OFFICIAL

Western Australian Planning Commission
GOVERNMENT OF WESTERN AUSTRALIA

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Dear Sir/Madam

EXTENSION OF APPROVAL PERIOD - LOT 500 MADIGAN ROAD DEVELOPMENT PLAN
WAPC REFERENCE: SPN/0244M-1

Pursuant to Clause 28 (2), Part 4, Schedule 2 of the Planning and Development (Local Planning Schemes) Regulations 2015, the Western Australian Planning Commission on 10 October 2025, approved an extension of the approval period for the Lot 500 Madigan Road Development Plan for a further period of five years, expiring on 19 October 2030.

A copy of the current approved structure plan is attached to this emailed correspondence.

Yours sincerely

Sam Boucher.

Ms Sam Boucher
Secretary
Western Australian Planning Commission
17 October 2025

Jim Davies & Associates Pty Ltd
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Our Ref: J7547a
Your Ref:

14 February 2025

Olivia Abrugiato
Development Manager
DevelopmentWA

via email: olivia.abrugiato@developmentwa.com.au

Dear Olivia,

REVISED STRUCTURE PLAN AMENDMENT – MADIGAN ROAD, KARRATHA
IMPACT OF PROPOSED SCHOOL SITE IN STAGE 3 ON THE LOCAL WATER MANAGEMENT STRATEGY

JDA previously prepared a Local Water Management Strategy (LWMS) to support the Madigan Road Structure Plan. A revised structure plan amendment is now proposed to include a School in Stage 3 (see Plan 1 attached).

Presented below is a summary of an assessment of the impact of the school site on the water management strategy outlined in the approved LWMS as follows:

- *Proposed Structure Plan amendment*
- *Local Water Management Strategy Background*
- *Impact of Proposed School Site on the Local Water Management Strategy*

Revised Structure Plan Amendment

The original Madigan Rd Structure Plan (TPG, 2010) is comprised of urban development with mixture of varying residential densities (R12.5 to R60), mixed use commercial and various pockets of public open space integrated with drainage (see Figure 1).

A previous Structure Plan Amendment in 2020 included a 4.0 ha school site adjacent to Madigan Road, in Stage 2 of the Madigan Estate. JDA (2020) reviewed this amendment and concluded the school site did not alter the principles or objectives of the approved water management strategy.

A revised Structure Plan Amendment is now proposed to relocate a 3.5 ha school site further south to Stage 3 of the Madigan Estate, and co-locate with 2.5 ha of Public Open Space (POS) (see Figure 1).

Local Water Management Strategy

JDA previously prepared the "*Madigan Road Urban Development, Karratha – Local Water Management Strategy*" (ref: J4755i dated 11 March 2011) to support the original Madigan Road Structure Plan (TPG, 2010). The report was approved by the (then) Department of Water and City of Karratha in 2011.

A key principle and objective of the surface water management strategy is to manage surface water flows from rainfall events to protect infrastructure and assets from flooding and inundation by:

- Managing up to the 100yr ARI flood event within the development.
- Use of swales through 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.

These objectives are achieved using a stormwater management system that consists of a series of shallow drainage swales that safely convey stormwater from the Study Area to Madigan Creek. The drainage swales also attenuate peak surface water flows, and provide water quality treatment for the proposed development prior to discharge. Due the large rainfall intensity and volumes experienced in the Pilbara region, conveyance of stormwater is via open drainage systems rather than underground pipe systems.

Impact of Proposed School Site on the Local Water Management Strategy

The area occupied by the proposed school site in the original structure plan comprises of residential lots.

From a drainage perspective, the LWMS indicates this area contributes to drainage Catchments 2, 3 and 4 (see Figure 2). Stormwater runoff from these Catchments flow into drainage swales that discharge east into Madigan Creek.

For the proposed school site, stormwater can continue to discharge east to Madigan Creek. For the areas of Catchments 3 and 4 west of the school site, this can combine with Catchment 8 and discharge west to Madigan Road. Catchment 2 can continue to discharge towards Madigan Creek.

Minimal change in rainfall runoff (loss model) will occur with the change in land use from residential lots and road to school.

Consequently, the revised structure plan amendment to include the school site in Stage 3 of Madigan Estate does not the alter the principles and objectives of the LWMS, or the method of managing stormwater runoff.

The revised amendment does not require a revision of the LWMS, nor impact on the Structure Plan. Further technical details on design refinements are to be presented in an Urban Water Management Plan during detail engineering design at subdivision.

Should you have any queries or need to discuss further, please do not hesitate to contact Matthew Yan on 6380 3423.

References

JDA (2011) *Madigan Road Urban Development, Karratha – Local Water Management Strategy,* for LandCorp, report J4755i dated 11/3/2011.

JDA (2020) *Proposed Structure Plan Amendment – Madigan Road, Karratha, Impact of Proposed School Site on the Local Water Management Strategy,* for DevelopmentWA, report J6911a dated 24/8/2020.

Yours sincerely,

Matthew

JDA Consultant Hydrologists

Encl.
Plan 1: Structure Plan - Madigan Road, Karratha (File: 19-314 ST-1)(Element, 30 October 2024)
Figure 1: Madigan Road Revised Structure Plan Amendment
Figure 2: Stormwater Drainage Catchments

Legend

Structure Plan Boundary

Land Use and Density

- R20 Residential R20
- R25 Residential R25
- R30 Residential R30
- R60 Residential R60
- R-AC2 Mixed Use (Ground Floor Retail / Commercial)
- Public Purpose: School
- Public Open Space
- Future Residential
- Future Public Open Space
- Indicative Drainage Area

Other

- Future Easement Requirement For Existing 133Kv Power Lines – Width of Easement TBC'
- Heritage Site and 20m Buffer
- * Local Development Plan required for R60 Development
- Roundabout
- Intersection Treatment
- Restricted Movement Intersection (Left In Only)
- Arterial Road (20.5m)
- Local Road (17.9m)
- Local Road (16m)
- Local Road (15m)
- Local Road (12m)
- Access Lane (6m)
- Future Road Connection
- Dual Use Path
- Cycle Path

Notes

1. Flood Crossing
2. All Weather Crossing
3. Potential future development sites subject to zoning changes
4. Existing power lines shall remain in situ and incorporated as part of the future east-west road reserve
5. Reserve may be reduced to 17.5m if footpath is located in POS

Structure Plan

Madigan Road, Karratha

0 50 100m

Date: 30 Oct 2024 Scale: 1:5000@ A3 File: 19-314 ST-1 A Staff: MD GW Checked: MD

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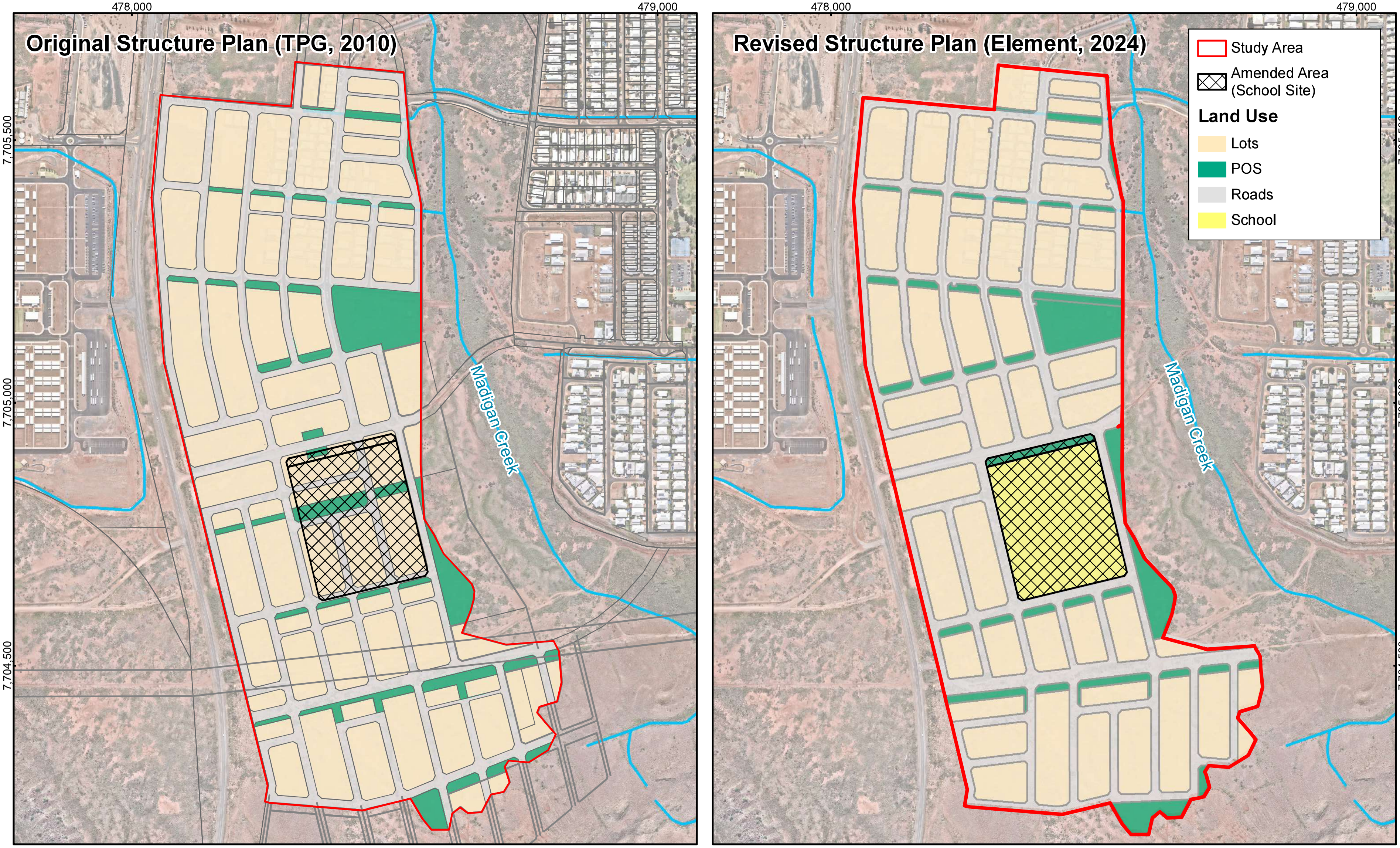

Data Source: TPG (2011), Element (2024), Nearmap (2024)

Coordinate System: GDA 94, Zone 50

JDA Consultant Hydrologists

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0 100 200 300 400 Meters

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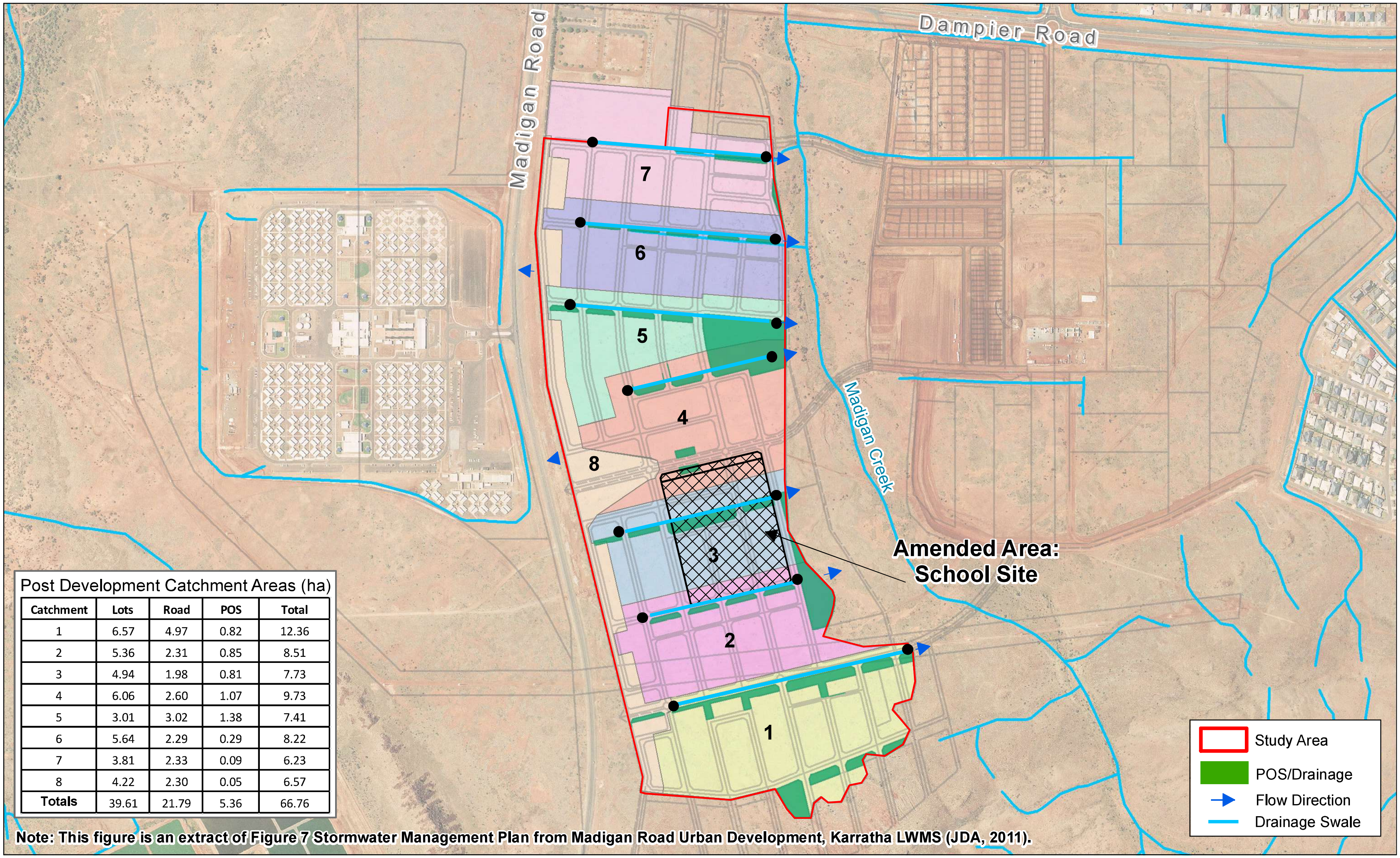
Development WA
Proposed Structure Plan Amendment - Madigan Road, Karratha
Impact of Proposed School Site on the Local Water Management Strategy

Figure 1: Madigan Road Revised Structure Plan Amendment



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

Note: This figure is an extract of Figure 7 Stormwater Management Plan from Madigan Road Urban Development, Karratha LWMS (JDA, 2011).

Data Source: TPG (2010)

Coordinate System: GDA 94, Zone 50

JDA Consultant Hydrologists

Job No. J7547

Scale: 1:11,000

0 200 400 600 800 Meters

N

Development WA

Proposed Structure Plan Amendment - Madigan Road, Karratha

Impact of Proposed School Site on the Local Water Management Strategy

Figure 2: Stormwater Drainage Catchments

LandCorp

Madigan Road Urban Development, Karratha
Local Water Management Strategy

March 2011

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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

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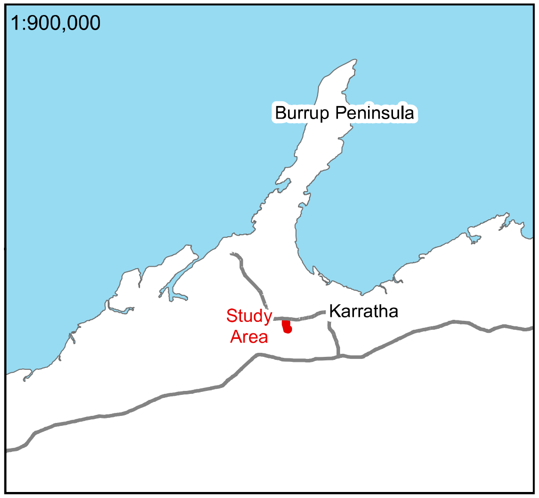
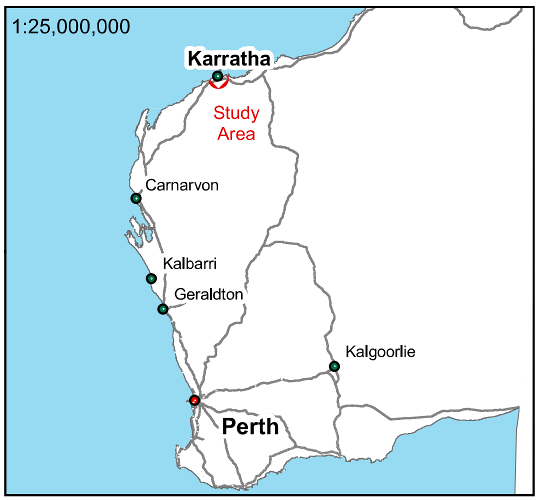
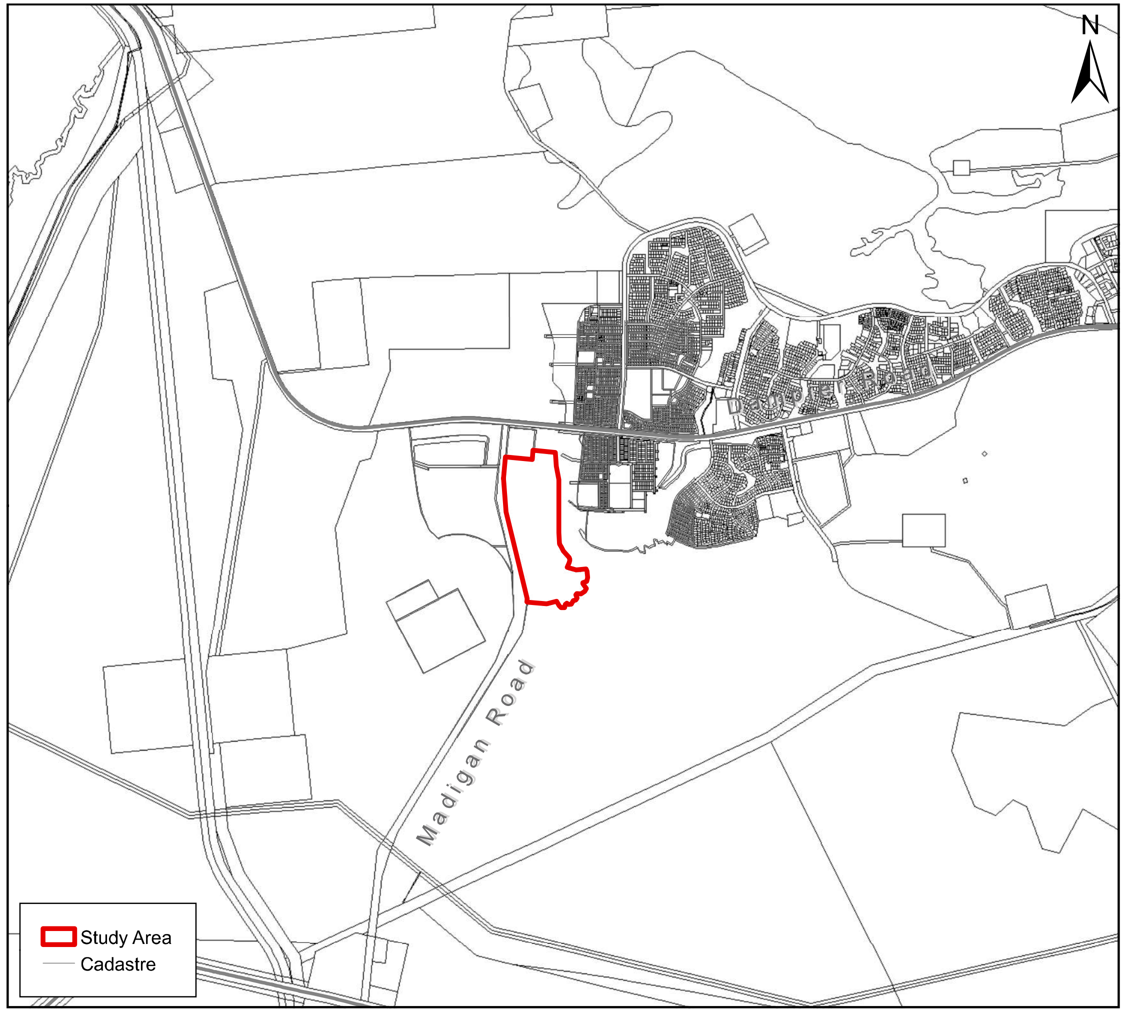
FIGURES







Data Source: WA Atlas (2010)

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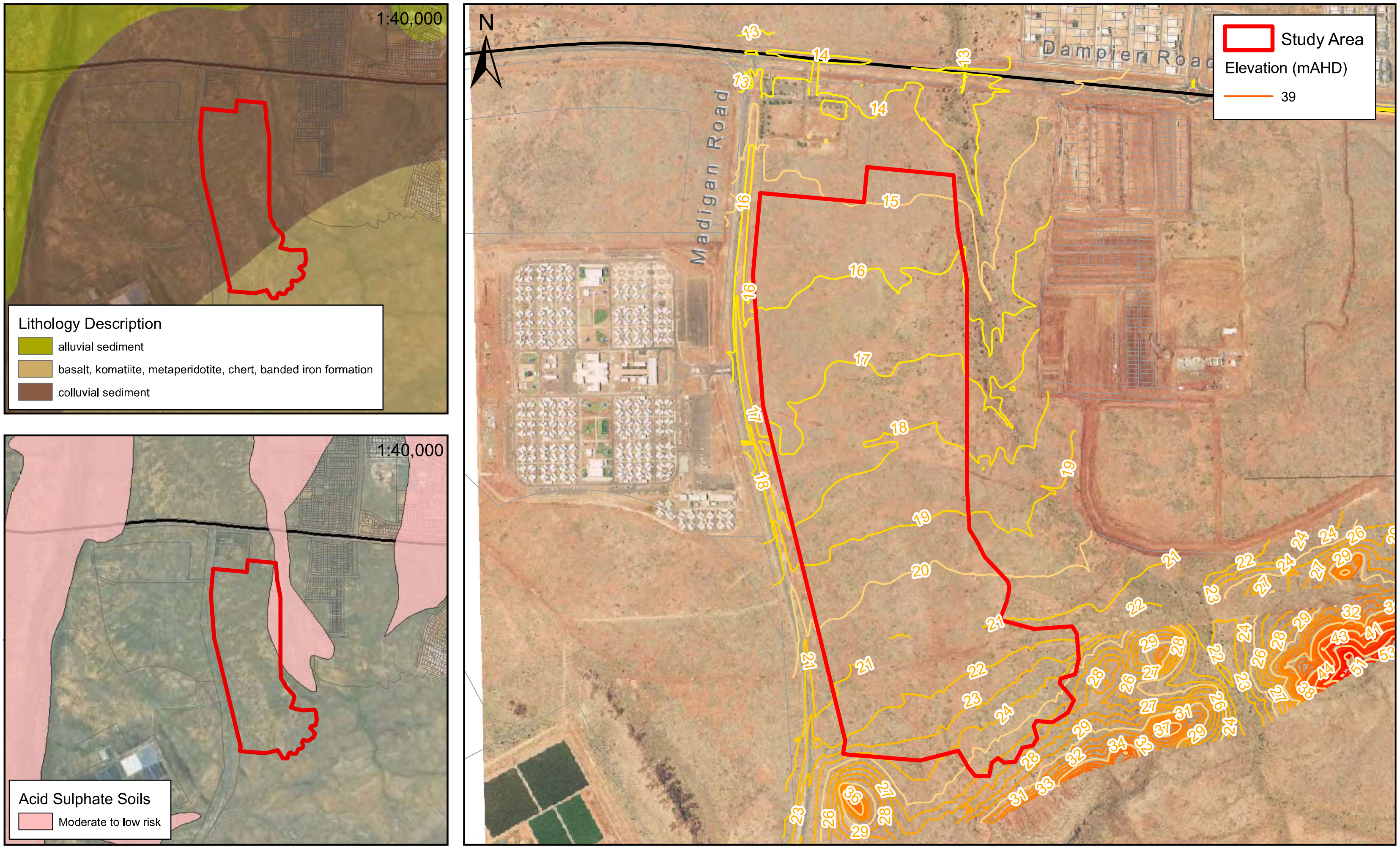
LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 1: Location Plan



Data Source: DEC (2008), WA Surface Geology (2010), Landgate (2010)

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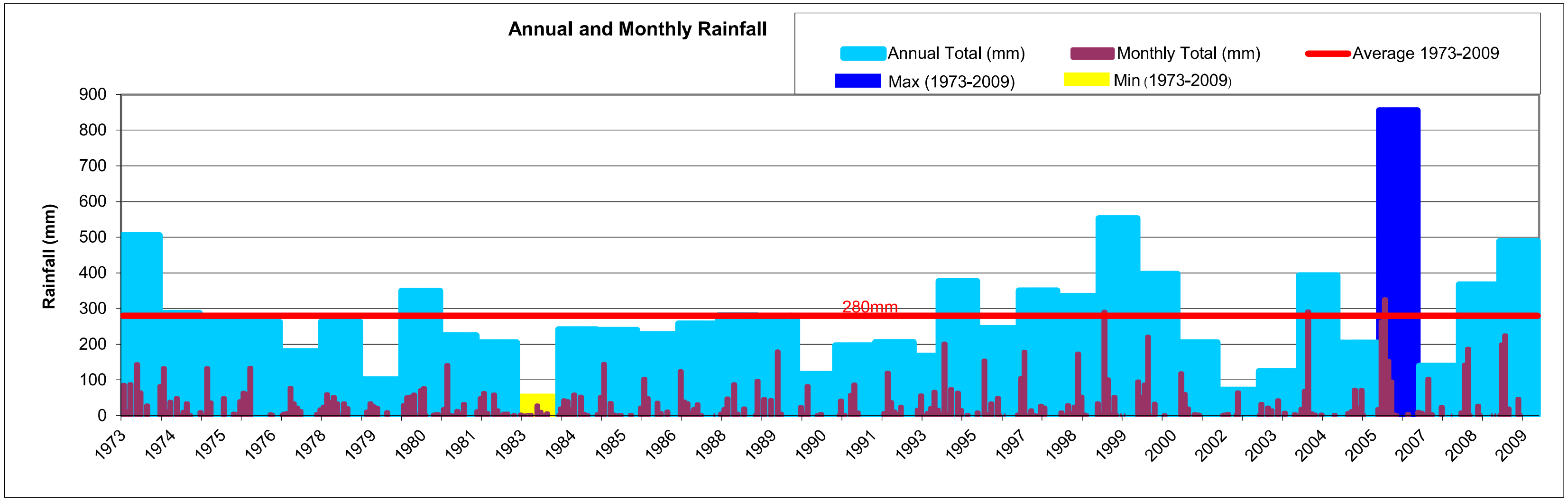
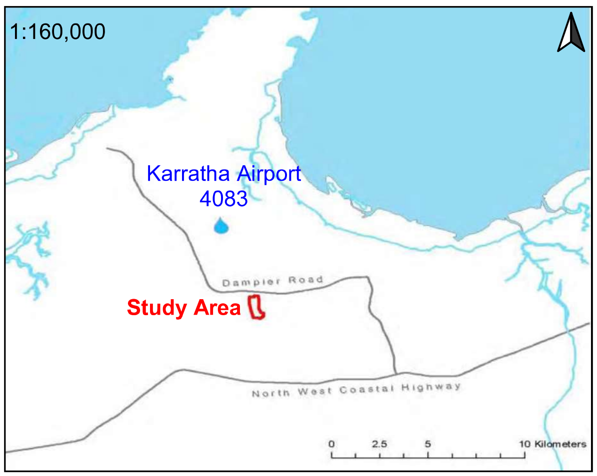
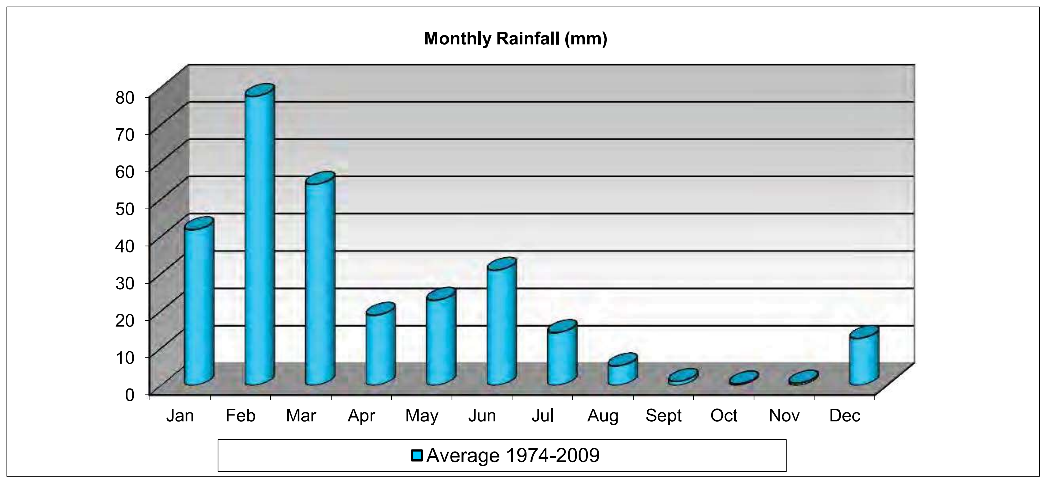
Madigan Road Urban Development, Karratha - LWMS
Figure 2: Environmental Setting







Data Source: Bureau of Metereology (2010)

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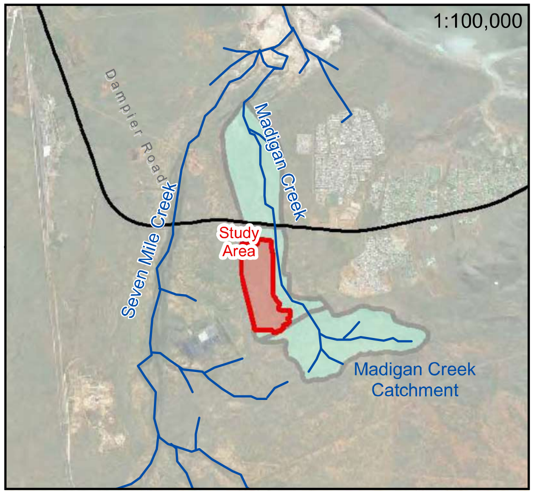
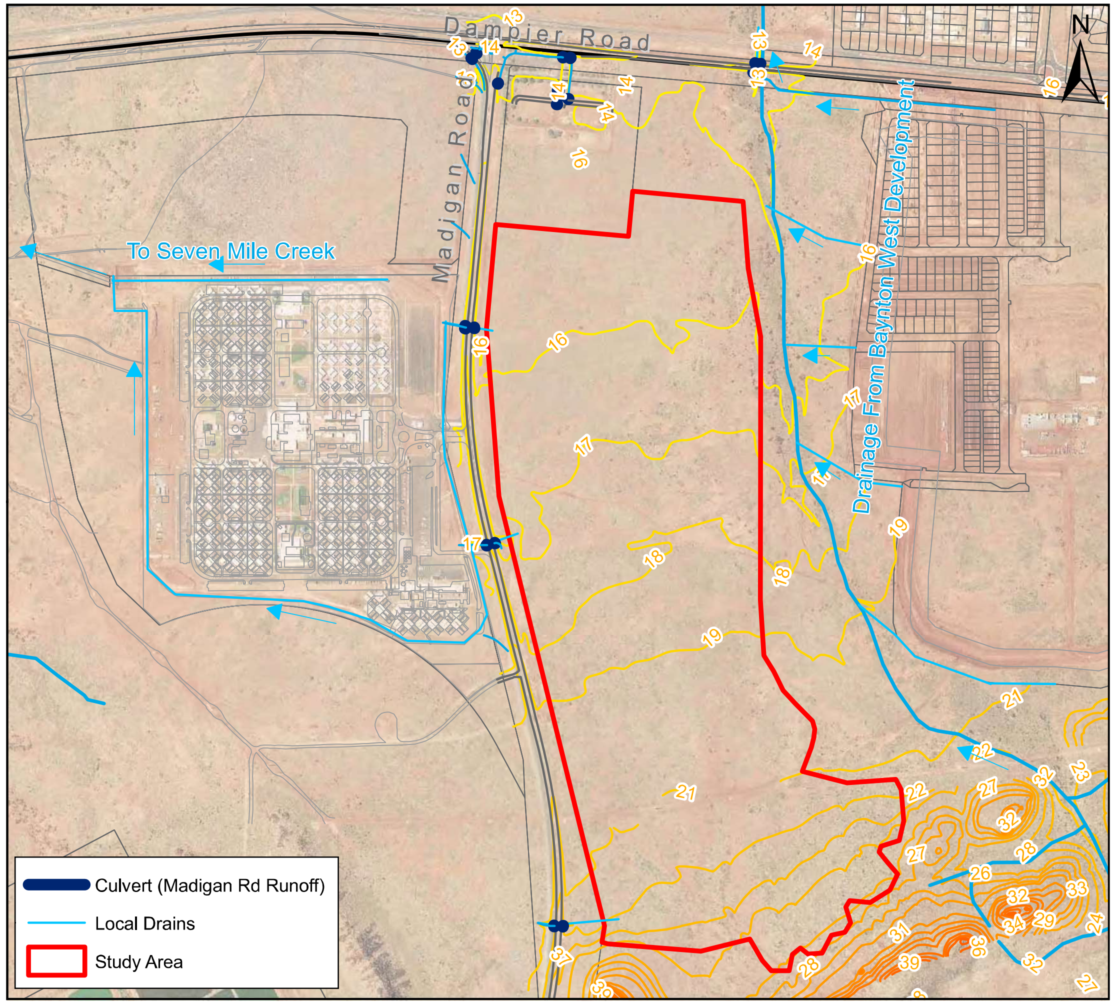
Figure 3: Karratha Airport Annual and Monthly Rainfall





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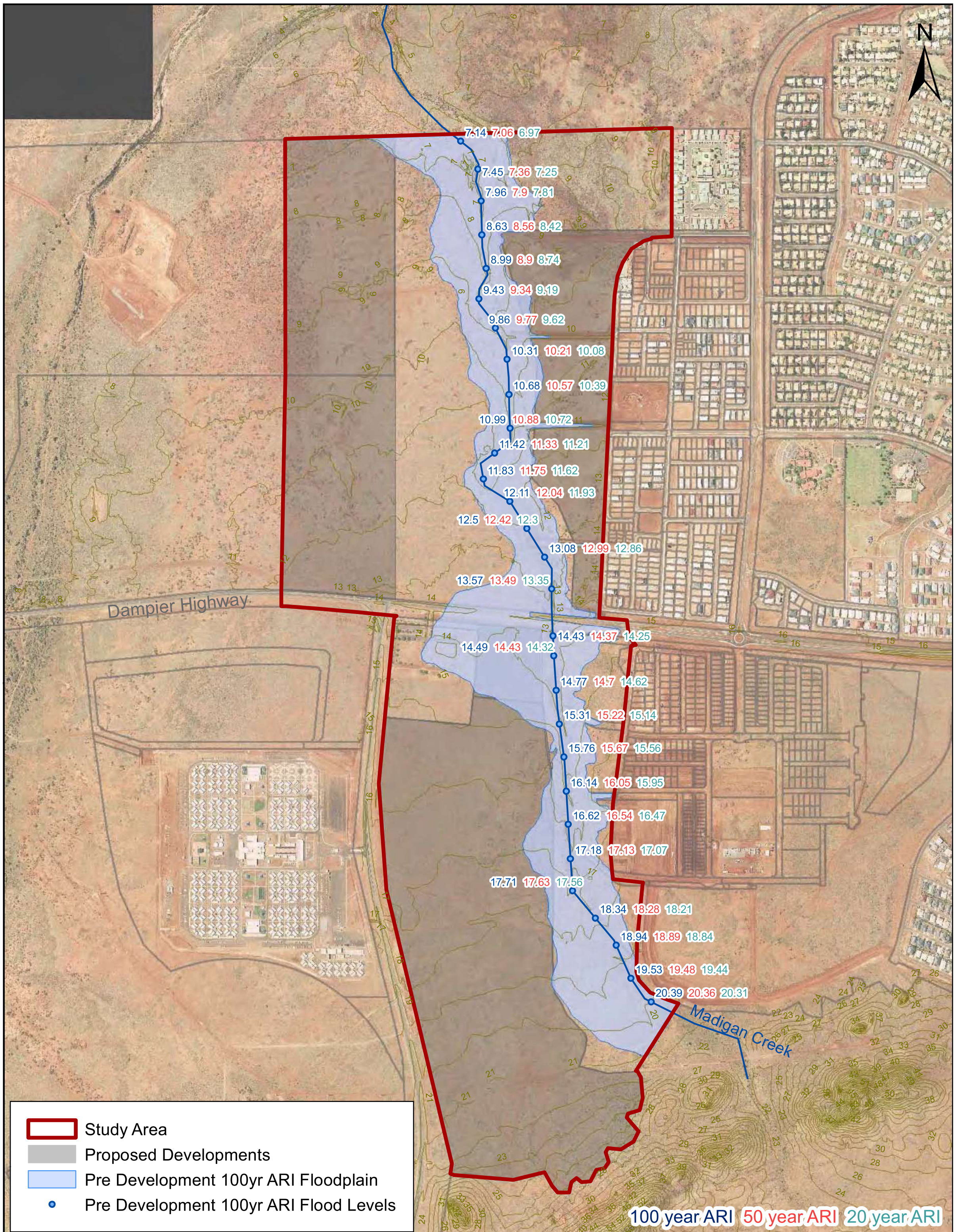
LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 4: Surface Hydrology



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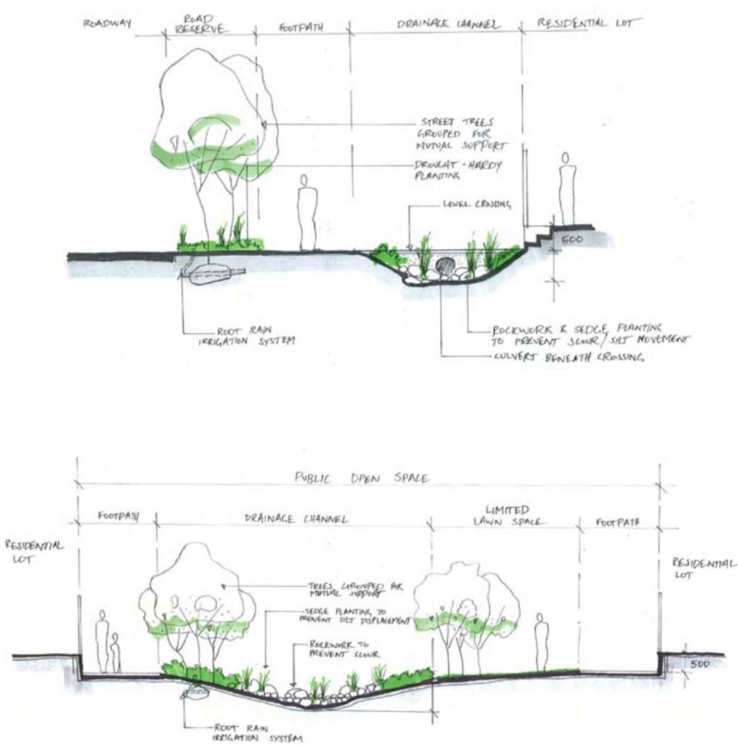
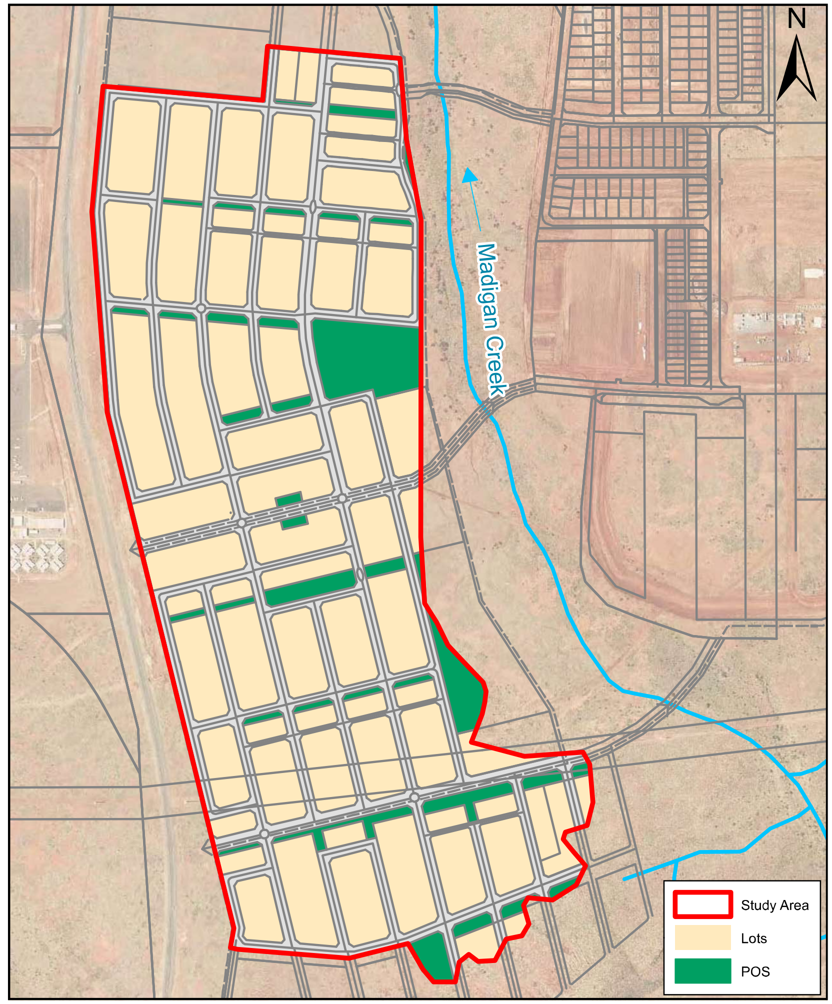
Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA Consultant Hydrologists	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





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0 200 400 600 800 Meters

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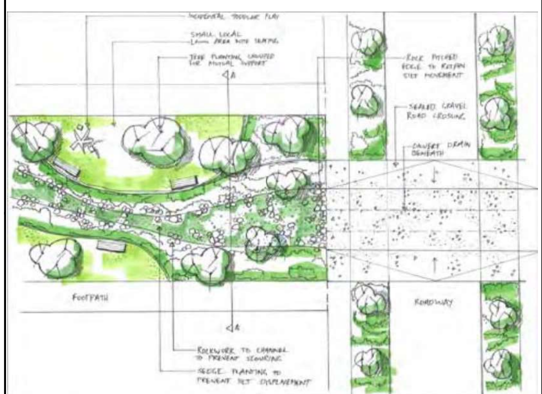
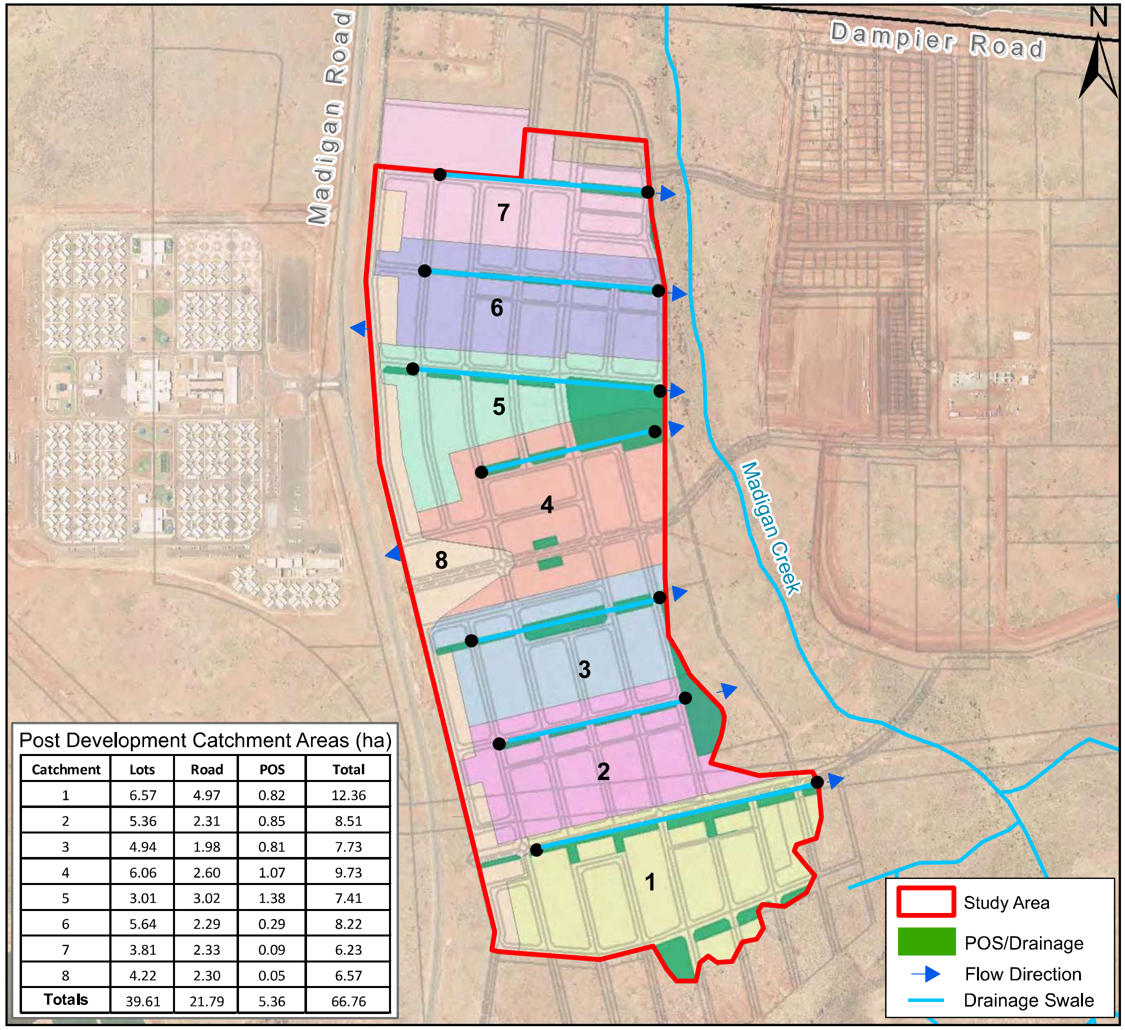
Madigan Road Urban Development, Karratha - LWMS
Figure 6: Local Structure Plan

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)

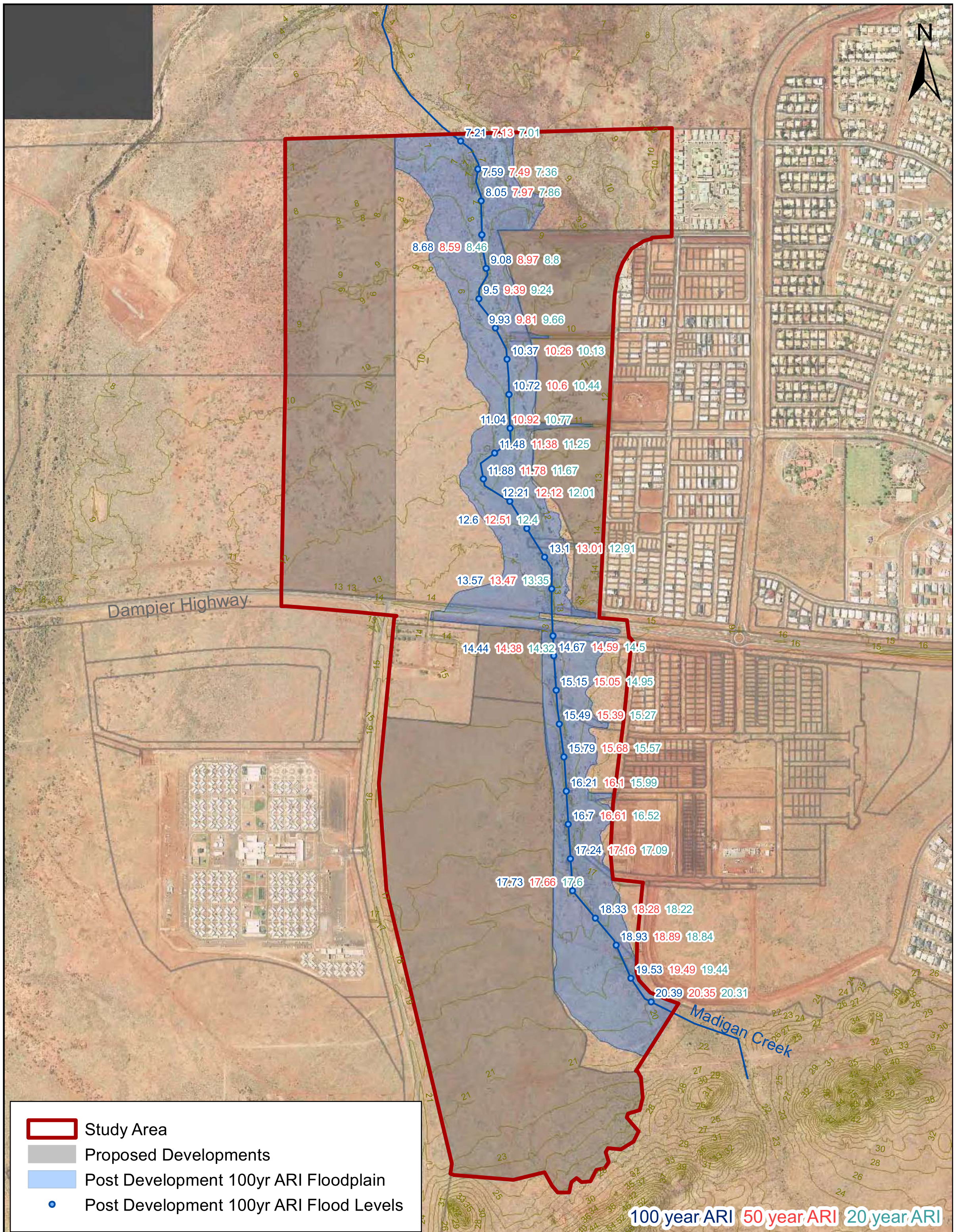
Catchment	Lots	Road	POS	Total
1	6.57	4.97	0.82	12.36
2	5.36	2.31	0.85	8.51
3	4.94	1.98	0.81	7.73
4	6.06	2.60	1.07	9.73
5	3.01	3.02	1.38	7.41
6	5.64	2.29	0.29	8.22
7	3.81	2.33	0.09	6.23
8	4.22	2.30	0.05	6.57
Totals	39.61	21.79	5.36	66.76

Data Source: TPG (2010), EPCAD (2011)

JDA

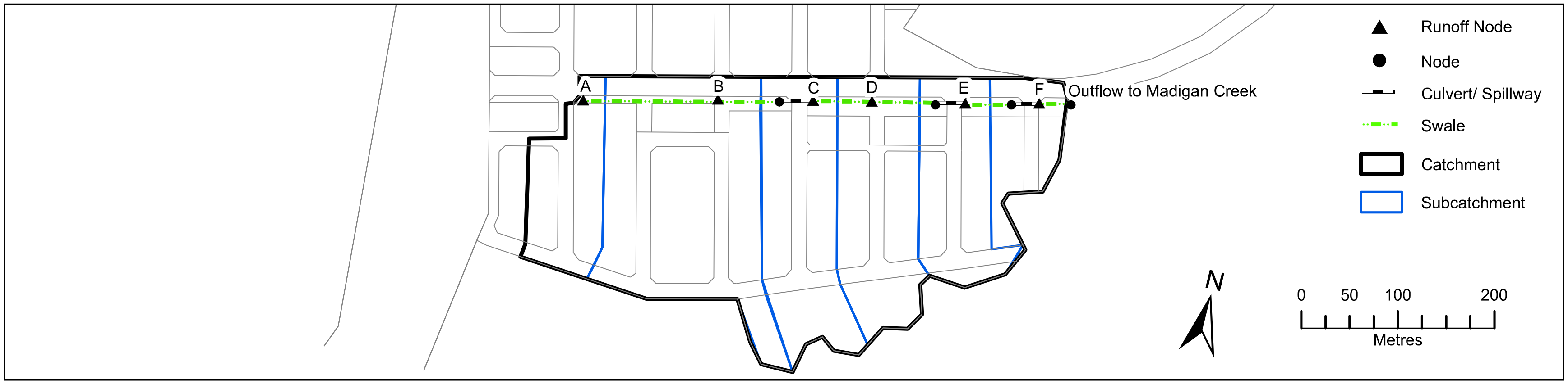
Job No. J4755
Scale: 1:11,000
0 200 400 600 800 Meters

LandCorp
Madigan Road Urban Development, Karratha - LWMS
Figure 7: Stormwater Management Plan



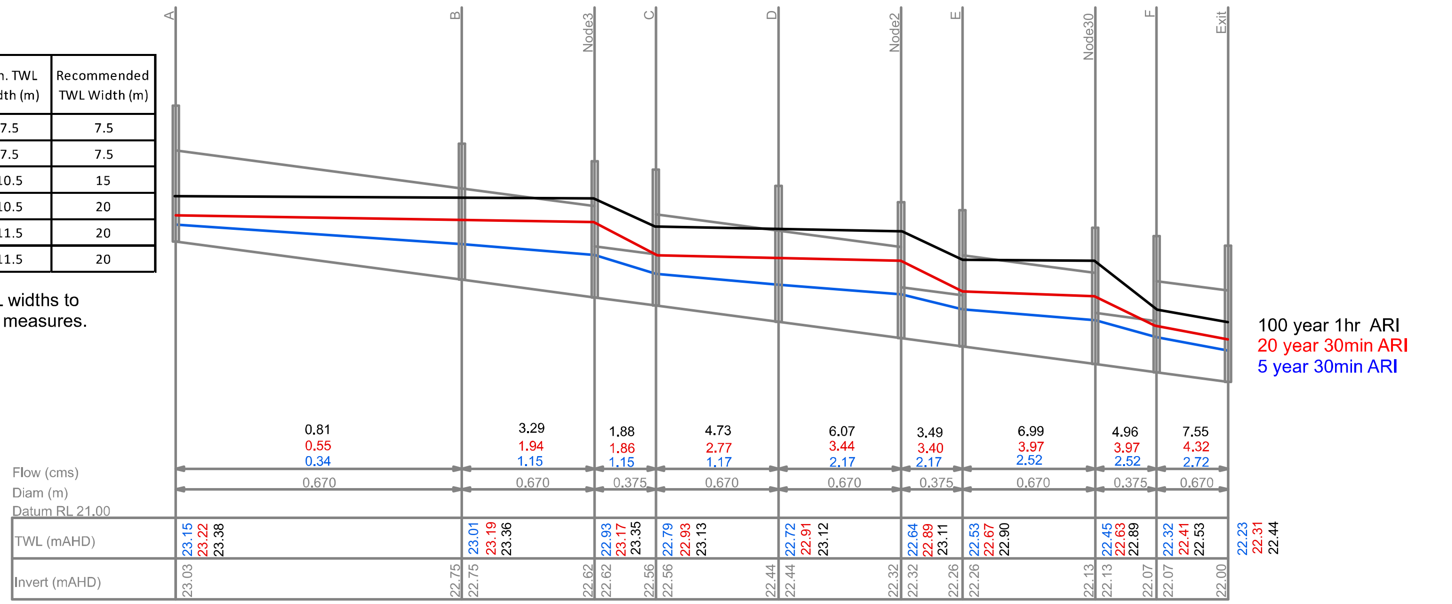
Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA	Job No. J4755 Scale 1:15,000 © COPYRIGHT JIM DAVIES & ASSOCIATES PTY. LTD. 2011	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)



Job No. J4755

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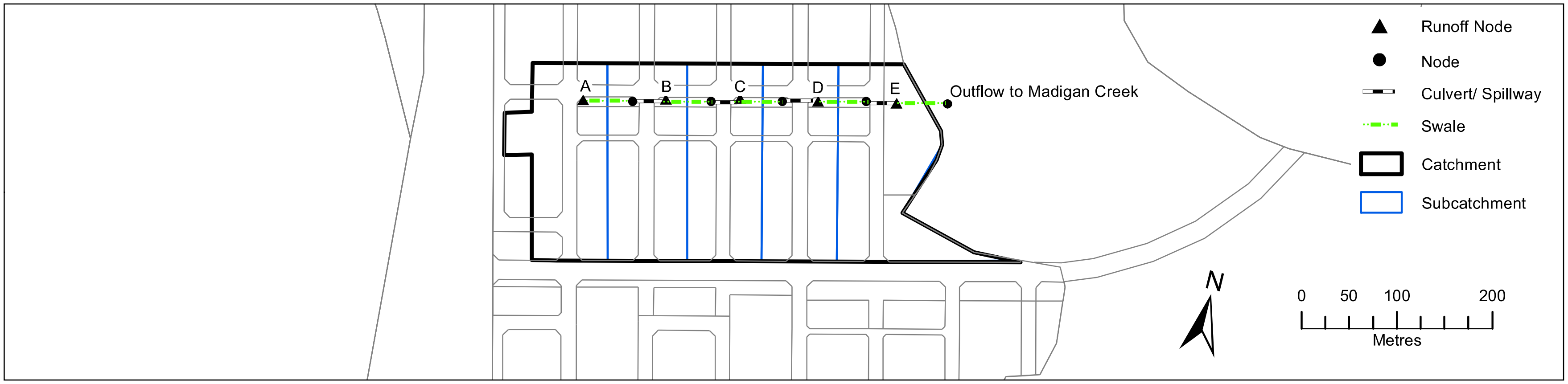
LandCorp

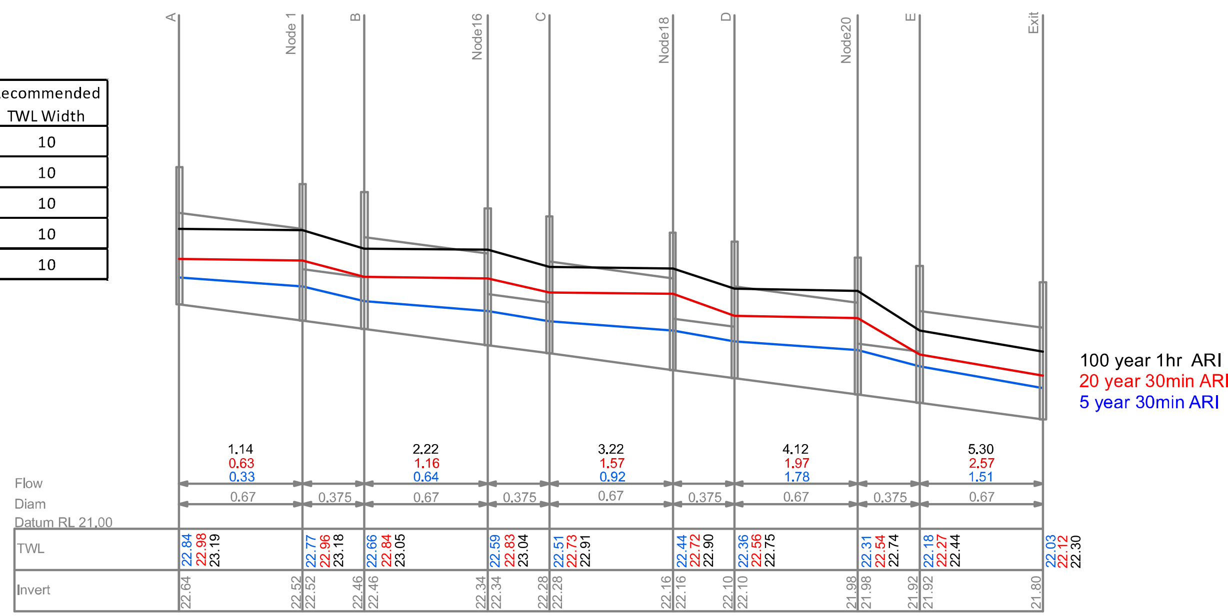
Madigan Road Urban Development, Karratha - LWMS

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)



Job No. J4755

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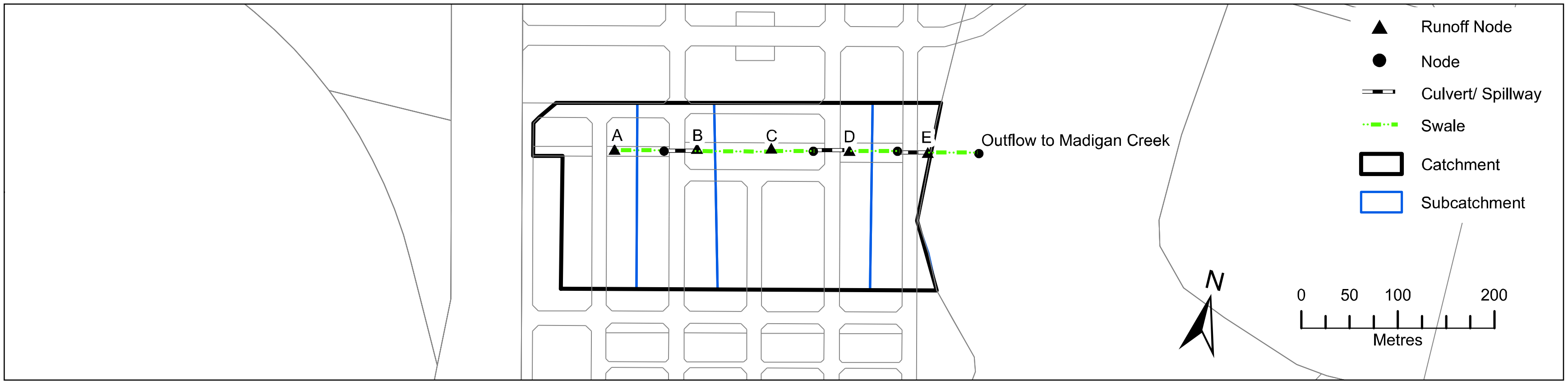
LandCorp

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)

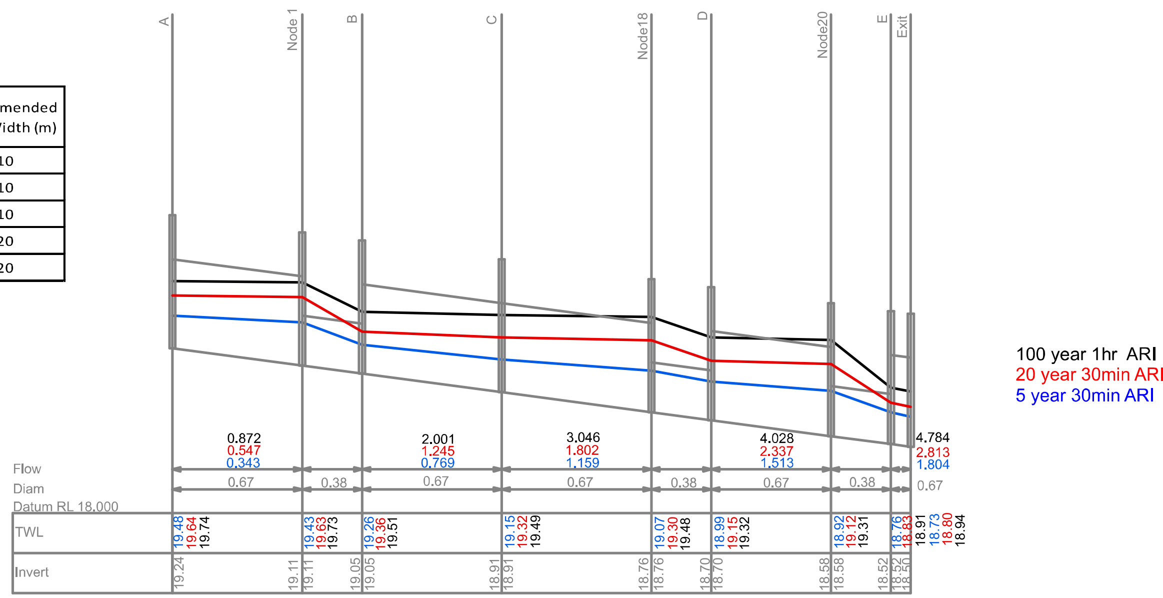
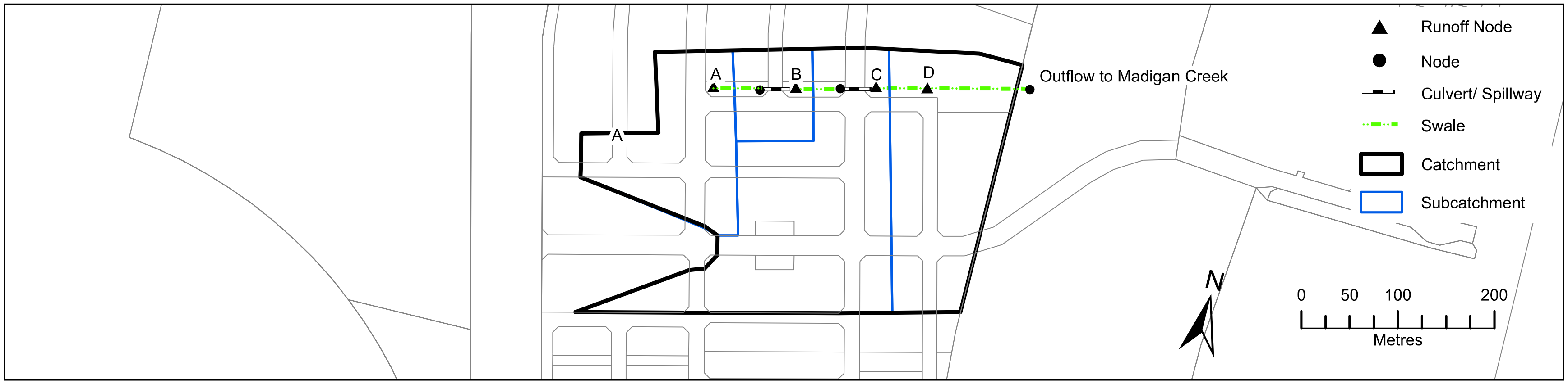
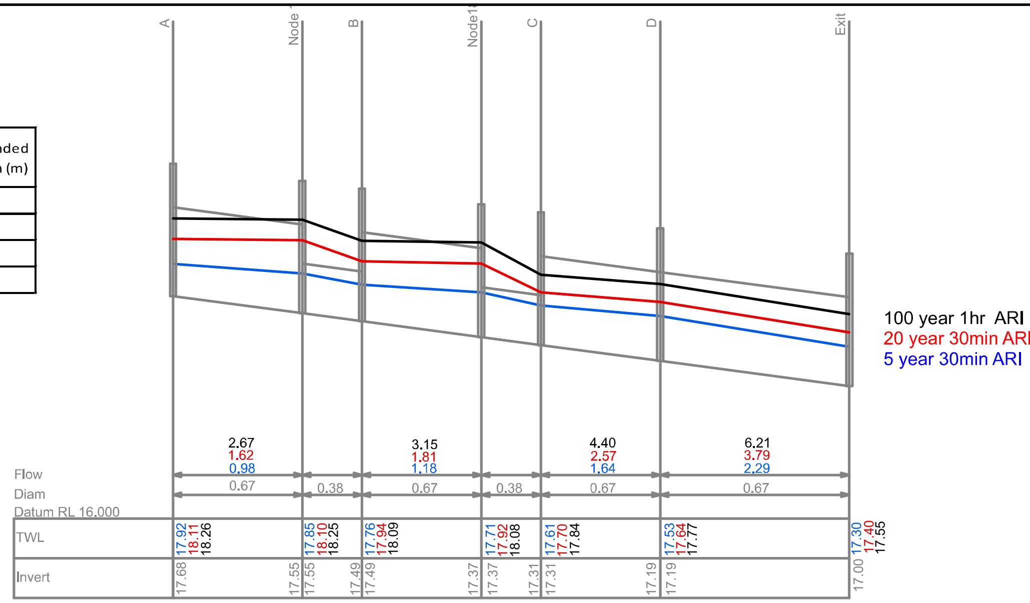


Figure 11: Catchment 3 Profile Plot for 5yr, 20yr & 100yr ARI



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)



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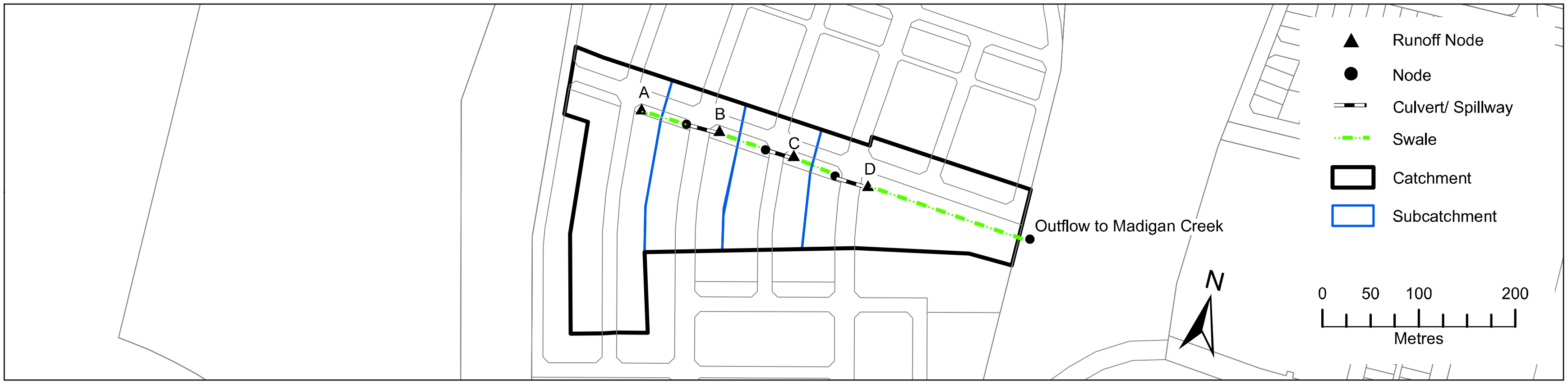
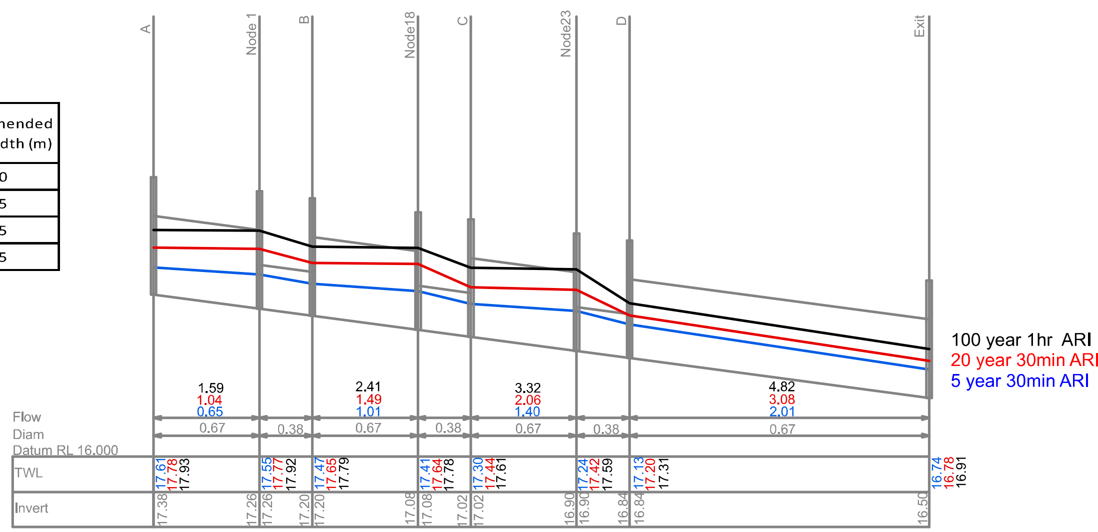
Madigan Road Urban Development, Karratha - LWMS

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)



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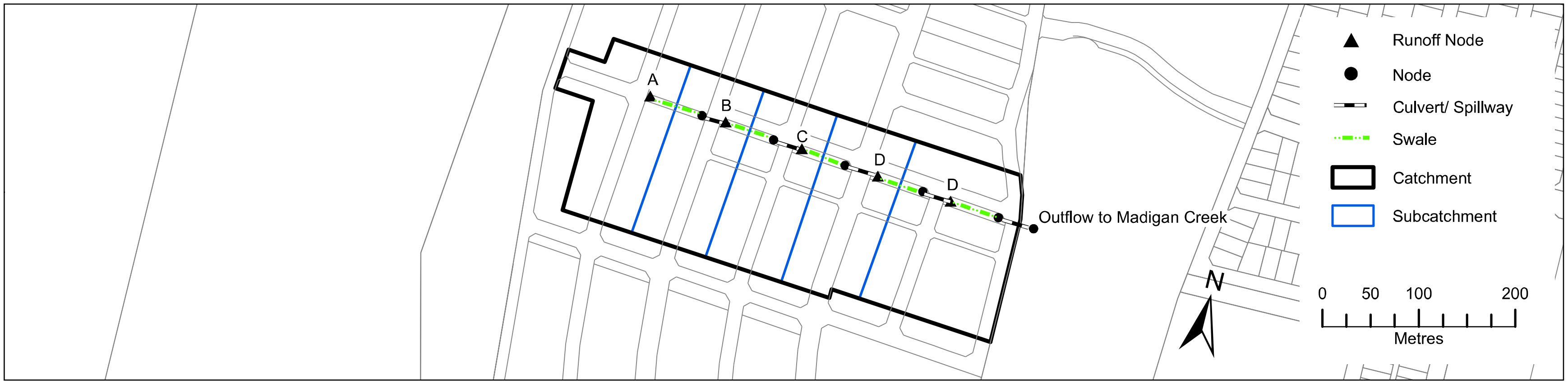
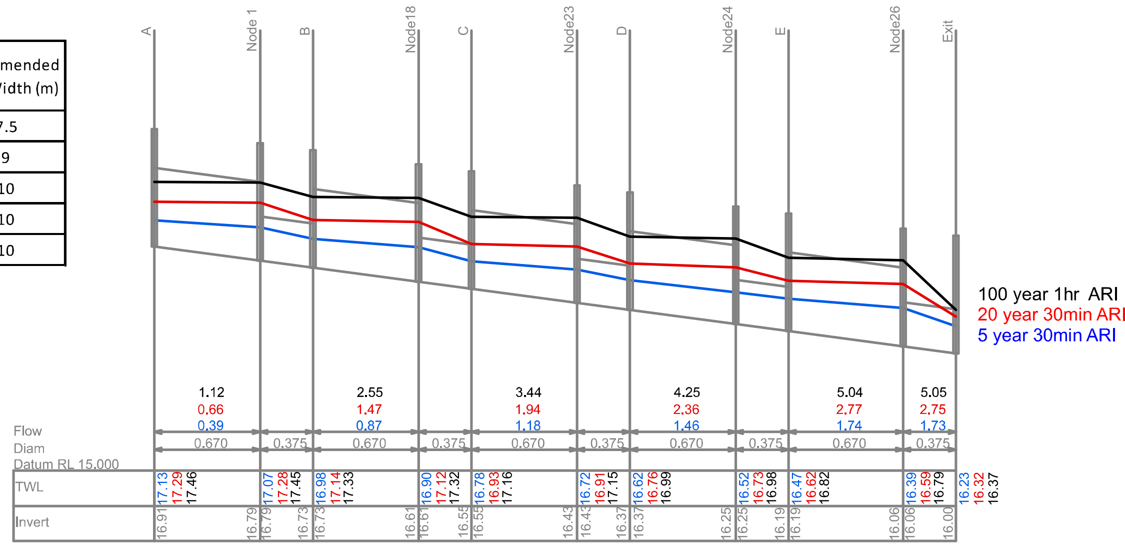
Madigan Road Urban Development, Karratha - LWMS

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)



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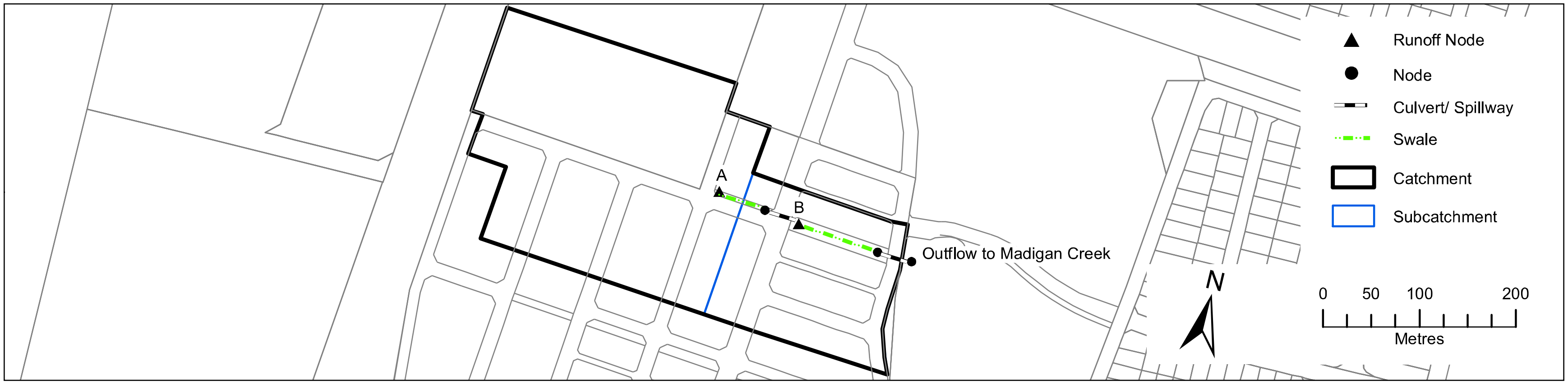
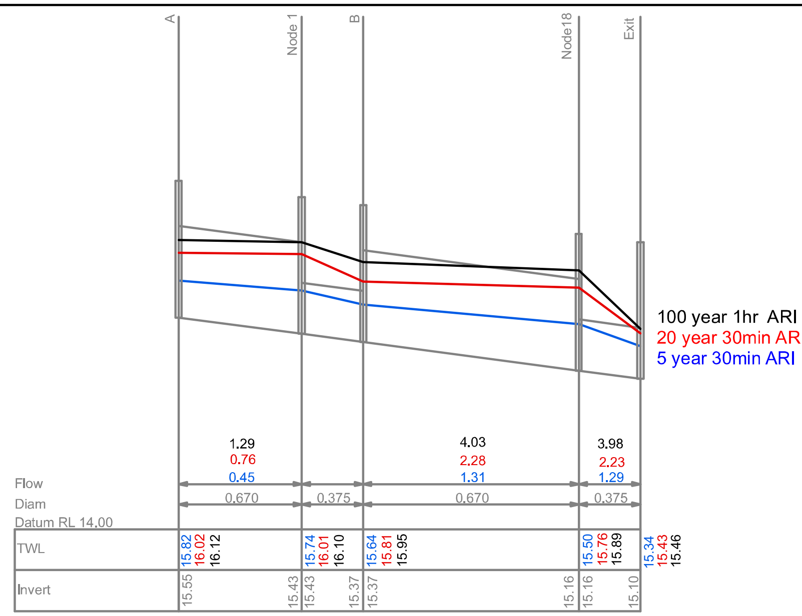
Madigan Road Urban Development, Karratha: LWMS

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 Consultant Hydrologists]

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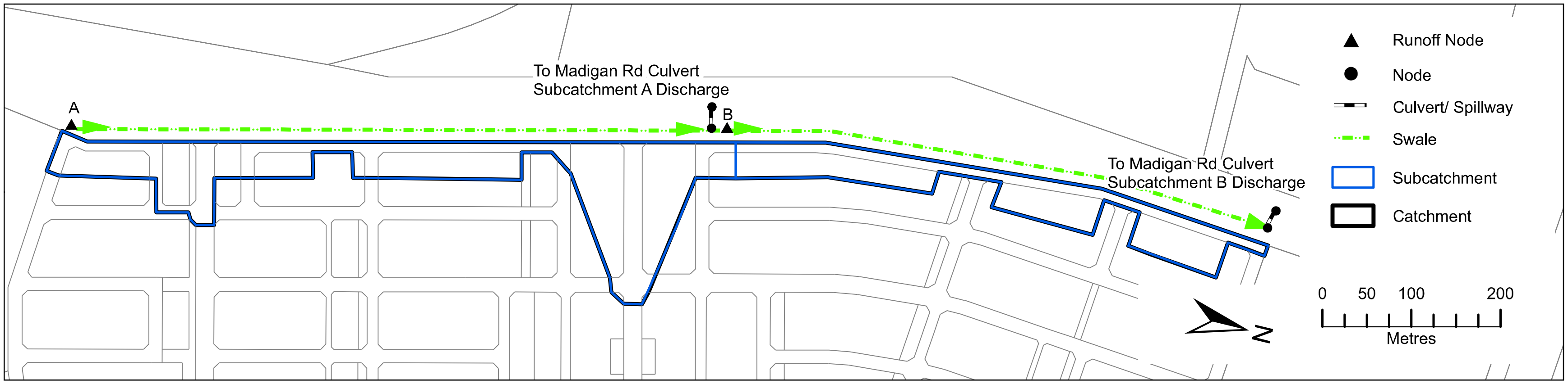
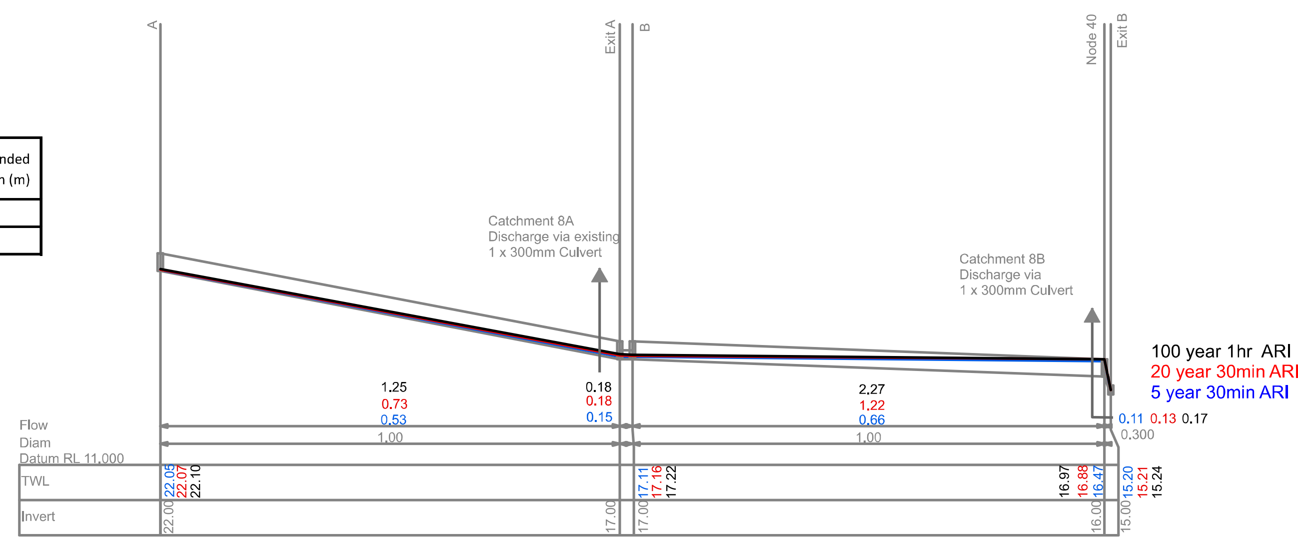
Madigan Road Urban Development, Karratha - LWMS

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)

JDA Consultant Hydrologists

Job No. J4755

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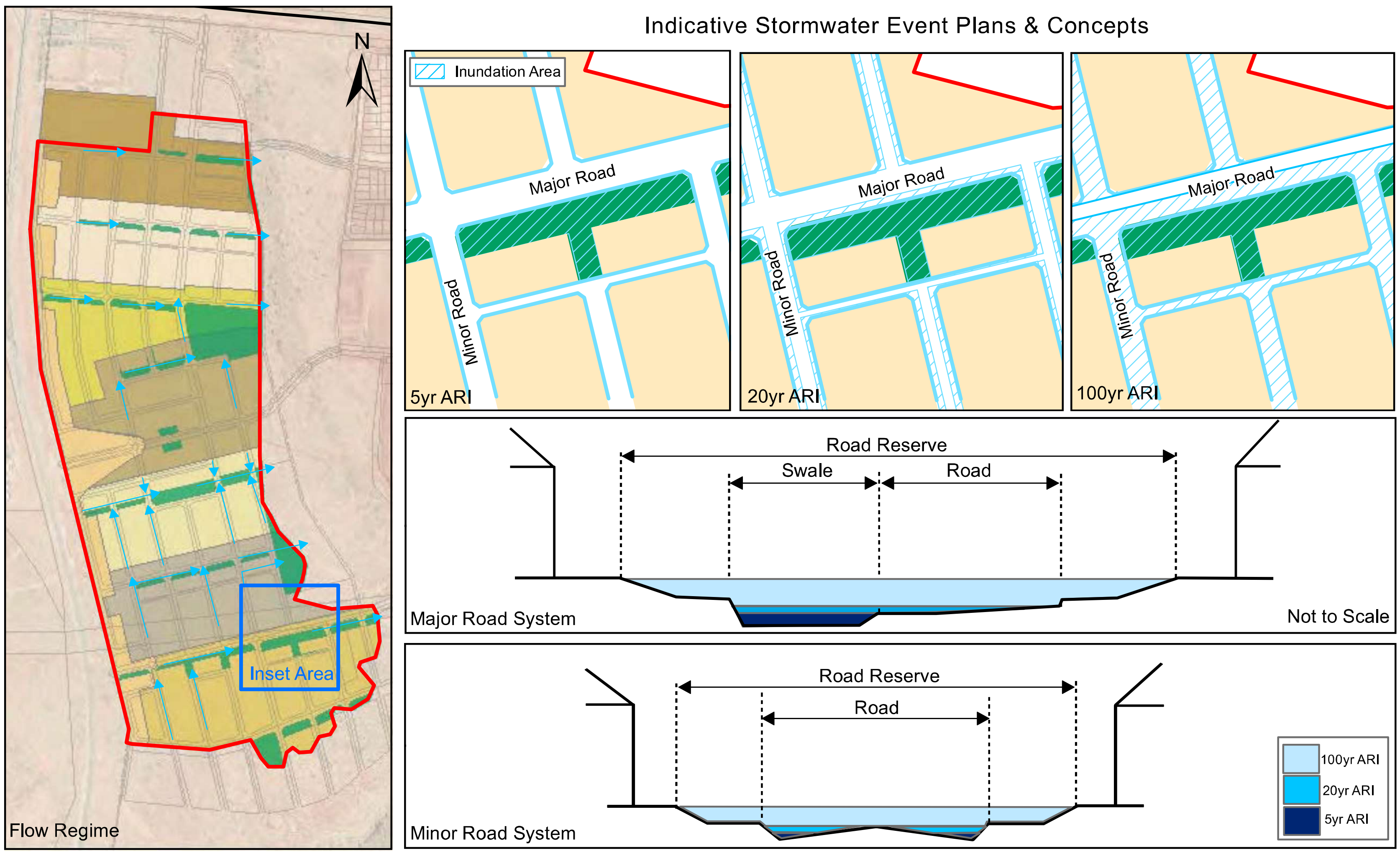
Madigan Road Urban Development, Karratha - LWMS

Figure 16: Catchment 8 Profile Plot for 5yr, 20yr & 100yr ARI



Data Source: TPG (2010)

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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	**Date:** March 2011
Name of Plan: Madigan Road, Karratha	
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

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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>.

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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.

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LandCorp

Madigan Creek Flood Study

Karratha

December 2010

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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.

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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).

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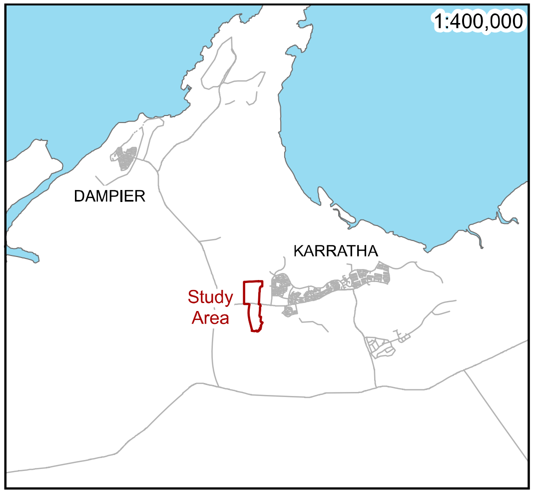
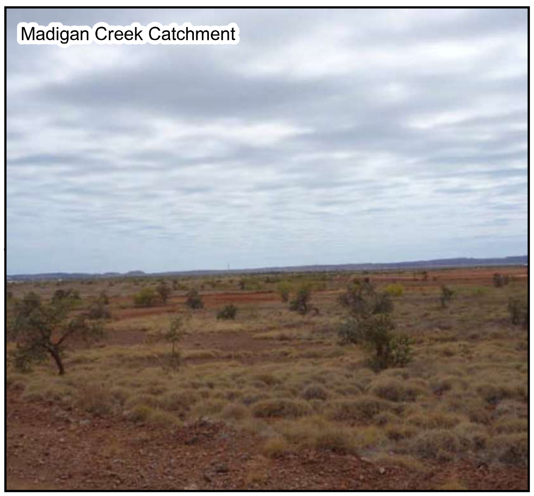
FIGURES





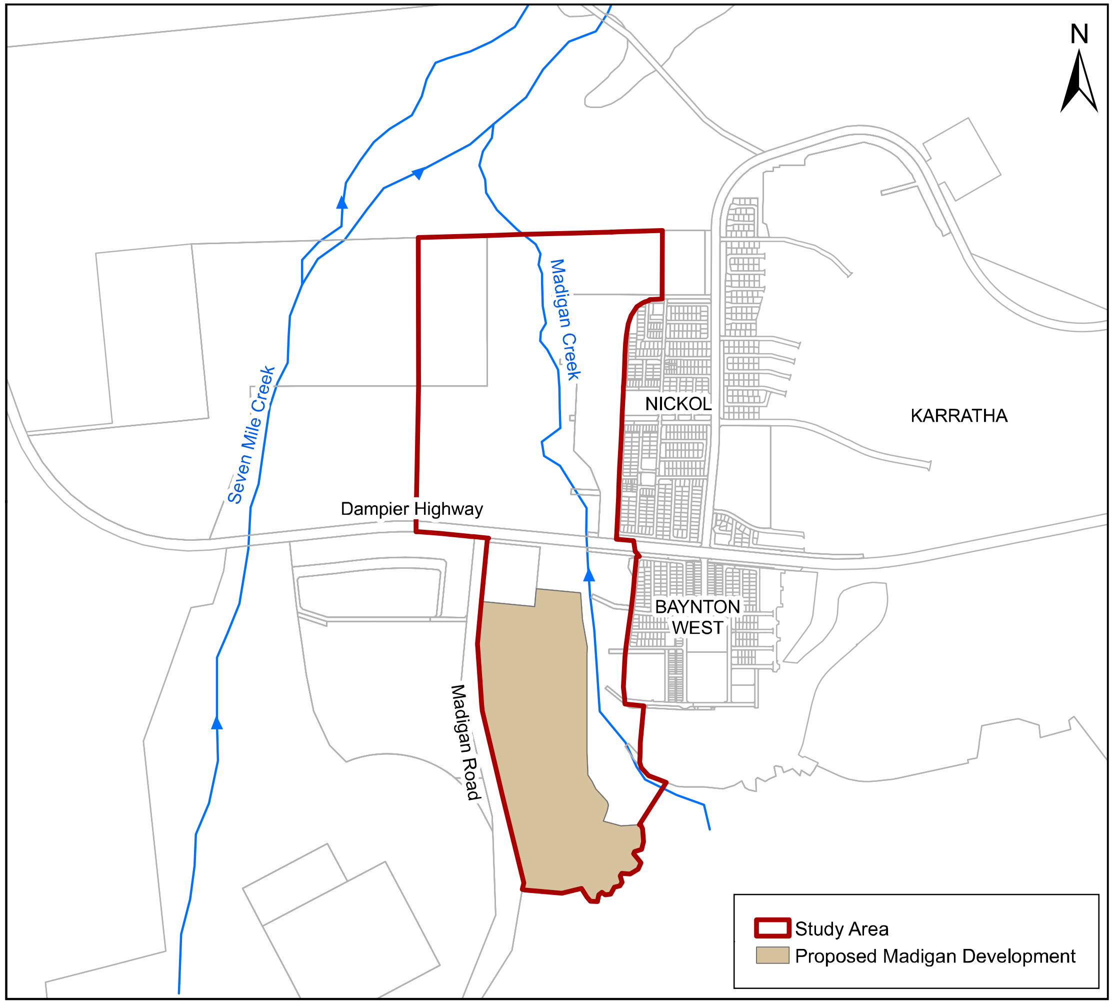


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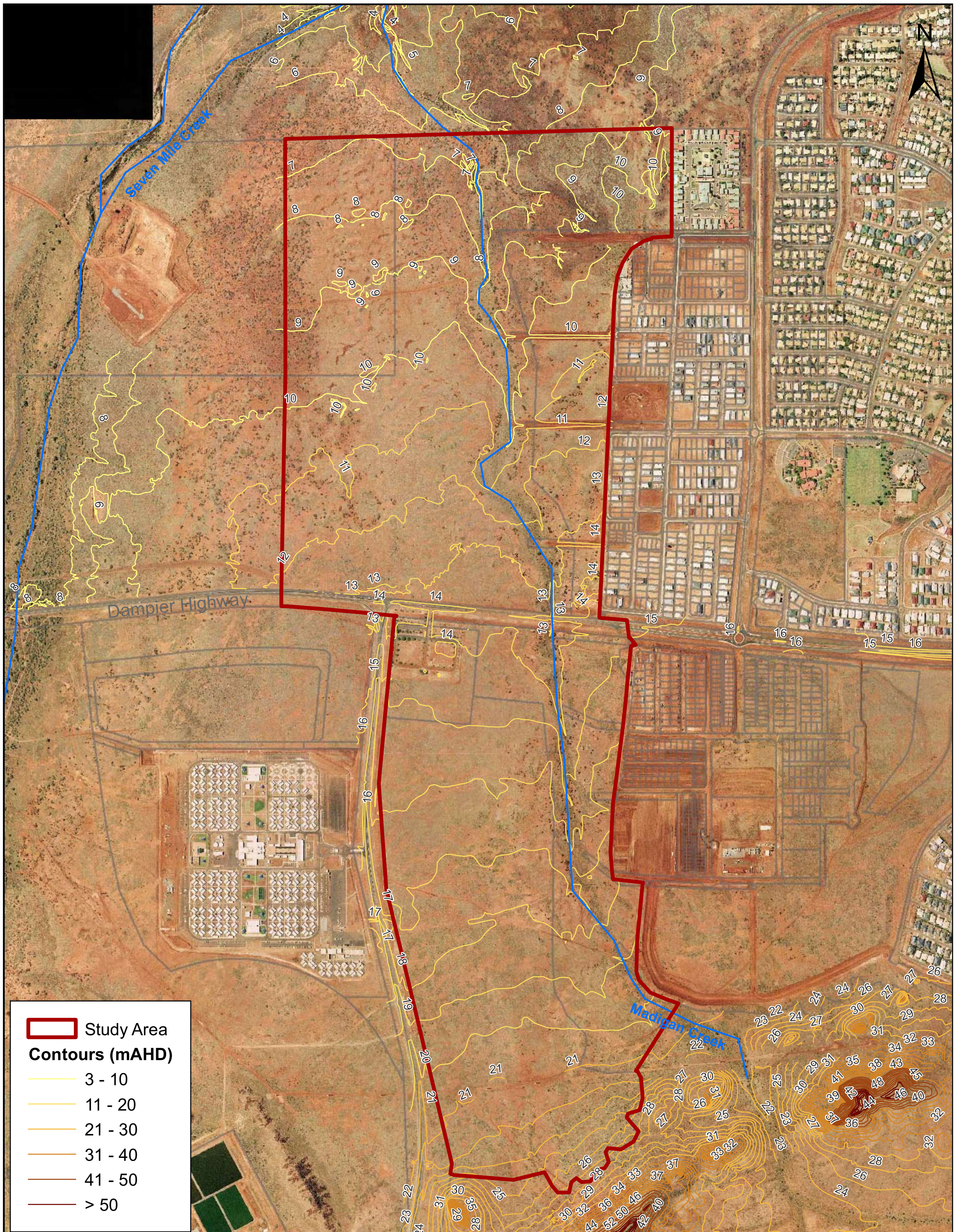
Figure 1: Location Plan



Data Source: Karratha Aerial Photo (Landgate, 2008)

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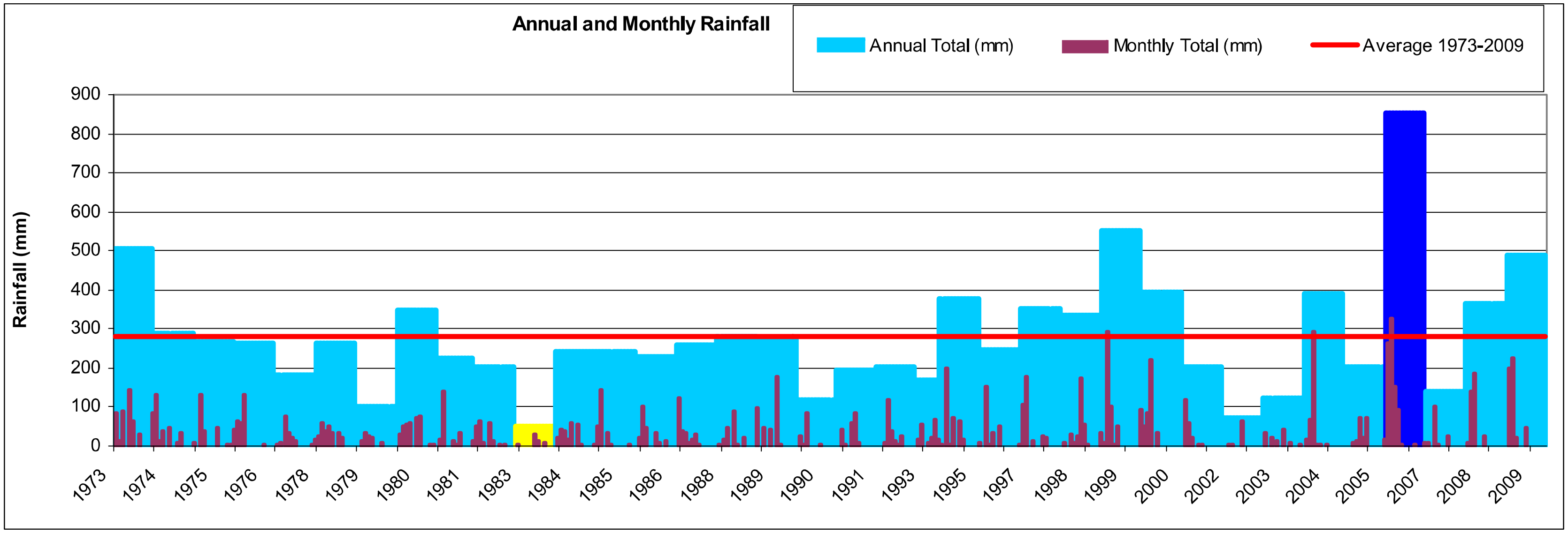
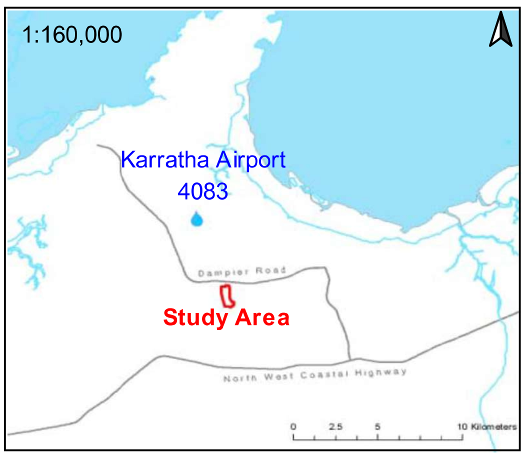
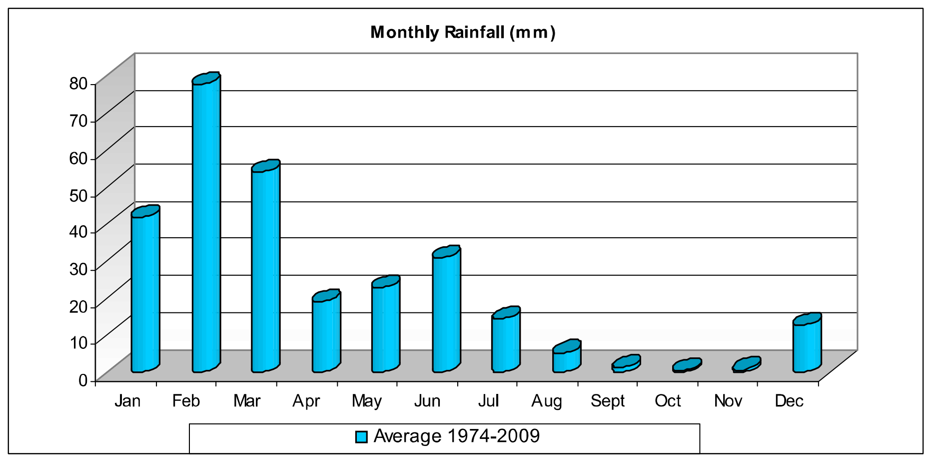
		Figure 2: Aerial Photograph and Topography







Data Source: Bureau of Metereology (2010)

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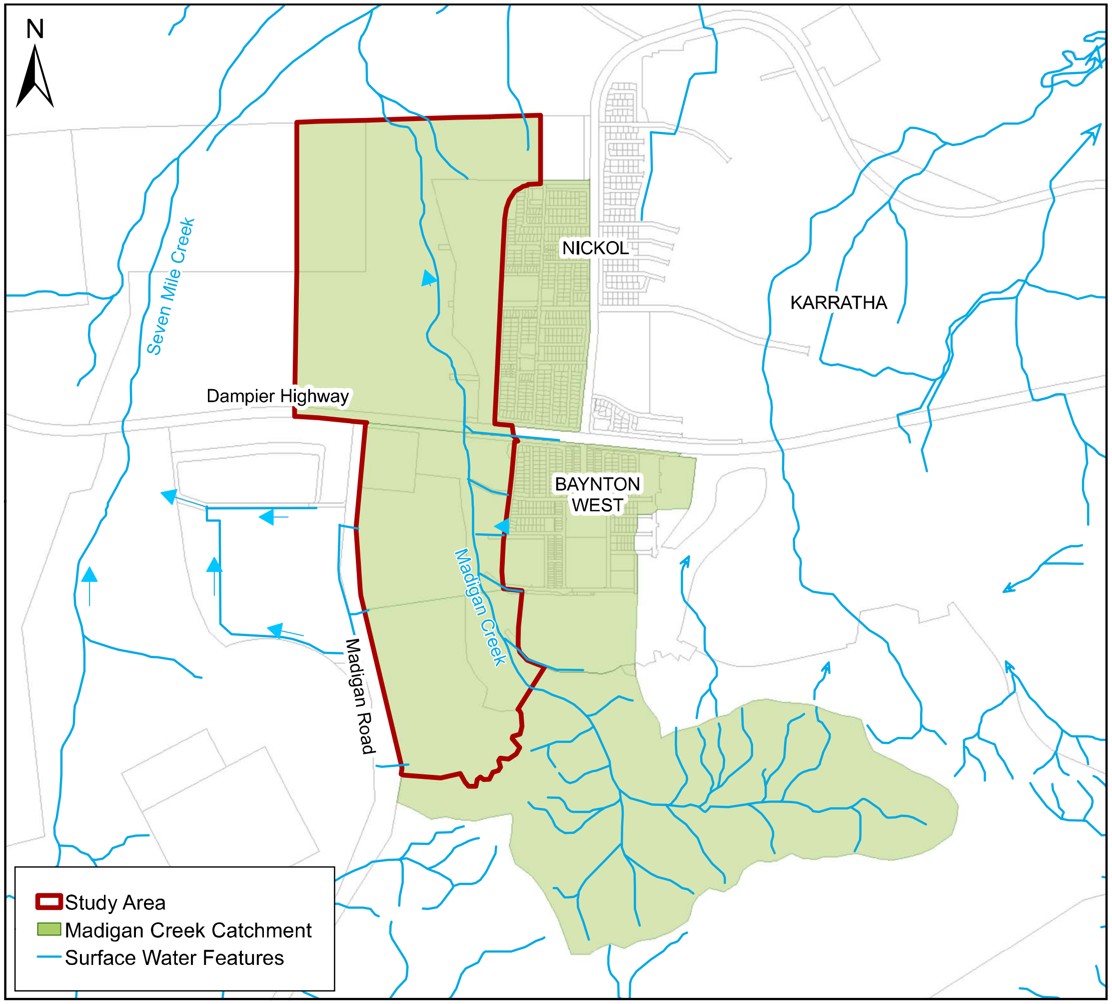
Figure 3: Karratha Airport Annual and Monthly Rainfall



Local Drain Adjacent to Dampier Highway (Baynton West)

Madigan Creek at the Upstream Boundary of the Study Area

Data Source: Whelans (2010)

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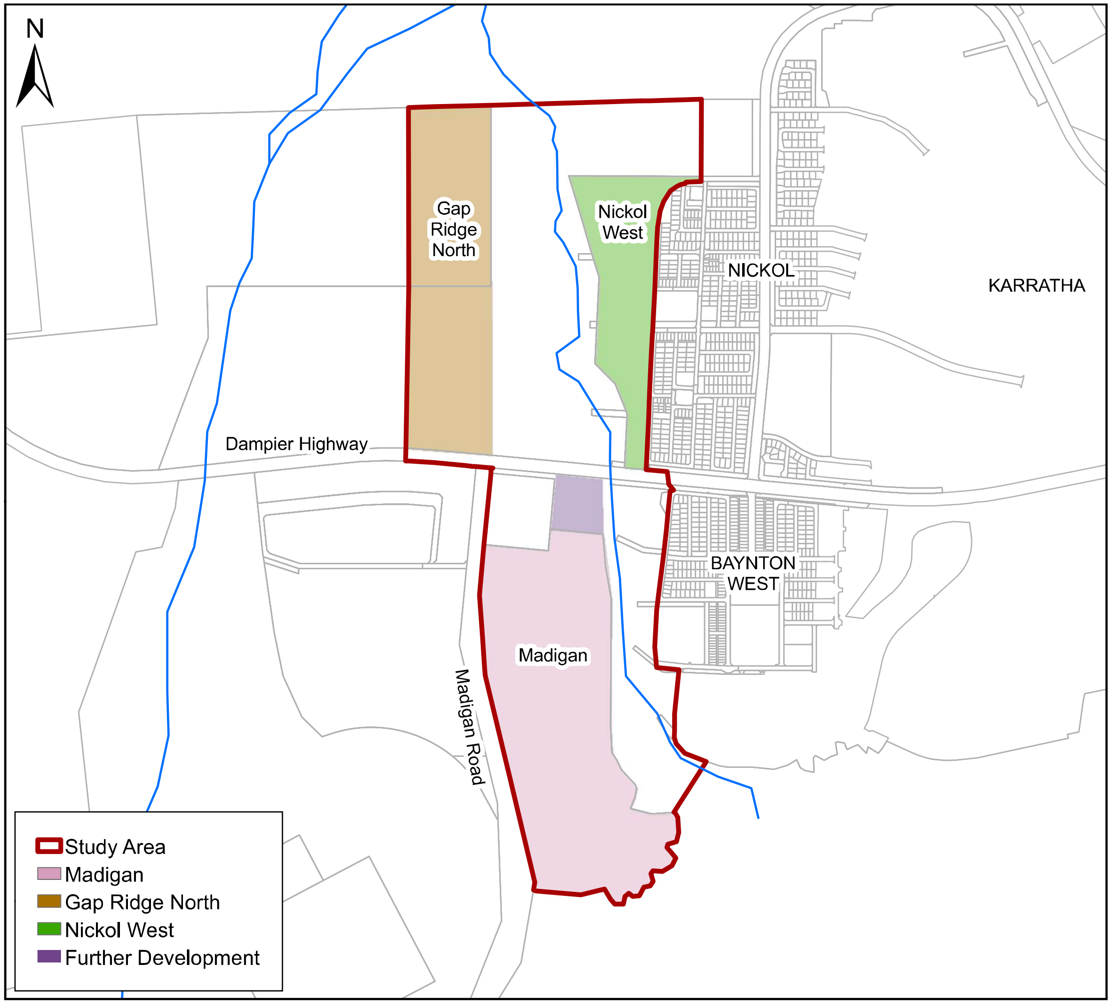
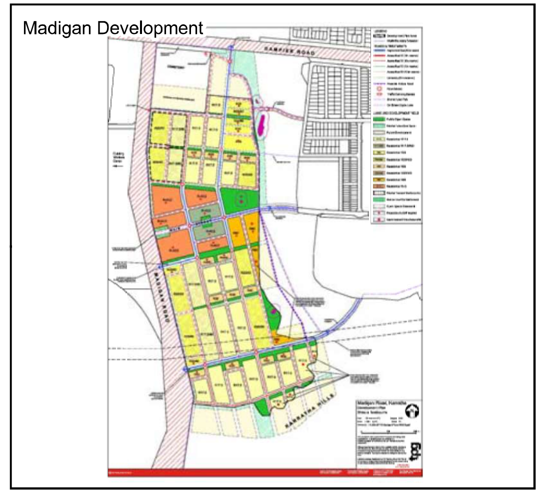
Figure 4: Existing Surface Drainage





Data Source: TPG (2010)

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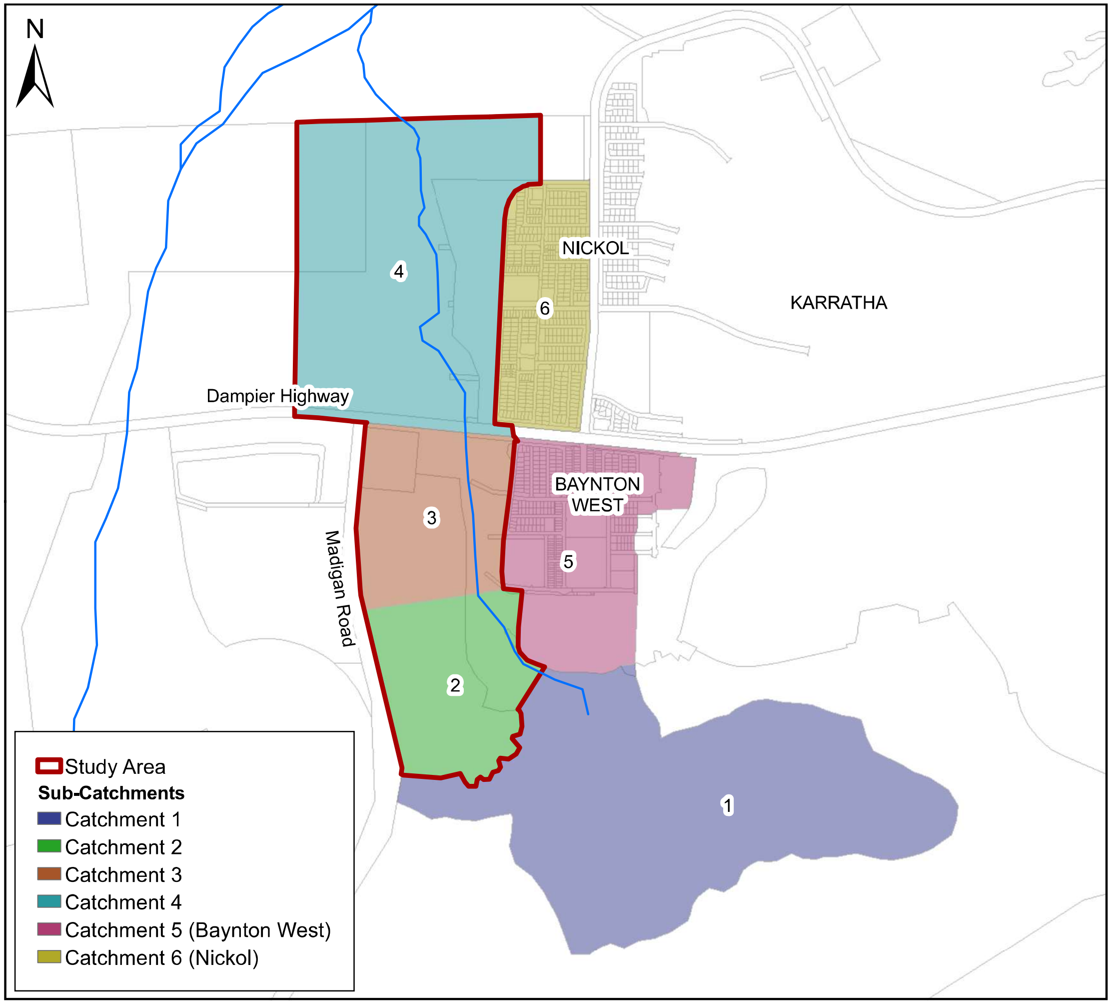
Figure 5: Proposed Developments



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)

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Figure 6: Madigan Creek Sub-Catchments

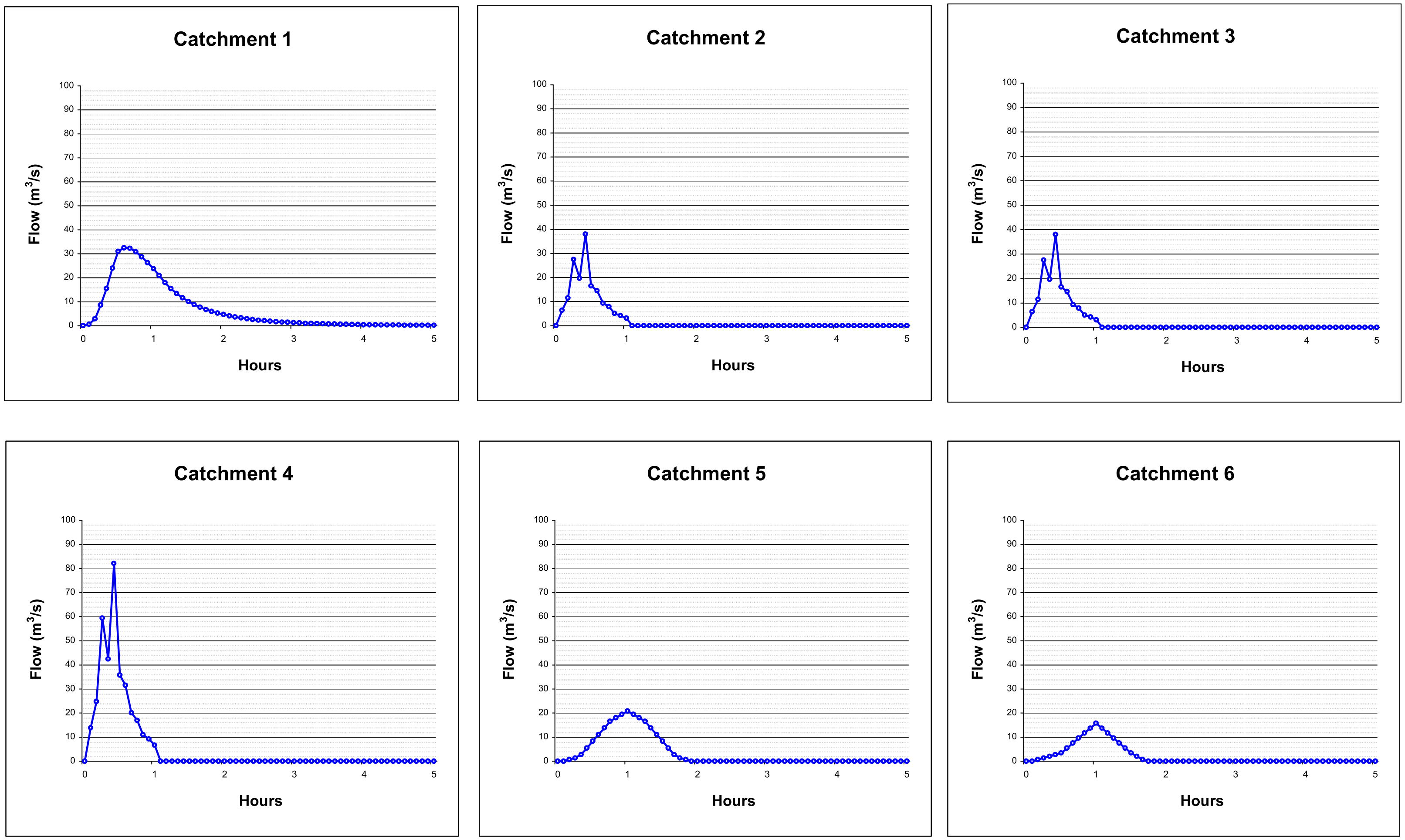

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Figure 7: Design Hydrographs - 20 Year ARI

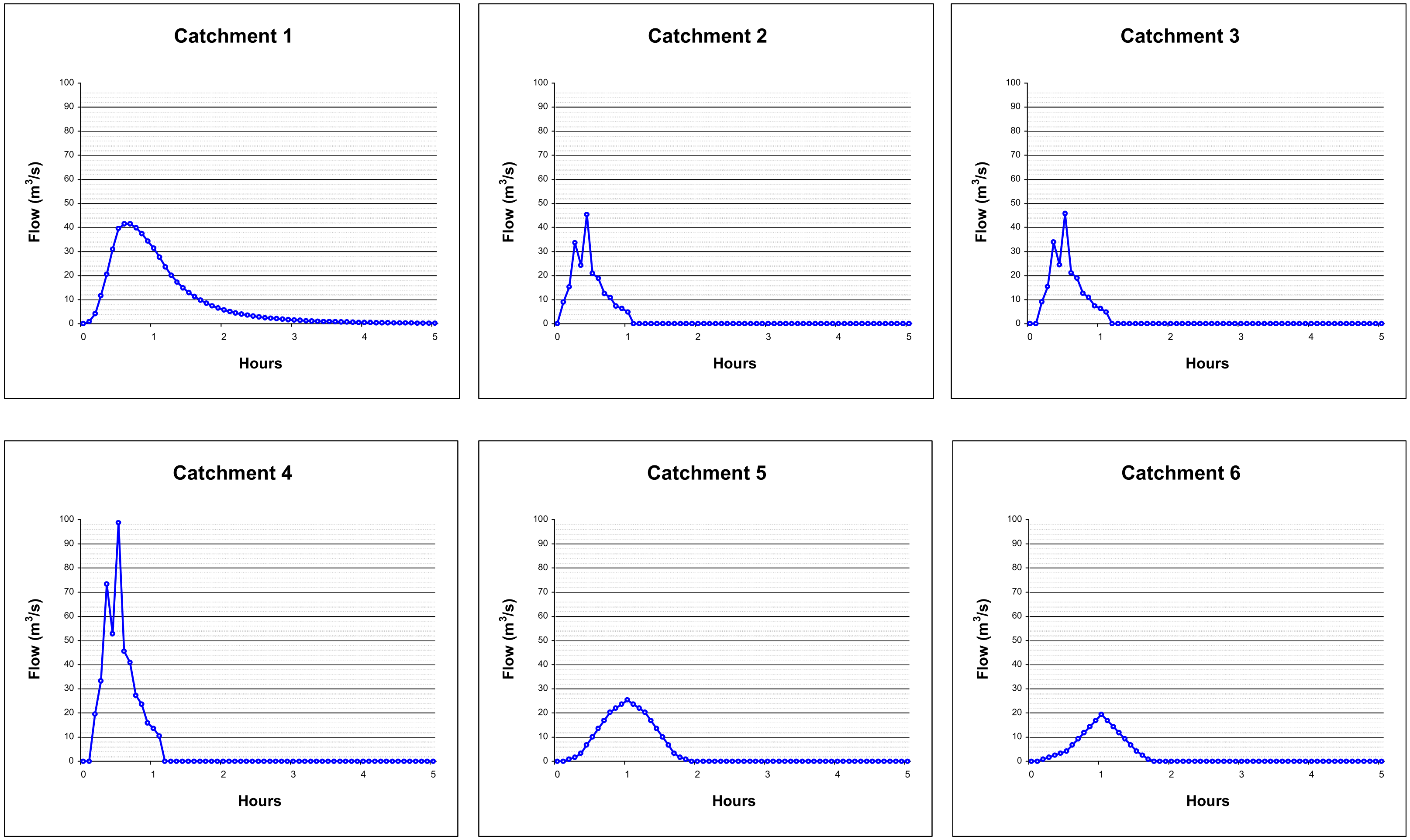

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Figure 8: Design Hydrographs - 50 Year ARI

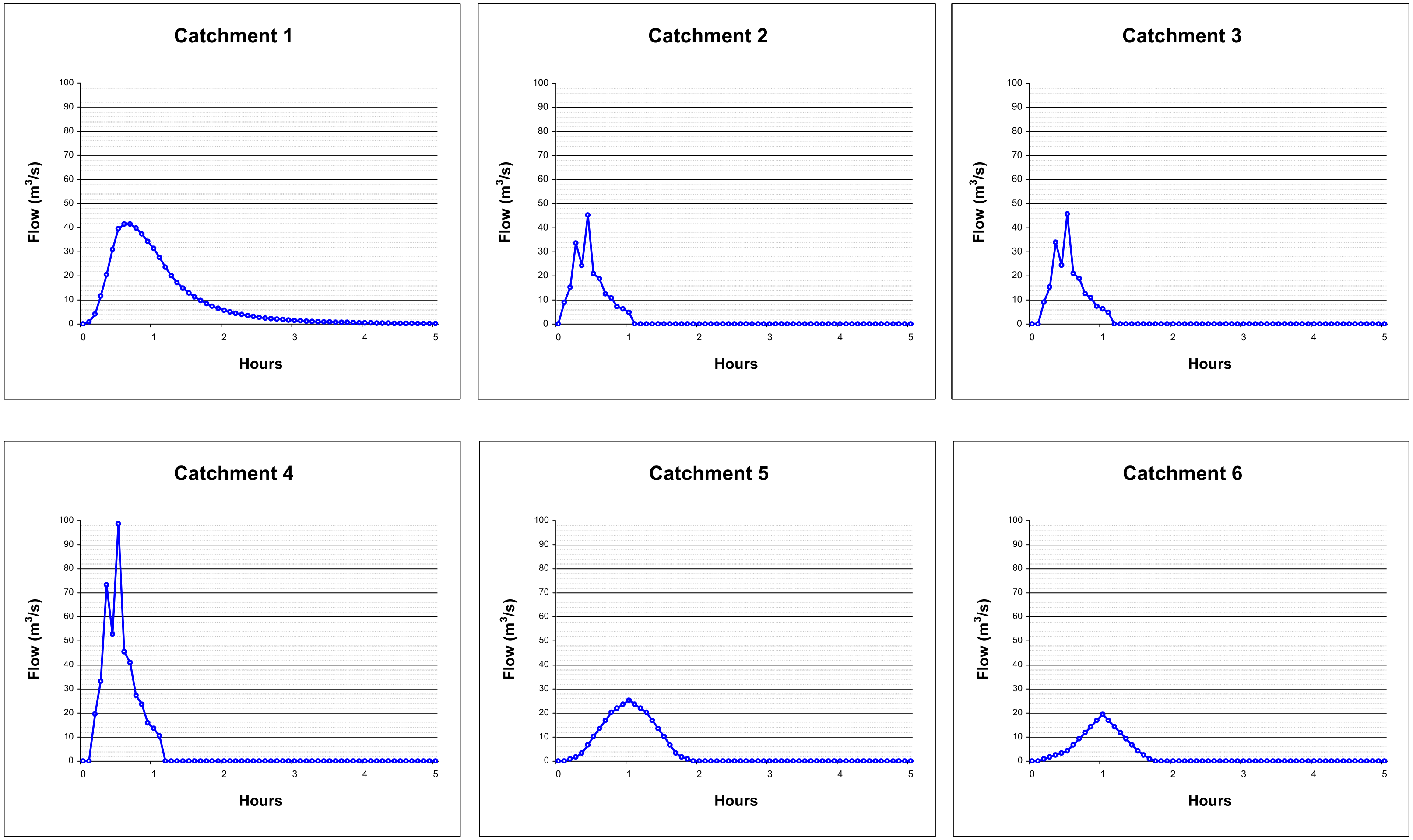

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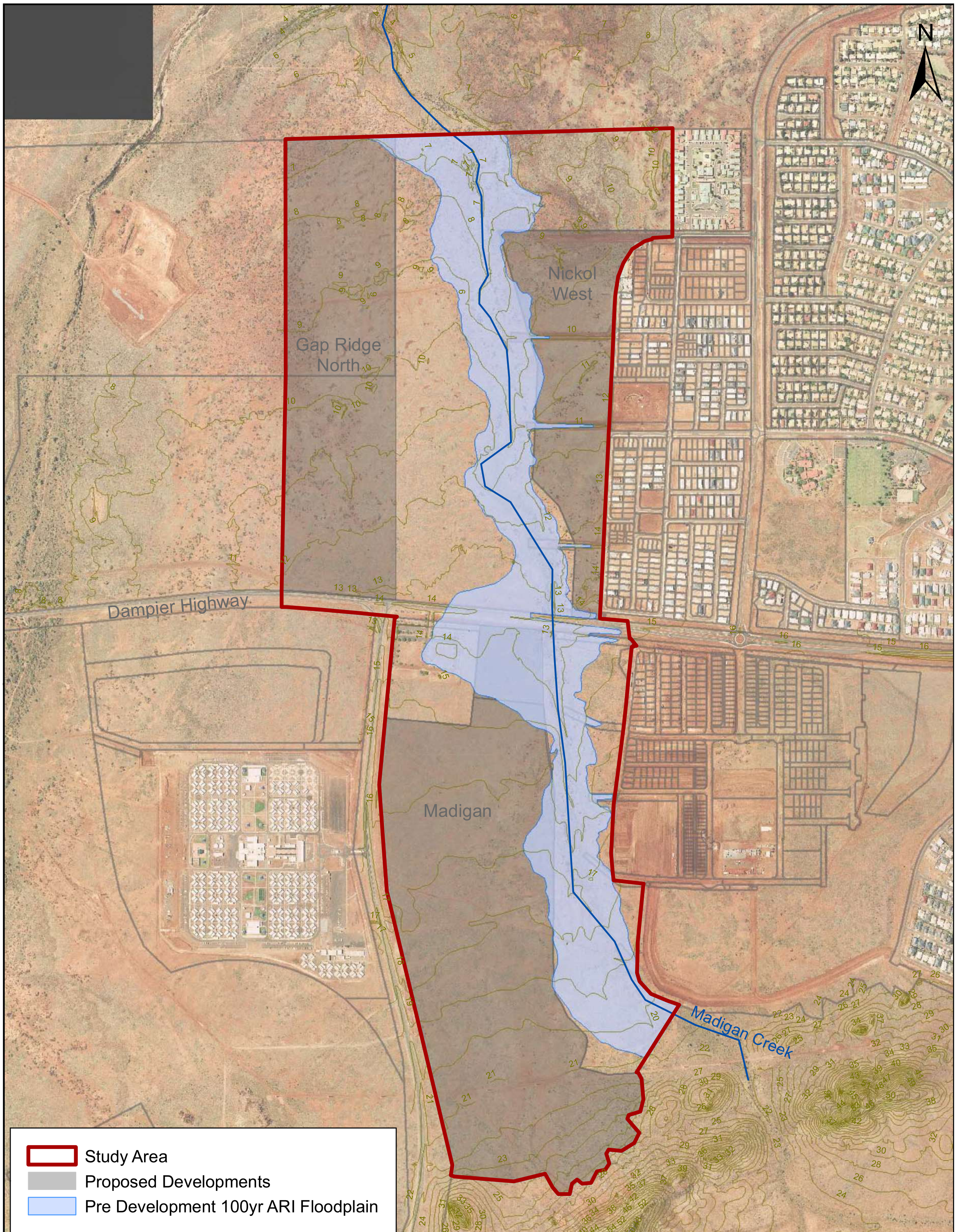
Figure 9: Design Hydrographs - 100 Year ARI



Data Source: Karratha Aerial Photo (Landgate, 2008)

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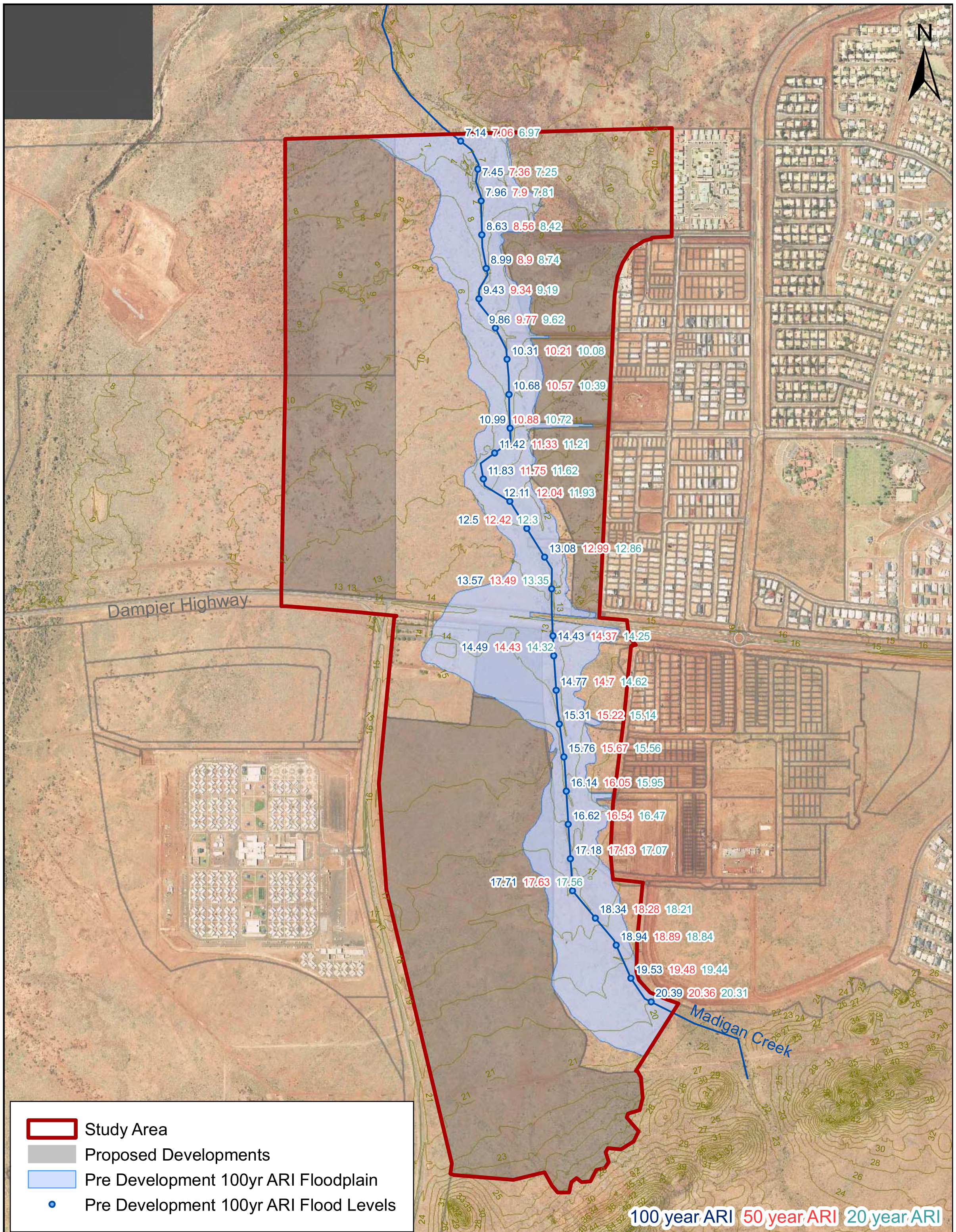
Figure 10: 100 year ARI Pre-Development Floodplain



Data Source: Karratha Aerial Photo (Landgate, 2008)

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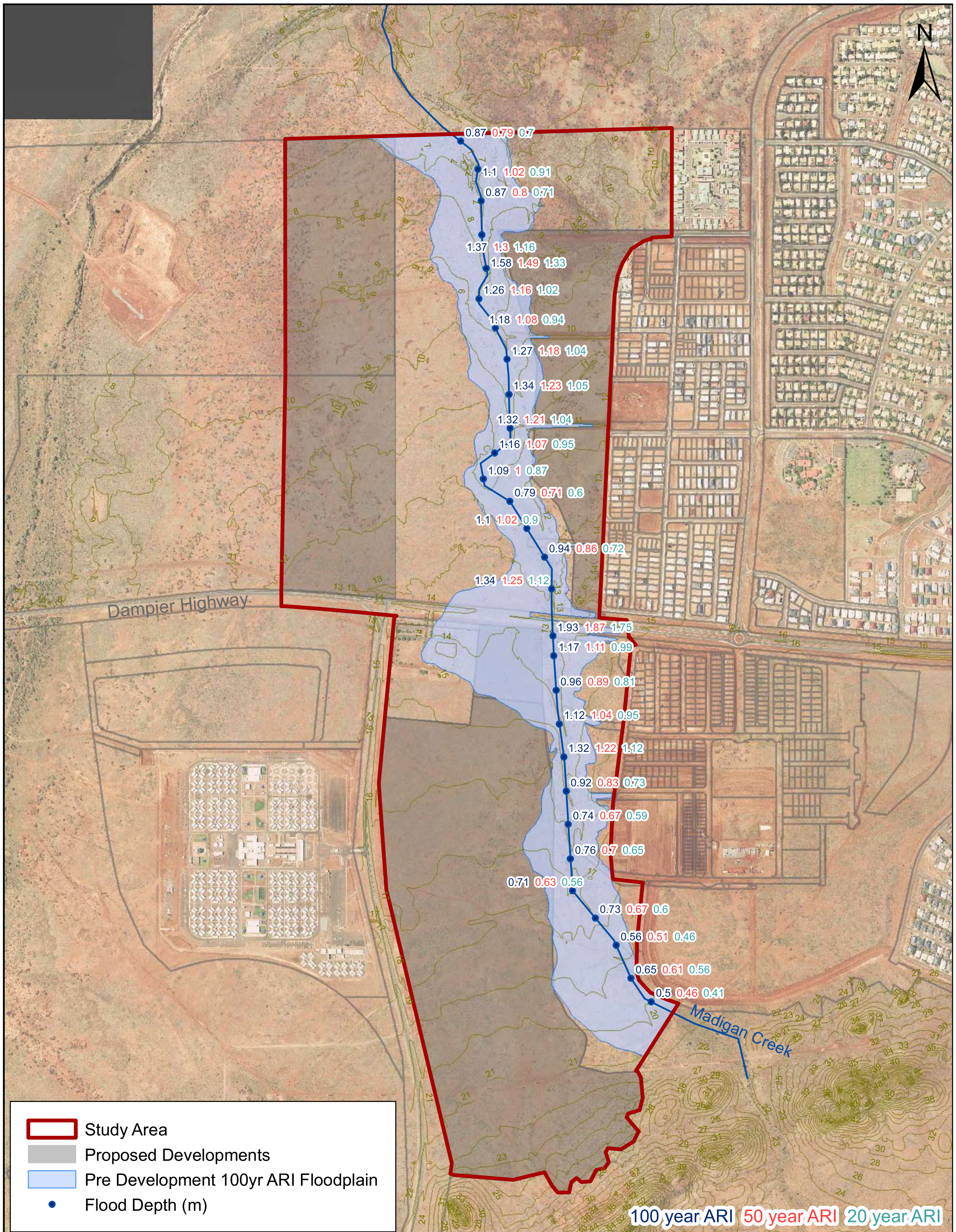
Figure 11: 20, 50 & 100 year ARI Pre-Development Flood Levels



Data Source: Karratha Aerial Photo (Landgate, 2008)

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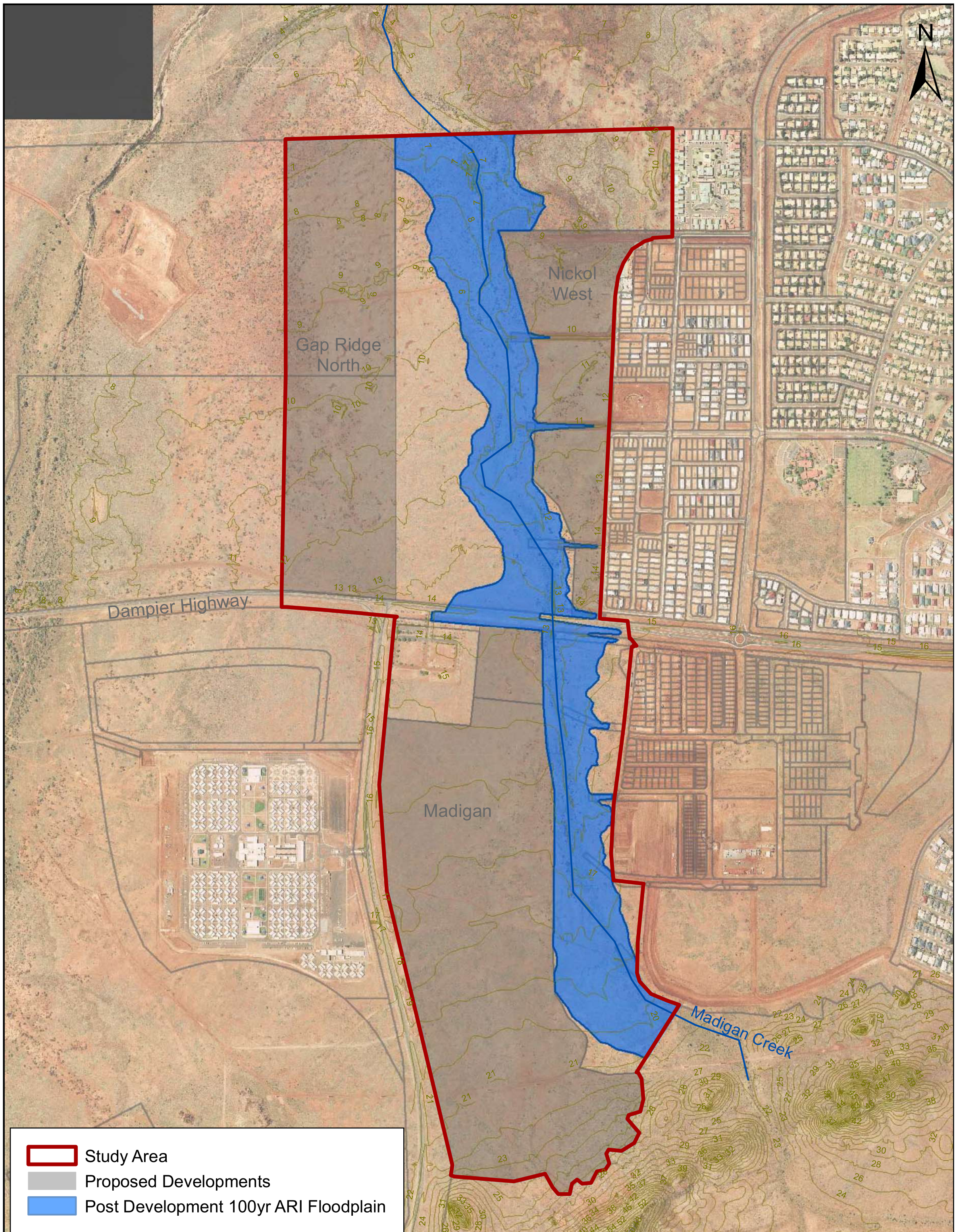
JDA Consultant Hydrologists	Job No. J4755 Scale 1:15,000 © COPYRIGHT JIM DAVIES & ASSOCIATES PTY. LTD. 2010	LandCorp Madigan Creek Flood Study **Figure 12: 20, 50 & 100 year ARI Pre-Development Flood Depths**



Data Source: Karratha Aerial Photo (Landgate, 2008)

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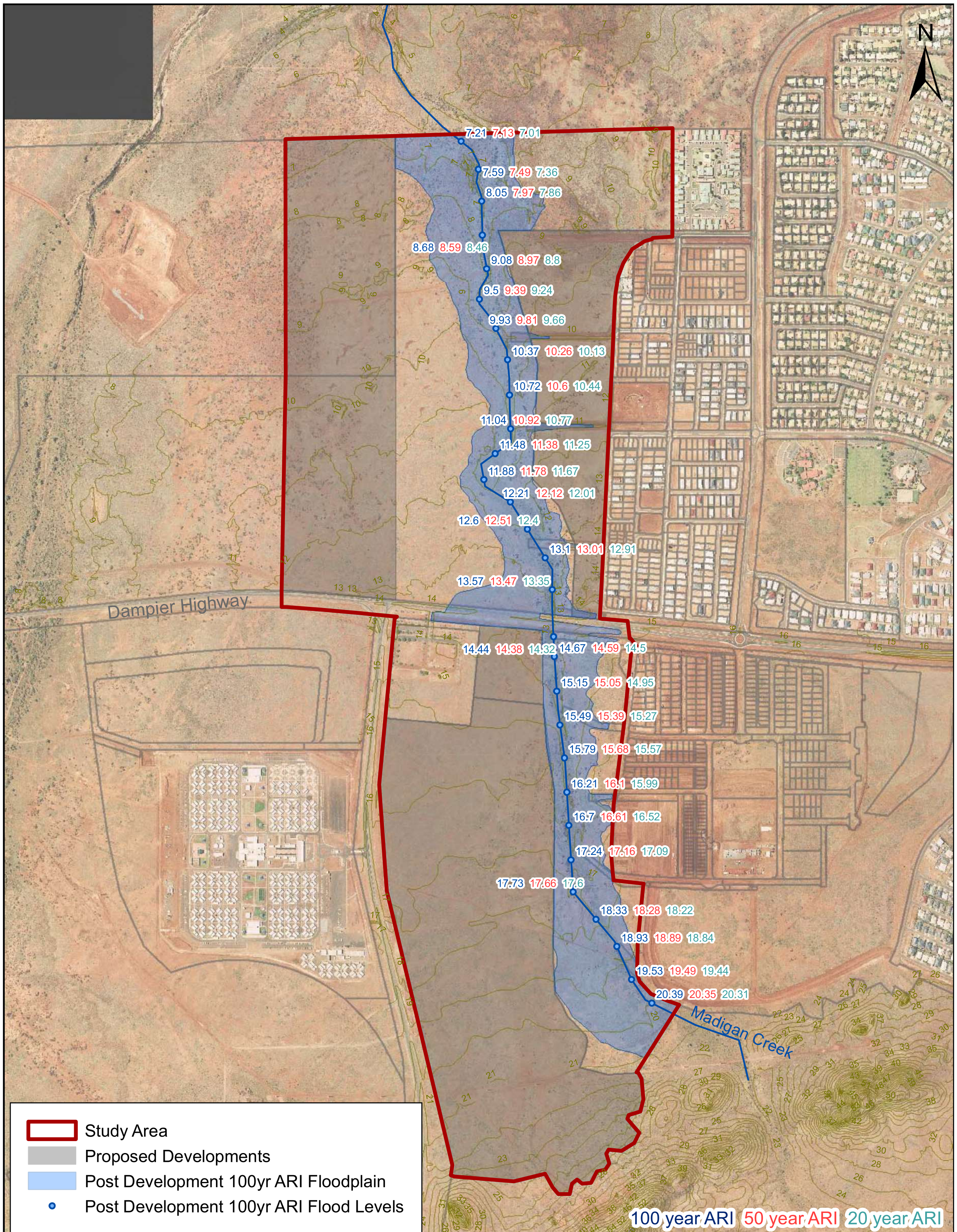
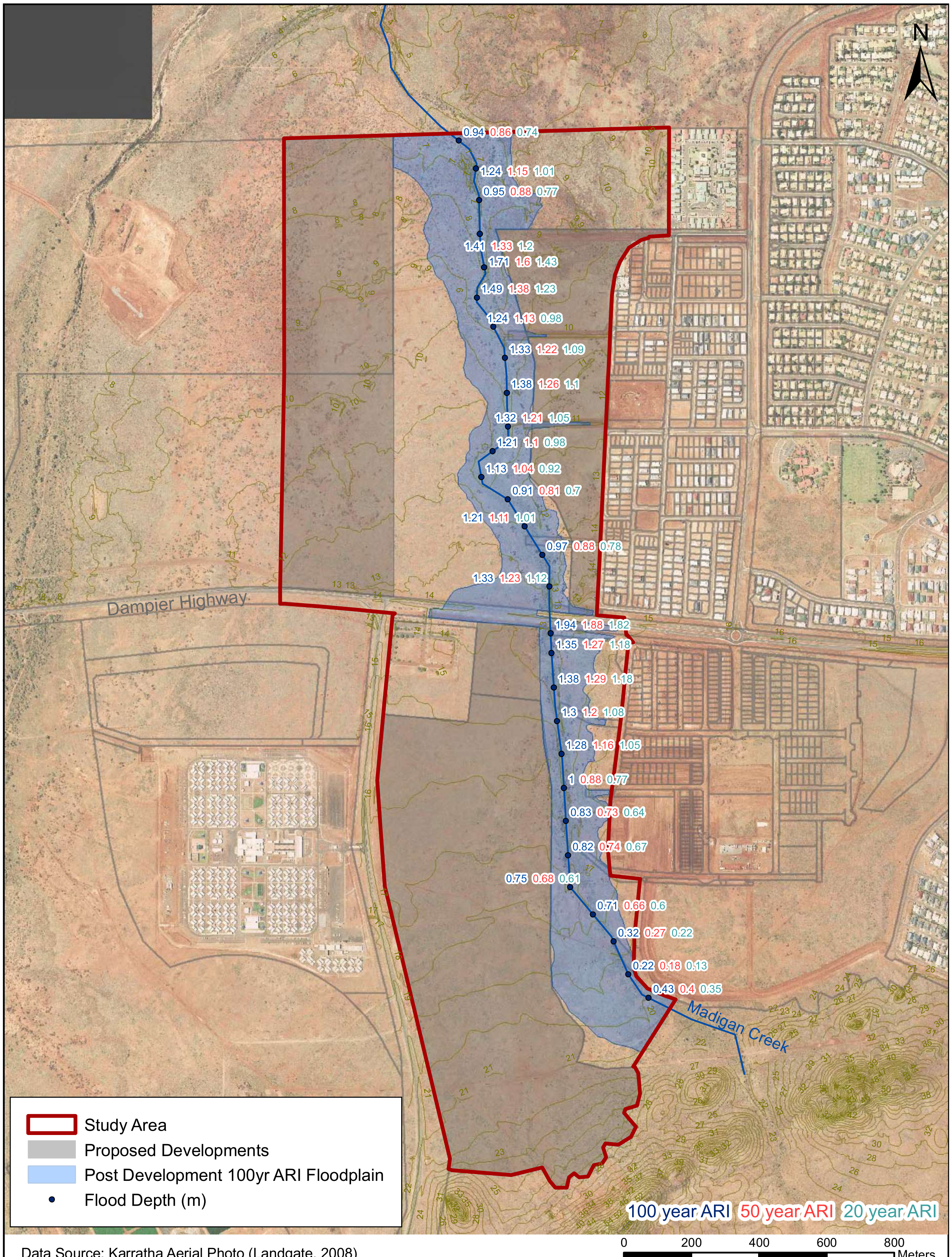
Job No. J4755 Scale 1:15,000 © COPYRIGHT JIM DAVIES & ASSOCIATES PTY. LTD. 2010	LandCorp Madigan Creek Flood Study **Figure 13: 100 year ARI Post-Development Floodplain**



Data Source: Karratha Aerial Photo (Landgate, 2008)

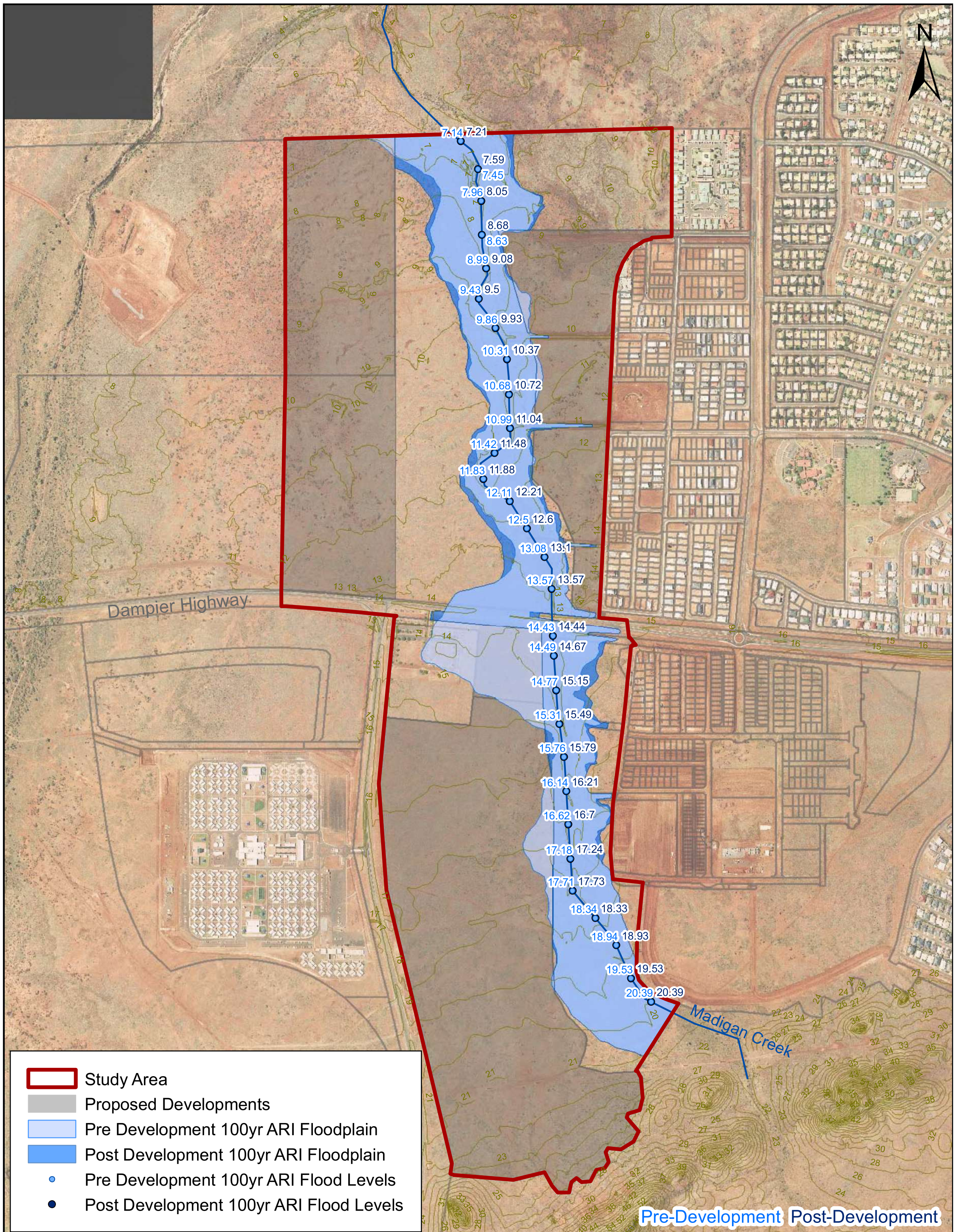
0 200 400 600 800 Meters

JDA Consultant Hydrologists	Job No. J4755 Scale 1:15,000 © COPYRIGHT JIM DAVIES & ASSOCIATES PTY. LTD. 2010	LandCorp Madigan Creek Flood Study **Figure 14: 20, 50 & 100 year ARI Post-Development Flood Levels**



Data Source: Karratha Aerial Photo (Landgate, 2008)

JDA Consultant Hydrologists	Job No. J4755 Scale 1:15,000 © COPYRIGHT JIM DAVIES & ASSOCIATES PTY. LTD. 2010	LandCorp Madigan Creek Flood Study **Figure 15: 20, 50 & 100 year ARI Post-Development Flood Depths**



Data Source: Karratha Aerial Photo (Landgate, 2008)

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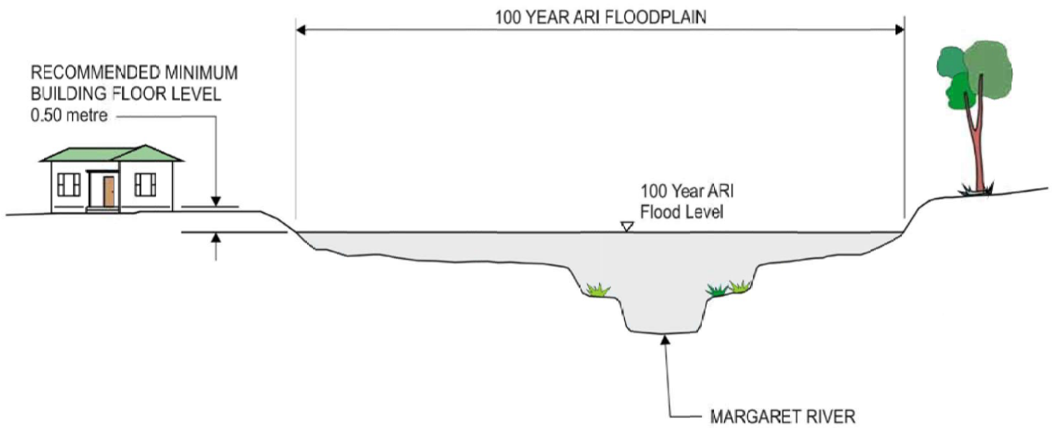
Figure 16: Pre and Post-Development 100 year ARI Floodplains

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)

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Figure 17: Floodplain Strategy

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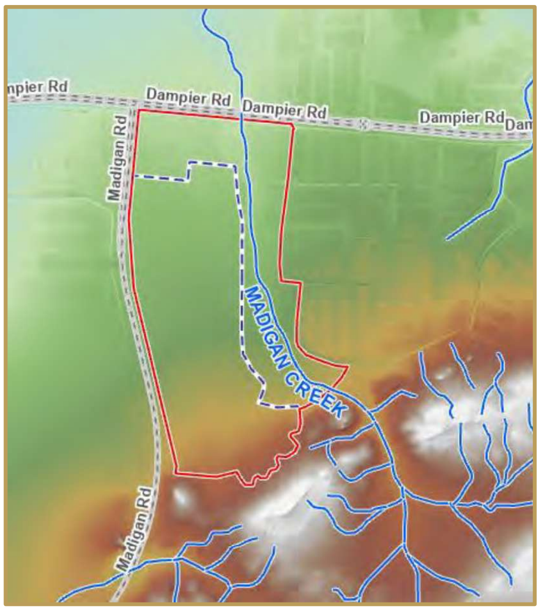
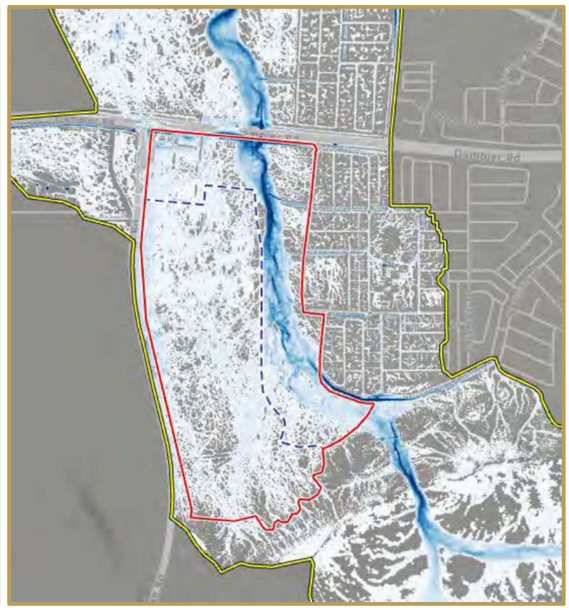
DEVELOPMENTWA

Madigan Creek Flood Study





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APPENDICES

1. INTRODUCTION

JDA was engaged by *Development WA* to assess the impacts of the proposed Madigan Road Structure Plan on the 100-year ARI (i.e. 1% Annual Exceedance Probability, AEP) flooding regime of Madigan Creek which is located to the western edge of the Karratha Townsite.

This report supersedes JDA (2012a) and assumes full acquaintance thereof.

1.1 Scope of Works

The JDA Scope of Works includes:

- Desktop review of relevant previously published studies;
- Collation and analysis of available gauged rainfall data;
- Application of new design rainfall intensities (IFDs) and up-to-date methodologies for simulation of catchment response to design hydraulic stresses;
- Review of available topography data;
- Review and analysis of the Madigan Creek hydrological model;
- Review and update of the Madigan Creek hydraulic model;
- Simulation of the 1% AEP design storm and subsequent mapping of the maximum flood extent, depth, level and velocities for the existing conditions;
- Simulation of the 1% AEP design storm with the inclusion of the proposed structure plan and associated road crossings;
- Calculation and mapping of eventual flood rise associated with the proposed infrastructure and subsequent assessment of the impacts against the *Department of Water and Environmental Regulation* (DWER) Floodplain Management Policy guidelines; and
- Calculation of the 1% AEP flood level difference between using the updated ARR2019 methodology (Ball et al, 2019) and that previously published in JDA (2012a).

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 two decades was Tropical Cyclone Monty that crossed the Dampier coastline on 1 March 2004. Records from the *Bureau of Meteorology* show that 323 mm 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 City of Karratha 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, 60 km^2 in size, is significantly larger than for Madigan Creek (5.46 km^2), and the main channel is larger and more defined.

1.3 ARR2019

The Australian Rainfall and Runoff (ARR2019) methodology (Ball et al., 2019) was used for the estimation of flood discharges. While ARR1987 temporal patterns for design rainfall were based on an Average Variability Method (AVM), ARR2019 recommends using an ensemble of 10 different temporal patterns for rainfall distribution over time applied to each storm duration for each AEP. The magnitude of the critical design flood discharge at selected locations of interest is then estimated from the weighted median of the hydrographs ensemble, selecting the temporal pattern that generates the next higher peak discharge above the calculated median.

ARR2019 also includes the use of revised Intensity-Frequency-Design (IFD) curves by BoM for rainfall intensities and, by extension, depths for design storms.

Although ARR2019 generally provides regional loss model parameters developed in association with rainfall IFD and other hydrologic parameters, coverage across Australia is not complete. In the Karratha coastal region, the ARR2019 datahub does not provide any advice regarding loss model parameters.

2. FLOODPLAIN MANAGEMENT

The main objective of effective floodplain management is to protect the population, infrastructure and the environment by preventing damage from flooding, limiting the effect of flooding on individuals and communities, and preserving ecological and amenity values.

Floodplain management in Western Australia is guided by the *Department of Water and Environmental Regulation* (DWER) through the provision of advice and recommendation for guidelines for a proposed development on floodplains with the object of minimising flood risk and damage. DWER uses the following guiding principles for their Floodplain Management Policy to ensure proposed development in flood-prone areas is acceptable with regard to major flooding:

- Proposed development has adequate flood protection from a 1% AEP flood event; and
- Proposed development does not detrimentally impact on the existing 1% AEP 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.

2.1 Existing Development

The presence of the drainage structures in the floodplain can alter the flow and influence the flooding regime. Existing structures identified in the 1% AEP floodplain of Madigan Creek are Dampier Highway culverts and floodway.

Currently, the drainage infrastructure at Dampier Hwy consists of 4 x 1500mm pipe culverts with an adjacent floodway; these culverts were installed in 2012 as part of the Dampier Hwy road duplication civil works.

2.2 Proposed Development

To ensure adequate flood protection is provided to future development, the DWER's Floodplain Management Policy is:

- For proposed development located outside of the 1% AEP floodplain, a minimum building floor level of 0.50 m above the adjacent 1% AEP flood level; and
- For proposed development located within the 1% AEP floodplain, DWER will provide advice on each proposal based on its merits (see below). Factors that will be examined are the maximum still water level (mAHD), depth of flow (m), flow velocity (m/s), hazard (VxD) and potential flood damage. If the proposed development is considered acceptable, a minimum building Finished Floor Level (FFL) of 0.50 m above the adjacent 1% AEP flood level will be recommended.

A failure to properly adhere to these recommendations will result in 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 area of interest is not threatened, and future development can be protected with the application of adequate land-use planning principles.

2.3 Development within the Floodplain

DWER generally allows development within the floodplain to have a maximum impact of 150 mm rise above the pre-development 1 in 100 AEP flood level but assesses each proposal based on its merits. For example, the maximum allowable upstream impact provided to Main Roads WA for the Dampier Highway lane duplication works was 300 mm.

However, for Madigan Creek, a reduced flood level rise was applied by DWER of 50 mm in the 1% AEP flood levels as a result of development fill and the two proposed road crossings.

3. SITE DESCRIPTION

3.1 Existing Site Layout and Land Use

The Study Area, shown in Figure 1, is located on the western edge of the City of Karratha in the north-west of Western Australia. Figure 1 also shows the Study Area is bound by Madigan Road to the west, Dampier Road to the north and interfaces with the Madigan Creek drainage path to the east. The nearest residential development areas are Baynton West to the east of Madigan Creek and south of Dampier Road, and Nickol which is located north-east of the Study Area. The Karratha Cemetery is located at the intersection of Dampier Road and Madigan Road, immediately north of the proposed Structure Plan (SP).

The land use within the Study Area is primarily native vegetation such as low tussock and spinifex grass.

3.2 Proposed Structure Plan

The Structure Plan shown in Figure 2 was provided to JDA by Elements in August 2020 on behalf of Development WA. Figure 2 shows that the Structure Plan includes two floodways traversing Madigan Creek, namely Prancing Avenue and Gardugarli Road which have already been constructed. For pre-development scenario JDA assumed the Study Area to be as depicted in the Light Detection and Ranging (LiDAR) survey completed in 2010 by LandCorp (LandCorp, 2010).

3.3 Topography

Figure 3 shows the pre-development topography sourced from the LandCorp LiDAR survey completed in 2010 with ground elevation information imposed on a 1 m quadrilateral grid. The topography shows a gradient falling south-to-north, the presence of relatively high steeply-sloped hills south of the Study Area where the majority of Madigan Creek's catchment lies.

The topography within and along the eastern edge of the Study Area, Baynton West and Nickol presents gentle to flat slopes with the highest elevations found in the southern portion (i.e. ≈24 mAHD) and lowest in the northern portion (i.e. ≈13 mAHD), a total drop of approximately 11 m over a distance of 1.5 km, which equates to an average slope of circa 0.007 m/m.

3.4 Climate & Rainfall Data

The City of Karratha is characterised by hot and wet climate with periodic heavy rainfalls in summer and autumn, and relatively mild and dry winter and spring seasons.

Figure 4 shows the historical rainfall data collected at the two Bureau of Meteorology (BoM) rain gauging stations closest to the Study Area, namely Karratha Aero (BoM Site ID: 4083) and Dampier Salt (BoM Site ID: 5061).

Figure 4 bottom panel shows that the long-term 30-year annual rainfall is 284 mm, which compares to the short-term 10-year average of 317 mm, or an increase of circa 10%. The highest annual rainfall recorded between the period of 1971 and 2019 was 855 mm in 2006.

The average annual pan evaporation is approximately 3,590 mm (Luke *et al*., 1988).

4. HYDROLOGIC ASSESSMENT

4.1 Design Rainfall Analysis

Intensity-Frequency-Duration (IFD) curves for design rainfall intensities and depths were calculated using both the ARR1987 & ARR2019 design manuals.

Table 1 and Figure 5 present the ARR1987 IFD data for design storms total rainfall depths.

TABLE 1: KARRATHA ARR1987 IFD DATA (MM)

DURATION	1-year	2-year	5-year	10-year	20-years	50-years	100-year
5Mins	6.6	8.9	13.3	16.1	19.7	24.8	28.8
6Mins	7.4	10.0	14.8	18.1	22.1	27.8	32.4
10Mins	10.0	13.6	20.3	25.0	30.7	38.8	45.3
20Mins	14.7	20.1	30.6	37.7	46.7	59.3	69.7
30Mins	17.9	24.6	37.8	46.8	58.0	74.0	87.0
1Hr	23.6	32.7	51.1	63.8	79.9	103.0	122.0
2Hrs	29.0	40.6	65.0	82.2	104.0	135.4	161.4
3Hrs	32.1	45.0	73.2	93.6	119.1	156.6	187.8
6Hrs	37.5	53.0	88.8	115.2	148.8	198.6	240.0
12Hrs	44.9	64.0	109.7	144.0	187.2	252.0	307.2
24Hrs	56.2	80.4	138.2	181.7	237.1	319.2	391.2
48Hrs	70.6	100.8	172.8	226.1	294.2	396.0	484.8
72Hrs	77.0	110.2	188.6	247.0	321.1	432.7	527.8

Table 2 and Figure 6 present the ARR2019 IFD design storm rainfall depth.

TABLE 2: KARRATHA ARR2019 IFD DATA (MM)

Duration	1 EY	1 in 2 AEP	1 in 5 AEP	1 in 10 AEP	1 in 20 AEP	1 in 50 AEP	1 in 100 AEP
5Mins	4.8	6.2	8.3	10.0	11.8	14.2	16.1
6Mins	5.3	6.6	9.5	11.6	13.8	16.6	18.9
10Mins	8.3	10.7	14.4	17.2	20.4	24.6	28.0
20Mins	12.6	16.3	21.8	26.1	30.8	37.2	42.2
30Mins	15.3	19.7	26.4	31.5	37.1	44.8	50.9
1Hr	19.7	25.6	34.3	41.0	48.5	58.7	66.7
2Hrs	24.2	31.7	43.3	52.3	62.2	76.0	87.0
3Hrs	27.2	35.8	49.8	60.7	72.8	89.6	103.0
6Hrs	33.4	44.8	64.9	80.5	98.1	123.0	143.0
12Hrs	42.1	57.6	86.7	110.0	136.0	172.0	203.0
24Hrs	53.8	74.7	116.0	148.0	185.0	237.0	279.0
48Hrs	67.4	94.1	147.0	188.0	235.0	299.0	350.0
72Hrs	74.7	104.0	162.0	207.0	257.0	324.0	376.0

Table 3 presents the percentage difference between ARR1987 and ARR2019. Note that all percentage differences are negative numbers, indicating that the ARR2019 IFD is lower than ARR1987. Decreases for the 1% AEP design storm range from 28% to 46%.

TABLE 3: KARRATHA DIFFERENCE BETWEEN ARR1987 AND 2019 IFD DATA (%)

EY	1	0.69	0.2	0.1	0.05	0.02	0.01
AEP (%)	63.2	39.35	18.13	≈10	5	2	1
AEP (1 in X)	1.58	2.54	5.52	≈10	20	50	100
ARI (year)	1	2	5	10	20	50	100
Duration	↓	↓	↓	↓	↓	↓	↓
5Mins	-27	-30	-37	-38	-40	-43	-44
6Mins	-28	-34	-36	-36	-38	-40	-42
10Mins	-17	-21	-29	-31	-33	-37	-38
20Mins	-14	-19	-29	-31	-34	-37	-39
30Mins	-15	-20	-30	-33	-36	-39	-41
1Hr	-17	-22	-33	-36	-39	-43	-45
2Hrs	-17	-22	-33	-36	-40	-44	-46
3Hrs	-15	-20	-32	-35	-39	-43	-45
6Hrs	-11	-16	-27	-30	-34	-38	-40
12Hrs	-6	-10	-21	-24	-27	-32	-34
24Hrs	-4	-7	-16	-19	-22	-26	-29
48Hrs	-4	-7	-15	-17	-20	-24	-28
72Hrs	-3	-6	-14	-16	-20	-25	-29

Note that the 50% AEP does not correspond exactly to the 2-year ARI, but to the 1.44-year ARI; similarly, the 20% AEP does not correspond exactly to the 5-year ARI IFD, but to the 4.48 year ARI.

The change in rainfall IFD depth from 1987 to 2019 is consistent with other sites along the Pilbara coast, including Port Hedland to the east, with similar changes occurring in rainfall. It is assumed that these revised IFD depths are correct, and that necessary checks have been performed by BoM for Karratha based on local data.

The ARR2019 IFD was used for the hydraulic modelling described in Sections 4 and 5 below.

4.2 Hydrology

The Madigan Creek drainage catchment to Dampier Road comprises four (4) main sub-catchments shown in Figure 7 and in Table 4.

TABLE 4: MADIGAN CREEK CATCHMENT AREAS

Sub Catchment	Area	
	Ha	Km²
Madigan Creek Main External	195.3	1.953
Baynton West Development	54	0.54
Madigan SP 1	47.6	0.476
Madigan SP 2	61.4	0.614
Total	**358.3**	**3.583**

Four pipe culverts 1.5 m in diameter under Dampier Road convey Madigan Creek water northward to the confluence with Seven Mile Creek further downstream as shown in Figure 7.

4.3 MIKEFLOOD-FM Model

MIKEFLOOD-FM was used along with "rain on-grid" to simulate Madigan Creek and areas of urban development catchment hydrology for the 1% AEP storms and associated ensembles of temporal patterns (TP). Storage depression and variable overland flow paths are automatically simulated. Details of the model setup and parameters are further described in Section 5 below.

5. HYDRAULIC MODEL DESCRIPTION

5.1 MIKEFLOOD

The Madigan Creek hydraulic model is MIKEFLOOD, which couples the 2D overland flow model MIKE21FM (described in Section 5.2) and the 1D model MIKE11 (described in Section 5.3) used to simulate hydraulic structures such as pipe and box culverts, bubble-in and bubble-up stormwater pits, side entry pits, etc.

5.2 MIKE21-FM

5.2.1 Topography

MIKE21FM uses a tessellated triangular unstructured Flexible Mesh (FM) to define the topography using LiDAR surveys completed in 2011 and 2012 by LandCorp. The overall resolution is equivalent to the 2 m grid Digital Elevation Model (DEM) shown in Figure 8.

5.2.2 Boundary Conditions

Three hydraulic boundaries simulate the interface of Madigan Creek with Seven Mile Creek 1% AEP flood. These boundaries are constant still water levels sourced from JDA (2012b) and shown in Figure 8.

The constant water levels imposed at the three boundaries (BND) locations are as follows:

- BND1: 10.61 mAHD;
- BND2: 10.10 mAHD; and
- BND3: 7.70 mAHD.

5.2.3 Initial Inundation and Baseflow

The initial inundation depth resulting from forcing the three hydraulic boundaries described in Section 5.2.2 above is shown in Figure 8.

A dry start was applied to the remaining topography.

5.2.4 Design Rainfall & Loss Model

Using ARR2019, four (4) rainfall ensembles were generated for different 1% AEP storm durations, namely 30 minutes, 1, 2 and 3 hours duration, each with ten (10) different temporal patterns, totalling 40 MIKEFLOODFM model simulations. The ten different temporal patterns are permutations of the three main types of storm rainfall distributions: front-loaded, rear-loaded and uniform.

As described in Section 1.3, no regional model loss parameters have been provided as part of ARR2019. In lieu of any other new information about Karratha losses, the hydrologic loss model from the Karratha Coastal Vulnerability Study (JDA, 2012b) (also the loss model for the Pilbara in ARR1987) was adopted for both pre and post development scenarios. This assumed an initial loss of 40 mm and a continuing loss of 5 mm/hr. This loss model was adopted after comparing peak flows from XP Storm with flow gauging data from stations on the Harding River and Tanberry Creek. This approach was developed in discussion with the (then) Department of Water.

5.2.5 Discharge Cross-Sections

Two discharge cross-sections (i.e. XS1 and XS2 shown in Figure 8) have been selected where discharge hydrographs are extracted from the model for determination of the critical duration and temporal pattern.

5.2.6 Additional Model Parameters

The following secondary model parameters were adopted in MIKE21FM:

- Uniform Manning's M (n^{-1}): 20 (n = 0.05);
- Drying Depth: 0.001 m;
- Flooding Depth: 0.002 m;
- Wetting Depth: 0.0021 m;
- Uniform and constant value of 0.2 for Eddy Viscosity formulation; and
- Adaptive time-stepping scheme: 0.05 s minimum, 0.5 s maximum to ensure the critical Courant-Friederich-Lévy (CFL) number 0.8 is maintained.

5.3 MIKE11

A total of 38 culverts were included in the MIKE11 model, sourced mainly from surveyed datasets published in JDA (2012 & 2013) including those shown in Figure 8.

The MIKE11 model comprises an array of input files with key structure specifications, specifically:

- network module, which contains information on the details of culverts including location, size, length inverts, Manning's number, and entry and exit energy losses;
- cross-section module, which contains information on the natural surface sections at structure locations;
- boundary module, which includes information on boundary condition for coupling with MIKE21FM;
- hydraulic parameters module; and
- simulation file which links the four above datasets to create the framework through which MIKE11 is coupled with MIKE21FM via MIKEFLOOD.

6. FLOOD MODELLING RESULTS

6.1 Scenarios

The hydraulic model was used to assess two (2) main scenarios, specifically:

- Pre-Development Conditions:
- Post-Development Conditions:

Post-Development Conditions have been compared with JDA (2012a) for 1% AEP.

6.2 Pre-Development

Discharge hydrographs at XS1 and XS2 were used to identify the critical design storm duration and temporal pattern.

Table 5 presents summary results at XS1 for the four rainfall ensembles. The highest calculated median of the maximum discharges is 17.8 m^3/s in the 2 hour storm.

Similarly, Table 6 presents the summary results at XS2 adjacent to the proposed Structure Plan. The highest median is 26.1 m^3/s also in the 2 hour storm.

The 2 hour storm duration with TP08 was identified to be critical for the Study Area.

Details of discharge hydrographs ensembles are provided in Appendix A.

Figure 9 shows 1% AEP pre-development flood mapping for TP08 with both maximum water depth colour palette (m) and Tag Points showing maximum flood water level (mAHD), depth (m), velocity (m/s) and hazard as a product between Velocity and Depth (VxD).

TABLE 5: PRE-DEVELOPMENT MODEL RESULTS AT XS1

Storm Duration	0.5 hr	1.0 hr	2.0 hr	3.0 hr
Temporal Pattern	**Max. Flow [m^3/s]**	**Max. Flow [m^3/s]**	**Max. Flow [m^3/s]**	**Max. Flow [m^3/s]**
TP01	4.9	17.8	12.9	13.9
TP02	5.4	16.1	13.9	17.6
TP03	5.0	13.5	17.9	13.1
TP04	5.0	14.7	24.1	21.2
TP05	4.9	13.5	18.4	11.0
TP06	5.4	12.8	12.7	21.8
TP07	4.9	16.5	14.9	25.1
TP08	4.9	12.3	17.7	12.3
TP09	5.0	13.7	20.9	14.1
TP10	5.4	15.4	24.9	14.5
Maximum	**5.4**	**17.8**	**24.9**	**25.1**
Mean	**5.1**	**14.6**	**17.8**	**16.4**
Median	**5.0**	**14.2**	**17.8**	**14.3**
Closest to Simulated	**5.00**	**14.7**	**17.9**	**14.5**
Closest TP	**TP03**	**TP04**	**TP03**	**TP10**

TABLE 6: PRE-DEVELOPMENT MODEL RESULTS AT XS2

Storm Duration	0.5 hr	1.0 hr	2.0 hr	3.0 hr
Temporal Pattern	**Max. Flow [m³/s]**	**Max. Flow [m³/s]**	**Max. Flow [m³/s]**	**Max. Flow [m³/s]**
TP01	4.9	18.1	21.6	24.9
TP02	5.2	17.0	23.1	28.7
TP03	4.9	15.8	26.0	18.1
TP04	4.9	16.3	31.4	29.0
TP05	4.9	15.3	27.2	17.5
TP06	5.2	15.1	17.4	34.7
TP07	4.9	17.4	23.2	37.9
TP08	49	14.8	26.1	18.9
TP09	4.9	15.8	29.2	22.1
TP10	5.2	16.7	32.0	23.2
Maximum	**5.2**	**18.1**	**32.0**	**37.9**
Mean	**5.0**	**16.2**	**25.7**	**25.5**
Median	**4.9**	**16.1**	**26.1**	**24.0**
Closest to Simulated	**4.9**	**16.3**	**26.1**	**24.9**
Closest TP	**TP03**	**TP04**	**TP08**	**TP01**

6.3 Post-Development

Figure 10 shows 1% AEP post-development flood mapping results.

Figure 11 shows the difference between the pre- and post-development scenario, specifically:

- Post-development flood level is lower over the area around Karratha Cemetery and along the western edge of the proposed Structure Plan;
- Post-development flood level rises less than 50 mm across the whole Madigan Creek floodplain, except for locally higher flood level in the vicinity of the two road crossings;
- Post-development flood level over Dampier Road rises (+0.01 m) and further downstream (up to +0.02 m).

Figure 12 shows the 100-year ARI flood mapping for the Study Area as published in JDA,2012.

Figure 13 shows the difference in flood levels between the revised JDA post-development flood model using ARR2019 compared to JDA (2012a). It can be seen that the post-development Madigan Creek floodplain simulated with ARR2019 is on average approximately 0.1 m lower than JDA (2012a), by up to 0.6 m immediately south of Dampier Road and around Karratha Cemetery.

This is mostly associated with the JDA (2012a) model having a constant water level boundary along Dampier Road at 14.66 mAHD, sourced from GHD (2009), whereas the current JDA post-development model has better definition in that location.

All Tag Points TP1 to TP11 show lower post-development flood levels than in JDA (2012a) by up to 0.82 m along Dampier Road.

On Figure 13 the localised increase in water level (indicated by red colour) of up to 0.2 m at the margins of the floodway at the southern end are associated with the different modelling approaches between current and JDA (2012a).

Development levels should be a minimum of 0.5 m above post-development water levels.

7. CONCLUSIONS

JDA concludes that:

- This flood study for Madigan Creek using ARR2019 supersedes JDA (2012a);
- This flood study focuses on the proposed Madigan Structure Plan and its potential impacts on the Madigan Creek flooding regime;
- The ARR2019 Karratha IFD design rainfall estimates are significantly lower than in ARR1987, up to -46% for the identified critical storm duration of 2 hours;
- This flood study uses a larger model area compared to JDA (2012a) to adequately simulate the 1% AEP flood hydraulics;
- 1% AEP post-development flood mapping using ARR2019 in this flood study shows a flood level rise above pre-development generally less than 0.05 m as recommended by DWER;
- 1% AEP post-development flood levels in this study are approximately 0.1 m lower on average than estimated in JDA (2012a), probably associated with lower rainfall IFD;
- 1% AEP post-development flood levels in this study are locally higher (up to 0.2 m) than estimated in JDA (2012a), associated with improvements in modelling methods;
- DWER recommends a minimum Finished Floor Level (FFL) 0.5 m above the post-development 1% AEP flood level.

8. REFERENCES

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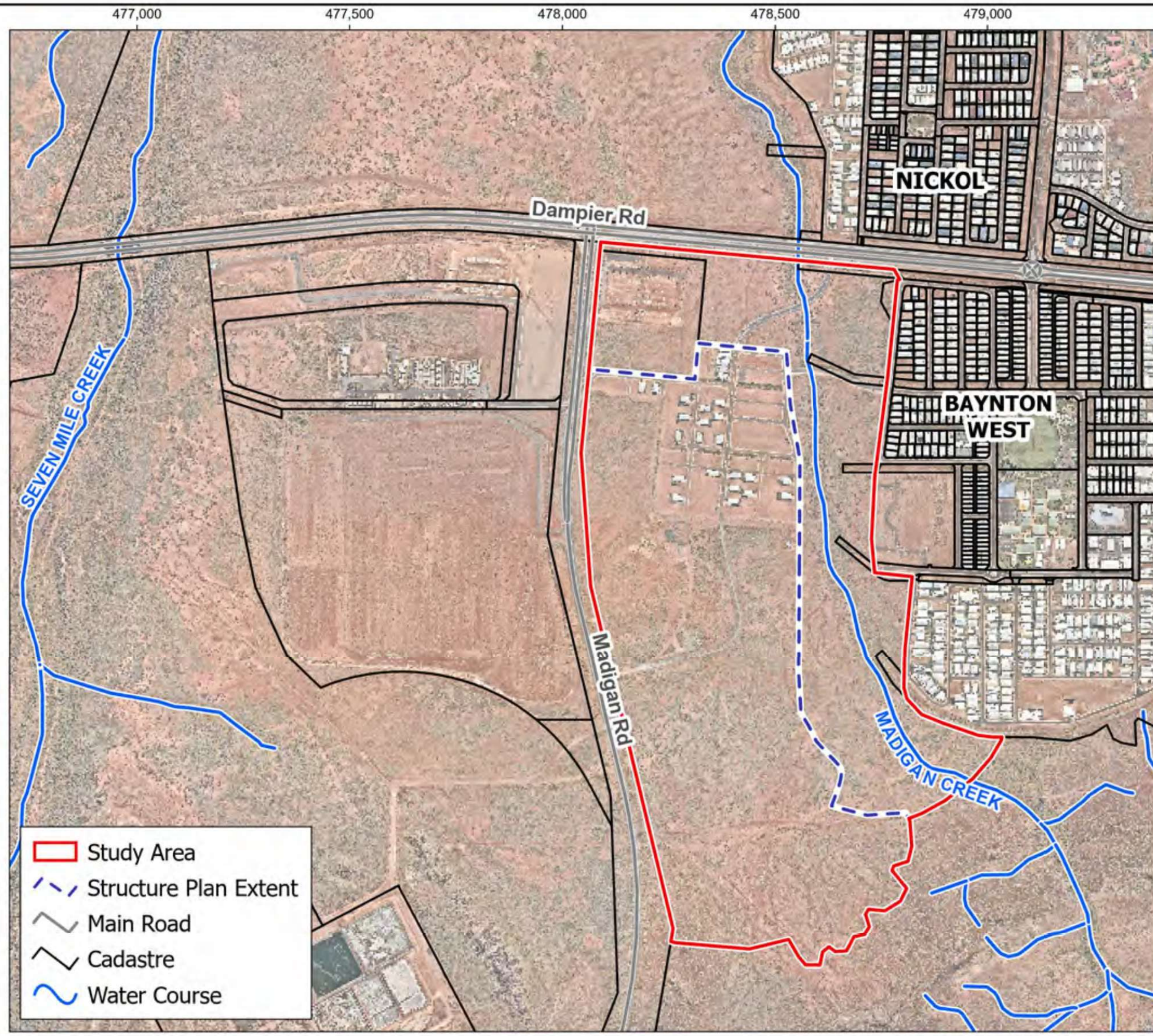
Luke, G.L., Burke, K.L. & O'Brien, T.M. (1988). 'Evaporation Data for Western Australia – Technical Report No. 65', Perth: W.A. Department of Agriculture, Division of Resource Management.

FIGURES



Data Source: Nearmap Digital Imagery, 24 April 2020;

Coordinate System: GDA2020 MGA Zone 50

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Job No. J6919

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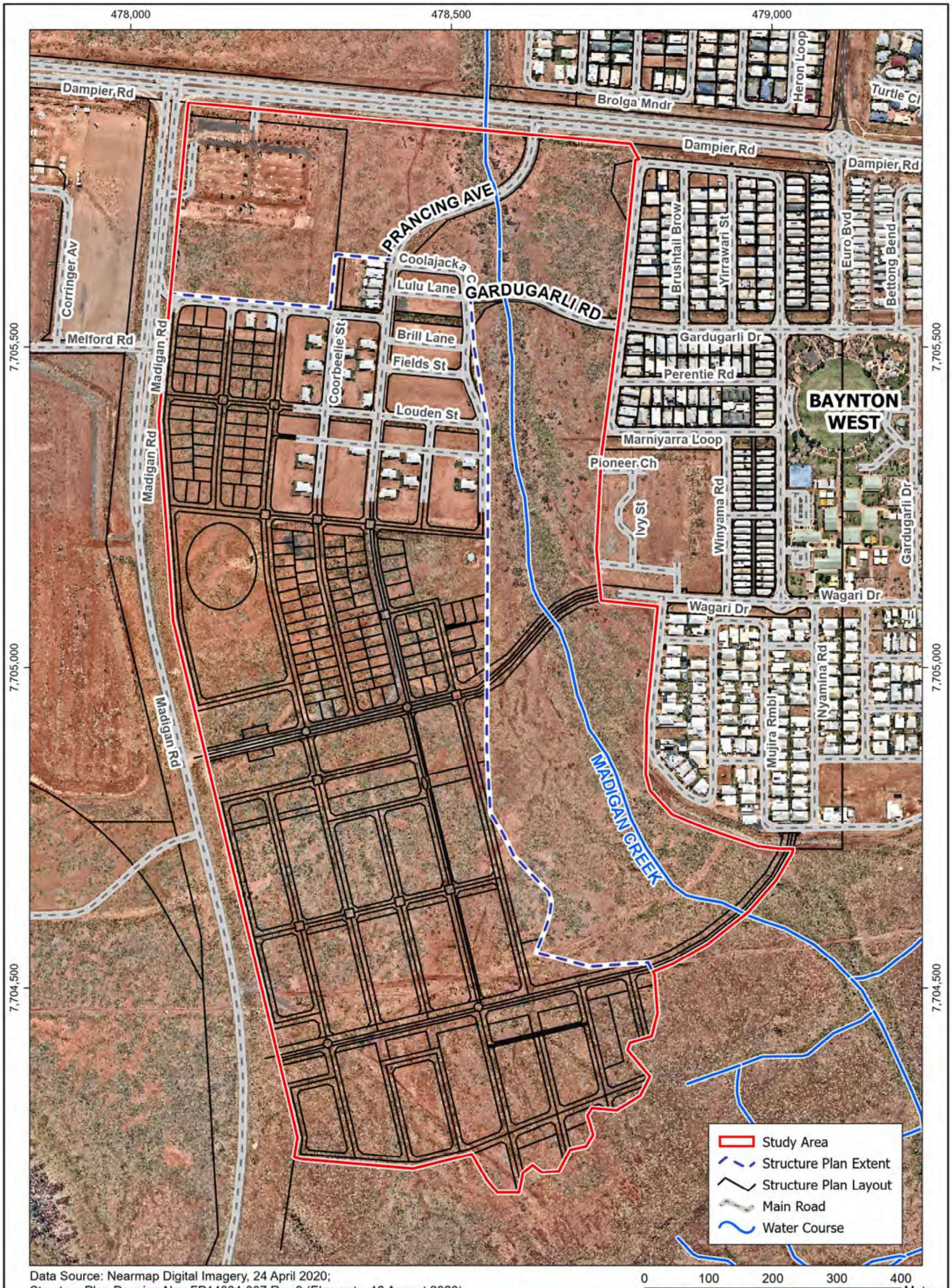
Figure 1: Location Plan



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Structure Plan Drawing No.: FP14004-007 Rev.9 (Elements, 18 August 2020);

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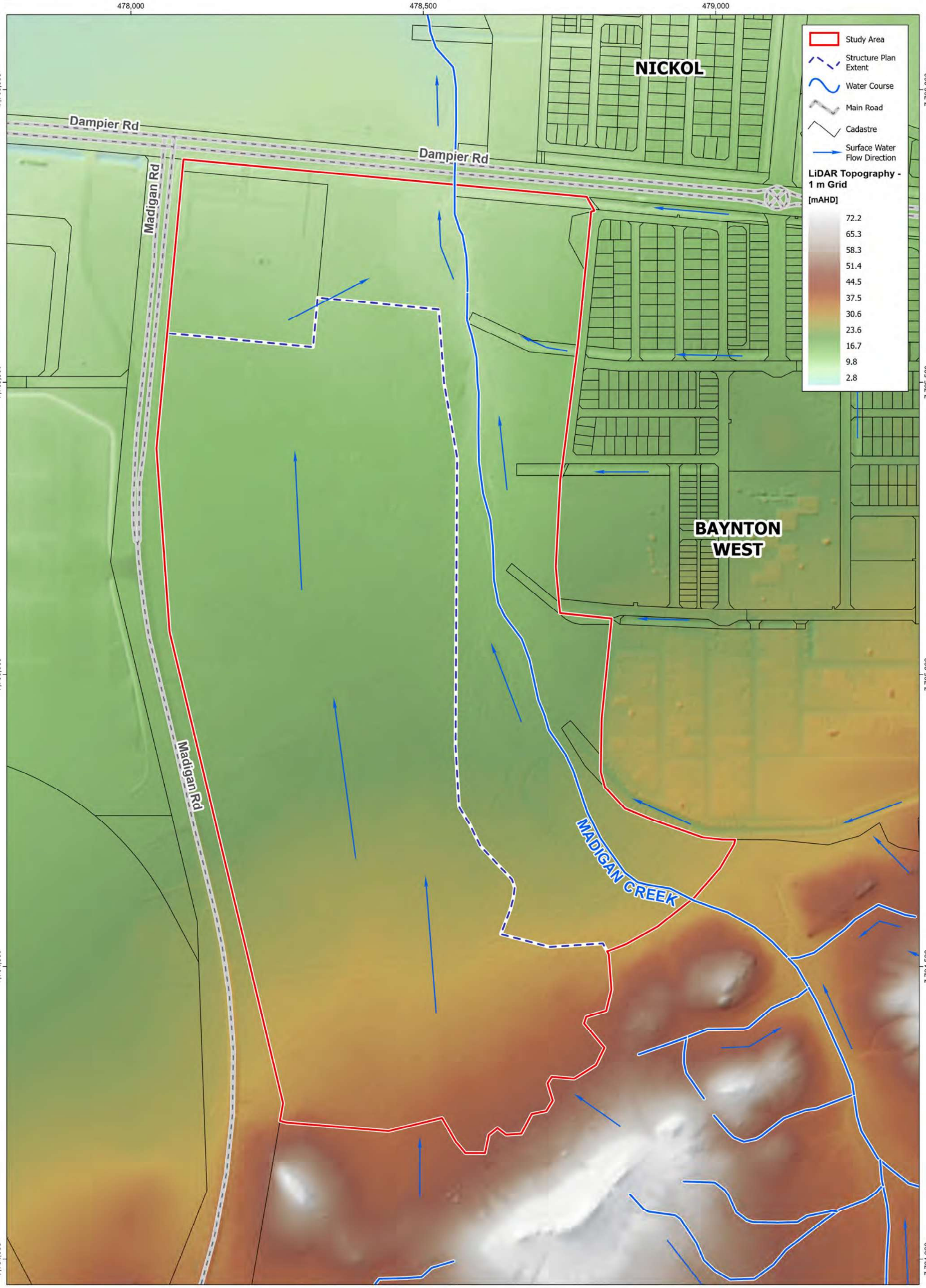
Figure 2: Proposed Structure Plan



Data Source: Ground LiDAR Topography Survey (LandCorp, November 2010 & May 2012);

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Job No. J6919

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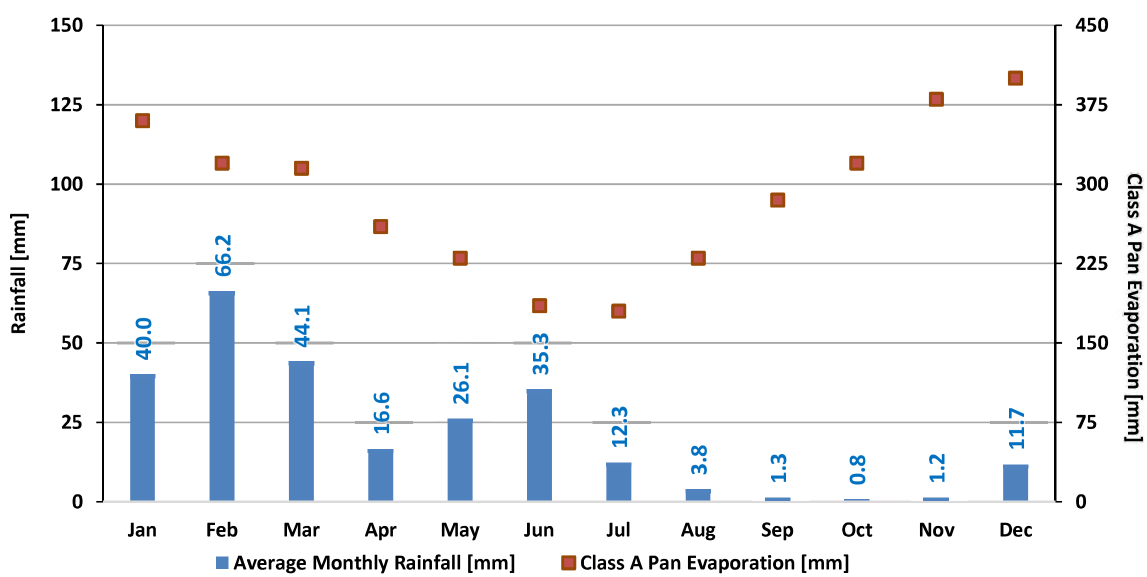
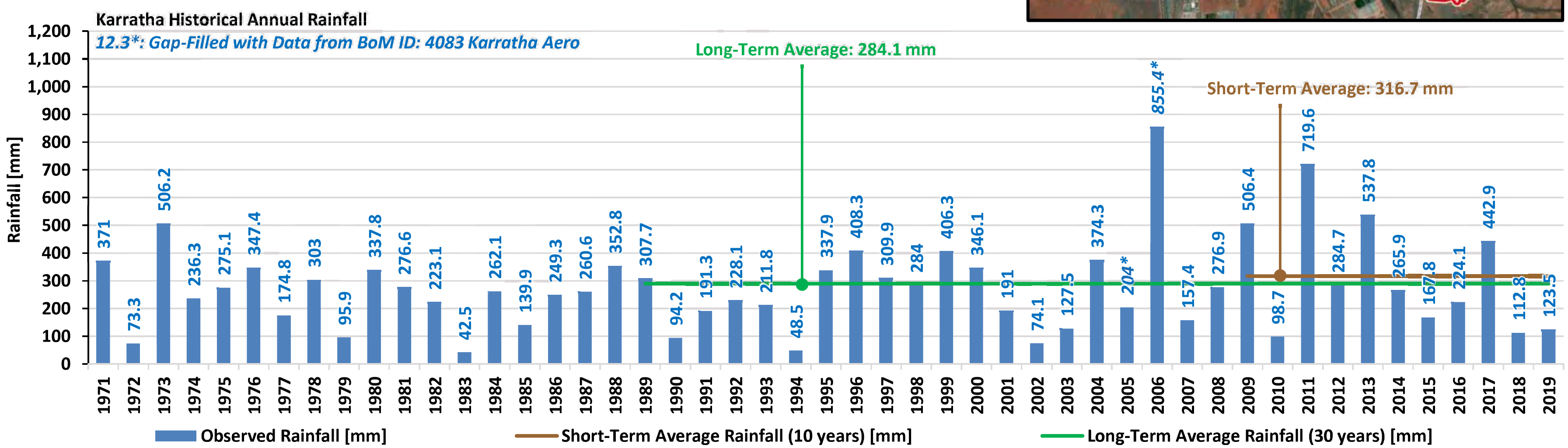
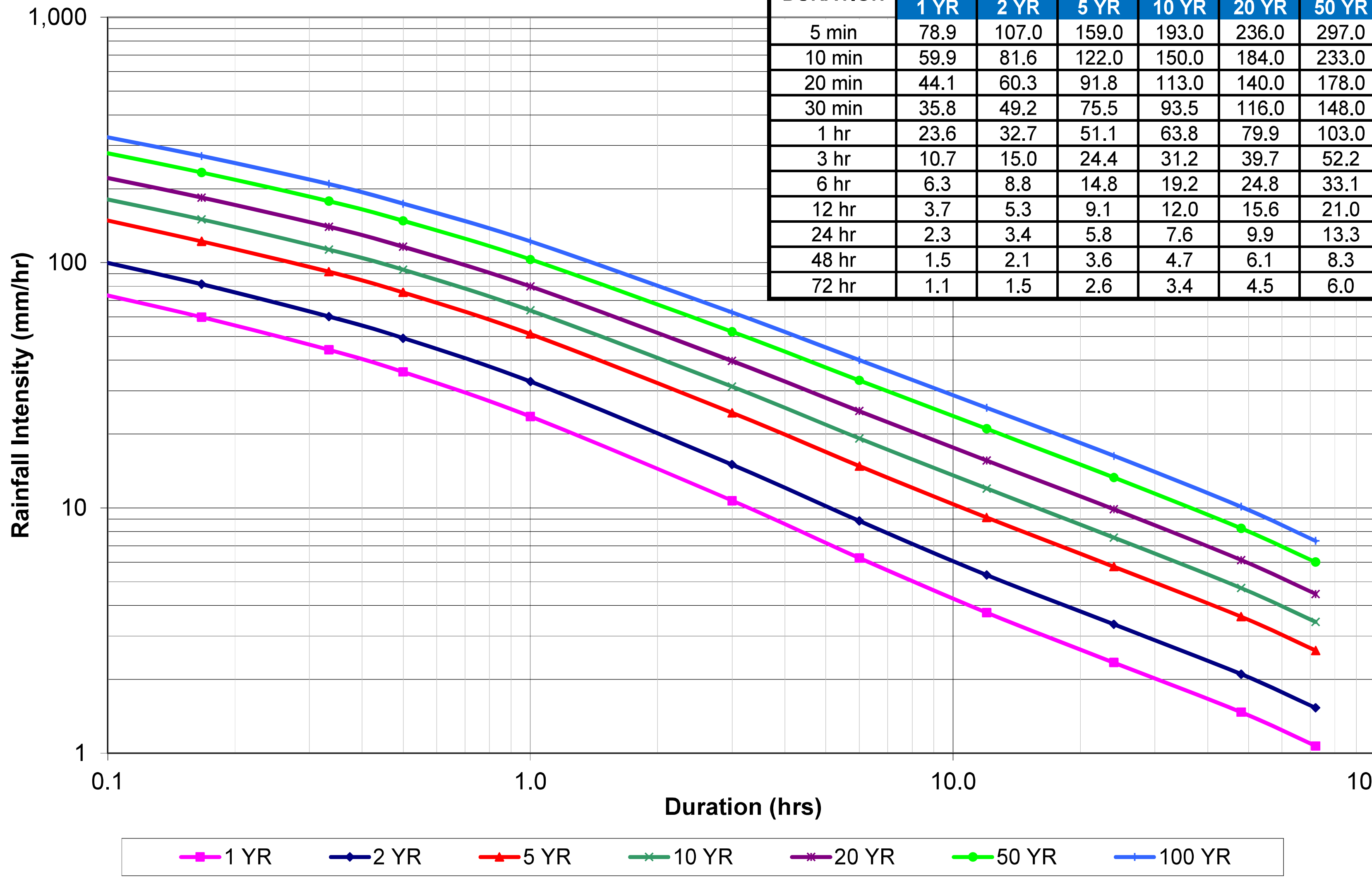
Figure 3: Topography





Data Source: Karratha Aero and Dampier Salt Rain Gauging Stations IDs: 4083 and 5061 (Bureau of Meteorology, 2020); Evaporation Data for Western Australia (Luke, *et al.*, 1987);

JDA	Job No. J6919	DevelopmentWA Madigan Creek Flood Study **Figure 4: Historical Rainfall Data**



DURATION	Rainfall Intensity [mm/hr]						
	1 YR	2 YR	5 YR	10 YR	20 YR	50 YR	100 YR
5 min	78.9	107.0	159.0	193.0	236.0	297.0	345.0
10 min	59.9	81.6	122.0	150.0	184.0	233.0	272.0
20 min	44.1	60.3	91.8	113.0	140.0	178.0	209.0
30 min	35.8	49.2	75.5	93.5	116.0	148.0	174.0
1 hr	23.6	32.7	51.1	63.8	79.9	103.0	122.0
3 hr	10.7	15.0	24.4	31.2	39.7	52.2	62.6
6 hr	6.3	8.8	14.8	19.2	24.8	33.1	40.0
12 hr	3.7	5.3	9.1	12.0	15.6	21.0	25.6
24 hr	2.3	3.4	5.8	7.6	9.9	13.3	16.3
48 hr	1.5	2.1	3.6	4.7	6.1	8.3	10.1
72 hr	1.1	1.5	2.6	3.4	4.5	6.0	7.3

Data Source: Bureau of Meteorology 1987 IFD Dataset, Point Source Karratha E: 479105 N: 7704550;

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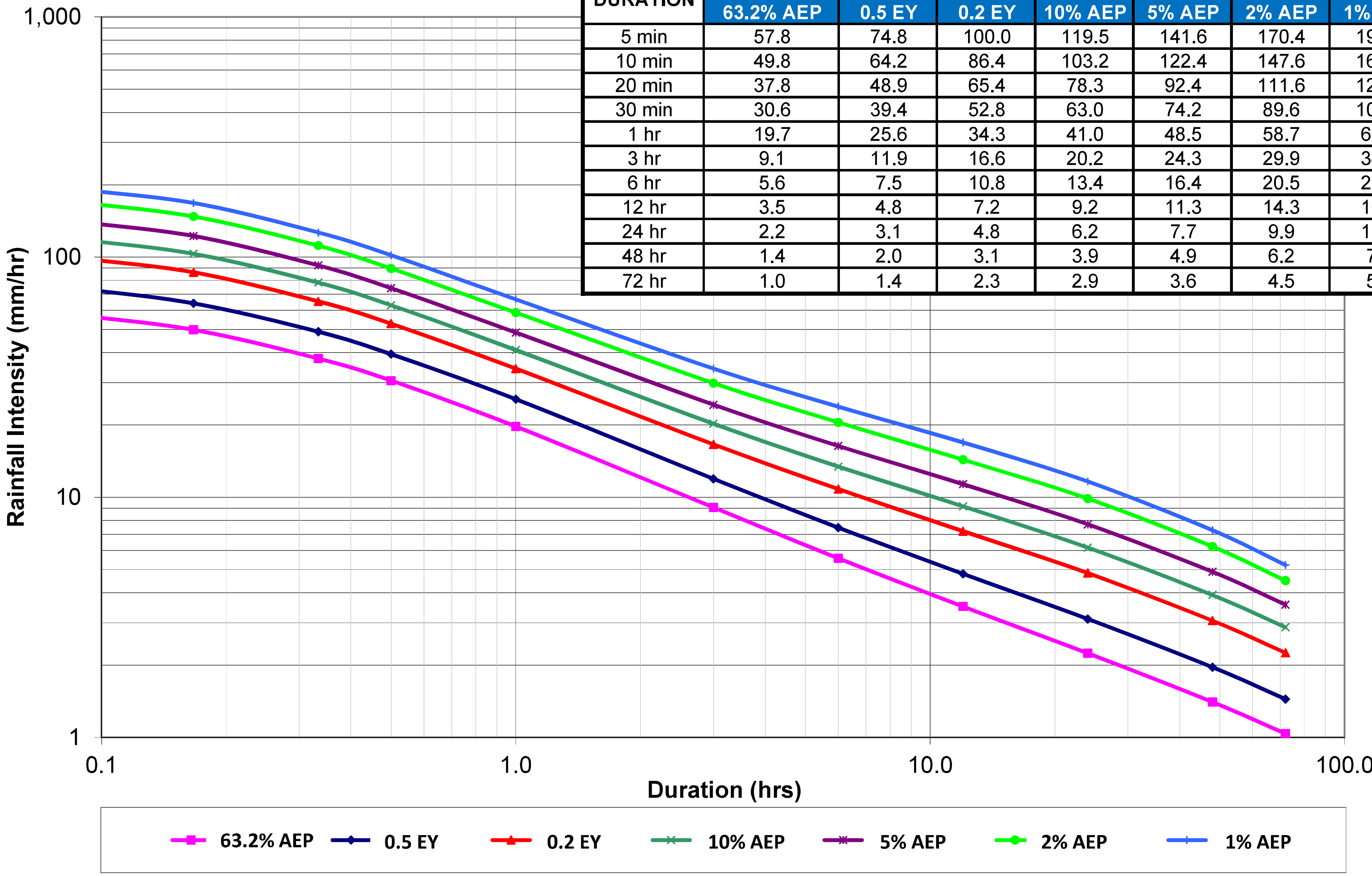
Figure 5: Karratha AR&R1987 Intensity-Frequency-Duration (IFD) Curves



DURATION	Rainfall Intensity [mm/hr]						
	63.2% AEP	0.5 EY	0.2 EY	10% AEP	5% AEP	2% AEP	1% AEP
5 min	57.8	74.8	100.0	119.5	141.6	170.4	193.2
10 min	49.8	64.2	86.4	103.2	122.4	147.6	168.0
20 min	37.8	48.9	65.4	78.3	92.4	111.6	126.6
30 min	30.6	39.4	52.8	63.0	74.2	89.6	101.8
1 hr	19.7	25.6	34.3	41.0	48.5	58.7	66.7
3 hr	9.1	11.9	16.6	20.2	24.3	29.9	34.3
6 hr	5.6	7.5	10.8	13.4	16.4	20.5	23.8
12 hr	3.5	4.8	7.2	9.2	11.3	14.3	16.9
24 hr	2.2	3.1	4.8	6.2	7.7	9.9	11.6
48 hr	1.4	2.0	3.1	3.9	4.9	6.2	7.3
72 hr	1.0	1.4	2.3	2.9	3.6	4.5	5.2

Data Source: Bureau of Meteorology 2019 IFD Dataset, Point Source Karratha E: 479105 N: 7704550 (BoM, 2020);

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Figure 6: Karratha AR&R2019 Intensity-Frequency-Duration (IFD) Curves

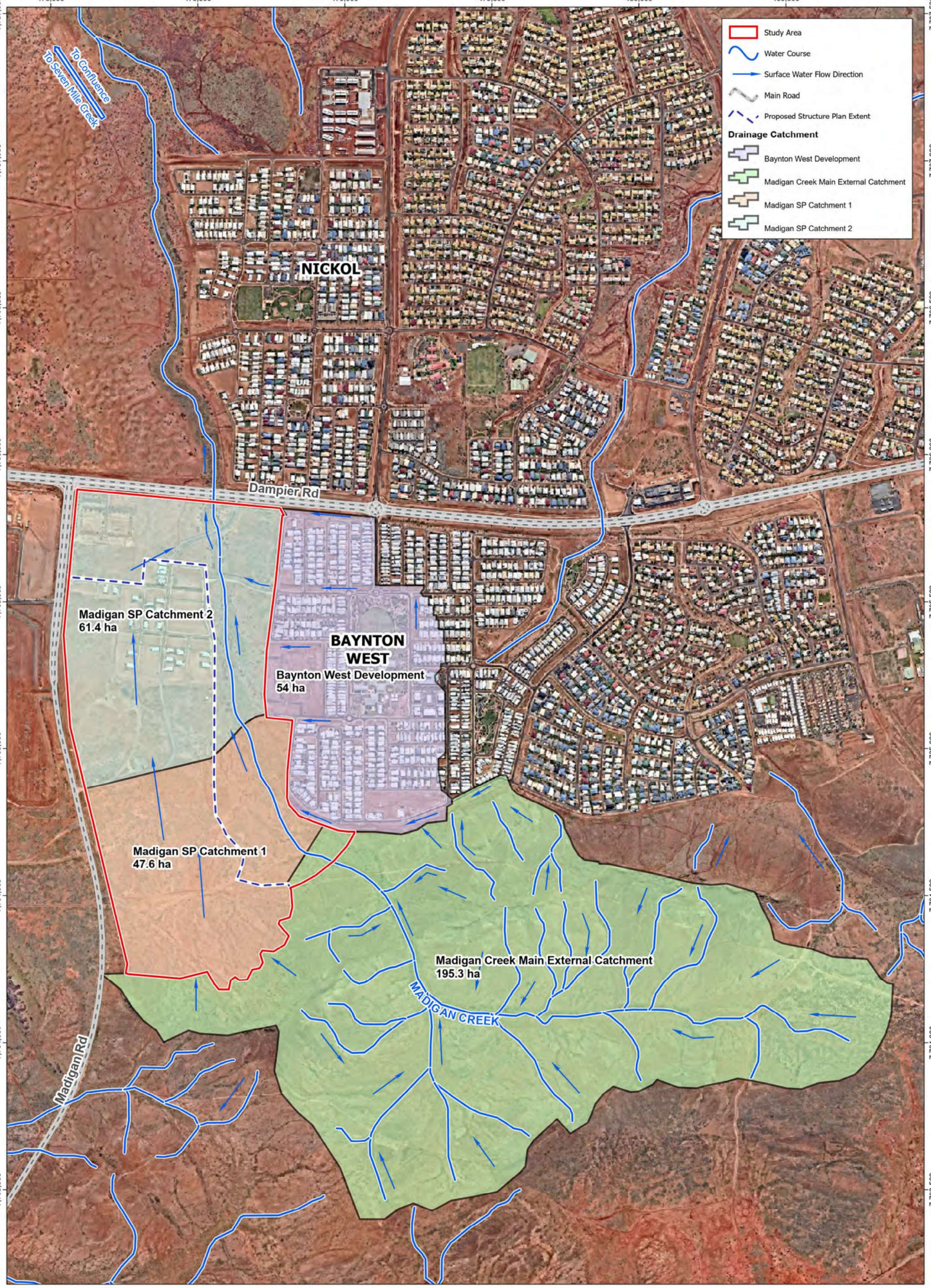

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Figure 7: Drainage Catchments and Hydrology Mapping

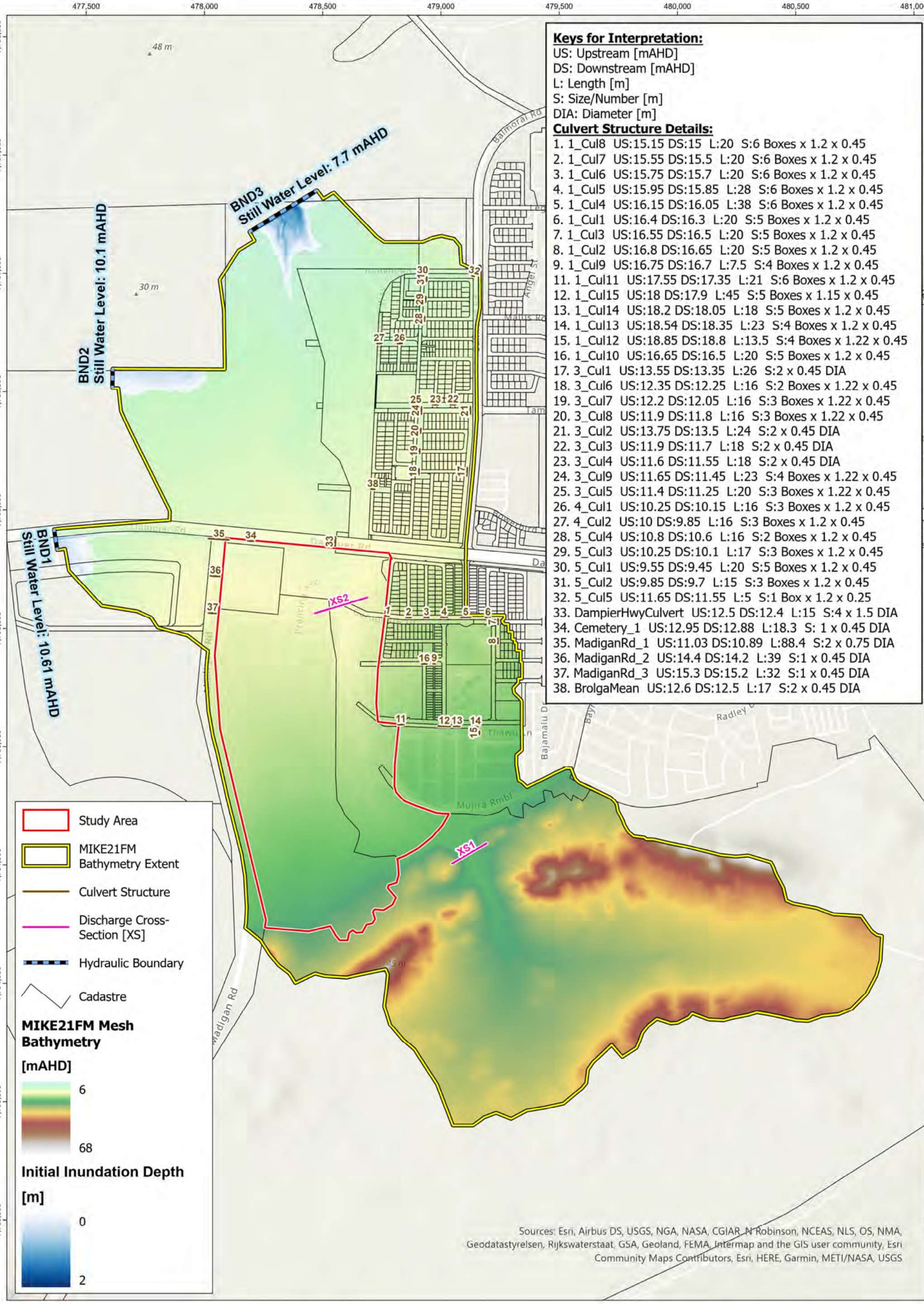

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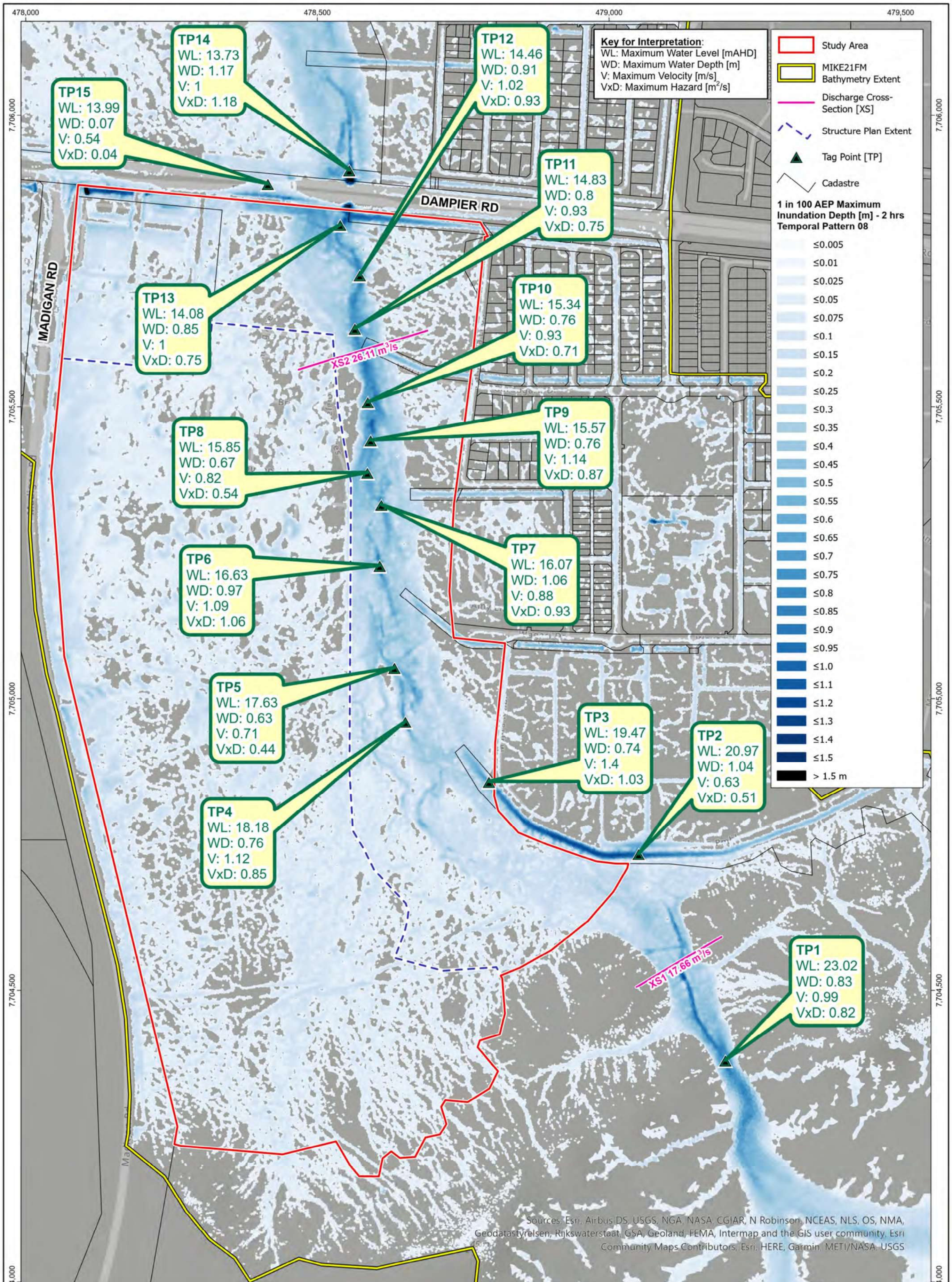
Figure 8: MIKE FLOOD Hydraulic Model Setup



Data Source:

Coordinate System: GDA2020 MGA Zone 50

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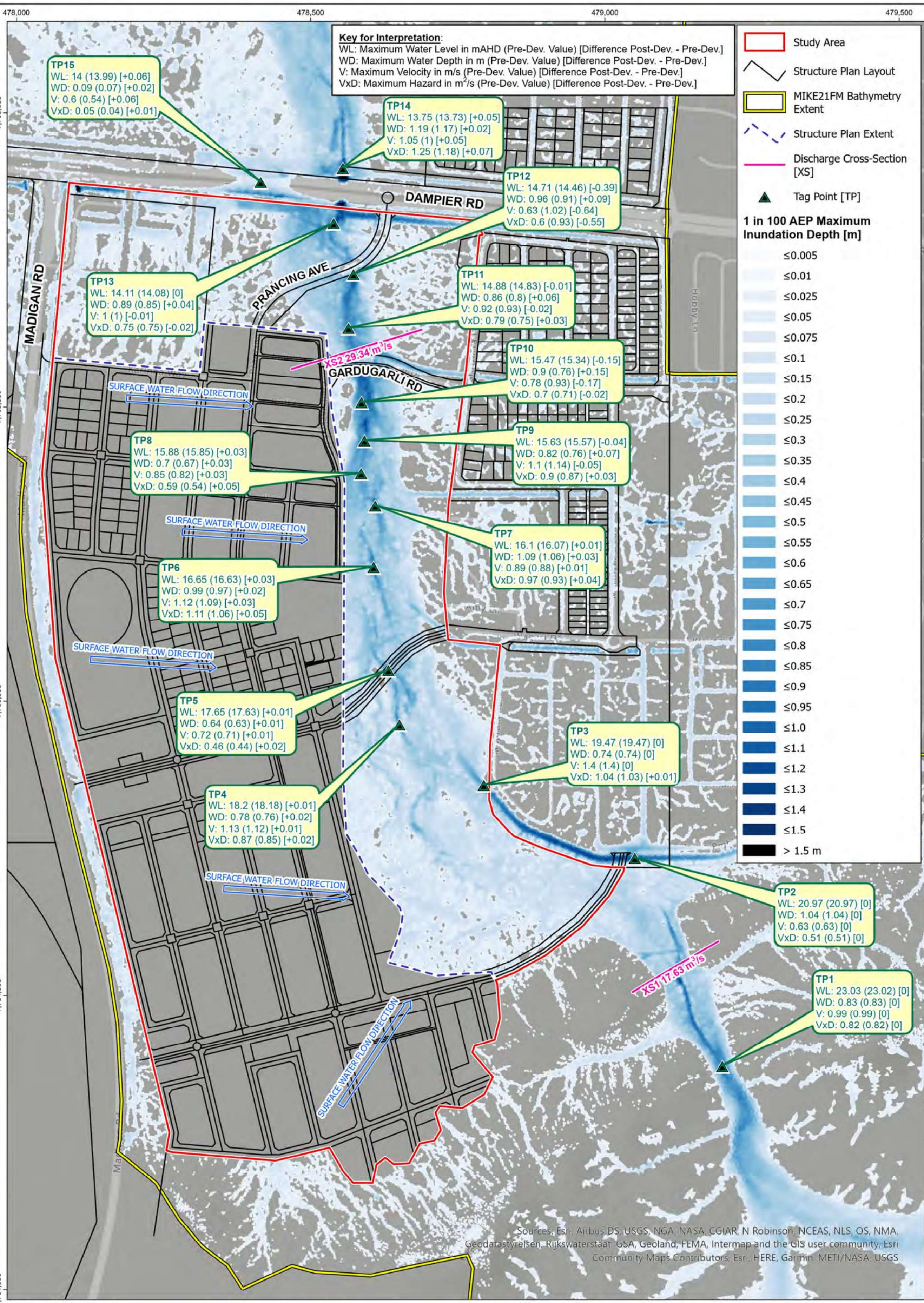
Figure 9: Existing Conditions 1% AEP Flood Mapping



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Coordinate System: GDA2020 MGA Zone 50

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Scale: 1:6,000 @A3

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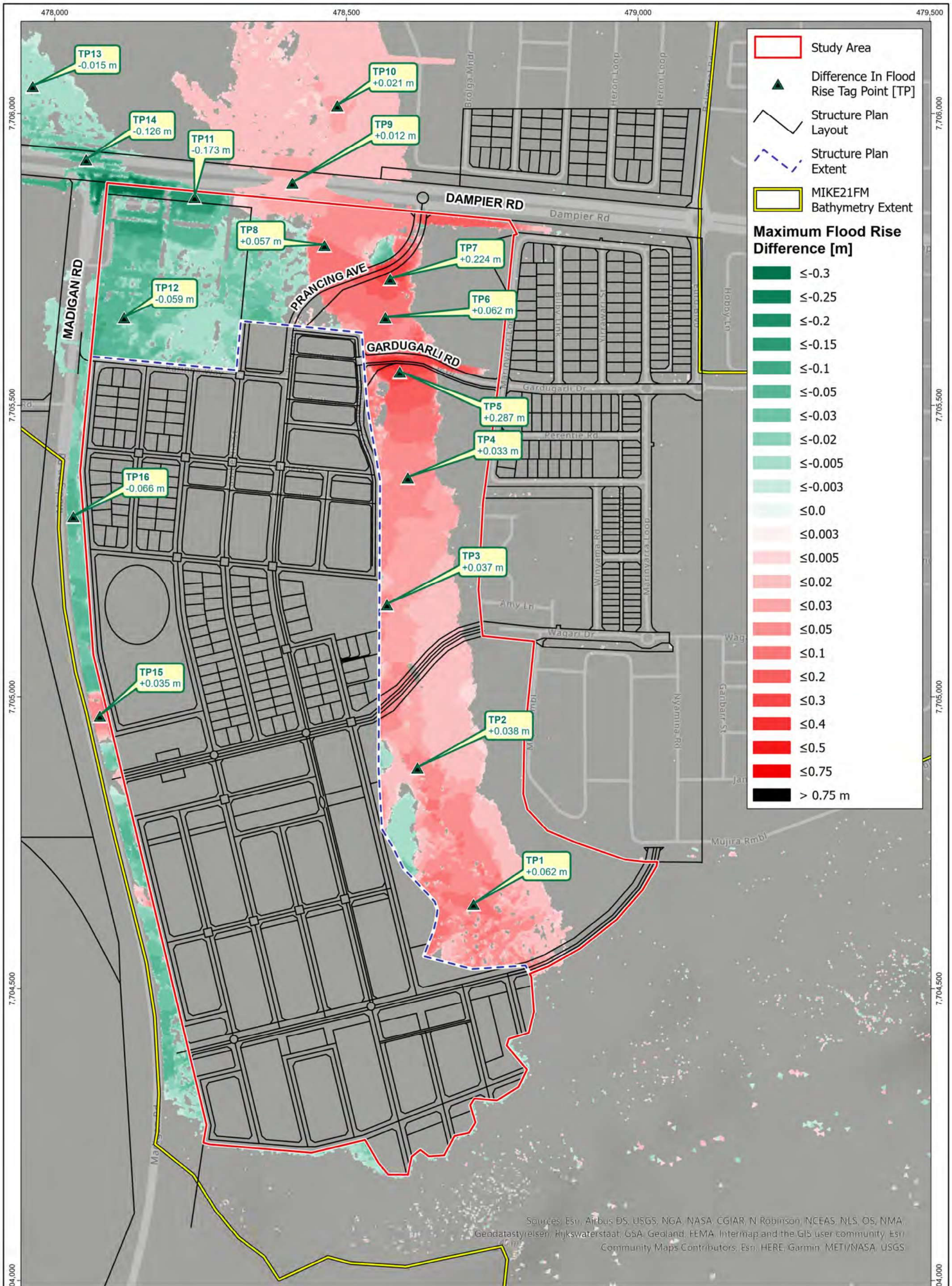
Figure 10: 1% AEP Post-Development Flood Mapping



Data Source:

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Job No. J6919
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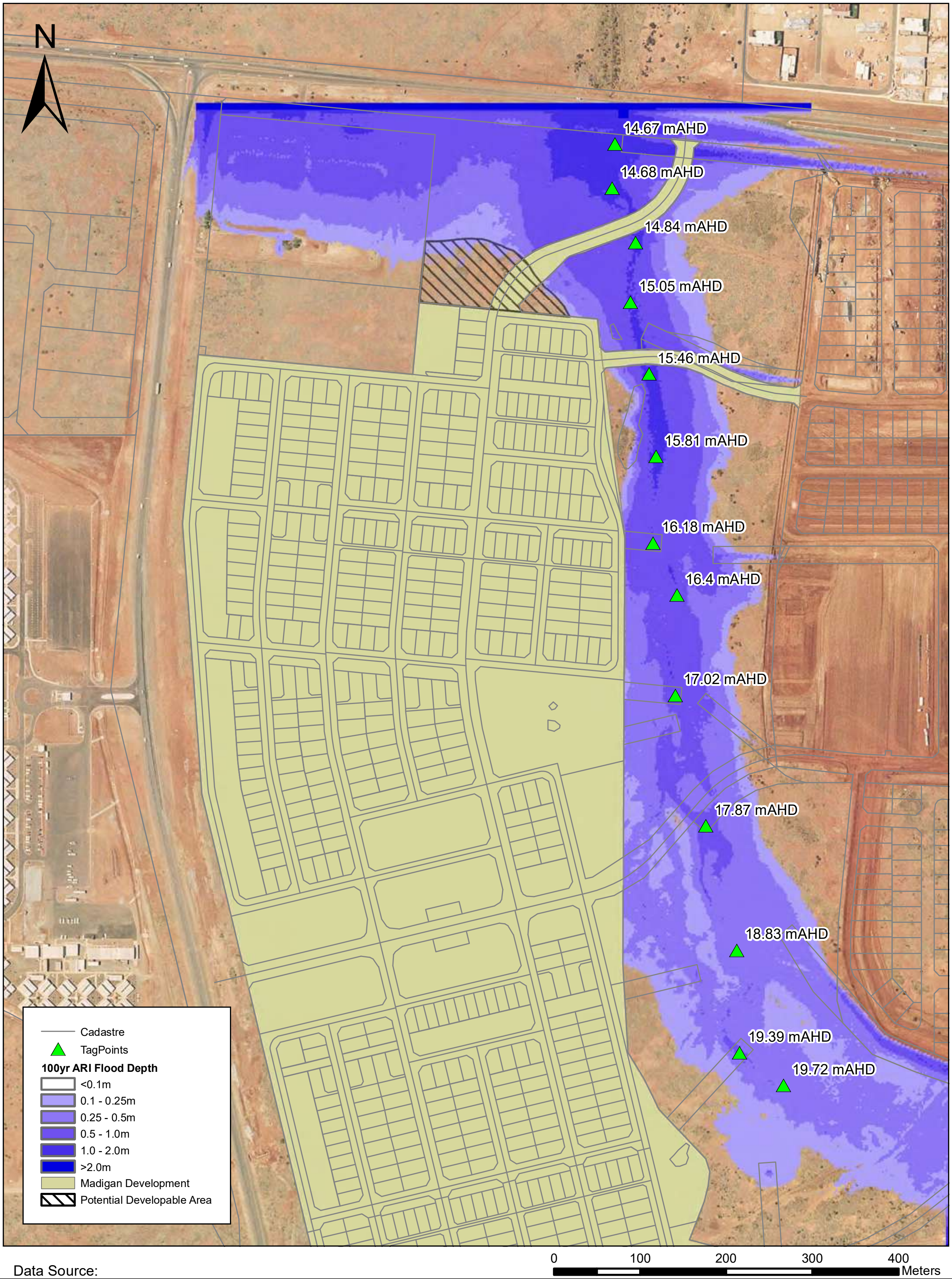
Figure 11: Madigan Creek Post-Development Flood Rise Compared to Pre-Development Conditions



Data Source:

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Job No. J6919

Scale 1:6,000

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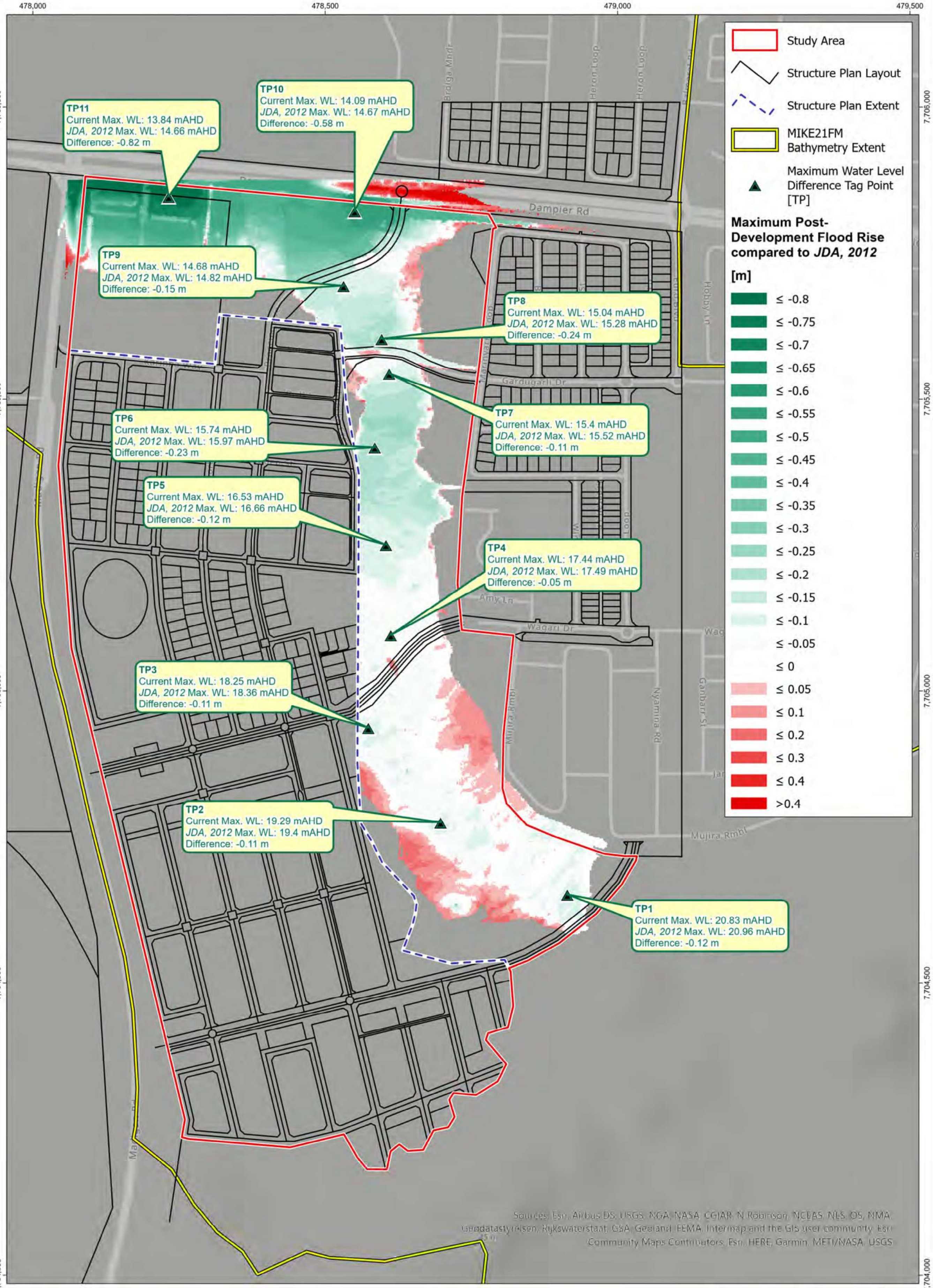
Figure 12: Madigan Creek Post Development 100yr ARI Flood Depth & Levels from JDA, 2012



Data Source:

Coordinate System: GDA2020 MGA Zone 50

Job No. J6919

Scale: 1:6,000 @A3

0 150 300 450 Metres

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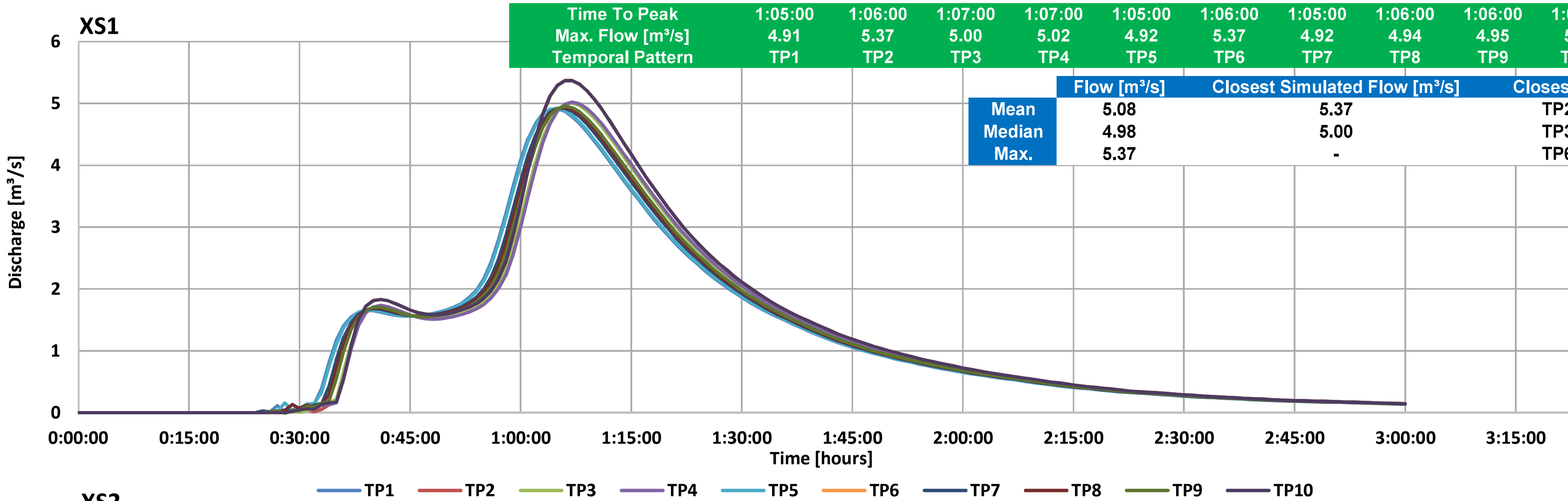
Figure 13: Madigan Creek 1% AEP Post-Development Flood Rise compared to *JDA, 2012*

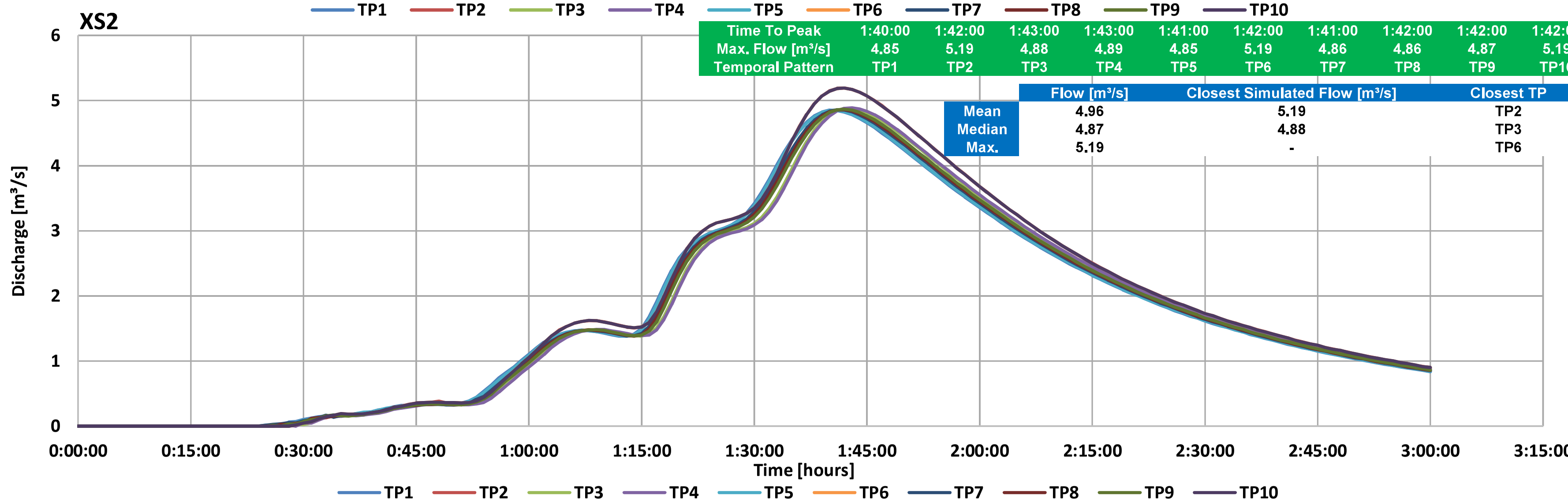
APPENDIX A

MIKE21FM Hydraulic Ensembles –
Madigan Creek Catchment Hydrology Results



Time To Peak	1:05:00	1:06:00	1:07:00	1:07:00	1:05:00	1:06:00	1:05:00	1:06:00	1:06:00	1:06:00
Max. Flow [m³/s]	4.91	5.37	5.00	5.02	4.92	5.37	4.92	4.94	4.95	5.37
Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10

	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	5.08	5.37	TP2
Median	4.98	5.00	TP3
Max.	5.37	-	TP6



Time To Peak	1:40:00	1:42:00	1:43:00	1:43:00	1:41:00	1:42:00	1:41:00	1:42:00	1:42:00	1:42:00
Max. Flow [m³/s]	4.85	5.19	4.88	4.89	4.85	5.19	4.86	4.86	4.87	5.19
Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10

	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	4.96	5.19	TP2
Median	4.87	4.88	TP3
Max.	5.19	-	TP6

NB: see Figure 8 for Cross-Section Locations; XS1 starts at [E]479048-[N]7704507 and ends at [E]479193-[N]7704592; XS2 starts at [E]478468-[N]7705566 and ends at [E]478689-[N]7705632;

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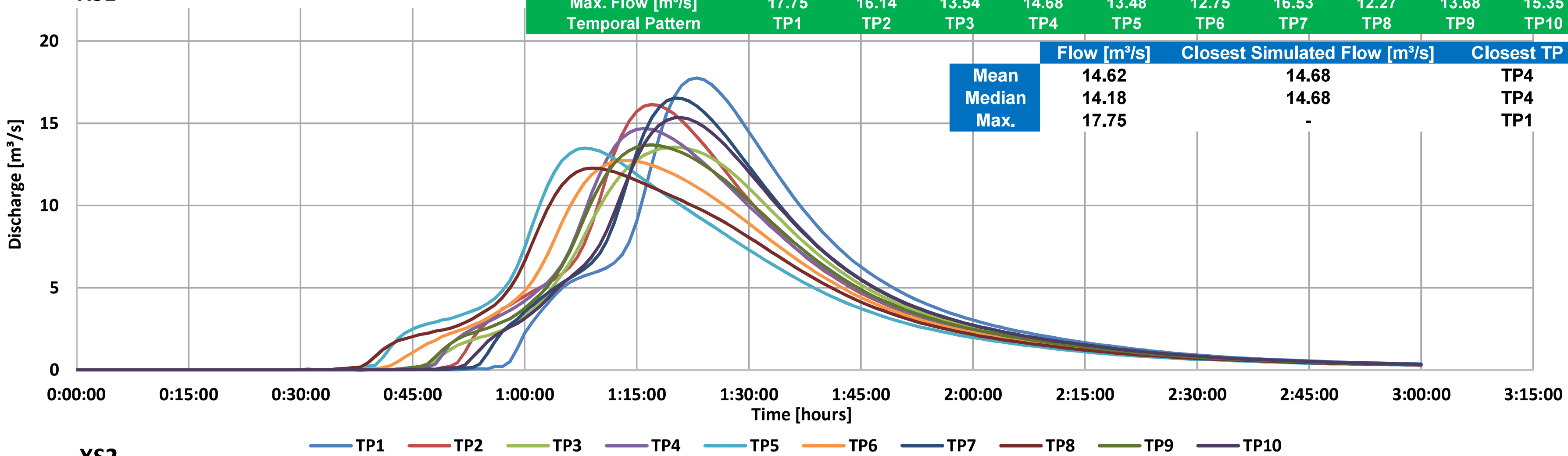
Figure A1: MIKE Catchment Hydrology Results - 1 in 100 AEP 30 Minutes

XS1

Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10
Time To Peak	1:23:00	1:17:00	1:20:00	1:16:00	1:08:00	1:13:00	1:20:00	1:09:00	1:17:00	1:21:00
Max. Flow [m³/s]	17.75	16.14	13.54	14.68	13.48	12.75	16.53	12.27	13.68	15.35

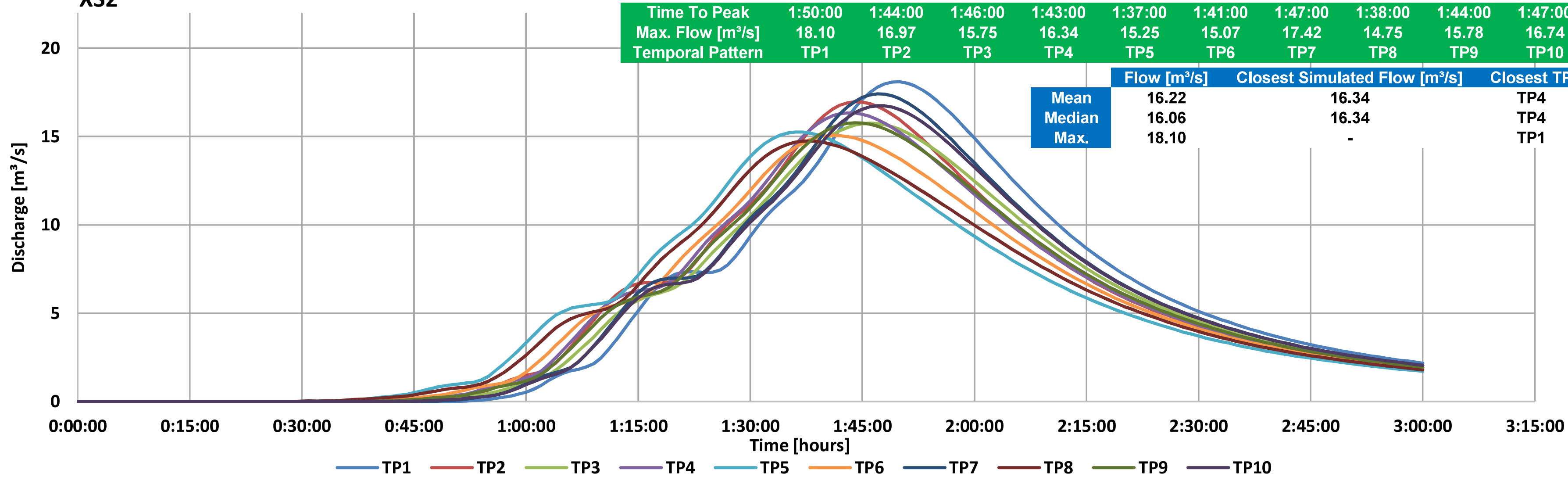
	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	14.62	14.68	TP4
Median	14.18	14.68	TP4
Max.	17.75	-	TP1



XS2

Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10
Time To Peak	1:50:00	1:44:00	1:46:00	1:43:00	1:37:00	1:41:00	1:47:00	1:38:00	1:44:00	1:47:00
Max. Flow [m³/s]	18.10	16.97	15.75	16.34	15.25	15.07	17.42	14.75	15.78	16.74

	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	16.22	16.34	TP4
Median	16.06	16.34	TP4
Max.	18.10	-	TP1



NB: see Figure 8 for Cross-Section Locations; XS1 starts at [E]479048-[N]7704507 and ends at [E]479193-[N]7704592; XS2 starts at [E]478468-[N]7705566 and ends at [E]478689-[N]7705632;

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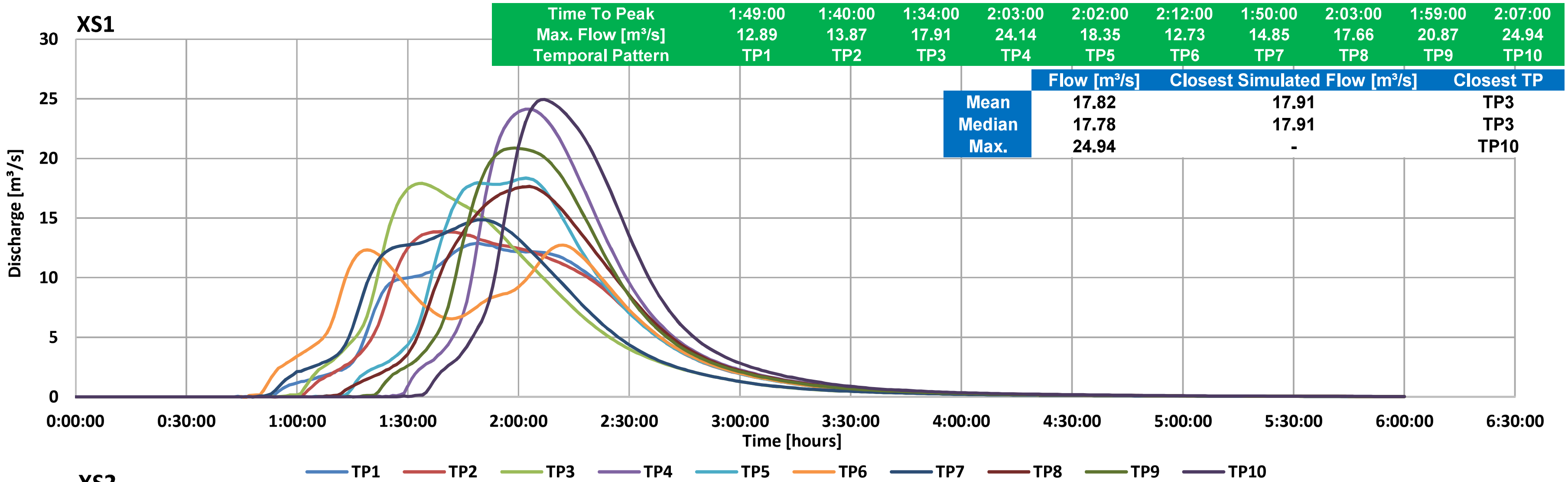
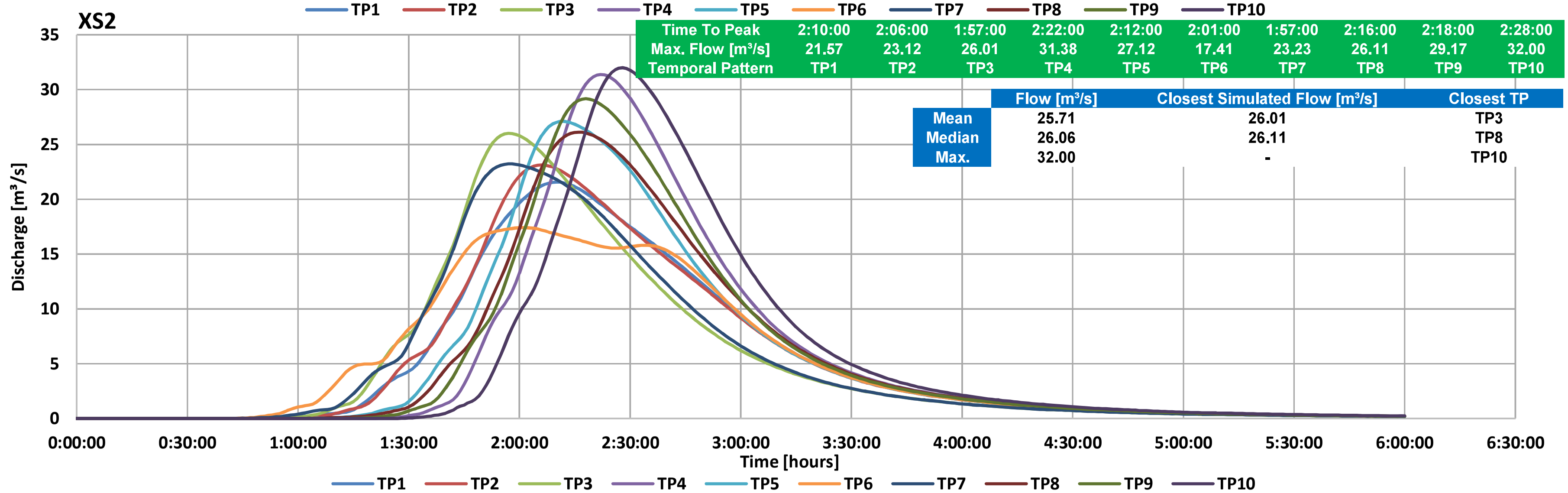
Figure A2: MIKE Catchment Hydrology Results - 1 in 100 AEP 1 Hour



Time To Peak	1:49:00	1:40:00	1:34:00	2:03:00	2:02:00	2:12:00	1:50:00	2:03:00	1:59:00	2:07:00
Max. Flow [m³/s]	12.89	13.87	17.91	24.14	18.35	12.73	14.85	17.66	20.87	24.94
Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10

	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	17.82	17.91	TP3
Median	17.78	17.91	TP3
Max.	24.94	-	TP10



Time To Peak	2:10:00	2:06:00	1:57:00	2:22:00	2:12:00	2:01:00	1:57:00	2:16:00	2:18:00	2:28:00
Max. Flow [m³/s]	21.57	23.12	26.01	31.38	27.12	17.41	23.23	26.11	29.17	32.00
Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10

	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	25.71	26.01	TP3
Median	26.06	26.11	TP8
Max.	32.00	-	TP10

NB: see Figure 8 for Cross-Section Locations; XS1 starts at [E]479048-[N]7704507 and ends at [E]479193-[N]7704592; XS2 starts at [E]478468-[N]7705566 and ends at [E]478689-[N]7705632;

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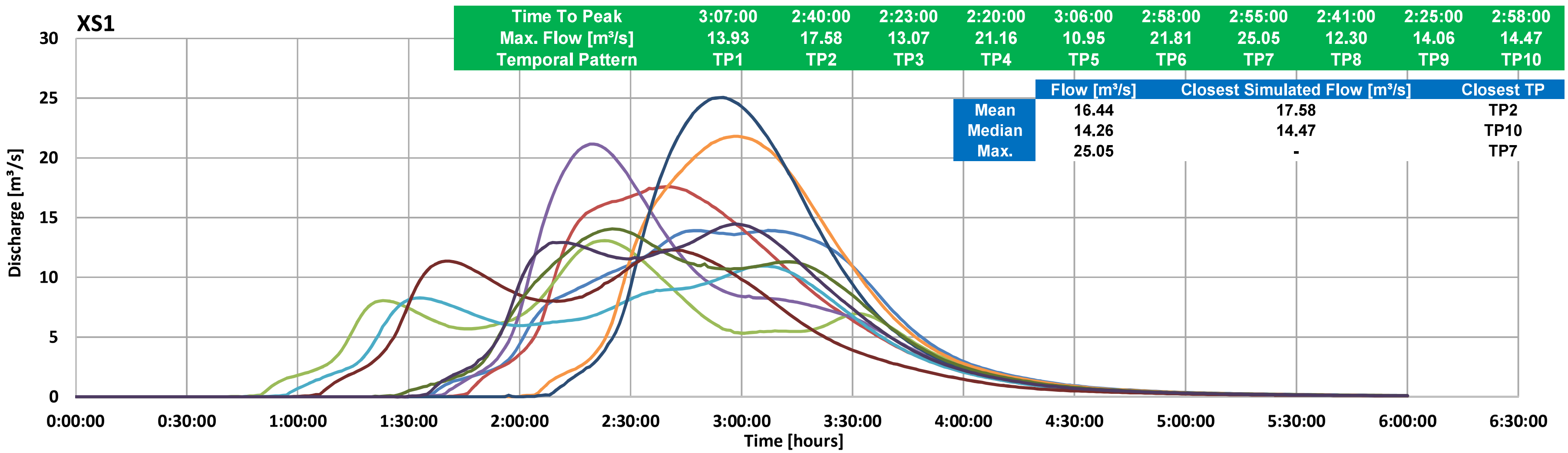
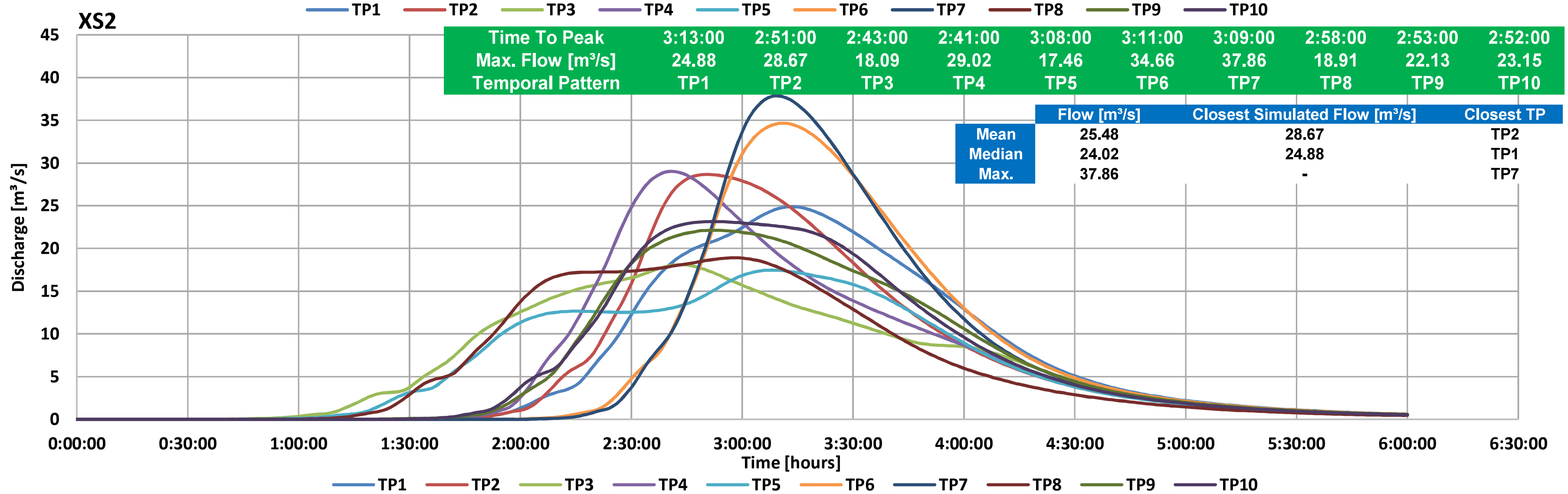
Figure A3: MIKE Catchment Hydrology Results - 1 in 100 AEP 2 Hours



Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10
Time To Peak	3:07:00	2:40:00	2:23:00	2:20:00	3:06:00	2:58:00	2:55:00	2:41:00	2:25:00	2:58:00
Max. Flow [m³/s]	13.93	17.58	13.07	21.16	10.95	21.81	25.05	12.30	14.06	14.47

	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	16.44	17.58	TP2
Median	14.26	14.47	TP10
Max.	25.05	-	TP7



Temporal Pattern	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10
Time To Peak	3:13:00	2:51:00	2:43:00	2:41:00	3:08:00	3:11:00	3:09:00	2:58:00	2:53:00	2:52:00
Max. Flow [m³/s]	24.88	28.67	18.09	29.02	17.46	34.66	37.86	18.91	22.13	23.15

	Flow [m³/s]	Closest Simulated Flow [m³/s]	Closest TP
Mean	25.48	28.67	TP2
Median	24.02	24.88	TP1
Max.	37.86	-	TP7

NB: see Figure 8 for Cross-Section Locations; XS1 starts at [E]479048-[N]7704507 and ends at [E]479193-[N]7704592; XS2 starts at [E]478468-[N]7705566 and ends at [E]478689-[N]7705632;

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DevelopmentWA
Madigan Creek Flood Study
Figure A4: MIKE Catchment Hydrology Results - 1 in 100 AEP 3 Hours

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Engineering a better future for over 20 years!

Madigan Estate Karratha

Proposed Structure Plan Amendment

Transport Impact Assessment

PREPARED FOR:
Development WA

January 2025

Document history and status

Author	Revision	Approved by	Date approved	Revision type
M Rasouli	r01	B Bordbar	20/12/2024	Draft
M Rasouli	r01a	B Bordbar	17/01/2025	Final

File name: t24.014.mr.r01a

Author: Mohammad Rasouli

Project manager: Mohammad Rasouli

Client: Development WA

Project: Madigan Estate Karratha, Structure Plan Amendment

Document revision: r01a

Project number: t24.014

TABLE OF CONTENTS

REPORT FIGURES

REPORT TABLES

1 Summary

In 2012, Element prepared a Structure Plan (SP) for Madigan Estate in Baynton, Karratha. The SP was designed to facilitate subdivision and development of the land. Amendments were made in March 2021, including adding a primary school site, adjusting residential densities, and introducing a new roundabout intersection on Dampier Road. Transcore conducted a Transport Impact Assessment (TIA) to assess the traffic impact in 2021.

Currently, DevelopmentWA has made further amendments to the approved Structure Plan and subdivision plans for Madigan Estate. As part of these amendments, the planned location for the primary school site is being relocated to a more southern position. In its place, additional dwellings will be constructed, forming what is known as the Stage 2D subdivision.

Transcore reviewed the amended SP and updated the 2021 TIA to reflect the latest amended SP. This TIA documents the outcome of the modelling and analysis.

Based on the updated modelling and analysis, it was determined that the traffic generation of the amended SP, has not undergone significant changes compared to the approved SP. Additionally, the intersections on Dampier Road and Madigan Road, as outlined in the amended SP, are projected to operate satisfactorily and well within capacity during the AM and PM peak hours in future.

2 Introduction and Background

In 2012, Element prepared a Structure Plan (SP) for Lot 500 Madigan Road, also known as Madigan Estate, located in Baynton, Karratha. The purpose of the SP was to facilitate the organised and appropriate subdivision and development of the land. A copy of the approved Structure Plan is provided in **Appendix A**.

In March 2021, the approved SP underwent amendments to reflect several changes, including the inclusion of a primary school site, adjustments to residential densities, and the addition of a new full movement roundabout intersection on Dampier Road.

Transcore prepared a Transport Impact Assessment (TIA) in March 2021 to evaluate the traffic impact of the proposed amended SP. Currently, Development WA is making further amendments to the approved Structure Plan and subdivision plans for Madigan Estate in Karratha. As part of these latest amendments, the location of the proposed school site is being relocated to a more southern position. In its place, additional dwellings will be constructed, forming the Stage 2D subdivision.

This TIA will assess the traffic generation and distribution of the latest amended SP and will evaluate the traffic operations of the intersections on Madigan Road and Dampier Road as outlined in the latest amended SP.

Figure 1 shows the location of the subject site. The surrounding land uses to the east and north are predominantly existing and future residential areas. Karratha Cemetery is located to the north of the site and fronting Dampier Road. The subject site also shows the progress of Stage 1A development and the existing road network which has been developed for Stage 1A.

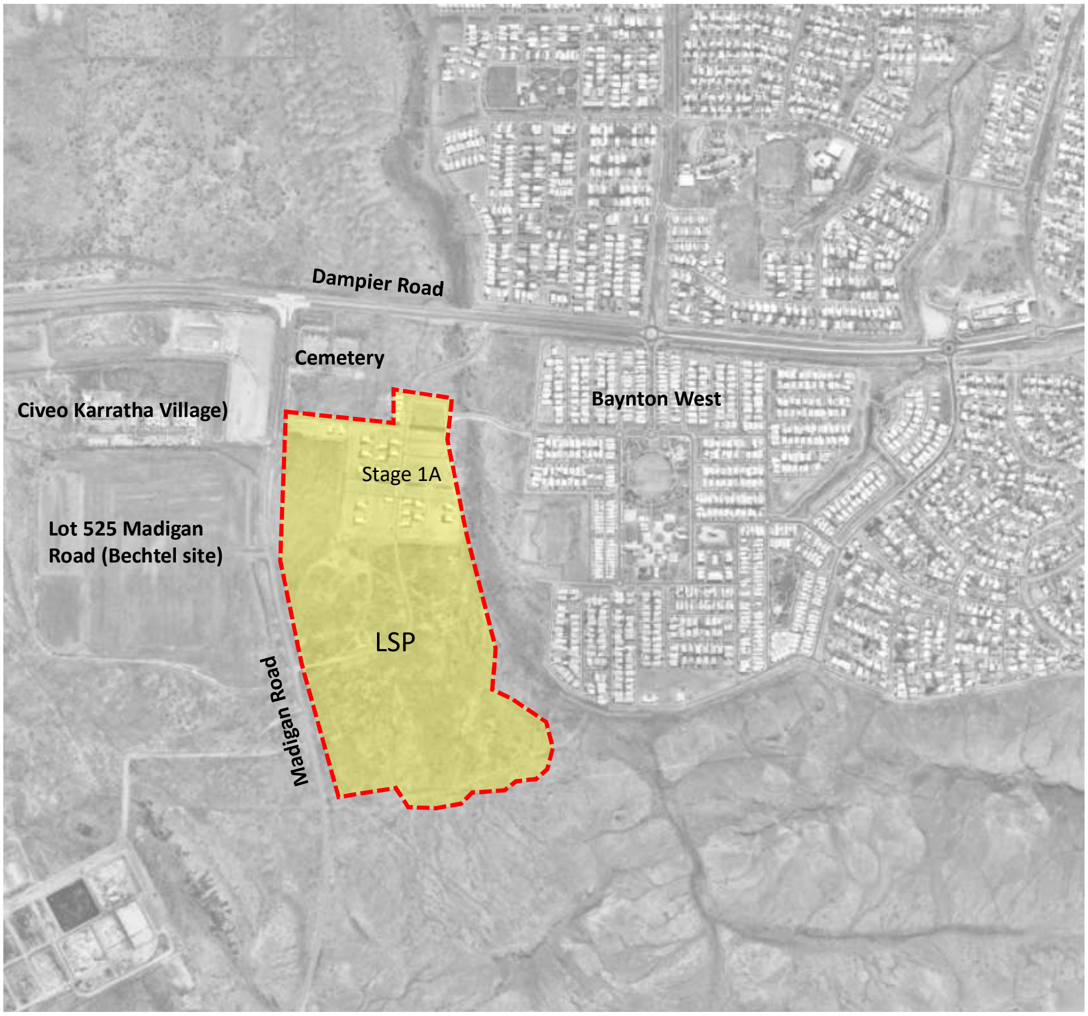


Figure 1: Location of the subject site

3 Proposed Amended Structure Plan

The proposed amended SP is provided in **Appendix B**. The proposed land uses within the amended SP are summarised in **Table 1**. As part of these latest amendments, the location of the proposed school site within the approved SP is being relocated to a more southern position. In its place, additional dwellings will be constructed, forming the Stage 2D subdivision.

Table 1: Proposed land uses within the amended SP

Proposed land uses	
Northern Portion (based on Subdivisions)	
Stage 1	128
Stage 1C &2A	62
Stage 2B	50
Stage 2C&2D	77
Sub-total	317
Southern Portion (based on Structure Plan)	
Sub-total	441
Total	**758**
Retail / Commercial GFA (Notional)	1000m2
Primary school	430 students

4 Existing Situation

4.1 Existing Land Use

The southern part of the site currently is mainly vacant. Stage 1A development is progressing towards the northern part of the site. Karratha Cemetery is located to the north of the site and fronting Dampier Road. Baynton west residential locality is located to the east of the subject site. Madigan Road forms the western boundary of the site.

4.2 Existing Road Network

The existing road network and its classification in the Main Roads WA functional road hierarchy is illustrated in **Figure 2**.

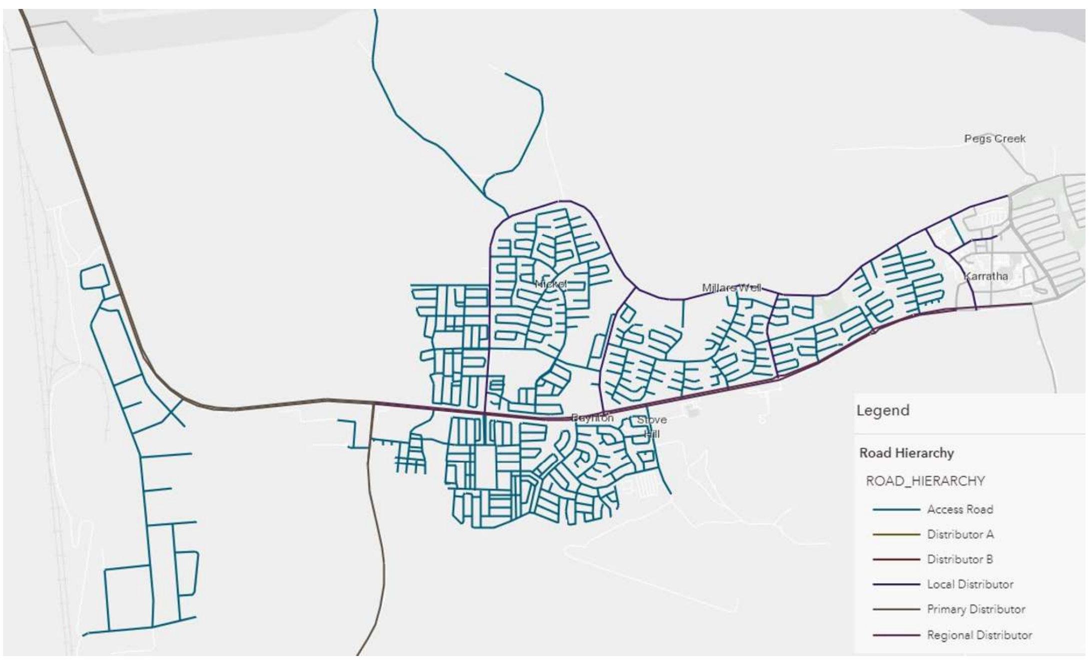


Figure 2: Existing road network and road hierarchy

Dampier Road north of the subject site, is a dual carriageway, four lanes divided road with solid median in the vicinity of subject site. It is classified as a *Regional Distributor* road in the Main Roads WA *Functional Road Hierarchy to the east of Madigan Road and* operates under the speed limit of 70km/h (refer **Figure 3**).

Currently there is a left in / left out intersection on Madigan Road which provides access / egress to Stage 1A development. The intersection of Madigan Road / Dampier Road is a signalised intersection.

Madigan Road forms the western boundary of the site and is a single carriageway road in the vicinity of subject site. It is classified as a Primary Distributor road in the Main Roads WA Functional Road Hierarchy and operates under the speed limit of 80km/h in the vicinity of the amended SP area (refer **Figure 3**).

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.

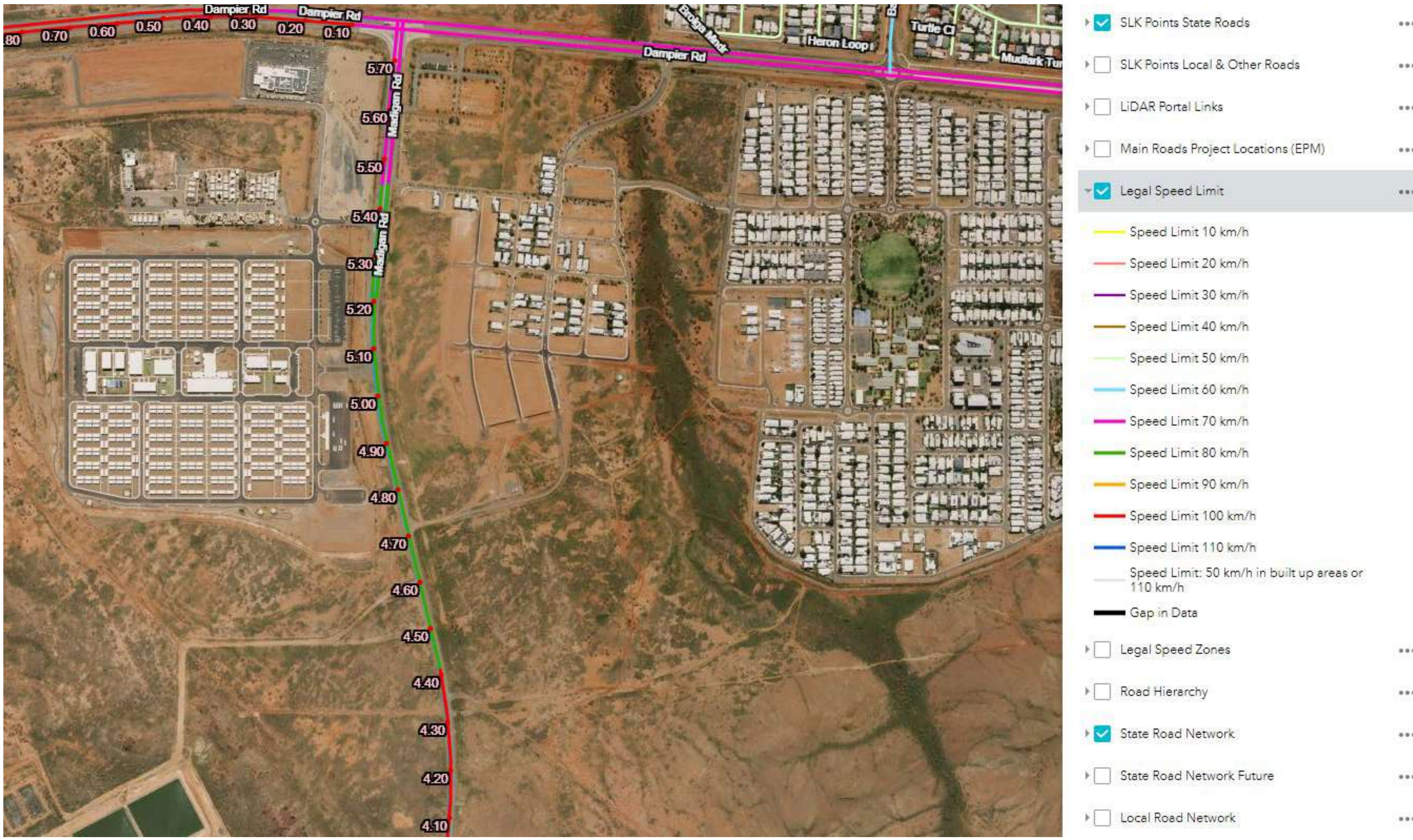


Figure 3: Existing speed limits

4.3 Existing Traffic Volumes

Existing average weekday traffic (AWT) volumes on surrounding roads have been obtained from Main Roads WA and are illustrated in **Figure 4**.

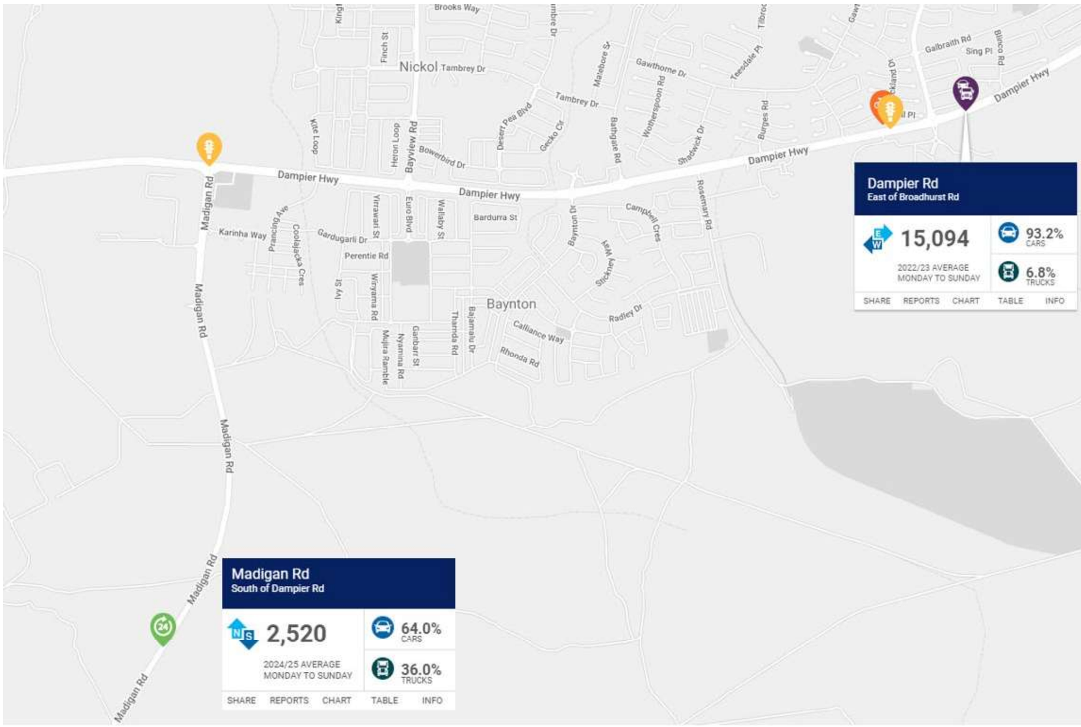


Figure 4: Existing traffic volumes (Source: Main Roads WA traffic map)

4.4 Public Transport

Figure 5 shows the existing bus routes which connect different parts of Karratha to the City Centre. Currently, the site does not have convenient access to the public transport services, however, a high frequency bus service is being considered to connect the east and west of the Karratha urban area and pass through the city centre. This new bus service aims to connect the newer emerging residential areas including Madigan Estate to the west and Mulataga to the east.

Figure 5: Existing bus routes

4.5 Pedestrian and Cyclist Facilities

The Future Works Report Footpaths 2013-2023 provides a guide for ongoing development of footpath networks in the Shire of Roebourne projected over the next ten years. **Figure 6** shows the existing paths along Dampier Road and internal road network within Baynton West locality which has been developed since 2013. It is expected that the proposed pedestrian and cycle paths of the amended SP would also connect to the surrounding paths once fully developed.

Figure 6: Bike map

4.6 Changes to the surrounding road network

Figure 7 illustrates the transport infrastructure in the vicinity of the site and future urban development areas to the west of Madigan Road. The proposed changes to the surrounding road network as part of the proposed amended SP would be installation of a new roundabout on Dampier Road and two priority-controlled T-intersections on Madigan Road.

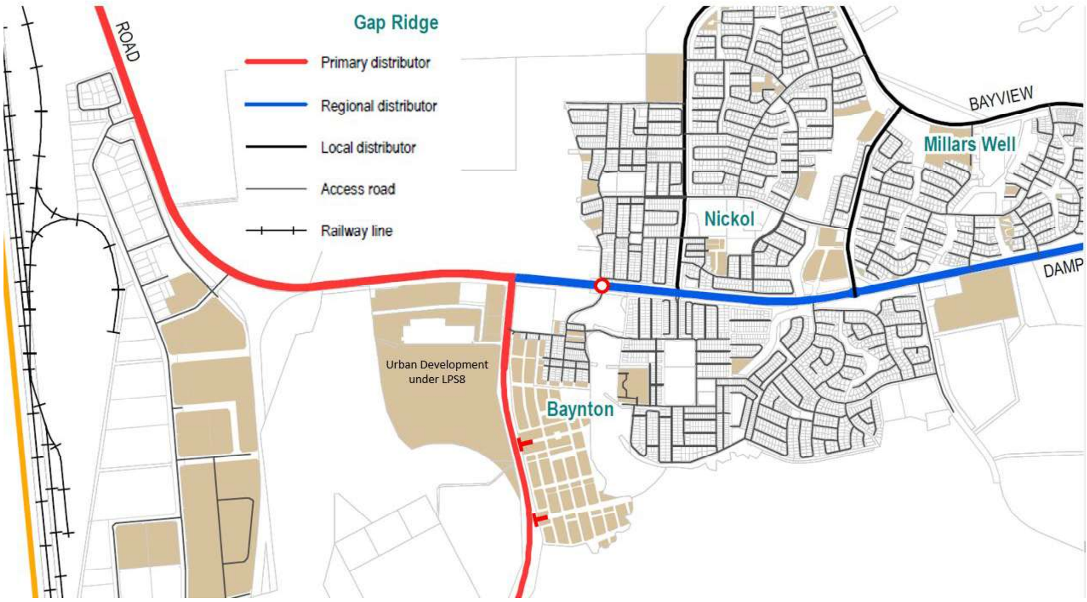


Figure 7: Transport infrastructure

The Karratha Regional Land Supply Assessment (August 2020) report indicates several key road upgrades or construction projects by 2035 including construction of Karratha Western Bypass (Dampier Road to Madigan Road) which would be constructed as 2- lane road to reduce heavy vehicle traffic on the corresponding section of Madigan Road in Karratha townsite.

5 Proposed Internal Transport Network

5.1 Road Hierarchy

The proposed hierarchy of roads within the amended SP was established through transport modelling undertaken for the site and are illustrated in **Figure 8** which is line with the hierarchy and classification of the approved SP.

Figure 8: Proposed road hierarchy

Neighbourhood Connectors (Arterial Roads)
The two proposed east-west roads and the main north-south road within the amended SP area are classified as Neighbourhood Connector roads with 20.5m reserves.

Access Streets
The majority of the proposed internal roads are classified as Access Street C (16m) or Access Street D (12m and 15m) roads. The typical cross section of these Access Streets would entail 4.5m verges on both sides, with embayed parking provided in the verges as appropriate, such as for visitor parking for rear loading lots.

The access streets abutting the proposed primary school are recommended to be constructed to the 17.9-metre Access Street B cross-section standard, which allows for on-street parking.

5.2 Public Transport

The standard of the two proposed neighbourhood connector roads which connect to the existing road network of Baynton West locality would be able to accommodate any future buses within the amended SP area subject to the justified demand.

5.3 Pedestrian and Cyclist Facilities

Figure 9 outlines the proposed pedestrian and cyclist network for the proposed amended SP. In accordance with the LN guidelines, shared paths are proposed on one side of the neighbourhood connector roads with a footpath on the other side. The shared paths (dual use paths) are also provided along the access street B which forms the boundary of the proposed school site.

The proposed shared paths (dual use paths) within the amended SP area provide strong north-south and east-west linkages between neighbourhood focal points and key attractions such as the local centre, local and regional open space areas as well as linkages with the Baynton West residential area and the proposed school site.

Figure 9: Proposed pedestrian and cyclist road network

5.4 Integration with Surrounding Area

The proposed land uses for the proposed amended SP area are in line with the proposed land uses within the approved SP area. The road network of the amended SP area is proposed to connect to the neighbouring Baynton West residential area at a number of locations to improve permeability of the amended SP area. The proposed road network of the amended SP area also facilitates connection to surrounding regional roads including Dampier Road and Madigan Road.

6 Analysis of the Transport Network

6.1 Assessment Period

The assessment year that has been adopted for this analysis is 2035, with the assumption of full development of the amended SP area.

6.2 Traffic generation and distribution

The daily traffic generation rates used for this transport assessment are 8.5 vehicle trips per day (vpd) per dwelling and 1 vehicle per hour (vph) per dwelling, which are higher than the peak hour trip generation rates of 0.8vph per dwelling recommended in the Western Australian Planning Commission (WAPC) Transport Impact Assessment Guidelines (2016). The trip rate of 8.5vpd per dwelling is consistent with the trip rate used for the approved SP.

For the proposed primary school within the amended SP area the trip rate used is 1.0 vph per student during the school peak periods (typically 8-9am and 3-4pm) and 2vpd per student overall. For this assessment, the Education Department's standard 430 student primary school design has been assumed, so this primary school is assumed to attract traffic flows of 860vpd.

The proposed retail area of up to 500m² NLA and commercial area of up to 500m² GFA within the amended SP area would also attract approximately 765vpd adopting the trip rates sourced from RTA NSW trip generation guidelines.

Table 2 and **Table 3** summarise the trip generation of the amended SP area during a typical weekday. It is expected that about 20% of the total trips would be internal and the balance would be external.

Accordingly, the proposed amended SP area is expected to generate approximately 7,743vpd external trips.

The distribution of the extranal trips is established by the location of trip productions and attractors for work trips, education trips and other trips (shopping, social, recreational, etc.) among all the land uses in the surrounding area.

Table 2: Trip generation of the amended SP area during a typical weekday

Land use	Quantity	Daily Rate	AM peak	PM peak	Cross Trade	Daily Trips (Total)	Daily Trips (Internal)	Daily Trips (External)
Primary School	430	2.00	1.00	1.00	0.20	860	172	688
Retail	500	1.2	0.123	0.123	0.20	600	120	480
Commercial	500	0.33	0.011	0.042	0.20	165	33	132
Dwellings	758	8.5	1	1	0	6443	0	6443
TOTAL TRAFFIC						**8068**	**325**	**7743**

Table 3: External peak hour trips

Land use	Quantity	AM Trips	PM Trips	AM		PM	
				IN	OUT	IN	OUT
Primary School	430	344	344	172	172	172	172
Retail	500	49	49	25	24	25	24
Commercial	500	4	17	2	2	8	8
Dwellings	758	758	758	190	568	474	284
TOTAL TRAFFIC		**1156**	**1168**	**389**	**766**	**679**	**489**

6.3 Traffic flow forecast on Surrounding roads

Figure 9 shows the projected (2035) daily traffic volumes on the amended SP internal roads.

Figure 10: Projected daily traffic volumes

The 2035 weekday peak hour traffic volumes at the key intersections were established by utilising the 2035 daily traffic projections and converting the daily traffic volumes to peak hour volumes. For the conversion of the daily traffic volume to peak hour volumes, it was assumed that the in/ out traffic split for the residential component of the traffic would be approximately 70%/ 30% during the weekday PM peak hour and reverse for the weekday AM peak hour.

Figure 10 illustrates the weekday AM and PM peak hour traffic projections in 2035 for the main intersections on Dampier Road and Madigan Road.

The 2035 projected traffic volumes on Dampier Road and Madigan Road have been established by applying 2% traffic growth per year to the existing traffic counts on these roads.

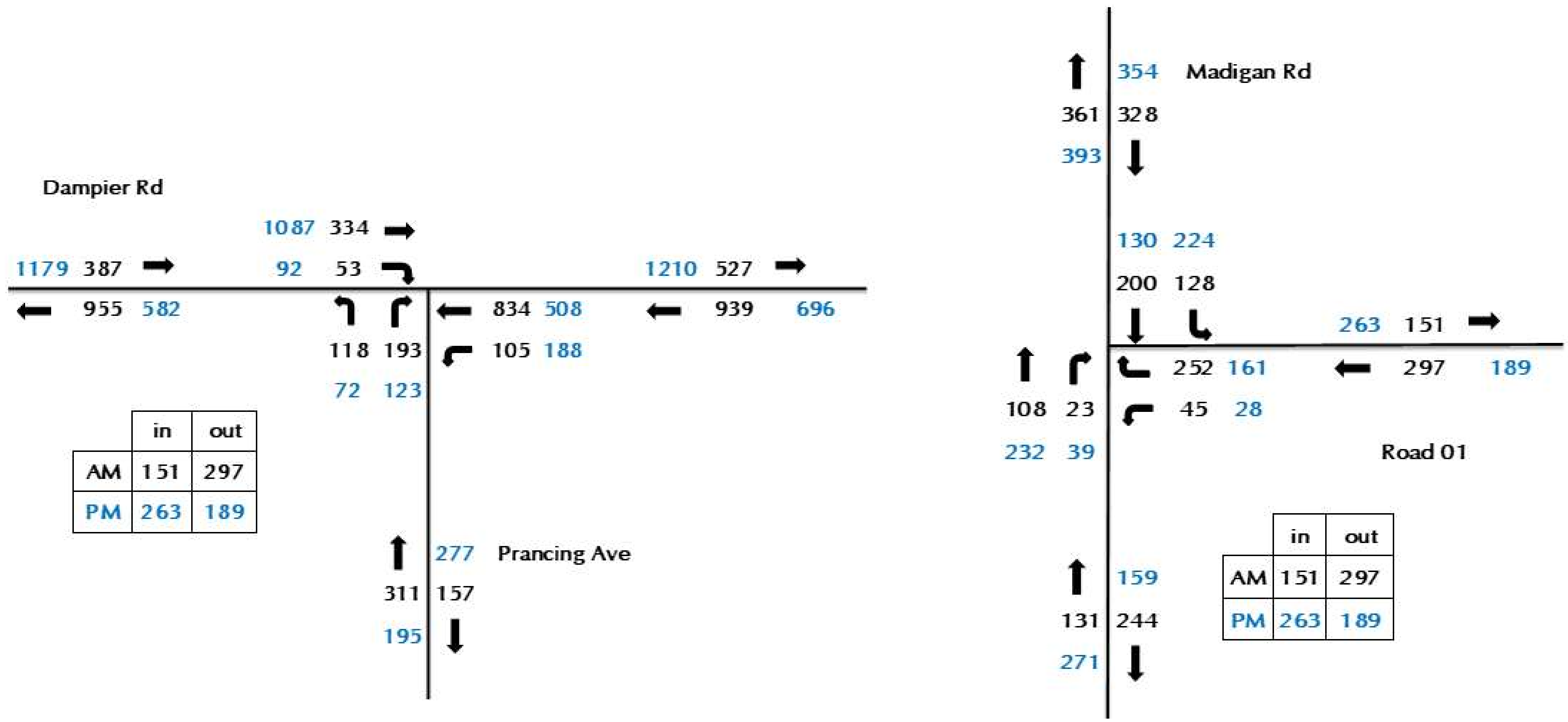


Figure 11: Total (2035) traffic – Weekday AM and PM peak hours

6.4 Roads and Intersections

The proposed road network to accommodate the proposed amended SP traffic volumes has been detailed in section 5 of this report, including the details of the proposed road hierarchy in section 5.1. **Figure 12** details the proposed intersection controls for key intersections within the amended SP area.

A roundabout is proposed at the existing left in/ left out intersection on Dampier Road to improve traffic circulation and traffic operations.

The northern intersection on Madigan Road is constructed as a left in only intersection as per the approved SP. The central and southern intersections on Madigan Road are proposed to operate as priority-controlled T-intersections with appropriate turn lanes on Madigan Road. The posted speed limit along Madigan Road in the vicinity of the LSP central intersection on Madigan Road is 80kmh. The SIDRA layout modelled for the central intersection on Madigan Road includes left and right turn lanes of 125m which satisfies Austroads requirements for the design speed of 90kmh.

Roundabouts are recommended for the intersections adjacent to the local centre, the proposed primary school, and major intersections within the amended SP area. These roundabouts will provide for effective circulation and the control of speed along the major roads.

There are also several 4-way intersections within the amended SP that do not warrant the provision of the roundabouts. For these intersections, suitable threshold treatments including signage and line marking similar to the existing constructed 4-way intersection within the existing subdivisions are recommended on the minor roads as shown in **Figure 12**.

Figure 12: Intersection treatments

6.5 Intersection Analysis

The operation of the key intersections on Dampier Road and Madigan Road has been analysed for the weekday AM and PM peak hours in 2035.

Capacity analysis was undertaken using the SIDRA computer software package. SIDRA is an intersection modelling tool commonly used by traffic engineers for all types of intersections. SIDRA outputs are presented in the form of Degree of Saturation, Level of Service, Average Delay and 95% Queue. These characteristics are defined as follows:

- **Degree of Saturation (DoS)**: is the ratio of the arrival traffic flow to the capacity of the approach during the same period. The Degree of Saturation ranges from close to zero for varied traffic flow up to one for saturated flow or capacity.
- **Level of Service (LoS)**: is the qualitative measure describing operational conditions within a traffic stream and the perception by motorists and/or passengers. In general, there are 6 levels of service, designated from A to F, with Level of Service A representing the best operating condition (i.e. free flow) and Level of Service F the worst (i.e. forced or breakdown flow).
- **Average Delay**: is the average of all travel time delays for vehicles through the intersection.
- **95% Queue**: is the queue length below which 95% of all observed queue lengths fall.

The results of the SIDRA analysis are attached in **Appendix C** and briefly discussed in the following paragraphs. The modelled geometry for intersections is shown in **Figure 13**. The SIDRA layout modelled for the central intersection on Madigan Road includes left and right turn lanes of 125m which satisfies Austroads requirements for the design speed of 90kmh.

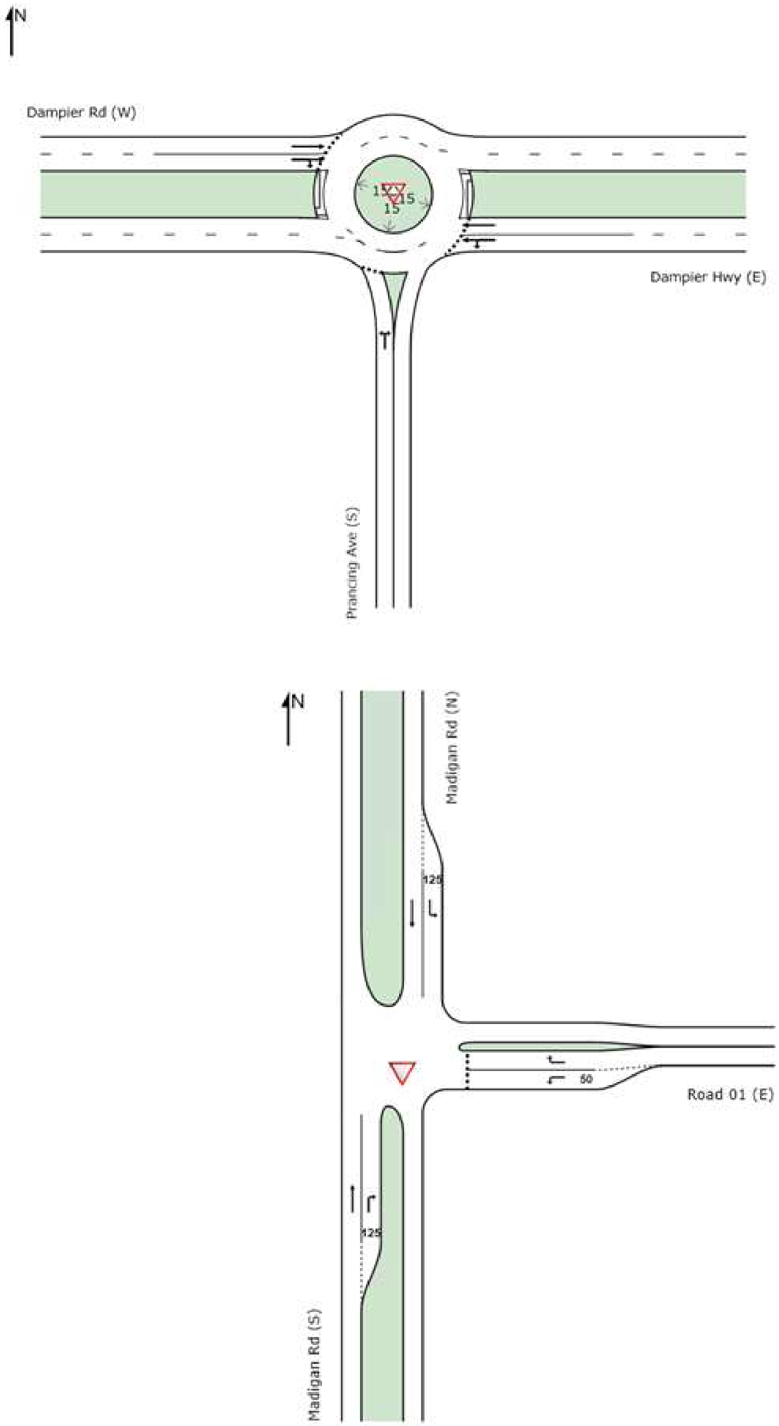


Figure 13: SIDRA Layouts

6.5.1 Roundabout intersection on Dampier Road

The SIDRA analysis results indicate that the roundabout intersection on Dampier Road would operate satisfactorily with overall level of service A during the AM and PM peak hours in 2035 with minimal queues and delays on all approaches of the roundabout intersection.

6.5.2 The main intersection on Madigan Road

The SIDRA analysis results indicate that the main intersection on Madigan Road (central intersection) would operate satisfactorily at an overall LoS A or B in 2035 during the AM and PM peak hours and with minimal queues and delays on all approaches of the intersection. The southern intersection on Madigan Road is also expected to operate satisfactorily as it would carry less traffic than the central intersection. However, the same intersection layout is also proposed for the southern intersection on Madigan Road.

6.6 Access to Frontage Properties

The WAPC *Liveable Neighbourhoods* policy requires that "Development along integrator B and neighbourhood connector streets with ultimate vehicle volumes over 5,000 vehicles per day should be designed either so vehicles entering the street can do so travelling forward, or are provided with alternative forms of vehicle access. Wider lots with paired driveways and protected reversing areas in the parking lane may be used on streets with up to 7,000 vehicles per day."

All of the roads within the proposed amended SP area are expected to carry less than 5,000vpd, so no restriction on vehicular access is required.

5.7 Pedestrian/ Cycle Network

The proposed network of shared paths for pedestrians and cyclists is described in section 4.3 of this transport assessment. This network of paths will provide an excellent level of accessibility and permeability for pedestrians and cyclists within the proposed amended SP area.

7 Conclusion

In 2012, Element prepared a Structure Plan (SP) for Lot 500 Madigan Road, also known as Madigan Estate, located in Baynton, Karratha. The purpose of the SP was to facilitate appropriate subdivision and development of the land.

In March 2021, the approved SP underwent amendments to include a primary school site and adjustments to residential densities. Transcore prepared a Transport Impact Assessment (TIA) at that time to evaluate the traffic impact of these proposed changes.

Currently, Development WA is making further amendments to the approved Structure Plan and subdivision plans for Madigan Estate. As part of these latest amendments, the proposed school site is being relocated to a more southern position, allowing for the construction of additional dwellings in its place.

Access and egress to the amended SP area will be facilitated via a roundabout intersection, replacing the existing left-in/left-out intersection on Dampier Road and the left-in-only intersection at the northern part of the SP area. Priority-controlled T-intersections will also be established on Madigan Road, with appropriate turn lanes.

The posted speed limit along Madigan Road in the vicinity of the LSP central intersection on Madigan Road is 80kmh.Accordingly, The SIDRA layout modelled for the central intersection on Madigan Road includes left and right turn lanes of 125m which satisfies Austroads requirements for the design speed of 90kmh.

Traffic modelling and analysis for the proposed structure plan amendment indicate that the changes will not significantly alter the road hierarchy or the standards of the road network outlined in the approved SP.

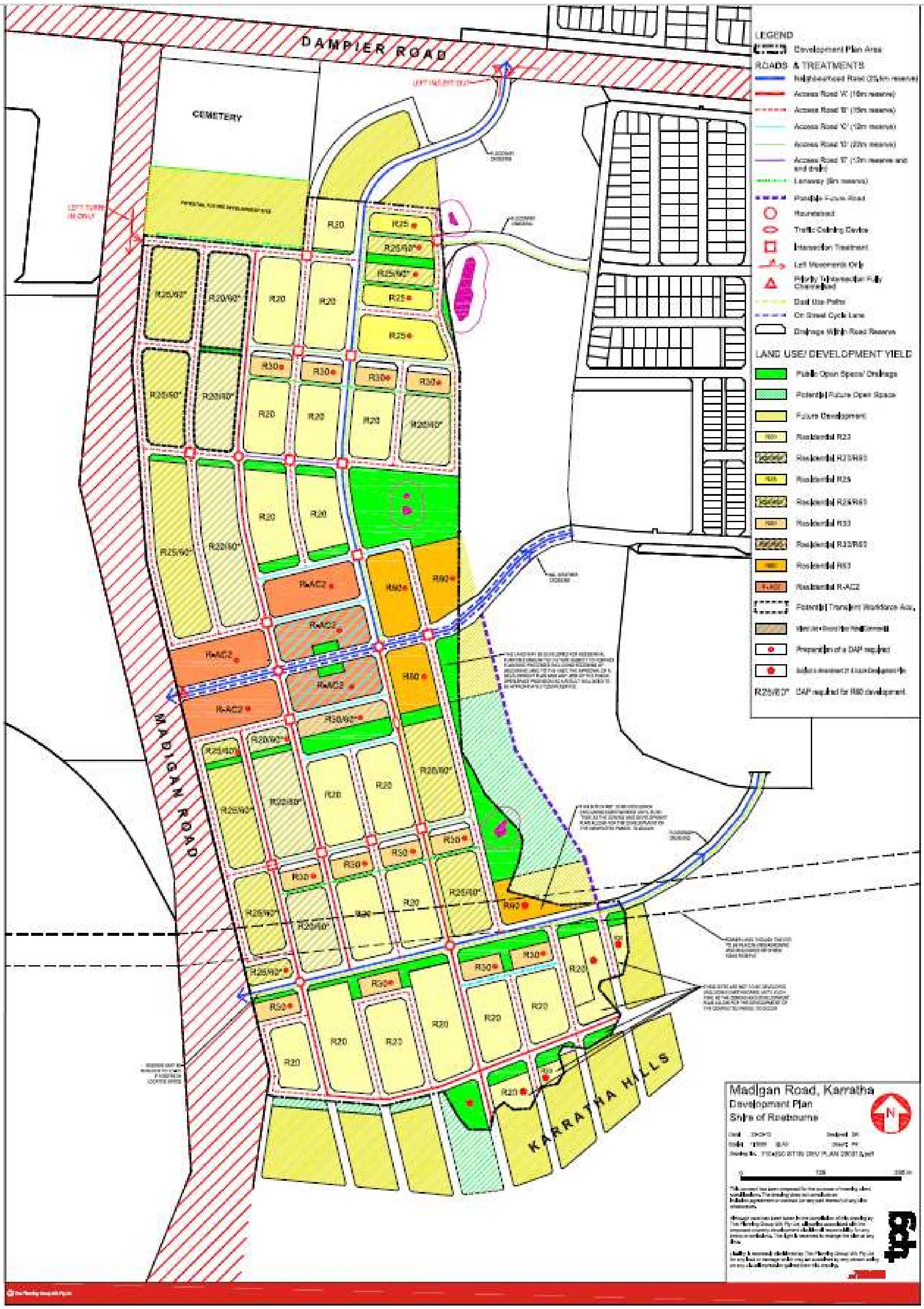
Based on the updated modelling and analysis, it has been determined that the traffic generation resulting from the amended SP has not significantly deviated from the approved SP. Furthermore, the intersections at Dampier Road and Madigan Road, as outlined in the amended SP, are projected to operate satisfactorily and well within capacity during peak hours in 2035.

Appendix A

APPROVED LOCAL STRUCTURE PLAN

transcore

Engineering a better future for over 20 years!



DAMPIER ROAD
CEMETERY
MADIGAN ROAD
KARRATHA HILLS
LEGEND
Development Plan Area
ROADS & TREATMENTS
Traffic Calming Device
Intersection Treatment
Dual Use Paths
On Street Cycle Lane
Drainage Within Road Reserve
LAND USE/ DEVELOPMENT YIELD
Public Open Space/ Drainage
Potential Future Open Space
Future Development
Potential Transient Workforce Acc.
Madigan Road, Karratha
Development Plan
Shire of Roebourne

Appendix B

PROPOSED AMENDED LOCAL STRUCTURE PLAN

transcore

Engineering a better future for over 20 years!

Structure Plan

Madigan Road, Karratha

element.

Appendix C

SIDRA OUTPUTS

Engineering a better future for over 20 years!

MOVEMENT SUMMARY

Site: [Madigan Rd & Rd 01 - 2035 - AM (Site Folder: 2035)]

Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance															
Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Madigan Rd (S)															
8	T1	108	40.9	114	40.9	0.098	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	89.9
9	R2	23	2.0	24	2.0	0.026	9.3	LOS A	0.1	0.8	0.45	0.67	0.45	54.6
Approach		131	34.1	138	34.1	0.098	1.6	NA	0.1	0.8	0.08	0.12	0.08	80.7
East: Road 01 (E)															
10	L2	45	2.0	47	2.0	0.048	5.8	LOS A	0.2	1.3	0.35	0.58	0.35	54.0
12	R2	252	2.0	265	2.0	0.505	13.2	LOS B	3.2	24.1	0.69	1.00	1.07	48.8
Approach		297	2.0	313	2.0	0.505	12.1	LOS B	3.2	24.1	0.64	0.94	0.96	49.5
North: Madigan Rd (N)															
1	L2	128	2.0	135	2.0	0.074	7.5	LOS A	0.0	0.0	0.00	0.65	0.00	69.5
2	T1	200	42.3	211	42.3	0.183	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	89.8
Approach		328	26.6	345	26.6	0.183	3.0	NA	0.0	0.0	0.00	0.25	0.00	80.6
All Vehicles		756	18.2	796	18.2	0.505	6.3	NA	3.2	24.1	0.27	0.50	0.39	64.7

MOVEMENT SUMMARY

Site: [RB - Dampier Rd & Prancing Ave - 2035 - AM (Site Folder: 2035)]

Site Category: (None)
Roundabout

Vehicle Movement Performance															
Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Prancing Ave (S)															
10	L2	118	2.0	124	2.0	0.550	11.0	LOS B	3.4	25.9	0.79	1.01	1.05	45.8
12	R2	193	2.0	203	2.0	0.550	15.0	LOS B	3.4	25.9	0.79	1.01	1.05	45.1
Approach		311	2.0	327	2.0	0.550	13.5	LOS B	3.4	25.9	0.79	1.01	1.05	45.4
East: Dampier Hwy (E)															
1	L2	105	2.0	111	2.0	0.397	5.6	LOS A	3.2	28.1	0.29	0.48	0.29	51.5
2	T1	834	22.7	878	22.7	0.397	6.3	LOS A	3.2	28.1	0.30	0.48	0.30	53.1
Approach		939	20.4	988	20.4	0.397	6.2	LOS A	3.2	28.8	0.30	0.48	0.30	52.9
West: Dampier Rd (W)															
8	T1	334	22.7	352	22.7	0.207	7.1	LOS A	1.3	12.4	0.51	0.59	0.51	52.6
9	R2	53	2.0	56	2.0	0.207	10.6	LOS B	1.3	11.6	0.51	0.61	0.51	51.8
Approach		387	19.9	407	19.9	0.207	7.6	LOS A	1.3	12.4	0.51	0.59	0.51	52.5
All Vehicles		1637	16.8	1723	16.8	0.550	7.9	LOS A	3.4	28.8	0.44	0.61	0.49	51.3

MOVEMENT SUMMARY

Site: [Madigan Rd & Rd 01 - 2035 - PM (Site Folder: 2035)]

Site Category: (None)
Give-Way (Two-Way)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Madigan Rd (S)														
8	T1	232	40.9	244	40.9	0.213	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	89.8
9	R2	39	2.0	41	2.0	0.045	9.3	LOS A	0.2	1.3	0.45	0.69	0.45	54.6
Approach		271	35.3	285	35.3	0.213	1.4	NA	0.2	1.3	0.06	0.10	0.06	82.2
East: Road 01 (E)														
10	L2	28	2.0	29	2.0	0.027	5.3	LOS A	0.1	0.7	0.27	0.53	0.27	54.3
12	R2	161	2.0	169	2.0	0.403	14.5	LOS B	2.0	15.1	0.72	0.96	0.98	47.9
Approach		189	2.0	199	2.0	0.403	13.2	LOS B	2.0	15.1	0.66	0.90	0.88	48.8
North: Madigan Rd (N)														
1	L2	224	2.0	236	2.0	0.130	7.5	LOS A	0.0	0.0	0.00	0.65	0.00	69.4
2	T1	130	42.3	137	42.3	0.119	0.0	LOS A	0.0	0.0	0.00	0.00	0.00	89.9
Approach		354	16.8	373	16.8	0.130	4.8	NA	0.0	0.0	0.00	0.41	0.00	75.8
All Vehicles		814	19.5	857	19.5	0.403	5.6	NA	2.0	15.1	0.17	0.42	0.23	68.7

MOVEMENT SUMMARY

Site: [RB - Dampier Rd & Prancing Ave - 2035 - PM (Site Folder: 2035)]

Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Prancing Ave (S)														
10	L2	72	2.0	76	2.0	0.283	6.6	LOS A	1.4	10.5	0.64	0.82	0.64	48.9
12	R2	123	2.0	129	2.0	0.283	10.6	LOS B	1.4	10.5	0.64	0.82	0.64	48.3
Approach		195	2.0	205	2.0	0.283	9.1	LOS A	1.4	10.5	0.64	0.82	0.64	48.5
East: Dampier Hwy (E)														
1	L2	188	2.0	198	2.0	0.312	5.8	LOS A	2.3	19.0	0.36	0.52	0.36	51.4
2	T1	508	22.7	535	22.7	0.312	6.6	LOS A	2.3	19.0	0.38	0.51	0.38	52.8
Approach		696	17.1	733	17.1	0.312	6.4	LOS A	2.3	20.3	0.37	0.52	0.37	52.5
West: Dampier Rd (W)														
8	T1	1087	22.7	1144	22.7	0.554	7.0	LOS A	5.2	47.6	0.56	0.56	0.56	52.5
9	R2	92	2.0	97	2.0	0.554	10.5	LOS B	5.1	45.5	0.57	0.58	0.57	51.9
Approach		1179	21.1	1241	21.1	0.554	7.3	LOS A	5.2	47.6	0.56	0.57	0.56	52.5
All Vehicles		2070	18.0	2179	18.0	0.554	7.2	LOS A	5.2	47.6	0.50	0.57	0.50	52.1

Bushfire Management Plan:
Structure Plan Amendment: Madigan Estate, Baynton

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BPAD
Bushfire Planning & Design
Accredited Practitioner
Level 2

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DOCUMENT TRACKING

Project Name	Bushfire Management Plan: Structure Plan Amendment: Madigan Estate, Baynton
Project Number	24PER9629
Project Manager	Kristy Oliver
Prepared by	Kristy Oliver
Reviewed by	Eva Cronin (BPAD Level 2 – 45482)
Approved by	Eva Cronin (BPAD Level 2 – 45482)
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Last saved on	12 May 2025

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ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from DevelopmentWA (the client).

Version control		
Version	**Purpose**	**Date**
v1	Draft – Submission to client	17 April 2025
v2	Final – Submission to client	12 May 2025

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1. Introduction

1.1 Proposal details

Eco Logical Australia (ELA) was commissioned by DevelopmentWA to prepare an updated Bushfire Management Plan (BMP) to support a Structure Plan amendment required due to the relocation of the school site within Madigan Estate, Baynton (hereafter referred to as the subject site, Figure 1). ELA originally prepared the approved Structure Plan BMP in 2021 (ELA 2021a). The subject site is located within the City of Karratha and will result in an intensification of land use through the development of residential lots, a school, mixed use precinct, and public open spaces [POS] (Figure 2).

The subject site is within a designated bushfire prone area (Area 2) as per the *Western Australia State Map of Bush Fire Prone Areas* (DFES 2024; Figure 3), which triggers bushfire planning requirements *under State Planning Policy 3.7 Bushfire* (SPP 3.7; Western Australian Planning Commission [WAPC] 2024) and reporting to accompany submission of the subdivision application in accordance with the associated *Planning for Bushfire Guidelines* (the Guidelines; WAPC 2024).

The subject site is zoned as 'Urban Development' under the City of Karratha Local Planning Scheme No. 8. The subject site is bound by:

- A cemetery and Dampier Road to the north.
- Grassland to the south.
- Madigan Creek and adjacent residential development to the east.
- Madigan Road to the west.

Any future planning applications within the Structure Plan amendment area will need to meet the requirements of the Guidelines and policies/standards in place at the time – this includes subdivisions for individual stages. It should be noted that the Structure Plan initially prepared by ELA (2021a) was prepared prior to the majority of development in the northern part of the Structure Plan amendment area. Development north of Wagari Drive has since occurred/is in the process of occurring:

- Development in the north-east of the Structure Plan area pre-dated the 2021 BMP, occurring in 2012/2013.
- Stage 1C: Bushfire Management Plan (ELA 2021b), WAPC Approval 160527.
- Stage 2A: Bushfire Management Plan (ELA 2021b), WAPC Approval 161702.
- Stage 2B & 2C: Bushfire Management Plan (ELA 2024a), Subdivision application number 2024-04142.
- Stage 2D: Bushfire Management Plan (ELA 2024b), Subdivision application number 200930.

For detailed information regarding specific bushfire management strategies for these stages north of Wagari Drive, please refer to the relevant Bushfire Management Plans.

This assessment has been prepared by ELA Bushfire Consultant Kristy Oliver with quality assurance undertaken by Eva Cronin (FPAA BPAD Level 2 Certified Practitioner No. BPAD45482).

1.2 Purpose and application of the plan

The primary purpose of this BMP is to act as a technical supporting document to inform planning assessment. This BMP is also designed to provide guidance on how to plan for and manage the bushfire risk to the subject site through implementation of a range of bushfire management measures in accordance with the Guidelines. Due to the school being a vulnerable land use, this BMP also provides the inclusion of a broad consideration of bushfire emergency procedures (Section 5) as required under SPP 3.7.

1.3 Environmental considerations

SPP 3.7 policy objective 5.4 recognises the need to consider bushfire risk management measures alongside biodiversity conservation, environmental protection and landscape amenity values.

Any clearing (including re-clearing) of native vegetation onsite may require discussions with the local government, the Department of Water and Environmental Regulation and potentially the Department of Biodiversity, Conservation and Attractions to determine approvals requirements, during/post-approval of DA.

No revegetation is proposed within the subject site; however, if this changes, it will need to be addressed in a BMP Addendum or similar. All landscaping within the development will be maintained in a low-threat state.

Approval of this BMP by the City of Karratha provides the acknowledgement and agreement required by the City of Karratha to continue managing land as ceded to them (post-development), with classifications as follows:

- POS's to be managed in a low threat state as per Clause 2.2.3.2 (e) and (f), except for the following:
  - Heritage site within Stage 2C to be managed as Class G Grassland.
  - Heritage site to the south-east of the school site to be managed as Class C Shrubland.
- Road reserves managed in either a low threat state as per Clause 2.2.3.2 (e) and (f) or as Asset Protection Zones (APZs) where indicated.

Figure 1: Site Overview

Subject site
100m site assessment
150m site assessment

N

0 200 400 800
Metres

Datum/Projection:
GDA 1994 MGA Zone 50

24PER9629-OK Date: 19/11/2024

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Structure Plan

Madigan Road, Karratha

0 50 100m

Date: 11 Mar 2025 Scale: 1:5000@ A3 File: **19-314 ST-1 C** Staff: MD GW Checked: MD

element.

Level 18, 191 St Georges Terrace, Perth Western Australia 6000
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Figure 2: Site Plan

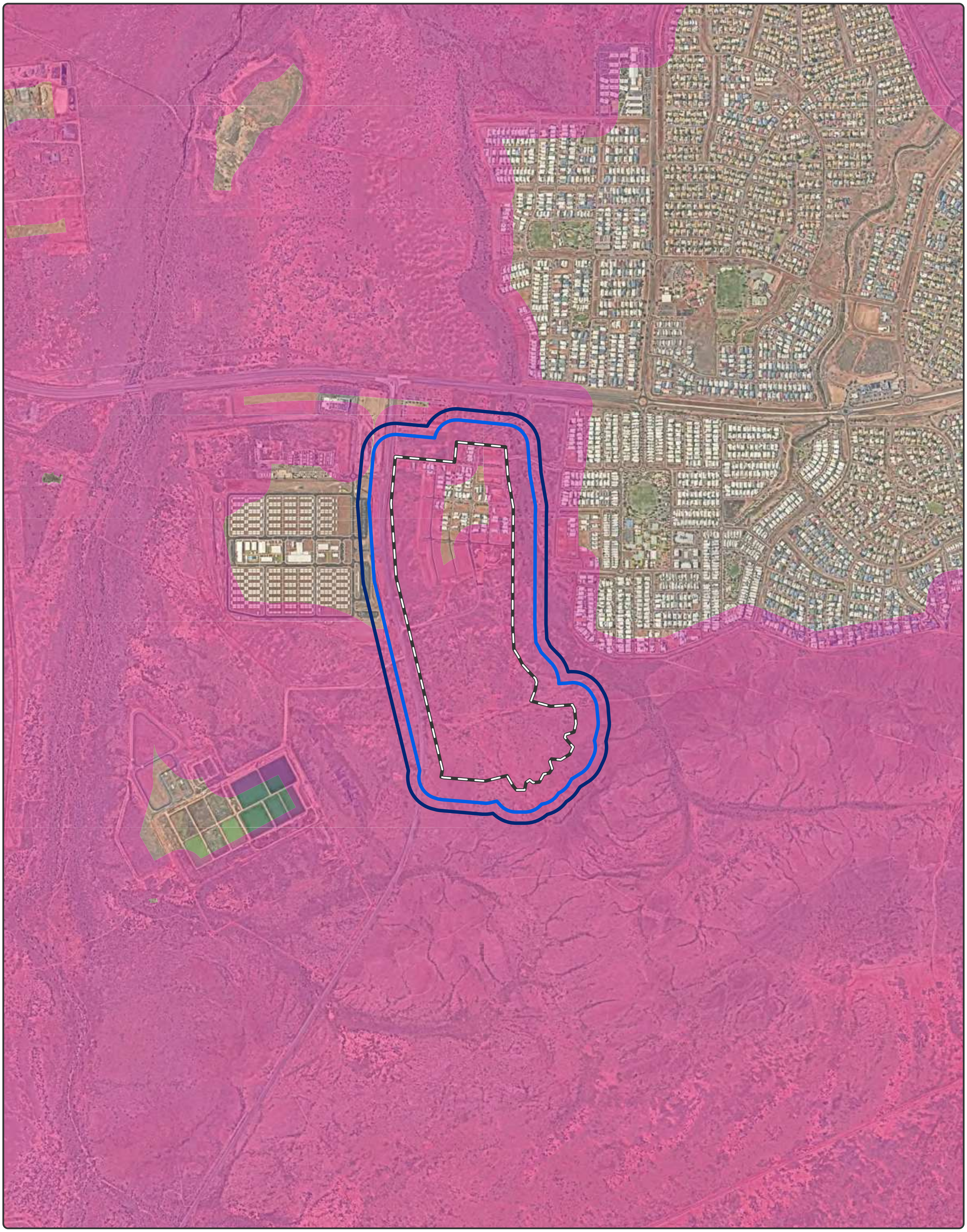

Figure 3: Bushfire Prone Areas

Subject site

100m site assessment

150m site assessment

Bushfire Prone Mapping (DFES 2024)

0 200 400 800

Metres

Datum/Projection:
GDA 1994 MGA Zone 50

24PER9629-OK Date: 14/04/2025

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2. Bushfire assessment results

2.1 Broader Landscape Assessment

As the entirety of the 2 km Broader Landscape Assessment (BLA) area was unable to be assessed while on-site, ELA has referred to Beard mapping (DPIRD 2019) to ascertain the majority of the vegetation is classified as grassland i.e. 'Abydos Plain - Roebourne_589 Short bunch-grass savanna / Grass-steppe' and 'Abydos Plain - Roebourne_157 Grass-steppe (Hummock grassland Triodia spp.)'. Site-based vegetation assessment generally revealed riparian areas to be Class C Shrubland (with a grassy understorey); as such, the riparian areas have been mapped as classified vegetation, and any other vegetated areas mapped as unmanaged grassland. Developed areas have been classified as low threat vegetation. Land to the west of the subject site is mostly vegetated; however, the development immediately west of the subject site will likely serve as a disruption to the impact from a bushfire coming from the west. The developed area to the north-east will likely minimise the chances of a significant fire run affecting the subject site from that direction. The topography of the subject site and broader landscape area is predominantly that of a flat to slightly undulating surface with the steepest area (upslope relative to the subject site) to the south of the subject site. Further to the north-west, the land has a gentle downslope (relative to the subject site).

2.1.1 Broader Landscape Assessment: Type A

The subject site relating to the Structure Plan amendment area is classified as a Type A broader landscape. Refer to Figure 4a–Figure 4c for the BLA. The assessment table is provided in below.

Table 1: Broader Landscape Assessment: Type A

CRITERIA	POINTS
Proximity of the planning proposal to a suitable destination is:	1
The road pattern from the planning proposal to a suitable destination is:	2
The predominant vegetation pattern is:	2
Exposure of the planning proposal to an identified external bushfire hazard (excluding Class G Grassland) is from:	2
	TOTAL POINTS
0-11 points (BLT A) 12-20 points (BLT B)	7
BROADER LANDSCAPE TYPE DETERMINED	TYPE A

2.1.1.1 Suitable destination

All lots are within 1 km of a suitable destination located in a non-bushfire prone area (i.e. BAL-LOW). This suitable destination comprises the existing school oval/POS area located to the east of Madigan Creek. Post-development there will be additional BAL-LOW areas within the subject site, including some locations within the proposed school site. An alternate suitable destination is the Karratha Leisureplex identified by the City of Karratha in the Local Emergency Management Arrangements Plan (CoK 2021) as the primary welfare/evacuation centre (located ~4 km to the east of the subject site). Refer to Figure 4c.

2.1.1.2 Road pattern

The road pattern to the school oval/POS, and the Karratha Leisureplex is simple and/or direct (limited intersections). Refer to Figure 4c.

2.1.1.3 Predominant vegetation pattern

The vegetation type is a mosaic pattern comprising a majority of mosaic pattern vegetation (i.e. grassland) and cleared vegetation (urban areas), with some classified vegetation associated with the creeks paralleling the Structure Plan amendment area. Refer to Figure 4b.

2.1.1.4 External bushfire hazard

While the creek lines (supporting vegetation other than Class G Grassland) paralleling the Structure Plan area are present in each quadrant, they are approximately only 100 m wide (measured perpendicular to the site) in parts to the east. As such, these areas are not generally considered to provide a substantial fire run (i.e. contiguous extent of vegetation of one kilometre or more). Thus, the exposure of the planning proposal to an identified external bushfire hazard (excluding Class G Grassland) is from two aspects (north-west and south-west). Refer to Figure 4b.

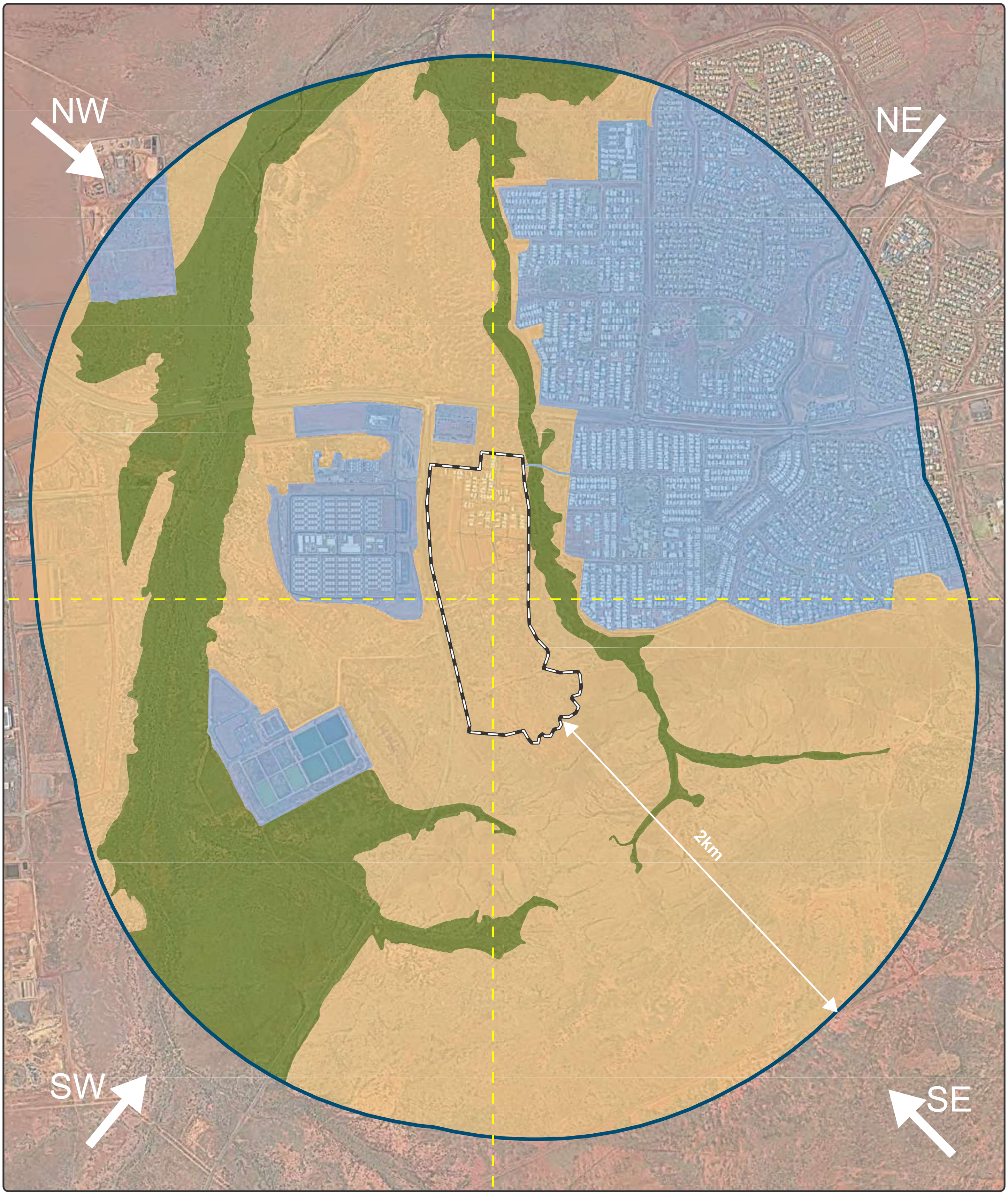

Figure 4a: Broader Landscape Assessment - Vegetation type and aspect assessment

Subject site

2km assessment buffer

Vegetation type

Low threat vegetation

Unmanaged grassland

All other classified vegetation

0 0.5 1

Kilometres

Datum/Projection:
GDA 1994 MGA Zone 50

24PER9629-OK Date: 14/04/2025

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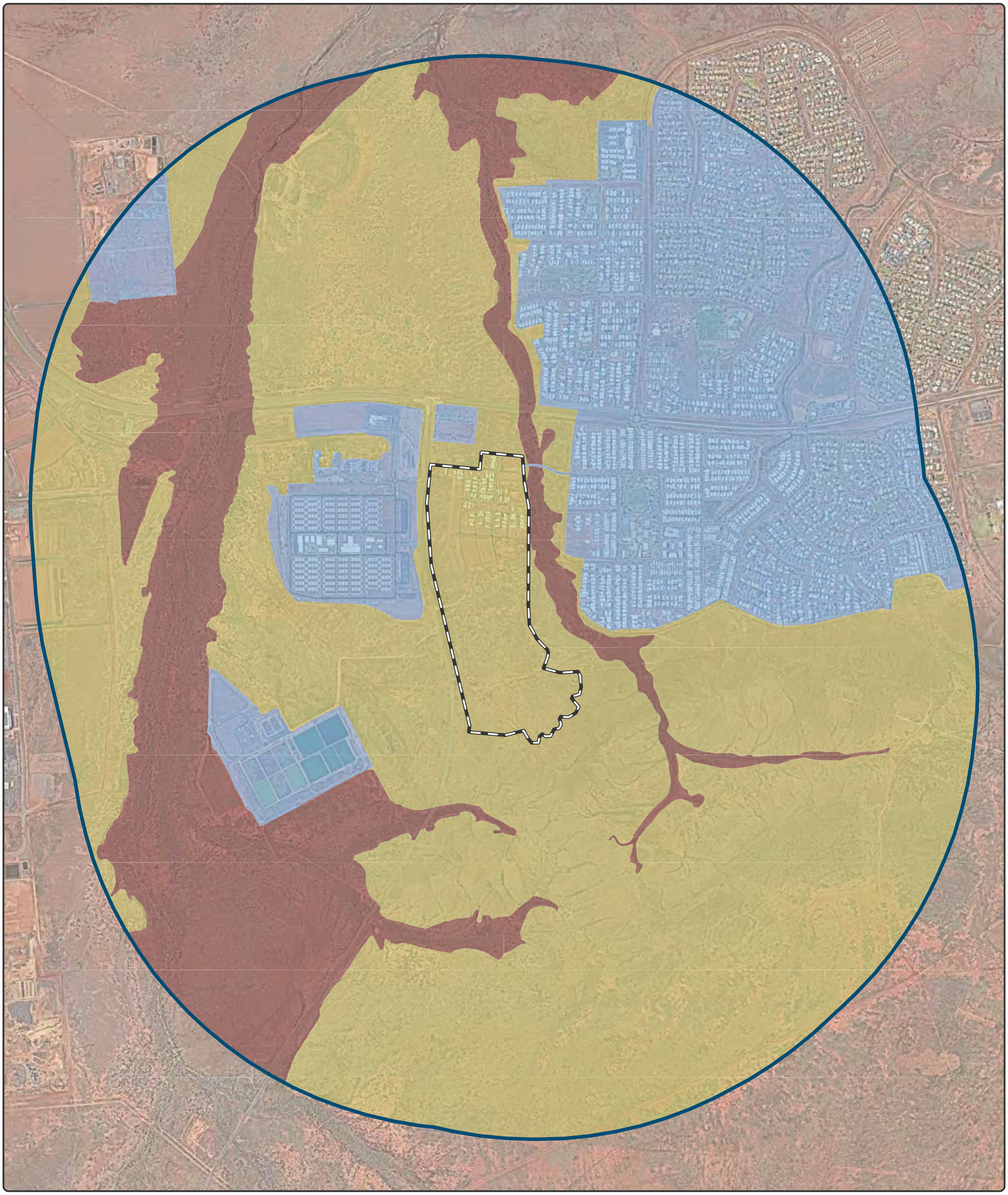


Figure 4b: Broader Landscape Assessment - Predominant vegetation pattern

Subject site

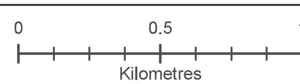
2km assessment buffer

Predominant vegetation

Cleared vegetation

Mosaic pattern

Large tracts of classified vegetation



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24PER9629-OK Date: 21/11/2024

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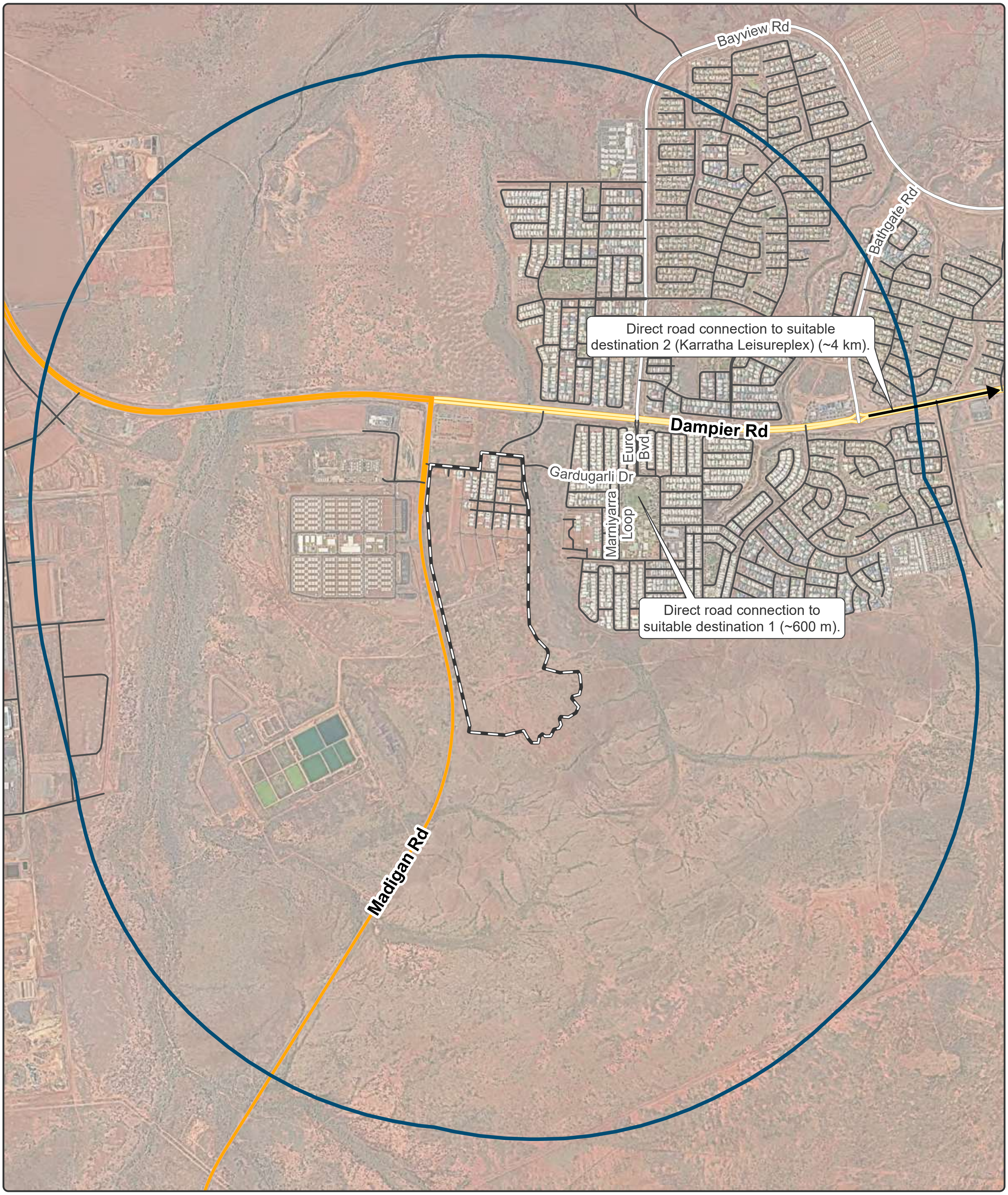

Figure 4c: Broader Landscape Assessment - Access routes

Subject site

2km assessment buffer

Access routes

Access Road

Local Distributor

Primary Distributor

Regional Distributor

0 0.5 1

Kilometres

Datum/Projection:
GDA 1994 MGA Zone 50

24PER9629-OK Date: 14/04/2025

2.2 Bushfire assessment inputs

The following section is a consideration of spatial bushfire risk and has been used to inform the bushfire assessment in this report.

2.2.1 Fire Danger Index

A blanket Fire Danger Index (FDI) 80 is adopted for Western Australia, as outlined in Australian Standard *AS 3959: 2018 Construction of Buildings in Bushfire Prone Areas* (SA 2018) and endorsed by Australasian Fire and Emergency Service Authorities Council (AFAC).

2.2.2 Vegetation classification and slope under vegetation

Vegetation and effective slope (i.e. slope under vegetation) within the subject site and surrounding 150 m (the assessment area) were assessed in accordance with the Guidelines and *AS 3959:2018* with regard given to the *Visual guide for bushfire risk assessment in Western Australia* (DoP 2016). The site assessment was undertaken on 29 October 2024.

The classified vegetation and effective slope for the subject site (pre-development) from each of the identified vegetation plots are identified below in Table 2 and Figure 5. Future detailed assessment at subsequent planning stages may result in refined vegetation classification and slopes and associated outputs (i.e. BAL Contour Map).

Table 2: Classified vegetation as per AS 3959: 2018 (pre-development)

Plot	Vegetation Classification	Effective Slope
1	Class C Shrubland	All upslopes and flat land (0 degrees)
2	Class G Grassland	All upslopes and flat land (0 degrees)
3	Excluded AS 3959: 2018 2.2.3.2 (c)	-
4	Excluded AS 3959: 2018 2.2.3.2 (e) & (f)	-

Photographs relating to each area and vegetation type are included in Appendix A.

2.2.2.1 Post-development assumptions

The post-development scenario within the subject site assumes the following:

- All vegetation will be cleared, with the exception of the:
  - Retained Class G Grassland in Stage 2C associated with the heritage site (that has been excluded under Clause 2.2.3.2 [c]).
  - Retained Class C shrubland associated with the heritage site to the south-east of the school site.
- Developed areas will be excludable under Clause 2.2.3.2 (e) and (f) of AS 3959:2018. Any plantings will be maintained as excluded vegetation in accordance with Clause 2.2.3.2 (f) of AS 3959:2018 or APZ standards in the Guidelines (Appendix B) as part of the subdivision works.
- Indicative APZs will be applied to areas adjacent to classified vegetation that are yet to be developed in order to reduce potential impacts to development from bushfires. This includes

road reserves and lot setbacks (where required). It is assumed road verges in already developed areas are managed to a low threat state as per Clauses 2.2.3.2 (e) and (f).

- The POS's (excluding the vegetation associated with the heritage sites) are to be managed to a low threat state as per Clause 2.2.3.2 (f) of AS 3959:2018.
- Residential lot landholders will maintain future landscaping in a low threat state as per Clause 2.2.3.2 (f) of AS 3959:2018 and in accordance with the City of Karratha Fire Mitigation Notice.

Outside the subject site, it has been assumed:

- Areas classified as excluded under Clause 2.2.3.2 (e) and (f) of AS 3959:2018 will continue to be managed in a low threat state as per Clause 2.2.3.2(e) or (f) or City of Karratha fire mitigation notice (i.e. roads, parks, urban development, maintained gardens around dwelling on residential lots etc.

The classified vegetation and effective slope for the subject site (post-development) from each of the identified vegetation plots are identified below in Table 3. Figure 6 displays the post-development vegetation classification, including areas excluded under clauses 2.2.3.2 (e) and (f), APZs and POS areas.

Table 3: Classified vegetation as per AS 3959: 2018 (post-development)

Plot	Vegetation Classification	Effective Slope
1	Class C Shrubland	All upslopes and flat land (0 degrees)
2	Class G Grassland	All upslopes and flat land (0 degrees)
3	Excluded AS 3959: 2018 2.2.3.2 (c)	-
4	Excluded AS 3959: 2018 2.2.3.2 (e) & (f)	-

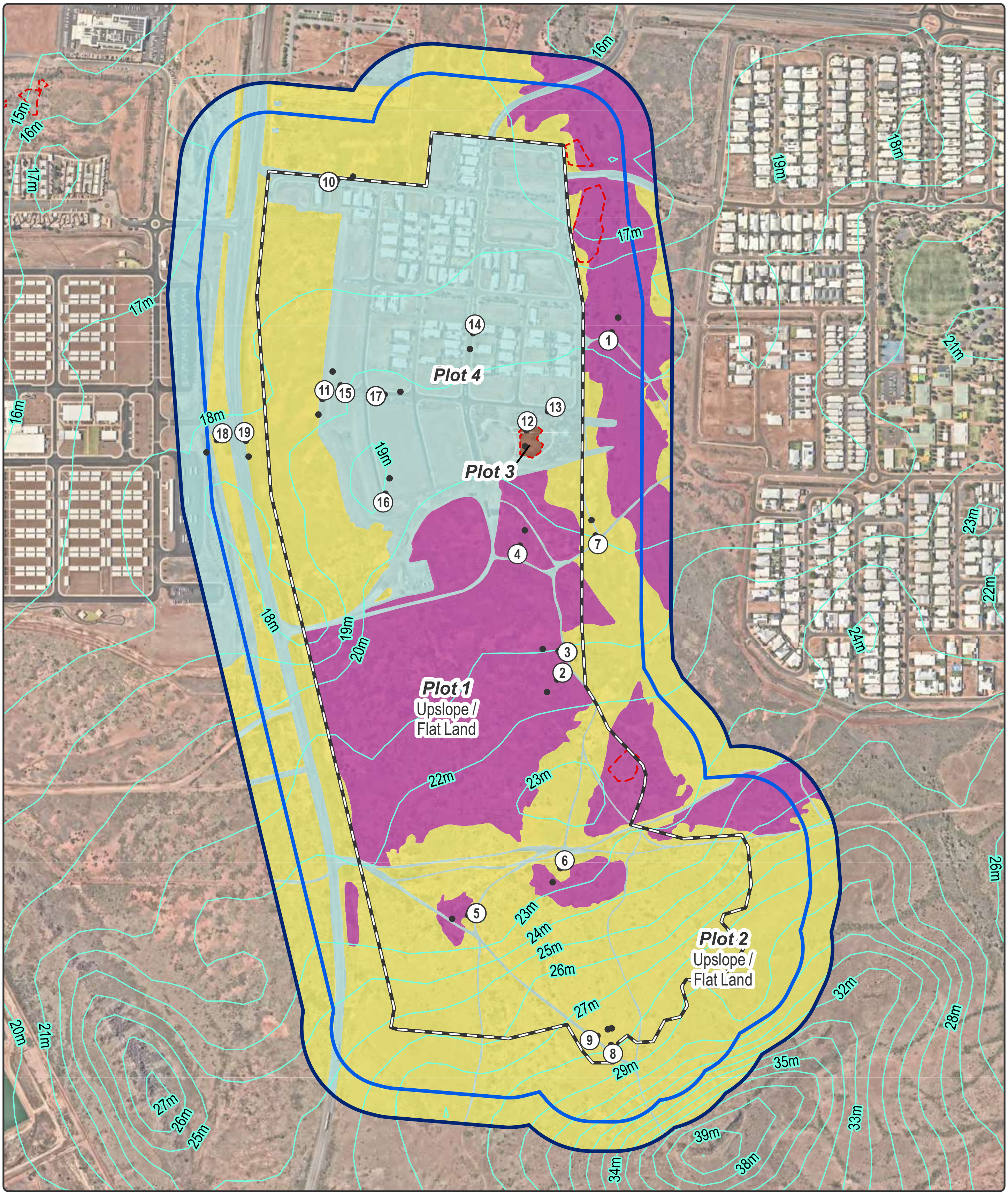

Figure 5: Vegetation Classification (Pre-development)

Subject site
100m site assessment
150m site assessment
Heritage areas
Contour (5m)
Photo location

Vegetation classification

Class C Shrubland
Class G Grassland
Excluded as per clause 2.2.3.2 (c)
Excluded as per clause 2.2.3.2 (e) and (f)

0 75 150 300
Metres

Datum/Projection:
GDA 1994 MGA Zone 50

24PER9629-OK Date: 14/04/2025

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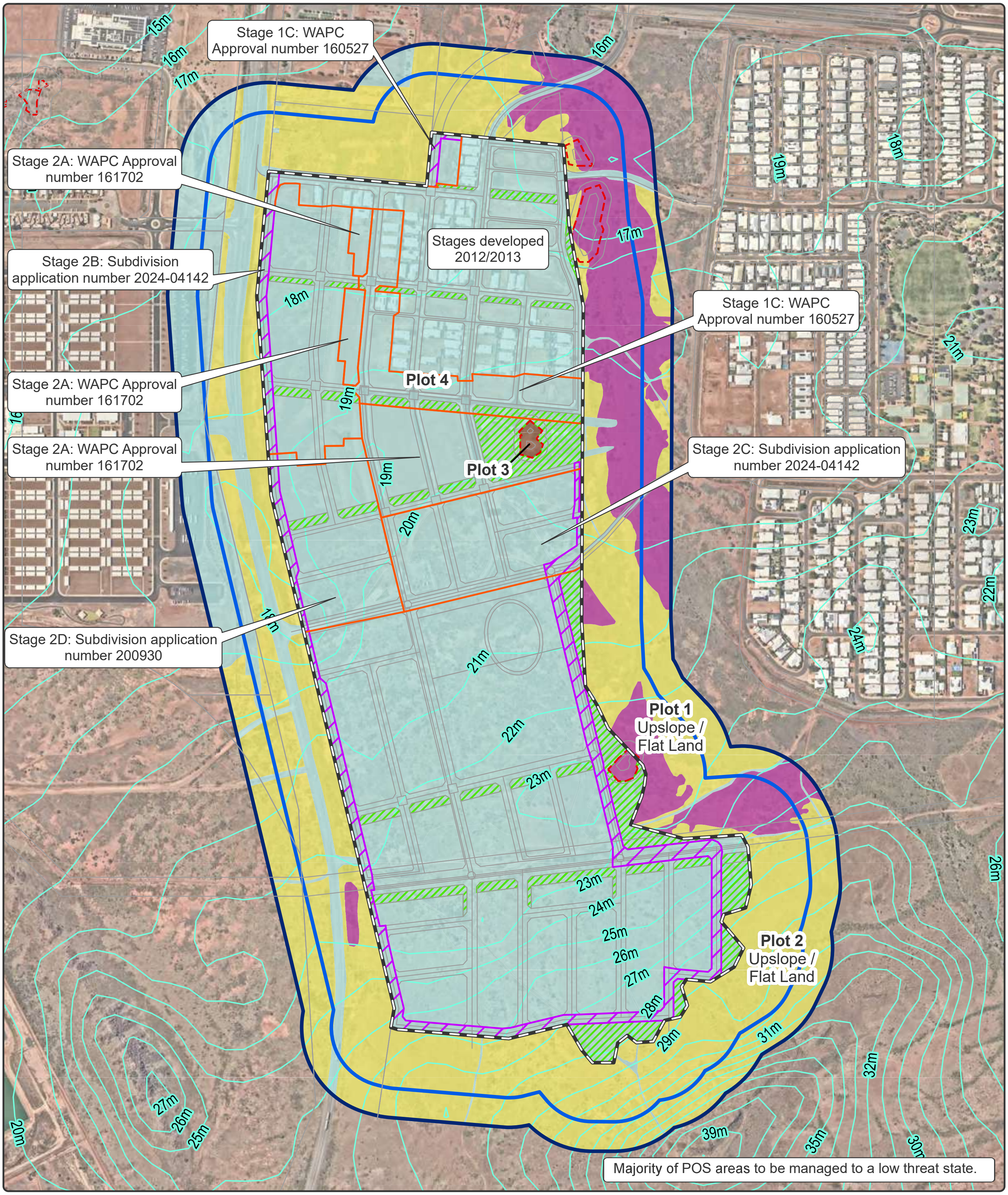

Figure 6: Vegetation Classification (Post-development)

- Subject site
- 100m site assessment
- 150m site assessment
- Heritage areas
- Subdivision stage boundaries
- POS
- Contour (5m)
- Asset protection zone (8 - 15 m)

Vegetation classification

- Class C Shrubland
- Class G Grassland
- Excluded as per clause 2.2.3.2 (c)
- Excluded as per clause 2.2.3.2 (e) and (f)

0 75 150 300
Metres

Datum/Projection:
GDA 1994 MGA Zone 50

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2.3 Bushfire assessment outputs

A Bushfire Attack Level (BAL) assessment has been undertaken in accordance with SPP 3.7, the Guidelines, AS 3959:2018 and the bushfire assessment inputs in Section 2.2. This approach was adopted as the structure plan concept contains sufficient detail to determine future lot layout, therefore a BAL assessment (in the form of a BAL Contour Map) will be more useful in demonstrating potential site risks.

2.3.1 BAL assessment

All land located within 100 m of the classified vegetation depicted in Figure 6 (i.e. post-development) is considered bushfire prone and is subject to a BAL assessment in accordance with AS 3959:2018.

A Method 1 BAL assessment (as outlined in AS 3959:2018) has been completed for the proposed development and incorporates the following factors:

- Fire Danger Index (FDI) rating.
- Vegetation class.
- Slope under classified vegetation.
- Distance between proposed subdivision area and the classified vegetation.

Based on the identified BAL, construction requirements for future buildings on the proposed residential lots can then be assigned. The BAL rating provides an indication of the expected level of bushfire attack (i.e. radiant heat flux, flame contact and ember penetration) that may be received by proposed buildings and subsequently informs the standard of construction (and any setbacks) required to increase building survivability.

2.3.2 Method 1 BAL assessment

Table 4 and Figure 7 display the Method 1 BAL assessment (in the form of BAL contours) that has been completed for the subject site in accordance with AS 3959:2018 methodology.

The BAL assessment factors in clearing of vegetation (and management of any subsequent planted vegetation), and APZs placed over residential cells/lots. Consequently, only two of the three plots listed in Table 2 (i.e. Plots 1 and 2) have been assessed in Table 4 as all other plots will either:

- Be cleared and maintained as per an exclusion under Clause 2.2.3.2 of AS 3959:2018.
- Are already excluded under Clause 2.2.3.2 of AS 3959:2018.
- Are located outside of the 100 m assessment area.

Table 4: Method 1 BAL calculation (BAL contours)

Plot	Vegetation Classification	Effective Slope	Separation distances required				
			BAL-FZ	BAL-40	BAL-29	BAL-19	BAL-12.5
1	Class C Shrubland	All upslopes and flat land (0 degrees)	<7	7–<9	9–<13	13–<19	19–<100
2	Class G Grassland	All upslopes and flat land (0 degrees)	<6	6–<8	8–<12	12–<17	17–<50
ALL OTHER PLOTS ARE EITHER EXCLUDED UNDER CLAUSE 2.2.3.2 OR GREATER THAN 100 M FROM THE SUBJECT SITE							

2.4 Identification of issues arising from the BAL assessment

Management measures will need to be factored into the development design as early as possible to ensure a suitable, compliant and effective bushfire management outcome is achieved to ensure protection of future life and property assets. Demonstration of compliance with the relevant requirements of SPP 3.7, the Guidelines and AS 3959 at future planning stages will also depend on the developer's ability to coordinate the timing and staging of clearing and development works within the subject site with those developments proposed on adjacent landholdings in the aim of avoiding bushfire impacts from temporary retained vegetation.

The indicative BAL assessment indicates portions of some residential cells, and the mixed use cell (F1) within the subject site are potentially exposed to BAL-40 and BAL-FZ ratings due to classified vegetation that is located outside the bounds of the subject site.

Future detailed design (which may include incorporating minimum setbacks/APZs on certain lots) will ensure dwellings can achieve ≤BAL-29. For the portion of the Structure Plan amendment area yet to be developed, an 8 m setback will be required for Cell A1 (from the northern boundary – this may be temporary in nature until future development to the north) and Cell H1 (from the western boundary - noting R30 residential density). Cell F1 (mixed use) should also have an 8 m setback from the western boundary. For areas that have already received subdivision approval, Cell E2 and Cell E6 are to have an 8 m setback applied as part of their respective stage subdivision BMPs.

With the above taken into account, ELA considers the post-development bushfire risk to the subject site from both within the subject site and adjacent areas can be adequately managed through the application of the acceptable solutions under the Guidelines and any additional specified management measures (refer to Section 3.1, 3.2, Figure 8a and Figure 8b).

Should there be any changes in development design or vegetation/hazard extent that requires a modified bushfire management response, then the above BAL ratings will need to be reassessed for the affected areas and documented in a brief addendum to this BMP.

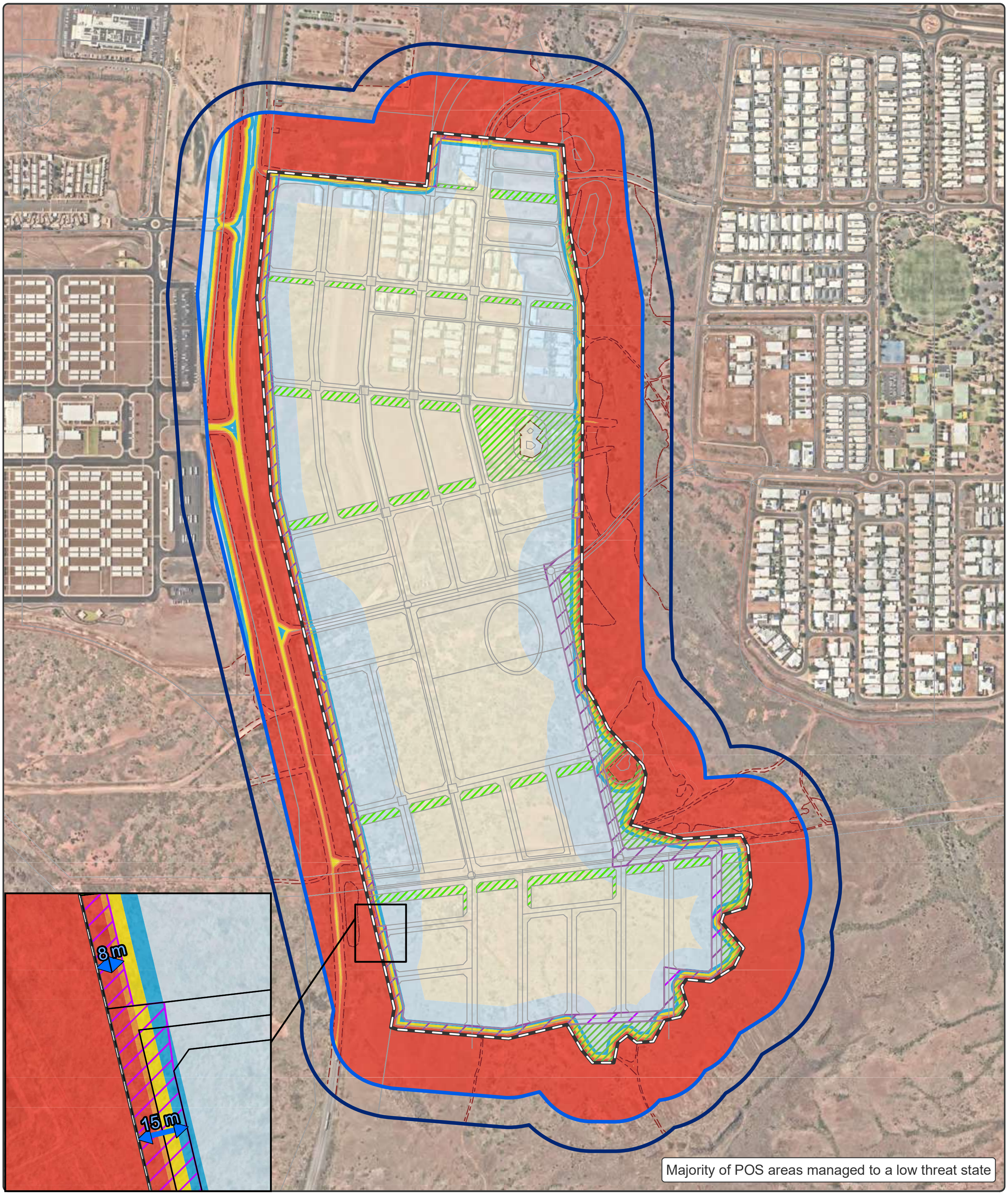

Figure 7: Bushfire Attack Level (BAL) Contours - (Post-development)

Subject site
100m site assessment
150m site assessment
Lot boundary
POS
Asset protection zone (8 - 15 m)
Bushfire hazard interface

Bushfire Attack Level (BAL)

BAL - 12.5
BAL - 19
BAL - 29
BAL - 40
BAL - FZ
BAL - LOW

0 75 150 300
Metres

Datum/Projection:
GDA 1994 MGA Zone 50

24PER9629-OK Date: 14/04/2025

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3. Assessment against the Bushfire Protection Criteria

3.1 Compliance

The proposed Structure Plan amendment is required to comply with policy measures 7.1 & 7.4 of SPP 3.7 and the Guidelines. Implementation of this BMP is expected to meet policy objectives 5.1–5.4 and policy outcomes 6.1–6.4 of SPP 3.7. Future planning applications within the subject site will be required to comply with SPP 3.7 and associated Guidelines that are in effect at that time.

In response to the above requirements of SPP 3.7 and the Guidelines, bushfire risk management measures, as outlined, have been devised for the proposed Structure Plan amendment in accordance with Guideline acceptable solutions to meet compliance with bushfire protection criteria.

Table 5 outlines the Acceptable Solutions (AS) that are relevant to the proposal and summarises how the intent of each Bushfire Protection Criteria has been achieved. No Outcomes Based (OB) Approaches have been proposed for this proposal. The Broader Landscape Assessment required for Element 1 is depicted in Figure 4a–Figure 4c. Bushfire Protection Criteria management measures are depicted in Figure 8a, and Figure 8b, where relevant.

Table 5: Summary of solutions used to achieve bushfire protection criteria

Bushfire Protection Criteria	AS	OB	N/A	Comment
Element 1: Location A1.1a Broader landscape Type A	☒	☐	☐	The subject site relating to the Structure Plan amendment area is classified as Type A and as such, no additional assessment is required. Refer to Section 2.1 for information on the BLA, including Figure 4a–Figure 4c. The proposed development is considered to be compliant with A1.1a.
Element 2: Siting and design A2.1 Siting and design	☒	☐	☐	While portions of some residential cells without perimeter roads, and the mixed use cell may be subject to BAL-40 and BAL-FZ, future detailed design can be refined in BMPs supporting future planning applications to ensure no habitable buildings will be located in these areas (indicated by indicative APZs/8 m setbacks in Figure 6, Figure 7 and Figure 8b). Furthermore, bushfire hazards immediately to the south and south-east will likely be temporary in nature and will be removed as future development occurs. Through the application of APZs/setbacks, the proposed development can achieve a radiant heat impact not exceeding 29kW/m^2 (BAL-29). The proposed development is considered to be compliant with A2.1 as any issues can be further addressed with design detail and/or ongoing hazard removal as future development proceeds.
A2.2 Asset Protection Zone (APZ)	☒	☐	☐	As the lot layout for areas yet to be developed are currently unconfirmed, only indicative APZs can be prescribed at this level of planning. APZs (including whether temporary or in-perpetuity) will be further defined in BMPs supporting future planning applications to ensure that all future habitable buildings on lots will be subject to a BAL rating of BAL-29 or lower. APZs will vary in width from 8 m on residential lots, to the width of the applicable road reserve. Future development may occur to the north, east and south of the subject site and thus, some bushfire hazards will be temporary in nature. APZs can be

Bushfire Protection Criteria	AS	OB	N/A	Comment
				removed as future development with and adjacent to the subject site no longer necessitates this requirement. Figure 6, Figure 7 and Figure 8b demonstrate that APZs can be accommodated within road reserves and where required, residential cells as per the Plan of Subdivision provided in Figure 2. Future planning applications may require APZs/associated setbacks on some lots where classified vegetation is immediately adjacent to the subject site, and where no perimeter road exists. Location of APZs that are maintained in accordance with requirements of '*Standards for Asset Protection Zones'* (WAPC 2024; Appendix B) will be confirmed at subsequent stages of the planning process. Should development be staged, in order to ensure lots within each stage are compliant with the BALs in this BMP, 50/100 m[1] APZs should cleared around each stage of subdivision (or to the extent possible within the developer's landholdings). This can be detailed in BMPs supporting future planning applications. The proposed development is considered to be compliant with A2.2.
A2.3 Clearing of native vegetation	☒	☐	☐	Owing to the intensification of land use for residential, mixed use and education purposes, it is unavoidable that the subject site will need to be cleared of native vegetation. However, vegetation will be retained within the 0.15 ha heritage site located within Stage 2C POS and the heritage site to the south-east of the school site. The proposed development is considered to be compliant with A2.3.
Element 3: Vehicular Access A3.1 Public roads	☒	☐	☐	The subject site is currently accessed by existing public roads, with further roads to be developed as the southern part of the Structure Plan area is developed. The Guidelines do not prescribe values for the trafficable (carriageway/pavement) width of public roads as they should be in accordance with the class of road as specified in the IPWEA Subdivision Guidelines, Liveable Neighbourhoods, Austroad Standards and/or any applicable standard in the local government area. All new public roads within the subject site will be constructed to comply with the requirements set out in the IPWEA Subdivision Guidelines and Vehicular access technical requirements in accordance with the Guidelines applicable at the time of development. This will be addressed in further detail at subsequent stages of the planning process. For reference, current vehicular access technical requirements are included in Appendix C. The existing and proposed public roads within the subject site and external to the subject site are a minimum of 6 m wide. ELA therefore consider the existing public road network would likely provide suitable access and egress for the community and emergency services personnel in the event of a bushfire. The proposed development is considered to be compliant with A3.1.

Bushfire Protection Criteria	AS	OB	N/A	Comment
A3.2 Access routes	☒	☐	☐	Currently arterial access/egress to/from the subject site through the main public road network is available via Euro Boulevard/Dampier Highway to the north-east of the site, allowing two-way travel. An EAW allowing two-way travel out to Madigan Road via Prancing Ave/Wagari Drive currently exists. As part of development in Stage 2D (Subdivision application number 200930), the EAW will be converted to a permanent secondary access/egress route that allows two-way travel via Wagari Drive/Madigan Road (Figure 8a). As part of the Structure Plan amendment, an additional access/egress route allowing two-way travel will be available south of Wagari drive, exiting to Madigan Road Figure 8a). All three routes provide access to suitable destinations. Subject to future development, Wagari Drive and the east–west road to the south of Wagari Drive will be established and will connect the subject site to the existing development east of Madigan Creek. Additionally (pending zoning changes) there will also be two local roads that allow access/egress from the southern portion of the subject site (Figure 8a). In total, there will be three major arterial roads allowing for two-way travel as part of the subject site development. Future development will also provide for two access/egress points to the east and two to the south. Should development be staged, it must be ensured two points of access, allowing two-way travel is available at all times. This can be detailed in BMPs supporting future planning applications. All roads will comply with the vehicular access technical requirements outlined in the Guidelines (Appendix C). The proposed development is considered to be compliant with A3.2a.
A3.3a No-through roads	☒	☐	☐	All roads will be through roads with the exception of the: • North–south road to the west of residential cell A1. • Eastern terminus of Wagari Drive. • Eastern terminus of the road south of Wagari Drive. The terminus of these roads are <200 m from the proposed lot boundary to an intersection where two-way access is provided and thus, a cul-de-sac can be considered as an acceptable solution. Should cul-de-sac turnaround heads (18 m in diameter) not fit entirely within the road reserve, then cul-de-sacs will need to reside within adjacent lots or POS. These cul-de-sacs are to remain in place until future road connections remove this requirement. In the event of staging, any temporary no-through roads will be detailed in individual BMPs relating to each stage. This can be detailed in BMPs supporting future planning applications. The proposed development is considered to be compliant with A3.3a.
A3.3b No-through-road requirements	☒	☐	☐	All public roads will meet the vehicular access requirements of the Guidelines (refer also A3.1), and will have a turnaround area of 18 m at the terminus.
A3.4 Emergency access way	☐	☐	☒	No Emergency Access Ways (EAW) are required for this Structure Plan. However, ELA note a previously approved, signposted emergency access way (EAW) is currently in place through Stage 2D along Wagari Drive that was required as part of the staging process for development to the north of Wagari Drive. Once Stage 2D is established this will be a permanent, public road. The proposed development is considered to be compliant with A3.4.

Bushfire Protection Criteria	AS	OB	N/A	Comment
A3.5a Perimeter roads	☒	☐	☐	The majority of cells have perimeter roads with the exception of A1, E2, E6, F1, H1. However, these cells abut Class G Grassland; a such, perimeter roads are not required. However, where staging results in residential cells abutting Class C Shrubland, a perimeter road (or FSAR) will be required. This can be detailed in BMPs supporting future planning applications. The proposed development is considered to be compliant with A3.5a.
A3.5b Fire service access route	☐	☐	☒	No fire service access routes are required or proposed due to either perimeter roads being present, or perimeter roads not being required due to the cells abutting Class G Grassland. However, where staging results in residential cells abutting Class C Shrubland, a temporary FSAR (or perimeter road) will be required. This can be detailed in BMPs supporting future planning applications. A3.5b is not applicable to this proposed subdivision.
A3.6 Battle-axe access legs	☐	☐	☒	Lot configurations for the southern part of the Structure Plan amendment area are not indicated at this stage; however, given the density of residential dwellings, should battle-axe legs be proposed, it is very likely they will be <50 m from a public road in a reticulated area. In the event they are >50 m from a public road, they will need to meet the requirements of the Guidelines with respect to battle-axe access legs. This can be detailed in BMPs supporting future planning applications. A3.6 is not applicable to this proposed subdivision.
Element 4: Water supply A4.1 Water supply for structure plans	☒	☐	☐	The surrounding areas have a reticulated water supply that will be extended to all proposed lots in accordance with the Water Corporation's Design Standard DS 63 Water Reticulation Standard. The proposed development is considered to be compliant with A4.1.
A4.2 Water supply for subdivision applications	☐	☐	☒	A4.2 is not applicable to Structure Plans.
A4.3 Water supply for existing habitable buildings(s)	☐	☐	☒	Development in the Structure Plan area has occurred prior to this updated Structure Plan BMP being developed. ELA notes all existing habitable dwellings in the northern portion of the Structure Plan area are connected to reticulated water. There are no existing dwellings in the southern portion of the subject site (south of Wagari Drive). The proposed development is considered to be compliant with A4.3.

NOTE: AS - ACCEPTABLE SOLUTION, OB - OUTCOMES BASED APPROACH, N/A- NOT APPLICABLE.

[1] 50 M APZ REQUIRED FOR CLASS G GRASSLAND, 100 M APZ REQUIRED FOR CLASS C SHRUBLAND.

3.2 Additional Bushfire Requirements

3.2.1 Development to the north of Wagari Drive

With the exception of the north-east of the Structure Plan area, the majority of development north of Wagari Drive has already taken place, or is scheduled to take place. Please refer to the relevant BMPs listed in Section 1.1 for specific bushfire management strategies for each stage.

3.2.2 Landscape management and hazard separation zones

All landscaping areas within the subject site (POS and road verges) will be maintained in a manner that will not result in classifiable vegetation.

3.2.2.1 Asset Protection Zones

Areas immediately adjacent to classified vegetation such as roads (e.g. Trevarton Drive) and some portions of residential cells without a perimeter road will be managed as APZs to ensure separation of bushfire hazards and property. This can be detailed further in BMPs supporting future planning applications and subject to Guidelines that are in operation at the time of development. Refer to Figure 8b for indicative location of APZs and refer to Appendix B for detailed information on APZs and their management in accordance with the Guidelines.

3.2.2.2 Clause 2.2.3.2 (f) of AS 3959:2018

This will include landscaping established and maintained as per Clause 2.2.3.2 (f) of AS 3959:2018. Adherence to Clause 2.2.3.2 (f) (i.e. managing vegetation to a 'low threat state') involves factors such as flammability, moisture content or fuel load. Flammability, moisture content and fuel load can be managed by any, or all of the following: reticulated and maintained lawn, removing lower tree branches and loose bark within 2 m of ground level, removing dead branches, managing and removing leaf litter, etc. Examples of vegetation able to achieve this Clause include grassland managed in a minimal fuel condition (nominal height of 100 mm), maintained lawns, maintained public reserves and parklands, cultivated gardens, nature strips and windbreaks.

3.2.3 Staging buffers – APZs and vehicular access

Should development take place in stages, it will be necessary to establish and maintain APZs (within the bounds of the developer's landholdings) around each stage to ensure separation is maintained between proposed lots and any retained temporary bushfire hazards. As a general guide, where the adjacent vegetation is Class G Grassland, 50 m APZs are to be established, where the adjacent vegetation is Class C Shrubland, 100 m APZs are to be established (the Class G Grassland separation width may vary should Class C Shrubland occur beyond the Class G Grassland, but is still within 100 m of the subject site). APZs are to be managed in accordance with the requirements of 'Standards for Asset Protection Zones' (Appendix B) and are to be maintained until such time as future development removes this requirement.

Vehicular access provisions, including maintaining a minimum of two points of access/egress for each stage, must also be addressed. This may involve established public roads or temporary EAWs until two public access roads are available.

3.2.4 School site and mixed use precinct

Site-specific BMPs and mitigation measures will be developed for any future planning applications associated with proposed development (located in bushfire prone areas) within the school site and mixed-use precinct.

The school site is categorised as a vulnerable land use due to future activities planned on the site and definitions within the Guidelines (WAPC 2024). Future planning applications (i.e. development applications) within the school site, therefore, may require a Bushfire Emergency Plan (in addition to a BMP) to ensure the intent of SPP 3.7 is achieved. Where applicable, this will be addressed at future planning stages. Where possible, habitable buildings associated with vulnerable land uses should be located in lowest risk areas of the development site (i.e. BAL-LOW).

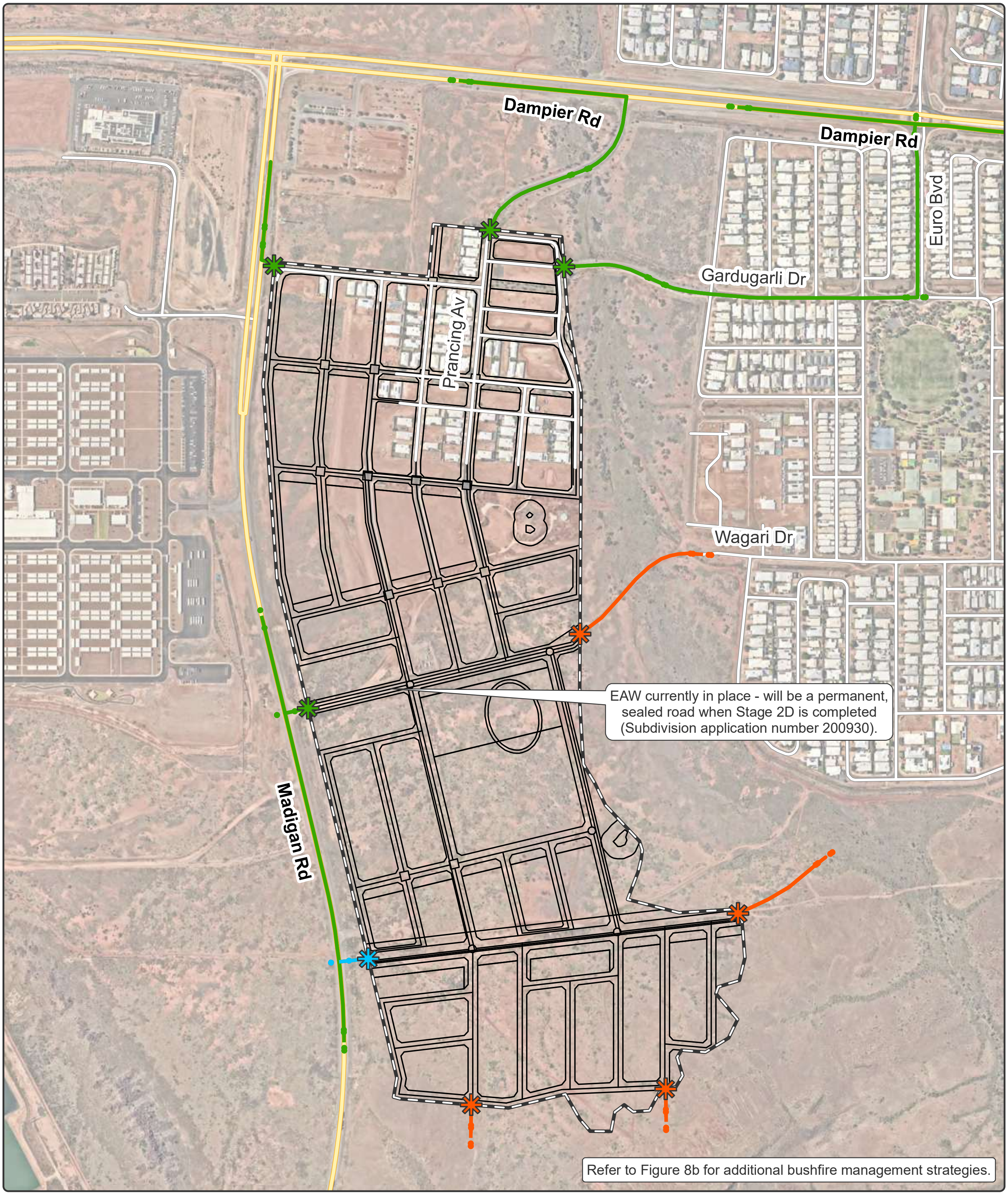

Figure 8a: Access / Egress points and routes

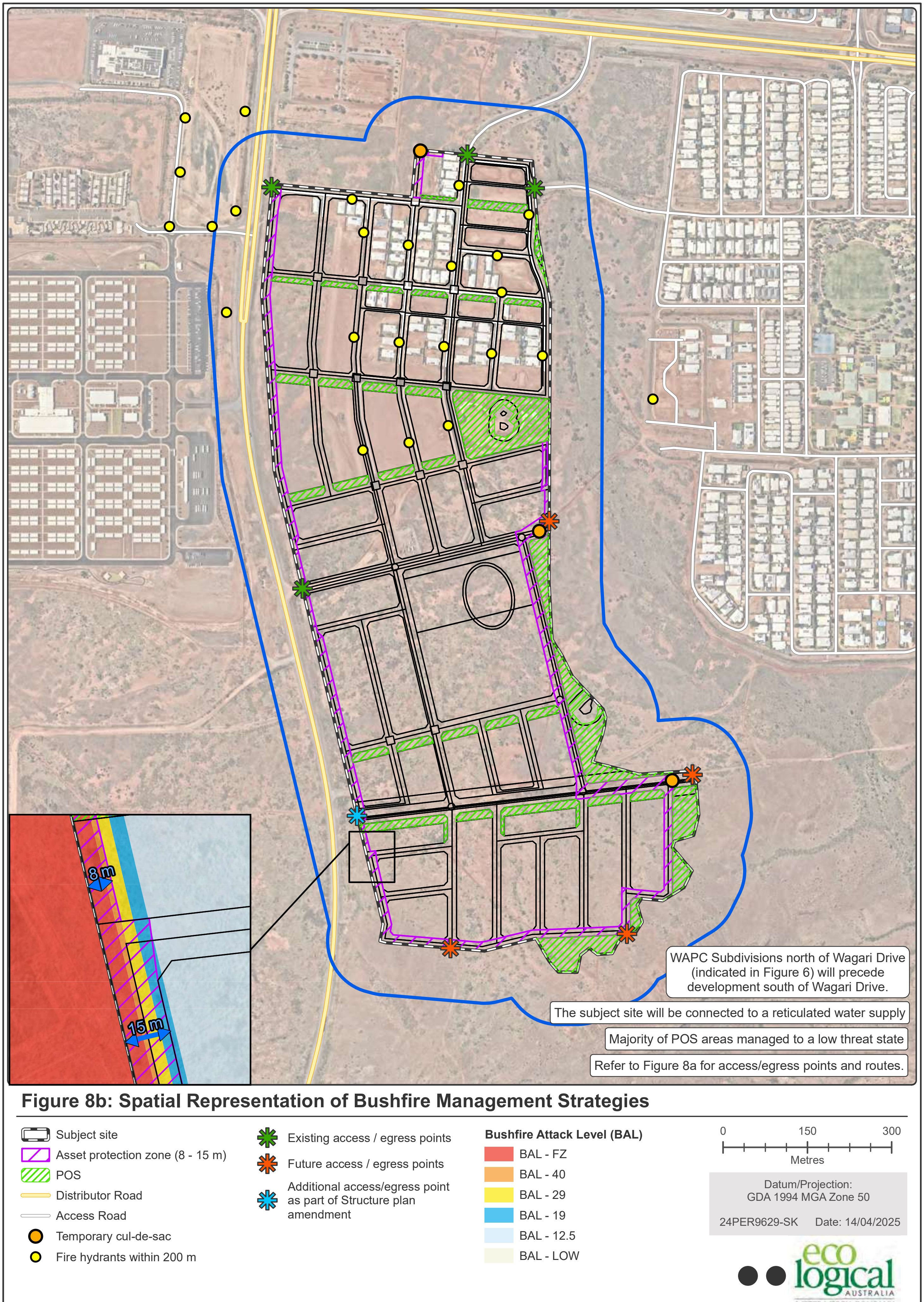

Figure 8b: Spatial Representation of Bushfire Management Strategies

4. Implementation and enforcement

Implementation of the BMP applies to DevelopmentWA, the City of Karratha, and future landowners to ensure bushfire management measures are adopted and implemented on an ongoing basis. This BMP has been prepared as a strategic guide to demonstrate how development compliance can be delivered at future planning stages in accordance with the Guidelines. In this respect, management measures documented in Section 3, where applicable, will be incorporated into development design as early as possible and confirmed through subdivision design.

Existing developments are required to meet the requirements specified in stage-specific BMPs (ELA 2021b, ELA 2024a, ELA 2024b). Future subdivision BMPs are required to meet the relevant commitments outlined in this BMP and are to comply with the relevant policy, standards and guidelines in place at the time of BMP preparation. The BMPs are to include the following detailed information (where applicable):

- Proposed lot layout, including any public open space (POS), drainage areas and retained vegetation.
- Landscaping design/plans in regard to POS, drainage areas and retained vegetation, consistent with the provisions of this BMP.
- Post-development classified vegetation extent and effective slope.
- A BAL contour map demonstrating that future dwellings can achieve BAL ratings of ≤BAL–29.
- Location and width of compliant APZs/setbacks where required.
- Details regarding how bushfire management will be addressed during development staging (i.e. staging APZ buffers, vehicular access, etc).
- Vehicular access provisions, including demonstration that a minimum of two access routes will be achieved for each stage of development in accordance with Acceptable Solution A3.2.
- Water supply provisions with regard to reticulated water.
- Provisions for Notification on Title for any future lots with BAL ratings ≥BAL–12.5 as a condition of subdivision.
- Assessment and compliance with acceptable solutions and/or outcomes based approaches of the bushfire protection criteria in the Guidelines.
- Proposed timing and responsibilities for implementation and management of bushfire mitigation measures.
- Requirements for construction of any Class 1, 2, 3 or associated 10a buildings as well as Class 9b buildings in accordance with AS 3959 to the assessed BAL rating at the building/construction stage.
- Identification of any proposed vulnerable land uses and the required bushfire response to address bushfire planning requirements under SPP 3.7 for such land uses.

5. Bushfire Emergency Procedures

In relation to vulnerable land uses, SPP 3.7 requires the consideration of broad bushfire emergency procedures and options for evacuation and an off-site shelter, as well as an on-site shelter. This section provides an overview of the key bushfire emergency considerations for the school site, with more detailed information to be provided in the Bushfire Emergency Plan (BEP) to be developed at later planning stages (where applicable).

5.1 Broad site risk analysis (key factors)

5.1.1 Occupant characteristics

The school is a primary school, so children will be aged between 6 to 12 years. Occupants will also include school staff.

5.1.2 Vegetation and bushfire hazard separation

The vegetation to the east of the school site is predominantly Class G Grassland, and Public Open Space and will be separated by a road. Separation in the north will include a road and residential lots. Once developed, the land to the north, north-east, west and south of the school will be excludable under Clause 2.2.3.2 (e) and (f). Additionally, land to the east of the Structure Plan area is marked as a future development site subject to zoning changes.

Within the school site, all vegetation will be managed to a low threat state, and where appropriate, an APZ will be placed over the vegetation.

5.1.3 Access/egress

The school site is surrounded by roads that will provide multiple suitable access/egress options.

5.1.4 Suitable on-site shelter and off-site evacuation refuge

There are a number of BAL-LOW areas within the subject site (including within the school site) that may be suitable as an on-site shelter.

Approved City of Karratha off-site evacuation refuges are provided in the City's Local Emergency Management Arrangements Plan (CoK 2021). Additionally, an existing school oval (publicly accessible) to the east of Madigan Creek could also provide an off-site evacuation refuge. Suitable off-site evacuation refuges will be determined as part of future planning stages.

6. Conclusion

In the author's professional opinion, the bushfire protection requirements listed in this assessment provide an adequate standard of bushfire protection for the proposed structure plan amendment. As such, the proposed subdivision is consistent with the aim and objectives of SPP 3.7 and associated guidelines and is recommended for approval.

7. References

Bureau of Meteorology, 2024, *Climate Data Online*, available from http://www.bom.gov.au/climate/data/.

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Department of Fire and Emergency Services (DFES), 2024, *Map of Bush Fire Prone Areas, [Online]*, Government of Western Australia, available from https://maps.slip.wa.gov.au/landgate/bushfireprone/.

Department of Planning (DoP), 2016, *Visual guide for bushfire risk assessment in Western Australia*. DoP, Perth.

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Eco Logical Australia (ELA), 2021b, *Bushfire Management Plan: Subdivision: Madigan Estate, Baynton (Stages 1C & 2A)*. Prepared for DevelopmentWA.

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Standards Australia (SA), 2018, *Construction of buildings in bushfire-prone areas, AS 3959: 2018*. SAI Global, Sydney.

Western Australian Planning Commission (WAPC), 2024, *State Planning Policy 3.7 Bushfire*. WAPC, Perth.

Western Australian Planning Commission (WAPC), 2024, *Planning for Bushfire Guidelines,* WAPC, Perth.

Appendix A – Classified Vegetation Photos

Plot	1	Classification or exclusion clause:	Class C Shrubland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 1

Classified vegetation within this plot is predominantly less than 2 m in height with a foliage cover greater than 30%. The understorey is characterised by dense low shrubs and grasses. This site is associated with Madigan Creek.

Vegetation is situated on flat land.

Plot	1	Classification or exclusion clause:	Class C Shrubland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 2

Classified vegetation within this plot is predominantly less than 2 m in height with a foliage cover greater than 30%. The understorey is characterised by dense low shrubs and grasses.

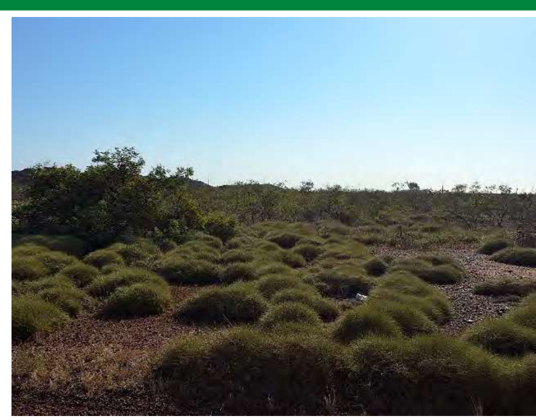
Vegetation is situated on flat land.

Plot	1	Classification or exclusion clause:	Class C Shrubland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 3 (background)

Classified vegetation within this plot is predominantly less than 2 m in height with a foliage cover greater than 30%. The understorey is characterised by dense low shrubs and grasses.

Vegetation is situated on flat land.



Plot	1	Classification or exclusion clause:	Class C Shrubland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 4

Classified vegetation within this plot is predominantly less than 2 m in height with a foliage cover greater than 30%. The understorey is characterised by dense low shrubs and grasses.

Vegetation is situated on flat land.

Plot	1	Classification or exclusion clause:	Class C Shrubland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 5

Classified vegetation within this plot is predominantly less than 2 m in height with a foliage cover greater than 30%. The understorey is characterised by dense low shrubs and grasses.

Vegetation is situated on flat land.

Plot	1	Classification or exclusion clause:	Class C Shrubland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 6

Classified vegetation within this plot is predominantly less than 2 m in height with a foliage cover greater than 30%. The understorey is characterised by dense low shrubs and grasses.

Vegetation is situated on flat land.

Plot	2	Classification or exclusion clause:	Class G Grassland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 7

Classified vegetation within this plot is predominantly grassland with foliage cover from the overstorey less than 10%.

Vegetation is situated on flat land.

Plot	2	Classification or exclusion clause:	Class G Grassland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 8

Classified vegetation within this plot is predominantly grassland with foliage cover from the overstorey less than 10%.

Vegetation is situated on flat land.

Plot	2	Classification or exclusion clause:	Class G Grassland
		Effective slope:	All upslopes and flat land (0 degrees)

Photo Point 9

Classified vegetation within this plot is predominantly grassland with foliage cover from the overstorey less than 10%.

Vegetation is situated on flat land.

Plot	**2**	**Classification or exclusion clause:**	**Class G Grassland**
		Effective slope:	**All upslopes and flat land (0 degrees)**

Photo Point 10

Classified vegetation within this plot is predominantly grassland with foliage cover from the overstorey less than 10%.

Vegetation is situated on flat land.

Plot	**2**	**Classification or exclusion clause:**	**Class G Grassland**
		Effective slope:	**All upslopes and flat land (0 degrees)**

Photo Point 11 (background)

Classified vegetation within this plot is predominantly grassland with foliage cover from the overstorey less than 10%.

The foreground comprises the APZ currently over Stage 2D.

Vegetation is situated on flat land.

Plot	**3**	**Classification or exclusion clause:**	**Excluded AS 3959-2018 2.2.3.2 (c)**
		Effective slope:	**-**

Photo Point 12 (foreground)

This plot relates to the heritage site within the POS of Stage 2C. While it involves the retention of Class G Grassland, this plot has been excluded under Clause 2.2.3.2 (c) as the POS has already been developed and is >20 m from classified vegetation to the east and >20 m from residential lots.

Plot	**4**	**Classification or exclusion clause:**	**Excluded AS 3959-2018 2.2.3.2 (e) and (f)**
		Effective slope:	**-**

Photo Point 13

This plot comprises the POS associated with Stage 2C. With the exception of the Class G Grassland plot that has been retained (left midground of photo, and illustrated in Photo Point 11), the remainder of the POS has been cleared and managed to a low threat state and as such, has been excluded under clause 2.2.3.2 (e) & (f) AS 3959:2018.

Plot	**4**	**Classification or exclusion clause:**	**Excluded AS 3959-2018 2.2.3.2 (e) and (f)**
		Effective slope:	**-**

Photo Point 14

This photograph depicts Prancing Ave in the northern portion of the subject site comprising roads, footpaths, vegetation managed to a low threat state and residential buildings with landscaped gardens.

This plot has been excluded under clause 2.2.3.2 (e) & (f) of AS 3959:2018.

Plot	**4**	**Classification or exclusion clause:**	**Excluded AS 3959-2018 2.2.3.2 (e) & (f)**
		Effective slope:	**-**

Photo Point 15

This plot has been excluded under clause 2.2.3.2 (e) & (f) of AS 3959:2018. This area currently comprises roads, a footpath and land cleared for development. Future development will involve residential buildings with landscaped gardens.

Plot	4	Classification or exclusion clause:	Excluded AS 3959-2018 2.2.3.2 (e) and (f)
		Effective slope:	-

Photo Point 16

This plot has been excluded under clause 2.2.3.2 (e) & (f) of AS 3959:2018. This area currently comprises roads, a footpath and land cleared for development. Future development will involve residential buildings with landscaped gardens.

Plot	4	Classification or exclusion clause:	Excluded AS 3959-2018 2.2.3.2 (e) and (f)
		Effective slope:	-

Photo Point 17

This plot has been excluded under clause 2.2.3.2 (e) & (f) of AS 3959:2018. This area currently comprises roads, a footpath and land cleared for development. Future development will involve residential buildings with landscaped gardens.

Plot	4	Classification or exclusion clause:	Excluded AS 3959-2018 2.2.3.2 (e) & (f)
		Effective slope:	-

Photo Point 18 (background)

This plot has been excluded under clause 2.2.3.2 (e) & (f) of AS 3959:2018. This area comprises a bus depot to the west of Madigan Road.

Plot	4	Classification or exclusion clause:	Excluded AS 3959-2018 2.2.3.2 (e) and (f)
		Effective slope:	-

Photo Point 19

This photo point depicts Madigan Road to the west of the subject site. Madigan Road has been excluded under clause 2.2.3.2 (e) & (f) of AS 3959:2018.

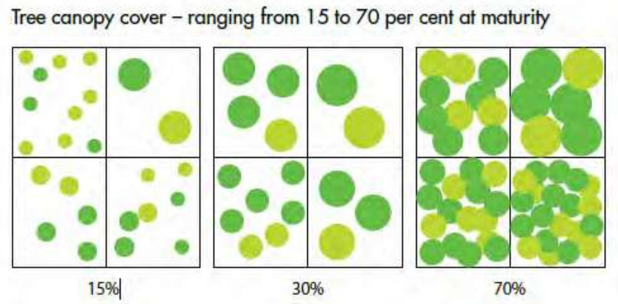
Appendix B – Standards for Asset Protection Zones

The following standards have been extracted from the *Planning for Bushfire Guidelines* (WAPC 2024).

Where a development site cannot be wholly located within an area with a radiant heat impact not exceeding 29 kW/m² (BAL-29) in its pre-development state, an indicative APZ is to be provided and meet the following requirements:

- **Width:** the APZ is to be measured from the development site, and of sufficient size to ensure the radiant heat impact of a bushfire does not exceed 29 kW/m² (BAL-29) in all circumstances.
- **Location:** the APZ is to be contained solely within the boundaries of the lot, except in instances where:
  - The vegetation on the adjoining lot(s) is, and will continue to be, low threat as per Clause 2.2.3.2 of AS 3959 or the requirements of Appendix B.2, Table 9 – APZ technical requirements, or an alternative standard in a local planning scheme, on an ongoing basis in perpetuity as agreed upon via a substantiated management agreement between the applicable landowners and the local government; or
  - The adjoining land is, and will remain in perpetuity, non-vegetated such as a sealed or unsealed road, or a water body.
- **Management:** the APZ is managed in accordance with the requirements of Appendix B.2, Table 9 – APZ technical requirements, or an alternative standard in a gazetted local planning scheme.

OBJECT	REQUIREMENT
Fences within the APZ	Should be constructed from non-combustible materials (for example, iron, brick, limestone, metal post and wire, or bushfire-resisting timber referenced in Appendix F of AS 3959).
Fine fuel load (combustible, dead vegetation matter less than 6 mm in thickness)	• Should be managed and removed on a regular basis to be maintained as low threat vegetation • Should be maintained at less than two tonnes per hectare (on average) • Mulches should be non-combustible such as stone, gravel, shells, rock or crushed mineral earth or wood mulch more than five millimetres in thickness.
Trees* (more than 6 m in height)	• Trunks at maturity should be a minimum distance of six metres from all elevations of the building • Branches at maturity should not touch or overhang a building or powerline • Lower branches and loose bark should be removed to a height of two metres above the ground and/ or surface vegetation. • Canopy cover within the APZ should be less than 15 per cent of the total APZ area • Tree canopies at maturity should be at least 5 m apart to avoid forming a continuous canopy. Stands of existing mature trees with interlocking canopies may be treated as an individual canopy provided the total canopy cover within the APZ does not exceed 15 per cent and is not connected to the tree canopy outside the APZ.

OBJECT	REQUIREMENT
	
Shrub* and scrub* (0.5 m to 6 m in height). Shrub and scrub more than 6 m in height are to be treated as trees.	• Should not be located under trees or within three metres of buildings • Should not be planted in clumps more than five square metres in area • Clumps should be separated from each other and any exposed window or door by at least 10 metres.
Ground cover*(less than 0.5 m in height. Ground cover more than 0.5 m in height is to be treated as shrub)	• Can be planted under trees but must be maintained to remove dead plant material, as prescribed in 'Fine fuel load' above • Can be located within two metres of a structure but three metres from windows or doors if more than 100 mm in height.
Grass	• Grass should be maintained at a height of 100 mm or less, at all times • Wherever possible, perennial grasses should be used and well-hydrated with regular application of wetting agents and efficient irrigation.
Defendable space	Within three metres of each wall or supporting post of a habitable building; the area is kept free from vegetation but can include ground cover, grass and non- combustible mulches as prescribed above.
Liquid petroleum gas cylinders	• Should be located on the side of a building farthest from the likely direction of a bushfire or on the side of a building where surrounding classified vegetation is upslope, at least one metre from vulnerable parts of a building • The pressure relief valve should point away from the house • No flammable material within six metres from the front of the valve • Must sit on a firm, level and non-combustible base and be secured to a solid structure.
Notes: * Plant flammability, landscaping design and maintenance should be considered – refer to explanatory notes provided in WAPC 2024 *Planning for Bushfire Guidelines*.	

Appendix C - Vehicular access technical requirements (WAPC 2024)

	1		2		3		4		5	
	PERIMETER ROADS		PUBLIC ROADS		EMERGENCY ACCESS WAY[3]		FIRE SERVICE ACCESS ROUTE[3]		BATTLE-AXE AND PRIVATE DRIVEWAYS[1]	
MAP OF BUSHFIRE PRONE AREAS DESIGNATION	Area 2	Area 1	Area 2	Area 1	Area 2	Area 1	Area 2	Area 1	Area 2	Area 1
Minimum horizontal clearance (metres)	12	8	See note 5		10	6	10	6	6	
Minimum vertical clearance (metres)	4.5									
Minimum weight capacity (tonnes)	15									
Maximum grade unsealed road[2]	See note 5		See note 5		1:10 (10% or 6º)					
Maximum grade sealed road[2, 4]					1:7 (14.3% or 8º)					
Maximum average grade sealed road					1:10 (10% or 6º)					
Minimum inner radius of road curves (metres)					8.5					

[1] DRIVEWAYS AND BATTLE-AXE LEGS TO COMPLY WITH THE RESIDENTIAL DESIGN CODES AND DEVELOPMENT CONTROL POLICY 2.2 RESIDENTIAL SUBDIVISION WHERE NOT REQUIRED TO COMPLY WITH THE WIDTHS IN THIS APPENDIX OR THE GUIDELINES.

[2] DIPS MUST HAVE NO MORE THAN A 1 IN 8 (12.5% - 7.1 DEGREES) ENTRY AND EXIT ANGLE.

[3] TO HAVE CROSSFALLS BETWEEN 3 PER CENT AND 6 PER CENT.

[4] FOR SEALED ROADS ONLY THE MAXIMUM GRADE OF NO MORE THAN 1 IN 5 (20 PER CENT) (11.3 DEGREES) FOR NO MORE THAN 50 METRES IS PERMISSIBLE, EXCEPT FOR SHORT CONSTRICTIONS TO 3.5 METRES FOR NO MORE THAN 30 METRES IN LENGTH WHERE AN OBSTRUCTION CANNOT BE REASONABLY AVOIDED OR REMOVED.

[5] AS OUTLINED IN THE INSTITUTE OF PUBLIC WORKS ENGINEERING AUSTRALASIA (IPWEA) SUBDIVISION GUIDELINES, LIVEABLE NEIGHBOURHOODS, AUSTROADS STANDARDS MAIN ROADS STANDARD, SUPPLEMENT, POLICY OR GUIDELINE AND/OR ANY APPLICABLE OR RELEVANT LOCAL GOVERNMENT STANDARD OR POLICY.

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ACOUSTIC MODELLING REPORT FOR STRUCTURE PLAN AMENDMENT

KARRATHA MADIGAN RESIDENTIAL ESTATE
MADIGAN RD KARRATHA WA 6714

REFERENCES

A. SPP 5.4 Road and Rail Noise Policy Sept 2019.

B. SPP 5.4 Road and Rail Noise Implementation Guidelines Sept 2019.

APPENDICES

BACKGROUND

1.1 ND Engineering was re-engaged to submit a new acoustic report for updating the previous reports essentially as follows:

a. This document was prepared to support the Madigan Structure Plan and that further modelling will be completed subject to subdivision approval;

b. Noise modelling utilising SoundPlan software with the specific aim of determining the use of Quiet House packages with Open Graded Asphalt road surface;

c. Data to be sourced from MRWA TrafficMap data circa 2010 and 2025/26;

d. Noise modelling prediction will be based on 2046, for a 20 year planning horizon, using recent MRWA email advice of a traffic growth rate of 1% per annum in the absence of MRWA traffic modelling;

e. Noise measurements from 2010 were used given that the traffic volumes to 2025/26 have not significantly change other than an increase in Heavy Vehicle traffic from 20% to 40%.

DISCUSSION

2.1 The detailed assessment is conducted via the FIGURES in APPENDIX A including the notes.

2.2 Issues with noise can be reduced by changing the road surface from the existing *14mm chip seal* to a *Dense graded asphalt* in line with the Southern end of Madigan Road which also has accommodation units, significantly less than on both sides of the Northern end of Madigan Road.

2.3 The road surface change results in a lower requirement for the application of Quiet House packages along Maddigan Road opposite the development.

RECOMMEDATION

3. The following recommendations are made:

a. Provision of a *Dense Graded Asphalt* road surface along the length of Maddigan Road opposite the estate; and

b. Where the noise modelling figures shows that Quiet House packages are required then they only need to be applied to the affected surfaces. See also APPENDIX A and APPENDIX O for more information.

4. If you require further advice please contact me.

Yours Sincerely

The Institution of Engineers, Australia
N. M. Della Gatta
MIEAust
Professional Engineer
Membership No. 1184788

20 MARCH 2026

APPENDIX A – ACOUSTIC MODELLING

A1. This appendix contains the following Figure:

FIGURE A1 – SITE WITH HOUSES & RESIDENTIAL FENCES
(with Dense Graded Asphalt & Madigan Rd elevated 1m)

A2. The following notes apply to the figures:

a. North is top of page;

b. Noise contours, receiver heights, are 1.4m above the residential ground level;

c. Night time noise levels are ~9dB(A) lower than day time noise levels thus rendering the day time noise levels as the determining noise modelling criteria;

d. CONCAWE modelling conditions have been adopted as per DWER 2021 guidelines;

e. Ground surface has been treated as hard surfaces with minimal ground or grass cover;

f. Road speeds remained at 80 kph.

g. Traffic volumes are based on MRWA Traffic Map 2025/26 data of 2961 vehicles average week day traffic volume inclusive of 40.6% Heavy Vehicles. Advice from MRWA is that predicted traffic volumes are expected to increase a 1% per annum resulting in a 2046 design horizon of 3613 average weekday traffic volume. MRWA also advises that the 40.6% Heavy Vehicles be continued to be also applied to the 2046 predictions;

i. Traffic source heights are as follows:

- Passenger vehicles (Austroads Class 1 and 2)	+0.5m
- Heavy vehicles (Austroads Class 3 and up) – Engine	+1.5m
- Heavy vehicles (Austroads Class 3 and up) – Exhaust	+3.6m;

j. The road surface detail provided by MRWA for the Northen end of Madigan Road is for a *14mm single chip single seal* which has a +3.5 dB(A) noise increase correction factor above a *Dense Graded Asphalt* which has a +0.0 noise correction factor.

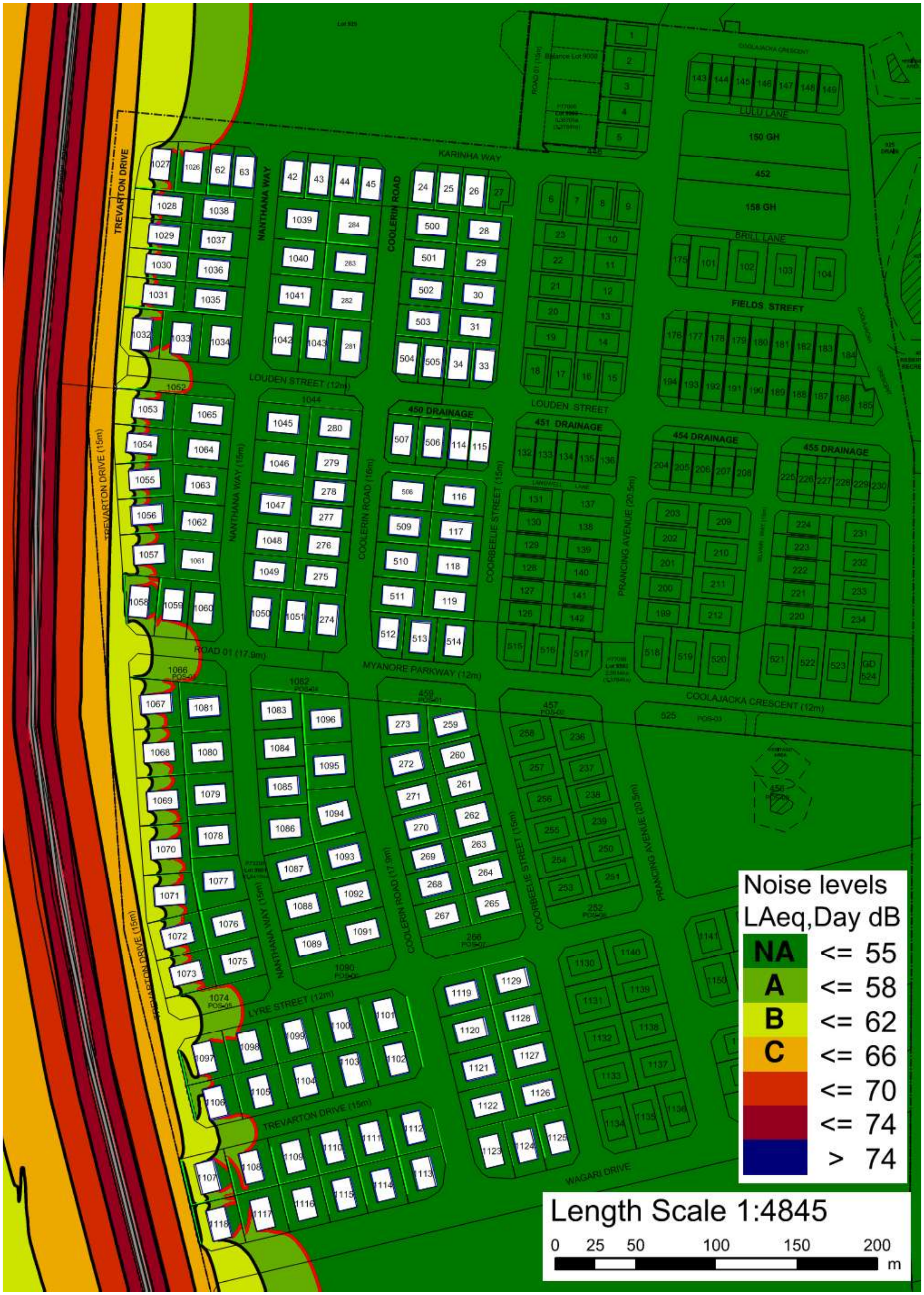
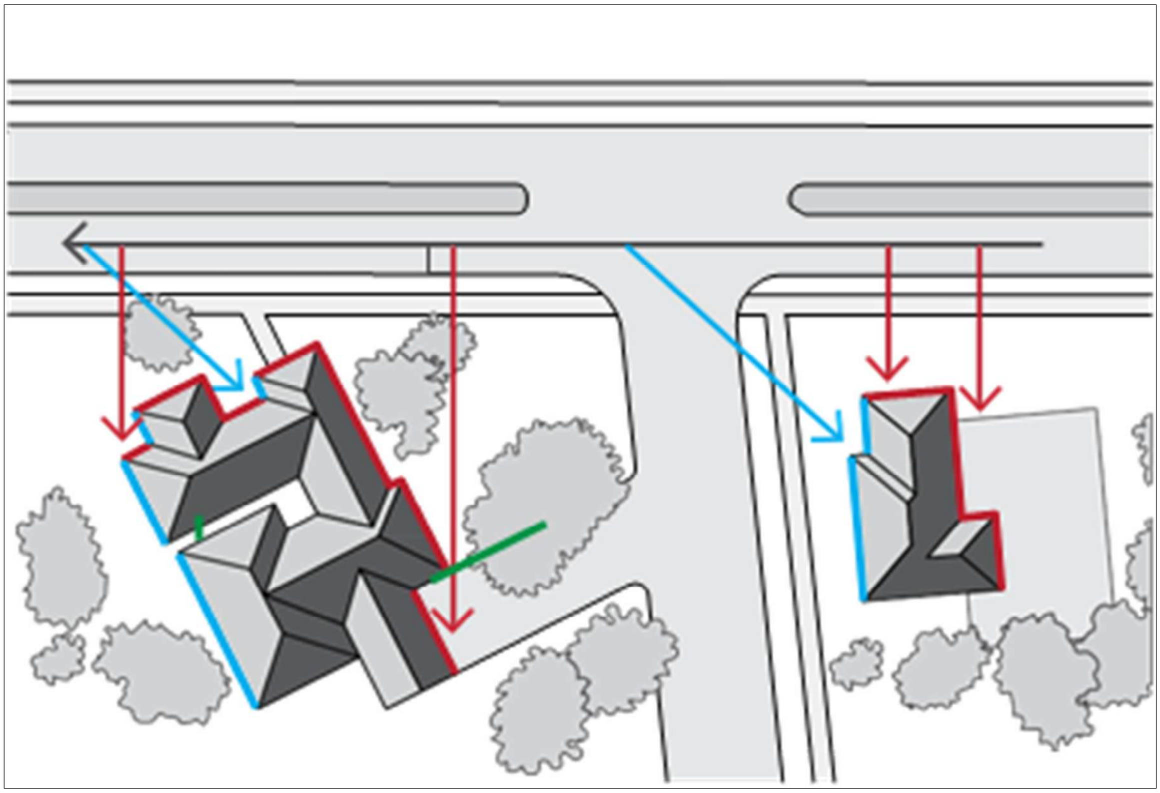


FIGURE A1 – SITE WITH HOUSES & RESIDENTIAL FENCES
(with Dense Graded Asphalt & Madigan Rd elevated 1m)

APPENDIX O – ORIENTATION

Road and Rail Noise Guidelines September 2019 page 18

Determining building face orientation



DETERMINING BUILDING FACE ORIENTATION

'Facing' the transport corridor (red):

Any part of a building facade is 'facing' the transport corridor if any straight line drawn perpendicular (at a 90-degree angle) to its nearest road lane or railway line intersects that part of the façade without obstruction (ignoring any fence).

'Side on' to transport corridor (blue):

Any part of a building facade that is not 'facing' is 'side on' to the transport corridor if any straight line, at any angle, can be drawn from it to intersect the nearest road lane or railway line without obstruction (ignoring any fence).

'Opposite' to transport corridor (green):

Neither 'side on' nor 'facing', as defined above.

FIGURE O1 – SPP5.4 ORIENTATION EXTRACT

APPENDIX P – PLANS

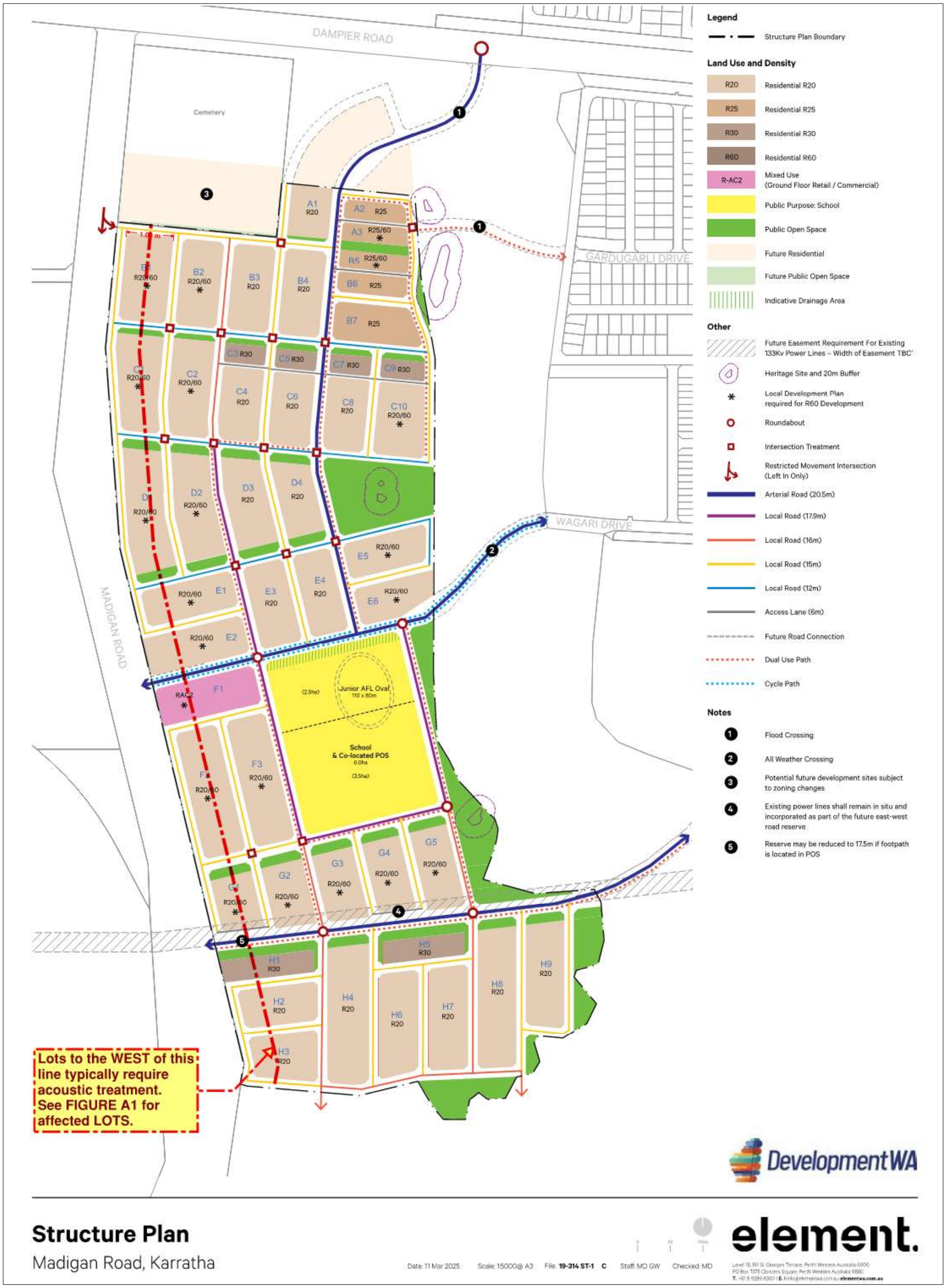


FIGURE P1 – STRUCTURE PLAN

APPENDIX SA – QUIET HOUSE A REQUIREMENTS

TABLE 3A – QUIET HOUSE 'A' REQUIREMENTS

MODIFIED Extract from SPP5.4 Table 3 – Quiet house requirements

Exposure Category A Quiet House A - ACOUSTIC RATINGS (Rw+Ctr) and EXAMPLE constructions

Orientation to corridor	Walls	External doors NB: **10mm** glass can be replaced with either: - 6.50 Hush glass; or - 6.76 Whisper glass.	Windows NB: **10mm** glass can be replaced with either: - 6.50 Hush glass; or - 6.76 Whisper glass.
FACING	**Bedrooms** and **Indoor living & Work areas** to **Rw+Ctr 45 dB** **Double Brick Option 1**: NA **Brick Veneer Option 2**: - Brick 110x230x76, 140 kg/m^2, 1273 kg/m^3; - 50 airgap + 75 steel stud with point ties & 75 fibrous insulation 11 kg/m^3; - 10 plasterboard. Overall 245w. Predicted Rw+Ctr 54 > 45. **Stud wall Option 3:** - 1x layer 16mm JH Linea Weatherboard 1x 21.9 kg/m^2 = 21.9 kg/m^2; - minimum 75 airgap including 75 steel studs & 75mm cavity insulation GlassWool or 75 fibrous insulation 11 kg/m^3; - 2x layers 13mm plasterboard 2x 9kg/m^2 = 18 kg/m^2. Overall 117w = 16 + (75) + 13 + 13. Predicted: Rw+Ctr 47 > 45	**Bedrooms:** **-** Fully glazed hinged door with certified **Rw+Ctr 28dB** rated door and frame including seals and 6mm glass **Other external doors** to **Rw+Ctr 25dB**, e.g. - 35mm solid core timber hinged door and frame system certified to **Rw 28dB** including seals; - Glazed sliding door with **10mm** glass and weather seals.	**Bedrooms:** - Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum **10mm** single or 6mm-12mm-**10mm** double insulated glazing **Rw+Ctr 28 dB.** Sealed awning or casement windows may use 6 mm glazing instead. **Indoor living and work areas** **-** Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing **Rw+Ctr 25dB.**
SIDE-ON	**Bedrooms** and **Indoor living & Work areas** to **Rw+Ctr 45 dB** As per FACING above.	**Bedrooms:** **-** Fully glazed hinged door with certified **Rw+Ctr 25dB** rated door and frame including seals and 6mm glass	**Bedrooms:** - Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum **10mm** single or 6mm-12mm-10mm

		Other external doors to **Rw+Ctr 22dB**, e.g. - 35mm solid core timber hinged door and frame system certified to **Rw 25dB** including seals; - Glazed sliding door with **10mm** glass and weather seals for bedrooms	double insulated glazing **Rw+Ctr 25 dB.** Sealed awning or casement windows may use 6 mm glazing instead. **Indoor living and work areas** - Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing **Rw+Ctr 22dB.**
OPPOSITE			
	Bedrooms and **Indoor living & Work areas** No specific requirements	**Bedrooms** and **Indoor living & Work areas** No specific requirements	**Bedrooms** and **Indoor living & Work areas** No specific requirements

1 – Ground floor roofs and ceilings to **Rw+Ctr 35dB**

Metal sheet roof with minimum 50mm anti-condensation insulation under,
with at least 10mm plasterboard ceiling;
with R1.3+ insulation or greater to meet energy efficiency requirements,
with average minimum 250mm ceiling cavity.

2 - Outdoor living areas

a. At least one outdoor living area located on the opposite side of the building from the corridor; and/or

b. At least one ground level outdoor living area screened using a solid continuous fence or other structure, including nearby residences, of minimum 2.0 metres height above ground level.

NB - A significant consideration is that for the Lots within the land cells closest to Madigan Road, are set so that the Outdoor Living Areas are shielded from Madigan Road by being paced on the Eastern sides so then there is no requirement to build a noise wall between the LOTS and Madigan Road. This determination needs to be made at the detailed design stage.

See also APPENDIX G – GENERAL REQUIREMENTS.

See also APPENDIX O – ORIENTATION for the façade orientation derivations.

APPENDIX SB – QUIET HOUSE B REQUIREMENTS

TABLE 3B – QUIET HOUSE 'B' REQUIREMENTS

MODIFIED Extract from SPP5.4 Table 3 – Quiet house requirements

REQUIRED Acoustic Ratings (Rw+Ctr) and EXAMPLE constructions

Orientation to corridor	Walls	External doors	Windows
		NB: 10mm glass can be replaced with either: - 6.50 Hush glass; or - 6.76 Whisper glass.	NB: 10mm glass can be replaced with either: - 6.50 Hush glass; or - 6.76 Whisper glass.
FACING			
	Bedrooms and **Indoor living & Work areas** to **Rw+Ctr 50 dB** **Double Brick Option 1:** NA **Brick Veneer Option 2:** - Brick 110x230x76, 140 kg/m^2, 1273 kg/m^3; - 50 airgap + 75 steel stud with point ties & 75 fibrous insulation 14 kg/m^3; - 10 plasterboard. Overall 245width. Predicted Rw+Ctr 54 > 50. **Stud wall**: - 1x layer 16mm JH Linea Weatherboard 1x 21.9 kg/m^2 = 21.9 kg/m^2; - minimum 103mm airgap including 75 steel studs with 28 resilient mounts & 75mm cavity insulation GlassWool or 75 fibrous insulation 11 kg/m^3; - 2x layers 13mm CSR Soundcheck 2x 13.0kg/m^2 = 26 kg/m^2. Overall 145w = 16 + (75 + 28) + 13 + 13 Predicted: Rw+Ctr 53 > 50	**Bedrooms:** - Fully glazed hinged door with certified **Rw+Ctr 31dB** rated door and frame including seals and 10mm glass **Other external doors:** to **Rw+Ctr 28dB**, e.g. - 35mm solid core timber hinged door and frame system certified to **Rw 28dB** including seals; - Glazed sliding door with 10mm glass and weather seals	**Bedrooms:** Total external door and window system area up to 40% of room floor area: Fixed sash, awning or casement with minimum 6mm single or 6mm-12mm-**6.38mm** double insulated glazing **Rw+Ctr 31 dB.** **Indoor living & Work areas:** - Up to 40% floor area: Sliding or double hung with minimum 6mm single pane or 6mm-12mm-**6.38mm** double insulated glazing **Rw+Ctr 28 dB**; and - Sealed awning or casement windows may use 6mm glazing instead **Rw+Ctr 28 dB.**
SIDE-ON			
	Bedrooms and **Indoor living & Work areas** **to Rw+Ctr 50 dB**	**Bedrooms:** - Fully glazed hinged door with certified **Rw+Ctr 25dB** rated door and frame	**Bedrooms:** Total external door and window system area up to 40% of room floor area:

	As per FACING above.	including seals and 6mm glass **Other external doors:** to **Rw+Ctr 22dB**, e.g. - 35mm solid core timber hinged door and frame system certified to **Rw 25dB** including seals; - Glazed sliding door with 10mm glass and weather seals.	- Sliding or double hung with minimum 10mm single or 6mm-12mm-10mm double insulated glazing **Rw+Ctr 25 dB**. - Sealed awning or casement windows may use 6mm glazing instead. **Indoor living & Work areas:** Up to 40% floor area: Sliding, casement or double hung with minimum 6mm single pane or 6mm-12mm-**6.38mm** double insulated glazing **Rw+Ctr 22 dB.**
OPPOSITE			
	Bedrooms and **Indoor living & Work areas to Rw+Ctr 50 dB** As per FACING above.	**Bedrooms:** **-** Fully glazed hinged door with certified **Rw+Ctr 25dB** rated door and frame including seals and 6mm glass **Other external doors** to **Rw+Ctr 22dB**, e.g. - 35mm solid core timber hinged door and frame system certified to **Rw 25dB** including seals; - Glazed sliding door with 10mm glass and weather seals for bedrooms	**Bedrooms:** - Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum 10mm single or 6mm-12mm-10mm double insulated glazing **Rw+Ctr 25 dB.** Sealed awning or casement windows may use 6 mm glazing instead. **Indoor living and work areas** - Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing **Rw+Ctr 22dB.**

1 - Roofs and ceilings of highest floors to **Rw+Ctr 35dB**
Metal sheet roof with minimum 50mm anti-condensation insulation under, with at least 10mm plasterboard ceiling; with R3.0+ insulation or greater to meet energy efficiency requirements, with average minimum 250mm ceiling cavity.

2 - Outdoor Living Areas (OLA) requirements:

a. At least one OLA located on opposite side of the building from traffic corridor; and/or
b. At least one ground level OLA screened using a close solid continuous fence or other close structure of minimum 2.4 metres height above ground level.

NB - A significant consideration is that for the Lots within the land cells closest to Madigan Road, are set so that the Outdoor Living Areas are shielded from Madigan Road by being paced on the Eastern sides so then there is no requirement to build a noise wall between the LOTS and Madigan Road. This above determination needs to be made at the detailed design stage.

See also APPENDIX SG – GENERAL REQUIREMENTS.

See also APPENDIX O – ORIENTATION for the façade orientation derivations:

APPENDIX SG – GENERAL REQUIREMENTS

(APPLICABLE TO ALL PACKAGES)

3 - Mechanical ventilation / air conditioning considerations: - Acoustically rated openings and ductwork to provide a minimum sound reduction performance of Rw 40dB into sensitive spaces; - Evaporative systems require attenuated ceiling air vents to allow closed windows; - Refrigerant-based systems need to be designed to achieve NCC fresh air ventilation requirements; - Openings such as eaves, vents and air inlets must be acoustically treated, closed or relocated to building sides facing away from the corridor where practicable.
4 - The airborne weighted sound reduction index (Rw) and traffic correction term (Ctr) are published by manufacturers/suppliers, can be determined by acoustical consultants or measured in accordance with AS ISO 717.1. Higher Rw+Ctr values infer greater sound insulation. All values are minimum Rw+Ctr.
5 - Example construction for different external wall ratings of Rw+Ctr 45dB and 50dB are provided and are based on the installation and sealing of joints and penetrations. Recommendations specific to this project are contained in the Quiet House tables. NB1: Use fibreglass insulation requirements being the greater of either the acoustic requirements or energy efficiency requirements. NB2: The use of polystyrene or any other board product including permicav for acoustic purposes is prohibited. All reference to insulation is to glass wool (GW) insulation.
6 - Window and external door sound reduction values provided are based on the provision of suitable acoustic seals to prevent sound leakage. To comply with the above ratings, all external glass windows and doors specified must have the following: - Operable windows and external doors must have a seal to restrict air infiltration fitted to each edge and doors must have a drop seal to provide an airtight seal when closed - Within doors or fixed framing, glazing must be set and sealed using an airtight arrangement of non-hardening sealant, soft rubber (elastomer) gasket and/or glazing tape, or be verified by manufacturer or approved person that the construction system as to be installed achieves the relevant Rw+Ctr value - In this context, a seal is foam or silicon-based rubber compressible strip, fibrous seal with vinyl fin interleaf or the like. Brush / pile type seals without this seal included are not allowed. - Glazing referenced can be monolithic, laminated or toughened safety glass.
7 - Any penetrations in a part of the building envelope must be acoustically treated so as not to degrade the performance of the building elements affected. Most penetrations in external walls such as pipes, cables or ducts can be sealed through caulking gaps with non-hardening mastic or suitable mortar.

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

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

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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 1.47×10^6.

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)

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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

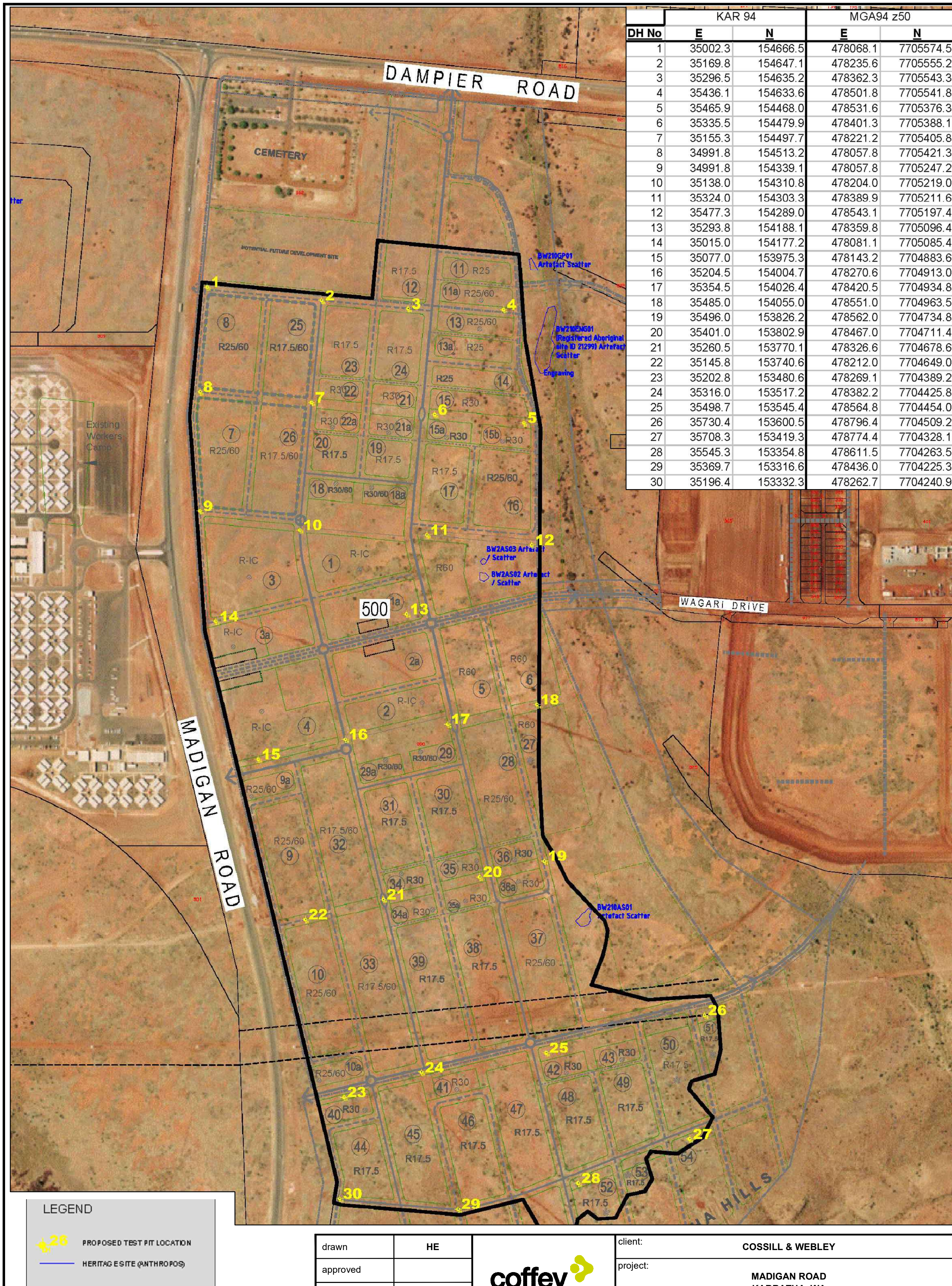
Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As 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



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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
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drawn	HE	client:	COSSILL & WEBLEY
approved		project:	MADIGAN ROAD KARRATHA, WA
date	15/11/10		
scale	1:5000	title:	SITE PLAN SHOWING TEST LOCATIONS
original size	A3	project no: GEOTPERT02828AS	fig no: FIGURE 1 rev:

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EXAMPLE OF GILGAI SOILS

drawn	HE	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:

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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:

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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:	

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Appendix A

Results of Field Investigation

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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.

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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)

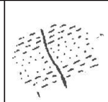
(A 0.075 mm particle is about the smallest particle visible to the naked eye)

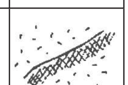
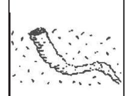
FIELD IDENTIFICATION PROCEDURES				USC	PRIMARY NAME
COARSE GRAINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate 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

		IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.				
		DRY STRENGTH	**DILATANCY**	**TOUGHNESS**	**USC**	**PRIMARY NAME**
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm	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.	

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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: 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**

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	15.5 – 14.0	0.0 – 1.7		CI	**GRAVELLY CLAY**, medium plasticity, brown red; gravel, fine to coarse grained, sub-angular, friable; with some sand, coarse grained ....0.6m, becoming clayey gravel Grading into	D			Sub-angular to sub-rounded gravel at ground surface, fine to coarse grained
				B	13.5 – 13.0	1.7 – 2.9			**WEATHERED ROCK**, fine grained; residual soil to highly weathered; rock is highly fractured; low to very low strength ....2.3m, rock fragments becoming low to medium strength	D			
					12.5 – 12.0	2.9 – 3.5			EXCAVATION TP01 TERMINATED AT 2.90 m				

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:52

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

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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

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	HP >500kPa; HP >500kPa; B; HP >500kPa; HP =500kPa	15.5; 15.0	0.0; 0.5		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
					14.5	1.0		CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled pale brown; gravel, fine to medium grained Grading into	D	H		
					14.0	1.5; 2.0			**WEATHERED ROCK**, fine grained; highly weathered; rock is highly fractured; some medium to high strength clasts within layer				
					13.5; 13.0; 12.5; 12.0	2.5; 3.0; 3.5			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
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

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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	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	HP >500kPa		0.0		CH	**CLAY**, high plasticity, brown / dark brown; with some sand, medium to coarse grained	D	H		
				HP >500kPa	15.0	0.5			....0.5m, trace gravel				
				HP >500kPa					....0.8m, gravel content increasing	D			
				HP >500kPa	14.5								
				B		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			
		N			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

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Engineering Log - Excavation

Excavation No. **TP04**
Sheet No. 1 of 1
Project No. **GEOTPERT02828AS**

Client : ***Cossill & Webley Consulting Engineers***
Date excavated **19/10/10**
Principal :
Date completed **19/10/10**
Project : ***Madigan Road***
Logged by : **PCW**
Location : ***Karratha***
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

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; HP >500kPa; HP >500kPa; HP >500kPa	15.5–13.0	0.0		CI	**CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained ....0.5m, trace gravel	D	H		Trace rootlets in top 300mm
						0.9		GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown; gravel, fine to coarse grained Grading into	D - M	H		
						1.4			**WEATHERED ROCK**, fine grained; residual soil to highly weathered, dark grey/green; localised pockets of gravelly clay				
						2.5			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
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

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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	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 (0.25m), HP >500kPa (0.5m), HP >500kPa (0.75m), HP >500kPa (1.0m)	16.0 / 15.5	0.0 – 0.5		CI	**CLAY / SANDY CLAY**, medium plasticity, brown; friable; with some sand; trace of gravel, fine grained ....0.4m, trace of gravel, fine to coarse grained	D	H		Rootlets/tree roots in top 0.3m
						0.7		GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown; gravel, fine to coarse grained Grading into	D	H		
				B (1.3m – 1.6m)	15.0 / 14.5 / 14.0 / 13.5	1.3			**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			
					13.0 / 12.5	2.90			Test depth reached EXCAVATION TP05 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

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

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Engineering Log - Excavation

Excavation No.	TP06
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: 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 / 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 / SANDY CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained	D	H		Up to 0.4m trace of roots
				HP >500kPa	16.0							X	
				HP >500kPa		0.5			....0.4m, with some gravel			X	
				HP >500kPa	15.5							X	
								GC / CH	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled cream grey; gravel, sub-angular,; trace of cobbles	D	H		
				HP >500kPa		1.0						X	
					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				
				B	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								

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

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Engineering Log - Excavation

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 :	

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

Principal :

Project : ***Madigan Road***

Location : ***Karratha***

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	HP >500kPa	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	15.5	0.5							
				HP >500kPa				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	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**
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: 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						×	
				B	14.5	1.5							
									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								

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.	**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)

Equipment type : Backhoe Method : Excavation dimensions :

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	16.0	0.0		CI	**CLAY**, medium plasticity, brown; friable; with some sand, fine to coarse grained	D	H		
				HP >500kPa	15.5	0.5			....0.6m, trace gravels increasing with depth				
				HP >500kPa		1.0							
				HP >500kPa	15.0			GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, clay, medium plasticity	D	H		
					14.5	1.5							
					14.0	2.0			Refusal on cemented layer, hard digging EXCAVATION TP09 TERMINATED AT 1.90 m				
					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
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**
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 / **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	HP >500kPa; HP >500kPa; HP >500kPa; HP >500kPa	16.5, 16.0	0.0 – 1.1		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	1.1 – 1.8		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	1.8 – 2.4			**WEATHERED ROCK**, fine grained, grey/green; residual soil to moderately weathered; highly fractured	D			
					14.0, 13.5, 13.0	2.4			Refusal, hard digging EXCAVATION TP10 TERMINATED AT 2.40 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

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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 :	

Engineering Log - Excavation

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 (0.0–3.0)		N (0.0–3.0)	Not Observed			0.0		CI	**CLAY**, medium plasticity, brown; friable; trace of gravel; trace of rootlets in top 300mm	D	H		
				HP >500kPa								×	
				HP >500kPa	16.5	0.5						×	
				HP >500kPa				CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, medium plasticity, brown mottled off white; gravel, fine to coarse grained, sub-angular	D	H	×	
				HP >500kPa	16.0	1.0						×	
					15.5	1.5			Grading into				
									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		
					15.0	2.0							
					14.5	2.5							
					14.0	3.0			Test depth reached EXCAVATION TP11 TERMINATED AT 3.00 m				
					13.5	3.5							
					13.0								

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG887024.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

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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)	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**, 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				
						2.0			**WEATHERED ROCK**, residual soil to slightly weathered; extremely low to medium strength rock, pale grey/grey	D	H		
					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

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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							
					15.0	2.5			Refusal on weathered rock EXCAVATION TP13 TERMINATED AT 2.30 m				
					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**
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	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		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	15.5	1.0, 1.5		GC	**CLAYEY GRAVEL**, fine to coarse grained, brown mottled off white; clay, medium plasticity; gravel and cobble content increasing with depth	D	H		
					15.0, 14.5, 14.0, 13.5, 13.0	2.0, 2.5, 3.0, 3.5			Refusal on cemented gravel layer, hard digging EXCAVATION TP14 TERMINATED AT 1.70 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.	**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 / 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	HP >500kPa (0.2m); HP >500kPa (0.45m); HP >500kPa (0.7m)	17.7	0.0	CI	**SANDY CLAY**, medium plasticity, brown / dark brown; trace of gravel, fine grained; trace rootlets in top 300mm	D	H	>400	
			B (0.8–1.0m); HP >500kPa (0.95m)		0.8	CL-CI / GC	**GRAVELLY CLAY / CLAYEY GRAVEL**, low to medium plasticity, gravel, fine to coarse grained ....1.8m, grading into rock, moderately weathered to residual soil, pale grey	D	H	>400	
					2.1		**WEATHERED ROCK**, fine grained, pale grey; residual soil to moderately weathered, cobbles up to moderate strength	D	H		
				14.7	3.0		Test depth reached EXCAVATION TP15 TERMINATED AT 3.00 m				

RL scale: 17.5, 17.0, 16.5, 16.0, 15.5, 15.0, 14.5, 14.0. Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 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.	*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 (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 (0.0–2.0)		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 >500kPa									
				HP >500kPa	17.5	0.5							
				HP >500kPa				GC	**CLAYEY GRAVEL**, fine to coarse grained, brown mottled off white; clay, medium plasticity; gravel is typically granite	D	H		
				HP >500kPa	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							

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.	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 penetrometer 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

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

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Engineering Log - Excavation

Excavation No.	**TP18**
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: 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	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	HP >500kPa		0.0	CI	**CLAY**, medium plasticity, brown / dark brown; friable; with some gravel; trace of sand, corase grained; hard	D	H		
				HP >500kPa HP >500kPa B HP >500kPa	17.5 17.0	0.5 1.0	GC / CH	**CLAYEY GRAVEL / GRAVELLY CLAY**, fine to coarse grained, clay, medium plasticity; trace cobbles; cobble content increasing with depth	D	H		
					16.5 16.0	1.5 2.0		**WEATHERED ROCK**, fine grained; residual soil to moderately weathered; recovered as gravel and cobbles, cobbles fine to medium grained, low to medium strength				
					15.5 15.0 14.5 14.0	2.5 3.0 3.5		Refusal on cemented layer, hard digging EXCAVATION TP18 TERMINATED AT 2.10 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

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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	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	19.5	0.0		SC	**CLAYEY SAND**, medium plasticity, brown / dark brown; clay, friable; with some gravel, fine to medium grained	D	H		
				B HP >500kPa HP >500kPa HP >500kPa	19.0 18.5 18.0	0.5 1.0 1.5		GP	**SANDY GRAVEL**, fine to medium grained, pale brown / brown; with some fines, low to medium plasticity; strongly cemented; trace of quartz flakes ....1.2m, becoming highly weathered rock, recovered as residual soil/cobbles	D	VD		
					17.5 17.0	2.0 2.5	Qz		**WEATHERED ROCK**, fine grained; residual soil to slightly weathered, low to high strength, brown/white/grey	D			
					16.5 16.0	3.0 3.5			Refusal on weathered rock, hard digging EXCAVATION TP19 TERMINATED AT 2.60 m				

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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

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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	support	ground water	samples & field tests	RL (m)	depth (m)	graphic log	classification symbol	material description	moisture condition	consistency / relative density	hand penetrometer kPa	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

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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)	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	**GRAVELLY CLAY**, medium plasticity, brown / dark brown; gravel, fine to coarse grained; friable	D	H		
				HP >500kPa	19.5							X	
				HP >500kPa		0.5			....0.4m, gravel content increasing; trace cobbles and coarse gravel			X	
				HP >500kPa	19.0							X	
				HP >500kPa					Grading to			X	
				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								
						2.30			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								

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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

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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; 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		
					18.0	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		
					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	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; 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				

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

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Excavation No.	*TP24*
Sheet No.	1 of 1
Project No.	*GEOTPERT02828AS*

Engineering Log - Excavation

Client	: *Cossill & Webley Consulting Engineers*	Date excavated	*20/10/10*
Principal	:	Date completed	*20/10/10*
Project	: *Madigan Road*	Logged by :	*PCW*
Location	: *Karratha*	Checked by :	

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)	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
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

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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; 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

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:54

coffey geotechnics

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 :	

Engineering Log - Excavation

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	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		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								×	
								GC	**CLAYEY GRAVEL**, fine to coarse grained, angular, grey/brown; clay is medium plasticity	D			
				HP >500kPa	21.5	0.5						×	
				HP >500kPa								×	
				HP >500kPa	21.0	1.0						×	
					20.5	1.5			Grading into				
									WEATHERED ROCK, redisual soil to moderately weathered, highly fractured; recovered as soil and gravel/cobbles, grey/pale grey, gravel/cobbles are angular				
					20.0	2.0							
					19.5	2.5							
									Test depth reached EXCAVATION TP26 TERMINATED AT 2.90 m				
					19.0	3.0							
					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
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

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:54

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

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	HP >500kPa HP >500kPa	26.0	0.0 – 0.5		GC	**CLAYEY GRAVEL**, fine to coarse grained, brown; clay, medium plasticity	D	H		Granite outcrops noted at surface close to testpit
					25.5, 25.0, 24.5, 24.0, 23.5, 23.0, 22.5	1.0, 1.5, 2.0, 2.5, 3.0, 3.5			Refusal on weathered rock EXCAVATION TP27 TERMINATED AT 0.60 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

GEOTPERT_01.GLB Log EXCAVATION GEOTPERT02828AS TESTPITS.GPJ DWG87024.GDW 22/11/2010 11:54

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 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	24.5	0.0		CI	**CLAY**, medium plasticity, brown; friable; trace of gravel; trace of rootlets	D	H		
				HP >500kPa HP >500kPa HP >500kPa	24.0	0.5 1.0		GC	**CLAYEY GRAVEL**, fine to coarse grained, clay, medium plasticity; with some boulders and cobbles	D			
					23.5 23.0 22.5 22.0 21.5 21.0	1.5 2.0 2.5 3.0 3.5			Refusal of weathered rock EXCAVATION TP28 TERMINATED AT 1.10 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
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.	**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	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	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						

Penetration scale: VE E 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 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 :

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
			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

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

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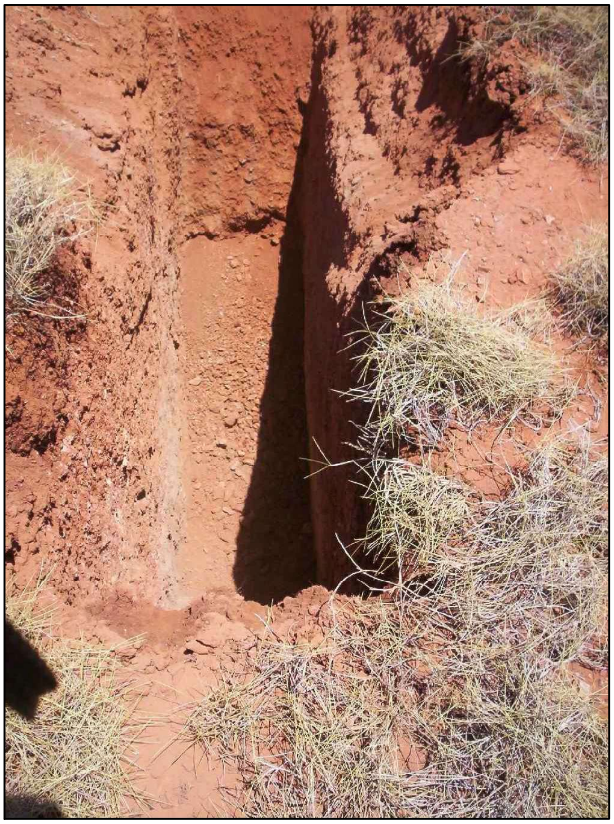

TP01.

TP01 - 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 - TP01		
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

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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:

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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:

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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:

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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:

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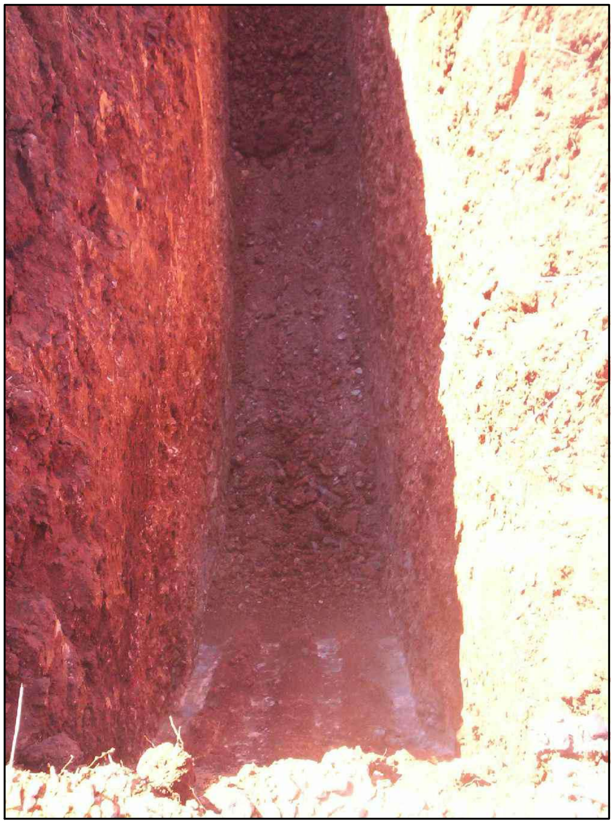

TP06.

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:

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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:

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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:

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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	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:

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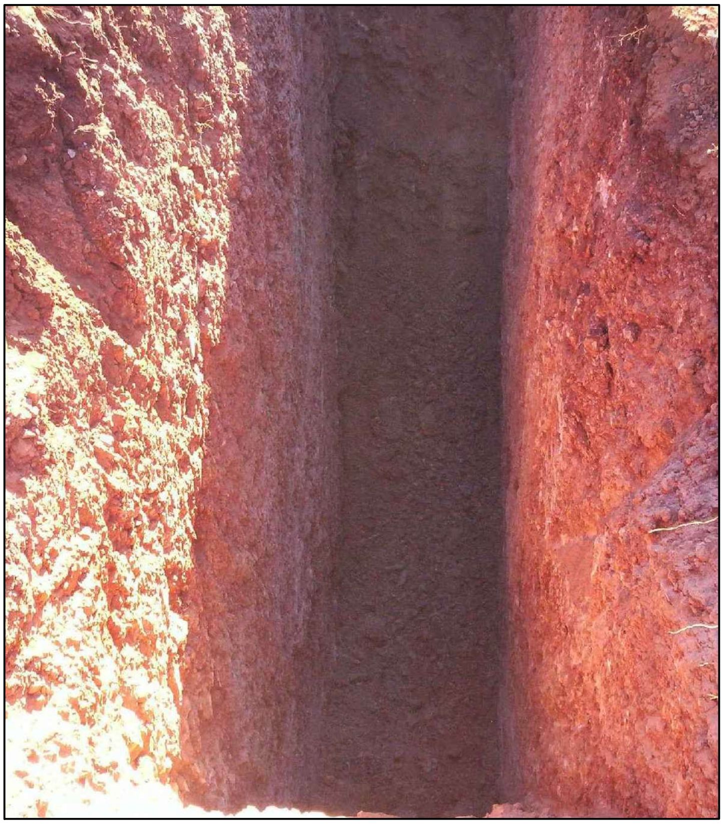
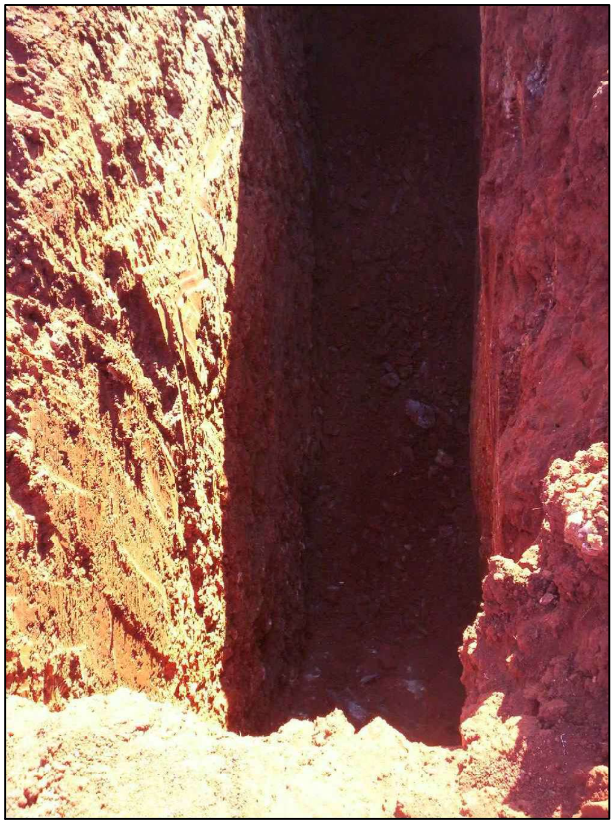


TP11.

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	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:

coffey geotechnics
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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	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 - TP16	
original size	A4		project no: GEOTPERT02828AS	fig no:	rev:

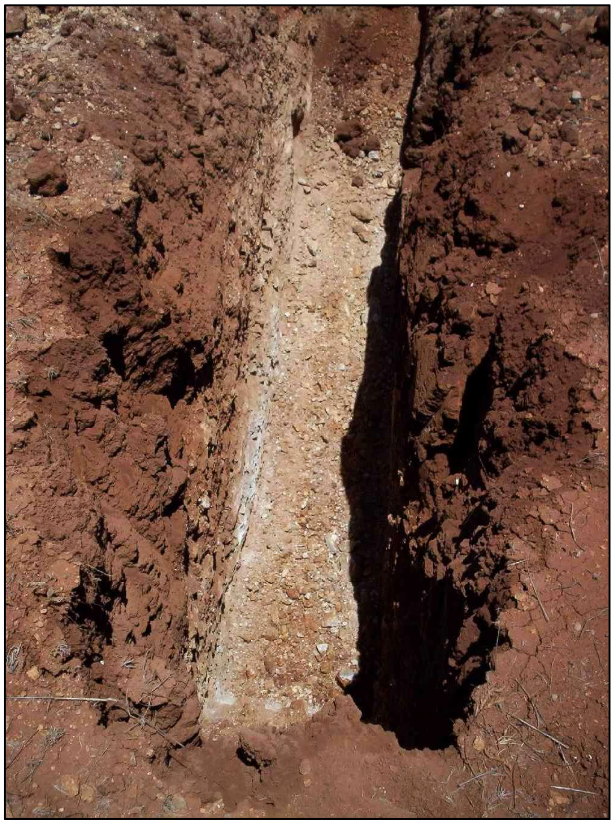
DWG: F:\GEOTPERT\00000\02828AS Madigan Road & Mulataga Sites-Karratha Cossill & Webley GI\DWG\GEOTPERT02828AS PHOTOS.dwg

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 GI\DWG\GEOTPERT02828AS PHOTOS.dwg



TP18.

TP18 - Stockpile.

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

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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	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:

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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.

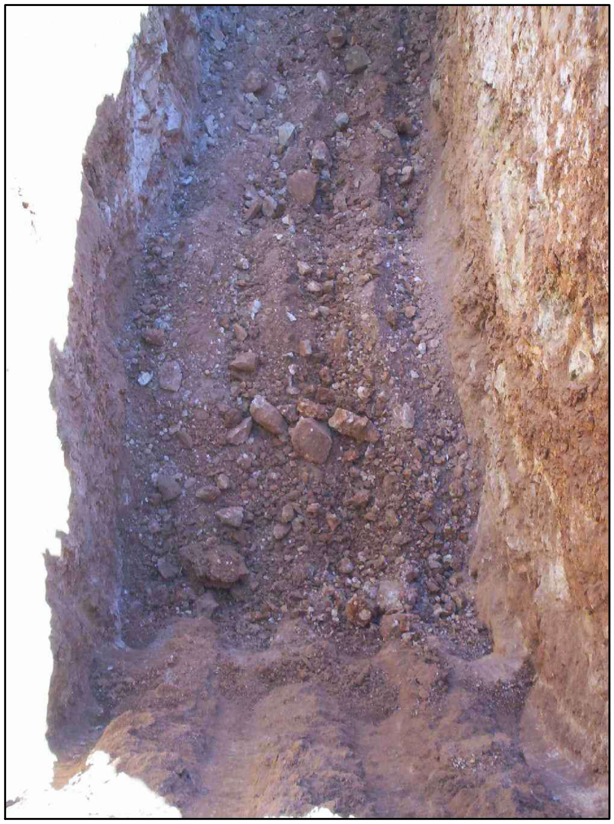
drawn	LB	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	COSSILL & WEBLEY CONSULTING ENGINEERS		
approved			project:	MADIGAN ROAD DEVELOPMENT SITE MADIGAN ROAD, KARRATHA		
date	3/11/10					
scale	NOT TO SCALE		title:	TEST PIT PHOTOGRAPHS - TP22		
original size	A4		project no:	GEOTPERT02828AS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

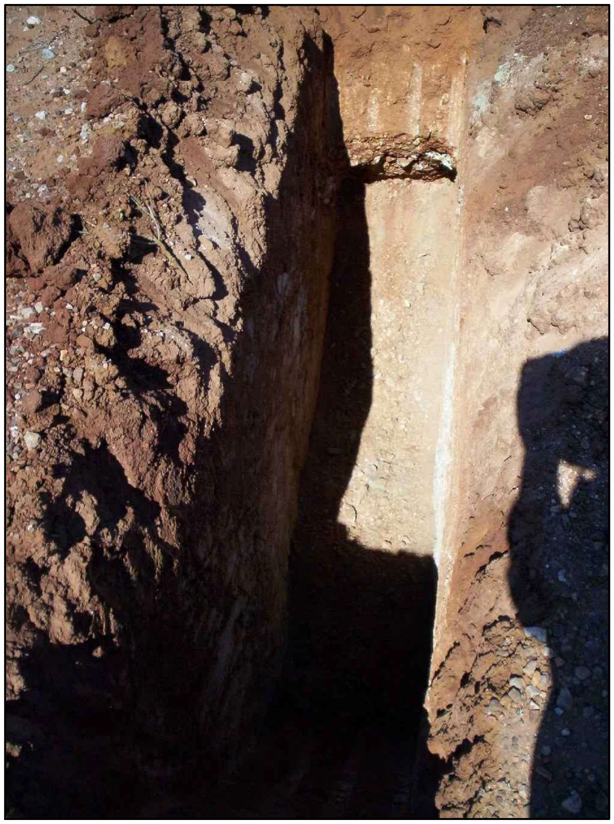


TP24.

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	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:

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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	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:

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

Appendix B

Results of Laboratory Testing

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- 03811MC

Issue No.: 1

This report replaces all previous isues 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

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WORLD RECOGNISED ACCREDITATION

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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- 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

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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

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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- 03813	TP05 @ 1.30 - 1.60m	9.8%

Comments:
Sample Supplied by client

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

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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

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

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269a Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
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Test Report

Report No.: WELS10S- 03818MC

Issue No.: 1

This report replaces all previous isues 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

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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

Form Number: R5019, Issue 4, Date: 5/10/2010

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

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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

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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- 03820	TP25 @ 0.00 - 0.50m	3.3%

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

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Test Report

Report No.: WELS10S-03811PSD
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

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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:

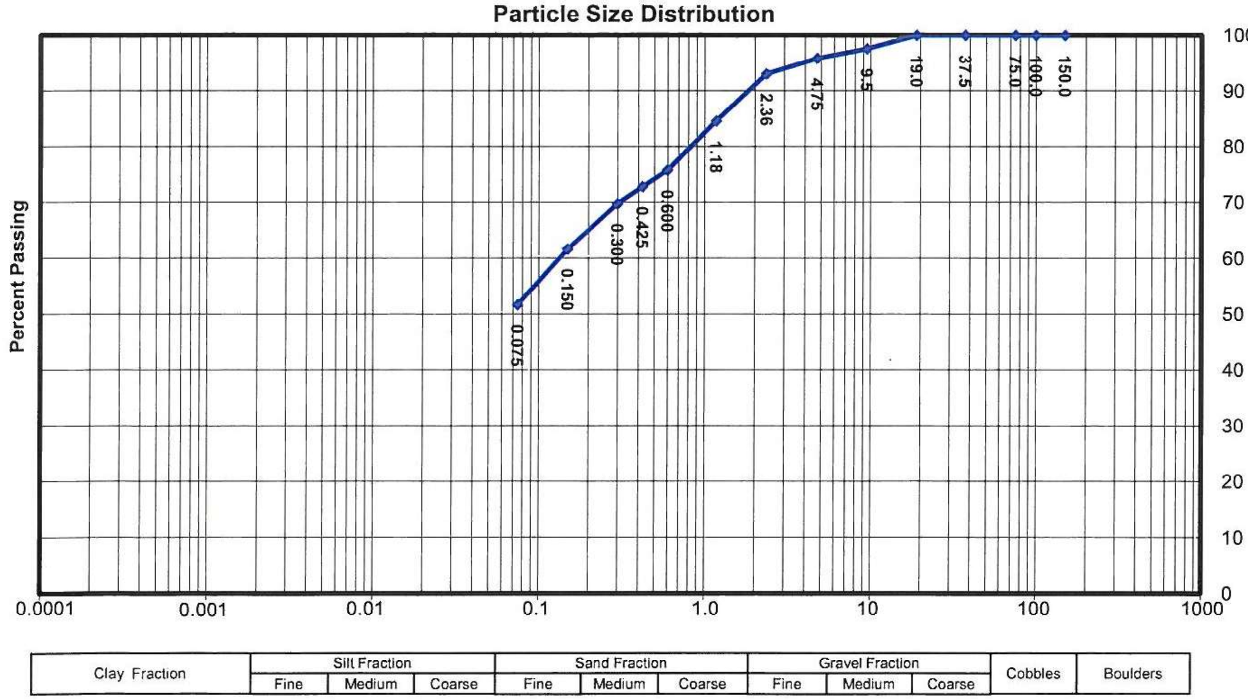
Test Results

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

Particle Size Distribution



Sieve Size (mm)

Comments:
Sample supplied by client

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Coffey Information Pty Ltd
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269A Treasure Road
Welshpool Western Australia 6106
Telephone: +61 8 6466 2400
Facsimile: +61 8 6466 2450

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SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

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

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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:

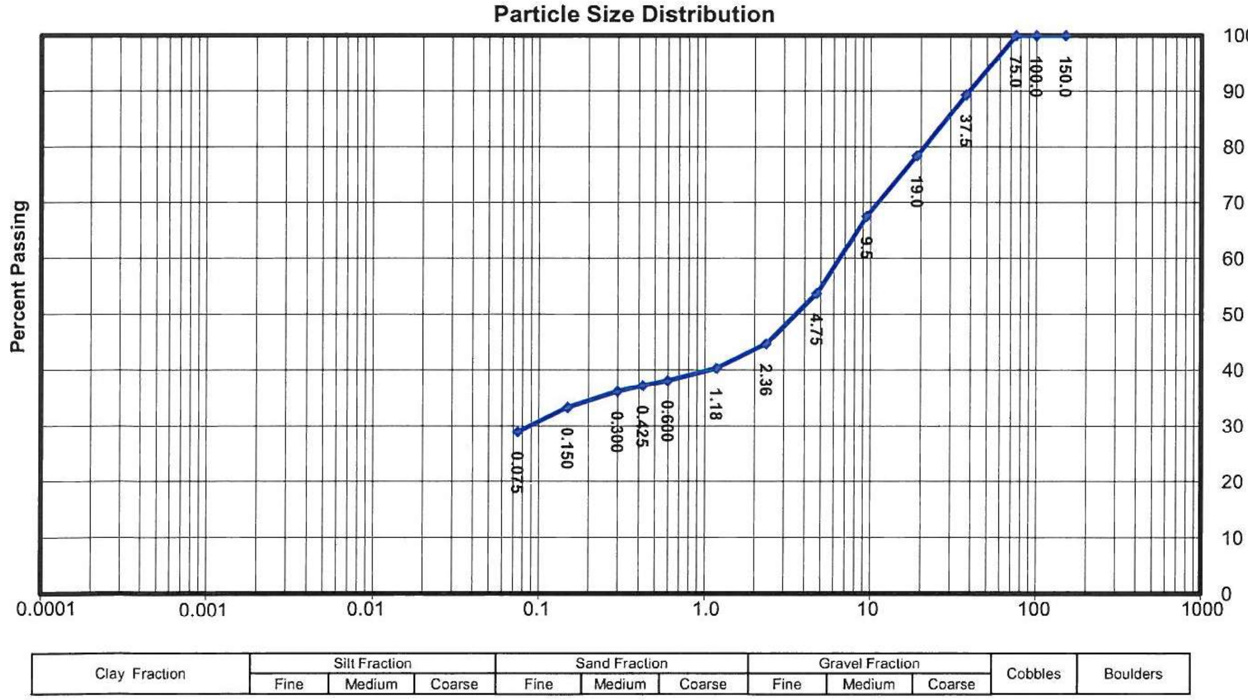
Test Results

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

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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

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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:

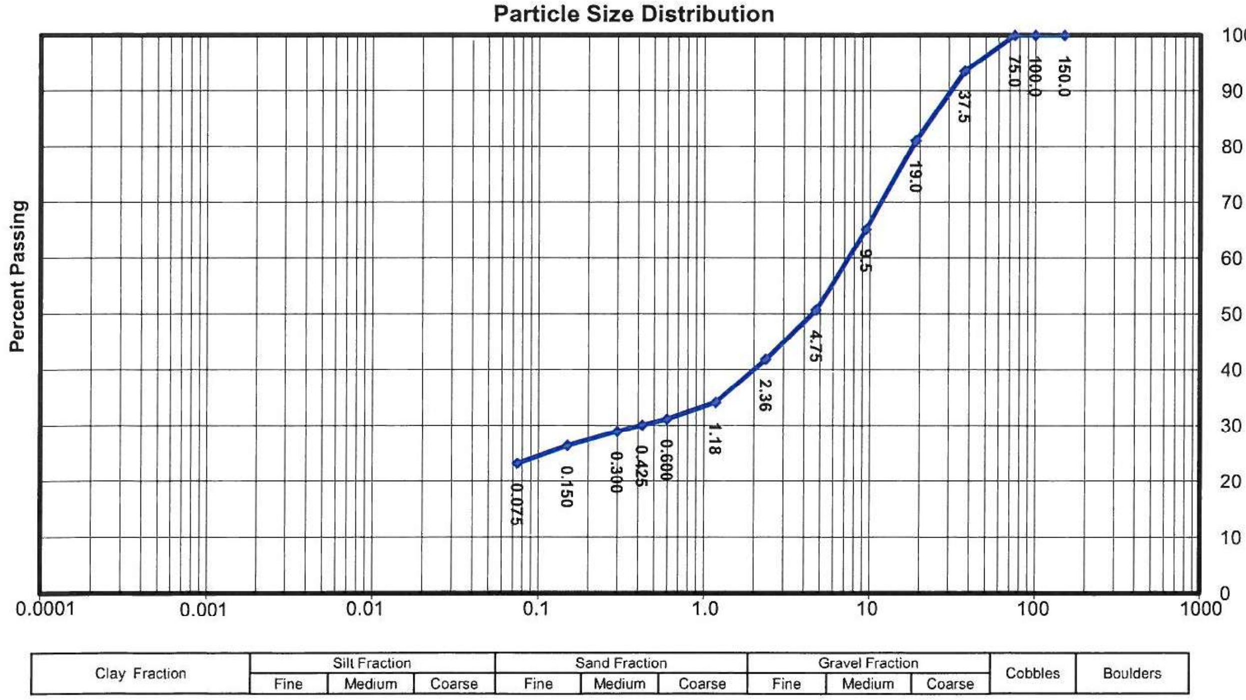
Test Results

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

Particle Size Distribution



Sieve Size (mm)

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
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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

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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:

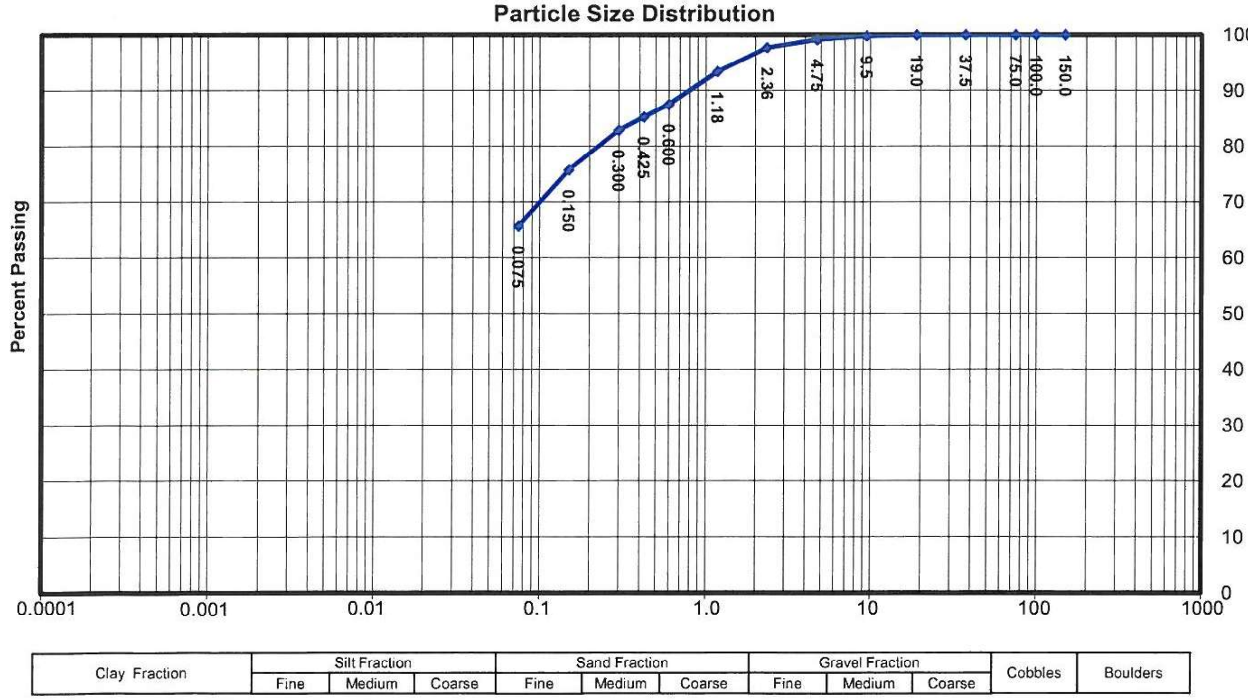
Test Results

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



Sieve Size (mm)

Comments:
Sample supplied by client

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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

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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:

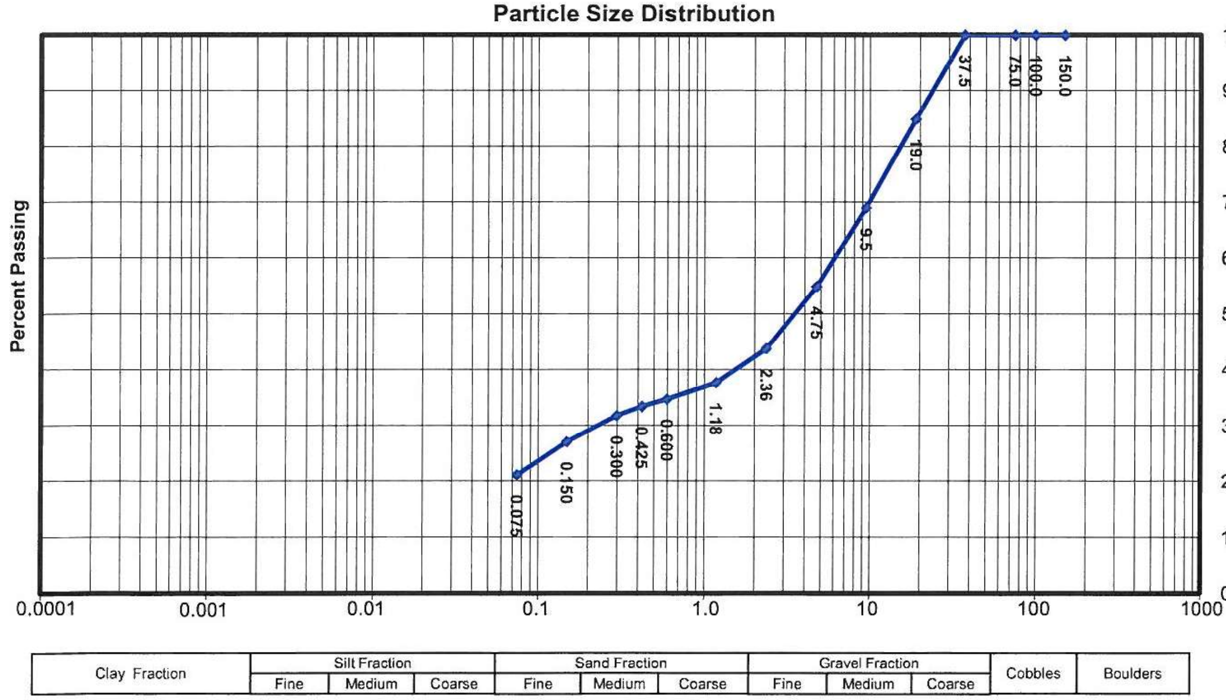
Test Results

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



Sieve Size (mm)

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

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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

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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:

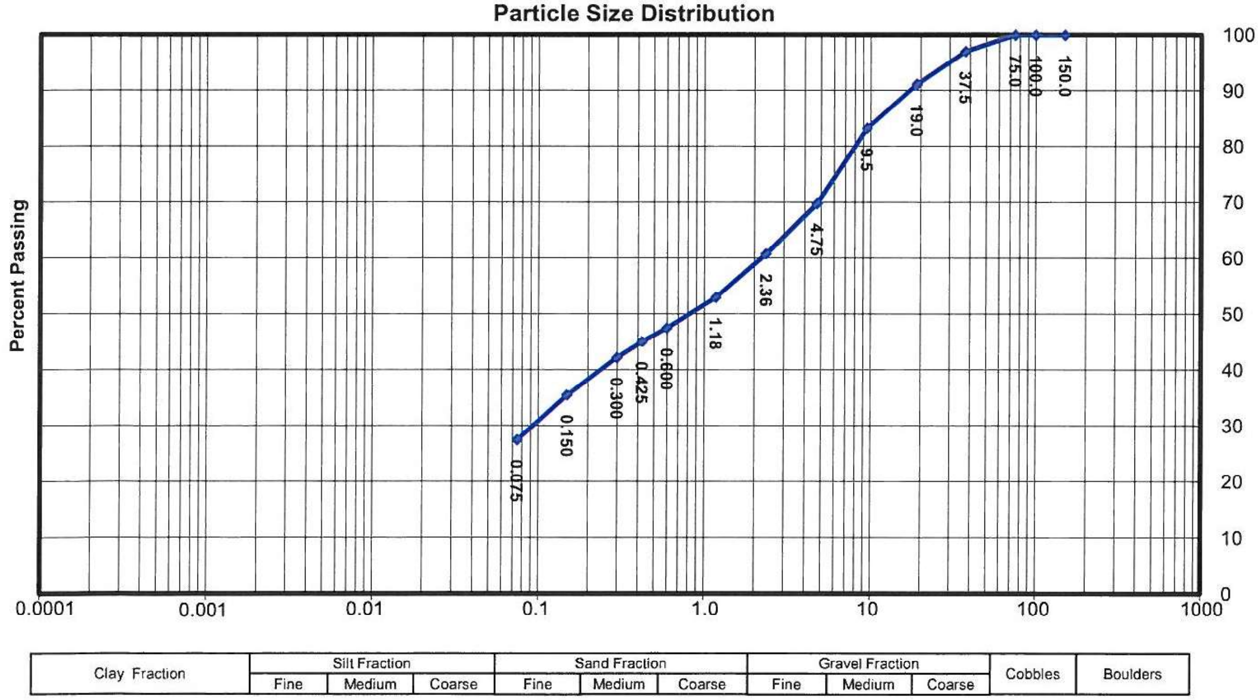
Test Results

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



Sieve Size (mm)

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

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Test Report

Report No.: WELS10S-03817PSD
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

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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:

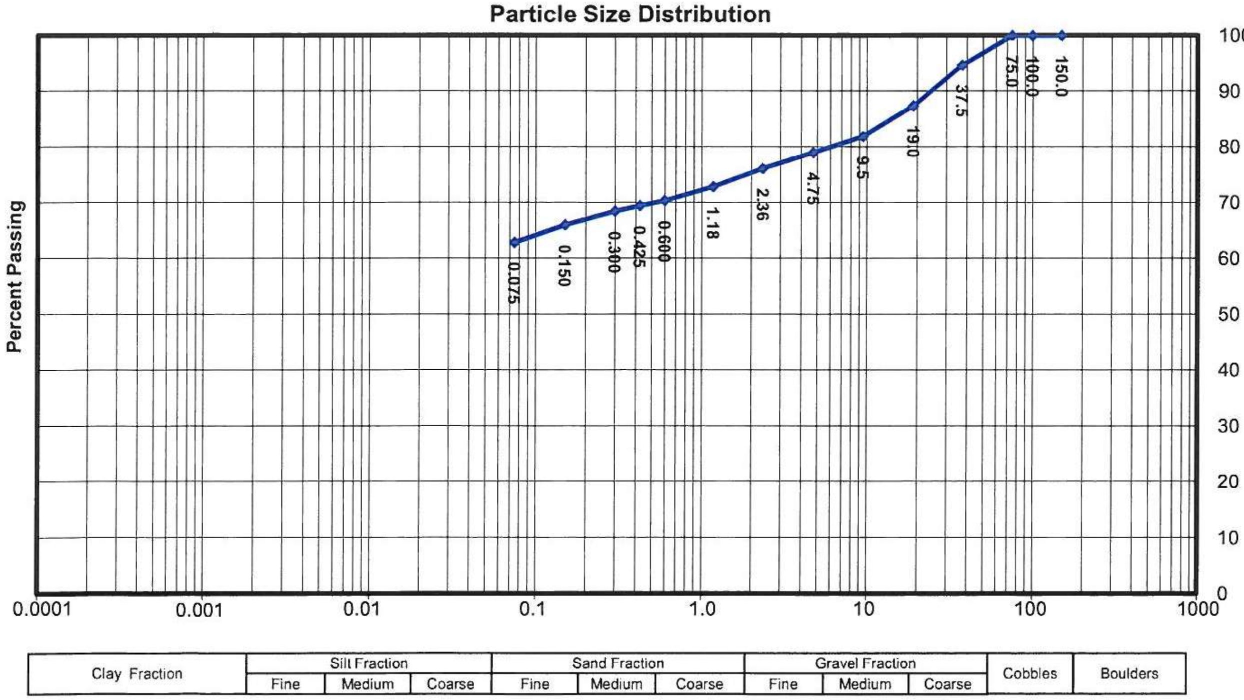
Test Results

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



Sieve Size (mm)

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

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Test Report

Report No.: WELS10S-03818PSD
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

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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:

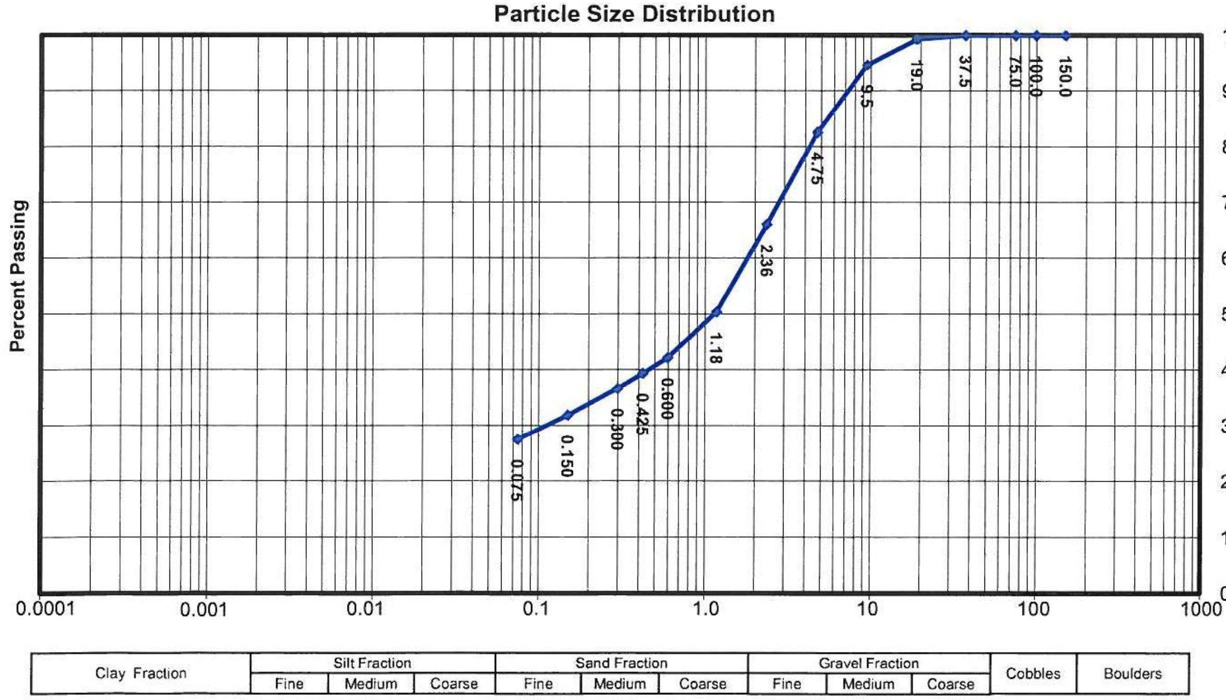
Test Results

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

Particle Size Distribution



Comments:
Sample supplied by client

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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

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Date of Issue: 18/11/2010

Sample Details

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

Other Sample Details:

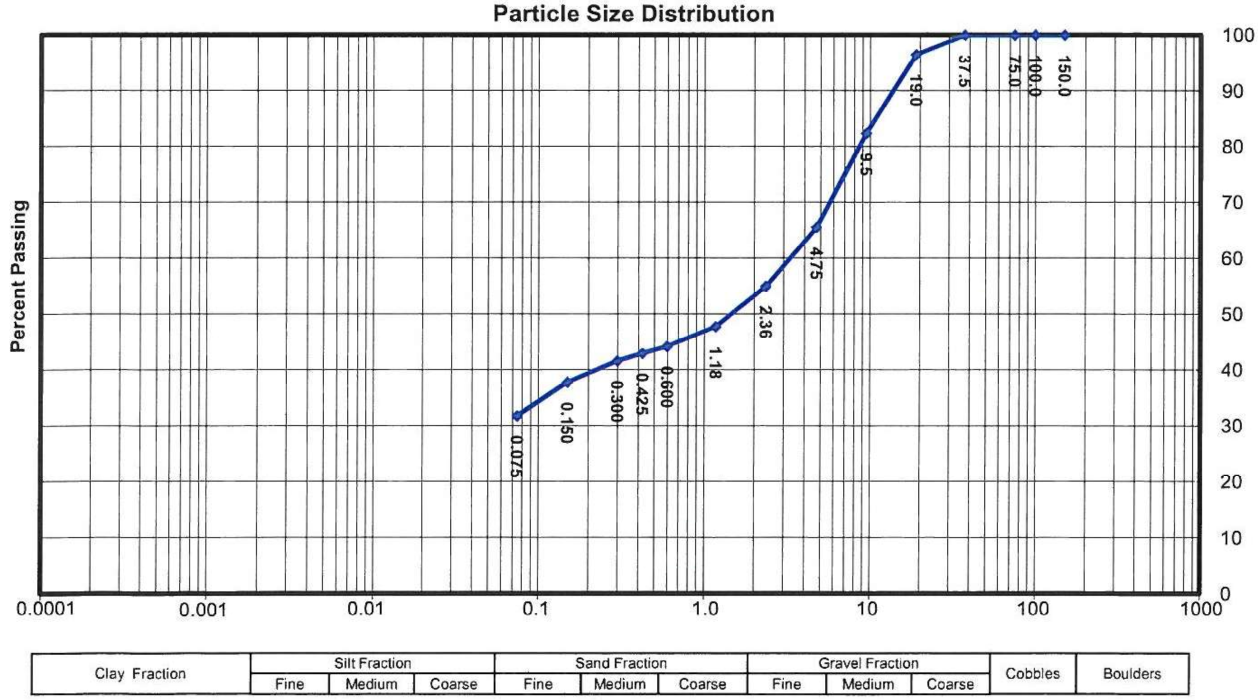
Test Results

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



Sieve Size (mm)

Comments:
Sample supplied by client

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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

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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:

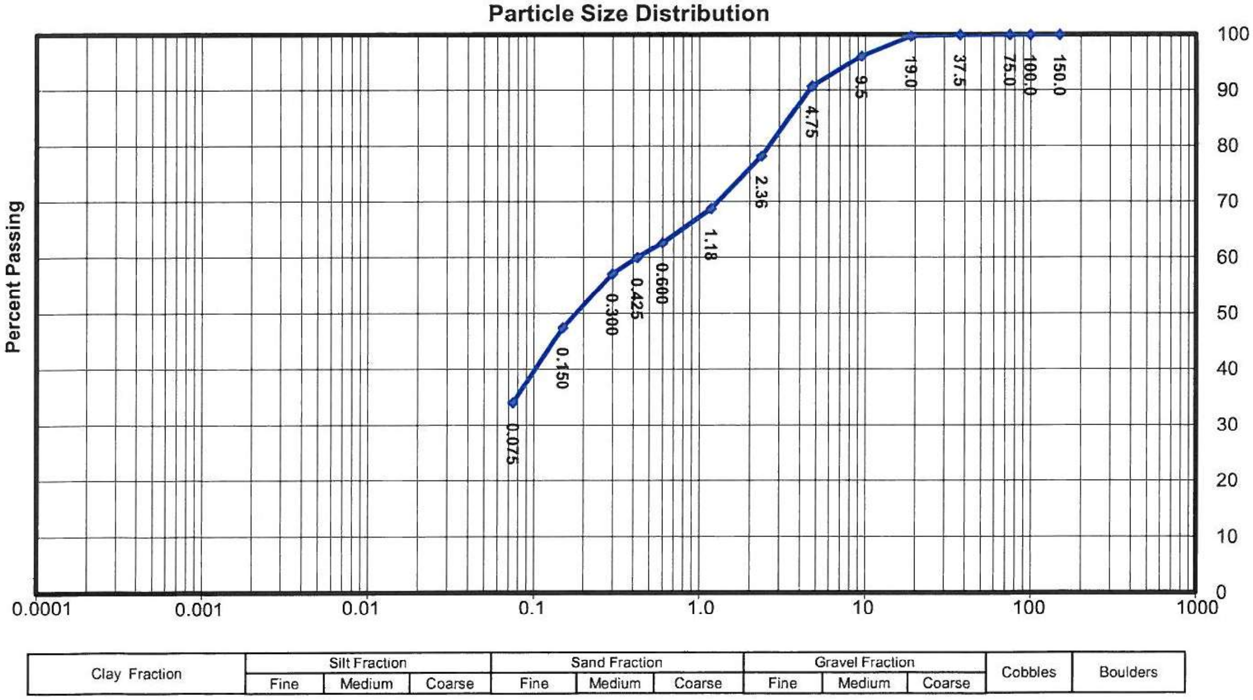
Test Results

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

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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

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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:

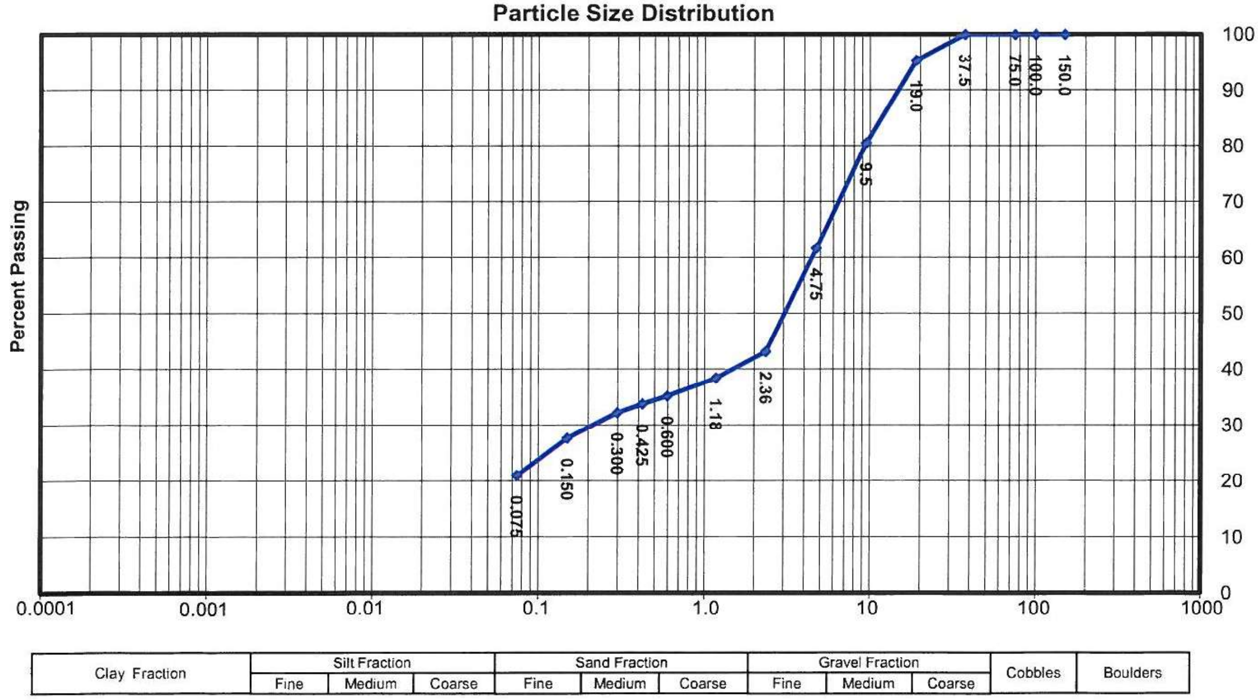
Test Results

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

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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:**

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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

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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:**

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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

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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:**

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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

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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:**

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

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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

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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:**

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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

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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:**

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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

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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:**

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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

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coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: WELS10S-03819-1
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:**

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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

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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:**

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Approved Signatory: Brad Truslove
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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

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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:**

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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.

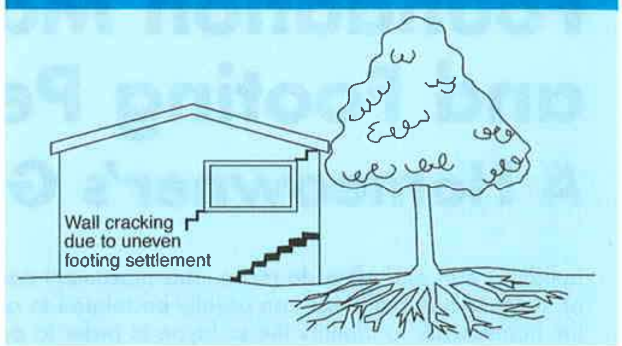
Seasonal swelling/shrinkage in clay

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

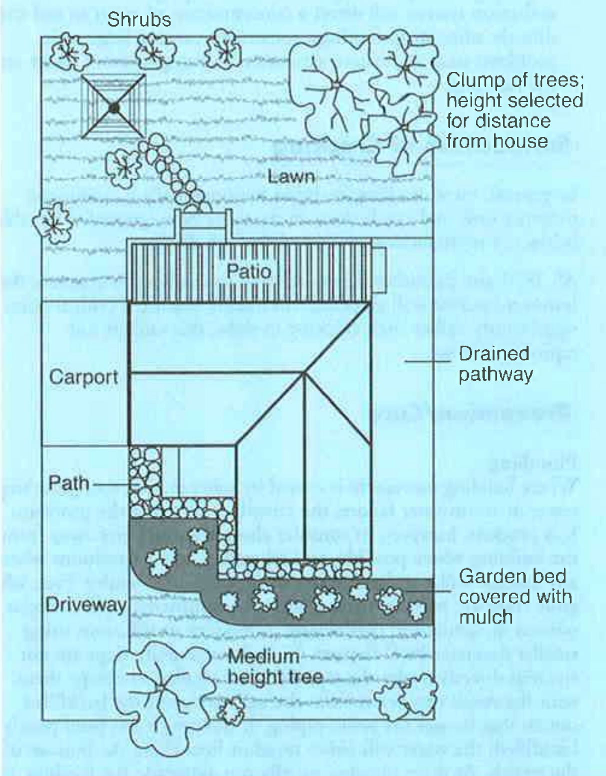
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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Madigan Road Residential Estate
Baynton West, Karratha
Stages 1C & 2
Engineering Servicing Report
February 2021

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Contents

1. INTRODUCTION

This report has been prepared by Cossill & Webley Pty Ltd (C&W) for DevelopmentWA and summarises the engineering considerations and relates to Stages 1C and 2 of the Madigan Road residential estate. The Stage 1C and Stage 2 land parcel assessed in this report is outlined in Figure 1 below and is herein referred to as the Site. Copies of Element's Structure Plan and Stage 2 Concept Plan can be found in Appendix A.

The Site is currently zoned Urban Development under the City of Karratha TPS No.8. The Site is subject to a proposed Local Structure Plan (LSP) amendment. As per Figure 1, the Site is expected to yield 172 lots and a primary school. We understand discussions have taken place with authorities for the size and location of the school.

The investigations and preparation of this report are based on a desktop study and preliminary advice from the various service authorities and is current as of February 2021.

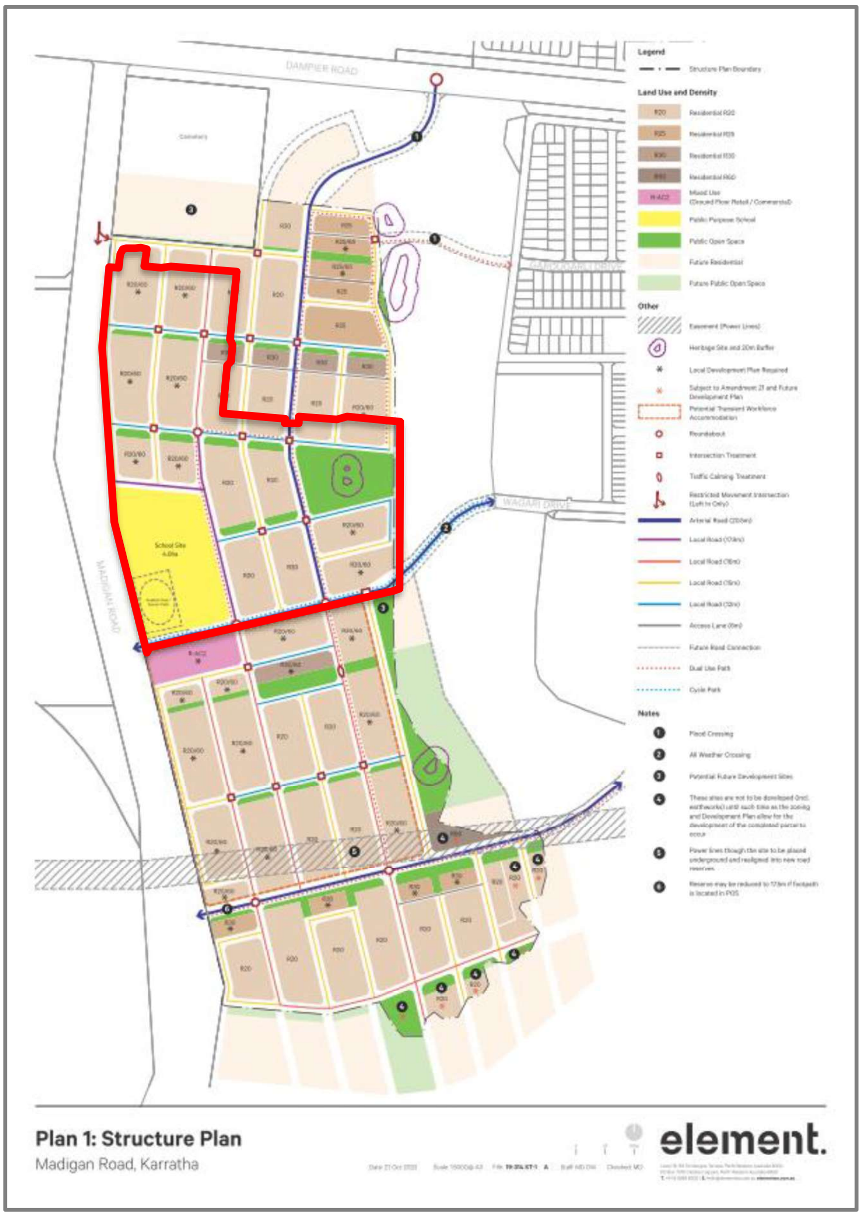


Figure 1 – Madigan Road Residential Estate, Local Structure Plan Map (Element) November 2020.

2. SITE DESCRIPTION

The Site is located 6km west from the Karratha City Centre and is in close proximity to Madigan Road and Dampier Road. The Site is bound by Madigan Road to the west, Madigan Creek to the east, existing Stage 1 development to the north and future staged development to the south. The Site comprises of Lot 9503 and part Lot 9501 and is approximately 23 hectares in area.

The Site is currently undeveloped except for an existing access track from Stage 1 to Madigan Road which acts as an egress route should Prancing Ave near Dampier Road and Gardugarli Drive be submerged during flood events. These two road crossings are designed as floodways and as such the access track to Madigan Road is required. The proposed future development of the Site will require the access track to remain open during construction. The remainder of the Site consists of low-lying scattered vegetation throughout save small areas within Lot 9503 which were earthworked as part of Stage 1. We are not aware of any historical land uses that may affect development of the Site.

Figure 2 – Aerial Photography (Nearmap, September 2020)

3. GEOTECHNICAL CONSIDERATIONS

3.1 Contamination Remediation

An internet search of the Contaminated Sites Database (https://www.der.wa.gov.au/your-environment/contaminated-sites) confirms no properties within the site are listed in the Contaminated Sites Database.

3.2 Environmental Assessment

An Environmental Assessment was previously undertaken across the entire Structure Plan area by Coffey Environments Australia Pty Ltd providing a detailed report titled *Preliminary Environmental Assessment Madigan, Karratha* dated 28 May 2010. This investigation did not highlight any significant existing flora or fauna on this Site and concluded development of the Site would not cause a significant impact on endangered species.

Coffey's report recommends retention of vegetation to the east of the Site where the existing Madigan Creek drainage channel is located. There is no proposal to clear vegetation in this area as a result of development of the Site.

A further review undertaken Eco Logical Australia in January 2021 also concluded that "no significant environmental values occur within or surrounding the site" (Eco Logical January 2021, *Structure Plan Environmental Due Diligence Review – Madigan Estate, Karratha*). A copy of Eco Logical's report is provided in Appendix B.

3.3 Geology

The Geological Survey of Western Australia's Dampier-Barrow Island 1:250000 Geological Map of the Site indicates the majority of the Site is generally characterised by sand, silt and clay with Gilgai surface in areas of expansive clay (Qwb) and Alluvial sand , silt and clay on floodplains (Qao). Refer to Figure 3 below.

Coffey Geotechnics Pty Ltd have previously undertaken a geotechnical report over the structure plan area, inclusive of the Site, titled *Report of Geotechnical Investigation Madigan Road Development* Site, dated 26 August 2011. Coffey Geotechnics note the ground conditions consist of a clay/sandy clay of varying depth of 0-1.2m overlaid a clayey gravel/gravelly clay of varying depth of 0.5-2.0m overlaid weathered rock.

The geology of the Site is typical of land within Karratha and can be suitable for residential development. The Site will require earthworking such that any Gilgai clay present is adequately treated and sufficient fill works are undertaken for road, lot and drainage grading.

The geology of the Site is consistent with conditions encountered in previous development in the region and is suitable for residential development.

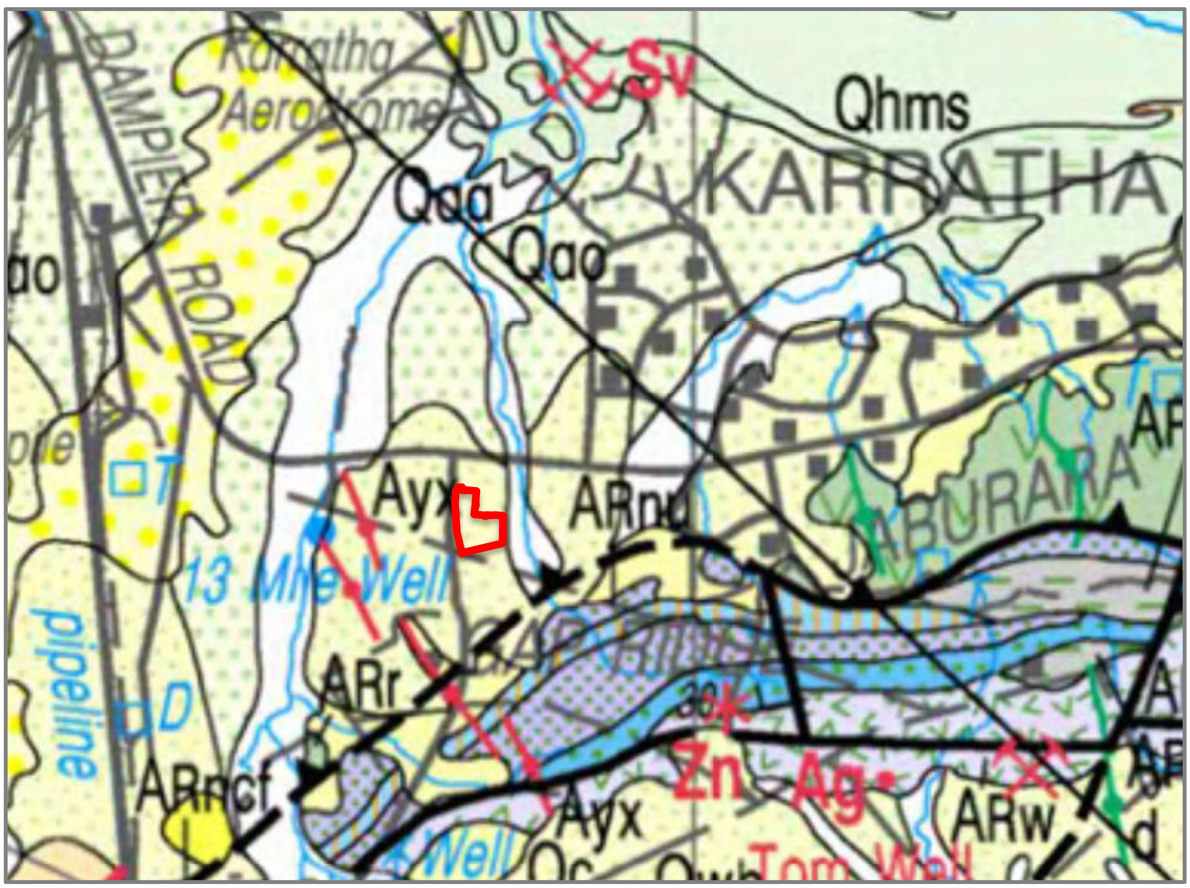


Figure 3 – Geotechnical Information (Geological Survey of WA)

3.4 Topography

The Site grades from RL18m AHD in the south to RL16m AHD in the north and follows a similar grade to the adjoining Madigan Creek as indicated in Figure 4.

The southern extent of the Structure Plan area consists of a hill ridgeline at approximately RL30m AHD with considerable grade down to RL20m AHD is reached and the land flattens to a consistent grade north.

Earthworks will be required to provide suitable grades for the Site's drainage requirements as detailed in Section 5 of this report. Import fill will be required to raise the Site above the 1% Annual Exceedance Probability (AEP) event from the adjacent Madigan Creek and will tie into existing Stage 1 levels. Levels described above relate specifically to the existing topography outside of Stage 1 works. Where Stage 1 works have been completed, earthworks levels have been raised to be clear of flood levels from the adjacent Madigan Creek. Stage 1 earthworks levels generally range from RL16-18m AHD.

Figure 4 – Natural Surface Contours (MNG Access 2021)

3.5 Groundwater

Coffey Geotechnics report (2011) noted that during the geotechnical investigation undertaken in October 2010 there was no groundwater discovered in any test pits. These test pits were dug to a maximum depth of 3m, however given the ground conditions and intense weather events in the region, it is not uncommon for a significant rise in the groundwater table over a short period of time. There is also the possibility of a perched water table following rainfall events which will dissipate over time and with grading of earthworks and appropriate house build design.

4. SITEWORKS & EARTHWORKS

Siteworks for residential development of the Site will comprise of clearing, earthworks and importation of structural fill to raise levels over the Site. The earthworks strategy for Madigan Road residential estate is primarily based on drainage requirements within the development and directly adjacent the site in Madigan Creek. The existing site is generally flat and low lying with little grade north towards Dampier Road and Madigan Creek with associated drainage impacts discussed in Section 5.

Existing ground conditions will consist of some pockets of Gilgai clay which may require removal or capping to the satisfaction of a Geotechnical Engineer. To meet development requirements and construct residential lots above flood levels, the site is required to be raised by importing fill.

The earthworks strategy has been developed to minimise fill requirements, whilst considering constraints such as flood requirements both internally and adjacent Madigan Creek, sewerage constraints and tie-in levels with existing infrastructure surrounding the site. Flood levels within the site are the major constraint in developing the site determining majority of the lots finished surface levels.

In order to ensure built form efficiencies, and reduce overall housing construction costs, it is proposed to earthwork the Site to create lot pads with a minimal slope to allow stormwater to flow off the lots assisting in reducing moisture in high clay ground conditions. Generally minimal retaining wall terracing will be used and only where required.

The supply of import fill material within the Karratha region has a considerable impact on the development of the Site. The site classification of the Site will be determined by the material characteristics of import fill material available at the time of development. Typically, site classifications within Karratha will be Class M or Class H in accordance with AS2870-2011.

5. DRAINAGE

JDA Hydrologists have previously undertaken detailed flood investigations across the site in 2010 and 2011 focussing on the impacts of Madigan Creek pre and post development of the development site. These investigations provided information to inform the Stage 1 design and set up design conditions for the entire Structure Plan area. Flood modelling of Madigan Creek allowed for combinations of events such as 1% AEP, storm surge and anticipated sea level rise. DevelopmentWA engaged JDA in 2020 to update the flood modelling based on updated inputs and modelling information.

JDA's updated 2020 post development 1% AEP flood modelling results are shown in Figure 5 below with report extracts from JDA's most recent report are provided in Appendix C.

The current approach in Karratha and the previous stage of development at Madigan Road Residential, is to deal with the conveyance of stormwater through the utilisation of the road carriageway to convey stormwater from lots and road reserves to open drains which in turn convey water to Madigan Creek then through to Nickol Bay.

Open drains through the development are cost effective in conveying stormwater drainage as with decreasing the extent of earthworks required to ensure the development site is above the 1% AEP flood level of Madigan Creek.

The existing site is generally flat with little grade north towards Dampier Road and Madigan Creek. In order to develop the site and grade stormwater from the site, sufficient open drains at each stage of development are required to grade and convey stormwater towards Madigan Creek.

Stage 2 will include a similar approach to Stage 1 and will continue the usage of open drainage through the development. Any stormwater infrastructure through the development will need to facilitate future staged development of the site.

Consistent with pre-development catchments and optimising earthworks for the estate a portion of the Site's development area drainage will flow west towards Madigan Road in accordance with agreed catchments with Main Roads WA.

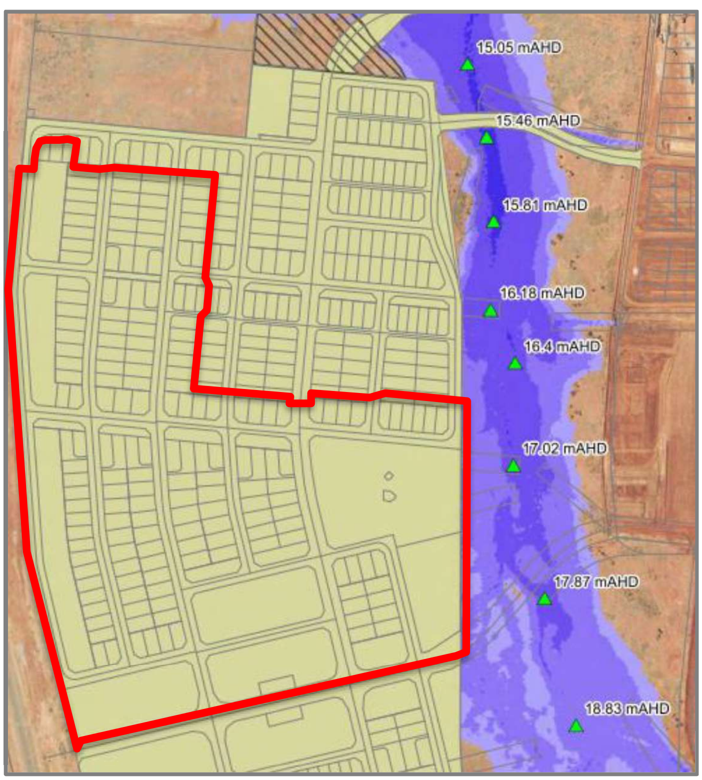


Figure 5 – Post Development 1% AEP Event Plan (JDA 2020)

6. ROADWORKS & FOOTPATHS

6.1 Existing Road Network

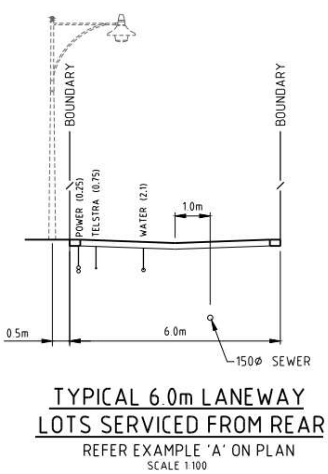
Access to the Site is existing Stage 1 development through a left-in left out off Dampier Road (Prancing Avenue), a left-in off Madigan Road and full access crossing to Baynton West along Gardugarli Drive across Madigan Creek. Both Gardugarli Drive and Prancing Avenue will act as floodways during major flood events and therefore a temporary all-weather access is provided at the southern end of the Site as an extension of Prancing Avenue through to Madigan Road.

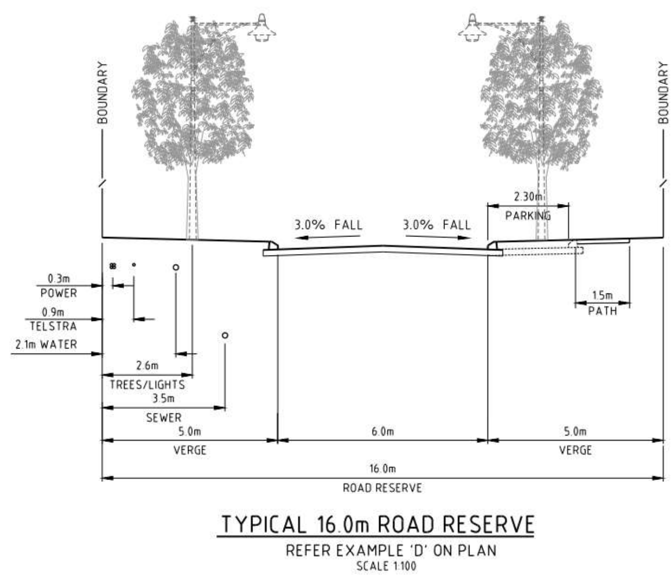
6.2 Proposed Road Network

The proposed road network will comprise of kerbed roads and asphalt to a road design consistent with the Local Structure Plan as shown in Figure 1. The extension of Prancing Avenue will consist of a 20.5m wide neighbourhood connector with painted medians consistent with the existing road network. Wagari Drive will also consist of a 20.5m neighbourhood connector albeit with an on-street cycle lane. Wagari Road will provide an all-weather access across Madigan Creek connecting to Baynton West and Madigan Road.

The extension of Wagari Road will provide for a fully channelised priority T-intersection with Madigan Road in accordance with transport assessment undertaken by Transcore in 2010.

Internal subdivision roads will be constructed to Liveable Neighbourhood Access Street standard with standard verge alignments comprising of 6m pavements and 6m laneways. Typical road cross sections are provided below in Figure 6.





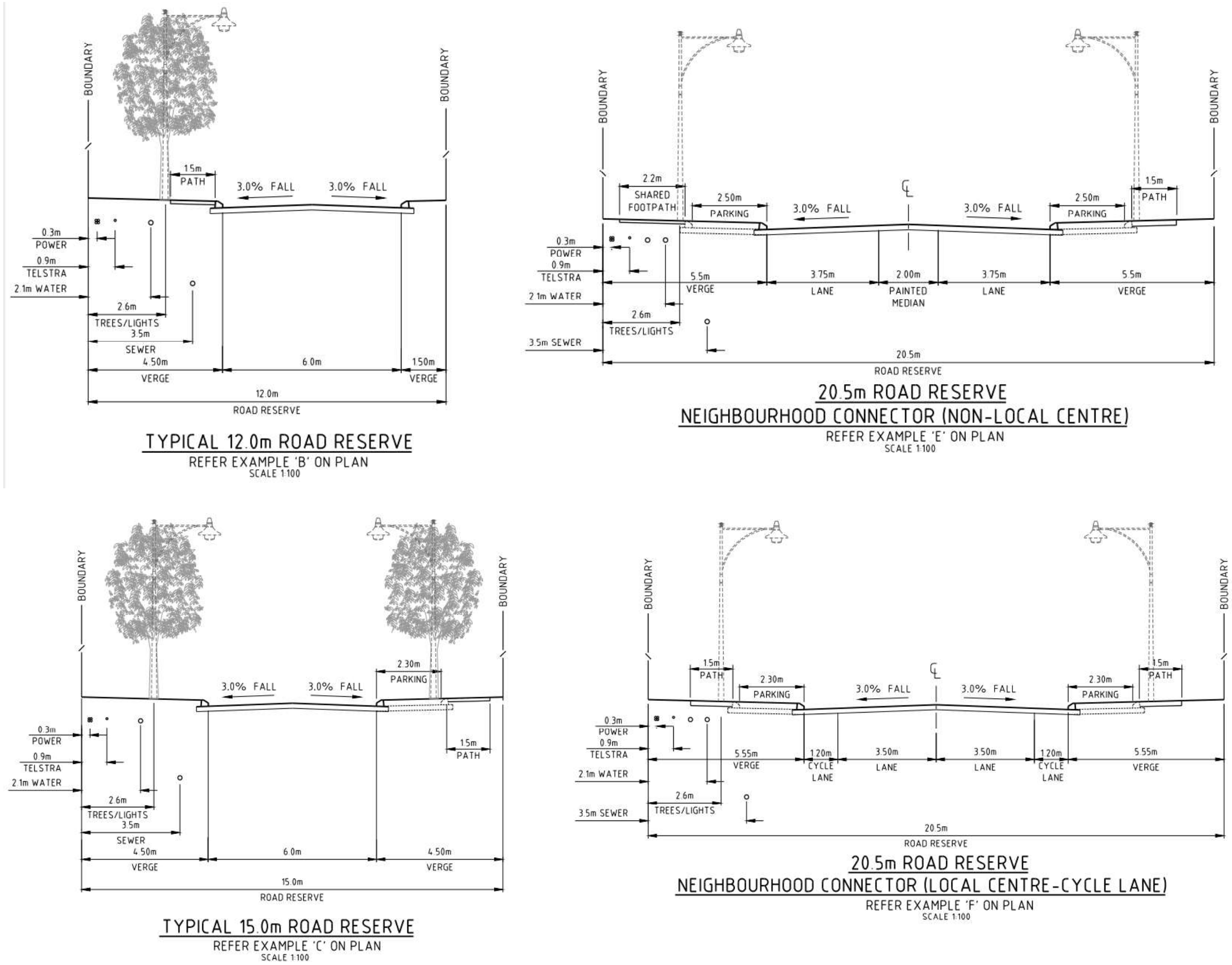


Figure 6 – Proposed Stage 2 Road Cross Sections (C&W)

6.3 Footpaths

Footpaths will be provided in accordance with the Local Structure Plan which will generally consist of a footpath on one side of the road as a minimum with an additional dual use path along Prancing Avenue and on-street cycle lanes along the extension of Wagari Drive from Baynton West, crossing Madigan Creek through to the intersection on Madigan Road.

6.4 Noise Attenuation

The Site is adjacent a heavy haulage route on Madigan Road and is expected noise levels from traffic will influence residential development adjacent Madigan Road. ND Engineering have undertaken an acoustic review of the Site with report titled *Acoustic Report, Karratha Madigan Residential Estate* dated September 2020. ND Engineering's report concluded noise amelioration can be effectively managed through a series of quiet house design packages and that there is no requirement to construct a physical barrier, such as a noise wall, between Madigan Road and the proposed residential lots. A copy of ND Engineering's acoustic report is provided in Appendix D.

7. WATER RETICULATION

The Site is located within the current boundary of the Water Corporation's Water Supply Scheme and overall planning for the scheme has made provision for residential development over the subject land.

Reticulation size pipework was extended to the Site as part of Stage 1 of the Site's development from Dampier Road and Gardugarli Drive (Baynton West) to service the initial stages of development of the Site.

Further upgrade of the water supply network will be required to facilitate Stages 1C and 2 of the development. It is expected the initial development phases of the Site can be adequately serviced from the existing network and construction of reticulation sized DN100 and DN150 water mains.

By the completion of Stage 2, water reticulation extensions will be required to adequately service the Site including the extension of DN200 water reticulation main in Wagari Road across Madigan Creek and a 370m extension of DN150 water reticulation main in Madigan Road to the proposed Madigan Road and Wagari Road intersection. Locations of the existing water mains are shown below in Figure 7.

We anticipate standard Water Corporation Headwork fees will apply.

Figure 7 – Existing Water Reticulation (Water Corporation Esinet 2021)

8. WASTEWATER RETICULATION

The Site falls within an existing sewer reticulation area and is captured by the wastewater catchment area for the existing wastewater pumping station located at Seven Mile Creek along Dampier Road (Karratha WWPS No.10 – Dampier Rd). Infrastructure for the wastewater pumping station includes a DN300 gravity sewer crossing Madigan Road which was constructed simultaneously with the Stage 1 Madigan Residential works connecting the residential estate and WWPS. Karratha WWPS No.10 and pressure main was commissioned in 2016. The existing WWPS has sufficient capacity to facilitate the projected wastewater flows from the Site.

The Water Corporation's strategy for this catchment is to extend the existing DN300 gravity sewer from Stage 1 at Madigan Road residential through to the southern end of Stage 2 before transitioning into a DN225 gravity sewer. Proposed extension of the DN300 gravity sewer is outlined in Figure 8.

The construction of DN300 gravity sewer through the Site is considered a Headworks item by Water Corporation and a refund to the developer of $600 per meter is provided at the completion of the works.

Ultimately WWPS No.10 will be graded out by a larger WWPS on the northern side of Dampier Rd, however the timing for this is in the long term with existing infrastructure fully capable of servicing the proposed development.

Standard Water Corporation sewerage headworks will apply.

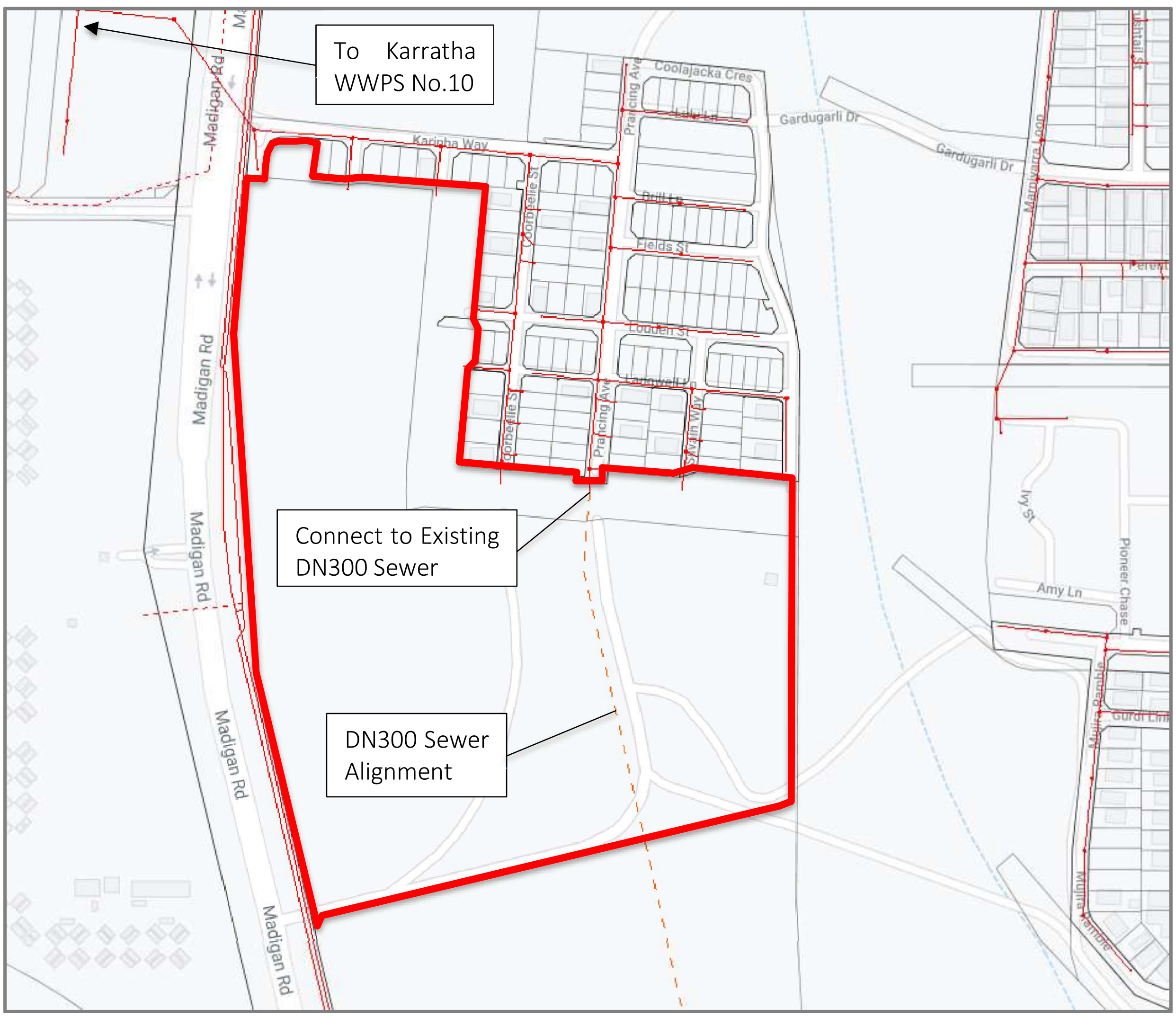


Figure 8 – Existing Sewer Reticulation (Water Corporation Esinet 2021)

9. ELECTRICAL POWER SUPPLY

The previous works undertaken at Madigan Road residential estate for Stage 1 included the extension of a looped HV network off 400mm high voltage (HV) feeder cables in Dampier Road. Additional extensions of HV underground power was provided throughout Stage 1 works in anticipation of further staged development of the residential estate.

The Site's proposed power demand will require standard residential power supply to each residential dwelling that can be initially extended off the existing power network. Stage 2 will include the further extension of HV power through the Site such that the development of subsequent stages can be extended off existing infrastructure.

All power to the proposed development will be underground and fed from transformers located strategically within the Site. Approximately 4.7 kVa per residential lot is required plus a minimum 250kVa for a primary school site, resulting in a total power demand 1.06MVa.

Further reinforcement of the power network may be required for the full development of the Site and can only be confirmed by Horizon Power through a Design Information Package (DIP) for the Site. A DIP was requested for the Site in late 2020 and is expected information from Horizon Power will be provided in early 2021.

10. TELECOMMUNICATIONS

The Stage 1 development included the installation of NBN Co pit and pipe network with anticipation to extend this network throughout the remainder of the development. NBN Co assets were constructed to Dampier Road where fibre infrastructure was extended to the Site. The remainder of the Madigan Rd residential estate is located within NBN Co's rollout map shown in Figure 9.

As part of these works DevelopmentWA (formerly LandCorp) signed a Master Developer Agreement with NBN Co to service the development with a new stage agreement required to facilitate subsequent staged works.

Under the Federal Government's new Telecommunications in New Developments Policy, developers are responsible for contributing to the cost of delivering the NBN™ network in new developments. This includes contributing to part of the costs of the build (installing pit & pipe) as well as a $600 per lot deployment change.

The Site will include the extension of pit and pipe infrastructure to NBN Co requirements which will enable NBN Co to draw fibre through the infrastructure to service proposed Site. NBN Co will cover the cost of fibre deployment and any additional off-site extensions required to service the site, should it be required. Suitable infrastructure was installed in the previous stage such that the extensive works would not be required for the initial development of the Site.

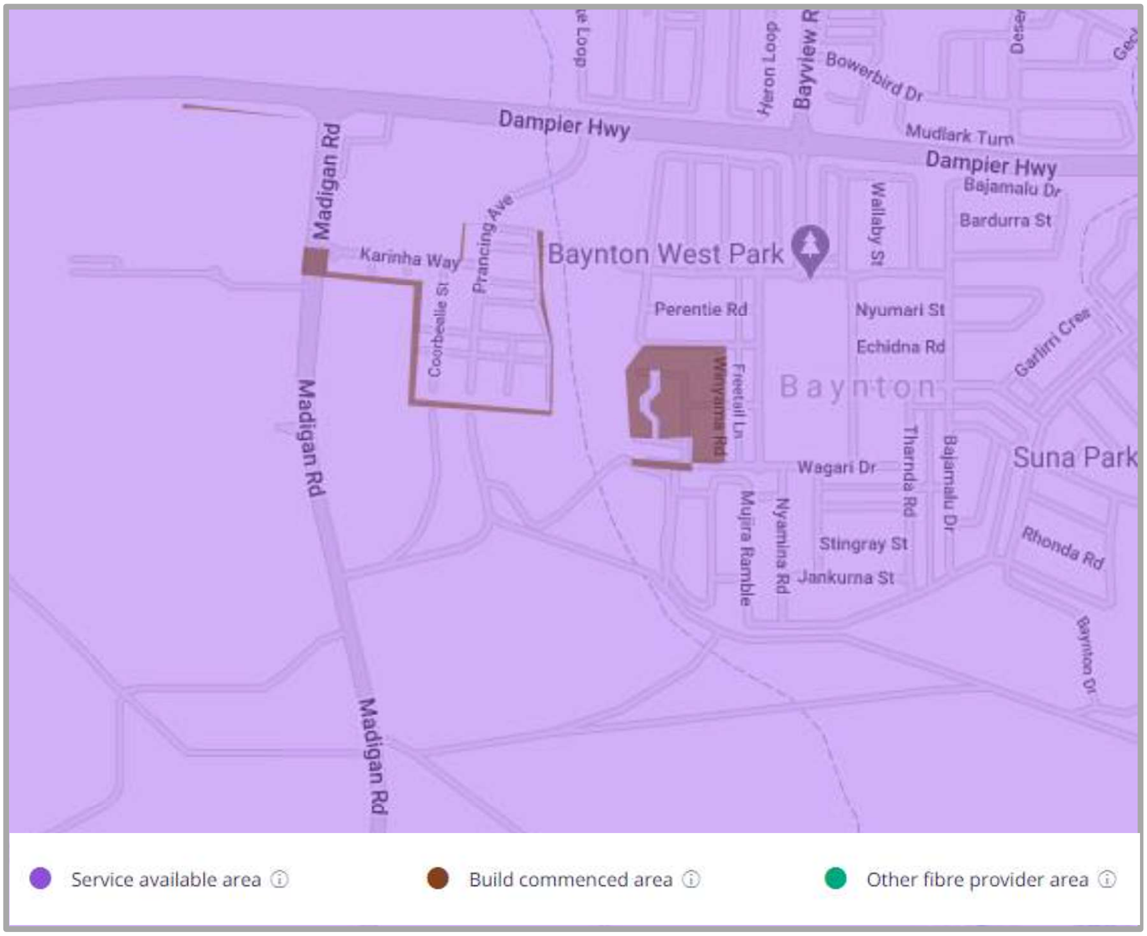


Figure 9 – NBN Co Roll-out Map

11. GAS SUPPLY

There is limited reticulated gas supply or demand within the Karratha region for residential consumption. This includes Stage 1 of the development where reticulated gas was not installed. It is not anticipated reticulated gas will be installed in the next phase of development.

12. CONCLUSION

The Site is developable given its location and zoning to support urban residential development. Earthworks, drainage and servicing works required to develop the Site are consistent with other urban development projects in the Karratha region.

Earthworks are required to accommodate clearance to flood water levels from the adjoining Madigan Creek as the drainage strategy is critical throughout the Site. Efficient design through frequent roadside drainage channels are required to ensure development levels are kept low without compromising livability on each lot.

Wastewater reticulation services have previously been extended to the site and no further upgrades are required to develop the Site.

Water reticulation main extensions will be required during the development of the Site however will not be required for the initial phase of development.

Design information is pending from Horizon Power through a DIP application to ascertain if offsite power upgrades or network reinforcements are required. We expect information being available from Horizon Power in early 2021.

Based on information available as discussed through this report, there are no engineering impediments to the development of the Site.

APPENDIX A

Element

Local Structure Plan and Subdivision Plan

Legend

Structure Plan Boundary

Land Use and Density

- R20 — Residential R20
- R25 — Residential R25
- R30 — Residential R30
- R60 — Residential R60
- R-AC2 — Mixed Use (Ground Floor Retail / Commercial)
- Public Purpose: School
- Public Open Space
- Future Residential
- Future Public Open Space

Other

- Easement (Power Lines)
- Heritage Site and 20m Buffer
- * Local Development Plan Required
- * Subject to Amendment 21 and Future Development Plan
- Potential Transient Workforce Accommodation
- Roundabout
- Intersection Treatment
- Traffic Calming Treatment
- Restricted Movement Intersection (Left In Only)
- Arterial Road (20.5m)
- Local Road (17.9m)
- Local Road (16m)
- Local Road (15m)
- Local Road (12m)
- Access Lane (6m)
- Future Road Connection
- Dual Use Path
- Cycle Path

Notes

1. Flood Crossing
2. All Weather Crossing
3. Potential Future Development Sites
4. These sites are not to be developed (incl. earthworks) until such time as the zoning and Development Plan allow for the development of the completed parcel to occur
5. Power lines though the site to be placed underground and realigned into new road reserves
6. Reserve may be reduced to 17.5m if footpath is located in POS

Plan 1: Structure Plan

Madigan Road, Karratha

0 50 100m

Date: 27 Oct 2020 Scale: 1:5000@ A3 File: **19-314 ST-1** **A** Staff: MD GW Checked: MD

element.

Level 18, 191 St Georges Terrace, Perth Western Australia 6000.
PO Box 7375 Cloisters Square, Perth Western Australia 6850.
T. +61 8 9289 8300 | **E.** hello@elementwa.com.au **elementwa.com.au**

LEGEND

- Application Area
- Existing Boundary
- Existing Contours / Survey
- Proposed Boundary
- Indicative Future Boundary

LOT SUMMARY

Subject Site	57.2199ha
Existing	
Lot 9501	53.8415ha
Lot 9503	3.3784ha
Proposed	
Residential Lots (Single Dwellings) (144)	8.7473ha
Residential Lots (Grouped Dwellings) (3)	0.2700ha
Public Purposes Reserve (1) (School Site)	4.0005ha
Public Open Space and Drainage Reserves (8)	1.8215ha
Balance Lots (2)	37.5353ha

Subdivision Plan

Madigan Road, Gap Ridge

Date: 27 Oct 2020 Scale: 1:2500 @ A3 1:1250 @ A1 File: 19-314 SU02A Staff: MR MD GW Checked: MD

element.

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APPENDIX B

Eco Logical Australia

Structure Plan Environmental Due Diligence Review

Madigan Estate, Karratha

14 January 2021

Level 1, Bishop's See
235 St Georges Terrace
Perth WA 6000
t: (08) 6218 2200

14 January 2021

Our ref: 20PER-17714

DevelopmentWA
40 The Esplanade
PERTH WA 6000

Attention: Olivia Abrugiato

Dear Olivia,

Structure Plan Environmental Due Diligence Review– Madigan Estate, Karratha.

Eco Logical Australia (ELA) were engaged by DevelopmentWA to undertake a desktop environmental due diligence review to determine potential environmental constraints and opportunities and inform a business case within land known as Madigan Estate, Karratha (Lot 500 on DP59331). Findings from the review are presented in Attachment A to this letter.

The overarching conclusion of this work is that no significant environmental values occur within, or surrounding the site and would require further consideration under both state and Commonwealth environmental legislation if they are proposed to be impacted into the future.

We hope that this information has been of assistance and if you have any questions about any aspect of this brief letter report, please contact me on 08 6218 2200.

Regards,

James Leonard

Senior Environmental Scientist

ATTACHMENT A – DESKTOP ANALYSIS

SITE DESCRIPTION

The subject site is located in the Shire of Roeburn to the south west of the Karratha township in the Pilbara region in Western Australia (WA) (Figure 1). The subject site has an area of 67.73 ha and is located east of Madigan Road and south of Dampier Road (Figure 1).

The subject site is situated between Baynton West housing estate to the east, a cleared area to the west, that until 2017, held a mining encampment and native vegetation to the north and south.

Shire of Roebourne Local Planning Scheme (LPS) No.8 identifies the site for future residential land use opportunities under an approved structure plan. The Madigan Development Plan was adopted by the Western Australian Planning Commission (WAPC) and the Shire of Roebourne on the 17 May 2012.

METHODOLOGY

This brief assessment of the environmental features of the subject site has involved a desktop literature and database review including review of the following:

- The Australian Government *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters database search (10 km buffer);
- The Western Australian Department of Biodiversity, Conservation and Attractions *NatureMap* tool (10 km buffer);
- Aerial photography to identify land use patterns, extent of remnant vegetation, relevant landscape matters and other possible matters relevant to the subject site;
- Mapping layers such as the topography, soil landscapes, geology, WA Contaminated Lands Register, hydrology and Environmentally Sensitive Areas (ESAs);
- Shire of Roeburn and Karratha Revitalisation Project policies and objectives.
- Coffey Environments 2010. Madigan Preliminary Environmental Assessment; and
- Madigan Development Plan 2012

ENVIRONMENTAL VALUES & RECOMENDATIONS

A brief summary of the environmental values assessed in this review of the subject site are provided in **Table 1** below.

Table 1: Summary of environmental values within the subject site

Value	Summary
Native vegetation	*No site-specific flora and vegetation surveys have been undertaken for the purpose of this advice. An assessment of the vegetation within the site has been undertaken using publicly available information, previous surveys and recent aerial imagery.* Based on IBRA (Interim Biogeographic Regionalisation for Australia) mapping, the subject site lies on the boundary of the Pilbara 1 – Chichester subregion and the Pilbara 4 – Roebourne subregion of the Pilbara bioregion. *Vegetation of the Pilbara 1* – Chichester subregion is described as shrub steppes on plains characterised by *Acacia inaequilatera* (Baderi) over *Triodia wiseana* (Limestone Spinifex) hummock grasslands, and tree steppes of *Eucalyptus leucophloia* (Snappy Gum) on ranges (Kendrick and McKenzie, 2001). *Vegetation of the Pilbara 4* – Roebourne subregion is described as consisting of grass savannah of mixed bunch and hummock grasslands and *Acacia stellaticeps* or *Acacia pyrifolia* (Banji Bush) and *Acacia. inaequilatera* dwarf shrub steppe on quaternary alluvial and older colluvial coastal and subcoastal plains. Triodia hummock grasslands dominate upland areas, while ephemeral drainage lines contain *Eucalyptus victrix* or *Corymbia hamersleyana* woodlands (Kendrick and Stanley, 2001). Aerial mapping illustrates that the vegetation throughout the subject site has been previously disturbed and cleared for high voltage power lines running through the subject site from west to east in the south; and services within the road shoulder of the Madigan Road. Aerial imagery shows that clearing began in 2012 for the initial stages of the Madigan Estate Development. This included clearing for access roads and associated infrastructure. Vegetation types within the subject site were previously described in the Preliminary Environmental Assessment (PEA) 2010 prepared by Coffey Environment as being uniform and consisted of a shrub steppe community of Acacia and *Triodia wiseana.* Dominant Acacia species were included *Acacia. pyrifolia* and *Acacia bivenosa*. Other native grasses were also present including *Eragrostis xerophila.* Since 2010, some clearing of this vegetation has occurred as described above. A review of aerial imagery details no drainage lines occurred over the subject site, however one natural drainage channel occurred immediately to the east of the subject site and is referred to as Madigan Creek. Vegetation of the riparian zone of Madigan Creek is similar to that of plains of the Chichester and Roebourne subregions and includes several different *Acacia* species including *A. coriacea.* (Coffey, 2010). Vegetation types have been reviewed to determine if they may contain habitat for conservation significant flora species or resemble any conservation significant ecological communities in the following section of this table.

Value	Summary
Threatened or Priority listed flora species and ecological communities	The PEA (Coffey 2010) and the Madigan Estate Structure Planning Document (TPG 2012) did not identify any records of any conservation significant species or Threatened Ecological Communities (TEC) within the subject site. Coffey Environments (2010) determined that it is possible for several of the Priority species to occur within and surrounding the subject site, and whilst occurrence was considered unlikely, this would only be able to be confirmed through a targeted flora survey. Coffey Environments (2010) also determined that the vegetation of within the subject site was not characteristic of the '*Stony Chenopod association of the Roebourne Plains* area' (Priority 1) TEC. ELA initially undertook a search of the Commonwealth Protected Matters Search Tool (PMST) using a 10 km buffer as a reference for this due diligence to understand if there are newly listed conservation significant species or communities that may occur within the subject site. Due to the radius of the search, numerous marine and other species were captured that are not considered to have the potential to occur within the site. The buffer range was subsequently reduced to 5 km (PMST 2020) and this is considered an appropriate scale to capture significant species relevant to the location of the subject site. The search tool (PMST 2020) did not identify any additional listed Threatened flora or Threatened Ecological Communities within 5 km of the subject site.
Threatened and Priority Fauna	There are a number of Threatened or Priority listed fauna species at Commonwealth and State levels that have been identified in the wider Karratha area. Majority of these are associated with the nearby coastal areas and significant habitat for migratory birds protected the Japan and Australian Migratory Bird Agreement (JAMBA) and the China and Australian Migratory Bird Agreement (CAMBA). Database searches were performed by Coffey to inform the PEA 2010 and the Structure Plan 2011. These being a PMST (50 km buffer), and a DEC search (now *Naturemap*), with a 15 km buffer. The table included in Attachment A presents the results of the 2010/11 searches updated by 2020 database searches undertaken by ELA. The table includes commentary of species habitat and whether they are known to or may occur in the area. The results indicate that the subject site and or its condition, including adjacent development is not preferred habitat for identified species. Of note is the Priority 4 listed Lined soil-crevice skink (Dampier) (*Notoscincus butleri). The habitat of N. butleri* has been associated with spinifex-dominated areas near creek and river margins and therefore may be present in the vicinity of Madigan Creek. It is unlikely that future planned and approved development within the identified structure plan area would impact on this species however, a site specific survey would be required to confirm these preliminary inferences.
Conservation areas and reserves	No conservation areas or reserves are located within or immediately adjacent to the subject site.
Wetlands and Environmentally Sensitive Areas (ESAs)	ELA undertook a review of relevant databases to determine if any wetlands or ESA's have been mapped within the subject site since the Preliminary Environmental Assessment (PEA) was completed by Coffey in 2010. No Environmentally Sensitive Areas (ESAs) are mapped within the subject site. The closest ESA's are located on Dampier Peninsula. Mapping dataset (DWER-046). The Directory of Important Wetlands in Western Australia dataset released by the DBCA (dataset-046) does not indicate that there are significant wetlands in the vicinity which would impact future development. The closest significant wetlands are located in Port Headland.

Value	Summary
Soils and Land Capability	The subject site is characterised as the Pilbara Craton Formation which comprises a mid-Archaean granite greenstone terrane and an overlying late-Archaean volcano-sedimentary sequence called the Hamersley Basin (GSWA, 2001). The subject site contains floodplain deposits of red-brown silty sand, which has been partially reworked by wind erosion over much of the subject site. The sand is underlain by Archaean bedrock, probably mafic volcanics at an expected depth ranging from 10-20m below surface. 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 (JDA 2011). Site topography is described as relatively flat, gently sloping to the north from the Karratha Hills in the south, with elevations of 26m Australian Height Datum (AHD), towards Dampier Road, 15m AHD at the northern boundary.
Acid Sulfate Soils	ELA undertook a review of relevant databases to determine if Acid Sulfate Soil risk within the subject site has changed since the Local Water Management Study (LWMS) was completed in 2011 (JDA 2011). The Department of Water and Environmental Regulation (DWER-053) dataset for Acid Sulphate Soil (ASS) 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), this is likely to be associated with the proximity of the adjacent creek line. The remainder of the subject site is mapped as "*No Known Risk*". It should be noted that earthworks or infrastructure may be designed and constructed in the narrow "*Moderate to Low risk*" margin as referred to above. To assess risk to ASS, further investigation may be required in accordance with relevant guidelines and agency requirements.
Hydrology	**Surface water:** The LWMS prepared by JDA Consultants (JDA 2011) describes that there are no drainage channels or permanent surface water features that exist within the subject site. Immediately adjacent to the east of the subject site is Madigan Creek, a major drainage line which is a non-perennial natural creek. The creek captures stormwarer runoff from the catchment formed within the Karratha Hills to the south of the subject site. The generally flat nature of site topography water runoff predominantly sheds naturally towards the north with minor runoff flowing west towards Seven Mile Creek. Figure 7 of the LWMS designed sub catchments for the capture, detention and release of stormwater toward Madigan Creek based on stages of development. The initial phases of construction would be required to be designed in accordance with conditions of development consent and LWMS. Therefore, surface water and stormwater management has been appropriately considered for this stage of the development. Any change to approved designs would require an amendment to engineering and earthworks approvals from the relevant authorities. **Flooding:** A Flood Study was 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 Road. Development catchments, drainage swales and POS areas proposed as part of Estate

Value	Summary
	infrastructure have been designed to contain the 20yr ARI rainfall event. It is noted that final drainage design, configuration and location is dependant on final earthworks, drainage and road design levels all of which would need separate engineering and earthworks approvals from the relevant authorities **Groundwater:** The *Hydrogeological Atlas* (DoW, 2010a) describes the hydrogeology of the subject site to be volcanic and sedimentary rock in greenstone belts, and illustrates that there is a single aquifer beneath the subject site, The Pilbara Fractured Rock aquifer. This acquirer consists of Precambrian granite-greenstone terrain overlain by surficial sediments in the river valleys. The water table is generally within 5 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 LWMS (JDA 2011) identified The Pilbara Fractured Rock Aquifer is not considered to be a suitable groundwater resource in terms of quality, being brackish to saline or yield for potable or non-potable requirements.
Contamination	No previous contamination assessments are available for the subject site. A search of the Contaminated Sites Database (dataset DWER-059) did not result in any confirmed contaminated sites within or in proximity to the subject site, however, this does not guarantee that the subject site is free from contamination. In order to support future development and in line with DER (2014), a Preliminary Site Investigation (PSI) would likely be required for the subject site to determine the actual site use and duration together with potentially contaminating activities.
Basic Raw Materials	The subject site is mapped by the Department of Mines, Industry Regulation and Safety (DMIRS) basic raw materials dataset (DMIRS-042 and 043) with the objective of identifying known basic raw material resources and protecting future resources. The subject site is mapped and described as containing: • *Eolian sand (ESd): Reddish brown, very fine- to medium-grained, clayey and silty quartz sand; eolian; low, parallel elongate and gently rounded dunes.* • *Outwash plain silty sand (OsSd): Reddish brown to yellowish brown, poorly sorted, silty quartz sand; alluvial; outwash plains.* • *Alluvial sand and gravel (ASdGr):* Dark red, medium- to coarse-grained, poorly sorted sand and gravel with cobbles and boulders; alluvial; channels.
Aboriginal and European Heritage	The Structure Plan document references a Heritage Survey for the subject site prepared by Anthropos Australis Pty Ltd & Context Anthropology Pty Ltd. This survey 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. Detailed consideration and protection of these sites was undertaken as part of the structure planning and assessment process and subsequently the development of a Cultural Heritage Management Plan (CHMP). The three sites within the subject site are located within POS areas to be protected. A review of the heritage survey or the CHMP has not been undertaken as part of this due diligence review. A search of the Department of Planning, Lands and Heritage Aboriginal Heritage Inquiry System (AHIS) identified the following sites, namely: • Site No.29306, 29307 and 29308 – located within and protected by POS areas of the subject site. • Site No. 29309 and 21299 – adjacent to the western bank of Madigan Creek outside of the subject site • Site No. 8959, 8960 and 8961 – Karratha West Access Road (previously considered and recorded as part of the structure plan assessment) If investigations or activities were to identify culturally significant materials within the site that have not been previously been identified or recorded, appropriate approvals to disturb the site, prior to commencement of any works via a Section 18 Application under the Aboriginal Heritage Act 1972 would be required.

Value	Summary
	A search of the Heritage Council of WA's database (INHERIT) indicated that the Karratha Cemetery (25224) immediately to the north of the subject site The airstrip located with Lot 50 is registered as a Municipal Heritage Place No. 14253 and is listed on the Municipal Inventory as an 'Airstrip- War Time'. There is limited information available as to the requirements to manage or retain the airstrip in its current location however it is recommended that early liaison with the Heritage Council to understand its status and any future impact to proposed development be undertaken as a priority. The MENSP identifies this area of the site for 'special protection' and it is therefore anticipated that retention of this feature may be required.
Surrounding Land Uses	The site is impacted by a number of surrounding land uses including but not limited to: • A cemetery to the north; • Continuation of the Baynton suburban expansion and residential development further to the east of the subject site; and • Previous mining camp tenements to the west
Bushfire	The subject site is located within a designated bushfire prone area as per the *Western Australia State Map of Bush Fire Prone Areas* (DFES 2018). This triggers bushfire planning requirements under *State Planning Policy 3.7 Planning in Bushfire Prone Areas* (SPP 3.7; WAPC 2015) and reporting to accompany submission of the development application in accordance with the associated *Guidelines for Planning in Bushfire Prone Areas v 1.3* (the Guidelines; WAPC 2017). A bushfire management plan for the subject site (structure plan area) was prepared by ELA (2020) for the site to inform planning constraints and potential protection measures (i.e. determination of minimum setbacks from vegetation to achieve a Bushfire Attack Level (BAL) rating of ≤BAL-29). The management plan that the bushfire protection requirements listed in the assessment provided an adequate standard of bushfire protection for the proposed development. As such, the proposed development is consistent with the aim and objectives of SPP 3.7 and associated guidelines.

Figure 1: Subject Site

Legend

Subject Site

0 150 300 600
Metres
Datum/Projection:
GDA 1994 MGA Zone 50

N

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20PER-17714 - JL Date: 14/01/2021

A1 Attachment A: Likelihood of occurrence assessment: Conservation significant fauna species

Species	2010 PMST	2010 DEC	2020 PMST	2020 *Naturemap*	Comment
Birds:					
Southern Giant-Petrel (*Macronectes giganteus*)	EN				Unlikely to be present due to an absence of the species preferred habitat.
Red Knot (*Calidris canutus*)			EN	IA	Unlikely to be present due to an absence of the species preferred habitat.
Curlew Sandpiper (*Calidris ferruginea*)			CR	Threatened	Unlikely to be present due to an absence of the species preferred habitat.
Great Knot (*Calidris tenuirostris*)			CR	Threatened	Unlikely to be present due to an absence of the species preferred habitat.
Greater Sand Plover, Large Sand Plover (*Charadrius leschenaultia*)			VU	Threatened	Unlikely to be present due to an absence of the species preferred habitat.
Lesser Sand Plover, Mongolian Plover (*Charadrius mongolus*)			EN	Threatened	Unlikely to be present due to an absence of the species preferred habitat.
Grey Falcon (*Falco hypoleucos*)			VU		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.
Peregrine Falcon (*Falco peregrinus*)		Sch 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.
Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) (*Limosa lapponica menzbieri*)			CR		Unlikely to be present due to an absence of the species preferred habitat.
Australian Bustard (*Ardeotis australis*)		P4			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 Stonecurlew (*Burhinus grallarius*)		P4			Unlikely to be present on the site.

Species	2010 PMST	2010 DEC	2020 PMST	2020 *Naturemap*	Comment
Eastern Curlew, Far Eastern Curlew (*Numenius madagascariensis*)		P4	CR	Threatened	Unlikely to be present due to an absence of the species preferred habitat.
Night Parrot (*Pezoporus occidentalis*)			EN		The habitat present on the site is degraded, and if present, the species would move to adjoining areas if disturbed
Australian Painted Snipe (*Rostratula australis*)			EN		Unlikely to be present due to an absence of the species preferred habitat.
Australian Fairy Tern (*Sternula nereis nereis*)			VU		Unlikely to be present due to an absence of the species preferred habitat.
Grey-tailed Tattler (*Tringa brevipes*)				P4	
Flock Bronzewing (*Phaps histrionica*)		P4			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.
Mammals:					
Northern Quoll (*Dasyurus hallucatus*)	EN	Sch 1		Threatened	Occasionally found in the region, though generally prefers rocky outcrops containing dens which were not identified during the site visit.
Greater Bilby (*Macrotis lagotis*)	EN				Unlikely to be present due to an absence of the species preferred habitat.
Ghost Bat (*Macroderma gigas*)		P4	VU		May infrequently visit the site, though unlikely to reside on the site due to the absence of caves.
Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*)	VU		VU		May infrequently visit the site, though unlikely to reside on the site due to the absence of caves.
Little North-western Mastiff Bat (*Mormopterus loriae cobourgiana*)		P1			Highly unlikely to be present on the site due to an absence of the species preferred habitat (mangroves).
Northern Short-tailed Mouse, Lakeland Downs Mouse, Kerakenga (*Leggadina lakedownensis*)			P4		

Species	2010 PMST	2010 DEC	2020 PMST	2020 *Naturemap*	Comment
Western Pebble-mound Mouse, Ngadji (*Pseudomys chapmani*)		P4			Potentially present in the Karratha hills area, though the Pebblemound Mouse occurred on the Burrup Peninsula in the past, but has not been recorded recently.
Lakelands Downs Mouse, Kerakenga (*Leggadina lakedownensis*)		P4			Highly unlikely to be present on the site owing to the degraded habitat present on the site.
Reptiles:					
Olive Python (*Liasis olivaceus barroni*).	VU	Sch 1	VU	Threatened	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.
Lined soil-crevice skink (Dampier) (*Notoscincus butleri*)			P4		has been associated with spinifex-dominated areas near creek and river margins therefore may be present in the vicinity of Madigan Creek.

REFERENCES

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Kendrick, P. and McKenzie, N. (2001). Pilbara 1 (PIL1 – Chichester subregion). *In: A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions in 2002*. Department of Conservation and Land Management, W.A.

Kendrick, P. and Stanley, F. (2001). Pilbara 4 (PIL4 – Roebourne synopsis). *In: A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions in 2002*. Department of Conservation and Land Management, W.A.

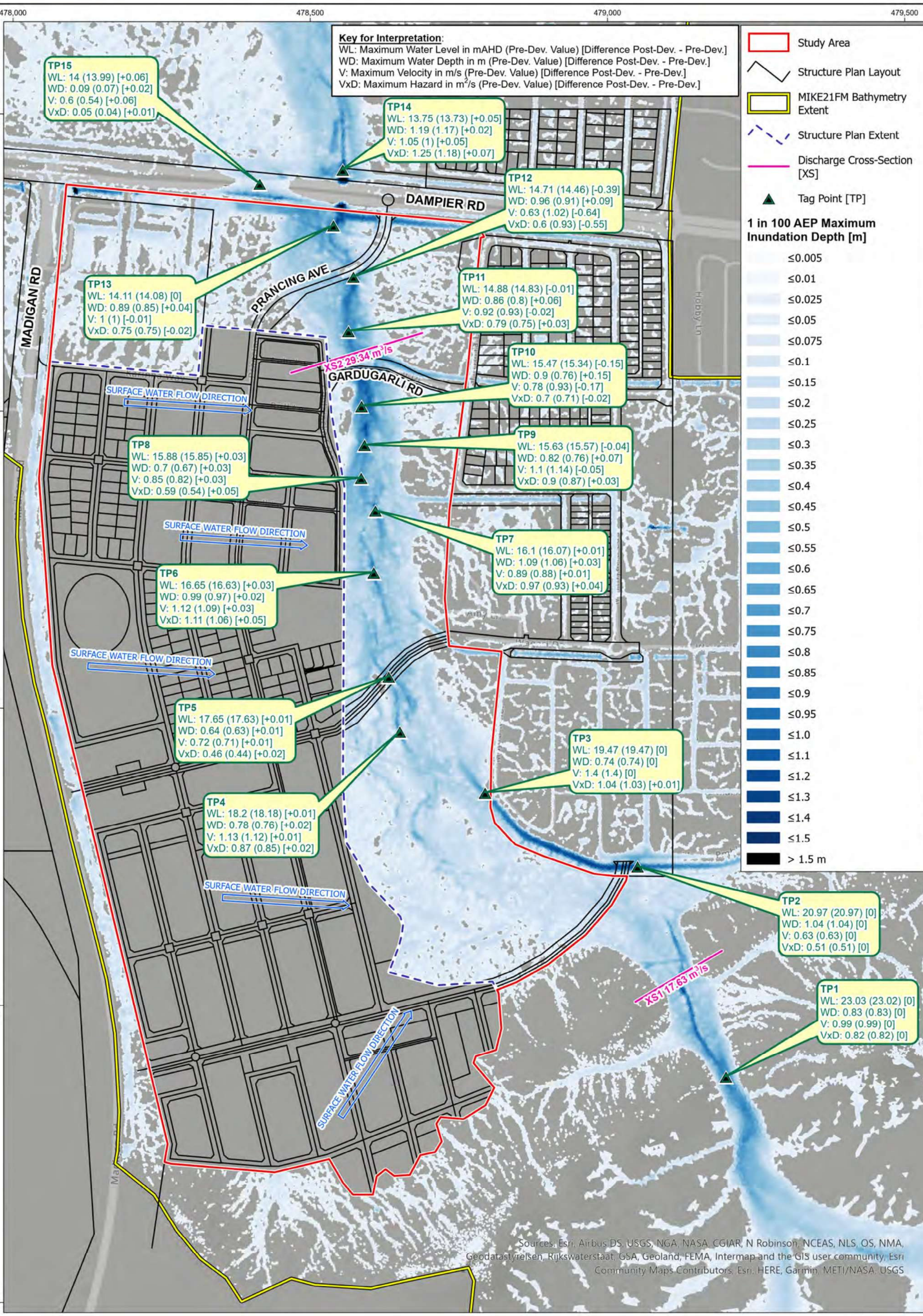
TPG Consultants. *Madigan Development Plan 2012* (endorsed by the WAPC 17 May 2012).

APPENDIX C

JDA Hydrologists

Madigan Creek Flood Study (Extract only)

September 2020



Data Source:

Coordinate System: GDA2020 MGA Zone 50

JDA

Job No. J6919

Scale: 1:6,000 @A3

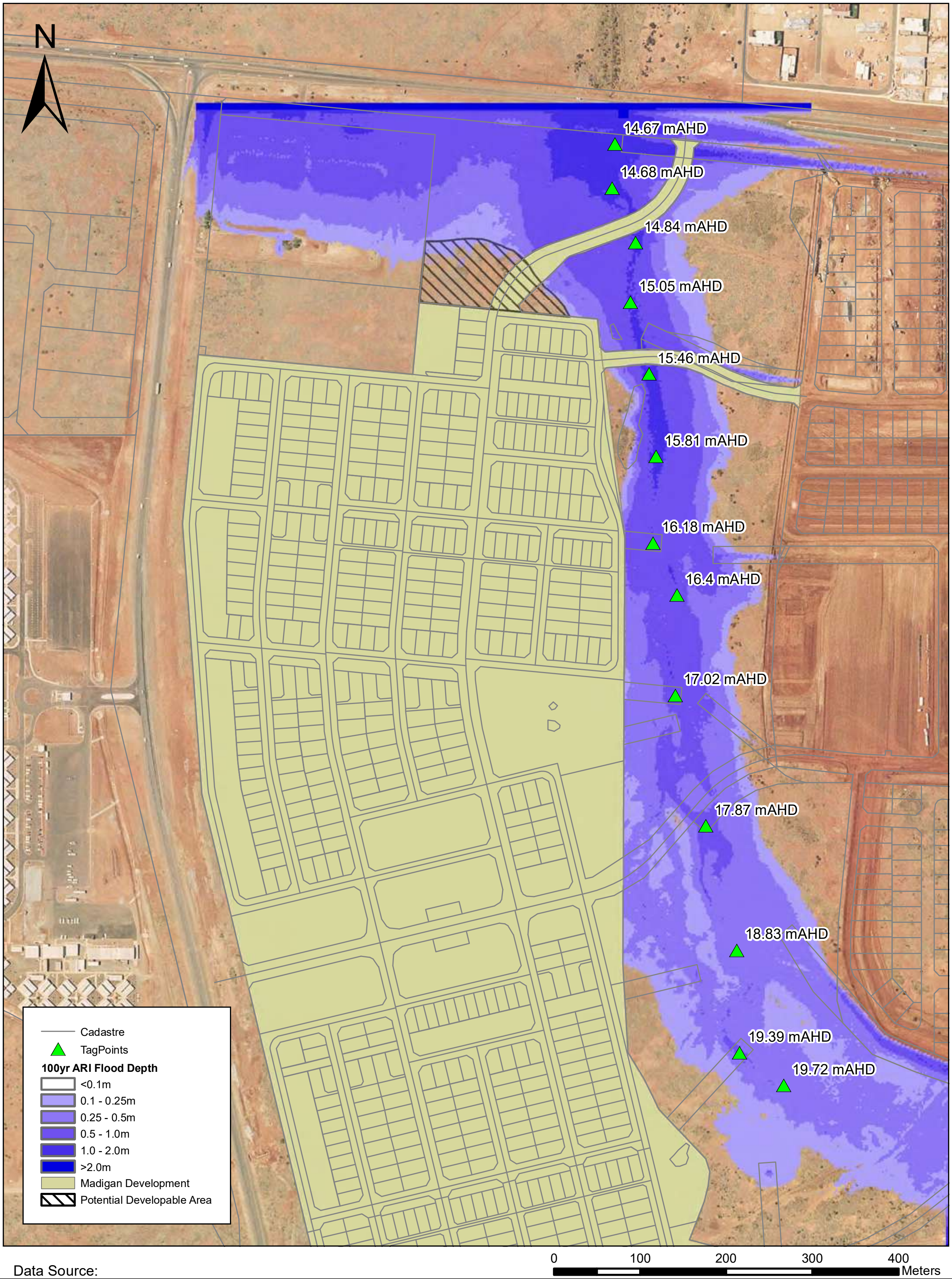
0 150 300 450 Metres

N

DevelopmentWA

Madigan Creek Flood Study

Figure 10: 1% AEP Post-Development Flood Mapping



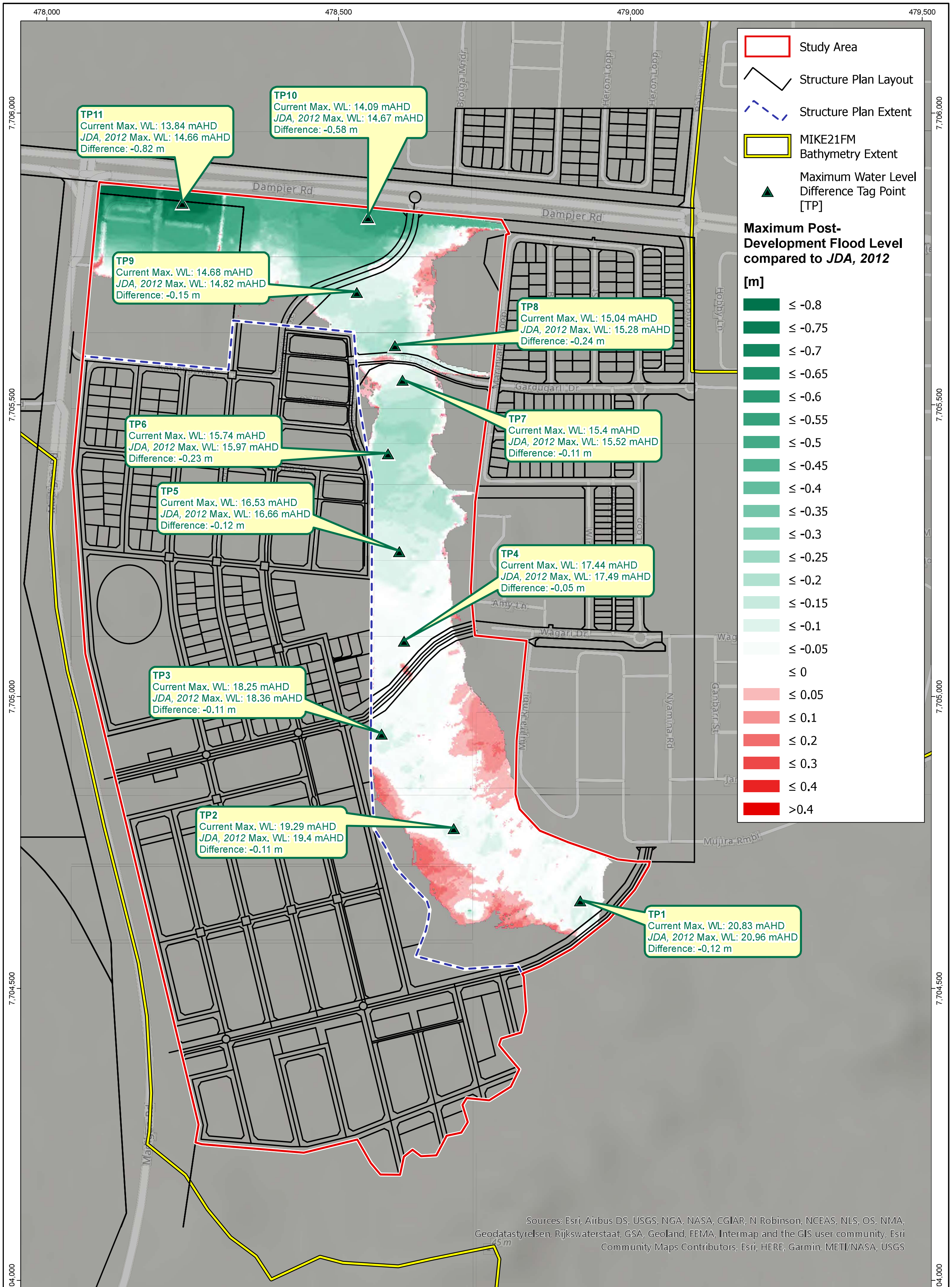
Data Source:

JDA

Job No. J6919
Scale 1:6,000

DevelopmentWA
Madigan Creek Flood Study

Figure 12: Madigan Creek Post Development 100yr ARI Flood Depth & Levels from JDA, 2012



Data Source:

Coordinate System: GDA2020 MGA Zone 50

JDA

Job No. J6919

Scale: 1:6,000 @A3

0 150 300 450 Metres

N

DevelopmentWA

Madigan Creek Flood Study

Figure 13: Madigan Creek 1% AEP Post-Development Flood Level compared to *JDA, 2012*

APPENDIX D

ND Engineering Consulting Engineers

Acoustic Report (1010105 Rev 2)

Madigan Road Karratha

10 September 2020

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ND Engineering
Consulting Engineers

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ACOUSTIC (SPP5.4) REPORT 1010105 Revision 2
KARRATHA MADIGAN RESIDENTIAL ESTATE
MADIGAN ROAD KARRATHA WA 6714

REFERENCES

A. SPP 5.4 Road and Rail Noise Policy Sept 2019.

B. SPP 5.4 Road and Rail Noise Implementation Guidelines Sept 2019.

C. ND Engineering Report No 10010105 Revision 1.1 ACOUSTIC ASSESSMENT PROPOSED RESIDENTIAL SUBDIVISION MADIGAN ROAD KARRATHA WA 6714, dated 20 October 2010

BACKGROUND

0.1 This report is a revision of the original report produced in 2010 which was then based upon the SPP 5.4 - 2009.

0.2 This revised report is based on using SPP 5.4 – September 2019, utilising SPP5.4 Guidelines' Table 2 *Noise exposure forecast* in conjunction with Table 3 *Quiet house requirements.* This does not involve any site visits nor site noise measurements nor noise modelling however it would be expected that at the time of development that noise measurements would be undertaken onsite by others when traffic volumes return to a normal level rather than the reduced traffic volumes during Covid-19 conditions.

SUMMARY

1.1 The following summarises the outcomes:

- 162.5 to 312.5m from centre of road Quiet House Package NIL not applicable;
- 122.5 to 162.5m from centre of road Quiet House Package A;
- 62.5 to 122.5m from centre of road Quiet House Package B;
- 32.5 to 62.5m from centre of road Quiet House Package C;
- Less than 32.5m from centre of road. Noise sensitive use is not recommended as there is no default Quiet House Package and an Engineered solution required.

1.2 A significant consideration is that if the Lots within the land cells closest to Madigan Road are set so that the outdoor living areas are shielded from Madigan Road by being paced on the Eastern sides then there is no requirement to build a noise wall between the LOTS and Madigan Road.

FIGURE 1.1 – SITE OVERVIEW

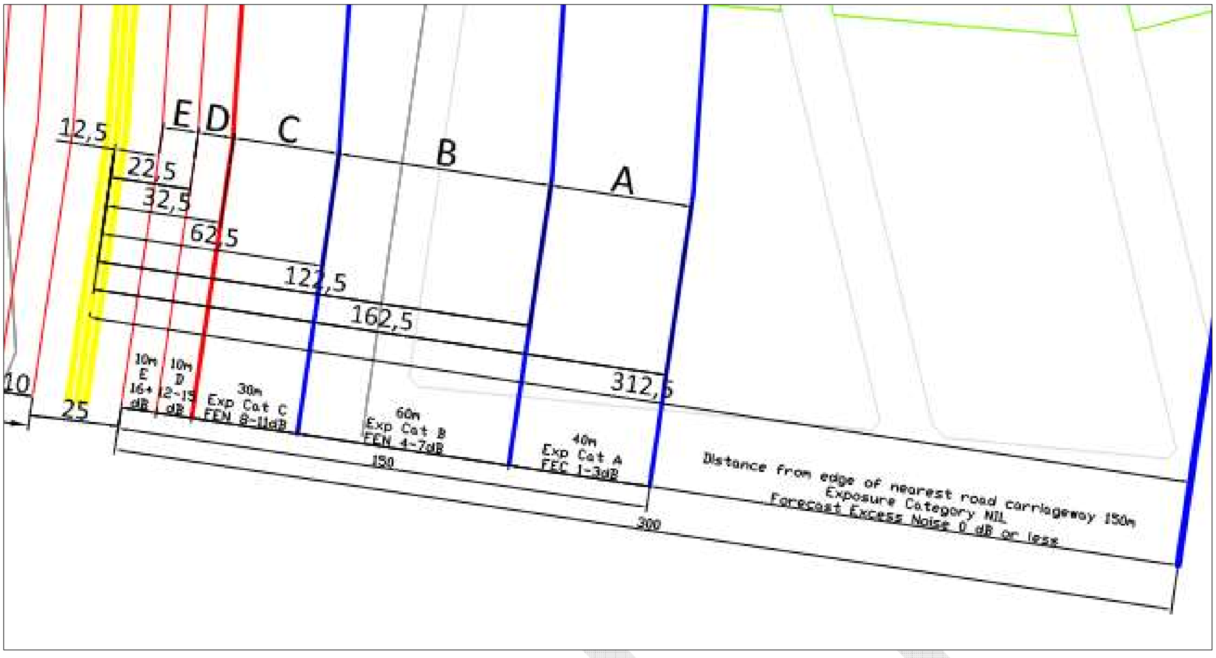

FIGURE 1.2 – QUIET HOUSE PACKAGES LOCATION OVERVIEW

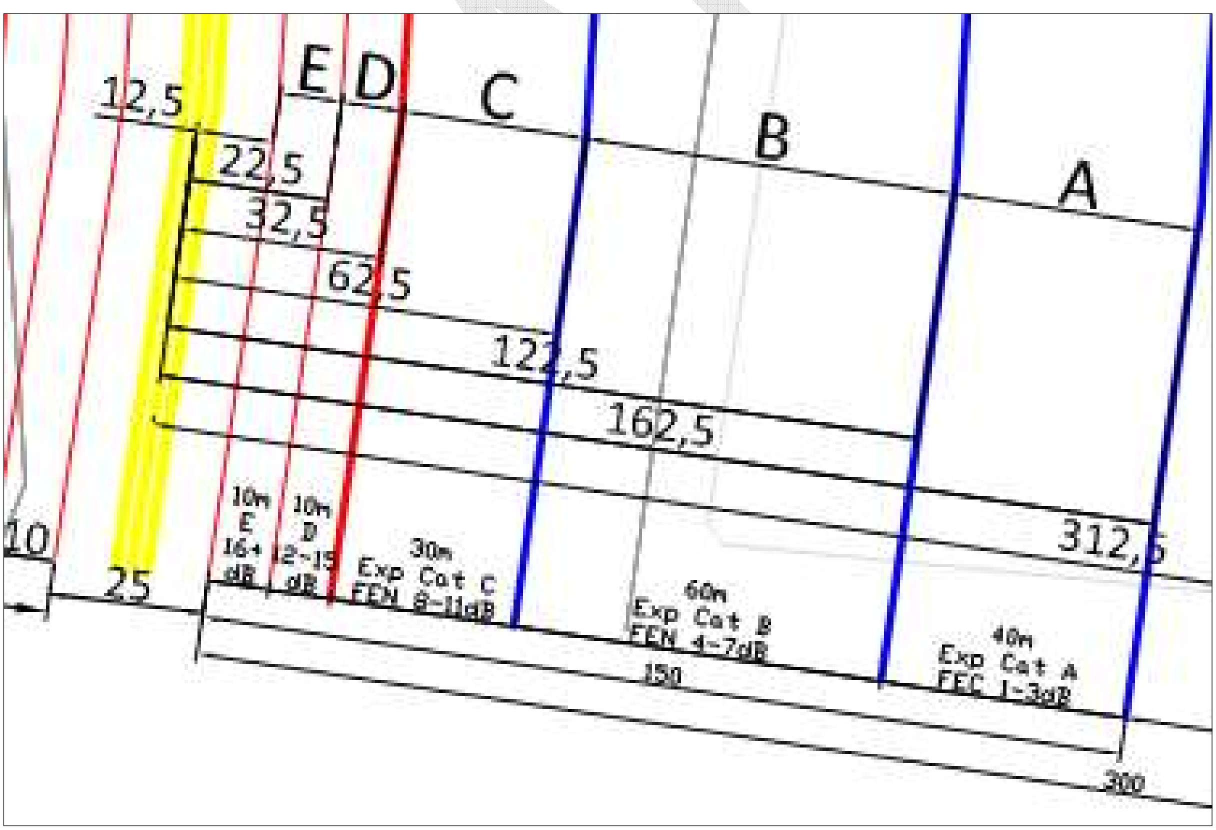

FIGURE 1.3 – QUIET HOUSE PACKAGES LOCATIONS IN DETAIL

TABLE A – SPP5.4 POLICY APPLICATION

Extract from Table 1 - Transport corridor classification and trigger distances		**Transport corridor and distances**		**Policy Application**
Transport corridor classification	**Trigger distances**			
Strategic freight and/or major traffic route *Either ≥ 500x Class 7 to 12 Austroads vehicles daily* *Or ≥ 50,000 per day traffic volume*	300 m from road carriageway edge	Madigan Rd	MRWA Hourly Volume Madigan Rd South of Dampier Rd Site 50098, 2019/20 data Monday to Friday 2031 Vehicles per Day including 725 Heavy Vehicles	Yes

Table 1: Transport corridor classification and trigger distances

Transport corridor classification	Trigger distance	Distance measured from
Roads		
Strategic freight and major traffic routes Roads as defined by Perth and Peel Planning Frameworks and/or roads with either 500 or more Class 7 to 12 Austroads vehicles per day, and/or 50,000 per day traffic volume	300 metres	Road carriageway edge

TABLE B – SPP5.4 GUIDELINES APPLICATION

Extract from Table 2 – Noise exposure forecast		Transport corridor and distances	(0) Forecast Noise Exposure Category
Transport corridor classification	**Number of lanes (both directions) including bus / priority lanes and entrance / exit ramps**	**Madigan Road** Assume total road width is 25m in order for use in Table 2.	**(1) Forecast Excess Noise Level dB** **(2) Exposure Category** **(3) Policy requirements for noise sensitive land use and/or development**
Strategic freight and/or major traffic route *Either ≥ 500x Class 7 to 12 Austroads vehicles daily* *Or ≥ 50,000 per day traffic volume*	2 to 4 lanes	150 to 300m from edge of assumed road width. 162.5 to 312.5m from centre of road.	(0) 55 to 50 dB (1) 0 or less dB (2) Not applicable (3) Quiet house package NIL
		110 to 150 m from edge of assumed road width. 122.5 to 162.5m from centre of road.	(0) 58 to 56 dB (1) 3 to 1 dB (2) A (3) **Quiet House Package A**
		50 to 110 m from edge of assumed road width. 62.5 to 122.5m from centre of road.	(0) 62 to 59 dB (1) 7 to 4 dB (2) B (3) **Quiet House Package B**
		20 to 50 m from edge of assumed road width. 32.5 to 62.5m from centre of road.	(0) 66 to 63 dB (1) 11 to 8 dB (2) C (3) **Quiet house package C**
		Less than 20 from edge of assumed road width. Less than 32.5m from centre of road.	Noise sensitive use is not recommended There is no default Quiet House Package. Engineered solution required.

Table continues overpage

Table 2: *Noise exposure forecast*

Transport Corridor Classification	Number of lanes (both directions), including bus/priority lanes and entrance/exit ramps	Forecast noise exposure category based on lot distance(m) from edge of nearest main road carriageway (not entrance/exit ramps) adjacent – 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	175	200	225	250	275	300
Strategic freight/major traffic route • 500 or more Class 7-12 Austroads vehicles per day, or • 50,000+ vehicles per day	2 to 4 lanes	72	68	66	65	63	62	61	61	60	59	59	58	57	57	56	55	54	53	52	51	50
	5 to 6 lanes	74	70	68	66	65	64	63	62	61	61	60	59	59	58	58	57	56	55	54	53	52
	7 to 8 lanes	76	72	69	68	66	65	64	64	63	62	62	61	60	60	59	58	57	56	55	54	53
	9 to 10 lanes	77	73	70	69	67	66	65	65	64	63	63	62	61	61	60	59	58	57	56	55	54
	10 or more lanes	78	74	71	70	68	67	66	66	65	64	64	63	62	62	61	60	59	58	57	56	56

Number of lanes (both directions), including bus/priority lanes and entrance/exit ramps	Forecast noise exposure category based on lot distance(m) from edge of nearest main road carriageway (not entrance/exit ramps) adjacent – 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
2 to 4 lanes	72	68	66	65	63	62	61	61	60	59	59	58	57	57	56
5 to 6 lanes	74	70	68	66	65	64	63	62	61	61	60	59	59	58	58
7 to 8 lanes	76	72	69	68	66	65	64	64	63	62	62	61	60	60	59
9 to 10 lanes	77	73	70	69	67	66	65	65	64	63	63	62	61	61	60
10 or more lanes	78	74	71	70	68	67	66	66	65	64	64	63	62	62	61

Forecast Excess Noise Level, dB	Exposure Category	Policy requirements for noise-sensitive land-use and/or development
0 or less	-	No further measures
1 to 3	A	Noise-sensitive land-use and/or development is acceptable, subject to:
-	*A+	Mitigation measures in accordance with an approved noise management plan;
4 to 7	B	
-	*B+	
8 to 11	C	or quiet house package as specified
-	*C+	
12 to 15	D	Noise-sensitive land-use and/or development is not recommended. There is no default quiet house option due to excessive forecast noise; professional design input is required in order to achieve compliance with relevant criteria. If noise-sensitive land-use and/or development is unavoidable, an approved noise management plan is required to demonstrate compliance with the noise target (see Table 1).
16 +	E	

* Assits to mitigate short term noise events from freight rail.

The noise levels in noise exposure forecast table are based on a number of assumptions including:

• Level and open ground between the noise source and the receiver and neutral weather effects

• All values include a +2.5 dB façade correction, typical ground absorption, some scattering from buildings in line with measured data for urban and rural scenarios; and include in-built cumulative noise factors for urban areas

• Development building outline is within 10metres of the lot boundary facing transport corridor

• Number of road lanes roughly scale with volume (at up to ~18,000/vehicle per day for a 2 lane road)

Road and Rail Noise **Guidelines**
September 2019

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Table 3: *Quiet house requirements*

Exposure Category	Orientation to corridor	Acoustic rating and example constructions: Walls	External doors	Windows	Roofs and ceilings of highest floors	Outdoor living areas	Mechanical ventilation / air conditioning considerations
A **Quiet House A**	Facing Side on	**Bedroom and indoor living and work areas to Rw+Ctr 45dB** • One row of 92mm studs at 600mm centres with: – Resilient steel channels fixed to the outside of the studs; and – 9.5mm hardboard or 9mm fibre cement sheeting or 11mm fibre cement weatherboards or one layer of 19mm board cladding fixed to the outside of the channels; and – 75mm glass wool (11kg/m3) or 75mm polyester (14kg/m3) insulation, positioned between the studs; and – Two layers of 16mm fire-protective grade plasterboard fixed to the inside face of the studs. – Single leaf of 150mm brick masonry with 13mm cement render on each face. – Double brick: two leaves of 90mm clay brick masonry with a 20mm cavity between leaves.	Bedrooms: • Fully glazed hinged door with certified Rw+Ctr 28dB rated door and frame including seals and 6mm glass Other external doors to Rw+Ctr 25dB, e.g. • 35mm solid core timber hinged door and frame system certified to Rw 28dB including seals • Glazed sliding door with 10mm glass and weather seals	Bedrooms: • Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum 10mm single or 6mm-12mm-10mm double insulated glazing (Rw+Ctr 28 dB). Sealed awning or casement windows may use 6 mm glazing instead. • Up to 60% floor area: as per above but must be sealed awning or casement type windows (Rw+Ctr 31dB). **Indoor living and work areas** • Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 25dB). • Up to 60% floor area: As per Bedrooms at up to 40% area (Rw+Ctr 28 dB). • Up to 80% floor area: As per Bedrooms at up to 60% area (Rw+Ctr 31dB).	To Rw+Ctr 35dB • Concrete or terracotta tile or metal sheet roof with sarking and at least 10mm plasterboard ceiling	At least one outdoor living area located on the opposite side of the building from the transport corridor and/or at least one ground level outdoor living area screened using a solid continuous fence or other structure of minimum 2 metres height above ground level.	• Acoustically rated openings and ductwork to provide a minimum sound reduction performance of Rw 40dB into sensitive spaces • Evaporative systems require attenuated ceiling air vents to allow closed windows • Refrigerant-based systems need to be designed to achieve National Construction Code fresh air ventilation requirements • Openings such as eaves, vents and air inlets must be acoustically treated, closed or relocated to building sides facing away from the corridor where practicable
	Opposite		As per 'Facing' above, except Rw+Ctr values may be 3dB less, e.g. glazed sliding door with 10mm glass and weather seals for bedrooms. No specific requirements	As above, except Rw+Ctr values may be 3dB less, or max % area increased by 20%			
A **Quiet House A+**	All	As per Quiet House A, except double leaf masonry / brick construction only.	As per Quiet House A	As per Quiet House A, except that • 'Side-on' requirements same as 'Facing'. • All windows comprise minimum 6 mm thick laminated or toughened glass in sealed awning or casement frames. Polymer (e.g. uPVC) window framing should be used. Evaporative air conditioning systems are not recommended. • No external doors for bedrooms with entry 'Facing' transport corridor	No specific requirements		
B **Quiet House B**	Facing	**Bedroom and indoor living and work areas to Rw+Ctr 50dB** • Single leaf of 90mm clay brick masonry with: – A row of 70mm x 35mm timber studs or 64mm steel studs at 600mm centres; – A cavity of 25mm between leaves; – 50mm glass wool or polyester cavity insulation (R2.0+) insulation between studs; and – One layer of 10mm plasterboard fixed to the inside face • Single leaf of 220mm brick masonry with 13mm cement render on each face	Bedrooms • Fully glazed hinged door with certified Rw+Ctr 31dB rated door and frame including seals and 10mm glass • Other external doors to Rw+Ctr 28dB, e.g. • As per Quiet House A Bedrooms.	Bedrooms: • Total external door and window system area up to 40% of room floor area: Fixed sash, awning or casement with minimum 6mm single or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 31 dB). • Up to 60% floor area: as per above but must be minimum 10 mm single or 6mm-12mm-10mm double insulated glazing (Rw+Ctr 34dB). **Indoor living and work areas** • Up to 40% floor area: Sliding or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 28dB). Sealed awning or casement windows may use 6 mm glazing instead. • Up to 60% floor area: As per Bedrooms at up to 40% area (Rw+Ctr 31 dB). • Up to 80% floor area: As per Bedrooms at up to 60% area (Rw+Ctr 34dB).	To Rw+Ctr 35dB • Concrete or terracotta tile or metal sheet roof, sarking and at least 10mm plasterboard ceiling, R3.0+ insulation	At least one outdoor living area located on the opposite side of the building from the corridor and/or at least one ground level outdoor living area screened using a solid continuous fence or other structure of minimum 2.4 metres height above ground level	
	Side-on	• 150mm thick unlined concrete panel or 200mm thick concrete panel with one layer of 13mm plasterboard or 13mm cement render on each face	As per Quiet House A 'Facing' above (Rw+Ctr values may be 3dB less, or max % area increased by 20%).				
	Opposite	• Double brick: two leaves of 90mm clay brick masonry with: – A 50mm cavity between leaves – 50mm glass wool or polyester cavity insulation (R2.0+) – resilient ties where required to connect leaves • Double brick: two leaves of 110mm clay brick masonry with a 50mm cavity between leaves and R2.0+ cavity insulation	As per Quiet House A 'Side-on' above.				
B **Quiet House B+**	All	As per Quiet House B example above, except use double leaf masonry construction only.	As per Quiet House B, except • No external doors for bedrooms with entry 'Facing' or 'Side-on' to transport corridor	As per Quiet House B, except that • 'Side-on' requirements become the same as Quiet House B 'Facing'. • All windows comprise minimum 6 mm thick laminated or toughened glass in sealed awning or casement frames. Polymer (e.g. uPVC) window framing should be used. • Evaporative air conditioning systems are not recommended.	As per Quiet House C (to Rw+Ctr 40dB).		

Cont. next page

Extract from Table 3 – Quiet House Requirements A & B

Road and Rail Noise **Guidelines**
September 2019

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Exposure Category	Orientation to corridor	Acoustic rating and example constructions: Walls	External doors	Windows	Roofs and ceilings of highest floors	Outdoor living areas	Mechanical ventilation / air conditioning considerations
C **Quiet House C**	Facing	**Bedroom and indoor living and work areas to Rw+Ctr 50dB** • As per Quiet House B example above	**Bedrooms** • External doors to bedrooms facing the corridor are not recommended. Other external doors to Rw+Ctr 30dB, e.g. • Fully glazed hinged door with certified Rw+Ctr 31dB rated door and frame including seals and 10mm glass. • 40mm solid core timber frame and door (without glass or with glass inserts not less than 6mm), side hinged with certified Rw 32dB acoustically rated door and frame system including seals	**Bedrooms:** • Total external door and window system area up to 20% of room floor area: Fixed sash, awning or casement with minimum 6mm single or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 31 dB). • Up to 40% floor area: as per above but must be minimum 10 mm single or 6mm-12mm-10mm double insulated glazing (Rw+Ctr 34dB). **Indoor living and work areas** • Up to 40% floor area: Sliding or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 31dB). Sealed awning or casement windows may use 6 mm glazing instead. • Up to 60% floor area: As per Bedrooms at up to 40% area (Rw+Ctr 34 dB).	To Rw+Ctr 40dB • To all bedrooms, 2 layers of 10mm plasterboard, or one layer 13 mm high density sealed plasterboard (minimum surface density of 12.5 kg/m2), affixed using steel furring channels beneath ceiling rafters / supports. • R3.0+ insulation batts laid in cavity. • Concrete or terracotta tile roof with sarking, or metal sheet roof with foil backed R2.0+ fibre insulation between steel sheeting and roof battens.	As per Quiet House B	• Acoustically rated openings and ductwork to provide a minimum sound reduction performance of Rw 40dB into sensitive spaces • Evaporative systems require attenuated ceiling air vents to allow closed windows • Refrigerant-based systems need to be designed to achieve National Construction Code fresh air ventilation requirements • Openings such as eaves, vents and air inlets must be acoustically treated, closed or relocated to building sides facing away from the corridor where practicable
	Side-on		As per Quiet House B 'Facing' above (Rw+Ctr values may be 3dB less, or max % area increased by 20%).				
	Opposite		As per Quiet House A 'Facing' above.				
C **Quiet House C+**	All	As per Quiet House B example above, except using double leaf masonry construction only. • Double brick: two leaves of 90mm clay brick masonry with: – A 50mm cavity between leaves – R2.0+ cavity insulation – resilient ties where required to connect • Double brick: two leaves of 110mm clay brick masonry with a 50mm cavity between leaves and R2.0+ cavity insulation	As per Quiet House C, except • No external doors for bedrooms with entry 'Facing' or 'Side-on' to transport corridor.	As per Quiet House C, except that • 'Side-on' requirements same as Quiet House C 'Facing' • All windows into habitable areas comprise minimum 6 mm thick glazing in sealed awning or casement frames. Polymer (e.g. uPVC) window framing and hardware which cannot rattle loose should be used throughout. • Evaporative air conditioning systems are not recommended.	To Rw+Ctr 45dB As per Quiet House C, except • the roof must be concrete or terracotta tile construction with sarking (i.e. no steel sheet roof option). • Ceilings to bedrooms must be constructed from at least 2 overlapping layers of flush plasterboard.		

Footnotes:

- The airborne weighted sound reduction index (Rw) and traffic correction term (Ctr) are published by manufacturers/suppliers, can be determined by acoustical consultants or measured in accordance with AS ISO 717.1. Higher Rw+Ctr values infer greater sound insulation. All values are minimum Rw+Ctr (dB)
- Example construction for different external wall ratings of Rw+Ctr 45dB and 50dB are provided and are listed within Specification F5.2 in Volume 1 Part F of the National Construction Code. These values are based on the installation and sealing of joints and penetrations in accordance with Specification F5.2.
- Window and external door sound reduction values provided are based on the provision of suitable acoustic seals to prevent sound leakage. To comply with the above ratings, all external glass windows and doors specified under requirements A, B and C must have the following:
  - Operable windows and external doors must have a seal to restrict air infiltration fitted to each edge and doors must have a drop seal to provide an airtight seal when closed
  - Within doors or fixed framing, glazing must be set and sealed using an airtight arrangement of non-hardening sealant, soft rubber (elastomer) gasket and/or glazing tape, or be verified by manufacturer or approved person that the construction system as to be installed achieves the relevant Rw+Ctr value
  - In this context, a seal is foam or silicon based rubber compressible strip, fibrous seal with vinyl fin interleaf or the like. Brush / pile type seals without this seal included are not allowed.
  - Glazing referenced can be monolithic, laminated or toughened safety glass
- Any penetrations in a part of the building envelope must be acoustically treated so as not to degrade the performance of the building elements affected. Most penetrations in external walls such as pipes, cables or ducts can be sealed through caulking gaps with non-hardening mastic or suitable mortar

Extract from Table 3 – Quiet House Requirements C

4.0 If you require further advice please contact me.

Yours Sincerely

N. M. Della Gatta
MIEAust
Professional Engineer
Membership No. 1184788

10 September 2020

APPENDIX 3

INDICATIVE TREE SPECIES

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 fi stula	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