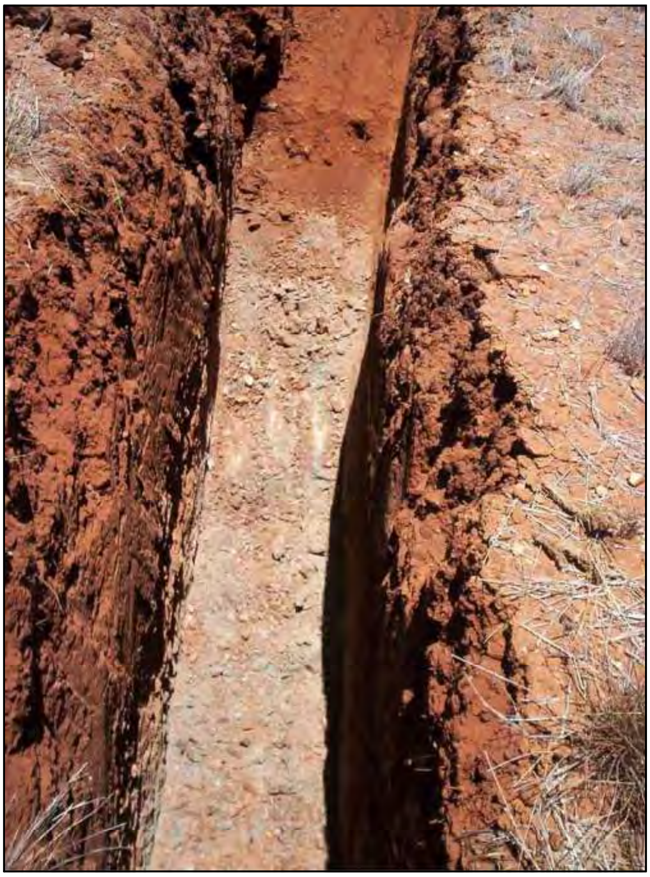
drawn	LB	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved		project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10		
scale	NOT TO SCALE	title:	TEST PIT PHOTOGRAPHS - TP01
original size	A4	project no:	GEOTPERT02828AS

fig no:

rev:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP02.

TP02 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP02
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

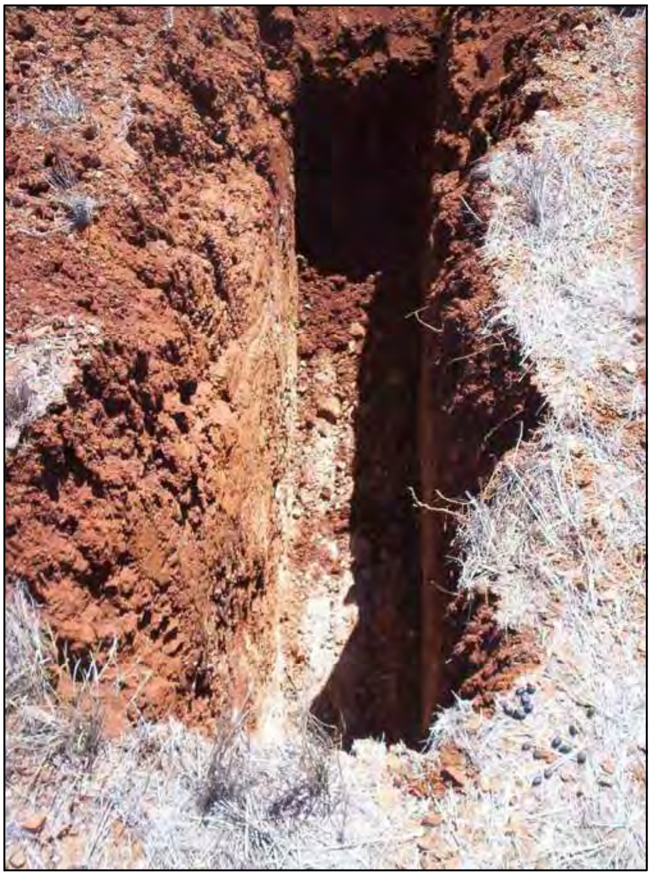
DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP03.

TP03 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP03
original size	A4		project no: GEOTPERT02828AS	fig no: / rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP04.

TP04 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP04
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

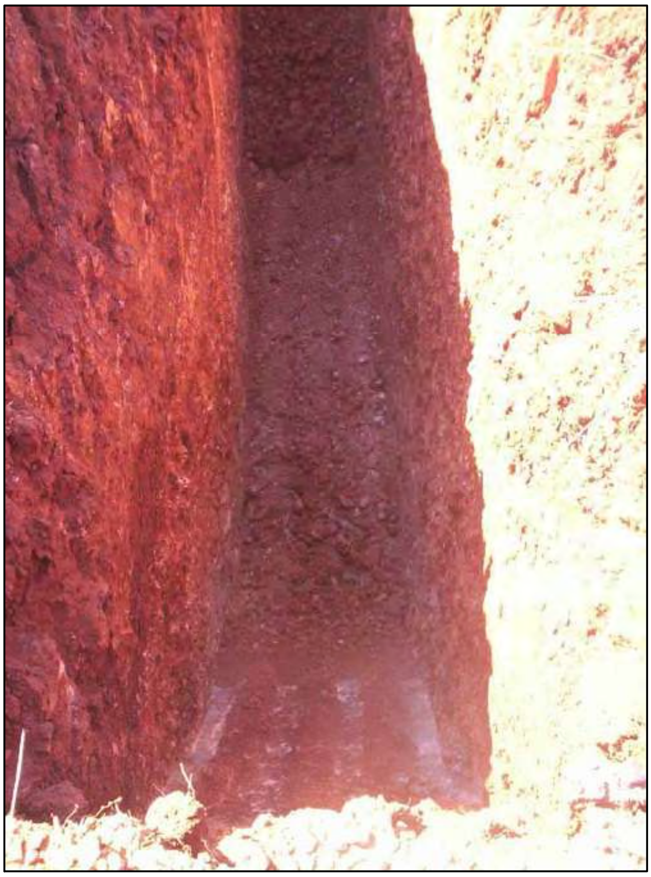
DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP05.

TP05 - Stockpile.

drawn	LB	**coffey geotechnics** SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP05	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP06.

TP06 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP06	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

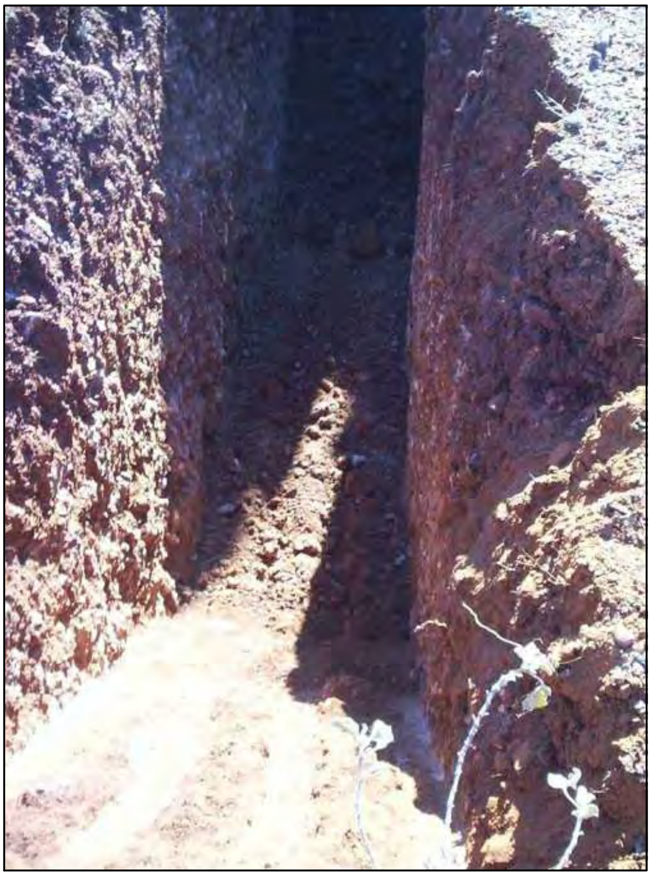
DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP07.

TP07 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP07	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP08.

TP08 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP08
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP09.

TP09 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP09
original size	A4		project no:	GEOTPERT02828AS fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

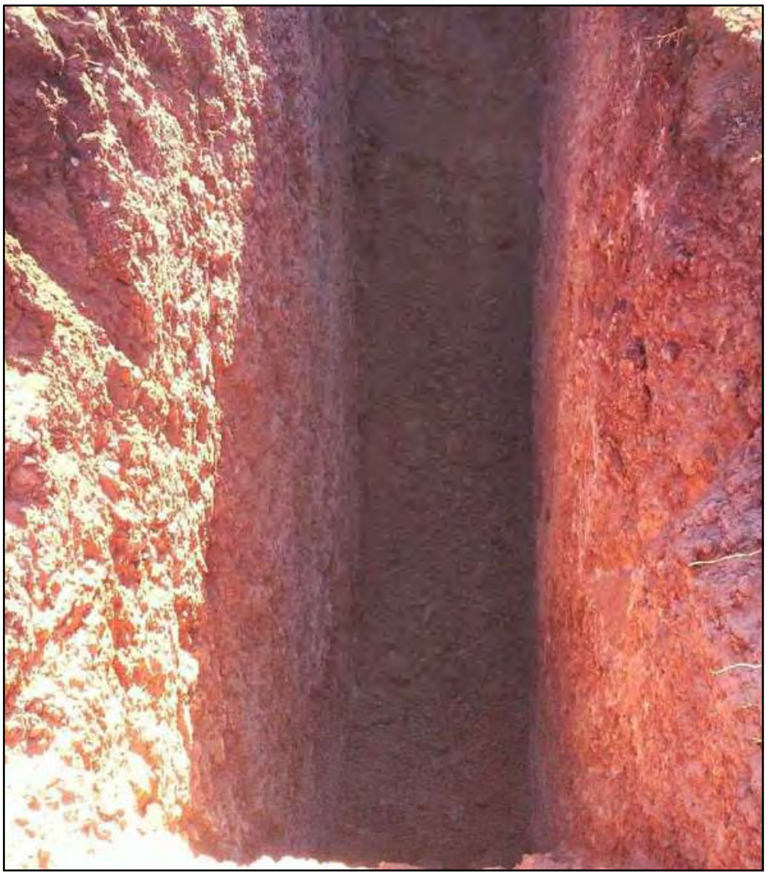
TP10.

TP10 - Stockpile.

drawn	LB	client:	**COSSILL & WEBLEY CONSULTING ENGINEERS**
approved		project:	**MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA**
date	3/11/10		
scale	NOT TO SCALE	title:	**TEST PIT PHOTOGRAPHS - TP10**
original size	A4	project no: **GEOTPERT02828AS**	fig no: rev:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP11.

TP11 - Stockpile.

drawn	LB	**coffey geotechnics** **SPECIALISTS MANAGING THE EARTH**	client:	**COSSILL & WEBLEY CONSULTING ENGINEERS**		
approved			project:	**MADIGAN ROAD DEVELOPMENT SITE** **MADIGAN ROAD, KARRATHA**		
date	3/11/10					
scale	NOT TO SCALE		title:	**TEST PIT PHOTOGRAPHS - TP11**		
original size	A4		project no:	**GEOTPERT02828AS**	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP12.

TP12 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP12
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP13.

TP13 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP13
original size	A4		project no: GEOTPERT02828AS	fig no: / rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP14.

TP14 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP14
original size	A4		project no: GEOTPERT02828AS	fig no: / rev:

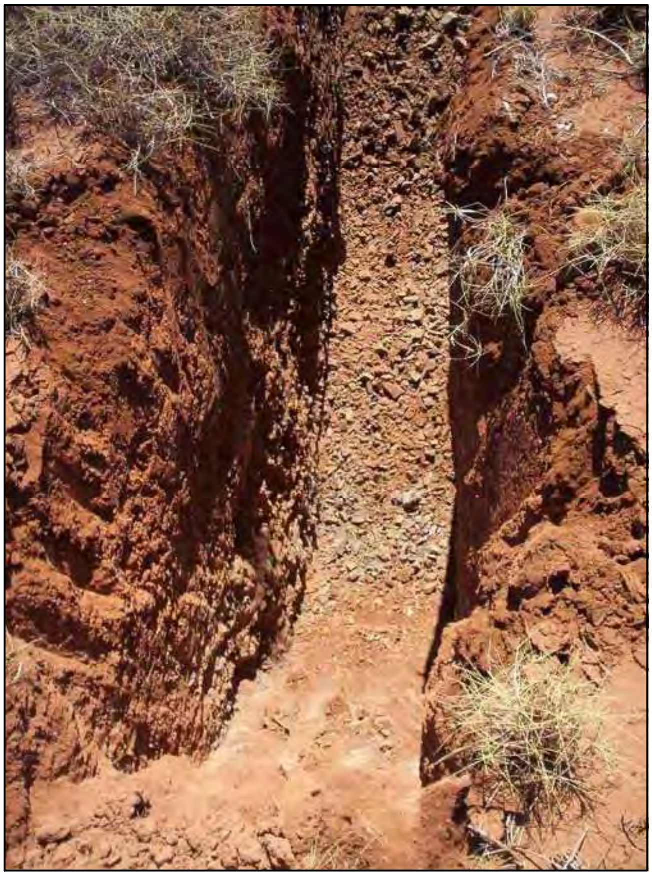
DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP15.

TP15 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP15
original size	A4		project no:	GEOTPERT02828AS fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP16.

TP16 - Stockpile.

drawn	**LB**
approved	
date	**3/11/10**
scale	**NOT TO SCALE**
original size	**A4**

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

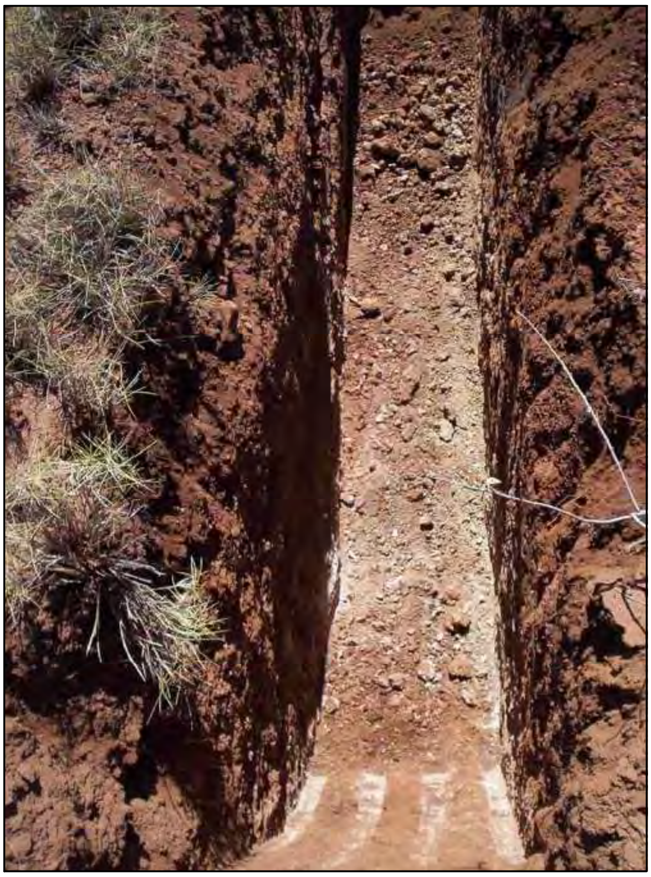
client: **COSSILL & WEBLEY CONSULTING ENGINEERS**

project: **MADIGAN ROAD DEVELOPMENT SITE**
MADIGAN ROAD, KARRATHA

title: **TEST PIT PHOTOGRAPHS - TP16**

project no: **GEOTPERT02828AS** fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



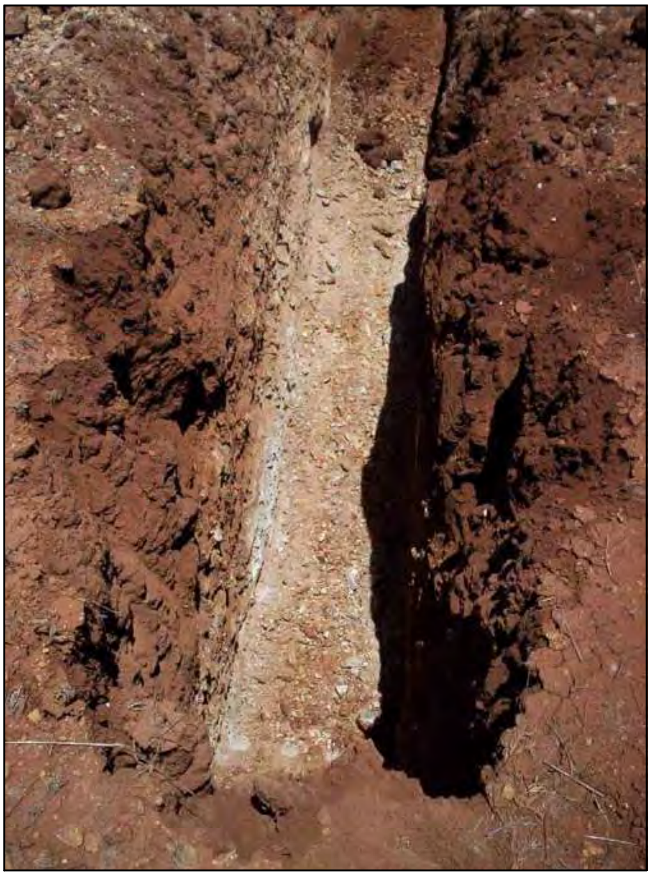
TP17.

TP17 - Stockpile.

drawn	LB	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved		project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10		
scale	NOT TO SCALE	title:	TEST PIT PHOTOGRAPHS - TP17
original size	A4	project no:	GEOTPERT02828AS fig no: rev:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP18.

TP18 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10					
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP18		
original size	A4		project no:	GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP19.

TP19 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10					
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP19		
original size	A4		project no:	GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP20.

TP20 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10					
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP20		
original size	A4		project no:	GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP21.

TP21 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10					
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP21		
original size	A4		project no:	GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP22.

TP22 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10					
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP22		
original size	A4		project no:	GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP23.

TP23 - Stockpile.

drawn	LB	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved		project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10		
scale	NOT TO SCALE	title:	TEST PIT PHOTOGRAPHS - TP23
original size	A4	project no:	GEOTPERT02828AS fig no: rev:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP24.

TP24 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP24	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP25.

TP25 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP25
original size	A4		project no:	GEOTPERT02828AS fig no: rev:

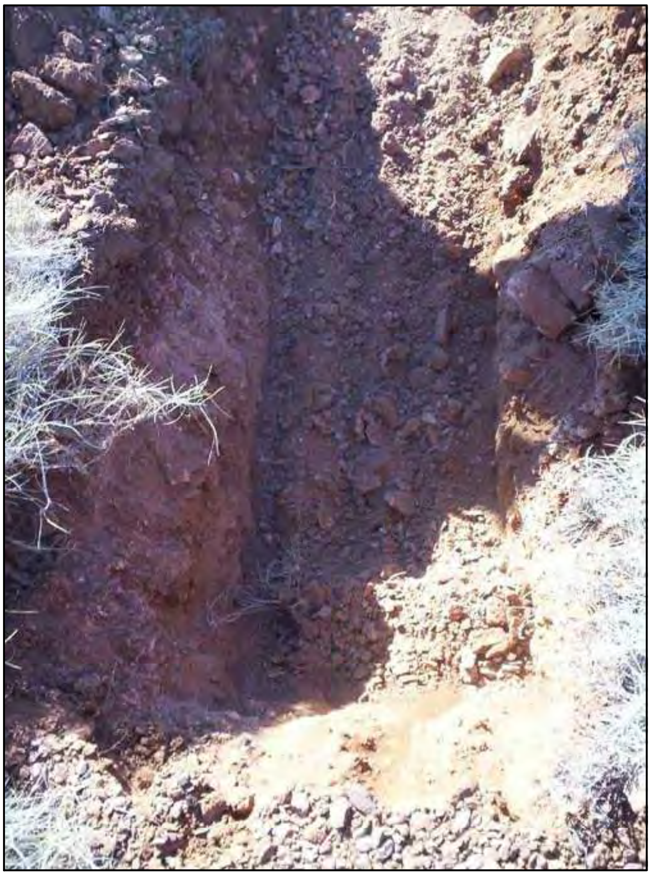
DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP26.

TP26 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP26
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP27.

TP27 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP27	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

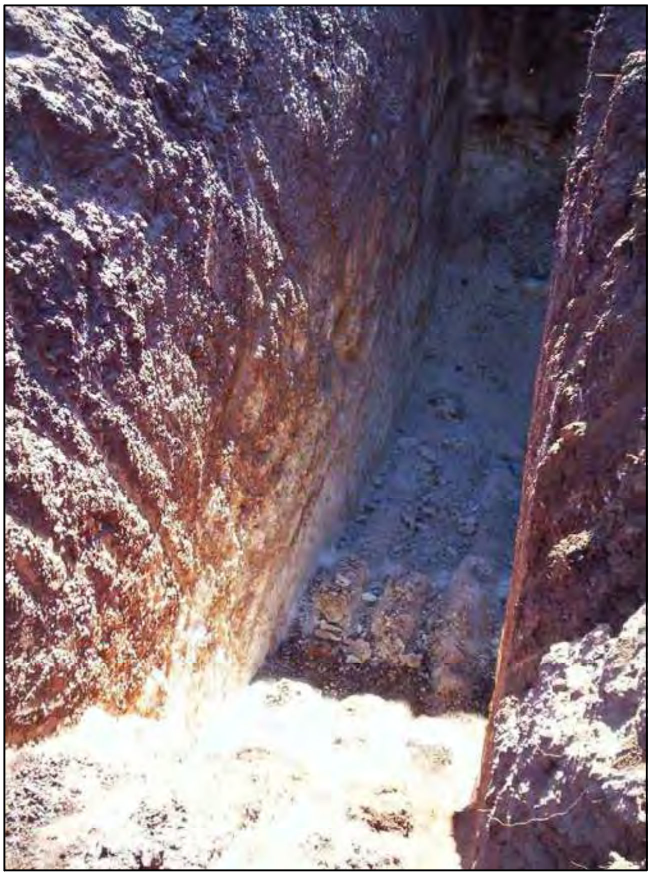
DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

TP28.

TP28 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS	
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA	
date	3/11/10				
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP28	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP29.

TP29 - Stockpile.

drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA
date	3/11/10			
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP29
original size	A4		project no: GEOTPERT02828AS	fig no: rev:

DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

Appendix B

Results of Laboratory Testing

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S- 03811MC

Issue No.: 1

This report replaces all previous isues of report no. WELS10S- 03811MC

Test Report

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W 10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accrediation requirements. Accredited for compliance with IOS IEC 17025

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below

Sample ID: see below

Other Sample Details:

Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03811	TP02 @ 0.60 0.90m	5.9%

Comments:

Sample Supplied by client

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Test Report

Report No.: WELS10S- 03813MC

Issue No.: 1

This report replaces all previous isues of report no. WELS10S- 03813MC

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W 10578
Location: Karratha

WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accrediation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full.)

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below

Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03813	TP05 @ 1.30 - 1.60m	9.8%

Comments:
Sample Supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Test Report

Report No.: WELS10S- 03815MC

Issue No.: 1

This report replaces all previous isues of report no. WELS10S- 03815MC

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W 10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accrediation requirements. Accredited for compliance with IOS IEC 17025
(This document may not be reproduced except in full.)

B Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below

Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03815	TP13 @ 0.00 - 0.50m	3.7%

Comments:
Sample Supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Test Report

Report No.: WELS10S- 03818MC

Issue No.: 1

This report replaces all previous issues of report no. WELS10S- 03818MC

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W 10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accrediation requirements. Accredited for compliance with IOS/IEC 17025
{This document may not be reproduced except in full.}

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below
Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03818	TP19 @ 0.40 - 0.70m	3.1%

Comments:
Sample Supplied by client

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Test Report

Report No.: WELS10S- 03820MC

Issue No.: 1

This report replaces all previous isues of report no. WELS10S- 03820MC

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W 10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accrediation requirements. Accredited for compliance with IOS/IEC 17025
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: see below
Sample ID: see below

Other Sample Details:
Date of Test: 11/11/2010

Test Results

Tested in accordance with AS1289.2.1.1

Sample Number	Sample Identification	Moisture Content
WELS10S- 03820	TP25 @ 0.00 - 0.50m	3.3%

Comments:
Sample Supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03811PSD
Issue No.: 1

Test Report

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03811
Sample ID: TP02 @ 0.60 - 0.90m

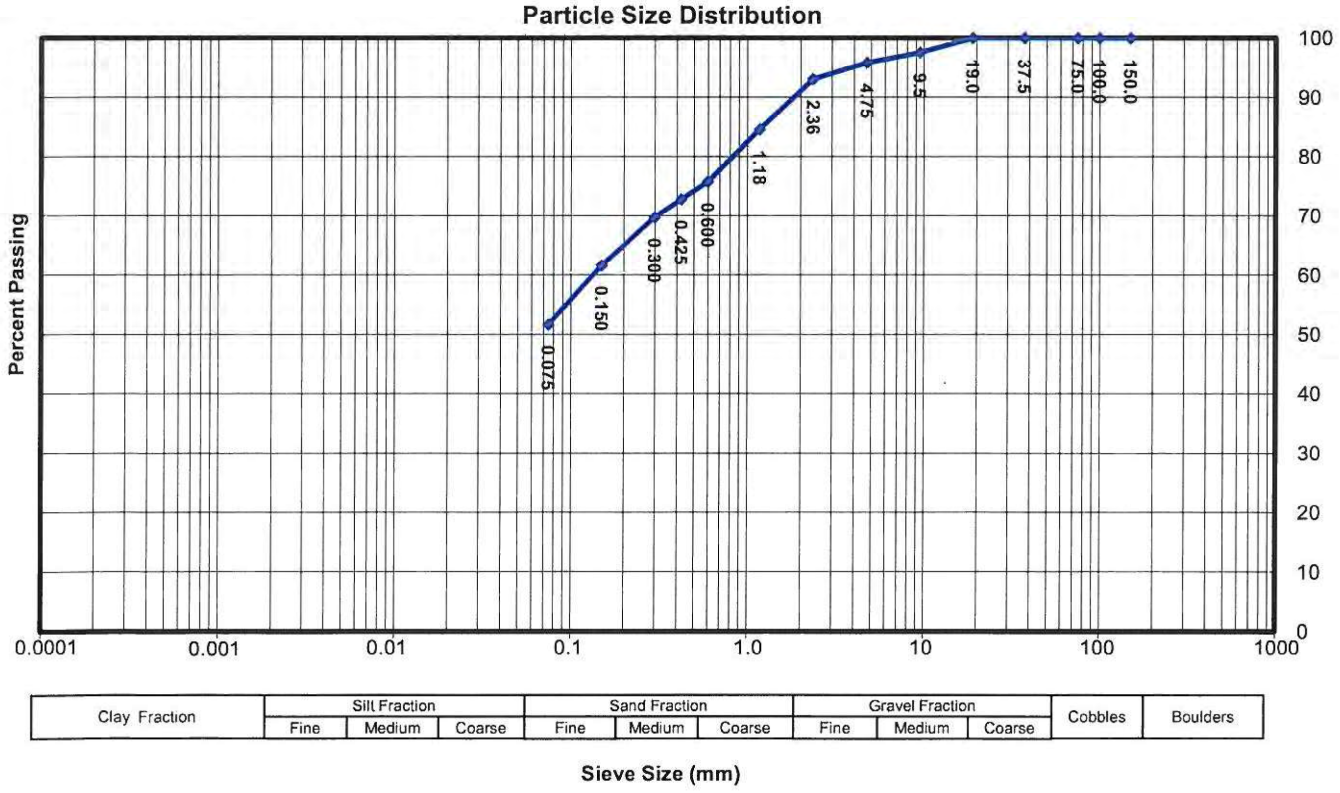
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	93
100.0	100	1.18	85
75.0	100	0.600	76
37.5	100	0.425	73
19.0	100	0.300	70
9.5	98	0.150	62
4.75	96	0.075	52



Comments:
Sample supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03812PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03812
Sample ID: TP03 @ 1.00 - 1.20m

Other Sample Details:

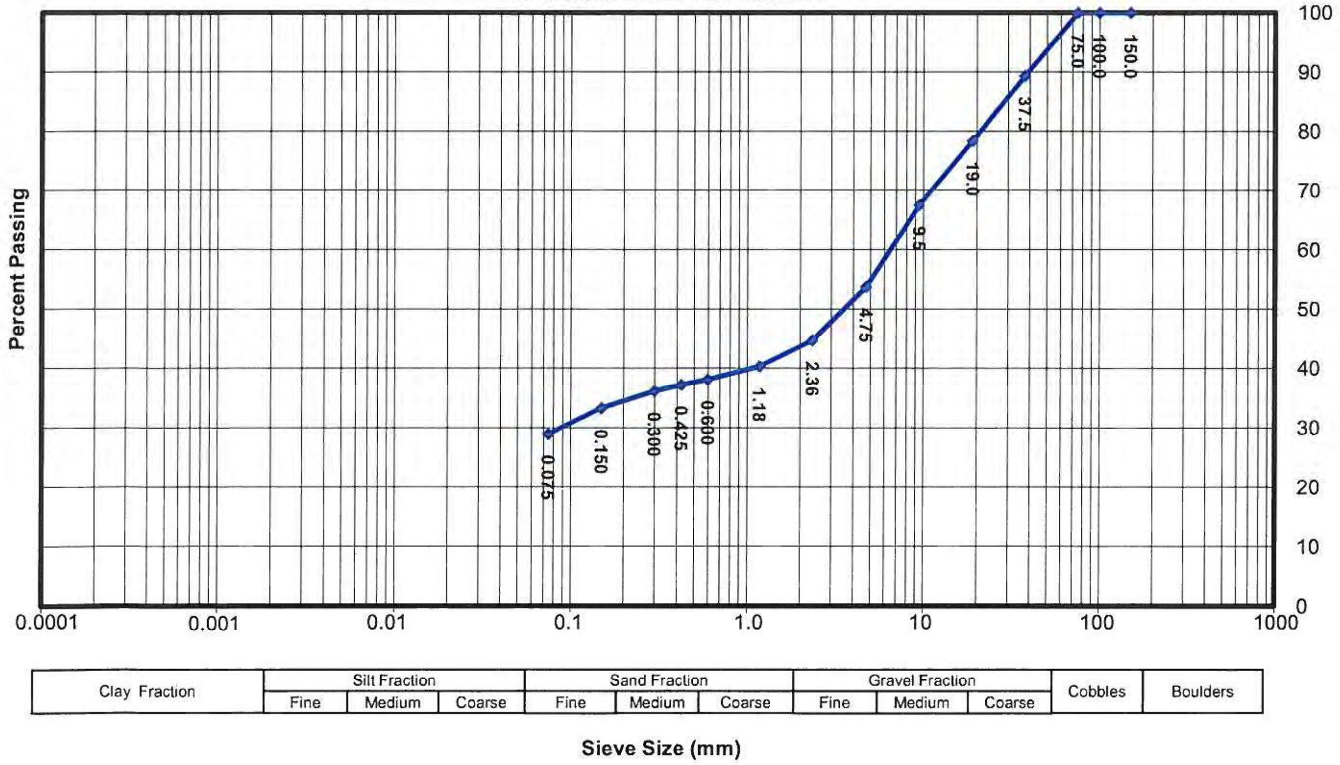
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	45
100.0	100	1.18	40
75.0	100	0.600	38
37.5	89	0.425	37
19.0	78	0.300	36
9.5	68	0.150	33
4.75	54	0.075	29

Particle Size Distribution



Comments:
Sample supplied by client
Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No.: WELS10S-03813PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03813
Sample ID: TP05 @ 1.30 - 1.60m

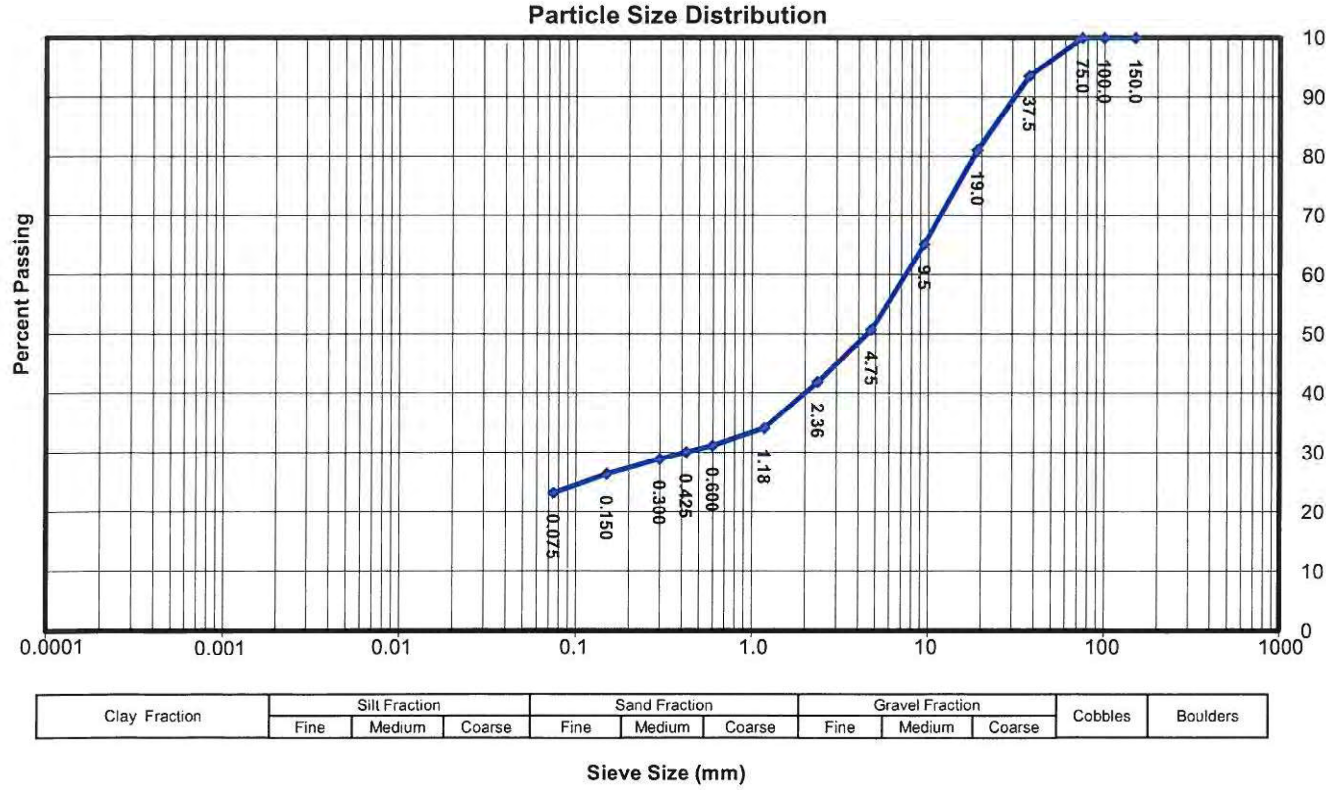
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 9/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	42
100.0	100	1.18	34
75.0	100	0.600	31
37.5	94	0.425	30
19.0	81	0.300	29
9.5	65	0.150	26
4.75	51	0.075	23



Comments:
Sample supplied by client
Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03814PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03814
Sample ID: TP12 @ 0.00 - 0.50m

Other Sample Details:

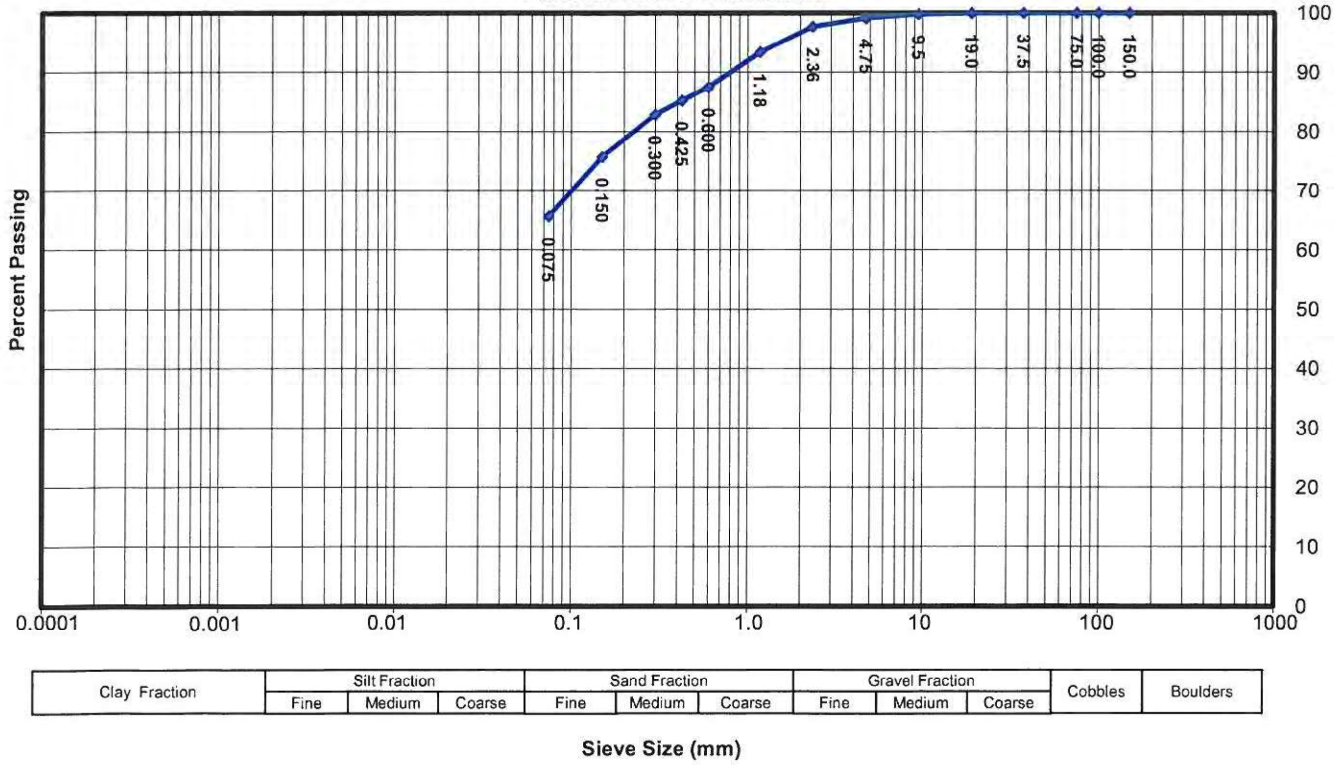
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	98
100.0	100	1.18	93
75.0	100	0.600	88
37.5	100	0.425	85
19.0	100	0.300	83
9.5	100	0.150	76
4.75	99	0.075	66

Particle Size Distribution



Comments:
Sample supplied by client

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03815PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03815
Sample ID: TP13 @ 0.00 - 0.50m

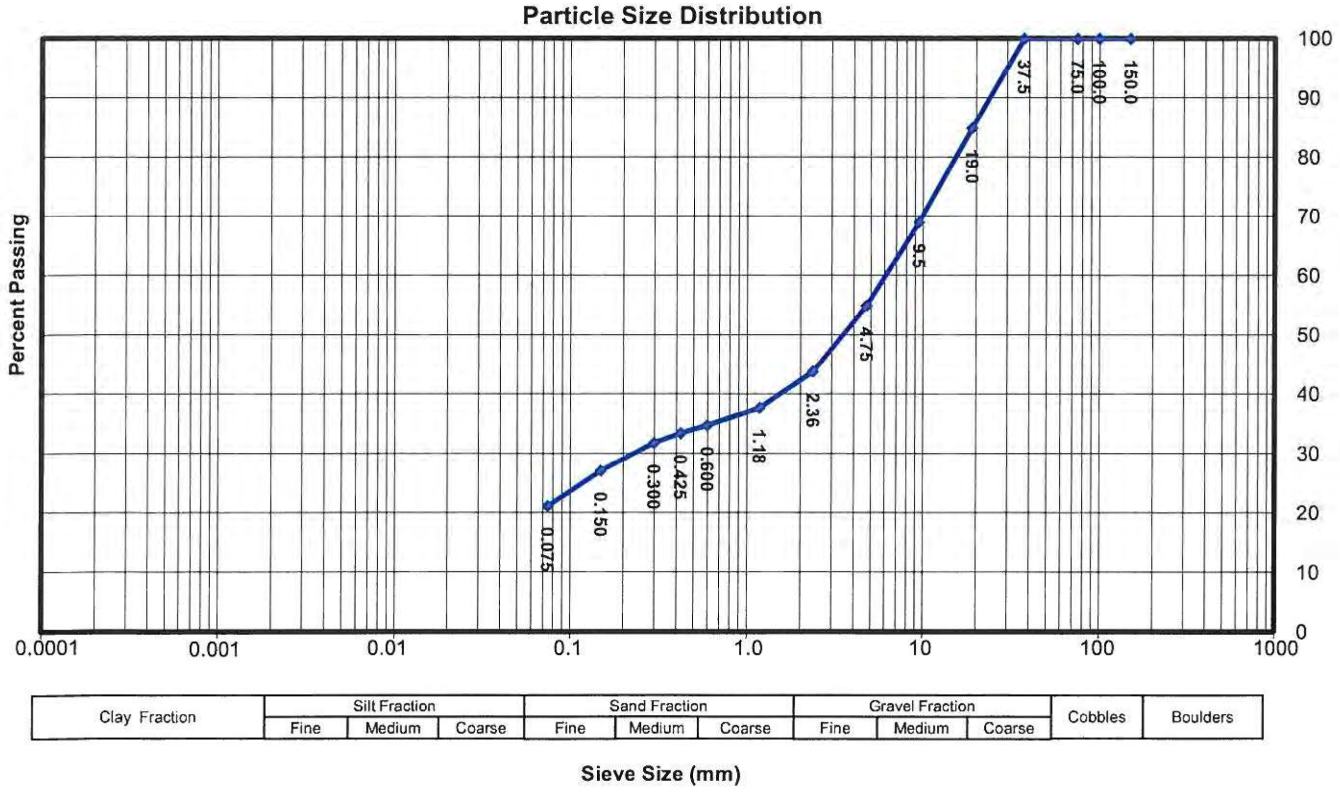
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	44
100.0	100	1.18	38
75.0	100	0.600	35
37.5	100	0.425	33
19.0	85	0.300	32
9.5	69	0.150	27
4.75	55	0.075	21



Comments:
Sample supplied by client
Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Test Report

Report No.: WELS10S-03816PSD
Issue No.: 1

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03816
Sample ID: TP15 @ 0.80 - 1.00m

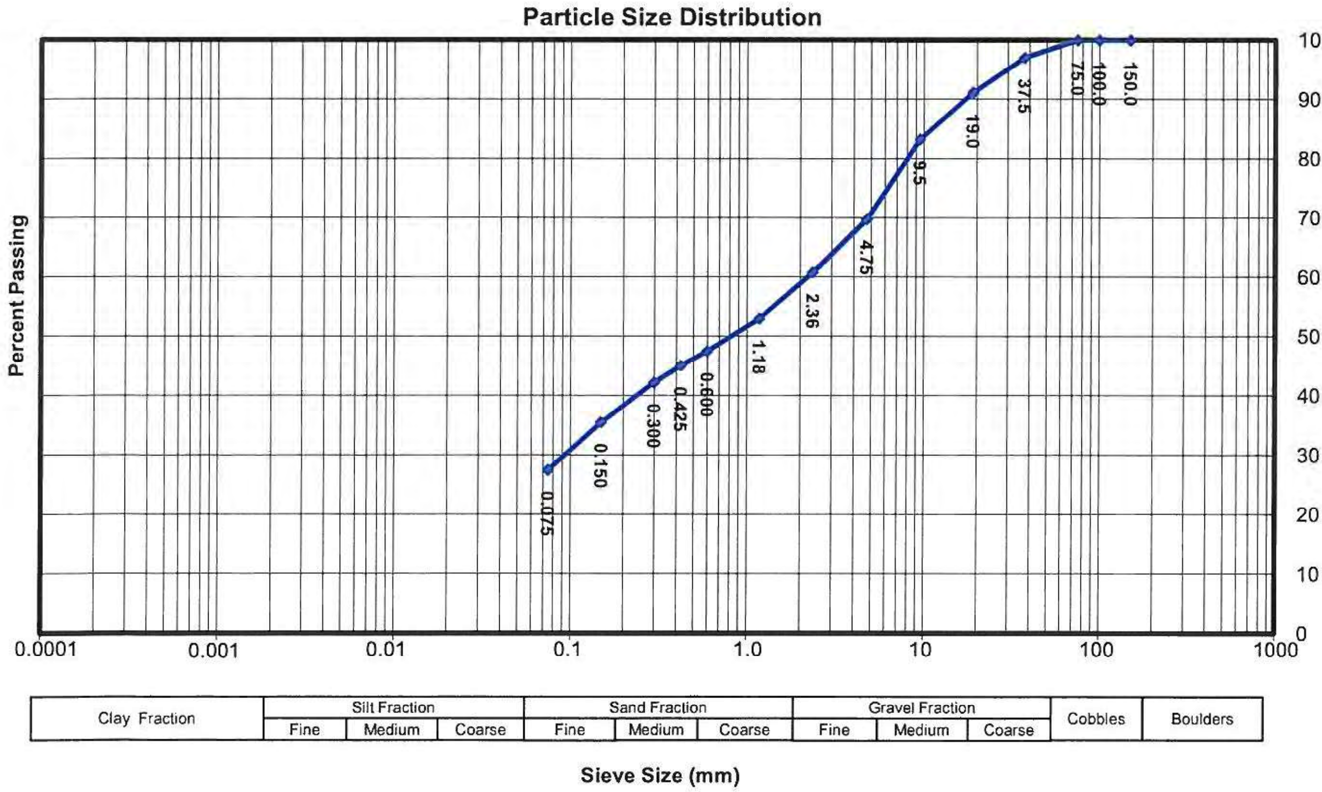
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	61
100.0	100	1.18	53
75.0	100	0.600	47
37.5	97	0.425	45
19.0	91	0.300	42
9.5	83	0.150	35
4.75	70	0.075	27



Comments:
Sample supplied by client
Deviation from standard method - Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No.: WELS10S-03817PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03817
Sample ID: TP18 @ 0.70 - 1.00m

Other Sample Details:

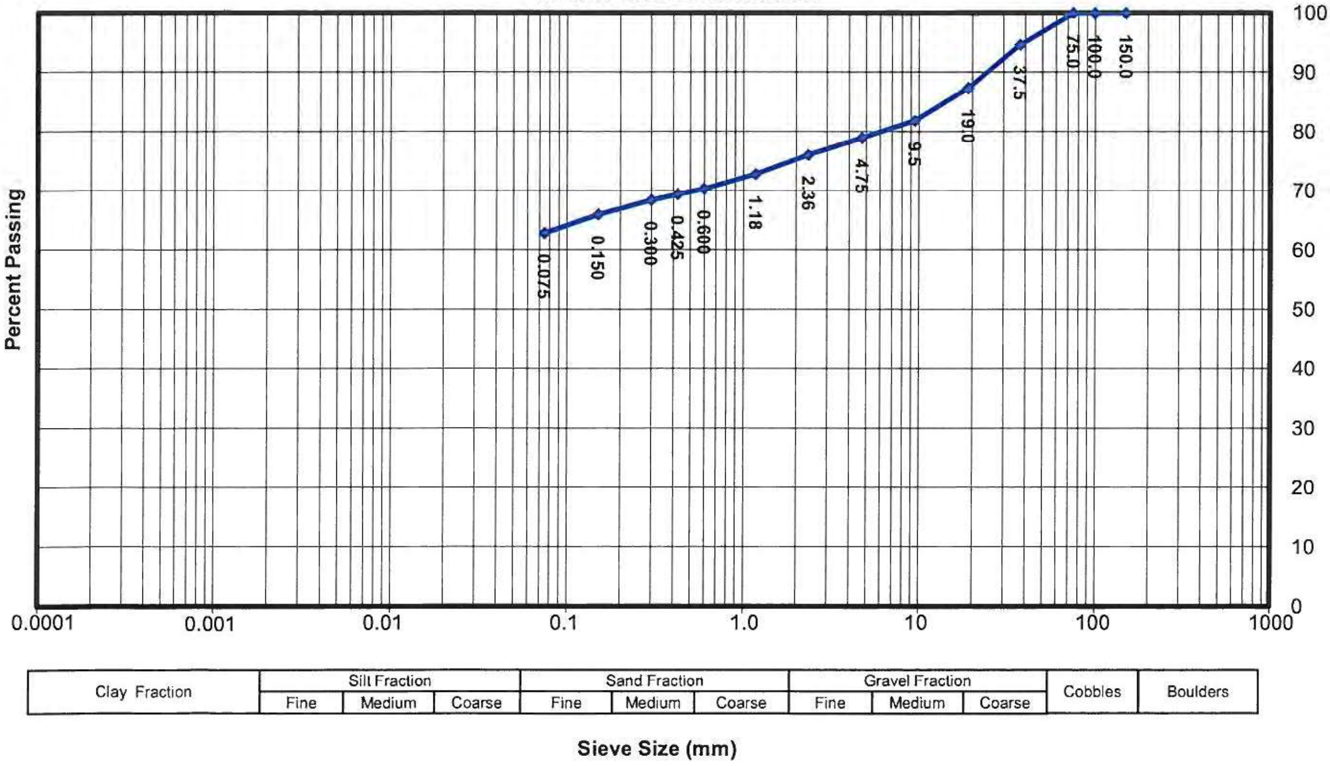
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	76
100.0	100	1.18	73
75.0	100	0.600	70
37.5	95	0.425	69
19.0	87	0.300	68
9.5	82	0.150	66
4.75	79	0.075	63

Particle Size Distribution



Comments:
Sample supplied by client
Deviation from standard method -Sample mass does not conform to minimum mass required as per AS1289.1.1 Part 5.7

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

Report No.: WELS10S-03818PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory: Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03818
Sample ID: TP19 @ 0.40 - 0.70m

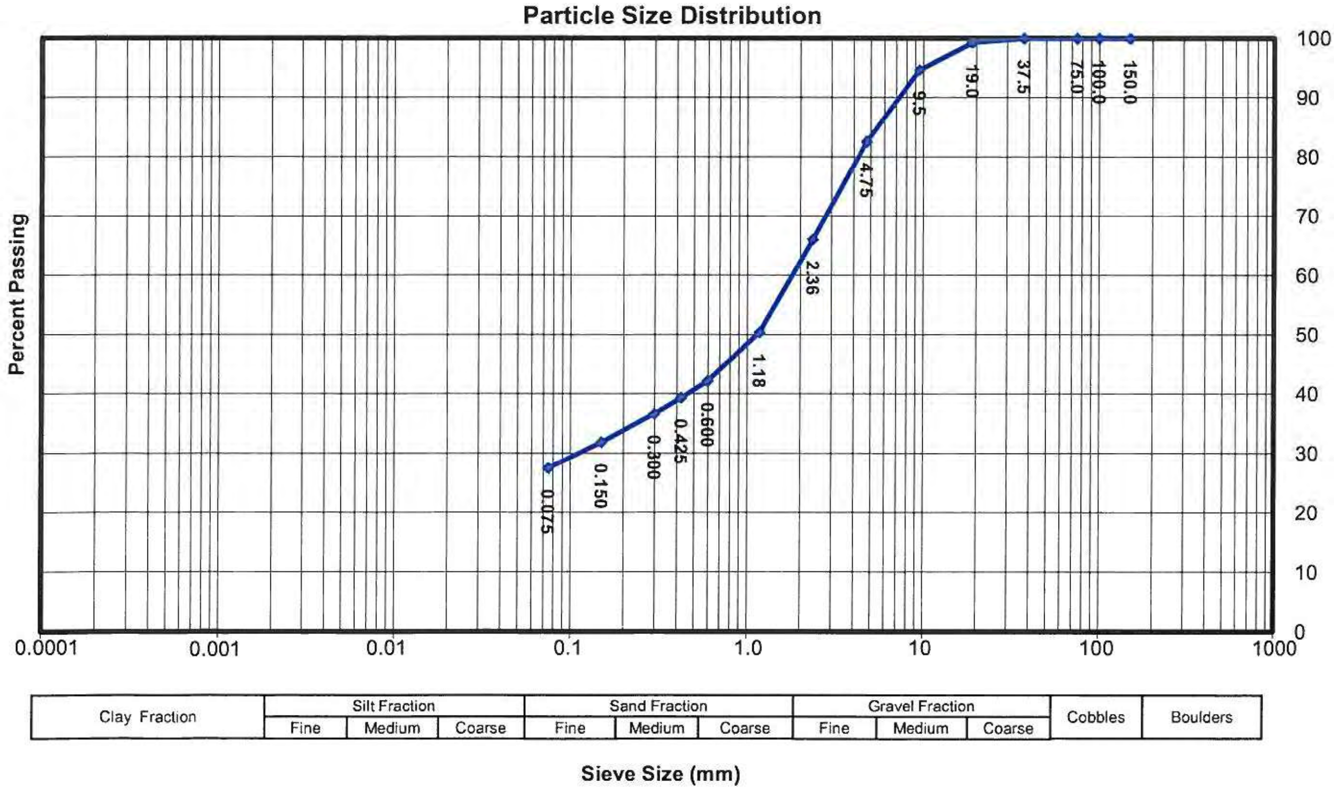
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	66
100.0	100	1.18	50
75.0	100	0.600	42
37.5	100	0.425	39
19.0	99	0.300	37
9.5	95	0.150	32
4.75	83	0.075	27



Comments:
Sample supplied by client

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Test Report

Report No.: WELS10S-03819PSD
Issue No.: 1

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025

(This document may not be reproduced except in full.)

B. Truslove

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03819
Sample ID: TP22 @ 0.50 - 0.70m

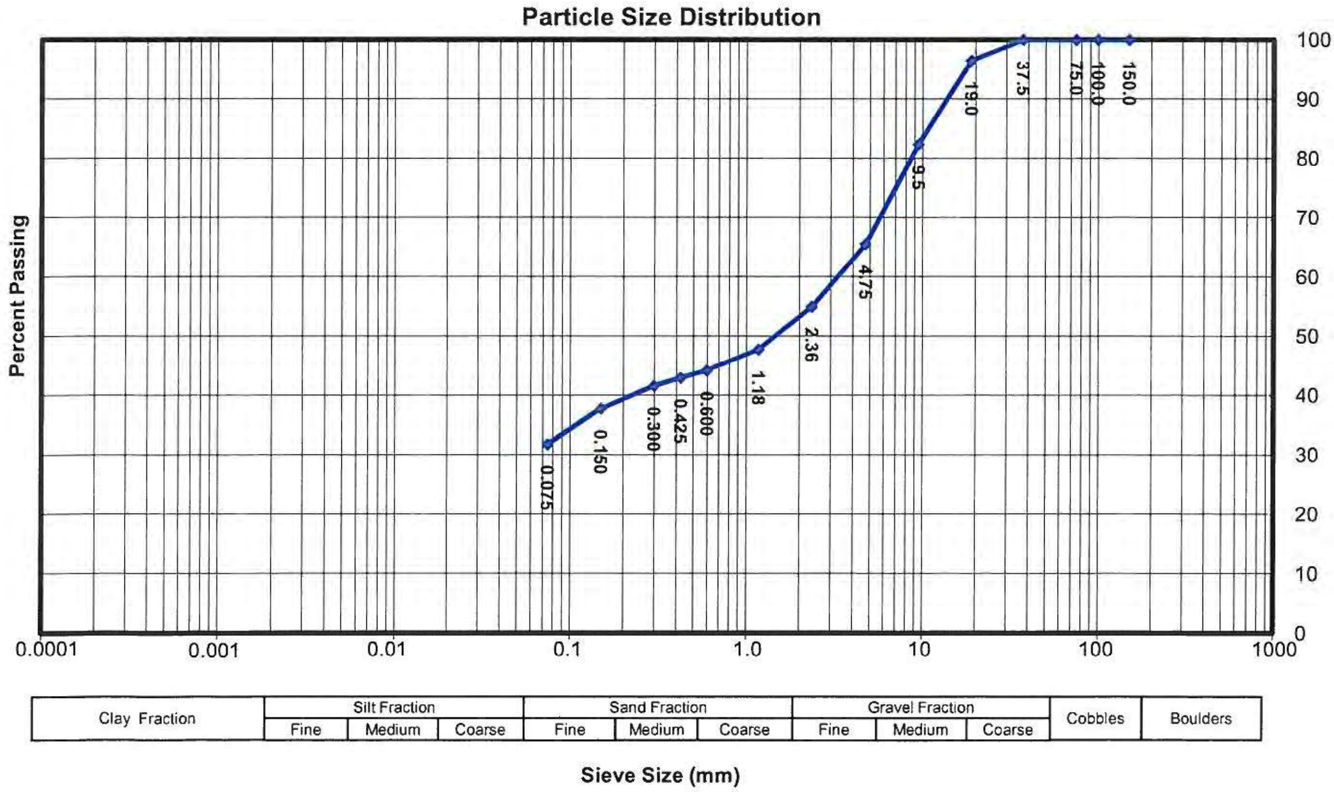
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	55
100.0	100	1.18	48
75.0	100	0.600	44
37.5	100	0.425	43
19.0	97	0.300	42
9.5	82	0.150	38
4.75	66	0.075	32



Comments:
Sample supplied by client

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No.: WELS10S-03820PSD
Issue No.: 1

Test Report

Client: Coffey Geotechnics - GEOTPERT02828AS
Client Address: Level 1,89-91 Burswood Road Burswood WA 6101
Principal: Cossill & Webley
Project: Madigan Road Development Site
Project No.: INFOWELS00653AA
Work Order No.: WELS10W10578
Location: Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03820
Sample ID: TP25 @ 0.00 - 0.50m

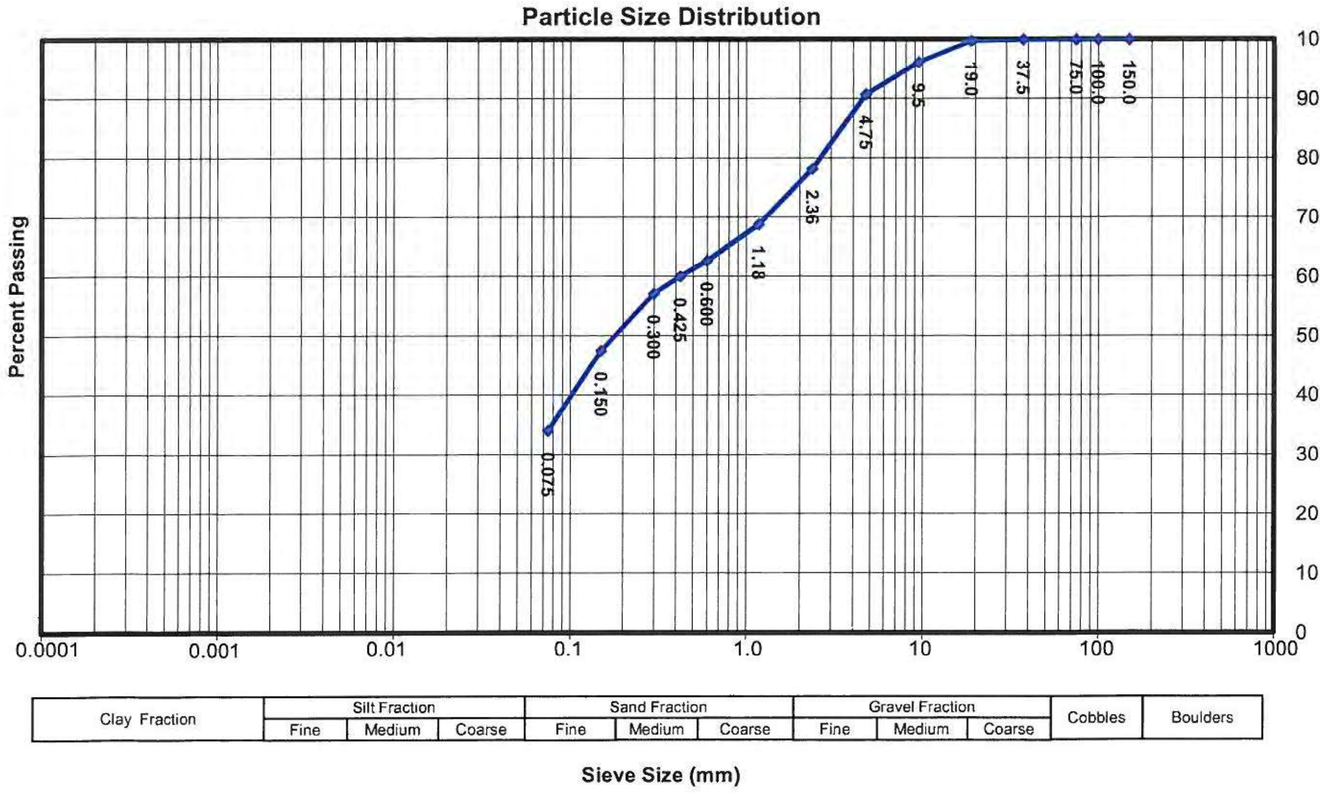
Other Sample Details:

Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	78
100.0	100	1.18	69
75.0	100	0.600	63
37.5	100	0.425	60
19.0	100	0.300	57
9.5	96	0.150	47
4.75	91	0.075	34



Comments:
Sample supplied by client

Welshpool Laboratory
Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No.: WELS10S-03821PSD
Issue No.: 1

Test Report

Client:	Coffey Geotechnics - GEOTPERT02828AS
Client Address:	Level 1,89-91 Burswood Road Burswood WA 6101
Principal:	Cossill & Webley
Project:	Madigan Road Development Site
Project No.:	INFOWELS00653AA
Work Order No.:	WELS10W10578
Location:	Karratha

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with IOS/IEC 17025.
(This document may not be reproduced except in full.)

B. Truslove
Approved Signatory:
Brad Truslove
NATA Accredited Laboratory Number: 431
Date of Issue: 18/11/2010

Sample Details

Sample No.: WELS10S-03821
Sample ID: TP29 @ 0.00 - 0.40m

Other Sample Details:

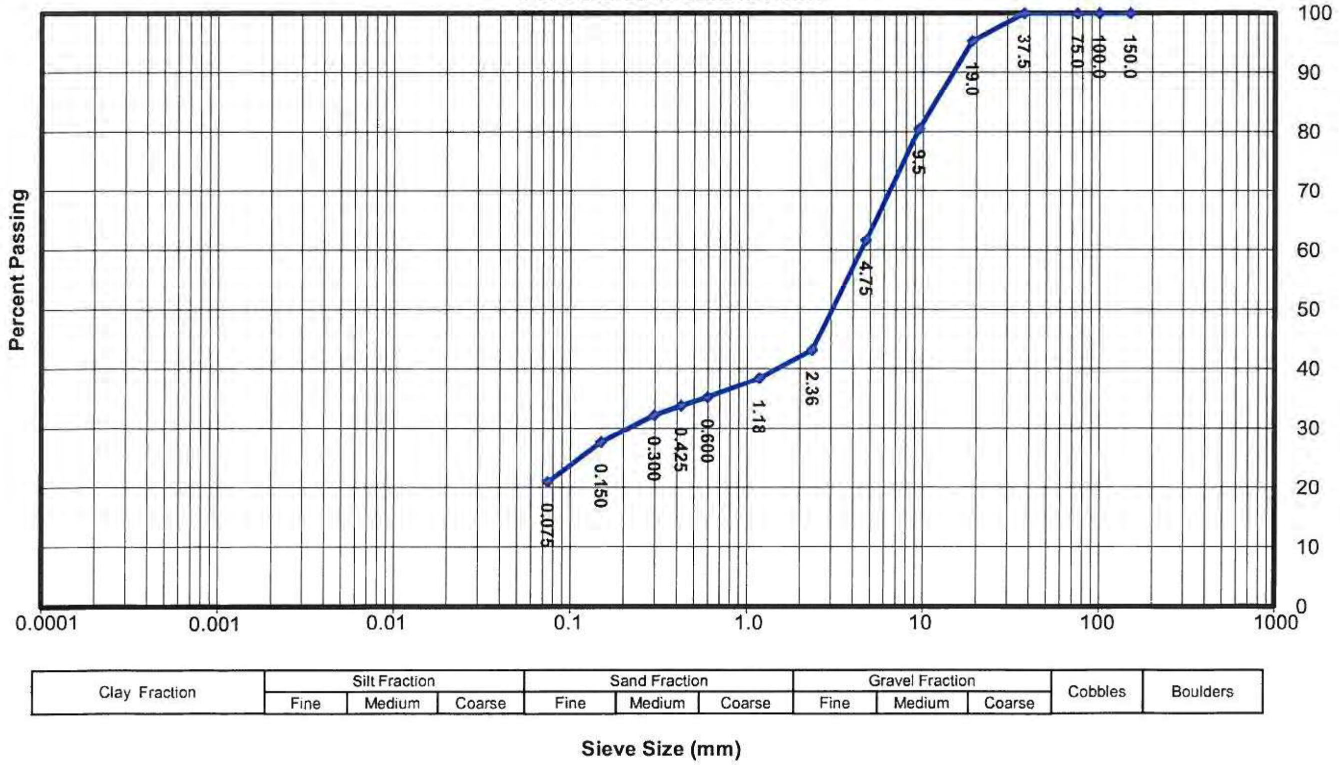
Test Results

Particle Size Distribution in accordance with AS1289.3.6.1

Date tested : 11/11/2010

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	100	2.36	43
100.0	100	1.18	38
75.0	100	0.600	35
37.5	100	0.425	34
19.0	95	0.300	32
9.5	80	0.150	28
4.75	62	0.075	21

Particle Size Distribution



Comments:
Sample supplied by client

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03811-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03811
Field Sample: 00001
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP02 @ 0.60 - 0.90m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	8.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	41	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	18	
Plasticity Index (%)	AS 1289.3.3.1	23	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03812-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

{This document may not be reproduced except in full.}

NATA
WORLD RECOGNISED ACCREDITATION

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03812
Field Sample: 00002
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP03 @ 1.00 - 1.20m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	8.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	56	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	23	
Plasticity Index (%)	AS 1289.3.3.1	33	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03814-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03814
Field Sample: 00004
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP12 @ 0.00 - 0.50m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	13.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	44	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	20	
Plasticity Index (%)	AS 1289.3.3.1	24	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03815-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

NATA
WORLD RECOGNISED ACCREDITATION

B Truslove
Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03815
Field Sample: 00005
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP13 @ 0.00 - 0.50m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	36	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	18	
Plasticity Index (%)	AS 1289.3.3.1	18	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03816-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

{This document may not be reproduced except in full.}

B Truslove
Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03816
Field Sample: 00006
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP15 @ 0.80 - 1.00m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1		
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	6.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	33	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	19	
Plasticity Index (%)	AS 1289.3.3.1	14	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03817-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03817
Field Sample: 00007
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP18 @ 0.70 - 1.00m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	47	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	20	
Plasticity Index (%)	AS 1289.3.3.1	27	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Material Test Report

Report No: WELS10S-03818-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03818
Field Sample: 00008
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP19 @ 0.40 - 0.70m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	7.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	33	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	17	
Plasticity Index (%)	AS 1289.3.3.1	16	

Comments

N/A

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

Material Test Report

Report No: WELS10S-03819-1
Issue No: 1

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

(This document may not be reproduced except in full.)

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03819
Field Sample: 00009
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP22 @ 0.50 - 0.70m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	4.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	32	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	19	
Plasticity Index (%)	AS 1289.3.3.1	13	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03820-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025.

{This document may not be reproduced except in full.}

B Truslove

Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03820
Field Sample: 00010
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP25 @ 0.00 - 0.50m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	5.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	30	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	16	
Plasticity Index (%)	AS 1289.3.3.1	14	

Comments

N/A

Welshpool, Perth Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
269A Treasure Road (Cnr Poole St)
Welshpool WA 6106

Phone: +61 8 6466 2400
Fax: +61 8 6466 2450

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03821-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd (Burswood)
Level 1,89-91 Burswood Road
Burswood WA 6100

Principal: Cossill & Webley
Project No.: INFOWELS00653AA
Project Name: GEOTPERT02828AS - Madigan Rd Development Site
Lot No.: **TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

This document is issued in accordance with NATAs accreditation requirements. Accredited for compliance with ISO/IEC 17025

(This document may not be reproduced except in full.)

B Truslove
Approved Signatory: Brad Truslove
(Laboratory Supervisor)
NATA Accredited Laboratory Number:431
Date of Issue: 18/11/2010

Sample Details

Sample ID: WELS10S-03821
Field Sample: 00011
Date Sampled:
Source:
Material:
Specification:
Sampling Method: Submitted by client
Project Location: Maddigan Road, Karratha, WA
Sample Location: TP29 @ 0.00 - 0.40m

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	7.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	36	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	17	
Plasticity Index (%)	AS 1289.3.3.1	19	

Comments

N/A

Appendix C

CSIRO Information Sheet on Foundation Maintenance

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

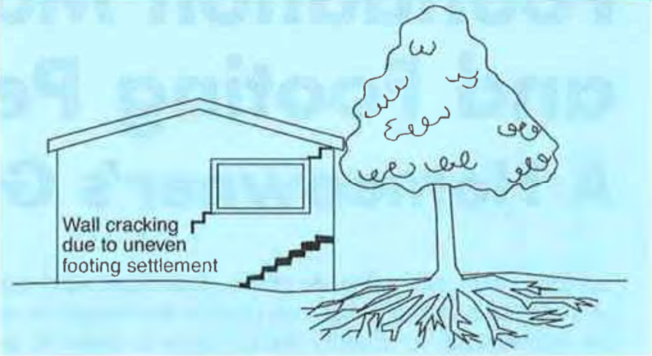
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

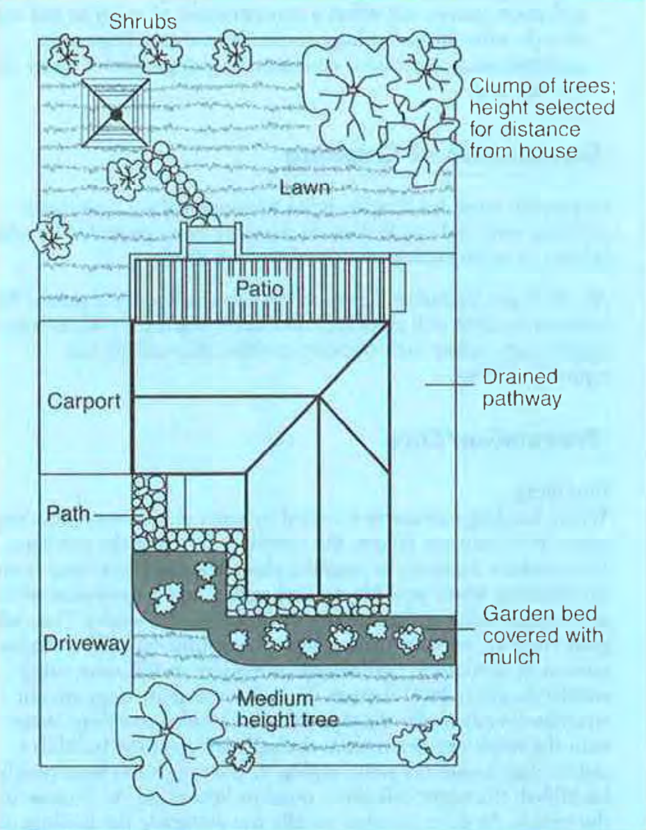
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

Distributed by
CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia
Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au
Email: publishing.sales@csiro.au

APPENDIX 4

INDICATIVE TREE SPECIES

This page has been left blank intentionally.

Species

General planting

Acacia stellaticeps
Cynanchum floribundum
Anigozanthus Bush Sunset
Anigozanthus Bush Tango
Anigozanthus Orange Cross
Acacia ancistrocarpa
Acacia arida
Acacia translucens
Alyogyne hakeifolia
Callistemon "Captain Cook"
Cassia oligophylla
Ipomca costata
Melaleuca glomerata
Azadirachta indica
Tababuia palmeri
Brachychiton gregorii
Eucalyptus terminalis

Trees for mass planting

Acacia aneura	Mulga
Acacia coriacea	Desert oak / Dogwood/ Wirewood
Brachychiton australie	Rock Kurrajong
Brachychiton gregorii	Desert Kurrajong
Eucalyptus aspera	Rough leaf range gum / brittle range gum
Cassia fistula	Golden shower
Eucalyptus coolibah	Coolibah
Eucalyptus dichromophloai	Variable barked bloodwood
Lysiphyllum cunninghamii	Native bauhimia
Melaleuca leucadendron	Cadjeput

Additional Plants for Parks, accent areas etc

Ground Covers & Small Shrubs

Dipteracanthus australasicus	Desert Petunia
Indigoferra georgei	Georges Indigo
Myoporum parvifolium	Creeping Boobialla
Teucrium racemosum	Grey Germanda
Acacia gregorii	Gregorys Wattle
Acacia hilliana	
Ipomoea brasiliensis	Goats Foot/Beach
Myoporum parvifolium	Creeping Boobiala
Grevilliea spp	

Shrubs

Acacia stellaticeps	
Senna artemisiodes ssp. Sturtii	Dense Cassia
Cynanchum fl oribundum	Dumara Bush
Anigozanthus Bush Sunset	Kangaroo Paw
Anigozanthus Bush Tango/Bush Gem	Kangaroo Paw
Anigozanthus Orange Cross Orange	Kangaroo Paw
Acacia ancistrocarpa	Fitzroy Wattle
Acacia arida	Arid White
Acacia translucens	Poverty Bush
Alyogyne hakeifolia	
Callistemon "Captain Cook"	Red Bottlebrush
Callistemon "Kings Park Special"	Red Bottlebrush
Cassia oligophylla	Limestone Cassia/Bloodbush
Ipomca costata	Morning Glory/Native Sweet Potato
Melaleuca glomerata	

Trees

Azadirachta indica	Neem Tree
Tababuia palmeri	Pink Trumpet Tree
Tipuana tipu	Yellow Jacaranda
Brachychiton gregorii	Desert Kurrajong
Eucalyptus terminalis	Bloodwood

This page has been left blank intentionally.

APPENDIX 5

LOCAL WATER MANAGEMENT STRATEGY & FLOOD STUDY

This page has been left blank intentionally.

LandCorp

Madigan Road Urban Development, Karratha
Local Water Management Strategy

October 2010

JDA Consultant Hydrologists

DISCLAIMER

This document is published in accordance with and subject to an agreement between JDA Consultant Hydrologists ("JDA") and the client for whom it has been prepared ("Client"), and is restricted to those issues that have been raised by the Client in its engagement of JDA. It has been prepared using the skill and care ordinarily exercised by Consultant Hydrologists in the preparation of such documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by JDA and the Client without first obtaining a prior written consent of JDA, does so entirely at their own risk and JDA denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this document for any purpose other than that agreed with the Client.

QUALITY ASSURANCE

JDA provides quality assurance through all aspects of the company operation and is endorsed to AS/NZS ISO 9001:2000 Quality Assurance Accreditation, with third party certification to Bureau Veritas Quality International.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

EXECUTIVE SUMMARY

This Local Water Management Strategy has been prepared to support a Development Plan for the Madigan Road Development Area, Karratha in accordance with Better Urban Water Management (WAPC, 2008). A summary of the water management strategy is provided below.

Principle	Key LWMS Elements
Water Quantity To maintain the total water cycle balance within development areas relative to the pre-development conditions.	• Maintain flow paths for existing catchments • Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels. • No lowering of groundwater levels. • Maximise infiltration opportunities where possible.
Water Quality To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.	• Use of treatment train approach to stormwater management • Application of source controls – including education to reduce nutrient application, use of native plantings and vegetated swales. • Application of structural controls – retention/detention areas and vegetated swales.
Water Conservation To maximise the reuse of stormwater	• Encourage implementation of water efficiency and demand management measures both internal and external of buildings. • Use of native plantings to minimise irrigation requirements.
Ecosystem Health To retain natural drainage systems and protect ecosystem health	• Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels to the Madigan Creek.
Economic Viability To implement stormwater systems that are economically viable in the long term	• Use of proven structural WSUD technology. • Use of source control techniques to minimise cost of nutrient management.
Public Health To minimise the public risk, including risk of injury or loss of life to the community	• Design in accordance with relevant design standards, best management practices, council regulations and government agency requirements.
Protection of Property To protect the built environment from flooding	• Identification of 100yr ARI flood levels for Study Area. • Protection of downstream areas by restricting stormwater discharge to existing levels for storm events up to 100yr ARI.
Social Values To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater	• Use of swales within public areas for stormwater conveyance. • Integration of drainage and POS functions.
Development To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability & precautionary principles.	• Urban water management in accordance with Better Urban Water Management (WAPC, 2008). • Development of the LWMS in accordance with government agency guidelines and best management practice recommendations.

1. INTRODUCTION

This document presents a Local Water Management Strategy (LWMS) in support of an urban residential development for approximately 68ha of land located at Madigan Road, Karratha, in the Shire of Roebourne, herein referred to as the Study Area (Figure 1).

1.1 Background

This document has been prepared to support a Structure Plan for the abovementioned property. It presents a recommended approach for total water cycle management within the proposed development area consistent with sustainability principles and the *Better Urban Water Management* (BUWM) (WAPC, 2001) process. The relationship of this document to this BUWM planning process is shown in Table 1.

The LWMS has been developed by JDA Consultant Hydrologists on behalf of LandCorp. The compilation of this document includes a range of expertise and guidelines from leading authorities including the Department of Water (DoW) and the Shire of Roebourne (SoR) to assist in achieving the implementation of best practice in sustainable urban development and urban water management within the Study Area.

Previous advice provided to JDA by the Department of Water for sites in the Pilbara Region of Western Australia indicates that they have not published any guidelines to assist with the preparation of LWMS's specifically for these areas. However, it is acknowledged that flood management with associated issues of erosion and sedimentation are dominant and that peak post development flow rates do not need to be detained to pre-development peak flow, but the velocity of the post development flow should be minimised. A summary of the Department's guidance requirements are presented in Section 1.3.

A copy of the LWMS Checklist has been included as Appendix A to assist the DoW and Shire in review of this document.

TABLE 1: INTEGRATED PLANNING AND URBAN WATER MANAGEMENT PROCESS

Planning Phase	**Planning Document**	**Urban Water Management Document and Status**
District	Shire of Roebourne Town Planning Scheme (TPS 8)	N/A
Local	Karratha City Growth Plan (CGP) Karratha Area Development Strategy (KADS)	Madigan Road Urban Development Local Water Management Strategy **THIS DOCUMENT**
Subdivision	Subdivision Application	Urban Water Management Plan (required for individual stages of development) **FUTURE PREPARATION**

1.2 Previous Studies

This LWMS uses the following key documents to define its content, principles, and objectives.

1.2.1 State Planning Policy 2.9 - Water Resources

The LWMS has been developed in accordance with regional and local principles and objectives of Integrated Urban Water Management (IUWM).

The Western Australian Planning Commission (2005) defines IUWM (also known as total water cycle management) as promoting

> '*management of the urban water cycle as a single system in which all urban water flows are recognised as a potential resource and where the interconnectedness of water supply, stormwater, wastewater, flooding, water quality, waterways, estuaries and coastal waters is recognised*'.

IUWM promotes water conservation measures, reuse and recycling of water and best practice in stormwater management (Western Australian Planning Commission 2005).

1.2.2 Stormwater Management Manual for WA

The Stormwater Management Manual for Western Australia was first published by the Waters and Rivers Commission in 1998 to define and describe in practical terms Best Management Practices (BMP's) to reduce pollutant and nutrient inputs to stormwater drainage systems as well as guidelines for the incorporation of water sensitive urban design principles. A major review of the Stormwater Management Manual was undertaken by the DoW, with additional input by other State and Local Government Authorities and sectors of the urban development industry. This revised version of the Stormwater Management Manual was officially launched in 2007, though some chapters were published in 2004.

DoW's current position on Urban Stormwater Management in Western Australia is outlined in Chapter 2: Understanding the Context of the Stormwater Management Manual for Western Australia (DoW, 2007), which details the management objectives, principles, and a stormwater delivery approach for WA. Principal objectives for managing urban water in WA are stated as:

- Water Quality: To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.
- Water Quantity: To maintain the total water cycle balance within development areas relative to the pre-development conditions.
- Water Conservation: To maximise the reuse of stormwater.
- Ecosystem Health: To retain natural drainage systems and protect ecosystem health.
- Economic Viability: To implement stormwater systems that are economically viable in the long term.
- Public Health: To minimise the public risk, including risk of injury or loss of life to the community.
- Protection of Property: To protect the built environment from flooding and waterlogging.
- Social Values: To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater.

- Development: To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

The Department of Water released the Decision Process for Stormwater Management in WA in August 2009 to provide a decision framework for the planning and design of stormwater management systems and assist in meeting the objectives specified above.

A copy of the Decision Process is contained as Appendix B with key elements summarised in Table 2.

1.2.3 Better Urban Water Management

This LWMS has been developed to be consistent with the framework and process detailed in the recently released guideline document Better Urban Water Management (WAPC, 2008).

This LWMS has been prepared to an appropriate level of detail to support the proposed Structure Plan for the Study Area. The document includes the principles, objectives and requirements of total water cycle management and a detailed description of the environmental conditions of the site. Constraints and opportunities on the site are well understood and considered in the planning process. The capacity of the site to sustain development, including consideration of ASS, impacts from groundwater and surface water, impacts on ecosystems and biodiversity and impacts on existing infrastructure is also examined.

An Urban Water Management Plan (UWMP) will be required prior to the subdivision of the land.

1.2.4 Karratha City of the North Plan

The Karratha City of the North Plan (KCNP) was adopted by the Shire of Roebourne on 18 May 2010. The plan comprises of a series of documents being:

- The Karratha City Growth Plan
- The Karratha City Growth Plan
- Karratha City Centre Master Plan
- Implementation Blueprint

The KNCP provides a basis for guiding decision makers in assessing rezoning, subdivision and development applications as well as the provision of infrastructure and community facilities over time.

1.3 Key Design Principles and Objectives

A summary of the key principles and objectives applicable to the LWMS for the Study Area based on the above and previous advice provided to JDA by the Department of Water (DoW) for preparation of LWMS's in the Pilbara Region are as follows:

- Towns in the Pilbara have been developed using open drains rather than piped drainage and this is appropriate due to the high rainfall intensities and runoff rates compared with the South West WA.
- Existing creeks and drains are retained as far as possible - working with the existing drainage system, rather than against it.
- Flood risk is the main issue from surface water, however groundwater levels also need to be checked.
- Management of erosion and sedimentation is important.
- Other water quality issues such as nutrient concentrations are of lower priority in the Pilbara.
- DoW accepts there will not be 2 years of predevelopment groundwater monitoring data and do expect any groundwater monitoring data to be supplied.
- DoW will not require any post development surface water or groundwater quantity or quality monitoring.
- The LWMS checklist contained in BUWM (WAPC, 2008) should still be used.

A summary of the key principles and objectives applicable to this LWMS for the Study Area in the Pilbara region based on agreement with DoW is presented in Table 2.

TABLE 2: LWMS KEY PRINCIPLES AND OBJECTIVES

<table>
<tr><th colspan="3">Key WSUD Guiding Principles</th></tr>
<tr><td colspan="3">• Facilitate implementation of sustainable best practice in water management in the Pilbara region
• Provide integration with planning processes and clarity for agencies involved with implementation
• To minimise public risk, including risk of injury or loss of life
• Protection of infrastructure from flooding and waterlogging
• Encourage environmentally responsible development</td></tr>
<tr><th>Category</th><th>Principles</th><th>Design Objectives</th></tr>
<tr><td>Water Supply and Conservation</td><td>• Consider all potential water sources in water supply planning.
• Integration of water and land use planning
• Sustainable and equitable use of all water sources having consideration of the needs of all users, including community, industry and environment
• Maximise the reuse of stormwater</td><td>• Minimise the use of potable water where drinking water quality is not essential, particularly ex-building use.
• Apply waterwise landscaping measures to swales in road reserve to reduce/avoid irrigation.</td></tr>
<tr><td>Surface Water Flows and velocity</td><td>• Protect development from flooding.
• Implement economically viable stormwater systems
• Retain natural drainage systems and protect and/or improve ecosystem health – For the Pilbara, reduce the stormwater velocity to prevent export of sediments.
• Ensure that stormwater management recognises and maintains social, aesthetic, and cultural values</td><td>• For flood management, manage up to the 100yr ARI event within the development.
• Use swales through the development to disperse flow throughout the development with the aim to minimise velocity. Swales sized to minimum 5yr ARI, with larger events flowing along road reserve.
• Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles consistent with DoW’s requirements.</td></tr>
<tr><td>Groundwater Levels</td><td>• Protect development from waterlogging</td><td>• Protect development from waterlogging</td></tr>
<tr><td>Water Quality</td><td>• Where development is associated with an ecosystem dependent upon a particular hydrologic regime, minimise discharge or pollutants to shallow groundwater and receiving waterway and maintain water quality in specified environment</td><td>• No sensitive ecosystems in vicinity. The receiving environment is Seven Mile Creek which discharges to the intertidal zone prior to discharging to the ocean.
• Nutrients not considered a priority in the Pilbara.</td></tr>
</table>

2. PRE-DEVELOPMENT ENVIRONMENT

The environmental conditions of the pre-development Study Area provide an important context for planning future water management strategies. This section describes the pre-development condition.

2.1 Location and Topography

The Study Area is approximately 68ha in size and is located about 6km west of the Karratha town site within the Shire of Roebourne (Figure 1). The Study Area is on the south side of Dampier Road, directly to the east of Madigan Road. The Baynton West residential development is located adjacent to the east of the Study Area.

The site is relatively flat, sloping gently from the Karratha Hills to the south towards Dampier Road. Elevation ranges from approximately 27 mAHD at the southern boundary of the Study Area to approximately 14 mAHD at the north (Figure 2).

2.2 Existing Land Use

The Study Area is currently under native vegetation consisting of low tussock and spinifex grass with no evidence of existing infrastructure.

Surrounding land use consists of the Karratha Hills to the south, Woodside Petroleum's Pluto Worker Camp to the west of Madigan Rd (on land identified for future urban development), Banyton West residential development to the east (currently under development) and Dampier Road to the north.

Also abutting the north of the site is the Karratha Cemetery. The entire east boundary and part of the north boundary is adjacent to land reserved for Public Open Space (POS) and drainage purposes.

2.3 Climate

Karratha has an arid climate characterised by hot summers with periodic heavy rain and mild winters with occasional rainfall.

The Pilbara coast experiences more cyclones than any other part of Australia. Since 1910 there have been 48 cyclones that have caused damaging wind gusts in excess of 90 km/h in the Karratha, Dampier and Roebourne region. On average this equates to about one every two years. About half of these cyclones have an impact equivalent to a category one cyclone. Ten of these: 1925, 1939, 1945, 1954, Shirley 1966, Sheila-Sophie 1971, Trixie 1975, Chloe 1984, Orson 1989 and John 1999 have caused very destructive wind gusts in excess of 170 km/h (BoM 2010).

The average annual rainfall for Karratha is 280 mm per year, with a maximum recorded annual rainfall of 855mm from records taken between 1974-2009 at Karratha Airport (BoM 2010). Most of the recorded precipitation is received during the wet season, as a result of tropical cyclones and local thunderstorms

Along the central Pilbara coast the cyclone season runs from mid December to April peaking in February. Figure 3 presents graphed rainfall data for Karratha Airport (BoM site 4083).

The average annual pan evaporation is approximately 3,590mm (Luke et al, 1988).

2.4 Geology and Soils

The entire Study Area is covered by floodplain deposits of red-brown silty sand, which has been partially reworked by wind action over much of the site. The sand may contain nodules or lenses of calcrete approximately 1m below the surface, and scattered pebbles throughout. The sand is underlain by Archaean bedrock, probably mafic volcanics at an expected depth ranging from 10-20m below surface. The upper few metres of the bedrock are weathered and fractured. Surface Geology is presented in Figure 2.

It is likely that perching of groundwater within the subsoil profile may occur above very low permeability horizons such as weathered bedrock and clayey materials. Consequently, opportunities for infiltration of stormwater are also limited.

2.5 Groundwater Hydrology

Groundwater occurs within a single aquifer known as the Pilbara Fractured Rock Aquifer.

Although there are no long term groundwater monitoring bores known to exist within the Karratha Area, the watertable is expected to be 5-10m below surface and may vary seasonally in depth by 2-3m in response to heavy rainfall. The groundwater is expected to be slightly brackish to saline, in the range 2,500 – 10,000 mg/L Total Dissolved Solids, but there may be more saline groundwater in localized areas of low permeability.

A site visit of September 8th 2010 also noted that there was no evidence of groundwater in any of the surface drainage systems (Madigan Creek).

2.6 Surface Water Hydrology

2.6.1 Existing Surface Drainage

No drainage channels or permanent surface water features exist within the Study Area. A major drainage channel to the east is described in Section 2.6.2.

The Study Area is subject to runoff from the hills to the south. Runoff sheds naturally to the north and west towards Seven Mile Creek catchment. However since construction of Madigan Rd, this flow is now restricted and builds up before flowing back east towards Madigan Creek. This is facilitated by the generally flat nature of the topography within the Study Area.

Along 3 locations on Madigan Rd there are single 300mm culverts which are located even distance apart. Due to the limited size of these culverts, these culverts are not considered to be sized for conveying flow from the Study Area. Instead they have been designed to convey surface runoff from the east side of the crowned Madigan Road back towards Seven Mile Creek.

2.6.2 Madigan Creek

A major drainage line occurs directly to the east of the Study Area. This feature is a non-perennial natural creek which conveys storm runoff from a catchment formed within the Karratha Hills to the south of the

Study Area. The creek flows northwards through 4 x 1500m culverts underneath Dampier Road towards the coast (Figure 4).

The unnamed creek, herein referred to as Madigan Creek is the subject of a separate flood study associated with the Madigan Road Urban Development currently being prepared by JDA.

The flood study aims to assess the following:

- Existing 100yr ARI flood levels along Madigan Creek from the southern limit of development downstream to north of Dampier Rd.
- The impact of altering the vertical profile of Dampier Rd, or of altering the culverts beneath Dampier Rd for Madigan Creek, on the 100yr ARI flood levels on the development site.
- The impact of a possible bridge crossings over Madigan Creek.

Main Roads Western Australia (MRWA) and the Shire of Roebourne have advised that Dampier Road has never been overtopped during any storm event. However no anecdotal evidence is available to support this. MRWA have advised that culverts need to be sized to convey 50yr ARI stormwater before overtopping the road.

No previous measurements for flow or water quality data is available for Madigan Creek.

2.7 Water Resources

Karratha is located within the Rights in Water and Irrigation Act 1914 Pilbara Surface Water and Groundwater Area.

There is no immediate infrastructure situated on local surface water courses (Seven Mile Creek or Madigan Creek) to provide a surface water resource. Similarly, the Pilbara Fractured Rock Aquifer is not considered to be a suitable groundwater resource in terms of quality or yield for potable or non-potable requirements.

However, water could potentially be sourced from existing Karratha supplies including the Harding Dam (surface water resource) and/or the Millstream Borefield (groundwater resource).

2.8 Acid Sulphate Soils

The Department of Environment and Conservation (DEC) Acid Sulphate Soil (ASS) mapping identifies a narrow margin on the eastern boundary of the Study Area as “Moderate to Low Risk” of acid sulphate soils occurring within 3m of natural soil surface (or deeper)” (DEC 2008), this is likely to be associated with the proximity of the adjacent creekline. The remainder of the site is mapped as “No Known Risk” (Figure 2).

2.9 Vegetation

Environmental Assessment performed by Coffey Environmental (2010) indicates the vegetation is not considered significant at the local, state or national level and there are no Threatened Ecological Communities (TEC) within the Study Area.

2.10 Aboriginal Heritage

Three Aboriginal archaeological sites have been identified within the Study Area as a result of an Aboriginal heritage survey (March 2010).

TPG (2010) advise that it is likely that a Section 18 clearance under the Aboriginal Heritage Act 1972 will be required for the development along with a comprehensive management plan where sites are to be retained.

3. PROPOSED DEVELOPMENT

The proposed Structure Plan (TPG, 2010) for the Study Area is shown in Figure 5. It shows that land use in the proposed development will consist of a mixture of varying densities of residential (R17.5 to R60), mixed use commercial and various pockets of public open space (POS) areas integrated with drainage.

The POS areas will have a dual function of provision of active and passive recreational form integrated with drainage swales to convey stormwater runoff to Madigan Creek. The drainage swales will vary in base width being smaller upstream and larger downstream all within the allocated POS area. They will have a shallow profile 0.575m and in some locations may form a special feature with an elevated footbridge etc.

The alignment with Madigan Creek will be retained as existing and the interface with the development to be integrated with potential future open space.

4. LOCAL WATER MANAGEMENT STRATEGY

The proposed Local Water Management Strategy for the Study Area is outlined in this section. It includes discussions regarding water use and conservation, and details key elements of groundwater and surface water with respect to demonstrated best management practice in water sensitive urban design.

Issues related to implementation are discussed in Section 5.

4.1 Water Use & Sustainability Initiatives

The supply and sustainable use of water within the proposed development are key components of the management strategy.

4.1.1 Water Sources

A development scale water reuse scheme is not planned for the Study Area.

Potable water supply to the Study Area is proposed from the scheme water serviced via an extension of the Water Corporation's existing infrastructure for the Karratha town. It is envisaged that potable water supply will be used for in and ex house uses.

The use of groundwater as a non-potable water supply source, particularly for POS irrigation purposes, is considered unlikely due to poor yields from the nature of the fractured rock aquifer. POS areas will be landscaped appropriately for the climatic conditions and any area requiring irrigation will be minimal. Irrigation water source will be from the scheme water supply.

4.1.2 Water Conservation

Development of the Study Area will lead to an increased demand for water for domestic supply as well as irrigation of public open space. Water conservation measures will be promoted to reduce scheme water consumption within the development and will be consistent with Water Corporation's "Waterwise" land development criteria which could include:

- Promotion of use of waterwise practices including water efficient fixtures and fitting (taps, toilets and appliances, waterwise landscaping, plumbing for grey water reuse).
- Use of native vegetation requiring less irrigation in proposed drainage swales and public areas.
- Rainwater tanks as one method of collecting roof stormwater for possible reuse. However given the low rainfall pattern of the region, viability will need to be assessed prior to implementation.
- Opportunities for localised capturing and storing of rainfall runoff within the drainage swales and Madigan Creek will also be investigated during landscape design to assist in enhancing the creek ecosystem and support vegetation growth.

Specific measures to achieve water conservation will be detailed in the UWMP.

4.1.3 Non Potable Water Supply & Water Balance

A water balance at the LWMS stage is generally requested to support the identification of excess water generated by the development for potential use as a non-potable water supply scheme.

Based on geotechnical investigations (Section 2.3) opportunities for infiltration (pre and post development) and storage of stormwater for reuse in the Study Area are limited. Furthermore, recharge and abstraction from the superficial aquifer for non potable use is considered unlikely due to the presence of subsurface clay.

Whilst development generally leads to an increase in the post development peak flow and volume of surface water discharge to the receiving environment, the limited infiltration and high runoff rates are similar for both pre and post development condition. Consequently, change in landuse to post development generates limited excess water from a water balance perspective.

4.2 Surface Water Management

Management of surface water in the Study Area following development involves mitigating the impacts from flooding and designing a suitable stormwater system to convey and improve water quality.

4.2.1 Flood Management Concepts

Local stormwater management is proposed to be undertaken consistent with water sensitive design practices and meet key objectives and criteria as detailed in Table 2. The main emphasis of the drainage design is to overcome the need for the traditional deep drainage gullies that currently exist throughout the town site and to integrate them into the POS (Figure 5).

The local stormwater management system will consist of a series of drainage swales with the aim of safely conveying stormwater from the Study Area to Madigan Creek. The drainage swales will also attenuate peak surface water flows, and provide water quality treatment for the proposed development prior to discharge from the Study Area. Due to the large rainfall intensity and volumes experienced in the Pilbara region, conveyance of stormwater is via open drainage systems rather than underground pipe systems.

The stormwater drainage system will be designed using a major/minor approach. The minor drainage system is defined as the system of swales, kerbs, gutters etc. designed to carry runoff generated by low frequency ARI storms, typically less than 5 year ARI. The major drainage system is defined as the arrangement of roads, drainage swales and open space areas planned to provide safe passage of stormwater runoff from extreme events which exceeds the capacity of the minor system.

As the Shire of Roebourne do not have a standard rainfall event (ARI) criterion for design of stormwater drainage systems, a design criteria of 20yr ARI has been adopted for the drainage swale sizing. This design criteria is consistent with that generally adopted by Main Roads WA.

4.2.2 Minor Road Design

Minor roads are all roads other than those that are located adjacent to the drainage swales. The minor roads will convey stormwater runoff generated by impervious areas from both the lots and the road reserve via the road gutter system into the main drainage swales.

These roads will be crowned at the centre with stormwater runoff contained within the depth of the kerb for rainfall events up to the critical 5yr ARI. For rainfall events greater, stormwater runoff may exceed the depth of the kerb and utilise part of the road reserve as the overland flow path prior to discharge into the drainage swale.

Locations were flow from the minor roads discharge into the drainage swale will be sufficiently protected by rock armour or engineering structures such as drop structures to assist in minimising or preventing scouring and erosion.

4.2.3 Drainage Swale Design

Drainage swales are arranged in an east-west orientation and form part of the POS. In some instances they are located adjacent to a road designed with a one way crossfall for runoff to flow directly into the drainage swale. They convey stormwater runoff from both the adjacent road and the minor roads to Madigan Creek by the shortest route.

The drainage swales are located within 15m wide POS areas and have an average base width of 7.5m. Their widths will vary within the POS area from being smaller upstream to wider downstream as the contributing flow areas increase. The will have a nominal depth of 0.575m to maintain a shallow profile for urban form and allow integration of drainage function with passive POS.

The drainage swales flow under cross roads via culverts and over cross roads as a spillway for events greater than 20yr ARI. The culverts have varying widths and a maximum height of 375mm to assist in maintaining a low profile of the swale. The spillway level of the cross road is nominally 200mm above the culvert resulting in swale depth of 575mm prior to overflow. Attenuation of flow is achieved within the drainage swale by the culverts.

Note that the use of culverts have been proposed to pass flow under the cross roads to minimise the occurrence of stormwater runoff and associated silt flowing over the cross roads during storm events. However during further detail design, there maybe opportunities to avoid the use of culverts and use the cross roads spillways for all conveyance where:

- Some dust/minor silt conveyance is acceptable to the Shire given its likely infrequency and low level of impact.
- A design solution to silting is out in place
- Topography or landscape design intent make a small bridge a more appropriate or attractive option to a shallow culvert.

At some locations, the drainage swale junction at cross roads maybe designed as a feature with elevated footpaths or pedestrian bridges over spillways. Similarly, cross road junctions along the eastern boundary road with Madigan Creek maybe designed into feature bridges with speed bumps for safety. Further detail of these designs will be investigated during detail design and presented in the subsequent Urban Water Management Plan (UWMP).

They will be landscaped with native vegetation to assist in improving water quality and contain strategically placed boulders to minimise scouring and erosion. French (1985) recommends a maximum design velocity of 1.1m/s to protect against erosion and scouring for Alluvial silts and ordinary firm loam which are considered representative of the Study Area.

For safety purposes, the product of depth and velocity shall not exceed 0.4m^2/s (IEAust, 2000).

The swales will not contain any permanent open water bodies, an approach consistent with the DoW's current policy on the use of constructed lakes for stormwater management.

Minimum building floor levels will be 0.5m above the estimated 100yr ARI flood level, consistent with Australian Rainfall & Runoff (AR&R) (Institution of Engineers, Australia 2000).

4.2.4 Pre-development Discharge Modelling

Pre-development modelling has been performed to determine discharge rates for post development comparison.

A simple method of analysis is using the Rational Method for the North West Region as outlined in AR&R (IEAust 2000). However, in this instance the size of the Study Area catchment is 0.68km^2, notably less than the minimum size of the range of catchments used (40.5 to 7980km^2) to derive the Rational Method formula for the North West. Consequently peak flow estimates from the Rational Method are not reliable.

An alternative method for estimating pre-development flow rates is using the rainfall runoff routing model RORB, which JDA are currently using to prepare the Madigan Creek Flood Study (separate to this report). Based on topographic contours, the Study Area falls within a sub-catchment of Madigan Creek from which pre-development flow estimates have been calculated as part of catchment modelling using RORB.

The loss model adopted in the Madigan Creek Flood Study assumed a 100% runoff coefficient with a 5mm initial loss and a 2mm/hr continuing loss. This loss model was similar to that adopted by GHD (2010) for the neighbouring Seven Mile Creek catchment. The Flood Study found that the 1hr rainfall event was the critical duration for all ARI's.

Modelling results from RORB from the Flood Study based on a pro-rata assessment of flows estimated for the Madigan Creek catchment ($[Area_1/Area_2]^{0.7}$) indicate flows for the Study Area as follows:

- 5yr ARI: 12 m^3/s
- 20yr ARI: 19 m^3/s
- 100yr ARI: 30 m^3/s

4.2.5 Post Development Stormwater System Design

Conceptual stormwater modelling was performed for the Study Area using the model XP-Storm to determine post development flood storage requirements and assess whether sufficient area has been provided within the POS for drainage purposes. Modelling was based on the proposed land use plan shown in Figure 5.

The design storms modelled by XP-Storm for pre-development were calculated internally by the model with reference to the methodology in Australian Rainfall & Runoff (AR&R) (Institution of Engineers, Australia 2000). The rainfall temporal pattern was assumed to be spatially uniform across the catchment. Storm durations modelled ranged from 10 minutes to 72 hours for the 5yr, 20yr and 100yr ARI storm events.

Six drainage swales are proposed with the post development catchments shown on Figure 6. Catchment boundaries are based on each drainage swale having a connecting minor road with a maximum length of 200m. This is the maximum length the minor road can be to convey the critical 5yr ARI 1hr rainfall event without flow exceeding the road gutter depth.

The drainage swales will have a minimum longitudinal grade of 1 in 500 with the downstream invert set at the current existing natural surface at the boundary of the Study Area. The elevations at these locations are approximately 0.5m above the adjacent invert of Madigan Creek. A free outfall condition into Madigan Creek was adopted for this modelling.

The drainage outlets into Madigan Creek are to be appropriately designed during detail design with sufficient protection such as rock armouring, drop structures or concrete spillways to prevent or minimise scouring and erosion.

The drainage swales have been designed to contain the critical 20yr ARI rainfall event within the designated POS area with a base width of 7.5m and a maximum flood depth of 0.575m prior to overflow onto the adjacent road and over the cross road spillway.

The loss model adopted for the modelling assumed a 1.5mm initial loss from both the Lot and Road Reserve areas. A conservative runoff rate of 100% was also applied to both these areas for the 5yr, 20yr and 100yr ARI rainfall events.

For the purposes of this LWMS in determining whether sufficient area has been allocated for drainage within the development plan, stormwater modelling has only been performed for drainage Catchment 3. That is, Catchment 3 is the largest post development drainage catchment within the Study Area (Figure 6). Consequently, as all drainage swales will have similar dimensions allocated within their POS areas (ie. 7.5m width), if stormwater modelling indicates that these swale dimensions are sufficient to accommodate drainage from Catchment 3, then the allocated area for the drainage swale will also be sufficient for all the other smaller catchments.

Details of the longitudinal section for the Catchment 3 drainage swale including inverts and culvert sizes are presented in Figure 7.

4.2.6 Post Development Stormwater System Modelling Results

Modelling results for the Catchment 3 drainage swale of flood levels and depth, flow and velocity for the 5yr, 20yr and 100yr ARI are presented in Figure 7.

Results indicate that the 7.5m wide drainage swale can sufficiently accommodate stormwater runoff for up to the critical 20yr ARI rainfall event within the swale design depth of 0.575m and without flow over the cross road spillway. For events greater up to the critical 100yr ARI rainfall event, flow occurs over the cross road spillway with a maximum depth of 0.11m and all flow is contained within the road reserve.

Consequently, to provide an indication of the flood levels in the other catchment drainage swales, the modelled upstream and downstream flood depths from Catchment 3 have been applied to the other drainage swale inverts as shown in Figure 8. Whilst it is acknowledged that these estimates are conservative as Catchment 3 is much larger than the other catchments, they provide an indication of the possible depth of fill required to achieve finished lot levels 0.5m above the 100yr ARI flood level.

Figure 8 also shows the indicative 100yr ARI flood area of Madigan Creek between the two developments either side of Madigan Creek. Further details of the Madigan Creek flood levels will be presented in the UWMP when the Madigan Creek Flood Study is completed.

Flows from the drainage swale outlet for the 5yr, 20yr and 100yr ARI are 3.2m^3/s, 5.0m^3/s and 6.9m^3/s respectively. To determine outflow estimates from the other catchment drainage swales, a pro-rata analysis of these flows based on catchment areas has been conservatively applied and is presented in Figure 8. Thus the resulting post development outflow from the Study Area to Madigan Creek is as follows:

- 5yr ARI: 13 m^3/s (pre-development 12 m^3/s)
- 20yr ARI: 21 m^3/s (pre-development 19 m^3/s)
- 100yr ARI: 29 m^3/s (pre-development 30 m^3/s)

These results indicate that the 5yr, 20yr and 100yr ARI post development flows are similar to pre-development.

It is noted that the downstream velocity at the outlet (1.5m/s) exceeds the recommended maximum design velocity of 1.1m/s to protect against scouring and erosion. However it is considered that refinement of the drainage swale dimensions (widening base width), modelling parameters and inclusion of engineering structures (where appropriate) during detail design will reduce velocity within the recommended design limit.

From a safety perspective, the product of velocity and flood depth should not exceed 0.4m^2/s. Although this applies to stormwater flow on the road system, it has also been conservatively applied to the drainage swales within the POS. Results presented on Figure 7 indicate that this criteria is satisfied for the 5yr ARI but is exceeded towards the downstream part of the drainage swale in the 20yr and 100yr ARI (average of 0.5m^2/s and 0.7m^2/s respectively).

However note that the other drainage catchments have smaller catchments than Catchment 3 and as such flow velocities and depths will be less and may not exceed this criteria. Notwithstanding, during detailed design wider flow corridors can be adopted for the 7.5m swales within the 15m wide POS to suit landscape design and assist in reducing flood levels and/or depths, flows and velocities. In addition, use of velocity reducing infrastructure such as drop structures etc or refinement of swale grades can also be adopted and will be presented in the UWMP.

A sensitivity analysis was also performed assuming a backwater condition of a 100yr ARI flood level in Madigan Creek being 0.5m above its existing invert. This results in a negligible impact on the 100yr ARI flood levels within the drainage swale.

Figure 9 presents a snapshot of the event plans for the 5yr, 20yr and 100yr ARI rainfall events.

Overall, the modelling results indicate that there is sufficient area within the allocated POS area to contain the required drainage swale for the post development catchments for up to the critical 100yr ARI event.

The final drainage swale configuration (area, side slopes etc) and location will be documented in the UWMP and will be dependent on final earthworks, drainage and road design levels for the development.

Minor changes (refinements) in catchment areas shown in this report are therefore considered likely to occur as detailed design proceeds.

Discussion regarding the system compliance with DoW requirements is contained in Section 4.7.

Landscaping design for POS areas will be undertaken in conjunction with detailed design and preparation of the UWMP for agency approval during subdivision.

4.3 Groundwater Management

A groundwater management strategy is required to ensure the required separation between building floor levels for development and groundwater level is achieved.

As discussed in Section 2.5, the watertable is expected to be 5-10m below the surface and may vary seasonally in depth by 2-3m in response to heavy rainfall. Consequently, as there is at least 2m of clearance to groundwater from the natural surface level, groundwater management such as subsoil drainage is currently not required.

Note that fill required to satisfy flood levels and geotechnical requirements are considered to be the critical factor in determining fill requirements rather than groundwater levels.

However, while this LWMS establishes criteria and the general approach for setting development levels, finished lot levels and fill requirements are a detailed design issue and will addressed during preparation of Urban Water Management Plans (UWMP's).

4.4 Vegetation Management

Native and endemic vegetation species are proposed to be incorporated into POS areas for landscaping treatments. Landscape plans and management details including planting locations and species will be prepared during detail design by a landscape consultant and summarised in the UWMP.

4.5 Water Quality Management

With respect to water quality management the LWMS proposes that the use of swales is appropriate treatment for minor events in the Pilbara region.

- **Non Structural Controls**
  Planning practices (wide road reserves to accommodate dedicated drainage swales)
  Construction practices (construction management, use of appropriate native plantings)
  Maintenance practices (of the swale systems)
  Structural Controls
  Infiltration of frequent events where possible (swales)
  Creation of ephemeral retention/detention areas
  Use of vegetated swales

Other water quality parameters such as oils, grease and hydrocarbons are considered to be treated by structural controls as specified by the Shire of Roebourne.

4.5.1 Assessment of Proposed Structural BMP's to Design Criteria

Table 3 details a summary from DoW's Stormwater Management Manual for Western Australia (2007) of expected pollutant removal efficiencies for vegetated swales and detention/retention systems in relation to the water quality design criteria previously discussed in Section 1.2. Expected nutrient input reductions via non structural measures calculated in Section 4.5.1 are also reported in Table 3.

While DoW (2007) does not provide expected pollutant removal efficiencies for all BMP's, application of a treatment train approach using a combination of non structural and structural measures detailed in Section 4.5 will therefore clearly achieve the design objectives for water quality.

Specific details on the location, scale of application, and responsibilities for individual BMP's will be addressed during development of the Urban Water Management Plan (UWMP).

TABLE 3: BMP WATER QUALITY PERFORMANCE IN RELATION TO DESIGN CRITERIA

Parameter	**Design Criteria via PDC(2006)** (required removal as compared to a development with no WSUD)	**Non Structural Controls** (refer Section 4.5.1) Nutrient Input Reduction	**Structural Controls** Nutrient Output Reduction [1]	
			Vegetated Swales	**Detention/ Retention Measures**
Total Suspended Solids	80%	-	60-80%	65-99%
Total Phosphorus	60%	45%	30-50%	40-80%
Total Nitrogen	45%	39%	25-40%	50-70%
Gross Pollutants	70%	-	-	>90%

1. Typical Performance Efficiencies via DoW (2007)

4.6 Construction Management

The potential presence of groundwater and acid sulphate soils may require management during construction of the proposed development.

4.6.1 Dewatering

Dewatering may be required for some elements of subdivision construction. Given the depth of construction, dewatering will only be in the superficial aquifer. As the volume of dewatering is generally minor and of a temporary nature, the overall impact on the aquifer will be minimal, although some drawdown will occur at the dewatering site.

Prior to the commencement of any dewatering, the construction contractor will prepare a Dewatering Management Plan consistent with the DoW's Water Quality Protection Note (WQPN 13, 2006) and apply for and obtain from DoW a "Licence to Take Water". All dewatering will be carried out in accordance with the conditions of this licence and the Dewatering Management Plan.

Where possible, construction will be timed to minimise groundwater impacts and dewatering requirement.

4.6.2 Acid Sulphate Soils

As previously discussed in Section 2.8, a narrow margin on the eastern boundary of the Study Area as "Moderate to Low Risk" of acid sulphate soils occurring within 3m of natural soil surface (or deeper)" (DEC 2008) (Figure 2).

During detail design, assessment and management of ASS is to be conducted in accordance with the Acid Sulphate Soil Guideline Series Identification and Investigation of Acid Sulphate Soils (DoE, 2004), including a Preliminary Site Assessment (PSA) involving a targeted soil and groundwater sampling and analysis program, detailed site assessment, and ultimately an ASS Management Plan if ASS occurs.

Should further investigations indicate the presence of ASS, during construction, appropriate handling methods will need to be employed by the construction contractor to manage any potential acid sulphate soils. Handling should be in accordance with the Acid Sulphate Soils Guidelines Series Treatment and Management of Disturbed Acid Sulphate Soils (DoE, 2004). These guidelines specify holding times and specific methods for treatment of such soils.

To confirm the status of soils, the site engineer/scientist will regularly inspect excavations and spoil, and ensure such soils where encountered are appropriately tested and managed before reuse or disposal.

4.7 Water Management Strategy Summary

Table 4 provides an overall summary of key elements of the proposed water management strategy for the Study Area, with an assessment of the strategy in relation to DoW (2007) principle objectives for stormwater management in Western Australia (Section 1.2.4).

TABLE 4: SUMMARY OF PROPOSED LOCAL WATER MANAGEMENT STRATEGY

Principle	Key LWMS Elements
Water Quantity To maintain the total water cycle balance within development areas relative to the pre-development conditions.	• Maintain flow paths for existing catchments • Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels. • No lowering of groundwater levels. • Maximise infiltration opportunities where possible.
Water Quality To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.	• Use of treatment train approach to stormwater management • Application of source controls – including education to reduce nutrient application, use of native plantings and vegetated swales. • Application of structural controls – retention/detention areas and vegetated swales.
Water Conservation To maximise the reuse of stormwater	• Encourage implementation of water efficiency and demand management measures both internal and external of buildings. • Use of native plantings to minimise irrigation requirements.
Ecosystem Health To retain natural drainage systems and protect ecosystem health	• Maintain 5yr, 20yr and 100yr ARI peak flows from the Study Area at or below current discharge levels to the Madigan Creek.
Economic Viability To implement stormwater systems that are economically viable in the long term	• Use of proven structural WSUD technology. • Use of source control techniques to minimise cost of nutrient management.
Public Health To minimise the public risk, including risk of injury or loss of life to the community	• Design in accordance with relevant design standards, best management practices, council regulations and government agency requirements.
Protection of Property To protect the built environment from flooding	• Identification of 100yr ARI flood levels for Study Area. • Protection of downstream areas by restricting stormwater discharge to existing levels for storm events up to 100yr ARI.

Social Values To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater	- Use of swales within public areas for stormwater conveyance. - Integration of drainage and POS functions.
Development To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability & precautionary principles.	- Urban water management in accordance with Better Urban Water Management (WAPC, 2008). - Development of the LWMS in accordance with government agency guidelines and best management practice recommendations.

5. IMPLEMENTATION

Implementation of the Local Water Management Strategy involves defining the roles and responsibilities of the developer and local authority, outlining further documentation required to support the development and defining operation, monitoring and maintenance of the stormwater system.

5.1 Roles and Responsibilities

Table 5 details the roles and responsibilities to undertake the implementation plan.

The operation and maintenance of the stormwater management system will initially be the responsibility of the developer within the Study Area. Responsibility for all areas will ultimately be reverted to the local authority. Preparation of the UWMP will be the responsibility of the developer.

TABLE 5: IMPLEMENTATION RESPONSIBILITIES

IMPLEMENTATION		RESPONSIBILITY	
LWMS Section	Action	Developer	Shire of Roebourne
5.2	Preparation of an Urban Water Management Plan to support subdivision	✓	
5.3	Construction of stormwater system	✓	
5.3	Stormwater system operation and maintenance		✓

5.2 Subdivision Process

A UWMP for the Study Area will be submitted by the developer to the Department of Water and the Shire of Roebourne as required under relevant conditions of subdivision. The UWMP will address:

- Detailed stormwater management design including the size, location and design of swales, integrating major and minor flood management capability, landscape plants for the swales as related to stormwater function, specific details of local geotechnical investigations and their impact on stormwater design;
- Detail measures to reduce velocity of stormwater discharge to prevent erosion and sediment transportation.
- Management of groundwater levels, and if any proposed dewatering is necessary;
- Agreed/approved measures to achieve water conservation and efficiencies of use including sources of water for non-potable uses and detailed designs, controls, management and operation of any proposed system;
- Management of sub-divisional works (management of soil/sediment including dust)
- Implementation plan including monitoring program, roles, responsibilities, funding and maintenance arrangements. Contingency plans should also be indicated where necessary

5.3 Stormwater System Operation and Maintenance

Ongoing operation and maintenance of the drainage system will be the responsibility of the Shire of Roebourne. The surface drainage system will require routine maintenance to ensure its efficient operation. It is considered the following operating and maintenance practices will be implemented periodically:

- removal of debris to prevent blockages
- cleaning of sediment build up and litter layer on the bottom of drainage swales

A summary of the proposed maintenance schedule is presented in Table 6 below.

TABLE 6: MAINTENANCE SCHEDULE FOR DRAINAGE INFRASTRUCTURE

Item	Maintenance Interval		
	Quarterly	Biannually	As required
Drainage Swales			
Removal of debris to prevent blockages	✓		
Inspect for erosion + sediment accumulation		✓	
Assess health of vegetation. Remove dead plants and replace where necessary.	✓		
Removal of sediment and leaf litter layer build up.			✓

5.4 Monitoring Program

The stormwater management system outlined in this LWMS focuses on implementation of current known best management practice without the requirement of a post development monitoring program.

6. REFERENCES

Department of Environment (2004), Treatment and Management of Disturbed Acid Sulphate Soils, Acid Sulphate Soils Guideline Series, October 2004.

Department of Environment and Conservation (2008), Acid Sulphate Soil Mapping.

Department of Indigenous Affairs (2009), Aboriginal Heritage Enquiry System.

Department of Water (2006) Dewatering of Soils at Construction Sites

Department of Water (2007), Stormwater Management Manual for Western Australia, August 2007.

French, Richard.H. (1985), Open Channel Hydraulics.

Institution of Engineers, Australia (2000), Australian Rainfall & Runoff

Institution of Engineers Australia (2006), Australian Runoff Quality.

Luke, G.L., Burke, K.L. & O'Brien, T.M. (1988). Evaporation Data for Western Australia – Technical Report 65. Perth: W.A. Department of Agriculture, Division of Resource Management.

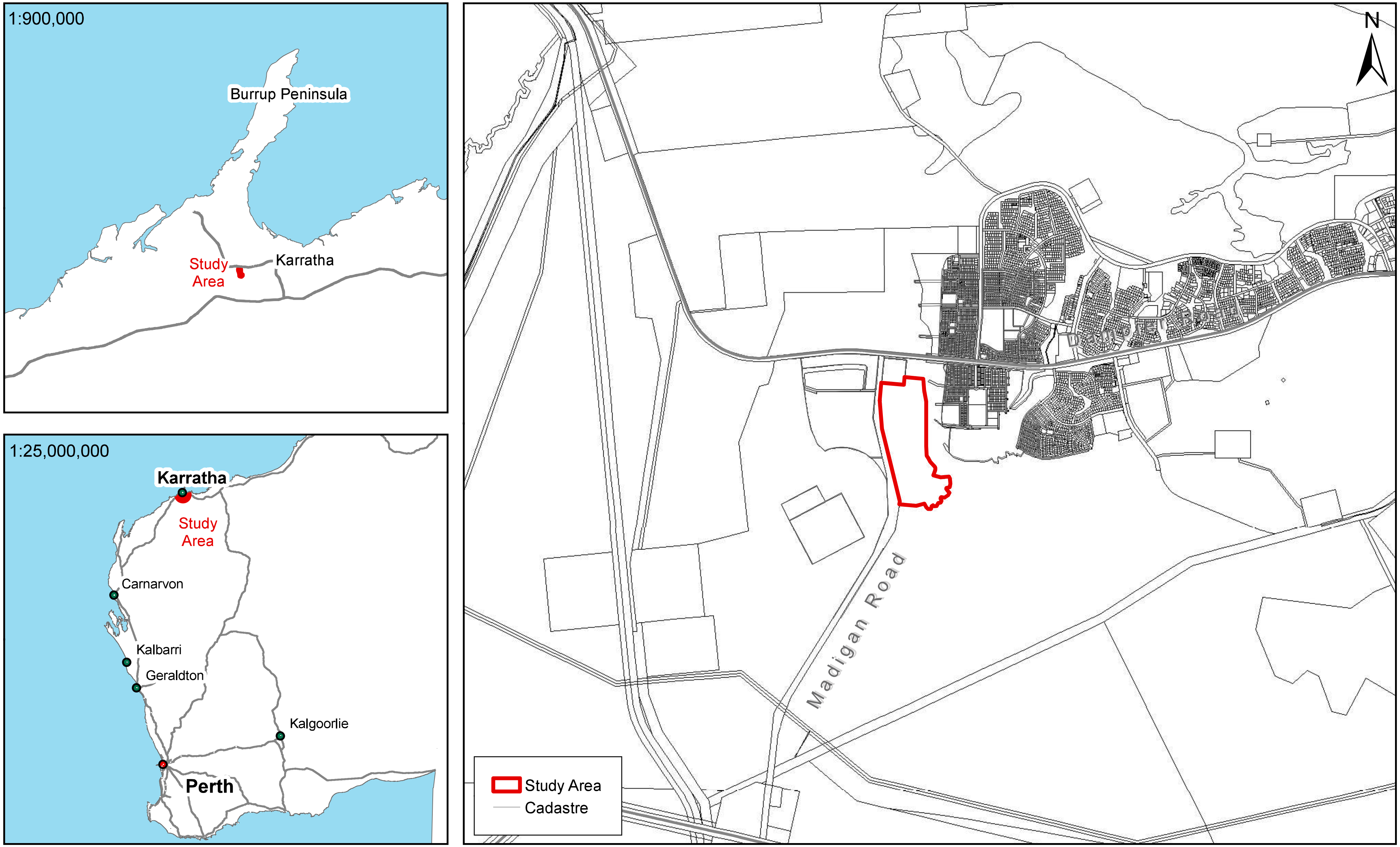
Western Australian Planning Commission (2003), WAPC Planning Bulletin 64, Acid Sulphate Soils, November 2003.

Western Australian Planning Commission (2005), Water Resources State Planning Policy 2.9.

Western Australian Planning Commission (2007), Liveable Neighbourhoods, A Western Australian Government Sustainable Cities Initiatives

Western Australian Planning Commission. (2008), Better Urban Water Management, October 2008

FIGURES



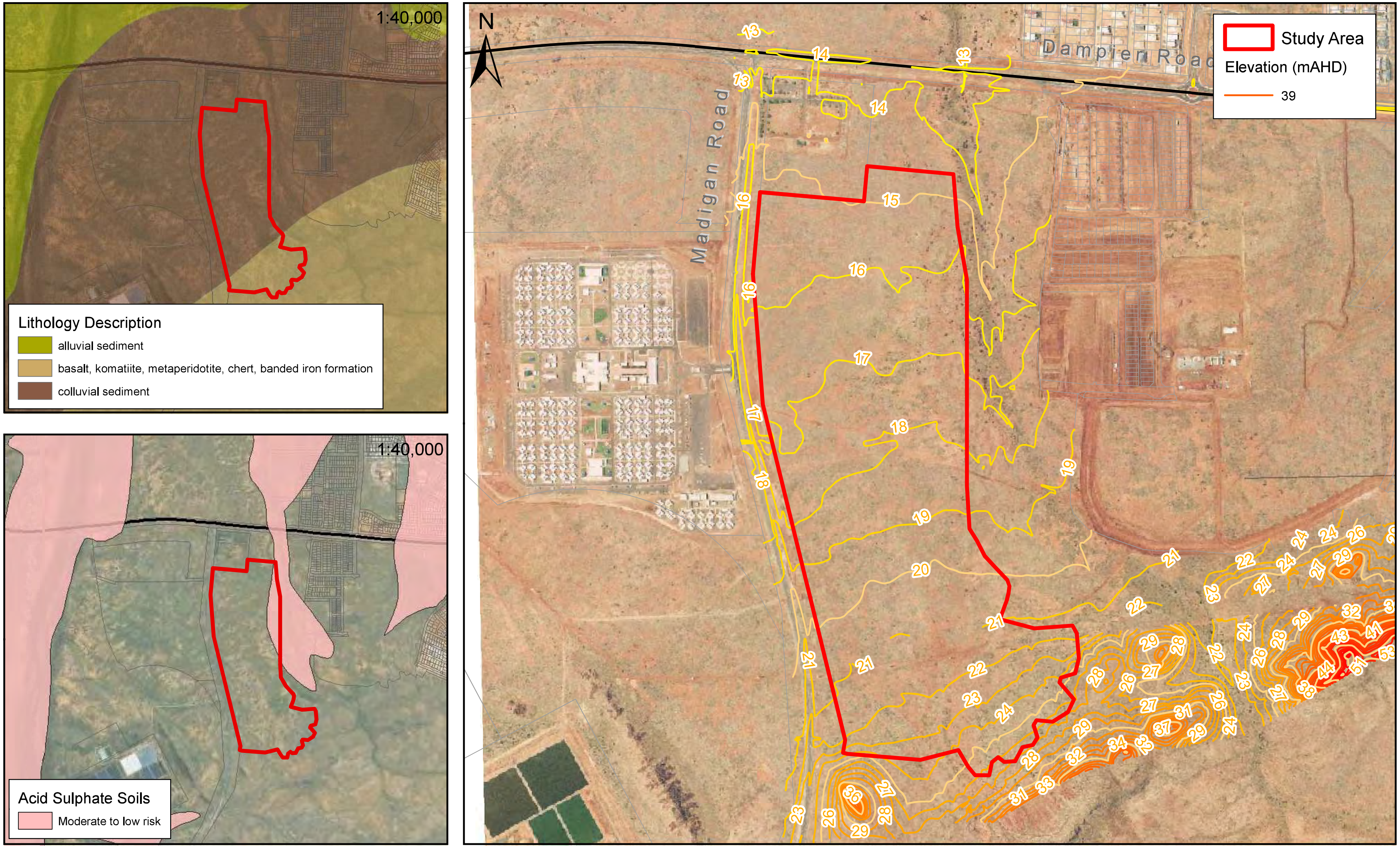
Data Source: WA Atlas (2010)

JDA Consultant Hydrologists

Job No. J4755
Scale: 1:60,000

LandCorp
Madigan Road Urban Development, Karratha - LWMS

Figure 1: Location Plan



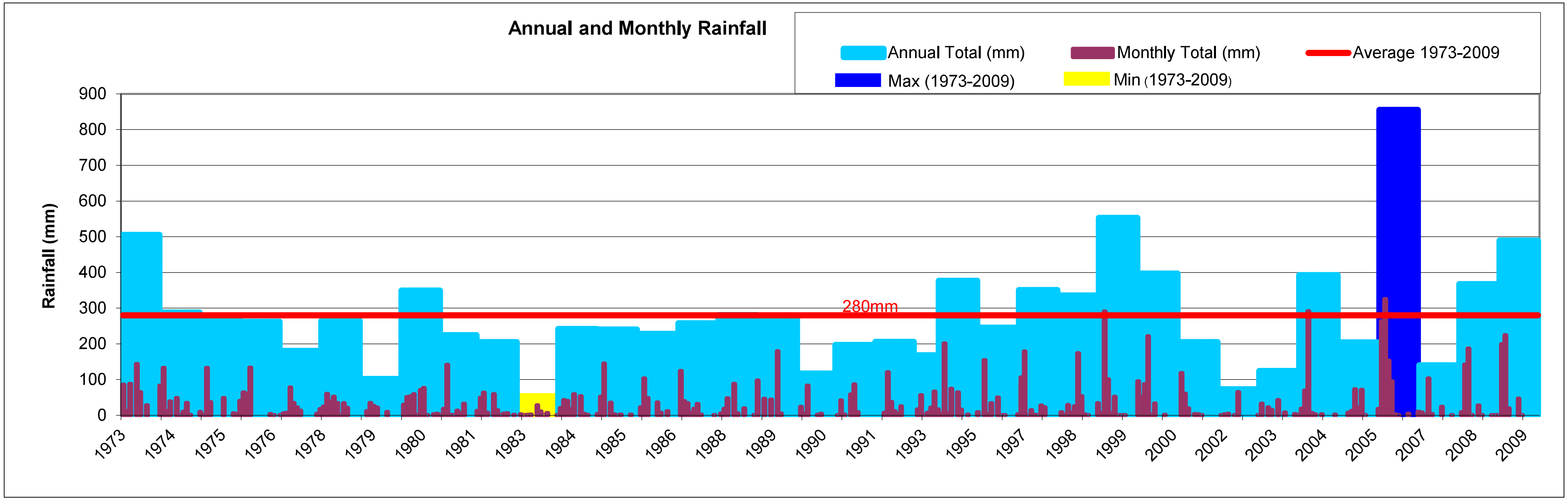
Data Source: DEC (2008), WA Surface Geology (2010), Landgate (2010)

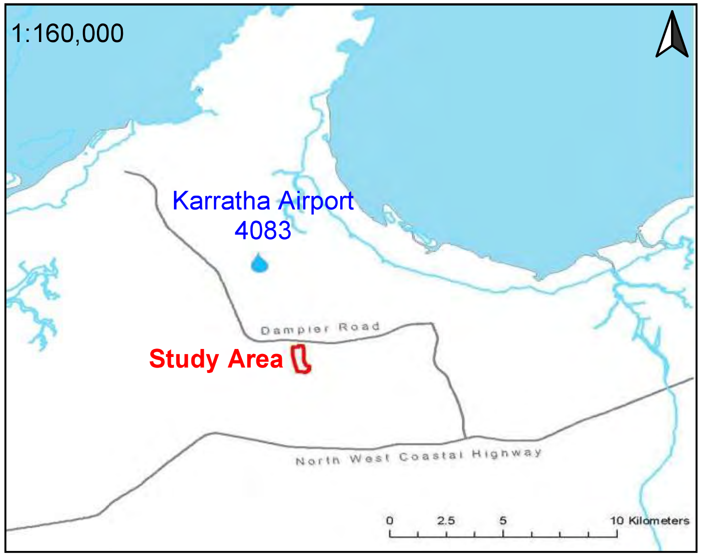
Job No. J4755
Scale: 1:13,000

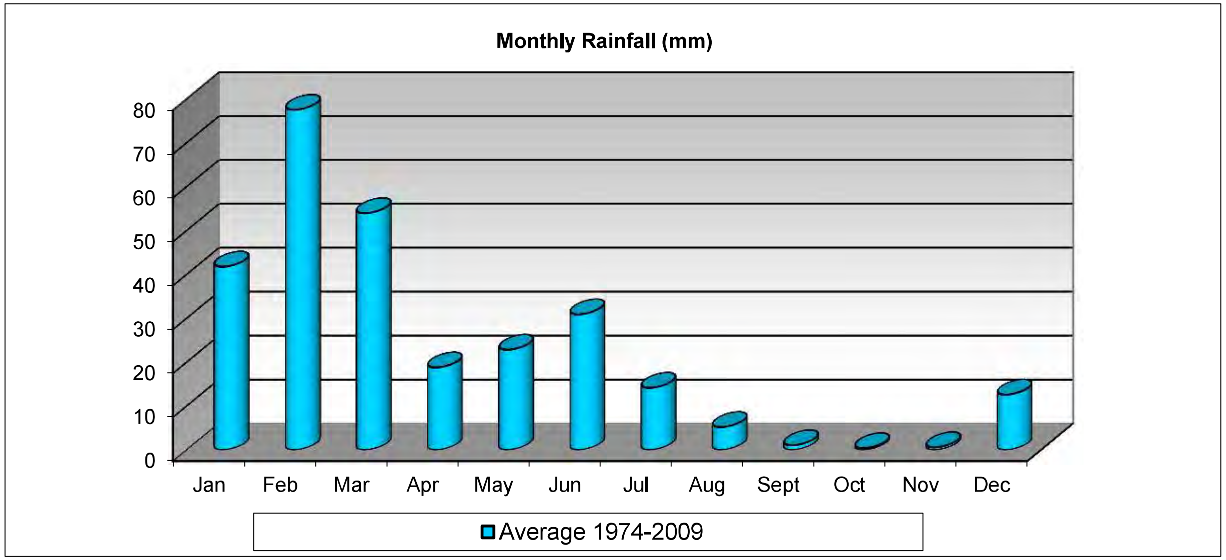
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS

Figure 2: Environmental Setting







Data Source: Bureau of Metereology (2010)

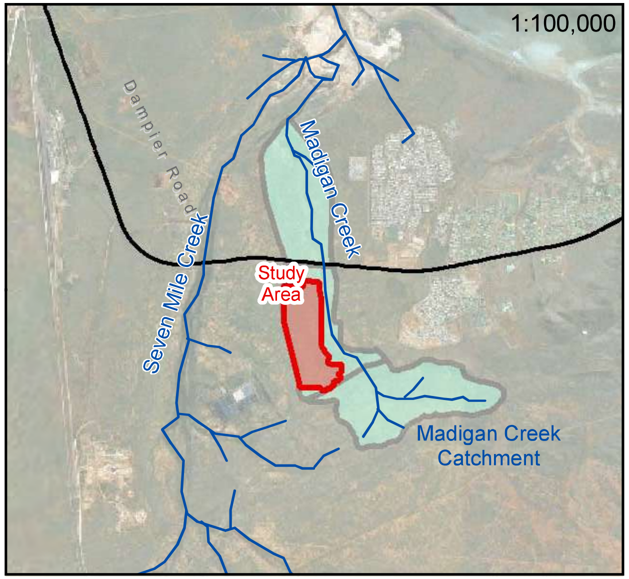
Job No. J4755

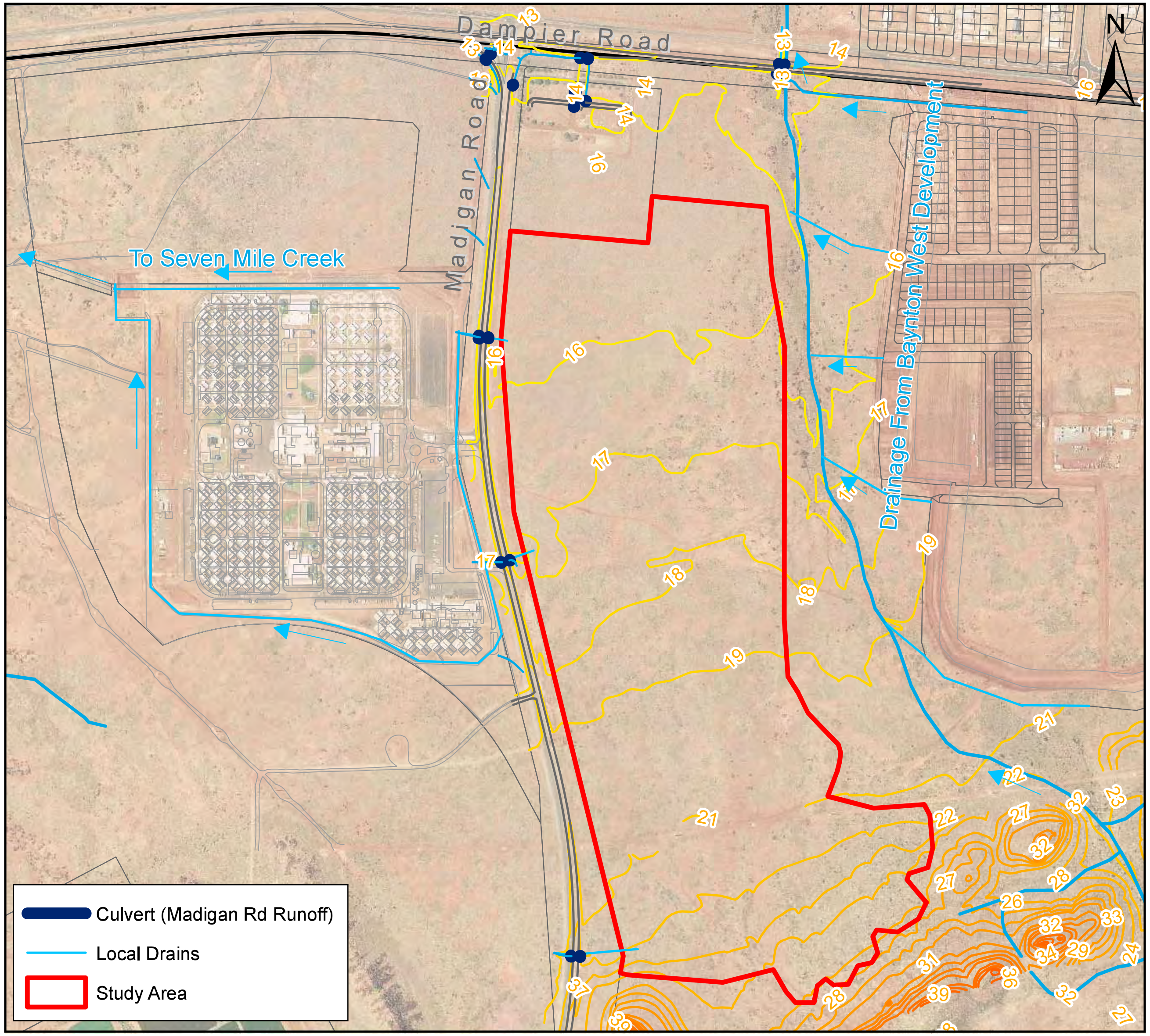
© COPYRIGHT JIM DAVIES & ASSOCIATES PTY. LTD. 2010

LandCorp

Madigan Road Urban Development, Karratha - LWMS

Figure 3: Karratha Airport Annual and Monthly Rainfall



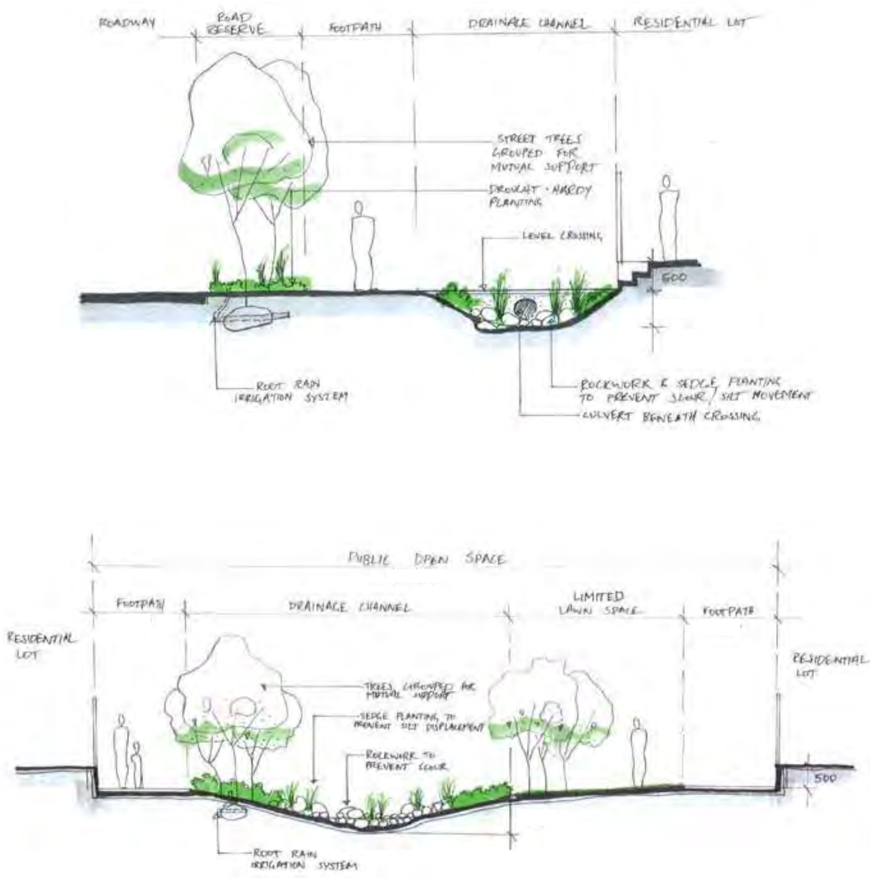


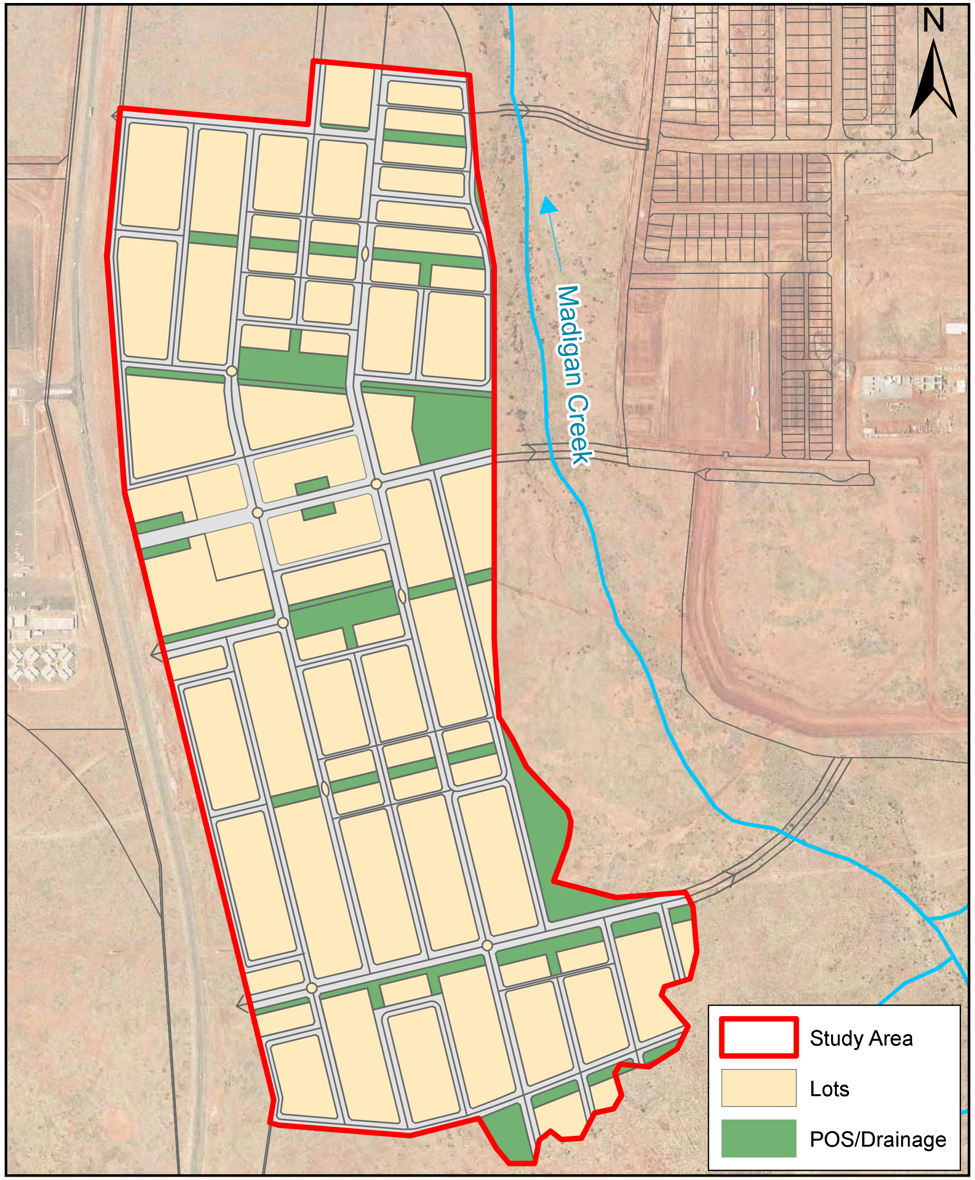
Data Source: DoW (2010)

Job No. J4755
Scale: 1:12,000
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 4: Surface Hydrology

Concept Drainage Swale Cross Sections





🟥	Study Area
▨	Lots
🟩	POS/Drainage

Data Source: TPG (2010), EPCAD (2010)

JDA Consultant Hydrologists

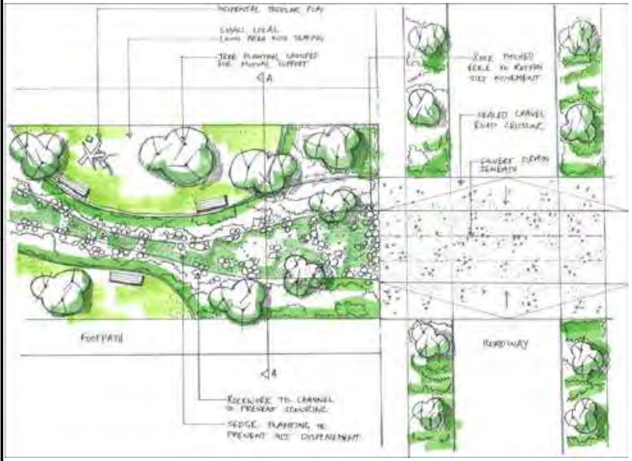
Job No. J4755
Scale: 1:10,000
0 200 400 600 800 Meters

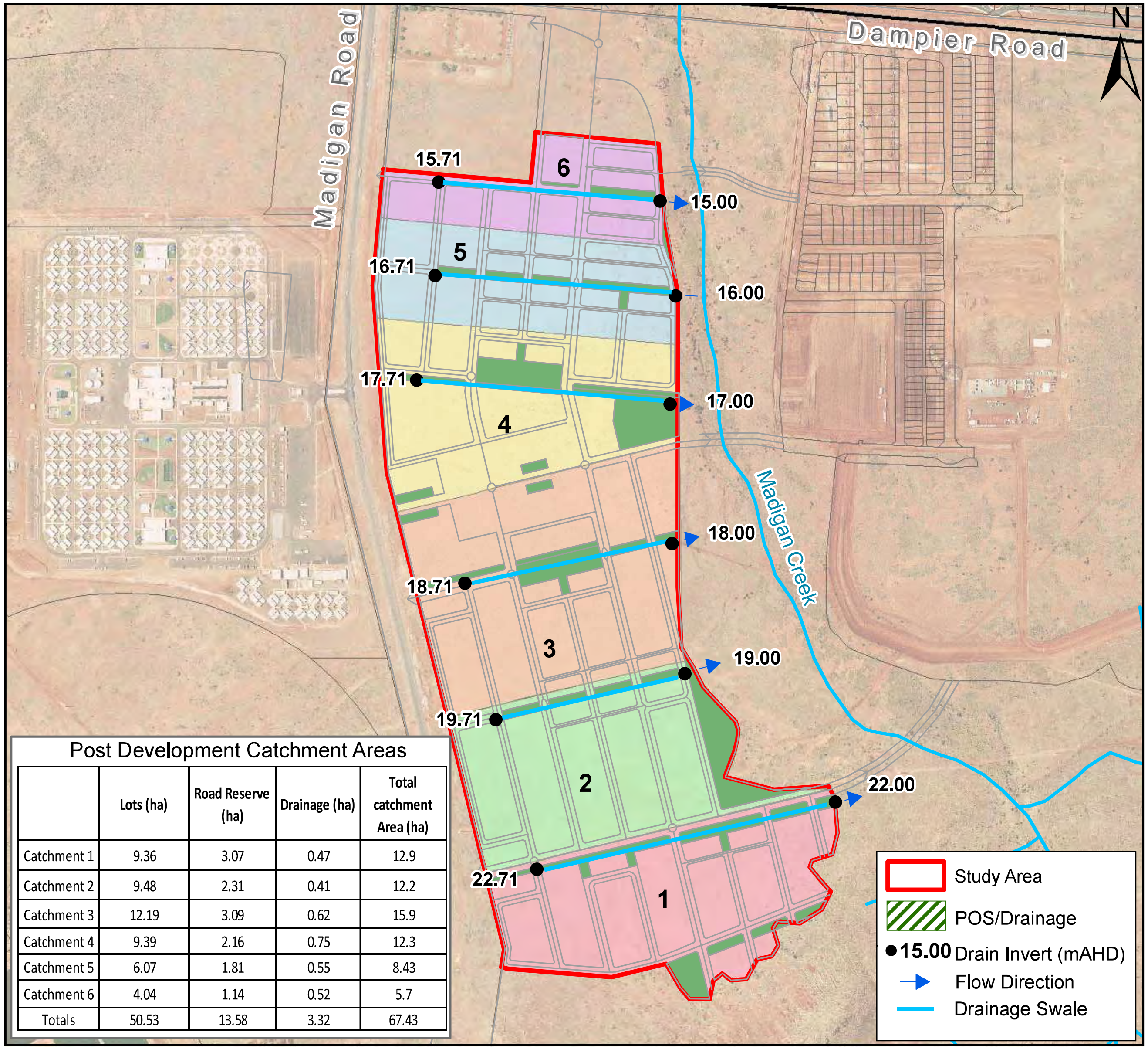
LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 5: Local Structure Plan

Stormwater Management Assumptions

- Drainage swales contained within POS areas
- Drainage swale width 7.5m within 15m wide POS
- Drainage swales have a shallow profile with 575mm depth
- Drainage swales flow under cross roads via culverts and over cross roads via spillways for events greater than 20yr ARI
- Culverts have varying widths and a maximum height of 375mm
- Downstream outlet invert set to existing natural surface (0.5m above existing Madigan Creek invert)
- Longitudinal gradient of swale 1:500
- Swales will be landscaped with native vegetation to assist in improving water quality and contain strategically placed vegetation and boulders to minimise scouring and erosion

Swale Design Concept





Post Development Catchment Areas

	Lots (ha)	Road Reserve (ha)	Drainage (ha)	Total catchment Area (ha)
Catchment 1	9.36	3.07	0.47	12.9
Catchment 2	9.48	2.31	0.41	12.2
Catchment 3	12.19	3.09	0.62	15.9
Catchment 4	9.39	2.16	0.75	12.3
Catchment 5	6.07	1.81	0.55	8.43
Catchment 6	4.04	1.14	0.52	5.7
Totals	50.53	13.58	3.32	67.43

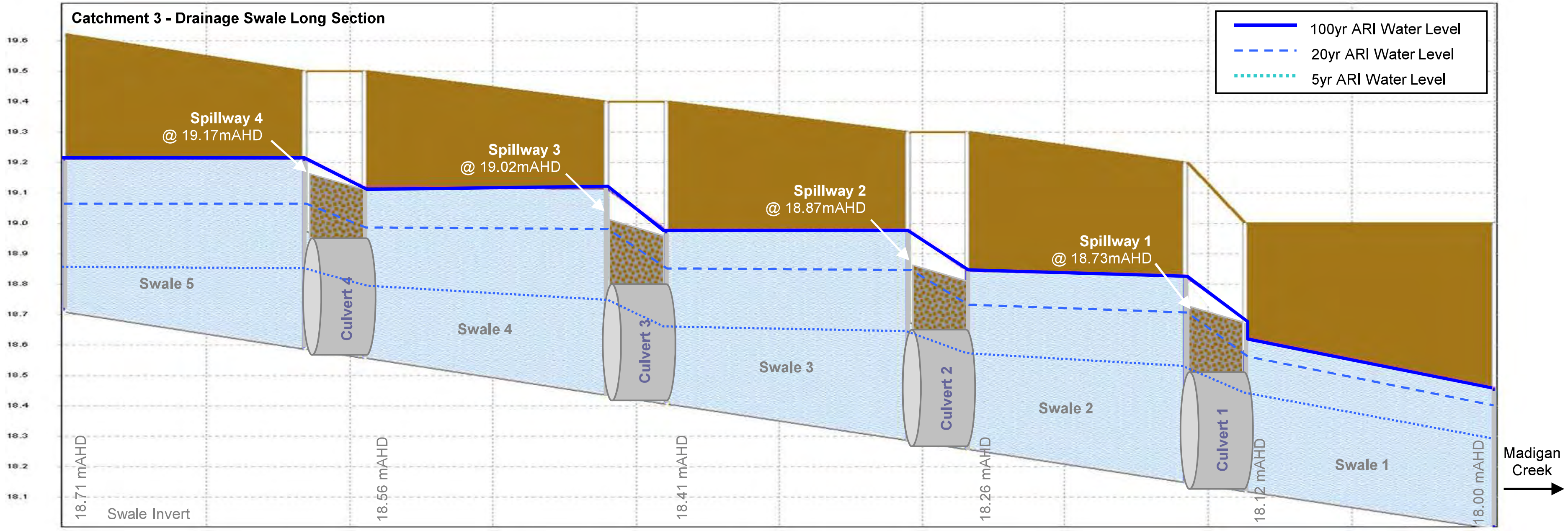
Data Source: TPG (2010), EPCAD (2010)

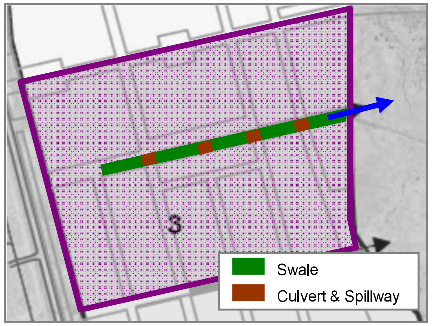
JDA Consultant Hydrologists

Job No. J4755
Scale: 1:10,636

0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 6: Stormwater Management Plan





SWALES

5yr ARI	U/S Depth	D/S Depth	Flow	Velocity
Swale 1	0.34m	0.28m	3.22 m^3/s	1.40 m/s
Swale 2	0.34m	0.38m	2.44 m^3/s	1.08 m/s
Swale 3	0.28m	0.36m	1.66 m^3/s	0.87 m/s
Swale 4	0.24m	0.33m	1.24 m^3/s	0.75 m/s
Swale 5	0.16m	0.27m	0.44 m^3/s	0.43 m/s

20yr ARI	U/S Depth	D/S Depth	Flow	Velocity
Swale 1	0.44m	0.39m	4.98 m^3/s	1.41 m/s
Swale 2	0.47m	0.54m	3.71 m^3/s	1.06 m/s
Swale 3	0.44m	0.55m	2.56 m^3/s	0.90 m/s
Swale 4	0.44m	0.54m	1.95 m^3/s	0.83 m/s
Swale 5	0.36m	0.47m	0.74 m^3/s	0.45 m/s

100yr ARI	U/S Depth	D/S Depth	Flow	Velocity
Swale 1	0.51m	0.46m	6.90 m^3/s	1.54 m/s
Swale 2	0.58m	0.73m	5.20 m^3/s	1.05 m/s
Swale 3	0.57m	0.68m	3.55 m^3/s	0.91 m/s
Swale 4	0.56m	0.71m	2.64 m^3/s	0.83 m/s
Swale 5	0.51m	0.61m	1.00 m^3/s	0.48 m/s

CULVERTS

5yr ARI	Flow	Velocity
Culvert 1	2.44 m^3/s	0.88 m/s
Culvert 2	1.66 m^3/s	0.85 m/s
Culvert 3	1.23 m^3/s	0.96 m/s
Culvert 4	0.44 m^3/s	0.82 m/s

20yr ARI	Flow	Velocity
Culvert 1	3.72 m^3/s	1.32 m/s
Culvert 2	2.52 m^3/s	1.22 m/s
Culvert 3	1.88 m^3/s	1.25 m/s
Culvert 4	0.67 m^3/s	0.90 m/s

100yr ARI	Flow	Velocity
Culvert 1	4.44 m^3/s	1.57 m/s
Culvert 2	2.66 m^3/s	1.30 m/s
Culvert 3	1.96 m^3/s	1.29 m/s

Details	(Height x Width)
Culvert 1	7.5m x 0.375m
Culvert 2	5.5m x 0.375m
Culvert 3	4.0m x 0.375m
Culvert 4	2.0m x 0.375m

SPILLWAY

5yr ARI	Depth	Flow	Velocity
Spillway 1	-	-	-
Spillway 2	-	-	-
Spillway 3	-	-	-
Spillway 4	-	-	-

20yr ARI	Depth	Flow	Velocity
Spillway 1	-	-	-
Spillway 2	-	-	-
Spillway 3	-	-	-
Spillway 4	-	-	-

100yr ARI	Depth	Flow	Velocity
Spillway 1	0.10m	0.78 m^3/s	0.74 m/s
Spillway 2	0.11m	0.96 m^3/s	0.80 m/s
Spillway 3	0.10m	0.77 m^3/s	0.73 m/s
Spillway 4	0.05m	0.19 m^3/s	0.83 m/s

JDA Consultant Hydrologists

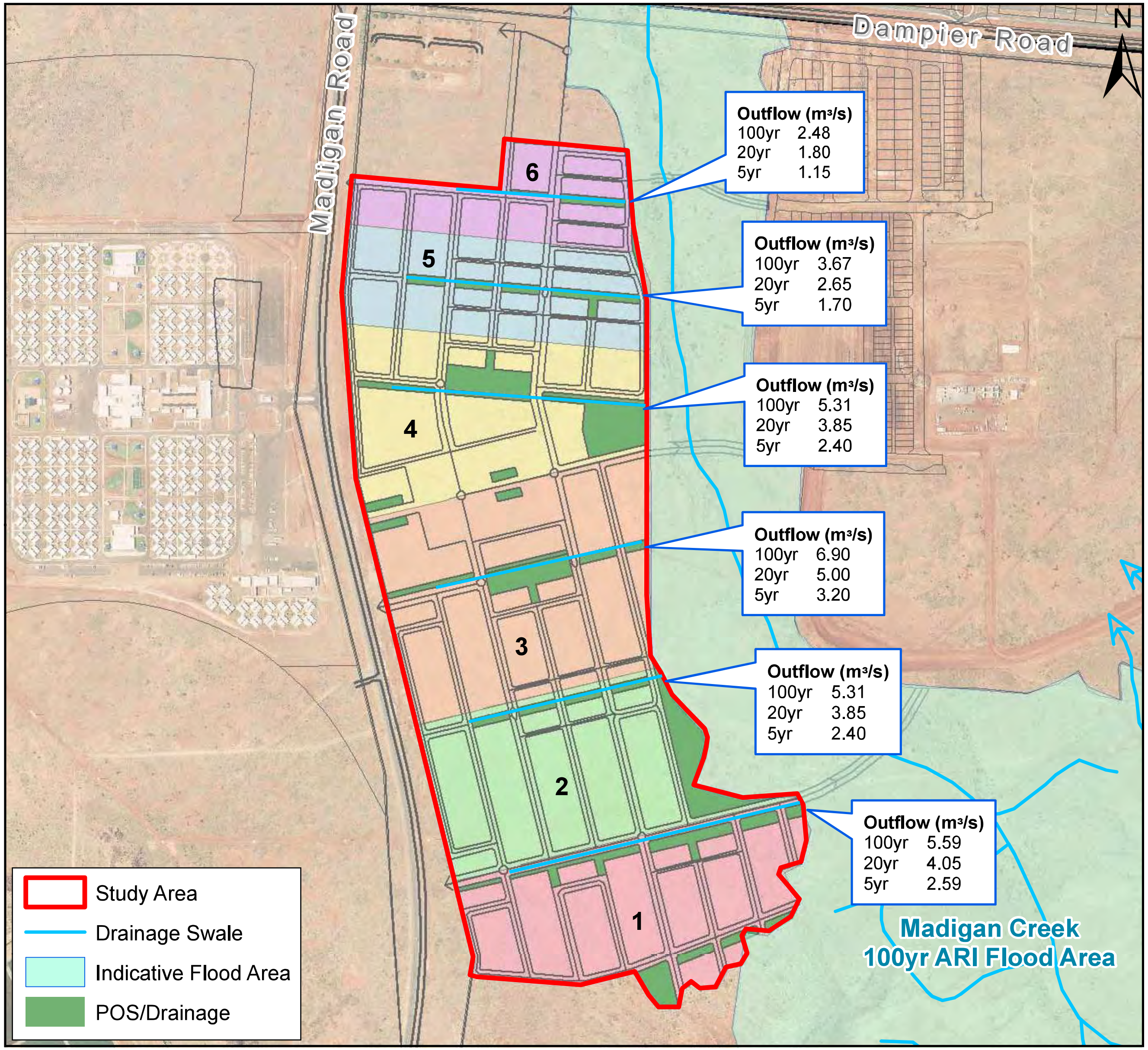
Job No. J4755
Not to Scale

LandCorp
Madigan Rd Development, Karratha - LWMS

Figure 7: Modelling Results of Catchment 3 Drainage Swale - Longitudinal Section

Post Development Flood Depths

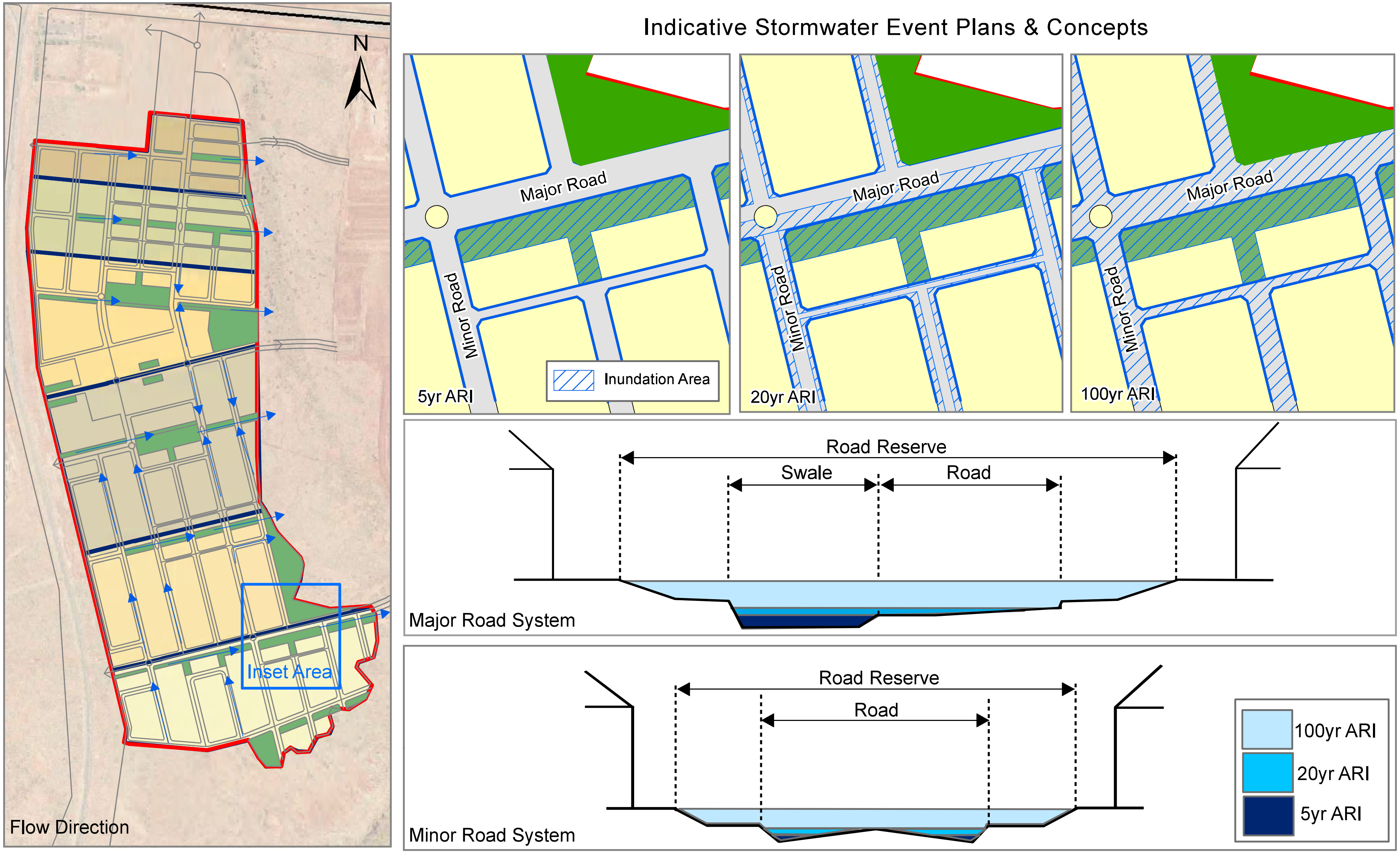
Downstream Flood Depths (m)						
Catchment	1	2	3	4	5	6
100yr	22.46	19.46	18.46	17.46	16.46	15.46
20yr	22.39	19.39	18.39	17.39	16.39	15.39
5yr	22.28	19.28	18.28	17.28	16.28	15.28
Drain Invert	22.00	19.00	18.00	17.00	16.00	15.00
Upstream Flood Depths (m)						
100yr	23.22	19.68	19.22	18.22	17.22	16.22
20yr	23.07	19.53	19.07	18.07	17.07	16.07
5yr	22.87	19.33	18.87	17.87	16.87	15.87
Drain Invert	22.71	19.17	18.71	17.71	16.71	15.71
Outflow (m³/S)						
100yr	5.59	5.31	6.90	5.31	3.67	2.48
20yr	4.05	3.85	5.00	3.85	2.65	1.80
5yr	2.59	2.40	3.20	2.40	1.70	1.15



Data Source: TPG (2010)

Job No. J4755
Scale: 1:11,006
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Develoment, Karratha - LWMS
Figure 8: Modelling Results



Data Source: TPG (2010)

JDA

Job No. J4755
Scale: 1:12,000

0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 9: 5yr, 20yr and 100yr ARI Event Plans

Suite 1, 27 York St, Subiaco WA 6008
PO Box 117, Subiaco WA 6904
Ph: +61 8 9388 2436
Fx: +61 8 9381 9279

www.jdahydro.com.au

info@jdahydro.com.au

LandCorp

Madigan Creek Flood Study

Karratha

December 2010

JDA Consultant Hydrologists

DISCLAIMER

This document is published in accordance with and subject to an agreement between JDA Consultant Hydrologists ("JDA") and the client for whom it has been prepared ("Client"), and is restricted to those issues that have been raised by the Client in its engagement of JDA. It has been prepared using the skill and care ordinarily exercised by Consultant Hydrologists in the preparation of such documents.

Any person or organisation that relies on or uses the document for purposes or reasons other than those agreed by JDA and the Client without first obtaining a prior written consent of JDA, does so entirely at their own risk and JDA denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this document for any purpose other than that agreed with the Client.

QUALITY ASSURANCE

JDA provides quality assurance through all aspects of the company operation and is endorsed to AS/NZS ISO 9001:2000 Quality Assurance Accreditation, with third party certification to Bureau Veritas Quality International.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

JDA were appointed by LandCorp, to conduct a Flood Study on Madigan Creek on the western edge of the Karratha townsite.

1.1 Background

Madigan Creek is shown in Figure 1 attached. The creek flows north from the Karratha Hills to the confluence with Seven Mile Creek. The Dampier Highway bisects the creek approximately halfway between the Hills and downstream confluence.

This Flood Study has been prepared to identify flooding impacts on the proposed Madigan Development of approximately 68ha of urban residential development. Madigan Creek flows along the eastern boundary of the development and the extent of flooding into the proposed development area is currently unknown.

Other proposed developments, Gap Ridge North and Nickol West, are located north of Dampier Highway and may also be influenced by the flooding regime of Madigan Creek. This report evaluates the extent of flooding within all of the proposed development areas.

The objectives of the study are to determine the extent of the 100 year Average Recurrence Interval (ARI) flood extent for Madigan Creek. Flood levels for the 20 and 50 year ARI events are also determined. The impacts of the proposed Madigan, Gap Ridge North and Nickol West developments on flood levels will be assessed. An upgrade and duplication of the Dampier Highway by Main Roads WA has also been proposed in future and implications of possible designs mentioned.

1.2 Existing Flood Information

There have been many tropical cyclones in the Pilbara region of Western Australia. These tropical storms are responsible for flooding and storm surges that threaten towns and infrastructure. Karratha is not located on or adjacent to a major river system which reduces the risk of severe flooding, however, localised flooding in low lying areas and along creeks does occur.

The most severe cyclone of the past decade was Tropical Cyclone Monty that crossed the Dampier coastline on March 1st 2004. Records from the Bureau of Meteorology show that 323mm of rainfall were recorded for Roebourne with severe flooding throughout the Pilbara. Sections of the Northwest Coastal Highway were washed away at the bridge over the Maitland River (BoM, 2010). Anecdotal evidence provided by staff from the Shire of Roebourne indicates that the Dampier Highway near Madigan Creek was overtopped during Tropical Cyclone Monty.

Seven Mile Creek flows to the west and north of Madigan Creek and is shown in Figure 1. A flood study for this creek was undertaken south of the Dampier Highway in support of a proposed development adjacent to Seven Mile Creek (GHD, 2009). The catchment for Seven Mile Creek (60km^2) is significantly larger than for Madigan Creek (5.46km^2), and the main channel is larger and more defined. Reference to the Seven Mile Creek flood study is made throughout this report.

2. CATCHMENT DESCRIPTION

The Madigan Creek catchment is located in the Pilbara region of Western Australia and has a number of environmental conditions that influence flooding response. This section describes the environmental context of the catchment and includes details of the site visit by JDA Consultant Hydrologists on the 8 September 2010.

2.1 Location

The Madigan Creek catchment is located approximately 6km west of the Karratha Townsite and is approximately 546ha in area. The catchment is within the Shire of Roebourne and includes the proposed Madigan Development. Residential developments Baynton West and Nickol form the eastern section of the catchment. Seven Mile Creek is located to the west (Figure 1).

2.2 Topography

The topography of the Madigan Creek catchment varies, with steep hills in the upper catchment and relatively flat, gently sloping topography in the remainder of the catchment. The Karratha Hills to the south of Study Area feature elevations as high as 74mAHD to 14mAHD near Dampier Highway and approximately 7mAHD at the northern boundary of the Study Area (Figure 2).

2.3 Climate

Karratha has an arid climate characterised by hot summers with periodic heavy rain and mild winters with occasional rainfall.

The Pilbara coast experiences more cyclones than any other part of Australia. Since 1910 there have been 48 cyclones that have caused damaging wind gusts in excess of 90km/h in the Karratha, Dampier and Roebourne region. This equates to about one cyclone every two years, on average. About half of these cyclones have an impact equivalent to a category one cyclone.

The average annual rainfall for Karratha is 280mm per year, with a maximum recorded annual rainfall of 855mm from records taken between 1974-2009 at Karratha Airport (BoM 2010). Most of the recorded precipitation is received during the wet season, as a result of tropical cyclones and local thunderstorms.

Along the central Pilbara coast the cyclone season runs from December to April peaking in February. Figure 3 presents graphed rainfall data for Karratha Airport (BoM site 4083).

The average annual pan evaporation is approximately 3,590mm (Luke et al, 1988).

2.4 Soils and Vegetation

The Madigan Creek catchment is entirely covered by floodplain deposits of red-brown silty sand, which has been partially reworked by wind action over much of the catchment. The sand may contain nodules or lenses of calcrete approximately one metre below the surface, and scattered pebbles throughout. The sand is underlain by Archaean bedrock, probably mafic volcanics at an expected depth ranging from 10-20m below surface. The upper few metres of the bedrock are weathered and fractured.

Undeveloped regions of the catchment feature low tussock and spinifex grass vegetation (Figure 2). An Environmental Assessment performed by Coffey Environmental (2010) indicates the vegetation is not considered significant at the local, state or national level and there is no Threatened Ecological Community (TEC) within the catchment.

2.5 Existing Drainage

The Study Area features only one significant surface water feature, Madigan Creek, that flows through the site from the Karratha Hills (south) to Seven Mile Creek (north) (Figure 4).

Madigan Creek is a non-perennially flowing natural channel that is not well defined and less than 1m in depth south of the Dampier Highway. The creek is restricted underneath the highway by four 1500m circular culverts (Figure 4). Flow also occurs over the highway via a floodway to the west of the culverts.

Along three locations on Madigan Road there are single 300mm culverts which are located even distance apart. Due to the limited size, these culverts are not considered to be sized for conveying flow from the Study Area. Instead they have been designed to convey surface runoff from the east side of the crowned Madigan Road back towards Seven Mile Creek.

No previous measurements for flow or water quality data are available for Madigan Creek.

2.6 Groundwater

Groundwater occurs within a single aquifer known as the Pilbara Fractured Rock Aquifer.

Although there are no long term groundwater monitoring bores known to exist within the Karratha Area, the watertable is expected to be 5-10m below surface and may vary seasonally in depth by 2-3m in response to heavy rainfall. The groundwater is expected to be slightly brackish to saline, in the range 2,500 – 10,000 mg/L Total Dissolved Solids, but there may be more saline groundwater in localized areas of low permeability.

A site visit of September 8th 2010 also noted that there was no evidence of groundwater in any of the surface drainage systems (Madigan Creek).

2.7 Land Use

Land use within the Study Area is a mixture of developed and undeveloped areas. The majority of the Study Area features sparse native vegetation consisting of low tussock and spinifex grass. Significant infrastructure includes the Dampier Highway that bisects the Study Area and Madigan Road on the western boundary (Figure 2). Near the corner of Madigan Road and Dampier Highway is the Karratha Cemetery.

The future Madigan and Gap Ridge North developments will be located within the western section of the Study Area. The proposed Nickol West residential development will be to the east of the creek.

Surrounding land use in the wider catchment consists of the Karratha Hills to the south and Banyton West and Nickol residential development to the east. Woodside Petroleum's Pluto Worker Camp is to the west of Madigan Road, but not within the Madigan Creek catchment.

3. HYDROLOGY

Hydrologic analysis of the Madigan Creek catchment was performed to calculate flood hydrographs for the study area for various design ARI storm events.

For this study, the hydrologic analysis involved modelling of flood hydrographs using RORB and validation of peak flows against estimates from Rational and Index Flood Methods.

The calculated flood hydrographs from sub catchment areas of the study area are used as input for hydraulic modelling. Details of the catchment hydrologic analysis are presented below.

3.1 Hydrologic Model

Hydrologic modelling for the Madigan Creek catchment was performed using the runoff routing model RORB. This model is a general runoff and stream flow routing program used to calculate flood hydrographs from rainfall. It calculates runoff as rainfall excess by subtracting losses from rainfall.

The model is areally distributed, nonlinear, and applicable to both rural and urban catchments. It has the capacity to model temporal and spatial variability in rainfall, as well as storage reservoirs and culverts. Reach storage is the main way in which RORB represents hydrologic processes. Reach storages are assumed to have storage-discharge relations of the form:

$$S = 3600kQ^m$$

where S is the storage (m^3), Q is the outflow discharge (m^3/s), m is a dimensionless exponent, and k is a dimensional empirical coefficient that is comprised of the product of k_r and k_c, where k_r is a dimensionless ratio called the relative delay time, and k_c is an empirical coefficient characterising the entire catchment and stream network. It is important to note that k_c can only be generally compared between models that have the same catchment sub-divisions and stream network, though some rough comparison can be made if the catchment is sub-divided differently.

Calibration of storm event runoff hydrographs (where available) in RORB is predominantly achieved by adjusting the m and k_c values to achieve the best fit, as well as the runoff coefficient R_c which is the runoff volume as a proportion of rainfall volume.

3.1.1 Catchment Data

The Madigan Creek catchment has a catchment area of 5.46 km^2. For modelling purposes, the catchment was divided into 6 sub-catchments based on topographic contours and aerial photography (Figure 6).

The sub-catchment areas and mainstream lengths for four of the six were calculated using ArcGIS and have been modelled in RORB as connected nodes. Two catchments representing the existing developments within the catchment have been estimated from previous drainage studies.

3.1.2 Rainfall

Rainfall input for the modelling of design storms was calculated internally by RORB, based on procedures from Australian Rainfall and Runoff (AR&R) (IEAust, 1997). This includes rainfall intensities and temporal patterns for all design storm durations (5min to 72hrs) and ARI's (20, 50 and 100 year) for Karratha.

The rainfall pattern was assumed to be spatially uniform across the catchment.

3.1.3 Parameters k_c and *m*

RORB parameters k_c and *m* are either estimated by best fit of estimated and/or observed stream flow hydrographs or based on existing published data.

As there is no hydrograph data available for the Madigan Creek catchment, k_c value was calculated from the regional relationship as the recommended procedure by AR&R (IEAust, 1997). The relationship applicable to the study area is for the North West as follows:

$$k_c = 1.06\, L^{0.87} S^{-0.46}$$

where *L* is the mainstream channel length (km), S slope (m/Km). With the mainstream channel length for the Madigan Creek catchment being 5.0km and slope 4.5m/km, the k_c value adopted for modelling is 2.15.

For the dimensionless exponent *m*, a value of 0.85 was adopted consistent with other similar studies, considered appropriate for Western Australian conditions (IEAust, 1997).

3.1.4 Loss Model

The loss model adopted in RORB model were used based on AR&R (IEAust, 1997) procedure. AR&R indicated for Pilbara with an initial loss of 40mm and continuing loss of 5mm/h. JDA used 5mm initial loss for 100yr, 50yr and 20yr ARI and 2mm continuing loss of all the storm events, consistent with other studies in Pilbara. The Seven Mile Creek study (GHD, 2009) used an initial loss of 5mm for 100yr ARI event and 15mm for the 10yr ARI event and a continuing loss of 2mm/h for both storm events.

3.1.5 Peak Flows

The RORB model was run based on the above parameters for the Madigan Creek catchment (sub-catchments 1 to 4) to generate peak flows for the 20, 50 and 100 year ARI rainfall events. These estimated peak flows are presented in Table 2 below.

TABLE 2: MADIGAN CREEK SUB CATCHMENT PEAK FLOW ESTIMATES

Location	Area (ha)*	Peak Flow Estimate (m^3/s)		
		20 year ARI	50 year ARI	100 year ARI
Madigan Creek Catchment	432	85	103	125

*Excludes catchments 5 and 6.

3.2 Model Calibration

Calibration of hydrographs and peak flow estimates generated from the RORB model could not be performed due to the absence of gauging station data within the Madigan Creek catchment. Validation of the RORB peak flows based on comparison with alternative flood estimation methods was performed instead.

3.2.1 Rational and Index Flood Methods

The Rational and Index Flood Methods use regionalisation techniques for estimating peak flows in catchments where there are ungauged sites or sites with limited streamflow data (Water & Rivers Commission, 1999). Equations adopted for validation of the Madigan Creek catchment for both methods are from relationships derived from gauged catchments in the North West region of Western Australia (IEAust, 1997).

Note that the Rational and Index Flood Methods only provide peak flow estimates up to the 50 year ARI event. The results were therefore extrapolated to estimate the 100 year ARI event peak flows.

Peak flow estimates from the two methods compared with the RORB model for the Madigan catchment are presented in Table 3 below. Peak flows estimated using Rational Method for 20, 50 & 100 year ARI range between 2% to 14% compared to the flows modelled in RORB.

TABLE 3: COMPARISON OF RORB PEAK FLOWS WITH RATIONAL & INDEX FLOOD METHODS

Flow Estimation Method	100yr ARI Peak Flows (m^3/s)			Difference Compared to RORB		
	20 yr ARI	50 yr ARI	100 yr ARI	20 yr ARI	50 yr ARI	100 yr ARI
RORB	85	102	125	-	-	-
Rational Method	73	104	137	14 %	2 %	9 %
Index Flood Method	24	39	40	70 %	39 %	68 %

3.3 Design Flood Estimation

3.3.1 Design Hydrographs

Based on the RORB model parameters described above, a series of RORB runs were performed to generate design hydrographs for the 20, 50 and 100 year ARI rainfall events with durations ranging from 1hr to 72hr. The critical duration was selected based on the highest peak of the flow hydrographs generated. The loss models and rainfall parameters used for the design hydrographs are as stated in Section 3.1.

Hydrographs were extracted from RORB at four locations as follows:

- Madigan Creek: sub-catchment 1 at location A.
- Madigan Creek: sub-catchment 2 at location B.
- Madigan Creek: sub-catchment 3 at location C.
- Madigan Creek: sub-catchment 4 at location D.

The hydrographs for sub-catchment 5 was generated from peak flow estimates from the Baynton West Development modelling (Wood & Grieve, 2008). The stormwater system in this development was designed for minimum flow attenuation. This hydrograph was adapted for sub-catchment 6 by scaling the area in the two catchments (Catchment 5: 64.8ha and Catchment 6: 46.5ha).

The RORB design hydrographs for the critical duration 20, 50 and 100 year ARI rainfall events are shown in Figures 7 to 10 with the peak flows presented in Table 4. The critical storm duration for all rainfall events was 1hr.

TABLE 4: RORB SUBCATCHMENTS DESIGN HYDROGRAPH PEAK FLOWS

Sub Catchments	Area (ha)	Peak Flow Estimate (m^3/s)		
		20 year ARI	50 year ARI	100 year ARI
1	178	32	41	50
2	55	38	46	54
3	55	38	46	54
4	144	82	99	116
5	69	21	25	30
6	47	14	17	20

4. FLOOD MODELLING PARAMETERS

Hydraulic modelling of Madigan Creek was undertaken to determine the 20, 50 and 100 year ARI flood levels which are then used to delineate the 100yr ARI floodplain. The software package used for this analysis was MIKE 11 (version 2009) developed by the Danish Hydraulic Institute (DHI).

4.1 MIKE 11 Preparation

MIKE11 is a 1D hydrodynamic modelling tool for simulating unsteady flows in river channels. In conjunction with MIKE-GIS, the model utilises the digital elevation model, inflow hydrographs determined from the catchment hydrology analysis (Section 3) and roughness parameters (Manning's n) to determine the flood levels and extent of the floodplain.

The model extent for Madigan Creek south of the Dampier Highway is east of Madigan Road to the Bayton West development. North of the Dampier Highway the model extends to Seven Mile Creek and is bounded by the Nickol West development and the catchment boundary to the east.

These areas are shown in Figure 5. The future Madigan Development and the proposed Gap Ridge North development are also shown.

4.2 Survey and DEM Inputs

Topographic information for the site was obtained through existing Landgate contours (and spot heights) and previous surveys conducted by Whelans. Both datasets are as recent as 2007. An additional survey was conducted by Whelans in September 2010 to provide greater resolution of the Madigan Creek channel and floodplain. The survey focused on the longitudinal profile of the creek and cross sections extending 200m left and right of the channel.

A digital elevation model (DEM) was then produced from the survey data for the Study Area. The Survey points were converted into a 10m resolution grid of elevations data points. Using the generated grid, the river network including the main Madigan Creek channel and smaller channels were extracted for the model. Similarly cross sections of the river network were extracted every 100m along the channel, extending 500m from the centre of the channel.

4.3 Infrastructure

The major infrastructure features that affect the channel are four culverts and a floodway on the Dampier Highway (Figure 4). These structures were incorporated into the MIKE 11 model with parameters as shown in Table 5. The culverts were surveyed as part of the additional Madigan Creek survey conducted by Whelans. The dimensions of this floodway were provided by Cossill & Webley (Drawing No. 6055-00-SK03). Although the floodway invert is located approximately 150m west of the culverts, it is below the obvert of the culverts. Information from the survey and engineering drawings of these features was incorporated into the hydraulic model (MIKE 11).

The hydraulic performance of the culverts was assessed to determine their ability to convey the flows in Madigan Creek prior to flow over the existing floodway. The culverts were found to be able to convey approximately 15m^3/s when the water level was just below the obvert of the culverts (ie. invert of the floodway). This capacity is insufficient to convey any of the critical 1hr duration storm events from 5yr ($35m^3/s$) to 100yr without flow over the Dampier Highway floodway.

TABLE 5: EXISTING DRAINAGE INFRASTRUCTURE

Culvert Parameters			
Type	Circular	Upstream Invert Level	12.50 m AHD
Diameter	1.5 m	Downstream Invert Level	12.40 m AHD
No. of Culverts	4	Length	15 m
Manning's n	0.020		
Floodway Parameters			
Floodway Invert	13.84 mAHD	Adjacent Road Elevation	14.54 mAHD
Type	Sloped	Width	240m

4.4 Roughness Parameters

The roughness parameter for the channel and floodplain adopted for this model is the Manning's Roughness Coefficient; *n.* The selection of parameter values is based on criteria outline by Chow (1981), aerial photography of the study area and JDA's site visit. Madigan Creek is a relatively shallow and minor channel a single value of roughness, Manning's n = 0.05 was adopted across the entire Study Area. This is consistent with the resistance value adopted in the Seven Mile Creek study (GHD, 2009).

4.5 Baseflow

The intermittent rainfall of Karratha (Section 2.2) means that the site is predominantly dry prior to major rainfall events. The site only averages 25 days of rainfall per year. Therefore the creek was considered to be dry and no baseflow was added to the hydrographs or initial conditions.

4.6 Boundary Conditions

A downstream boundary condition was defined for the MIKE11 model as the water level at the confluence with Seven Mile Creek. The 20 year, 50 year and 100 year ARI levels were determined by extrapolating the flood levels from the Seven Mile Creek Flood Study (GHD, 2009) 100yr ARI flood levels. The downstream condition adopted for Madigan Creek was a conservative water level of 5.1m AHD, plus an 0.8m increase to account for increase in water levels from climate change (unpublished). The resulting downstream condition was a level of 5.9m AHD and in shown in Table 6. Although these estimates are imprecise, the model results within the Study Area were generally insensitive to the value selected as the boundary condition.

TABLE 6: BOUNDARY CONDITIONS

Boundary Location	Type	Boundary Condition
Upstream	Inflow Hydrograph	Hydrograph A (Figures 7 to 9)
Downstream	Water Level	5.9mAHD

Inflow hydrographs for each sub-catchment, as outlined in Section 3 and Figures 7 to 9.

4.7 Validation

Validating the hydraulic modelling for Madigan Creek is difficult owing to the lack of data available. Anecdotal evidence from the Shire of Roebourne indicates that Dampier Highway was over-topped during Cyclone Monty in 2004. Bureau of Meteorology (BoM) records indicate that Roebourne (10km west of Karratha) experienced their highest two-day rainfall total since 1945. However, the BOM records are available for 24hr periods which do not allow for analysis of 1hr storm events which is critical for the Madigan catchment. Therefore it cannot be determined which 1hr ARI storm event Cyclone Monty was without further detailed investigation.

No anecdotal information is available about the frequency of the Dampier Highway being over-topped. The short duration of these storm events mean it is unlikely that many people would have seen this road being over-topped.

5. FLOOD MODELLING RESULTS

The validated model was used to determine the existing flood levels and the impacts from the proposed developments adjacent to Madigan Creek.

5.1 Scenarios

The model was used to determine the floodplain extent for the 100 year ARI design hydrograph and flood levels for the 5, 20 and 50 year ARI design hydrographs. The floodplain is defined as areas adjacent to rivers, stream and creeks that are subject to inundation from large flows caused by heavy rain (SCARM, 2000). The current pre-development conditions were modelled as a baseline scenario.

The proposed Madigan and Gap Ridge North developments have the potential to impact the floodplain and increase flood levels upstream. A post-development scenario was modelled featuring land within the developments that was prevented from being flooded. This replicated the importation of fill into the developments. A post-development floodplain was generated for the 100 year ARI design hydrographs and flood levels for the 20 and 50 year ARI design hydrographs were calculated.

5.2 Model Outputs

The floodplains for 100 year ARI events (pre and post-development) are determined by the extent of inundated areas. The maximum flood extent, determined by MIKE 11 modelling, is shown in Figure 10. The water level at the upstream extent of the Study Area is 20.39mAHD and 7.14mAHD at the downstream end (Figure 11). The depth of flow for the 100 year ARI event is shown in Figure 12, with the deepest flow reaching 1.93m, upstream of the Dampier Highway.

Figures 11 and 12 also show the maximum water levels during the 20 and 50 year ARI events respectively. Pre and post-development water levels are shown along with the maximum depth of flow along Madigan Creek.

5.3 100 year ARI Results

The 100yr ARI flood event is significant for floodplain management and the protection of infrastructure in the proposed developments. For the pre-development 100 year ARI flood event, the floodplain is generally restricted to within 200m either side of Madigan Creek. The shallow topography of the catchment allows for a wide floodplain despite depths are generally less than 1.5m. The largest inundated area is immediately upstream of Dampier Highway owing to restriction of flow through the culverts.

South of Dampier Highway the depth of flow in the creek is generally less than 1.2m in the pre-development scenario. Within the proposed Madigan Development area is there are two small areas that are flooded along the eastern boundary. Immediately upstream of the Dampier Highway there is a significant area that is flooded during the 100yr ARI event. Water flowing in the creek is backed up behind the highway embankment as it discharges through the culverts and over the floodway. The modelling indicates that the water depth is 1.93m immediately upstream of the highway (0.59m depth over the floodway) and flooding extends into the Karratha cemetery area.

Downstream of the highway, flood depths were generally around 1.3m. The floodplain generally follows the morphology of the creek although it widens significantly near the confluence with Seven Mile Creek. There is only a minor area of the proposed Gap Ridge North development that is inundated during the 100yr ARI event. There is some flooding along the western boundary of the proposed Nickol West development as shown in Figure 10.

Throughout the catchment, there is also some flooding of the adjacent stormwater drains that discharge from Baynton West and Nickol West. Note that modelling with the downstream boundary condition of 5.9mAHD and varying up to 7.0mAHD has negligible impact on water levels within the Study Area.

5.3.1 Infrastructure Performance

The large inundated area immediately upstream of the Dampier highway is caused by the design of the culverts and floodway for Dampier Highway. Based on advice from Main Roads WA, drainage infrastructure is designed based on the 50 year ARI flood event, so a large backwater and flow over the floodway is not unexpected. As discussed in Section 4.3, the culverts are able to convey approximately 15m^3/s prior to flow over the Dampier Highway floodway.

During the 100yr ARI pre-development scenario there is a discharge of approximately 99m^3/s through the culverts and over the floodway, causing a maximum flooding depth of 0.59m over the lowest point of the floodway. The post development discharge and depth are approximately 104m^3/s and 0.60m respectively.

The afflux across the highway is approximately 0.87m between the immediate upstream and downstream water levels during peak flow which is as expected over a floodway.

Further detail on the infrastructure performance and design is presented in Section 5.4.1.

5.3.2 Proposed Development Impacts

The importation of fill for the three proposed residential developments has an impact on the floodplain extent and flood levels as shown in Figures 13 to 15. A comparison of the pre and post-development floodplains is shown in Figure 16. Downstream of the Dampier Highway, the Proposed Gap Ridge North Development has a minimal impact on the flood levels as only a small portion floodplain is within the proposed development area. The Nickol West development, however, causes an increase in flood levels of approximately 0.10m in adjacent areas along the creek.

Upstream of the Dampier Highway there is considerable change to the floodplain extent. Fill in the proposed Madigan Development area restricts the available 100yr ARI floodplain area and therefore water levels increase up to 0.38m in the vicinity immediately upstream of Dampier Highway. Note that should fill for the Madigan Development extend up to Dampier Highway, an overland flow path must be maintained between the creek centreline and the floodway approximately 150m west.

5.4 Other ARI Results

Flood levels and depths for the 20 and 50 year ARI flood events are presented in Figures 11 and 12 respectively. The pre-development scenario for each event is consistent; however, the water levels for the 20 and 50 year ARI events are generally 0.19m and 0.08m less than the 100yr ARI results.

5.4.1 Infrastructure Performance

As mentioned above, the 50 year ARI storm event is used by Main Roads WA for the design of drainage infrastructure. Details of the discharge and flood depth for the pre-development scenario over the Dampier Highway are shown in Table 7. During the 50 year ARI event, there is a maximum flooding depth of 0.54m over the floodway and 21.4m^3/s discharging through the culverts.

TABLE 7: PRE-DEVELOPMENT DAMPIER HIGHWAY FLOOD INFORMATION

Storm Event	Max Discharge (m^3/s)	Max Flooding Depth[1] (m)	Peak Stage (mAHD)	Back water (m)	Upstream Stage[2] (mAHD)	Down-stream Stage[3] (mAHD)	Peak Discharge Culverts (m^3/s)	Peak Discharge Floodway (m^3/s)
20yr ARI	53	0.41	14.25	0.07	14.32	13.35	20	33
50yr ARI	78	0.53	14.37	0.06	14.43	13.49	21	57
100yr ARI	99	0.59	14.43	0.06	14.49	13.57	21	78

1. Maximum flooding depth from invert of floodway at 13.84mAHD.
2. Location is approximately 100m upstream from Dampier Highway.
3. Location is approximately 100m downstream from Dampier Highway.

The post-development results for the Dampier Highway are shown in Table 8. During the 50 year ARI storm event there is a slight increase in discharge across the floodway.

TABLE 8: POST-DEVELOPMENT DAMPIER HIGHWAY FLOOD INFORMATION

Storm Event	Max Discharge (m^3/s)	Max Flooding Depth[1] (m)	Peak Stage (mAHD)	Back water (m)	Upstream Stage[2] (mAHD)	Down-stream Stage[3] (mAHD)	Peak Discharge Culverts (m^3/s)	Peak Discharge Floodway (m^3/s)
20yr ARI	60	0.48	14.32	0.18	14.50	13.35	20	40
50yr ARI	82	0.54	14.38	0.21	14.59	13.47	21	61
100yr ARI	105	0.60	14.44	0.23	14.67	13.57	21	84

1. Maximum flooding depth from invert of floodway at 13.84mAHD.
2. Location is approximately 100m upstream from Dampier Highway.
3. Location is approximately 100m downstream from Dampier Highway.

5.4.2 Proposed Development Impacts

The impact from the proposed developments results in a similar increase in water levels as occurred in the 100yr ARI flood event. For both the 20 and 50yr ARI events, there is an average increase of 0.06m along the creek from the infilling of the floodplains within the proposed development areas (Figures 14 and 15). The largest increase is upstream of the Dampier Highway where the development will lead to an increase in flood levels of 0.33m (20 year ARI) and 0.36m (50 year ARI).

5.5 Dampier Highway Duplication

JDA have been advised by Jerome Goh (Main Roads Western Australia (MRWA)) that MRWA are currently designing a lane duplication for the Dampier Highway at the Madigan Creek crossing location.

Results from this flood study indicates that Dampier Highway is overtopped as frequently as during the 1hr 5yr ARI storm event. Consequently the design of the culverts and floodway are not sufficient to prevent a significant backwater upstream of the highway during the larger flood events (20, 50 and 100 year ARI events).

Recent discussion with Jerome Goh (MRWA) indicates that the post-development design of the highway upgrade will include the following design criteria:

- The serviceability and survivability for the 1 in 50 year ARI flood event.
- Preventing the backwater from exceeding 150mm

The post-development modelling performed in this report has assumed that the existing culverts and floodway will be retained. Consequently, should the capacity of the culverts be reduced, or the floodway removed, there may be detrimental impacts for floodplain management and potentially damage to infrastructure within the proposed residential developments.

6. FLOODPLAIN MANAGEMENT

The main objective of effective floodplain management is to provide protection to people, infrastructure and the environment by preventing damage to infrastructure from flooding, limiting the effect of flooding on individuals and communities, and preserving ecological and amenity values. This Section is based on best management practices outlined by SCARM (2000) and Waters and River Commission (2001).

Floodplain management in Western Australia is guided by the Department of Water (DoW) through the provision of advice and recommendation of guidelines for proposed development on floodplains with the object of minimising flood risk and damage. DoW uses the following guiding principles to ensure proposed development in floodprone areas is acceptable with regard to major flooding:

- Proposed development has adequate flood protection from a 100 year ARI flood event.
- Proposed development does not detrimentally impact on the existing 100 year ARI flooding regime of the general area.

Further details of the Strategy for existing development and proposed future developed are described below in the following sections.

6.1 Existing Development

The presence of the highway drainage structures on the floodplain can alter the flow and hence influence the flooding regime of the general area. Existing structures identified on 100 year ARI floodplain of the Madigan Creek are the Dampier Highway culverts and floodway.

As discussed in Section 5.5, the culverts do not convey the flow for Madigan Creek and the floodway is overtopped. These structures are may adversely affect major flooding following duplication of the highway without sufficient design.

6.2 Proposed Development

Future development on the floodplain has the potential to adversely impact on the natural flooding regime of the river. Similarly development can threaten the environmental factors that influence the waterway function.

To ensure adequate flood protection is provided to future development the recommended floodplain management strategy is (Figure 17):

- For proposed development located outside of the 100 year ARI floodplain, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level is recommended.
- For proposed development located within the 100 year ARI floodplain, the Department of Water will provide advice on each proposal based on its merits. Factors that will be examined are depth of flow, velocity of flow and potential flood damage. If development is considered acceptable, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level will be recommended.

A failure to properly adhere to these recommendations will result in a greater exposure to risks of flood damage. It should be noted that this information is related to major flooding only and other planning issues, such as environmental and ecological considerations, may also need to be addressed.

Structural flood mitigation measures, such as levees, bypass floodways, channel alignment and dams are not considered appropriate to mitigate flooding in Madigan Creek. Current development within the Study Area is not threatened and future development can be protected through appropriate land use planning. Future river crossings however should be designed to allow appropriate flow conveyance dependent upon the importance as an escape route during a major flood.

The type of fence on a property should also be approved by the Shire to ensure it does not adversely affect flood flow. For example, fences that allow the free flow of floodwaters (ie, post and rail type) are acceptable. However, solid or mesh fences aligned perpendicular to the flow are not acceptable as they may increase flood levels and are more prone to flood damage.

Structures related to stormwater management, such as detention basins or swales, may be required, but these should be determined through appropriate planning as the development progresses. It is recommended that stormwater management techniques follow the water sensitive urban design approach consistent with Stormwater Management Manual of Western Australia (DoE 2004) with critical infrastructure being located outside of the 100 year ARI floodplain.

In addition, any other proposed development within the 100 year ARI floodplain area including lot boundaries, firebreaks, clearing, roads and stormwater infrastructure are generally considered inappropriate and should be avoided if practical.

6.3 Emergency Response Procedures

Flood emergency response measures are required when flooding occurs above the design flood level, in this case, the 100 year ARI design flood. Emergency measures may include flood forecasting and warning, plans for the evacuation of the development and plans for the recovery of an area once the flood subsides (SCARM 2000).

It is recommended that the Shire of Roebourne in conjunction with the local emergency services prepare a Flood Emergency Plan for Madigan Creek once the final development structure plan has been approved. Included with this Emergency Plan should be some community education for new and existing residents. Education should involve community awareness of their role in the foreshore management and procedures for the defence and evacuation of the town during a flood event (SCARM 2000). Any emergency procedure should be consistent with the Shire of Roebourne’s Emergency Evacuation Plan (2009).

7. REFERENCES

Bureau of Meteorology Website (2010), Tropical Cyclones Affecting the Karratha/Dampier/Roebourne Region

Coffey Environmental (2010), 'Geotechnical Investigation for Karratha Townsite - Baynton West'

Department of Environment (DoE) (2004), *Stormwater Management Manual for Western Australia,* Perth, Western Australia.

GHD (2009) 'Seven Mile Creek Flood Study'

Institution of Engineers, Australia (1997), Australian Rainfall & Runoff Volume 1: A Guide to Flood Estimation.

Luke, G.L., Burke, K.L. & O'Brien, T.M. (1988). 'Evaporation Data for Western Australia – Technical Report 65', Perth: W.A. Department of Agriculture, Division of Resource Management

Shire of Roebourne (2009) Shire of Roebourne Local Community Emergency Management Arrangements

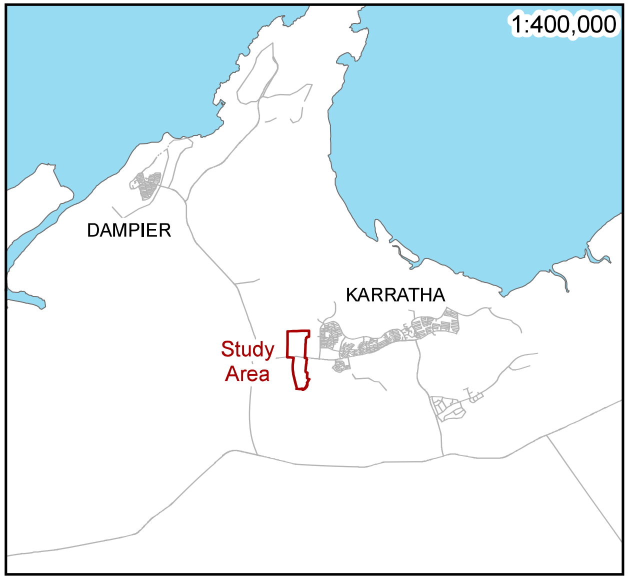
Standing Committee on Agriculture and Resource Management (SCARM) (2000), CSIRO, 'Floodplain management in Australia: best practice principles and guidelines' SCARM Report 73

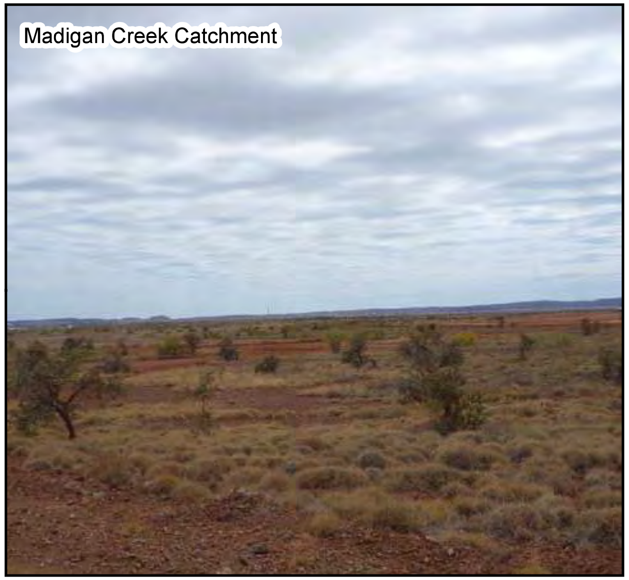
Water & Rivers Commission (1999) Surface Water Hydrology, An Introduction, Surface Water Hydrology Series Unpublished Report SWH 26.

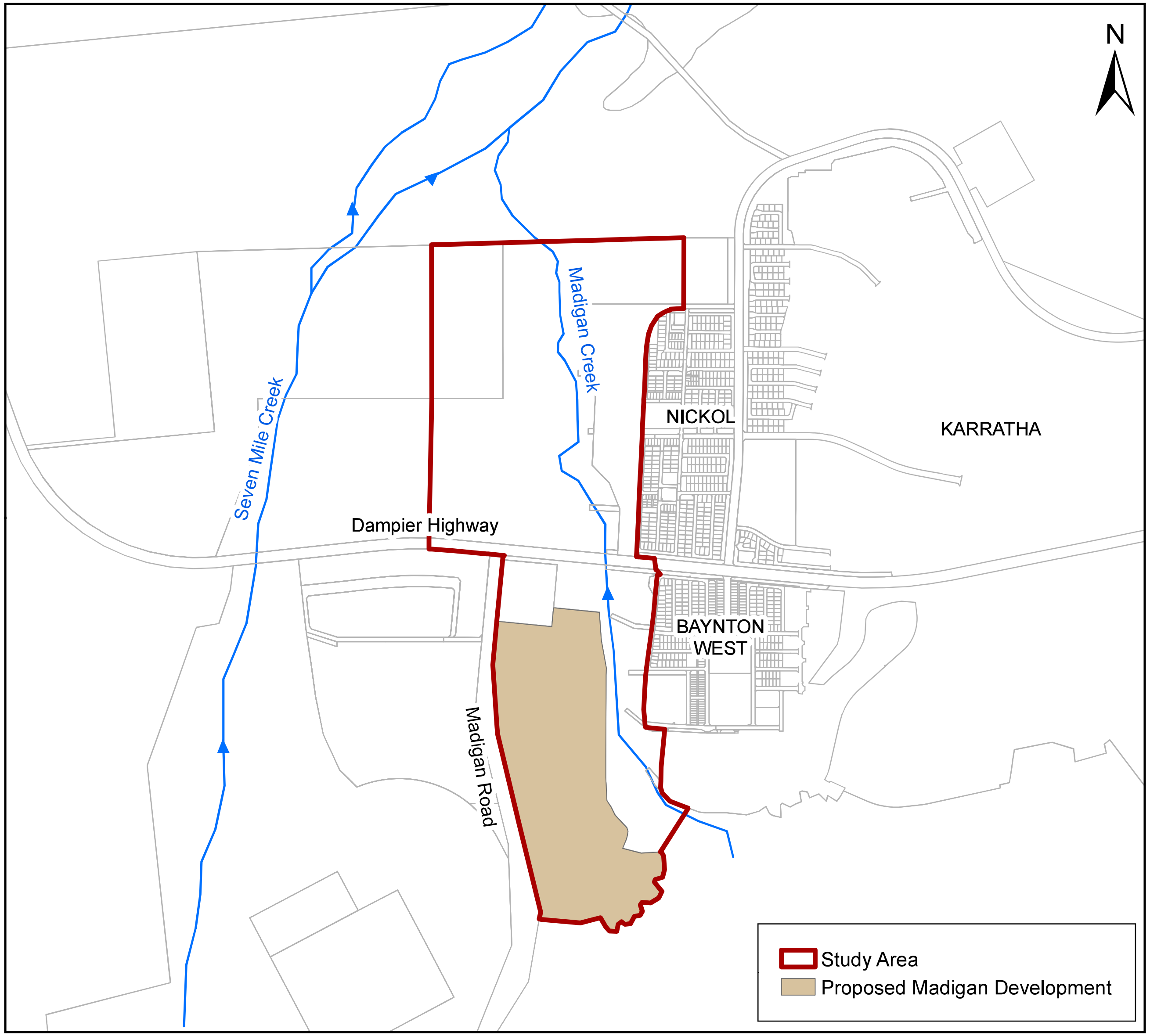
Water & Rivers Commission (WRC) (2001) *Determining foreshore reserves* Report No. RR 16.

Wood & Grieve (2008), Baynton West Karratha Stages 1 to 4 Drainage Report.

FIGURES

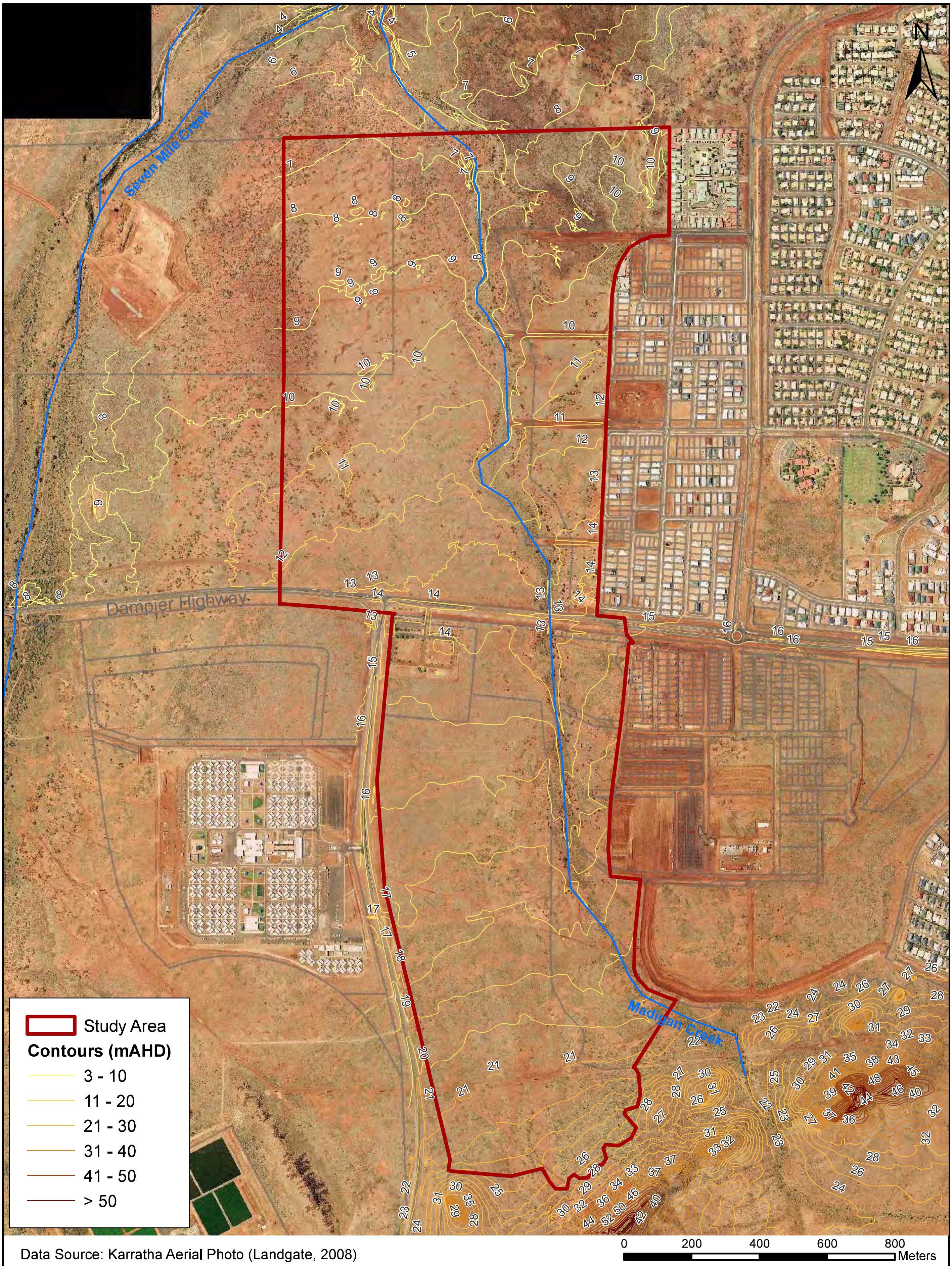






Job No. J4755
Scale: 1:30,000

LandCorp
Madigan Creek Flood Study
Figure 1: Location Plan

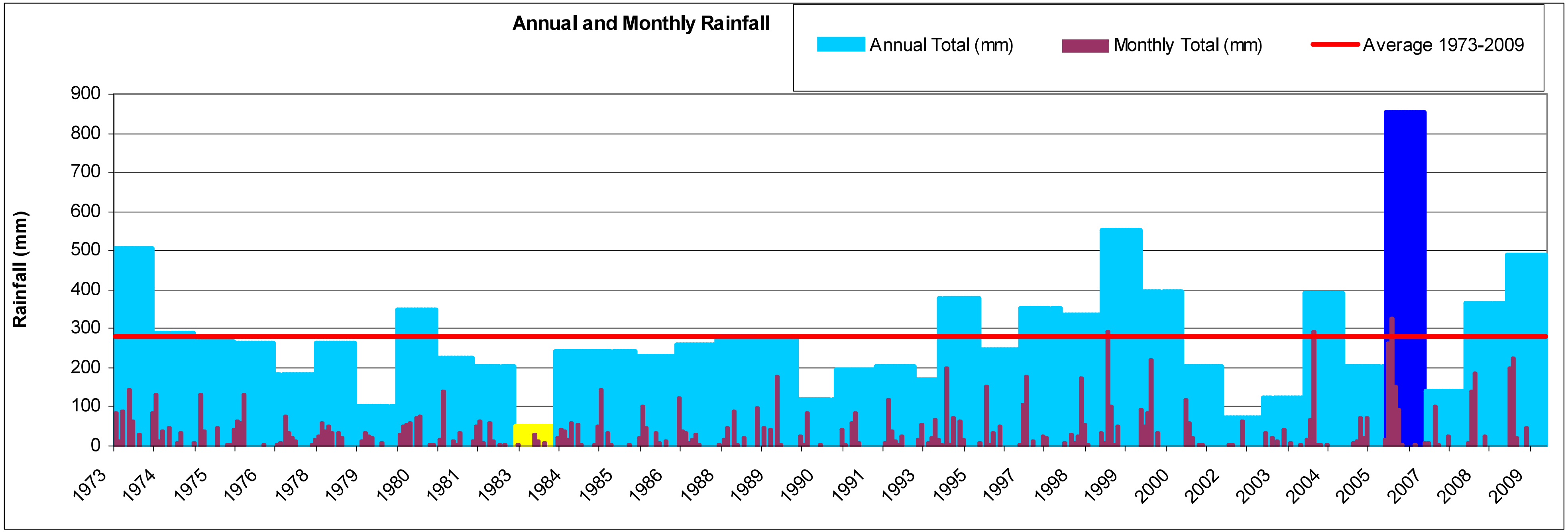


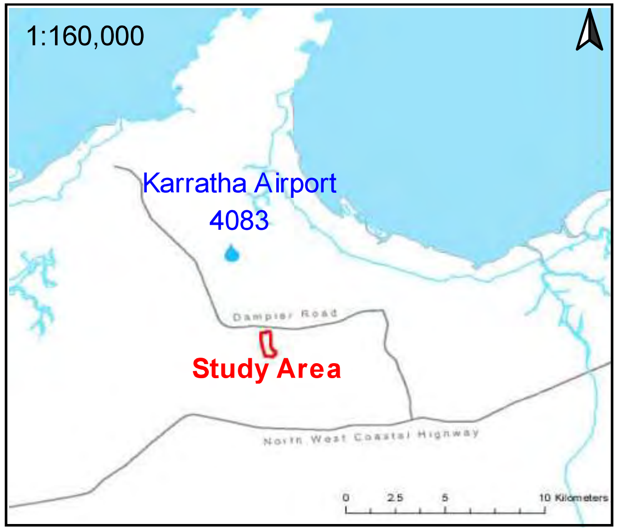
Data Source: Karratha Aerial Photo (Landgate, 2008)

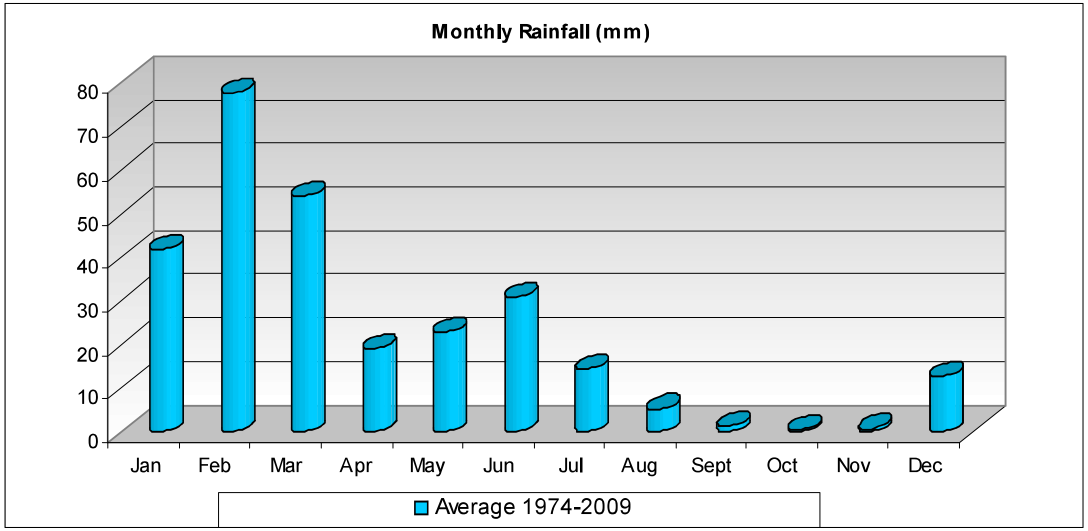
Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 2: Aerial Photograph and Topography





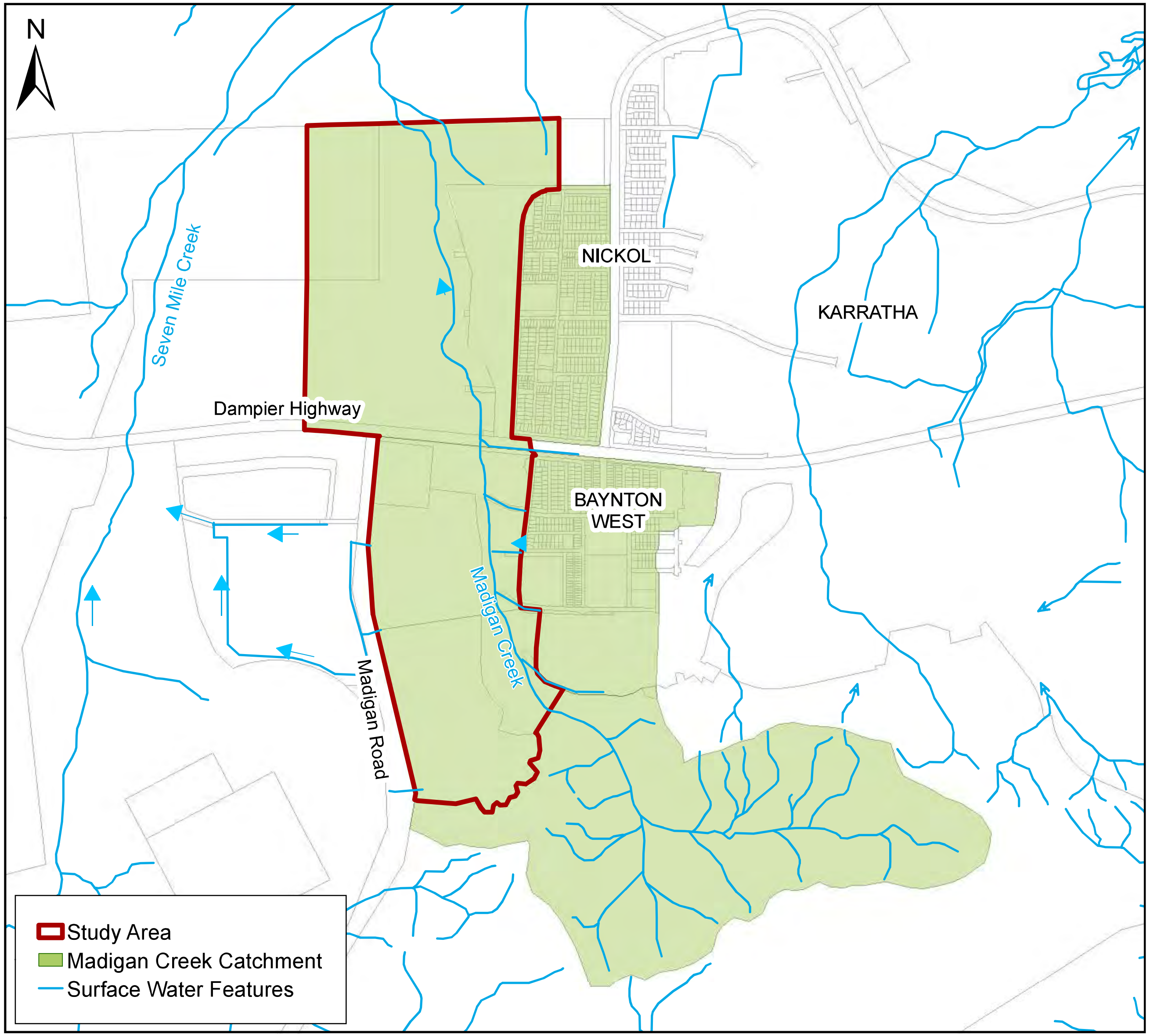


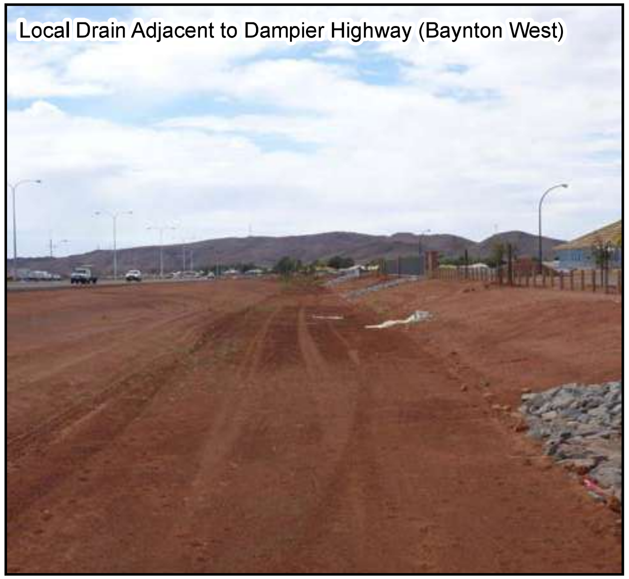
Data Source: Bureau of Metereology (2010)

Job No. J4755

LandCorp
Madigan Creek Flood Study

Figure 3: Karratha Airport Annual and Monthly Rainfall





Local Drain Adjacent to Dampier Highway (Baynton West)

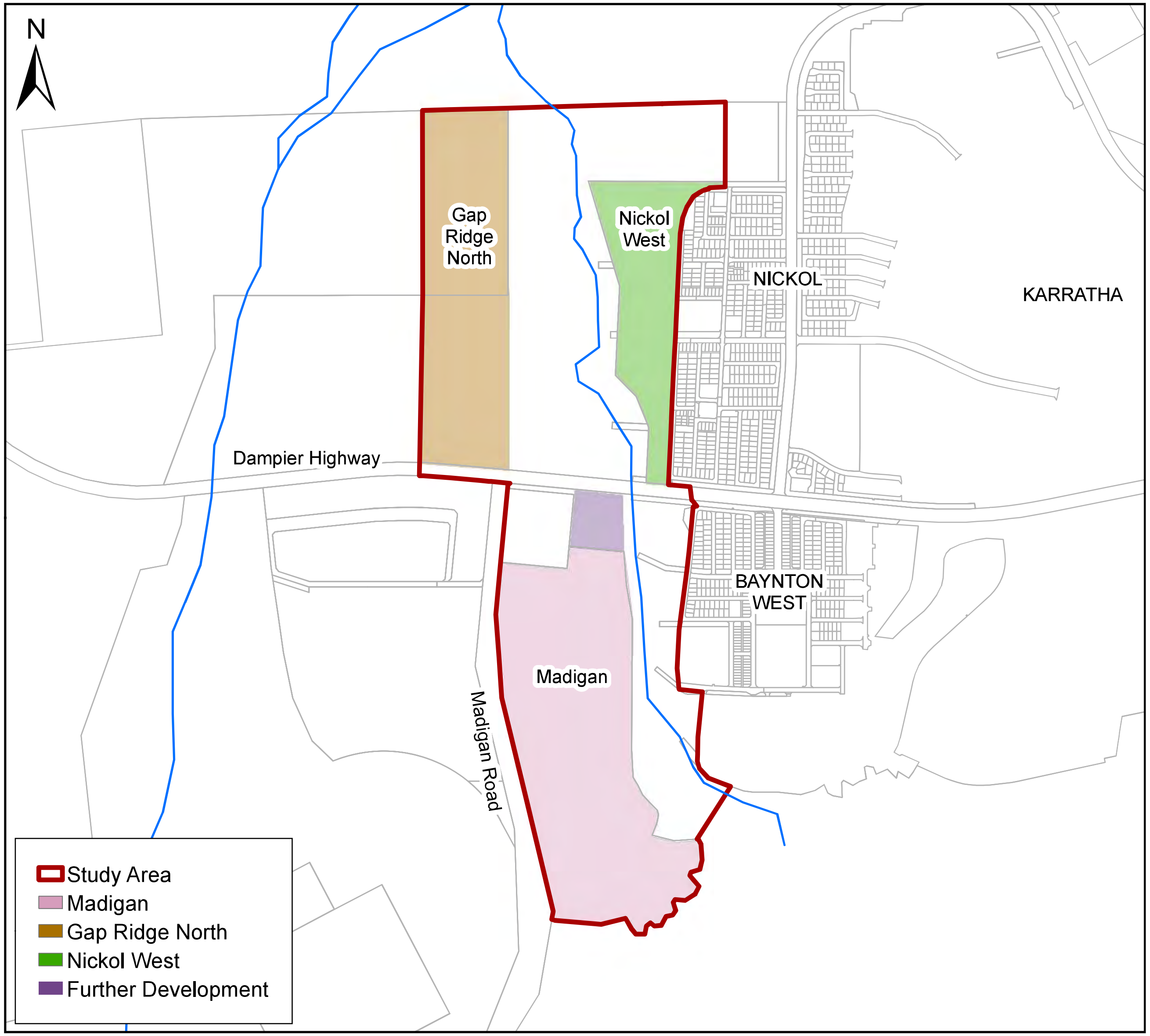
Madigan Creek at the Upstream Boundary of the Study Area

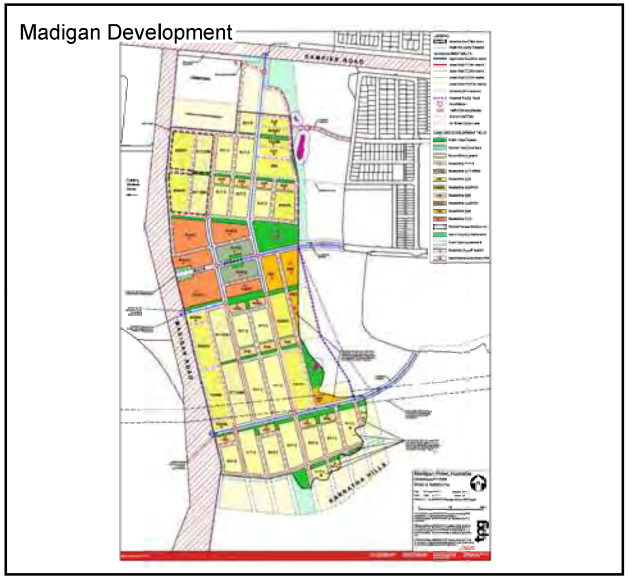
Data Source: Whelans (2010)

Job No. J4755
Scale: 1:30,000
0 200 400 600 800 Meters

LandCorp
Madigan Creek Flood Study

Figure 4: Existing Surface Drainage





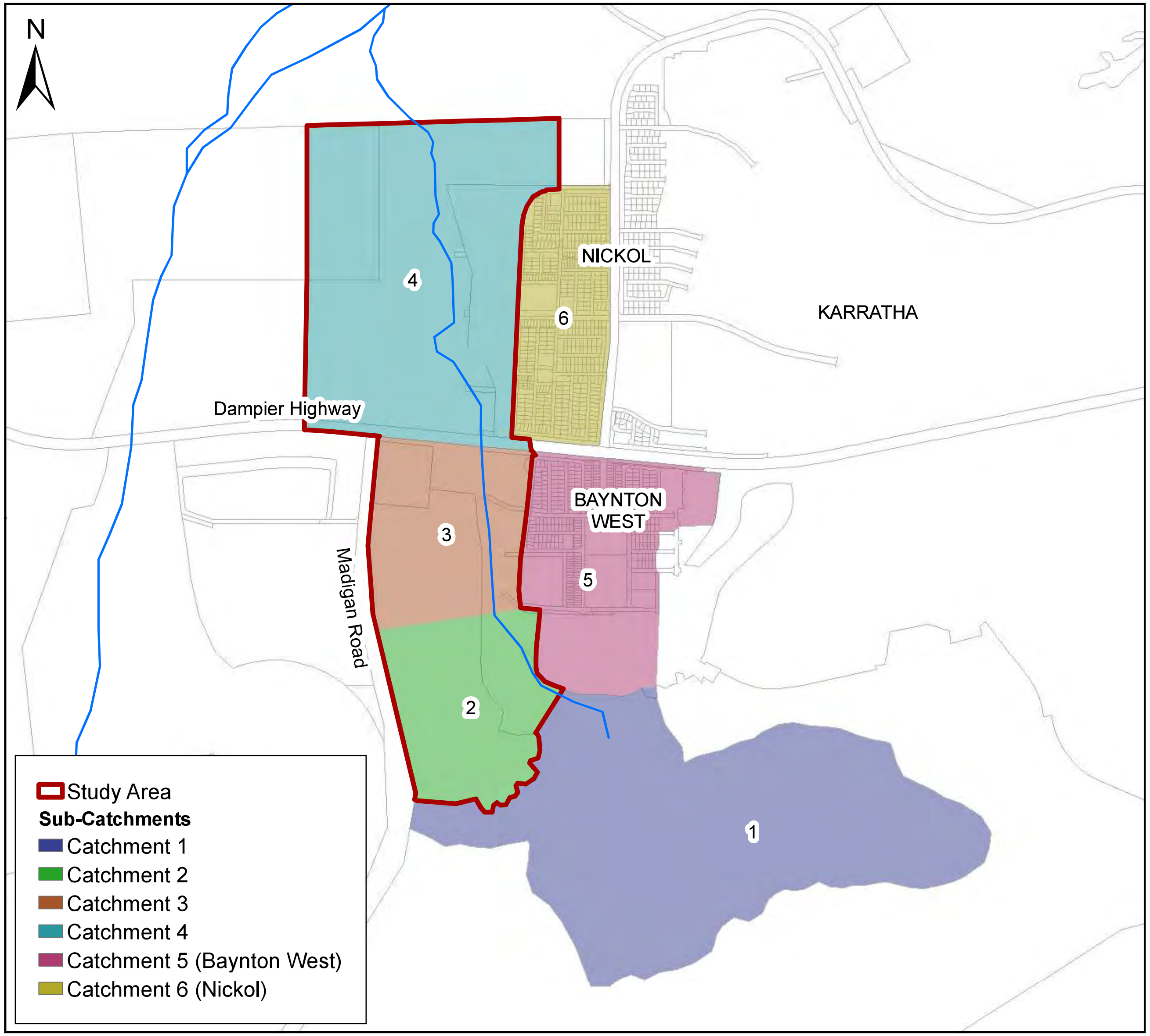
Data Source: TPG (2010)

JDA Consultant Hydrologists

Job No. J4755
Scale: 1:25,000

0 200 400 600 800 Meters

LandCorp
Madigan Creek Flood Study
Figure 5: Proposed Developments



Data Source: Whelans (2010)

Sub - Catchment Areas:

Catchment 1: 178.0ha
Catchment 2: 54.5ha
Catchment 3: 54.5ha
Catchment 4: 143.6ha
Catchment 5 (Baynton West): 68.7ha
Catchment 6 (Nickol): 46.5ha

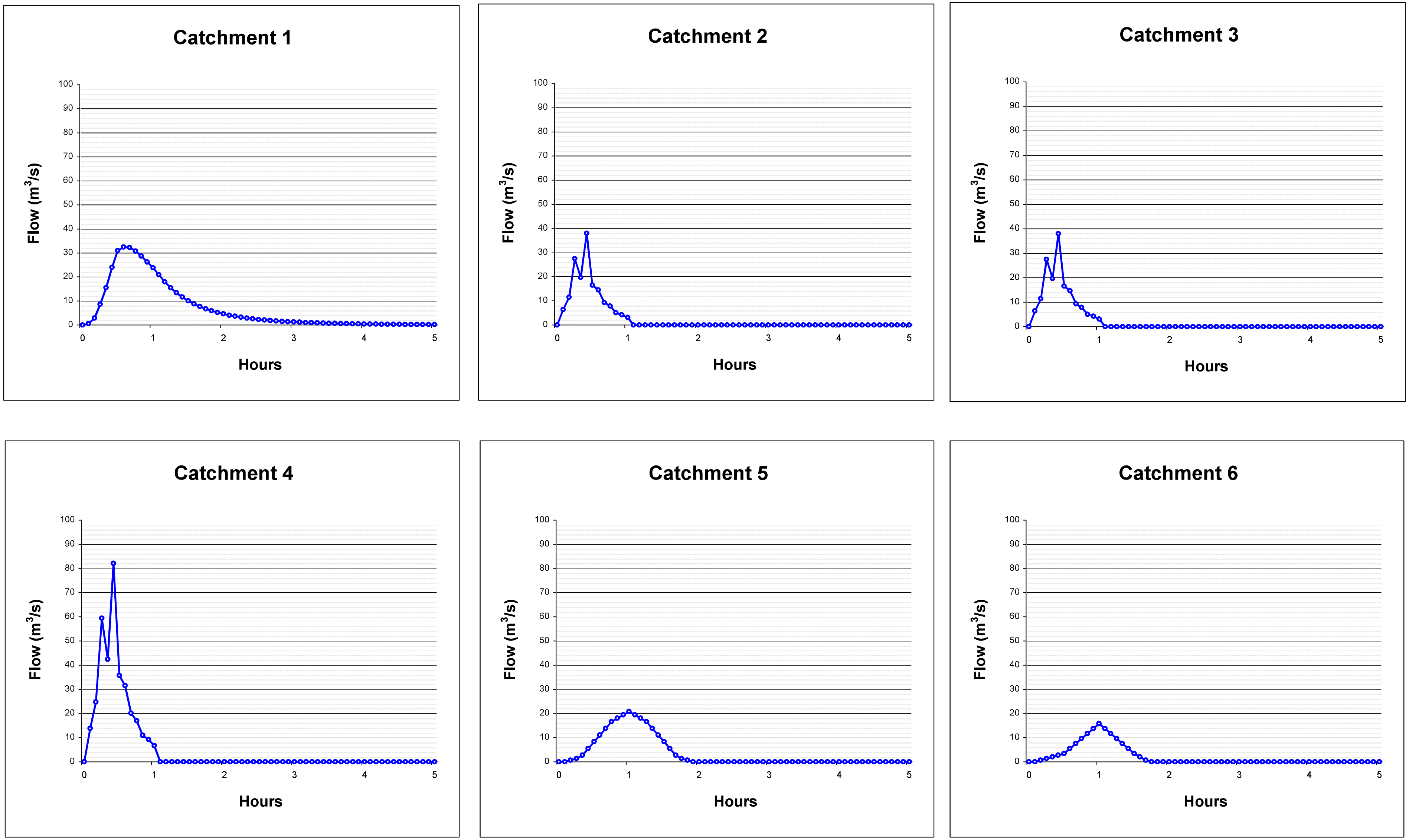
TOTAL: 545.8ha

Roughness Coefficient:
Manning's n = 0.05

Culverts under Karratha-Dampier Road

Job No. J4755
Scale: 1:30,000
0 200 400 600 800 Meters

LandCorp
Madigan Creek Flood Study
Figure 6: Madigan Creek Sub-Catchments

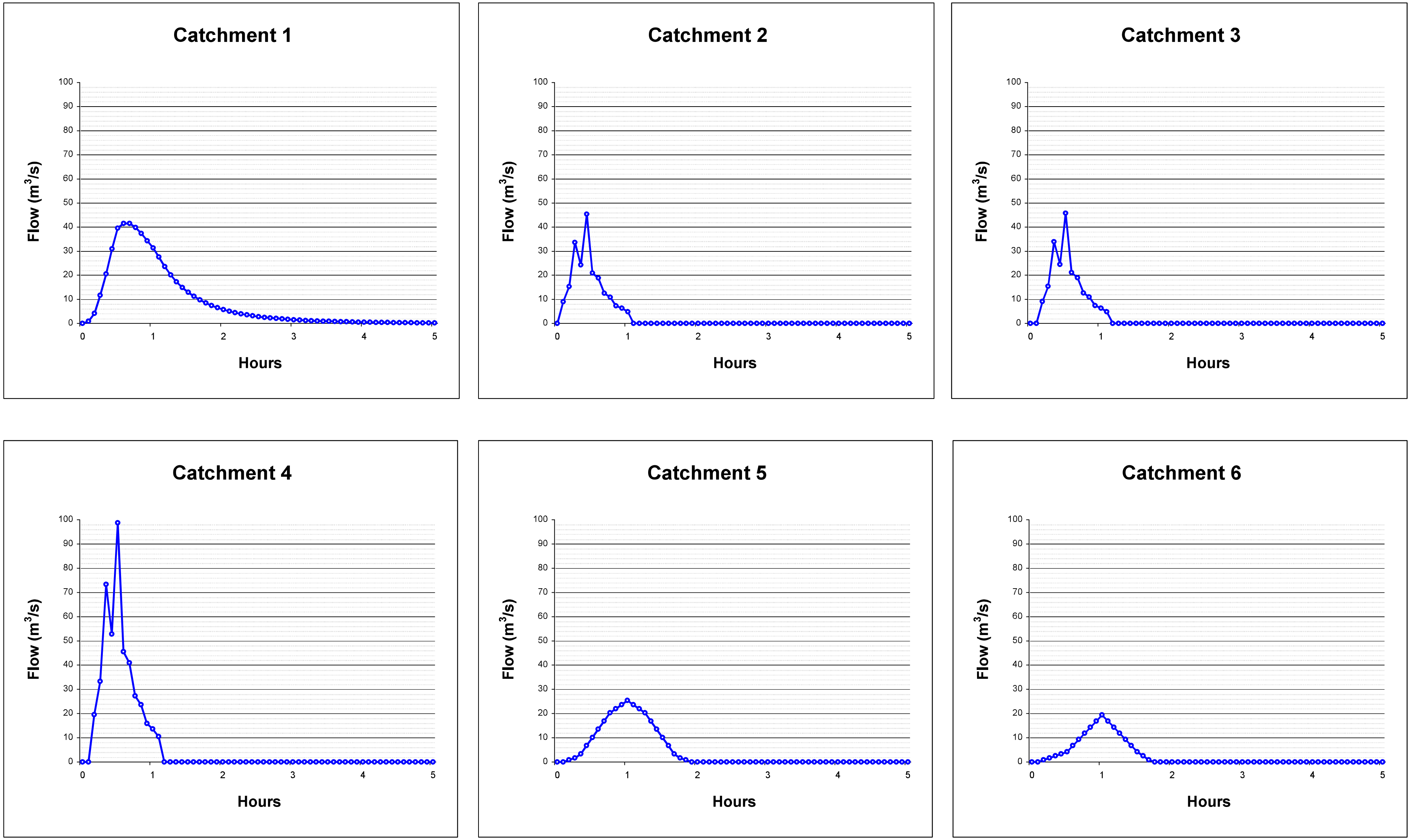


Job No. J4755

LandCorp

Madigan Creek Flood Study

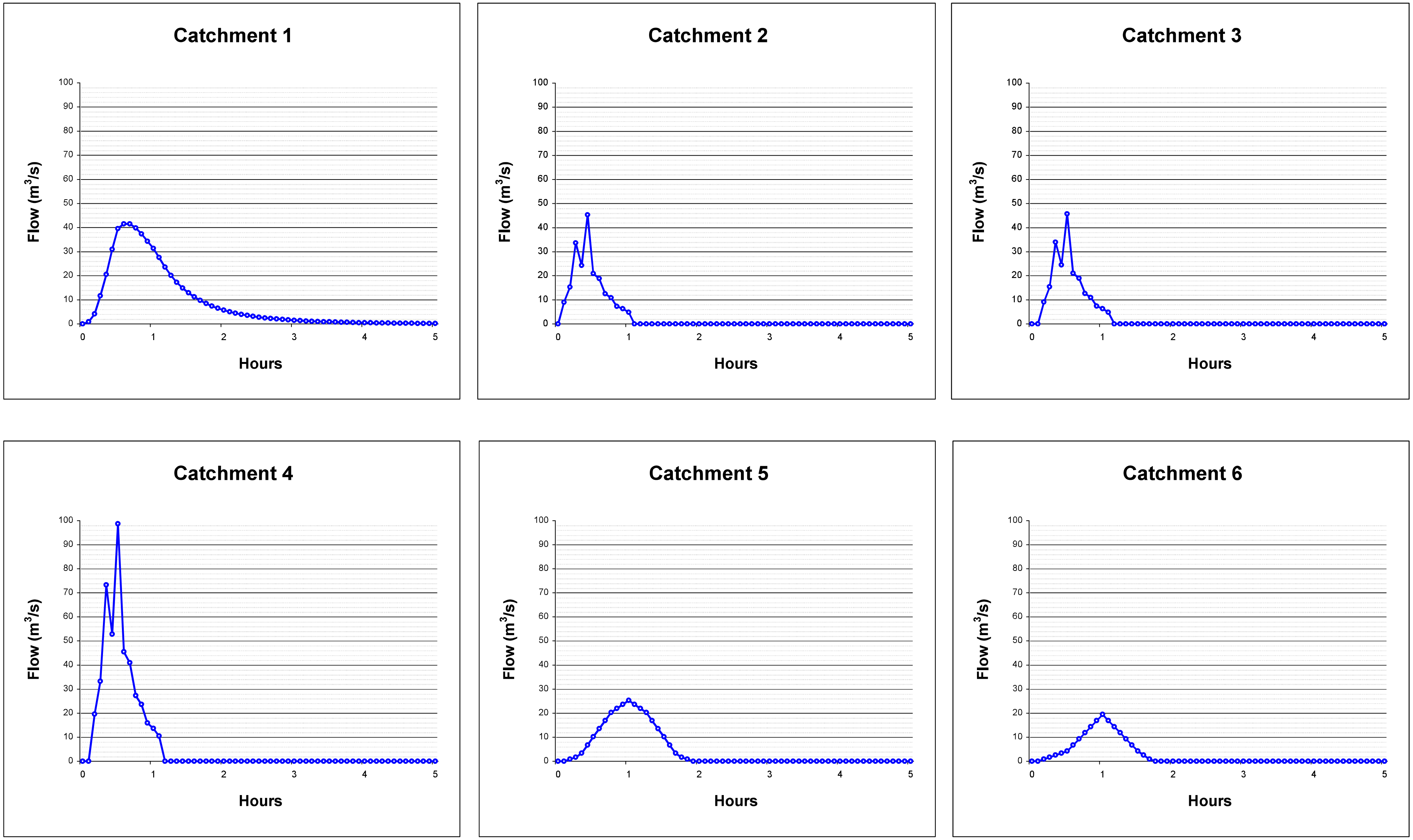
Figure 7: Design Hydrographs - 20 Year ARI



Job No. J4755

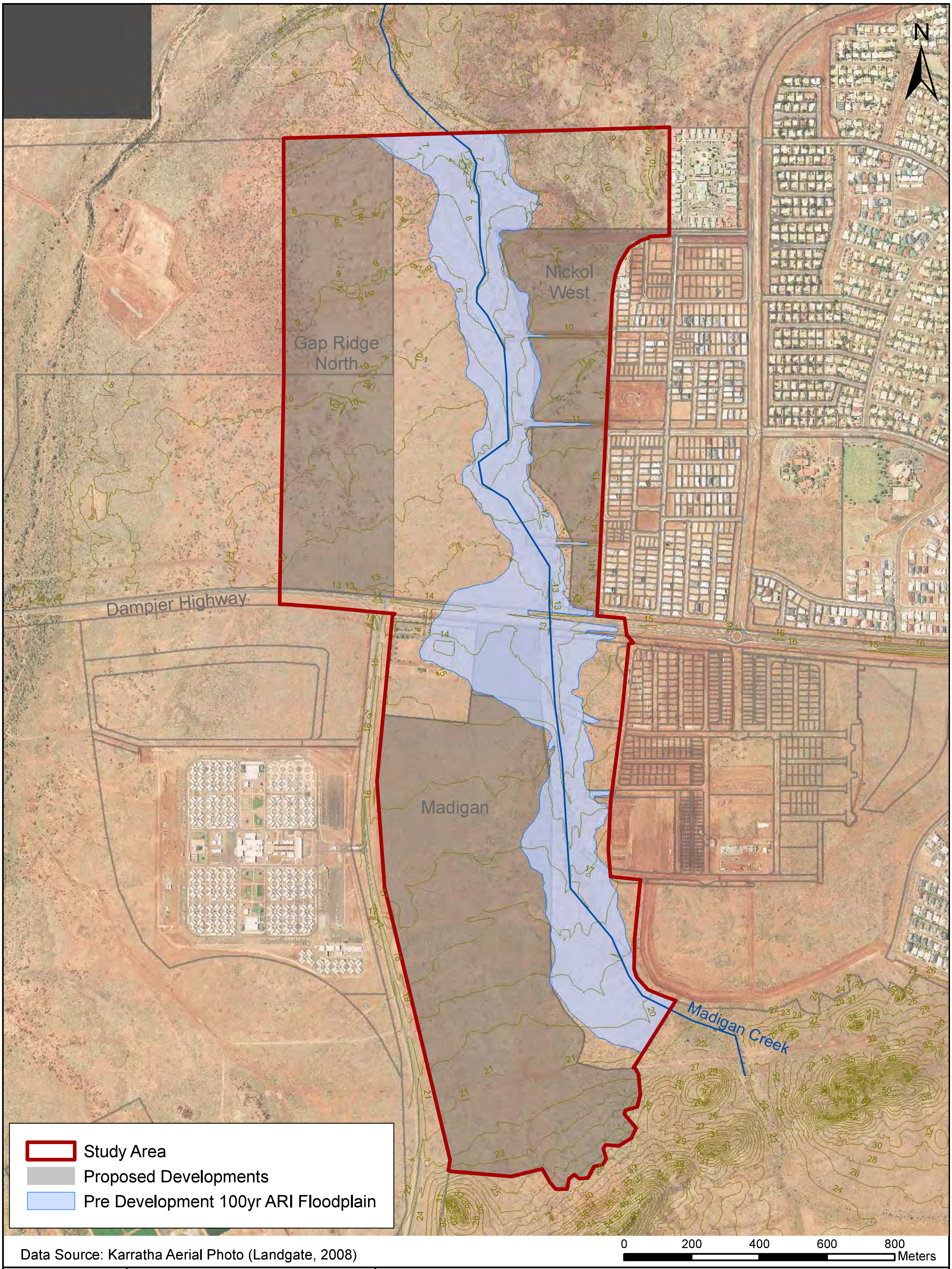
LandCorp
Madigan Creek Flood Study

Figure 8: Design Hydrographs - 50 Year ARI



Job No. J4755

LandCorp
Madigan Creek Flood Study
Figure 9: Design Hydrographs - 100 Year ARI

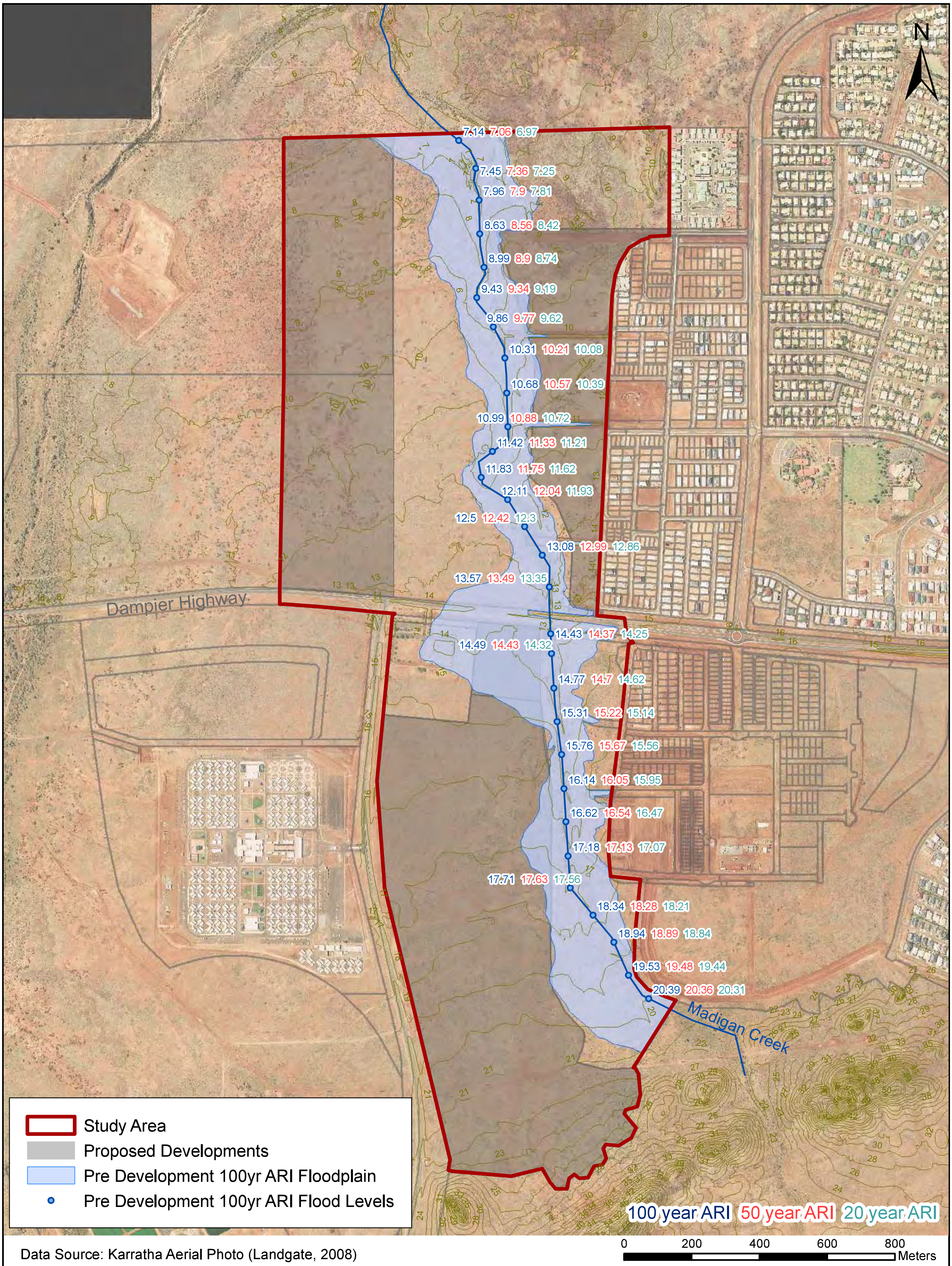


Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 10: 100 year ARI Pre-Development Floodplain



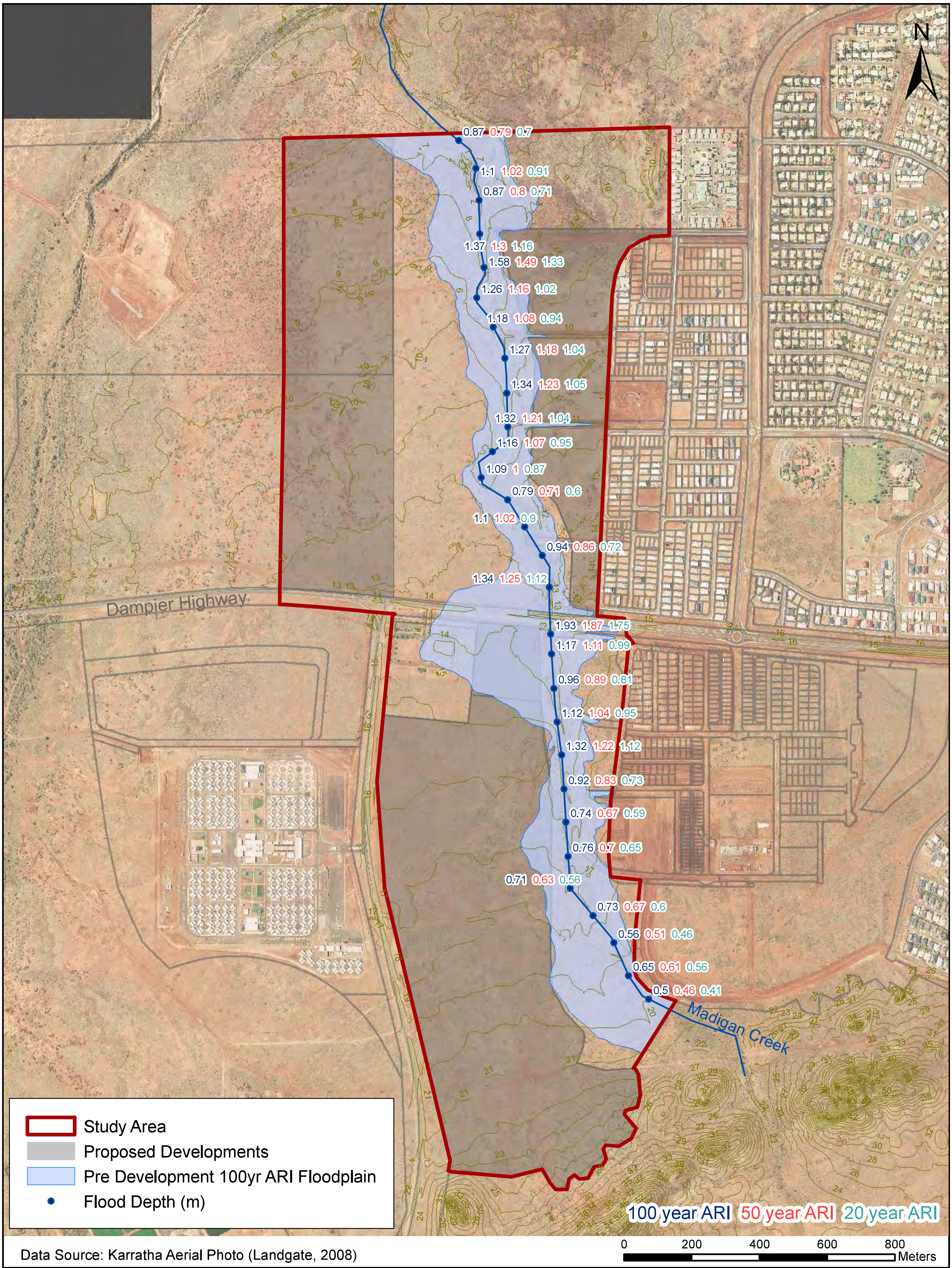
Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA Consultant Hydrologists

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 11: 20, 50 & 100 year ARI Pre-Development Flood Levels

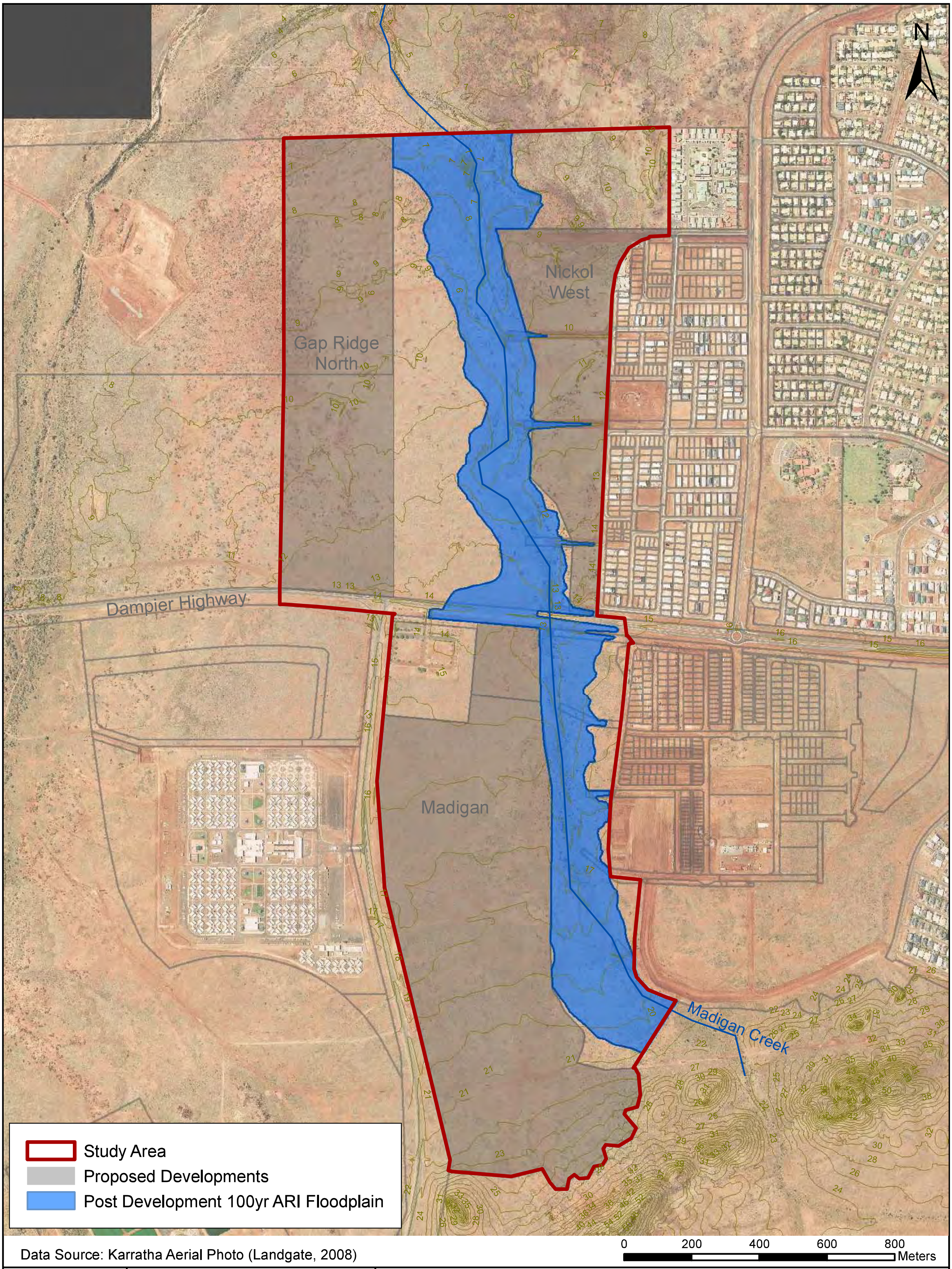


Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 12: 20, 50 & 100 year ARI Pre-Development Flood Depths



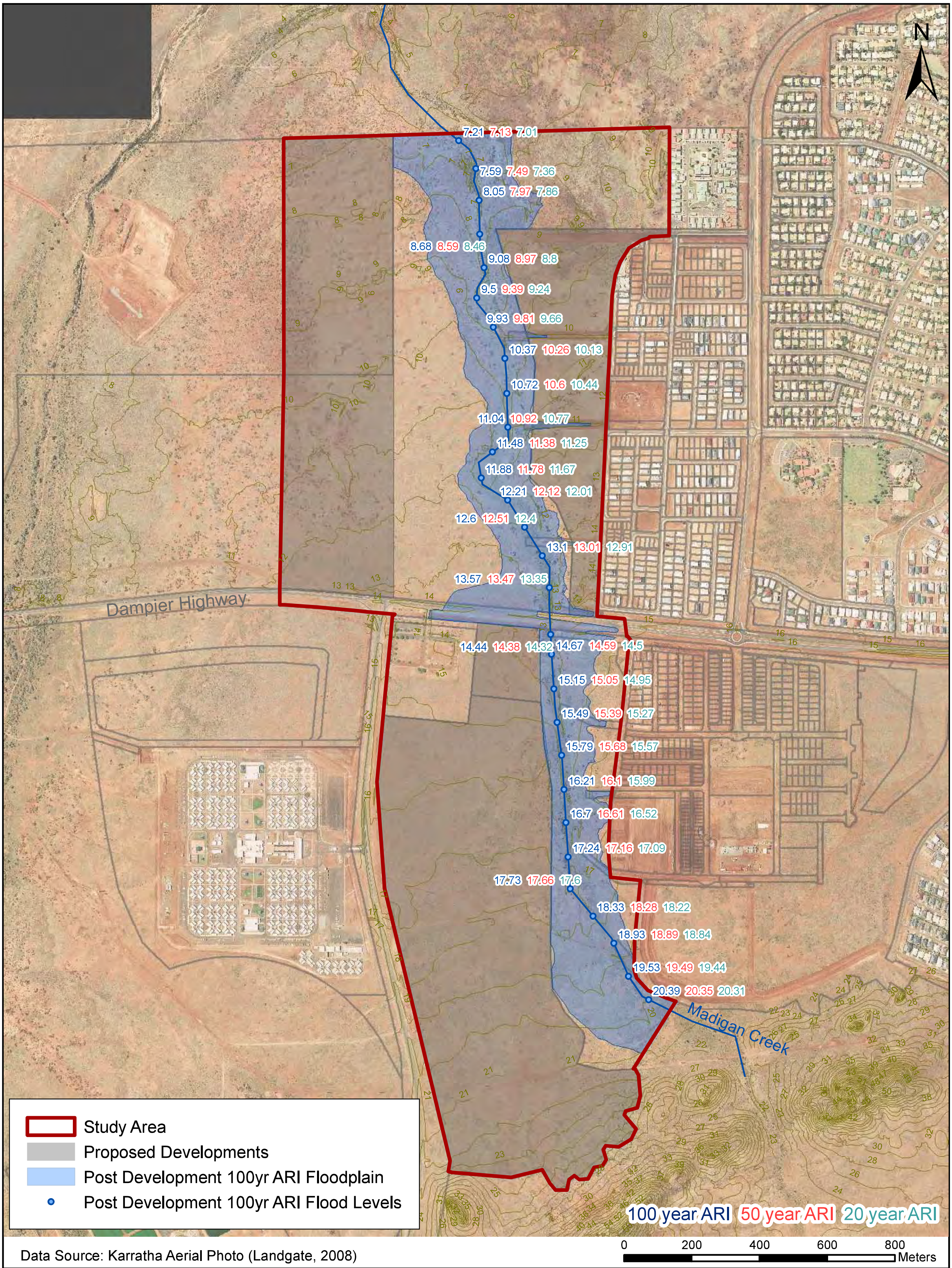
Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA Consultant Hydrologists

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 13: 100 year ARI Post-Development Floodplain

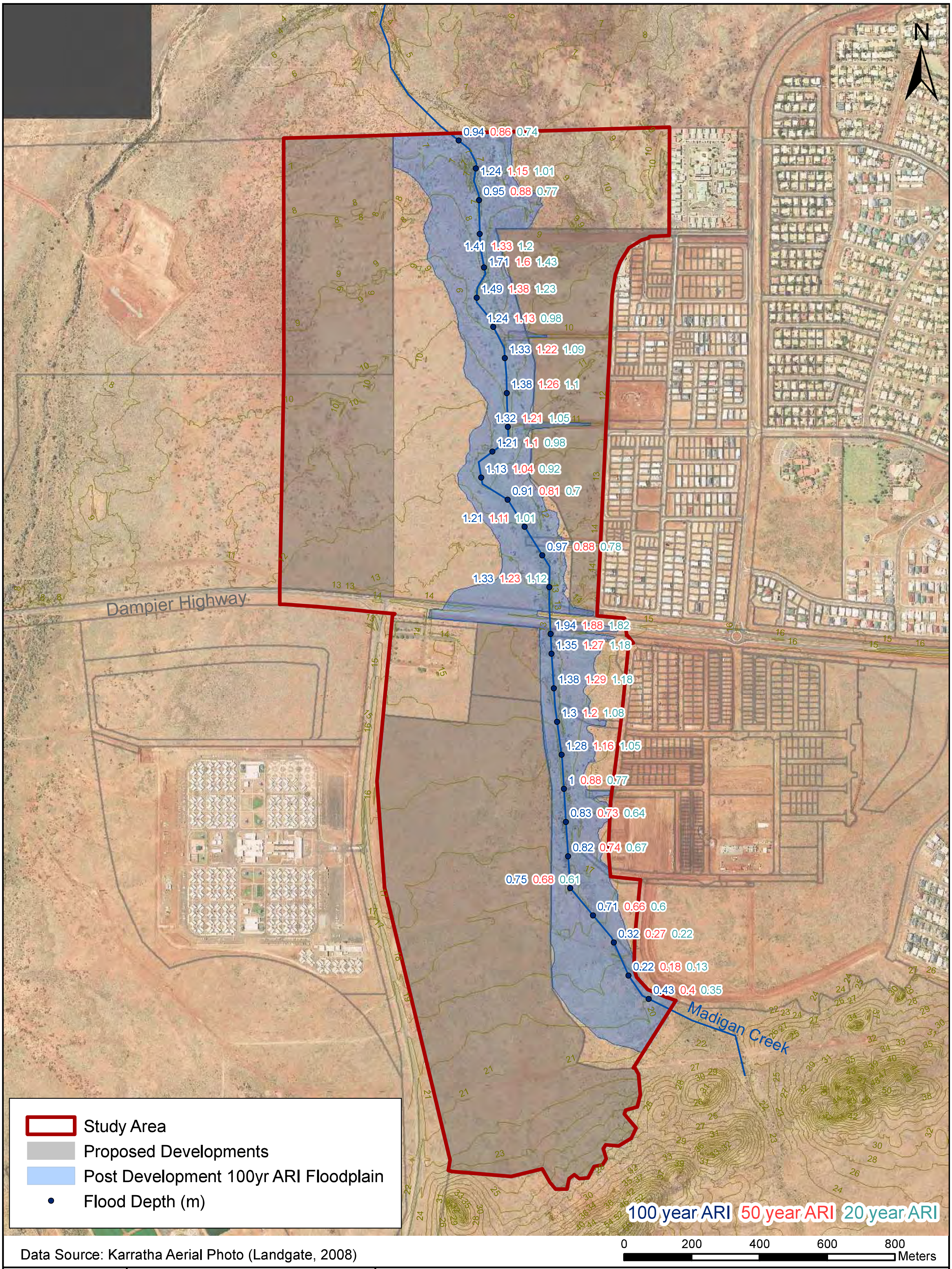


Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 14: 20, 50 & 100 year ARI Post-Development Flood Levels

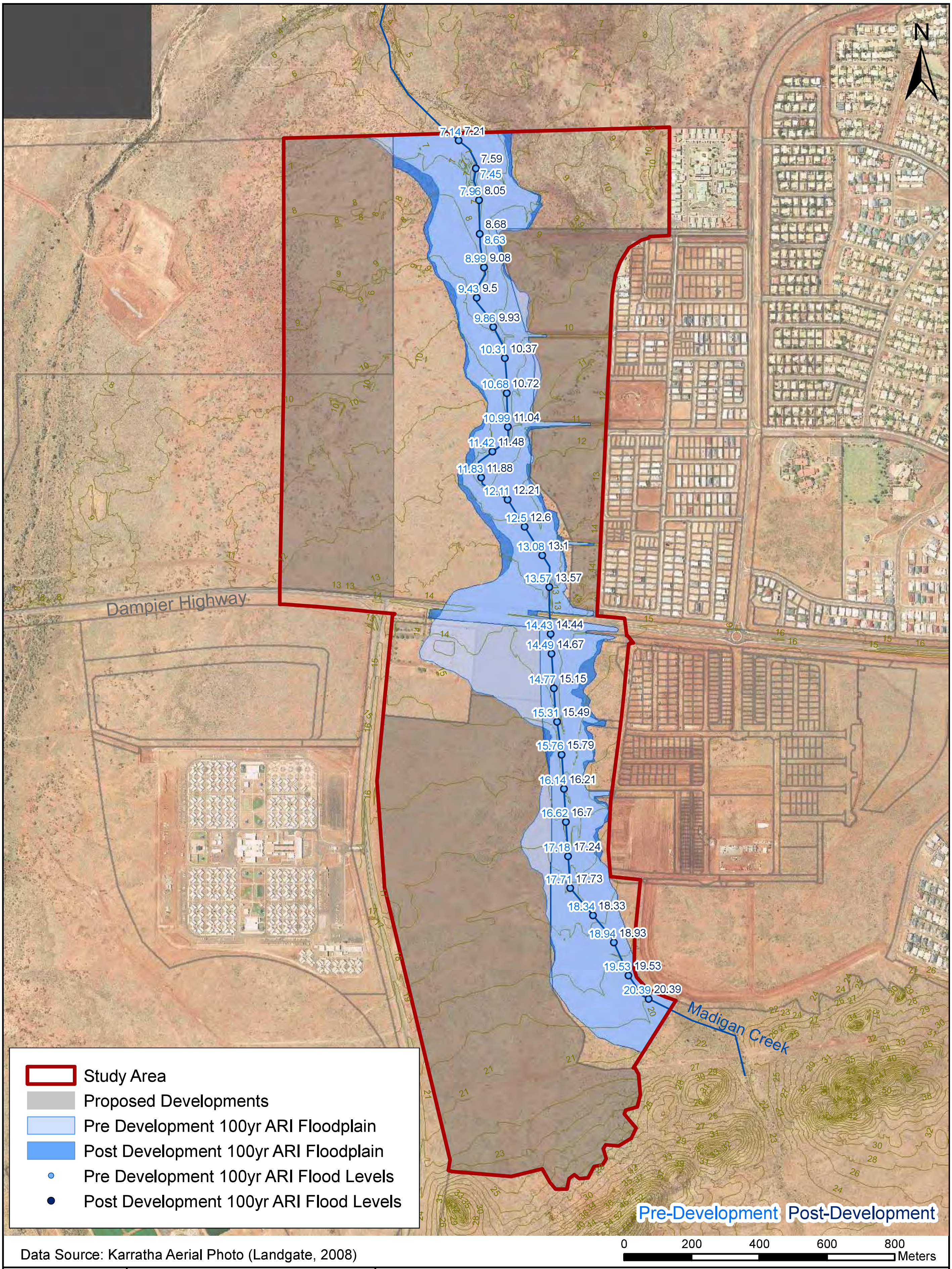


Data Source: Karratha Aerial Photo (Landgate, 2008)

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 15: 20, 50 & 100 year ARI Post-Development Flood Depths



Data Source: Karratha Aerial Photo (Landgate, 2008)

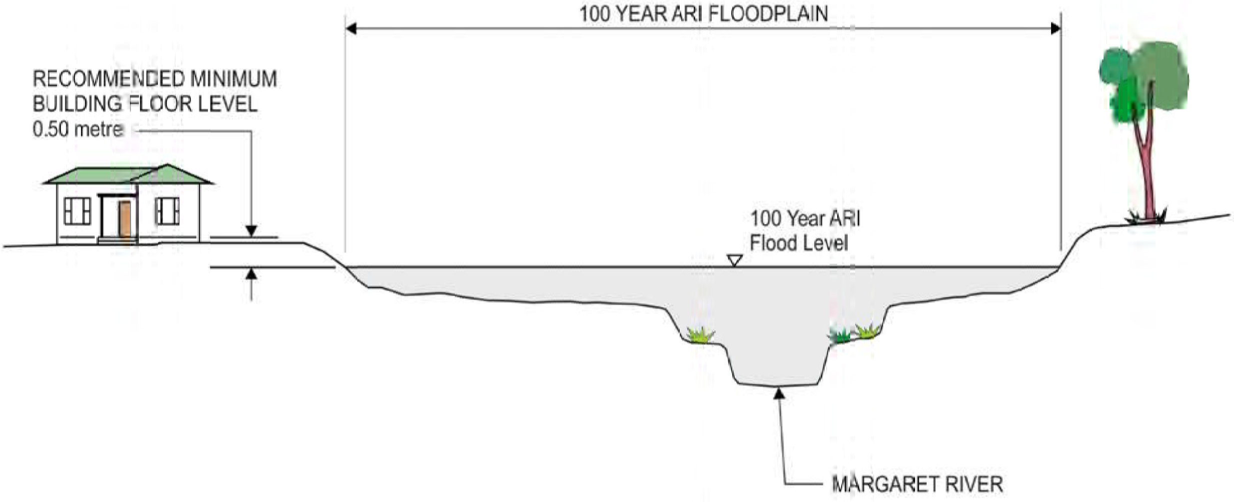
JDA Consultant Hydrologists

Job No. J4755
Scale 1:15,000

LandCorp
Madigan Creek Flood Study

Figure 16: Pre and Post-Development 100 year ARI Floodplains

RECOMMENDED FLOODPLAIN MANAGEMENT STRATEGY



(SCALE: DIAGRAMMATIC)

GENERAL NOTES

1. The 100 year ARI flood level is expected to occur, on average, once every 100 years. Floods higher than this level will occur but, on average, will be less frequent.

2. To ensure adequate flood protection is provided to future development the recommended floodplain management strategy is:

   2.1 For proposed development located outside of the 100 year ARI floodplain, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level is recommended.

   2.2 For proposed development located within the 100 year ARI floodplain, the Department of Water will provide advice on each proposal based on its merits. Factors that will be examined are depth of flow, velocity of flow and potential flood damage. If development is considered acceptable, a minimum building floor level of 0.50 metre above the adjacent 100 year ARI flood level will be recommended.

3. A failure to properly adhere to these recommendations will result in a greater exposure to risks of flood damage.

4. It should be noted that this information is related to major flooding only and other planning issues, such as environmental and ecological considerations, may also need to be addressed.

Data Source: Floodplain Management Strategy (DoW, 2010)

Job No. J4755

LandCorp
Madigan Creek Flood Study

Figure 17: Floodplain Strategy

Suite 1, 27 York St, Subiaco WA 6008
PO Box 117, Subiaco WA 6904
Ph: +61 8 9388 2436
Fx: +61 8 9381 9279

www.jdahydro.com.au

info@jdahydro.com.au

APPENDIX 6

ACOUSTIC REPORT

This page has been left blank intentionally.

EReport Number: 10010105

Revision Number: 1.1

ACOUSTIC ASSESSMENT

of a

PROPOSED RESIDENTIAL SUBDIVISION MADIGAN ROAD KARRATHA WA 6714

for

THE PLANNING GROUP WA
LEVEL 7, 182 ST GEORGES TERRACE
PERTH WA 6000

on behalf of

LANDCORP

PO Box 2124, Malaga WA 6944
ndengine@bigpond.net.au
T: (08) 9249 9619
F: (08) 9249 9622
M: 0412 679 431

ND Engineering
Consulting Engineers

nde

Index:

Revisions

Revisions to the report compared to the previous report, if any, are contained in italics for the paper copy and in red italics text for the PDF copy of the report.

Revision N°:	Date:	Comment	Status
1	18 October 2010	Issued for Approval	Superseded
1.1	**20 October 2010**	**Minor revisions**	**Current**

Author

Nick DELLA GATTA, BE (Mechanical) CPEng MIEAust

N. M. Della Gatta
MIEAust CPEng
Chartered Professional Engineer
Membership No. 1184788

References:

A. State Planning Policy 5.4 '*ROAD AND RAIL TRANSPORT NOISE AND FREIGHT CONSIDERATIONS IN LAND USE PLANNING*', gazetted 22 SEP 2009 Gazette No 169 Special.

B. Attachment 2 *IMPLEMENTATION GUIDELINES* May 2009
for SPP 5.4 'Road and Rail Transport Noise and Freight Considerations in Land Use Planning'.

C. Australian Standard 2107-2000
'Acoustics - Recommended design sound levels and reverberation times for building interiors'.

D. tpg Drawing No 710-200 ST1C Madigan Plans 051010, dated 11 OCT 10

SUMMARY

0.1 ND Engineering's opinion is that traffic noise impact on the proposed development can meet the requirements of Reference A, SPP 5.4, by:

a. Deferring the sale of land on the Western half of blocks 8, 7, 3, 4, 9a, 9, 10, 10a, 40 and 44 (See Figure 0 below) nominally within 82 metres from the centre line of Madigan Road until such time as the Ridge Gap Village construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route; and

b. Adjusting the shape of the block facing Dampier Road so that there will not be any residences North of the roundabout. See Figure 0 – BUFFER; and

c. Reassessing the noise levels prior to the sale of the deferred land once the construction camp ceases operation and if necessary once Madigan Road is no longer used as a heavy haulage route.

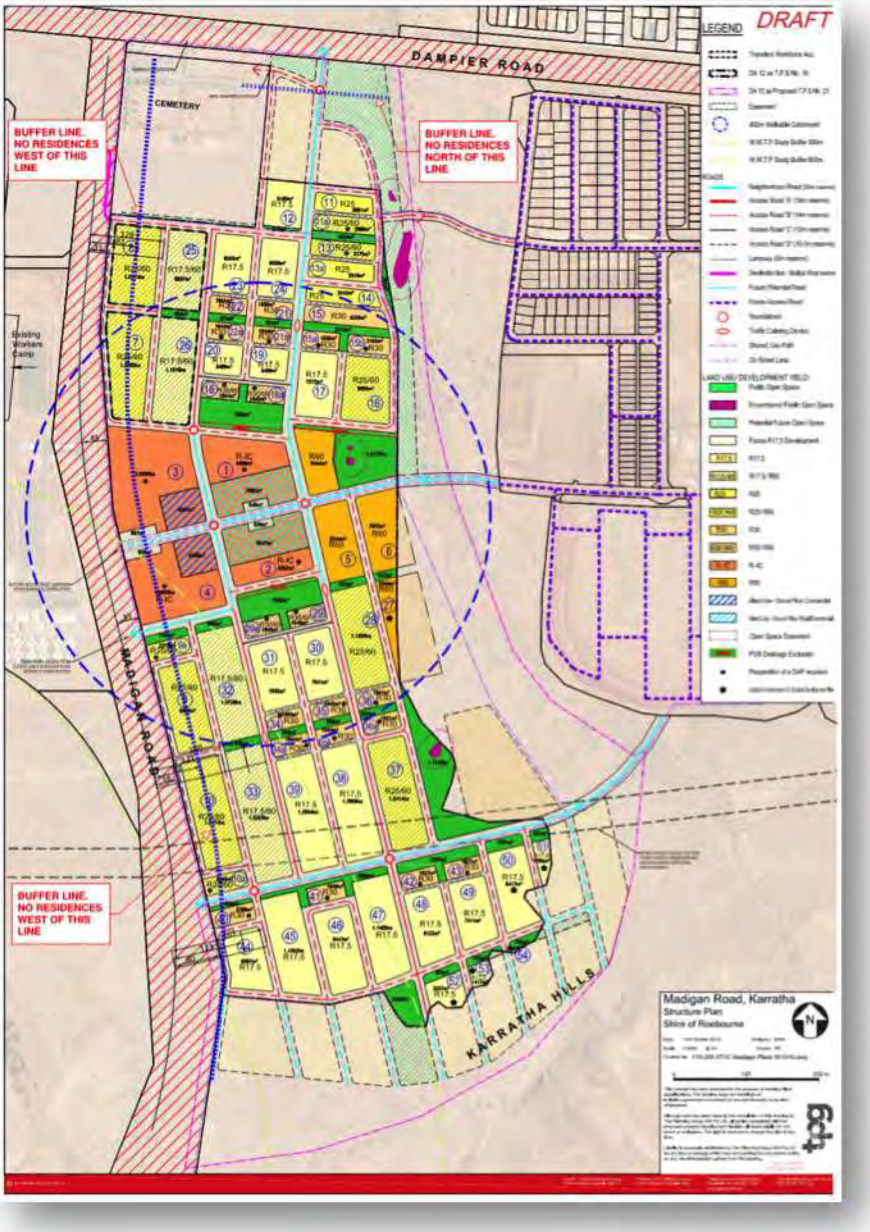


FIGURE 0 – BUFFER LINES

INTRODUCTION

1.1 ND Engineering was commissioned to conduct an acoustic assessment of the proposed development to determine the requirements for compliance with Reference A, SPP 5.4, noting that the construction of a barrier wall along Madigan Road and restrictions on the construction of dwellings was not desirable given anticipation that there would be reductions in traffic volumes in the next 5 to 10 years.

1.2 Compliance with Reference A, while negating a barrier wall along Madigan Road and restrictions on the construction of dwellings, was envisaged as being achievable by the creation of a buffer of land to be withheld from development until such time as closure of the construction camp and relocation of the heavy haulage route from Madigan Road, anticipated to be in the next 5 to 10 years respectively.

SITE DESCRIPTION

2.1 The site is located near the corner of Madigan Road and Dampier Road. See Annex A for details.

2.2 The Madigan Road average week day traffic count is about 3000 vehicles per day South of Dampier Road of which comprises about 80% light vehicles (Ausroads Class 1 and 2). Observations on site show that the traffic movement between:

a. 0500 to 0800 hours and 1600 to 2000 hours is predominantly light vehicles and buses associated with movement between Dampier Road and the Gap Ridge Village entry/exit producing hourly average noise levels of about LAeq 60 to 65 dB(A) at the measurement location; and

b. 0800 to 1600 hours is predominantly heavy vehicles producing hourly average noise levels of about LAeq 55 to 60 dB(A) at the measurement location.

2.3 The traffic volumes are currently 3000 vehicles per day and is expected to decrease significantly once the Ridge Gap Village construction camp ceases operation and again when Madigan Road is not longer used as a heavy haulage route. The reduction in traffic volume associated with the closure of the Ridge Gap Village is expected to reduce the noise levels by about 5 dB(A).

ASSESSMENT

The following subsections form the assessment:

- 3.0 Assumptions & Limitations.
- 3.1 Outdoor Noise Criteria.
- 3.2 Measurements.
- 3.3 Outdoor Noise Assessment.
- 3.4 Indoor Noise Assessment.

Assumptions & Limitations - Assessment

3.0 The following assumptions and limitations are made:

a. The noise measurements are based 'on the day' and cannot take into account any future mixes of traffic which may result in variations from the predicted noise levels.

b. The proposed development is as shown in Annex A;

c. The residences will be single storey residences in blocks 8, 7, Western half of 3 and 4, 9a, 9, 10, 10a, 40 and 44;

d. That the Gap Ridge Village located on the Western side of Madigan Road is anticipated to be closed and removed, without any future replacement, in approximately 5 years from now in 2015;

e. That the heavy haulage route currently on Madigan Road will be relocated approximately 10 years from now in 2020.

Outdoor Noise Criteria

3.1.1 Table 1 of Reference A, SPP 5.4, gives the following outdoor noise criteria.

Table 3.1 - Outdoor noise Criteria (Reference A's Table 1)

Time of Day	**Noise Target**	**Noise Limit**
DAY - 6am to 10 pm	$L_{Aeq(Day)}$ = 55 dB(A)	$L_{Aeq(Day)}$ = 60 dB(A)
Night - 10 pm to 6 am	$L_{Aeq(Night)}$ = 50 dB(A)	$L_{Aeq(Night)}$ = 55 dB(A)

3.1.2 The guidelines (see Reference B) associated with SPP 5.4 (see Reference A) provide two deemed to comply noise insulation packages for residential developments.

These two deemed to comply packages, Reference B's Package A Table 8 and Package B Table 9, are designed to ensure that the indoor noise standards in the policy are achieved for residential developments in areas where the outdoor noise levels are likely to be higher than the target noise levels by up to 8 dB(A).

3.1.3 Part of this noise assessment is to determine a demarcation point beyond which the application of the deemed to satisfy packages is not required as the noise levels will be below noise target.

Measurements

3.2.1 Measurements on site indicated at the development's Western site boundary parallel to Madigan Road, at the junction between blocks 7 and 8,outdoor noise levels were $L_{Aeq(Day)}$ = 61 dB(A) and $L_{Aeq(Night)}$ = 52 dB(A) prior to any adjustments.

3.2.2 Calculations indicate that at a distance 80 metes the outdoor noise levels reduce to $L_{Aeq(Day)}$ = 54 dB(A) and $L_{Aeq(Night)}$ = 46 dB(A) prior to any adjustments. These two noise levels are below the noise target.

Outdoor Noise Assessment

3.3 The outdoor noise levels, $L_{Aeq(Day)}$ = 54 dB(A) and $L_{Aeq(Night)}$ = 46 dB(A), are below the noise target therefore no further assessment is required with respect to Reference A and B.

Indoor Noise Assessment

3.4 The outdoor noise measurements, $L_{Aeq(Day)}$ = 54 dB(A) and $L_{Aeq(Night)}$ = 46 dB(A), are below the noise target therefore no further assessment is required with respect to Reference C, AS/ 2107:2000

CONCLUSIONS

4. ND Engineering's opinion is that traffic noise impact on the proposed development can be reduced to meet the requirements of Reference A, SPP 5.4, by:

a. Deferring the sale of land on the Western half of blocks 8, 7, 3, 4, 9a, 9, 10, 10a, 40 and 44 (See Figure 0 below) nominally within 82 metres from the centre line of Madigan Road until such time as the Ridge Gap Village construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route; and

b. Adjusting the shape of the block facing Dampier Road so that there will not be any residences North of the roundabout. See Figure 0 – BUFFER LINES; and

c. Reassessing the noise levels prior to the sale of the deferred land once the construction camp ceases operation and then later if necessary once Madigan Road is not longer used as a heavy haulage route.

RECOMMENDATIONS

5. The following recommendation are made:

a. Deferring the sale of land on the Western half of blocks 8, 7, 3, 4, 9a, 9, 10, 10a, 40 and 44 (See Figure 5 – BUFFER LINES below) nominally within 82 metres from the centre line of Madigan Road until such time as the construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route; and

b. Adjusting the shape of the block facing Dampier Road so that there will not be any residences North of the roundabout. See Figure 5 – BUFFER LINES; and

c. Reassessing the noise levels prior to the sale of the deferred land once the construction camp ceases operation and Madigan Road is no longer used as a heavy haulage route.

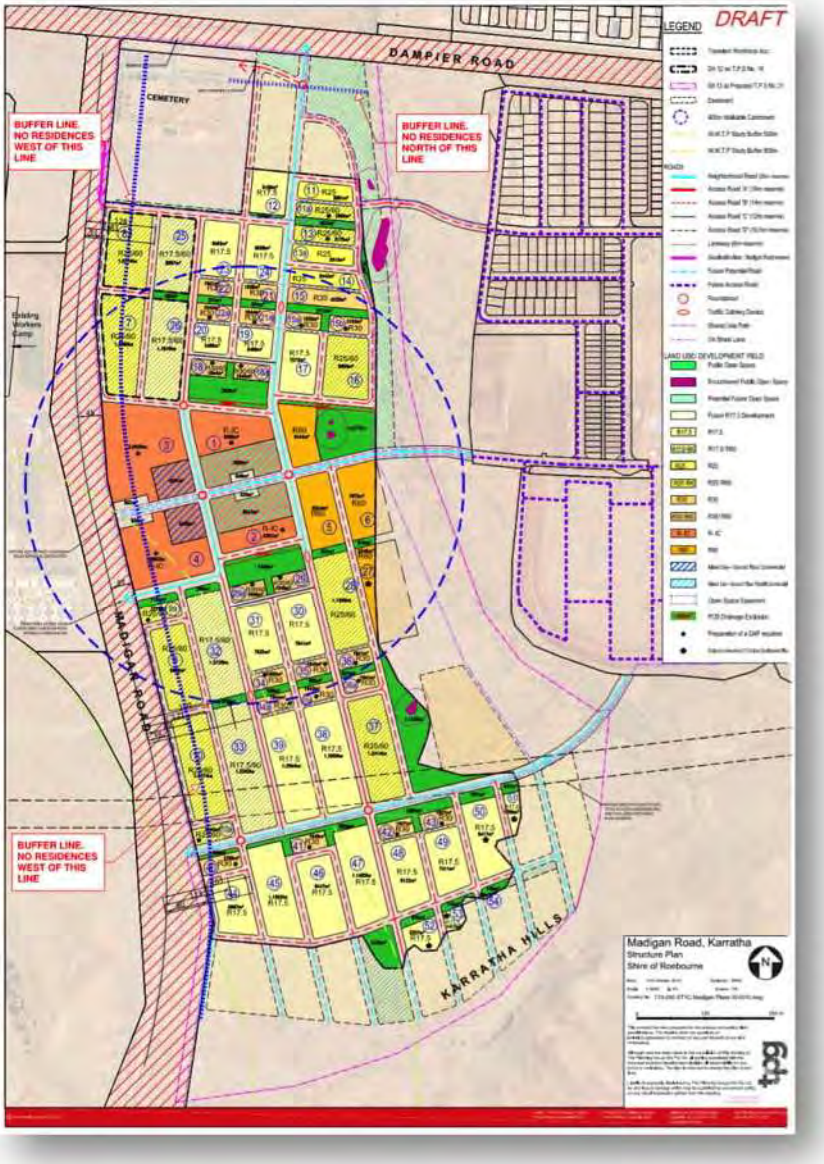


FIGURE 5 – BUFFER LINES

End of Report

Annexes:

A. Site Location.

B. Site Measurement Data.

C. Ancillary Data.

ANNEX A - Site Description

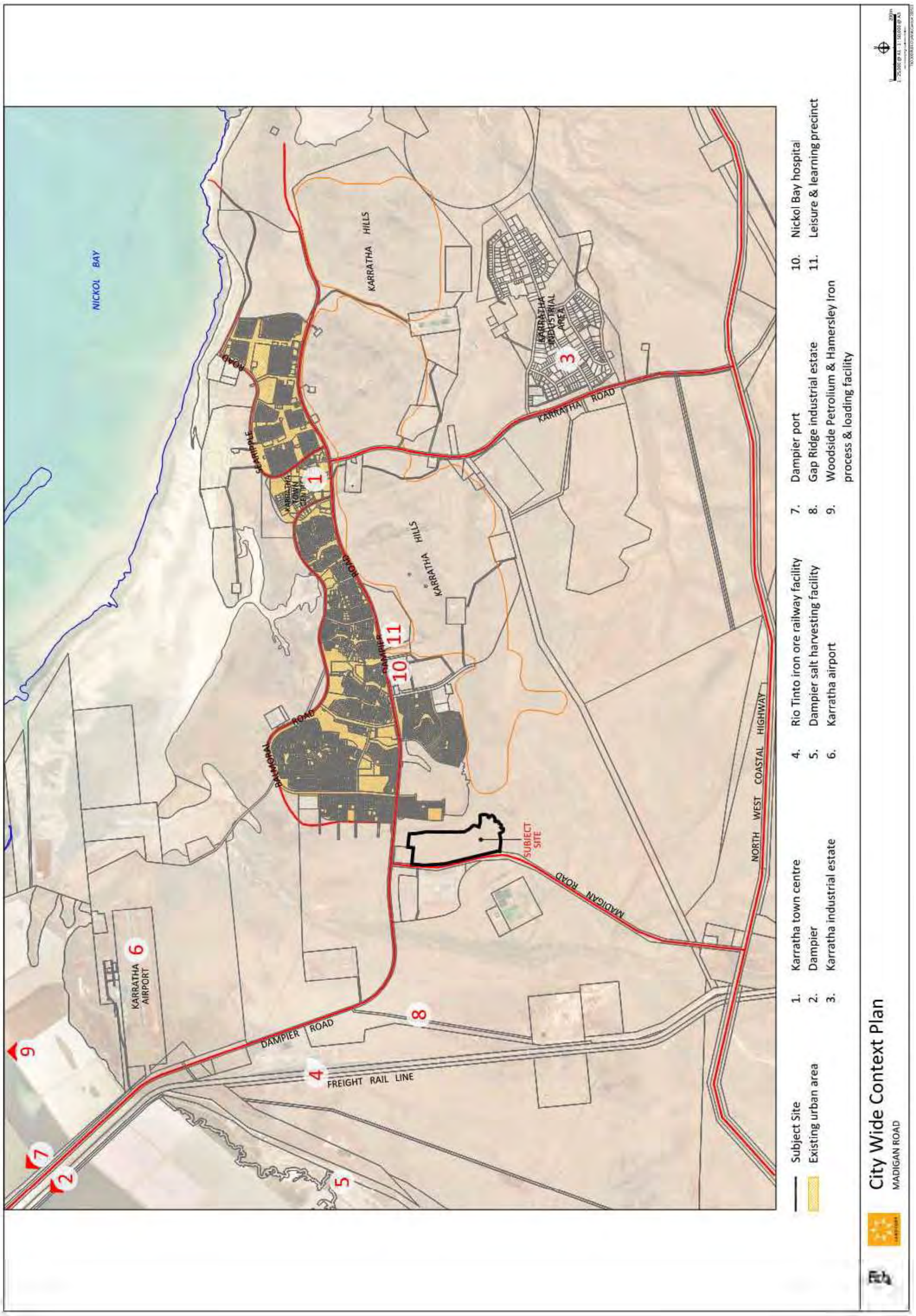
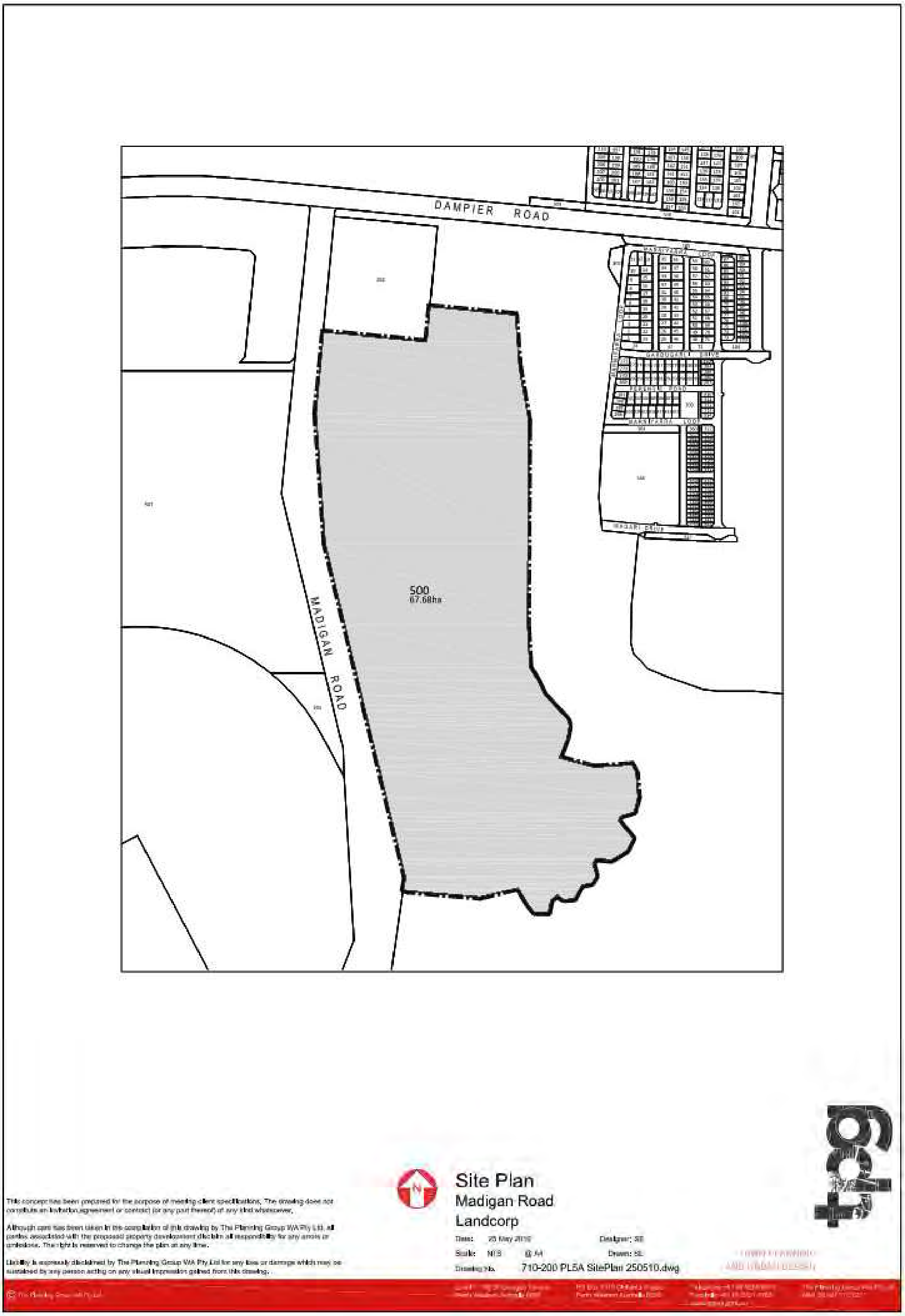


Figure A.1 – SITE LOCATION

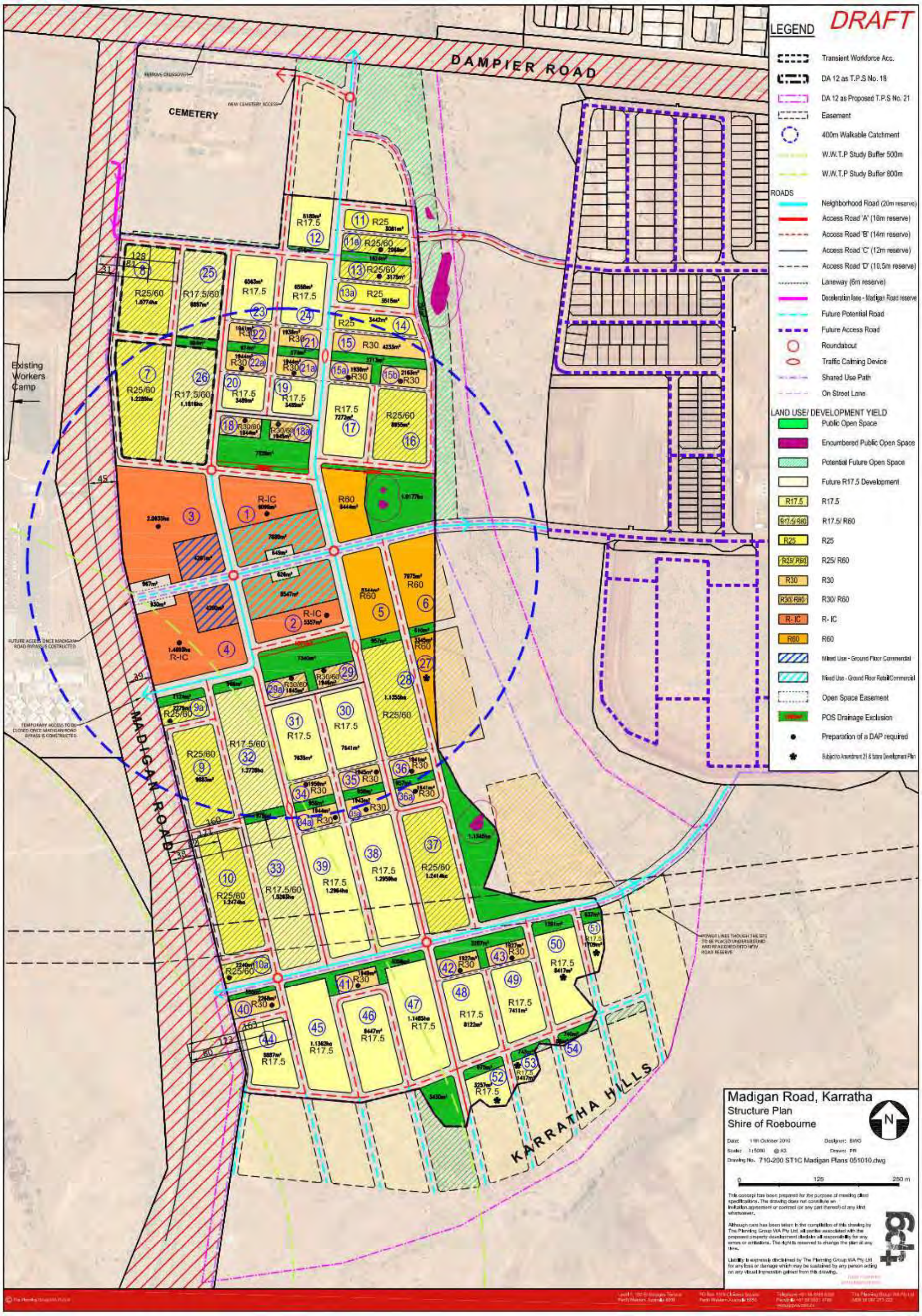


This concept has been prepared for the purpose of meeting client specifications. The drawing does not constitute an invitation, agreement or contract (or any part thereof) of any kind whatsoever.

Although care has been taken in the compilation of this drawing by The Planning Group WA Pty Ltd, all parties associated with the proposed property development disclaim all responsibility for any errors or omissions. The right is reserved to change the plan at any time.

Liability is expressly disclaimed by The Planning Group WA Pty Ltd for any loss or damage which may be sustained by any person acting on any visual impression gained from this drawing.

Figure A.2 – SITE PLAN



This concept has been prepared for the purpose of meeting client specifications. The drawing does not constitute an invitation agreement or contract (or any part thereof) of any kind whatsoever.

Although care has been taken in the compilation of this drawing by The Planning Group WA Pty Ltd, all parties associated with the proposed property development disclaim all responsibility for any errors or omissions. The right is reserved to change the plan at any time.

Liability is expressly disclaimed by The Planning Group WA Pty Ltd for any loss or damage which may be sustained by any person acting on any visual impression gained from this drawing.

Figure A.2 – DETAILED SITE PLAN

End of Annex A

ANNEX B - Site Measurement Data

B1 This appendix summarises the measurement details:

a. Measurements were taken by a HP3569A Type 1 Integrating Sound Level Meter with a ACO calibrator both having current NATA calibration certificates from NVMS Leederville WA.

b.	Duration of measurements	24 hours;
c.	Sampling time	30 minutes;
d.	Measurement days	Thursday 14th and Friday 15th October 2010.

e. Weather conditions at the time of measurements was warm nominally 25 to 35 oC, no cloud, no rain and generally no wind however the wind on the late afternoon of the 14th and early morning of the 15th caused measurements to be corrupted by wind and vegetation noise.

f. Speed limit 80 kph.

g. The Madigan Road average week day traffic count is about 3000 vehicles per day South of Dampier Road of which comprises about 80% light vehicles (Ausroads Class 1 and 2). Observations on site show that the traffic movement between:

(1) 0500 to 0800 hours and 1600 to 2000 hours is predominantly light vehicles and buses associated with movement between Dampier Road and the Gap Ridge Village entry/exit producing hourly average noise levels of about LAeq 60 to 65 dB(A) at the measurement location; and

(2) 0800 to 1600 hours is predominantly heavy vehicles producing hourly average noise levels of about LAeq 55 to 60 dB(A) at the measurement location.

h. The following table contains the measurement results:

MEASUREMENT RESULTS

TIME		Average Week Day Traffic count	Sound Levels LAeq dB(A)			
From	To		Measured	Normalised (to Traffic Count)	Day	Night
6.00	7.00	259.3	wind	64.0	60.9	
7.00	8.00	196.3	wind	60.8		
8.00	9.00	150.5	wind	57.7		
9.00	10.00	147.5	57.5	57.5		
10.00	11.00	129.4	55.5	56.0		
11.00	12.00	134.7	57.4	56.5		
12.00	13.00	133.6	57.8	56.4		
13.00	14.00	131.1	57.4	56.1		
14.00	15.00	145.8	59.5	57.4		
15.00	16.00	162.1	61.6	58.6		
16.00	17.00	212.5	62.5	61.7		
17.00	18.00	371.4	63.8	68.1		
18.00	19.00	287.1	62	65.2		
19.00	20.00	150.8	wind	57.8		
20.00	21.00	82.1	wind	50.8		
21.00	22.00	46.6	wind	44.2		
22.00	23.00	25.5	wind	37.3		52.4
23.00	0.00	9.9	wind	26.4		
0.00	1.00	5.6	wind	19.8		
1.00	2.00	6.5	wind	21.6		
2.00	3.00	6.3	wind	21.2		
3.00	4.00	5.1	45.7	18.8		
4.00	5.00	26	wind	37.5		
5.00	6.00	206.5	56.2	61.4		

End of Annex B

ANNEX C - Ancillary Data

C1. The information provided in this annex has been supplied to ND Engineering by *tpgwa* and has been included in the report, in order to preserve the information, for future reference during subsequent assessments.

WEEKLY VEHICLE COUNTS (VIRTUAL WEEK)

VirtWeeklyVehicle-8
Site: 50098.0SN
Description: **MADIGAN ROAD - S OF DAMPIER RD**
Filter time: **12:13 Friday, 20 March 2009 => 10:29 Wednesday, 1 April 2009**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,200) Headway(>0)

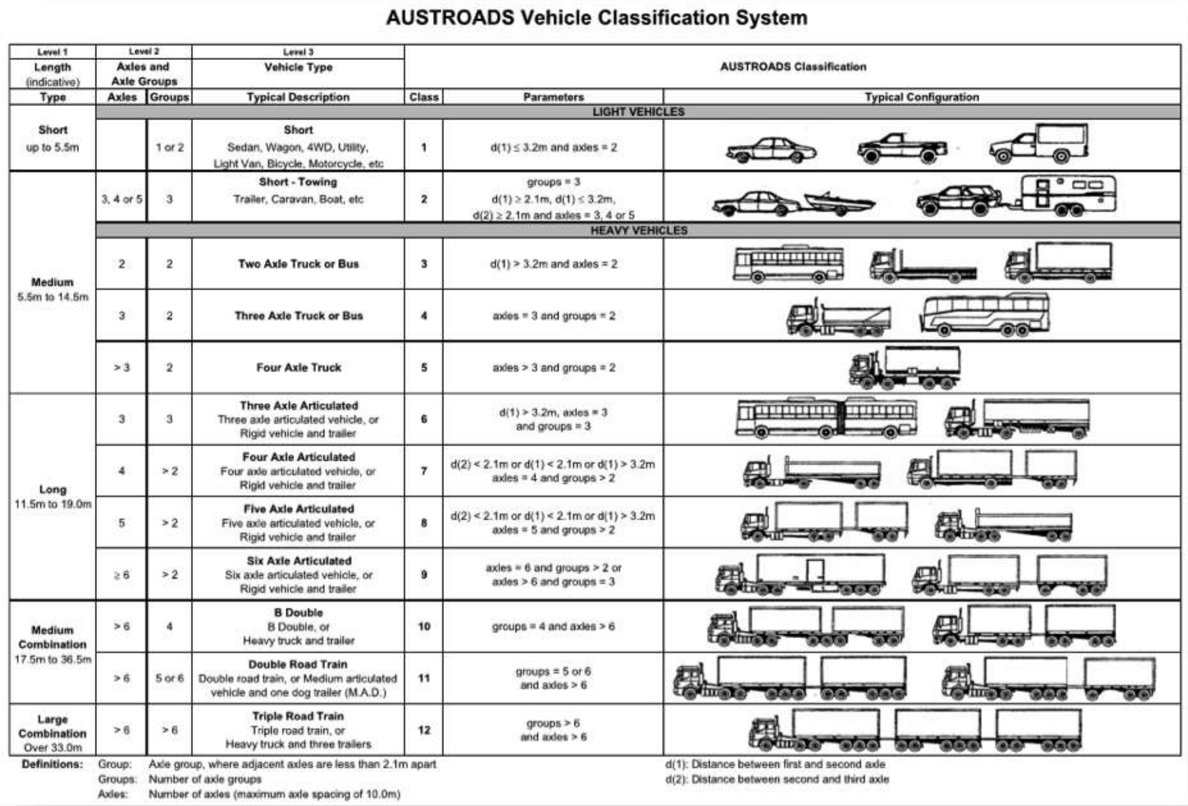
```
                Mon      Tue      Wed      Thu      Fri      Sat      Sun     Averages
                 1        2        3        4        5        6        7      1 - 5     1 - 7
Hour                                                                       |
0000-0100       3.5      6.0      4.5      9.0      8.0     11.0     43.0 |     5.6      12.8
0100-0200       8.0      5.5      4.5      4.0     12.0      5.0     28.5 |     6.5       9.9
0200-0300       8.0      8.0      4.0      3.0      7.0      3.5     27.5 |     6.3       9.3
0300-0400       5.5      3.5      4.0      9.0      6.0      9.0     14.0 |     5.1       7.3
0400-0500      27.0     23.0     21.5     29.0     36.0     40.5     25.5 |    26.0      28.3
0500-0600     169.5    174.5    173.5    320.0<   297.0<   298.0<    83.0 |   206.5     201.2
0600-0700     253.5<   281.0<   291.0<   201.0    222.0    161.0    114.0 |   259.3<    218.7<
0700-0800     192.0    204.5    209.5    199.0    159.0    112.5     98.5 |   196.3     166.0
0800-0900     147.0    154.0    152.5    163.0    134.0    123.0     99.0 |   150.5     137.3
0900-1000     153.0    143.5    156.5    129.0    148.0    114.0    140.5 |   147.9     141.0
1000-1100     135.5    151.0     96.5    126.0    143.0    111.0    174.5<|   129.4     133.8
1100-1200     125.0    138.0    111.0    162.0    144.0    116.0    172.5 |   134.7     138.2
1200-1300     136.0    133.0    129.0    135.0    133.5    130.0    170.5 |   133.6     139.2
1300-1400     127.5    130.0    105.0    154.0    137.5    134.0    173.5 |   131.1     138.7
1400-1500     136.0    146.0    162.0    134.0    153.0    118.5    168.0 |   145.8     144.9
1500-1600     151.5    133.0    180.0    178.0    185.0    152.5    151.5 |   162.1     158.8
1600-1700     206.0    201.5    247.0    210.0    214.0    194.5    212.5 |   212.5     209.5
1700-1800     310.0    336.0    414.0<   434.0<   415.5<   350.0<   216.5<|   371.4<    342.0<
1800-1900     326.0<   350.0<   242.0    301.0    201.0    208.5    207.5 |   287.1     260.8
1900-2000     165.5    181.5    117.0    182.0    106.5    117.5    130.5 |   150.8     141.8
2000-2100      85.0     79.5     72.0    115.0     70.5     86.5     70.0 |    82.1      80.8
2100-2200      33.5     51.5     49.0     47.0     53.5     53.5     42.5 |    46.6      47.1
2200-2300      27.0     16.0     27.0     26.0     32.5     46.0     20.5 |    25.5      28.1
2300-2400       7.5      9.0     11.0     15.0     10.0     37.0     15.0 |     9.9      15.3
                                                                           |
Totals     ________________________________________________________________|________________
                                                                           |
0700-1900    2145.5   2220.5   2205.0   2325.0   2167.5   1864.5   1985.0 |  2202.3    2110.1
0600-2200    2683.0   2814.0   2734.0   2870.0   2620.0   2283.0   2342.0 |  2741.1    2598.5
0600-0000    2717.5   2839.0   2772.0   2911.0   2662.5   2366.0   2377.5 |  2776.5    2641.8
0000-0000    2939.0   3059.5   2984.0   3285.0   3028.5   2733.0   2599.0 |  3032.5    2910.6
                                                                           |
AM Peak        0600     0600     0600     0500     0500     0500     1000 |
              253.5    281.0    291.0    320.0    297.0    298.0    174.5 |
                                                                           |
PM Peak        1800     1800     1700     1700     1700     1700     1700 |
              326.0    350.0    414.0    434.0    415.5    350.0    216.5 |

* - No data.
```

CLASS SPEED MATRIX

ClassMatrix-10

Site: 50098.0SN
Description: **MADIGAN ROAD - S OF DAMPIER RD**
Filter time: **12:13 Friday, 20 March 2009 => 10:29 Wednesday, 1 April 2009**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,200) Headway(>0)

```
Speed (km/h)                                                                                  Speed Totals
                                                                                          |
        _____________________________________________________________________________    |
                                        Class                                             |
            1      2      3      4      5      6      7      8      9     10     11     12 |
  10-20 |   21     .      1      1      1      .      .      .      1      1      1      . |     27   0.1%
  20-30 |   73     .      2      1      2      .      .      .      2      1      3      1 |     85   0.2%
  30-40 |   81     2      8     10      1      .      1      .      5      1     19     51 |    179   0.5%
  40-50 |  405     7     82     32     25      2      2      7     73     12    190     74 |    911   2.6%
  50-60 | 2291    42    464    109     52      5     11     14    371     22    402    216 |   3999  11.5%
  60-70 | 7583   147    930    335     66     16     17     60    666     62    553    102 |  10537  30.3%
  70-80 |10049   170    795    322     55     17     17     47    483     23    159     52 |  12189  35.0%
  80-90 | 4597    77    216    133      9      3      4      5     82      4     17      5 |   5152   4.8%
 90-100 | 1252    14     43     19      2      .      .      .     13      1      .      . |   1344   3.9%
100-110 |  270     1      9      .      .      .      .      .      .      .      .      . |    280   0.8%
110-120 |   63     .      3      .      .      .      .      .      1      .      .      . |     67   0.2%
120-130 |   12     .      1      .      .      .      .      .      .      .      .      . |     13   0.0%
130-140 |    4     .      .      .      .      .      .      .      .      .      .      . |      4   0.0%
140-150 |    1     .      .      .      .      .      .      .      .      .      .      . |      1   0.0%
150-160 |    1     .      .      .      .      .      .      .      .      .      .      . |      1   0.0%

|_________________________________________________________________________________________|_______________
        | 26703  460   2554    962    213     43     52    133   1697    127   1344    501|  34789
        | 76.8%  1.3%  7.3%   2.8%   0.6%   0.1%   0.1%   0.4%   4.9%   0.4%   3.9%   1.4%|
                                        Class Totals
```



AUSTROADS Vehicle Classification System

Level 1	Level 2		Level 3	AUSTROADS Classification		
Length (indicative)	Axles and Axle Groups		Vehicle Type			
Type	Axles	Groups	Typical Description	Class	Parameters	Typical Configuration
					LIGHT VEHICLES	
Short up to 5.5m		1 or 2	**Short** Sedan, Wagon, 4WD, Utility, Light Van, Bicycle, Motorcycle, etc	1	d(1) ≤ 3.2m and axles = 2	
Medium 5.5m to 14.5m	3, 4 or 5	3	**Short - Towing** Trailer, Caravan, Boat, etc	2	groups = 3 d(1) ≥ 2.1m, d(1) ≤ 3.2m, d(2) ≥ 2.1m and axles = 3, 4 or 5	
					HEAVY VEHICLES	
	2	2	**Two Axle Truck or Bus**	3	d(1) > 3.2m and axles = 2	
	3	2	**Three Axle Truck or Bus**	4	axles = 3 and groups = 2	
	> 3	2	**Four Axle Truck**	5	axles > 3 and groups = 2	
Long 11.5m to 19.0m	3	3	**Three Axle Articulated** Three axle articulated vehicle, or Rigid vehicle and trailer	6	d(1) > 3.2m, axles = 3 and groups = 3	
	4	> 2	**Four Axle Articulated** Four axle articulated vehicle, or Rigid vehicle and trailer	7	d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 4 and groups > 2	
	5	> 2	**Five Axle Articulated** Five axle articulated vehicle, or Rigid vehicle and trailer	8	d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 5 and groups > 2	
	≥ 6	> 2	**Six Axle Articulated** Six axle articulated vehicle, or Rigid vehicle and trailer	9	axles = 6 and groups > 2 or axles > 6 and groups = 3	
Medium Combination 17.5m to 36.5m	> 6	4	**B Double** B Double, or Heavy truck and trailer	10	groups = 4 and axles > 6	
	> 6	5 or 6	**Double Road Train** Double road train, or Medium articulated vehicle and one dog trailer (M.A.D.)	11	groups = 5 or 6 and axles > 6	
Large Combination Over 33.0m	> 6	> 6	**Triple Road Train** Triple road train, or Heavy truck and three trailers	12	groups > 6 and axles > 6	

Definitions:
Group: Axle group, where adjacent axles are less than 2.1m apart
Groups: Number of axle groups
Axles: Number of axles (maximum axle spacing of 10.0m)

d(1): Distance between first and second axle
d(2): Distance between second and third axle

End of Annex C