



City of Karratha

Dampier Stormwater Management Study

Report

Part A

June 2015

Executive Summary

Objectives of the flood and stormwater management study relate to protection of assets, safety of residents and safe guarding ongoing use of the drainage network.

Key objectives of this study are considered to be as follows:

- **Protect private and public infrastructure:** To provide adequate protection for infrastructure that has the potential to be damaged from floods and /or conveyance of stormwater.
- **Manage public safety:** To limit the risk of injury to residents that can result from uncontrolled flow of water and inundation in stormwater drainage systems and during flood events.
- **Provide options for ongoing management:** To provide an appropriate level of documentation for maintenance of drainage infrastructure within the community to manage potential nuisances to the community as a result of flooding.

A background review was undertaken to examine the existing drainage assets and original design intent for Dampier will meet future needs in accordance with various legislative requirements and principles for flood management. Overarching principles for drainage within Dampier that have guided the review of the drainage system include:

- The drainage system should be designed for the 100 yr ARI event using overland flow;
- Maximum flow velocities in open channels shall not exceed 2 m/s in lined open channels;
- Natural function of flood plains to convey flood waters is preserved and enhanced where possible;
- Detention storage areas may be provided at suitable locations to reduce peak flow rates to the capacity of downstream facilities;
- Runoff from constructed impervious areas should be retained where possible within the lot or road reserve for the 1 yr ARI event; and
- Provision shall be made for peak 1 in 100 year storm events such that the floor level of all buildings shall be a minimum of 500 mm above the standing water level in 100 year storm or 300 mm above the flowing water level/road reserve level to protect against inundation.

The review noted the general drainage conditions within Dampier were degraded with a number of encroachments identified which extended into the drainage reserve impacting flow paths with significant debris namely sediment and gross pollutants found to be impeding flow. In line with Section 195 of the Land Administration Act 1997 the City of Karratha has rights under Section 167 of the Planning and Development Act 2005 to maintain function of the asset located within the easement/reserves.

Modelling confirmed a number of existing flood management issues were identified with the drainage network resulting in the potential flooding of property during design storm events. To address the risks associated with the identified issues and drainage constraints structural (upgrade) and maintenance measures were proposed and included:

- Drainage infrastructure improvements to provide more efficient conveyance of flood water away from residential and commercial areas to more suitable downstream locations for management. Suggested improvement include:
 - Establishment of new culvert crossing and critical low points;

- Upgrade of existing undersized culvert crossings where conveyance requirements are not met;
- Reestablishment of the original swale profile including encroachment removal where critical; and
- Formal recognition of formal and informal drainage flow paths.
- Maintenance arrangements for ongoing drainage assets protection to minimise nuisance flooding; and
- Life cycle assessment consideration to achieve best value and design life for the drainage system and ultimately the communities benefit.

Table of contents

1.	Introduction.....	1
1.1	Background.....	1
1.2	Scope of work.....	1
1.3	Available data.....	2
1.4	Limitations.....	2
2.	Desktop Assessment.....	4
2.1	Documents reviewed.....	4
2.2	Gap analysis.....	4
2.3	Catchment characteristics.....	4
2.4	Existing drainage system.....	6
2.5	Legislative considerations.....	20
3.	Existing Scenario Flood Modelling.....	23
3.1	Model setup.....	23
3.2	Results.....	27
3.3	Encroachment impact.....	33
4.	Development Scenario Modelling.....	38
4.1	Development plan.....	38
4.2	Results.....	38
4.3	Development Impacts.....	42
5.	Stormwater Management Strategy.....	44
5.1	Objectives.....	44
5.2	Recommended stormwater network upgrades.....	45
5.3	Potential land amalgamation.....	54
5.4	Future development.....	57
6.	Asset Management and Maintenance.....	59
6.1	Dampier Drainage Network Assets.....	59
6.2	Risk management.....	59
6.3	Asset Capacity and performance.....	61
6.4	Life cycle management.....	62
7.	References.....	66

Table index

Table 1	Cases where overtopping of the primary channel occurred in the 100 yr ARI event.....	8
Table 2	Study area precinct description.....	16
Table 3	Manning's M used for modelling.....	24

Table 4	Impervious allowances used for modelling	24
Table 5	IFD design rainfall depth (mm)	24
Table 6	IFD design rainfall depth (mm)	25
Table 7	Impervious Allowances Used for Modelling	38
Table 8	Culvert upgrades, locations and details	46
Table 9	Overall cost estimate	52
Table 10	Indicative culverts upgrade timeline.....	53
Table 11	Summary of potential land amalgamation locations	54
Table 12	Drainage asset details	59
Table 13	Drainage risk register.....	60
Table 14	Asset upgrade.....	61
Table 15	Asset useful life.....	62
Table 16	Drainage network maintenance reference table	63
Table 17	Karratha drainage network maintenance schedule	64
Table 18	Recommended species for establishment in drainage reserves	65

Figure index

Figure 1	Dampier study area and drainage reserves	3
Figure 2	Comparison of rainfall intensities (GHD, 2010)	5
Figure 3	Typical cross-section of original drainage reserve (north-south).....	7
Figure 4	Typical cross-section of original drainage reserve (east-west).....	8
Figure 5	Typical cross-section of encroachment of drains	10
Figure 6	Overland flow paths	18
Figure 7	Subcatchments	19
Figure 8	Culvert locations	26
Figure 9	Peak flood depth, existing scenario, 5 Year ARI	29
Figure 10	Peak flood depth, existing scenario, 100 Year ARI	30
Figure 11	Peak flood velocity, existing scenario, 5 Year ARI	31
Figure 12	Peak flood velocity, existing scenario, 100 Year ARI	32
Figure 13	Encroachment impact, existing scenario, 5 and 100 Year ARI	36
Figure 14	Preliminary encroachment remediation strategy	37
Figure 15	Peak flood depth, development scenario, 5 year ARI	40
Figure 16	Peak flood depth, development scenario, 100 year ARI	41
Figure 17	Recommended culvert upgrades.....	49
Figure 18	Flood level incorporating recommended upgrades 100 year ARI	50

Figure 19	Cross over Detail	51
Figure 20	Redundant drainage reserves	56

Appendices

Appendix A – Culvert information

Appendix B - Site visit photos (2014)

Appendix C – 2010 encroachment reviews (in Part B)

1. Introduction

1.1 Background

Dampier was built as a closed town in the mid 1960's by Hamersley Iron to accommodate its workforce at the nearby iron ore export facility at Parker Point. It was soon recognised that the Dampier townsite would not accommodate the growing population in the area and in the 1970's the government commenced the development of Karratha. Karratha housed the workforce for the emerging oil and gas industries. Since this time little development has taken place in Dampier.

The Hamersley Range (Iron Ore) Agreement Act was amended in 1982 to enable Dampier, as well as Tom Price and Paraburdoo, to be transformed into a normal townsite. Subsequent normalisation proposals approved by the State Government in the same year contemplated that Hamersley Iron (HI) and the City of Karratha (City) would negotiate the transfer of assets and responsibilities from the company to the City. Since this time, there has been transfer of responsibility for Dampier services and assets to the City (roads, reserves, footpaths and other services).

Dampier today is an established coastal settlement of around 1,100 people with access to a range of local facilities, including a primary school, service station, general store, library, community centre and coastal recreation and boating facilities. There are 518 dwellings in Dampier, 392 of which are zoned R20 and 126 on land zoned R50. Approximately 80% of these dwellings are detached or semi-detached.

The City of Karratha has participated within the Pilbara Cities Vision which proposes that urban areas of Karratha and Dampier accommodate an expanded population of up to 50,000 people by 2026. As such, the City of Karratha has prepared a Local Planning Strategy to set long term directions for the City to meet these growth targets and to improve the lifestyle of existing and future City resident.

However one of the major outstanding issues for growth in Dampier is the stormwater management system and its ability to accommodate existing and future needs based on the predicted population growth.

This project has been commissioned by the City of Karratha to enable the City to better define issues surrounding stormwater management within Dampier. This work expands on previous work undertaken by GHD in 2010, the Dampier Drainage Review (GHD 2010), which identified drainage encroachments and made recommendation for future management, however the report scope lacked the required detail necessary to identify land and infrastructure requirements for future planning decisions.

1.2 Scope of work

The study area is that part of Dampier town site bounded by Lawson Drive, East Avenue, Patterson Crescent and Central Avenue. The study area, including designated drainage reserves, is shown in Figure 1.

The scope of work for this project was to:

- Identify flood risk and review the adequacy of the existing stormwater management system;

- Develop a stormwater management strategy which provides recommendations for improvements to the existing system and which will accommodate any potential need for stormwater upgrades as a result of future redevelopment in Dampier;
- Identify encroachment into drainage reserves that negatively impact stormwater flow and provide a basis for development solution to these encroachments;
- Identify land excess to stormwater drainage requirements which could be amalgamated into adjoining lots or new lots; and
- Develop recommended negotiation point that will form the basis for discussion with those that hold tenure of existing localised stormwater management system, which will lead to necessary action to improve and standardise the local stormwater management system.

Work on the project proceeded in three stages:

1. A site visit and desktop assessment of background data to confirm details of existing drainage reserves and to clarify legislative provisions, policy and other guidance material relating to the stormwater management system;
2. Detailed hydrologic and hydraulic modelling of the existing drainage system and production of flood maps; and
3. Development of the stormwater management strategy.

1.3 Available data

The following data were used in the study:

- LiDAR ground surface data, cadastre, imagery and other GIS data supplied by Rio Tinto Iron Ore and the City of Karratha;
- City of Karratha As-constructed drawings for Dampier townsite; and
- Relevant reports as referenced throughout the document.

1.4 Limitations

This report: has been prepared by GHD for City of Karratha and may only be used and relied on by City of Karratha for the purpose agreed between GHD and the City of Karratha as set out in Section 1.2 of this report. GHD otherwise disclaims responsibility to any person other than City of Karratha arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer Sections 1.2 and 1.3). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by City of Karratha and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.



Legend

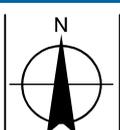
- Cadastre - 20140805
- Drainage Reserves

Paper size : A4

0 40 80 160 240 320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

Job Number	61-31033
Revision	B
Date	05 Aug 2014

Drainage Reserve Map

Figure 1

G:\61131033\GIS\Maps\Working\6131033_G001_RevB.mxd
 © 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate; Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805; GHD: Drainage Reserves - 20101017. Created by: mczekaj

2. Desktop assessment

This section presents the results of a desktop review undertaken for the study area.

An assessment of the possible original constructed drainage network was made based on the site inspection and review of topographic information. Earlier reports (Scott and Furphy 1982 and GHD 2006 and 2010) detailed the status of the existing drainage reserves throughout the townsite and these are referred to within this section of the report.

2.1 Documents reviewed

The following documentation was reviewed:

- Report on Preliminary Inspection of the Stormwater Drainage System at Dampier Western Australia Scott and Furphy Engineers, 1982.
- Dampier Stormwater Drainage Study, GHD, 2006.
- Dampier Drainage Review, GHD, 2010.
- Dampier Drainage Review Encroachments, Blocks 1 through 8, GHD, 2010.
- Dampier Drainage Review, Encroachment Review Update, City of Karratha, 2012.
- Dampier Coastal Vulnerability Study, JDA, 2012.
- Draft Dampier Townsite Redevelopment and Revitalisation Strategy, City of Karratha, 2013
- Dampier Townsite Drainage and Civil Plans, City of Karratha.
- Dampier Townsite LIDAR elevation data set, Rio Tinto, 2014.

2.2 Gap analysis

Preliminary work centred on review of the available data inputs for subsequent modelling and assessment of Dampier's stormwater drainage network identified the following gap:

- Supplied existing culvert information from City of Karratha noted 19 culverts which required on site culvert diameter confirmation, with incomplete as constructed or as designed data available. Refer to Appendix A for locations.
- Supplied LiDAR information is dated 2009 which underwent trothing exercise to confirm encroachment locations where possible. Lot level, building impacts and changes to road pavements since 2009 have not been considered within the context of this model.

2.3 Catchment characteristics

2.3.1 Climate

Dampier features hot summers with periodic heavy rainfall events and mild winters with occasional rainfall. Average annual rainfall for is 280 mm, with the maximum recorded annual rainfall being 855 mm (BoM, 2011). Rainfall is typically received during the summer wet season, with the formation of tropical cyclones and local thunderstorms between the months of December and April. Significant rainfall is associated with these cyclone systems with recent systems producing rainfalls of 140 mm and 190 mm from Cyclone Glenda and Claire respectively.

Average pan evaporation is high at approximately 3,590 mm (JDA, 2012).

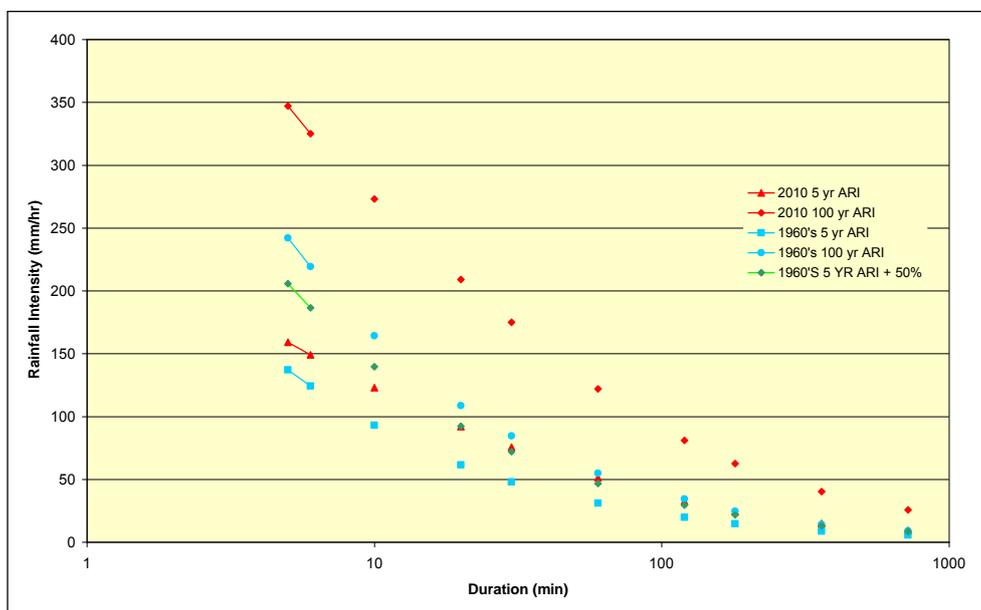
2.3.2 Comparison of 1960's and 2010 Design Rainfall Events

The 1960's design rainfall events (5 and 100 ARI events) obtained from the Bureau of Meteorology (BoM) were compared against the 2010 design rainfall events (5 and 100 ARI events) to assess whether there had been change in the rainfall intensity over the last 50 years (Scott and Furphy, 1988). The 1960's 5 yr ARI + 50% were also assessed according to drainage design standards certified in 1988 (Scott and Furphy 1988). Any variations in rainfall intensity estimations will be reflected in either the under or over design of infrastructure.

The analysis identified that particularly in the larger interval events such as the 100 years, the rainfall intensity had increased by as much as 64 %, with typical increases ranging from 30 – 50 %. The implications of this are that infrastructure constructed back in the 1960 was likely to have been under designed when compared to the same design guidelines today.

The likely cause of this variation is the period of record. Simply, back in 1958, the period of rainfall record was 50 years less than it is today resulting in less accurate estimates of design rainfall intensities when compared to today. The comparison of rainfall intensities for a range of occurrence intervals are provided in Figure 2.

Figure 2 Comparison of rainfall intensities (GHD, 2010)



2.3.3 Topography and soils

The coastal environment of Dampier is of a rocky nature, with rock underlying sand. The rocky plain slopes from the town site to the coast in a northerly aspect. Due to the predominance of rocks in the area, much of the infrastructure is built on imported fill.

Elevation within the study area ranges from sea level up to 65 m AHD in the eastern side of the study area along the railway. A majority of the town site resides at between 10 and 40 m AHD as shown in Figure 7 which presents supplied LiDAR information.

The Dampier Town Site catchments within the study area grade from the east to west from approximately 35 m AHD to 20 m AHD. The average width of the catchment (from east to west) is around 1.0 km.

Review of the supplied Rio Tinto LiDAR information confirmed the data was suitable for detailed flood modelling. Optimisation of the data resulted in elevation grid size of 4 m resulting in accurate modelling of encroachments whilst minimising model run time and chance for model instability.

2.3.4 Vegetation

The Dampier Town Site has components of residential land use. There are a number of open space areas within the catchment including POS in the form of open drainage reserves.

The vegetation within the catchment ranges from areas of established gardens with mature trees to areas of playing fields.

2.4 Existing drainage system

2.4.1 Design Standards

There is an absence of drainage design guidelines and record used for the Dampier townsite when constructed. Based on site observations and review of drainage literature, Dampier's drainage network operates as follows:

- Roads and drainage reserve channels used as the primary conveyance system for stormwater in the 1960's 5 yr ARI event with overspill to the drainage network in events greater than the 1960's 5 yr and up to the 1960's 5 yr + 50% ARI event. This occurs where a channel is defined in the drainage reserve.
- Roads only used as the primary conveyance system for stormwater in the 1960's 5 yr ARI event with overspill to the road reserve in events greater than the 1960's 5 yr and up to the 1960's 5 yr + 50% ARI event. This drainage scenario applies mainly to upper catchments where a channel is not present and all stormwater is directed to the road.

Based on current drainage design standards, it is likely that channels created within kerbed sections of the road were designed to cater for the 1960's 5 yr ARI event and that the combined system of the road channel and the drainage reserve which contains a defined channel, was designed to contain the 1960's 5 yr + 50% ARI flows within the drainage reserve boundary. With the rainfall intensities for corresponding recurrence intervals approximately 30 – 60 % less than they are today, there is a risk that the design of the drainage network does not meet the same design standards today. This is investigated in further detail in the next section of the report.

2.4.2 Original design

As the study area is built on a rocky plain, the infrastructure is built on fill rather than constructing roads and underground services through the rocky terrain. The houses and their servicing roads are located on fill that varies up to about 1 to 2 meters above the natural terrain (Photo 1).

The lots and their servicing roads are set out such that a single row of houses adjoins each street. This is considered an unusual arrangement for a greenfield site as the positioning of sewers and water mains being within lots on a services alignment is not preferred. This water infrastructure layout is more seen at in-fill developments. At the time of construction, though, it would have been considered the most cost effective configuration given the large volumes of fill that have been placed within the townsite.

Drainage reserves are located parallel and adjacent to each road, tending to run in an east-west direction (Photo 2). It is noted that the road design is such that generally the roads slope away from the drainage reserve towards the kerb and channel on lot frontage. A number of drainage reserves have been modified by residents through filling to provide for private rear entrances and gardens.



Photo 1 Typical fill of house pads

This photo also shows the original drainage flow path (GHD, 2014)



Photo 2 Remnant drainage reserve

Adjacent Robe Crescent, western end (GHD, 2014)

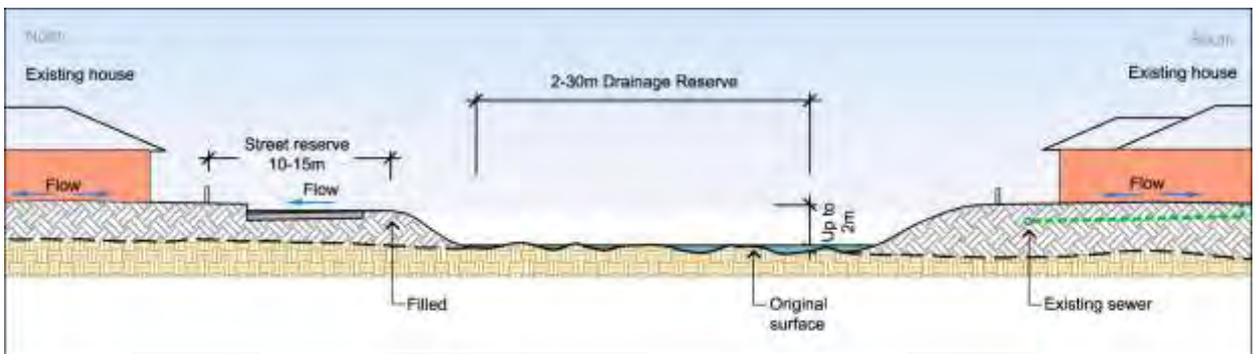
A concept sketch of a typical section across the drainage reserve, in the north-south direction is shown in Figure 3. A typical east-west section is shown in Figure 4.

Early design plans (Central Engineering Services, 1968) show fill extents which correspond approximately with the current house lots and roads. Between these filled areas, it is likely that an unfilled natural surface was retained as a drainage path and this has been referred to as the “drainage reserve”, even though this area is not wholly for drainage but rather “reserve” land. These paths have had little or no “formed” drainage channels throughout much of the study area but have relied on their significant capacity and the natural topography to facilitate drainage. The width of each flow path varies from street to street and along each street but is considered adequate to convey stormwater flow from the catchments, assuming no encroachment.

The 1982 Scott and Furphy report suggested that until the time of the report there had been limited reports of flooding in the townsite as a whole. Roads would have also conveyed stormwater toward the east and the west. The actual design rules followed in the design of the drainage paths is unknown but at the time the 1st Edition of Australian Rainfall and Runoff (1958) was the stormwater design reference available in Australia and it could be assumed that the design would have been based upon the rules similar to this document.

It was also noted in the Scott and Furphy report that in the study area only one culvert was constructed under East Avenue between Stuart and Robe Crescent. Since this time a number of additional culverts have been added to improve drainage out of the site.

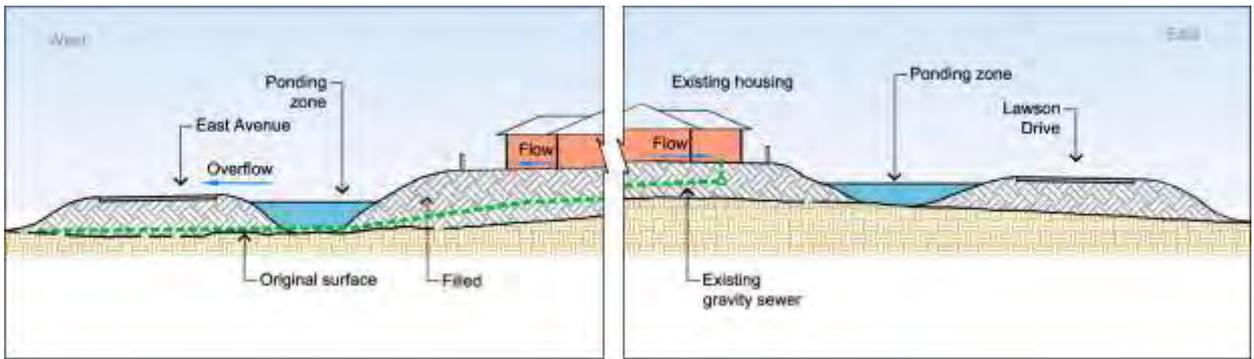
Figure 3 Typical cross-section of original drainage reserve (north-south)



Lawson Drive and East Avenue currently create a barrier which ponds water in the drainage reserve upstream of the roads (Figure 4), especially in locations where there are limited or no culverts or during significant events such as a cyclone. It is not clear that the original roads

would have caused the current level of inundation being experienced (especially along Lawson Drive and East Avenue), the original road levels and design are not known. It is likely, though not certain, that the original road level was lower than it is currently. It would be plausible that the level of the road was such that in major events it overtopped at low points allowing a high flow discharge to occur, reducing the inundation effects. The current roads have been recently resurfaced or constructed and appear to be filled to a significant amount over the surrounds. It was also noted that a number of new culverts had been installed adjacent to the study area as a measure to reduce inundation.

Figure 4 Typical cross-section of original drainage reserve (east-west)



In determining if the original drainage design was sufficient to handle the expected flows from the catchments, a typical residential sub-catchment within Dampier along Yule Crescent was examined. Yule Crescent drains to one of the narrowest drainage channels within the study area and is considered one of the more at risk drainage lines channels within the study area.

Model setup

During the 2010 drainage assessment the hydrologic behaviour of the Dampier Drainage network was assessed support the original design guidelines declared in 1982 and certified in 1988 by Scott and Furphy, where by drainage system including overland flow paths are capable of handling the 1960's 5 yr ARI + 50 %.

DRAINS is a program for designing urban stormwater drainage system and analysing flooding behaviour for piped drainage systems, open drainage systems and detention basins within rural and urban catchments. A unique catchment was created for each street based network based on the construction of the residential blocks. Details of the model setup can be found within Dampier Drainage Review (GHD, 2010). Design rainfall events were then modelled to evaluate if a typical original drainage reserve was of sufficient capacity.

The modelling showed that within most road networks with a drainage reserve of approximately 15 metres width and 1.5 m deep there is significant capacity within the drainage system to contain the 100 year ARI event within the drainage and road reserves. Modelling did identify potential overflow beyond the drainage swale into the road reserve in a number catchments. Along these road networks, the maximum water depth of the swale exceeded its identified top of bank with flow into the road reserve with the maximum depth in the road reserve being 0.14 m in Maitland Crescent. These cases are listed below.

Table 1 Cases where overtopping of the primary channel occurred in the 100 yr ARI event

Channel ID	Road Name	Channel Depth (m)	Water Depth (m)
ChB3_4 *	Pingandy Crescent	1.5	1.52
ChRd_B1_5b	Maitland Crescent	1.5	1.64
ChRd_B2_3	Durack Crescent	1.5	1.51

ChRd_B3_3	Stuart Crescent	1.5	1.52
ChRd_B3_6	Patteson Crescent	1.5	1.62
ChRd_B4_1	Hill Crescent	1.5	1.58
ChRd_B4_11	Hardey Crescent	1.5	1.54
ChRd_B5_4	Flinders Crescent	1.5	1.53
ChRd_B5_6	Namitjira Crescent	1.5	1.55
ChRd_B5_9	Lyndon Crescent	1.5	1.51

* channel only

The road drainage network as reported in Table 1 may not be a suitable size to contain the nominated 100 year ARI design event.

The 2010 DRAINS model was designed to support the original drainage design is capable of containing the design storm event. Given the drainage network was modelled using the 2010 100 yr ARI and demonstrated to function appropriately in this event in most instances, (being a greater rainfall intensity than the 1960 5 yr ARI + 50 % rainfall event) the original drainage design was considered appropriate for the expected flows.

As the DRAINS modelling did not account for tailwater interactions resulting from the consolidated drainage network, the impact of culverts on upstream open swale drain performance nor the potential for overland flow from extremal road catchment to impact the assessed drainage swale. In addition the impact of the drain conditions was not modelled within the DRAINS modelling so expected top water level for the existing drainage network was not defined.

2.4.3 2010 Drain conditions

As part of the work to develop the Dampier Drainage Strategy by GHD in 2010, a site survey of drainage reserves and their condition was undertaken. The survey assessed the level of drainage encroachment that exists within the reserves and recommended a remediation strategy based on the type of impact expected. The outcomes of this site survey are summarised below. Full details can be found within GHD (2010).

It was found that much of the original drainage reserves have been impacted with uncontrolled fill, typically placed by past and present landholders connecting a rear access to their properties. Photo 3 is typical of the problem where the entire drainage reserve has been infilled in Wilkie Crescent.

This encroachment into the drainage reserves, which is common across Dampier townsite, has created issues with ponding and flooding through the study area. Typically the fill in many locations blocks the original flow path or reduces its capacity significantly. The filling or encroachment has taken a number of forms across the townsite including:

- Extending gardens and their boundaries into the drainage reserve (Photo 4);
- Dumping of materials in the reserve;
- Creation of shortcut roads at the end of cul-de-sacs; and
- Filling of defined flow paths with non-engineered materials to create rear access and or hardstand areas.



Photo 3 Uncontrolled infill of drainage reserve

Wilkie Crescent blocking flow path (GHD, 2014)

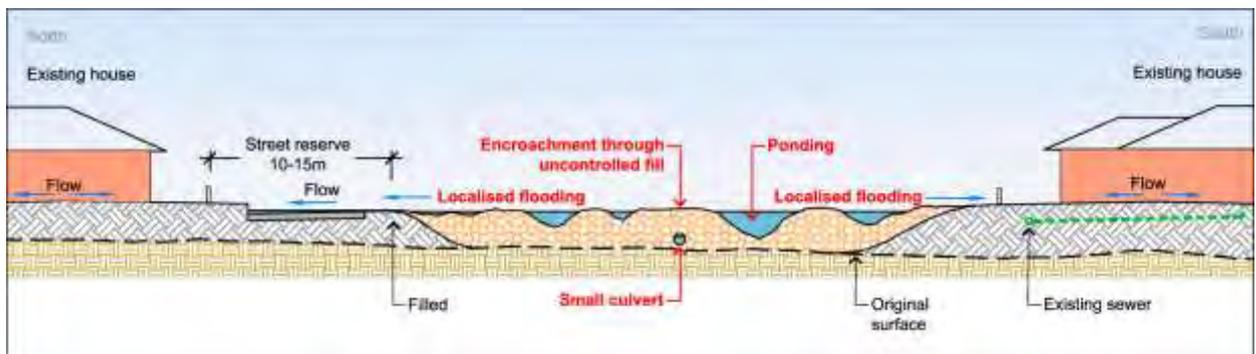


Photo 4 Fencing off of drainage reserve and encroachment

Typical across Dampier (GHD, 2014)

Figure 5 shows a typical detail in a north/south direction of how this encroachment has blocked or reduced the flow paths ability to remove stormwater from the study area. Excessive ponding in low lying and areas where encroachment has partially or completed blocked the drainage path has resulted in flooding shown in the photos taken during the 2006 study (Photo 5).

Figure 5 Typical cross-section of encroachment of drains



The culverts and road design in the lower areas, at the bottom of catchment, has also limited the ability of stormwater to be transferred downstream, and creates short-term ponding. The roads in the lower areas of the study area have been raised above the surrounding ground level. The Scott and Furphy Report (1982) reported the need for additional culverts but none were within the study area. The report did note that a number of locations within the study area were to be used for compensation or ponding. Ponding of water for short periods is a beneficial component of any drainage system but long-term ponding which doesn't drain should be minimised. Longer-term ponding creates conditions suitable for mosquitoes, which can bring disease or cause safety issues for children playing around water, along with issues of decaying material in standing water causing pollution and odour.

Some areas currently do not drain completely due to:

- Encroachment and inappropriate filling downstream;
- Insufficient capacity of downstream drainage structures;
- Poor positioning of drainage structures; and

- Changes in the drainage paths forcing water into locations it was not design to flow into during townsite construction.

As a result of infilling and property encroachment, parts of the drainage reserve no longer convey stormwater in a controlled fashion. Presumably these areas have uncontrolled stormwater flow and possible flooding in even minor rainfall events.

The roads in the study area convey stormwater flow in a controlled fashion to the main drainage paths at the eastern and western ends of the study area. The roads are generally sloped toward a single gutter and the house blocks are elevated relative to the road levels (Photo 6). The road and kerb itself has adequate capacity to convey local stormwater flows, from its current road catchment only, at depths approximately that of the gutter, as shown in Figure 2. Additional flows such as those arising from drainage channels resulting from encroachment may result in flow above capacity of the kerb and water entering adjacent blocks.



Photo 5 Pounded area as a result of encroachment

Pingandy Crescent (RTIO, 2006)

Photo 6 Typical existing road design

Patterson Crescent, kerb on one side of road (GHD, 2014)

2.4.4 2014 Drain conditions

A site survey of drainage reserves and their condition was undertaken on 17 July 2014 by Hayley Martin of GHD and Chris Sayer of the City of Karratha to confirm the encroachments and identify any additional or significantly modified drains which have occurred since the 2010 survey.

The survey confirmed the level of drainage encroachment that exists within the reserves and sought to clarify gaps within the City of Karratha supplied civil as-constructed information for flood modelling. The amendments to the 2010 survey reported with the Dampier Drainage Review Encroachment (GHD, 2010) documents are summarised below.

Photos taken during the site visit and referred to below are located at Appendix C.

Block 1

In general there were very little changes identified within Block 1, besides further growth of vegetation and movement of vehicles since 2010.

The culverts located between Lot 15 Durack Crescent and Lot 17 Minilya Crescent are as per the culvert plan, however the outlet of the 450Ø culvert is blocked and will require clearing. Ref. photos DSC04525-32.

The culvert noted on the culvert plan at Lot 27/28 DeGrey Crescent was unable to be located. It is suspected to have been buried.

A new fence on Lot 33 Ashburton Crescent has been installed (refer to photo DSC04516 in Appendix C). There is a gravel rear access with double gate into the property. It is recommended that the location of this fence (within property boundary) is confirmed by the City of Karratha. The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

The shed at the rear of Lot 35 Ashburton Crescent has been completed since the 2010 study, and has been incorporated within the flood model elevation grid. It is recommended the location of this shed (within property boundary) should be confirmed by the City of Karratha as part of the recommended network upgrade within Section 5.2. The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

It appears there is a new shed on Lot 53 Fitzroy Crescent, the estimated finished floor level has been incorporated within the flood model elevation grid (refer to photo DSC04517 in Appendix C).

The team was unable to locate the culvert on Central Avenue.

The culvert at Dampier Oval on The Esplanade is as per the culvert plan.

Block 2

In general there were not many changes identified within Block 2, besides further growth of vegetation and movement of vehicles.

A sea container at the back of Lot 299 Pinderi Crescent appears to lie within the property boundary, but this should be confirmed by the City of Karratha. The impact on the elevation grid was noted and incorporated into the final surface.

The location of the fence at the back of Lot 301 Pinderi Crescent should be confirmed by the City of Karratha to confirm that it lies within the property boundary. The impact on the elevation grid was noted and incorporated into the final surface.

The location of the shed and sea container at the back of Lot 304 Pinderi Crescent should be confirmed by City of Karratha. The impact on the elevation grid was noted and incorporated into the final surface.

The 2010 Block 2 Encroachments report indicated sheds were present at the back of Lot 298 Portland Crescent, these have since been identified as shipping containers and this has no impact on the elevation grid.

Block 3

In general there were not many changes identified within Block 3, besides further growth of vegetation and movement of vehicles.

The location of the sea container at the back of Lot 332 Elliot Crescent should be confirmed by City of Karratha. The impact on the elevation grid was noted and incorporated into the final surface. The fill material located behind Lot 270 Pingandy Crescent is within the drainage reserve; the impact on the elevation grid was noted and incorporated into the final surface. City of Karratha noted that this material should be removed.

The sea container noted at the back of Lot 271 Pingandy Crescent has since been removed; the elevation grid was amended to remove this obstruction.

Block 4a

Common changes identified within Block 4a include further growth of vegetation and movement of vehicles.

The rubble at the back of Lot 59 Gascoyne Crescent (refer to photo DSC0455 in Appendix C) is within the drainage reserve; the impact on the elevation grid was noted and incorporated into the final surface. The City of Karratha noted that this material should be removed.

A large tree at the back of Lot 68 Hardey Crescent has fallen over and may cause a disruption in the drainage path (photo DSC04570 in Appendix C). City of Karratha noted that this tree should be removed.

The location of the fence and shed on Lot 2,071 Fortesque Crescent should be confirmed by the City of Karratha (photo DSC04555 in Appendix C); the impact on the elevation grid was noted and incorporated into the final surface.

The fill at the back of Lot 1,071 Fortesque Crescent (photo DSC04556 in Appendix C) is within the drainage reserve; the impact on the elevation grid was noted and incorporated into the final surface. City of Karratha noted that this material should be removed.

The fence location of Lot 73 Fortesque Crescent is located within the property boundary the impact on the elevation grid and flow paths were noted and incorporated into the final surface.

Fill material, barrels and concrete mixer have been removed from the back of Lot 74 Fortesque Crescent.

The fill at the back of Lot 1,079 Berkeley Crescent (photo DSC04560 in Appendix C) is located within the property boundary. The impact on the elevation grid and flow paths were noted and incorporated into the final surface. The City of Karratha noted that this material should be removed. The City of Karratha is to check the scope of works stated for Lot 82 Berkley Crescent. The scope should read "Remove fence and relocate to within the property boundary". The elevation model does not include an obstruction at this location noting its removal.

The blue metal pile located behind Lot 95 Wooramel Crescent has since been removed.

Block 4b

Common changes identified within Block 4b include further growth of vegetation and movement of vehicles. From site inspection it appears that the rear access into Lot 184 Lockyer Crescent does not impact the drainage system (photo DSC04571 in Appendix C). The elevation grid is maintained.

The retaining wall and fill at the back of Lot 185 Lockyer Crescent should be checked by the City of Karratha to confirm they are within the property boundary (photo DSC04572 in Appendix C). The impact on the elevation grid and flowpaths were noted and incorporated into the final surface. The cubby house erected at the back of Lot 186 Lockyer Crescent should be checked by City or Karratha to confirm it is within the property boundary (photos DSC0473 and DSC0474 in Appendix C). The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

There is a new fence and rock retaining wall at the back of Lot 195 Forrest Crescent that should be checked by City of Karratha to ensure they are within the property boundary (photo DSC04582 in Appendix C). The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

The fence line at Lot 3,200 Forrest Crescent has shifted since the 2010 study. It appears it is still within the property boundary (photo DSC04580 in Appendix C). The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

The removal of sea container and multiple boats at the back of Lot 202 Gregory Crescent has occurred since 2010 (photo DSC04577 in Appendix C). This has been updated in the elevation model to reflect the removal of these obstructions.

It is recommended the City of Karratha check the fence location of Lot 214 Roe Crescent to ensure it is located within the property boundary. The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

There appears to be a backyard extension at Lot 216 Roe Crescent (photo DSC04579 in Appendix C). It is recommended the City of Karratha check it is located within the property boundary. The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

Block 5a

Common changes identified within Block 5a include further growth of vegetation and movement of vehicles. It is recommended the City of Karratha check the location of the shade structure erected at the back of Lot 99 Oakover Crescent to confirm if it is within the property boundary.

The caravan and blue metal pile located at the back of Lot 101 Oakover Crescent is within the drainage reserves (photo DSC04596 in Appendix C). The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

It is recommended the City of Karratha check the location of the sea container at the back of Lot 111 Lyndon Crescent to ensure it is within the property boundary (photo DSC04597 in Appendix C). The impact on the elevation grid and flow paths were noted and incorporated into the final surface. It is recommended the City of Karratha check the pool fence at the back of Lot 1,116 Lyndon Crescent in relation to the property boundary (photo DSC04598 in Appendix C). The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

It is recommended the City of Karratha check the shed location in relation to the property boundary at the back of Lot 124 Irwin Crescent (photo DSC04601 in Appendix C). The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

It is recommended the City of Karratha check the fence location at the back of Lot 128 Meda Crescent to ensure it is within the property boundary. The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

Block 5b

Common changes identified within Block 5a include further growth of vegetation and movement of vehicles. There is a new shed erected at the back of Lot 158 Burke Crescent. The impact on the elevation grid and flow paths were noted and incorporated into the final surface. It is recommended the City of Karratha check its location in relation to the property boundary. Refer to photo DSC04590 in Appendix C.

It appears that Lot 2,160 Burke Crescent is an empty block (photo DSC04588 in Appendix C).

The fill noted at Lot 173 Warburton Crescent has since been removed (photo DSC04587 in Appendix C). It is recommended the City of Karratha check the location of the sea container at the back of Lot 174 Warburton Crescent in relation to the property boundary (photo DSC04586 in Appendix C).

The impact on the elevation grid and flow paths were noted and incorporated into the final surface.

Block 6

There have been minimal changes in Block 6 since the 2010 study.



Photo 7 Dense vegetation growth

Wilkie Crescent blocking flow path (GHD, 2014)



Photo 8 Removal of sea container

Refer Photo 4. Gregory Crescent Dampier (GHD, 2014)

2.4.5 Missing culvert details and culvert assessment

A number of the culverts identified within City of Karratha supplied as constructed details did not contain diameter, invert or pipe type within the drawing. Investigation to determine these culvert details during the 2010 drainage assessment were unsuccessful with many culverts unable to be located during the site inspection, either due to overgrowth of vegetation or they have been buried. The subsequent site investigation conducted in 2014 sought to determine the culvert conditions, pipe diameter and pipe type of the missing culverts for modelling purposes.

The missing details of culverts have been noted on the attached plan mark-up within Appendix A. During the site investigation the condition of a number of existing culverts were noted and recorded as shown in Photos 9 and 10, further photos are available in Appendix C. In general the culvert condition was poor with significant debris namely leaf litter, sediment and gross pollutants found at the upstream end of the culverts resulting in blockage and reduced culvert capacity.



Photo 9 Blocked Culvert

Hardey Crescent (GHD, 2014)



Photo 10 Blocked culvert

Wooramel Crescent (GHD, 2014)

2.4.6 Dampier drainage catchments and flow paths

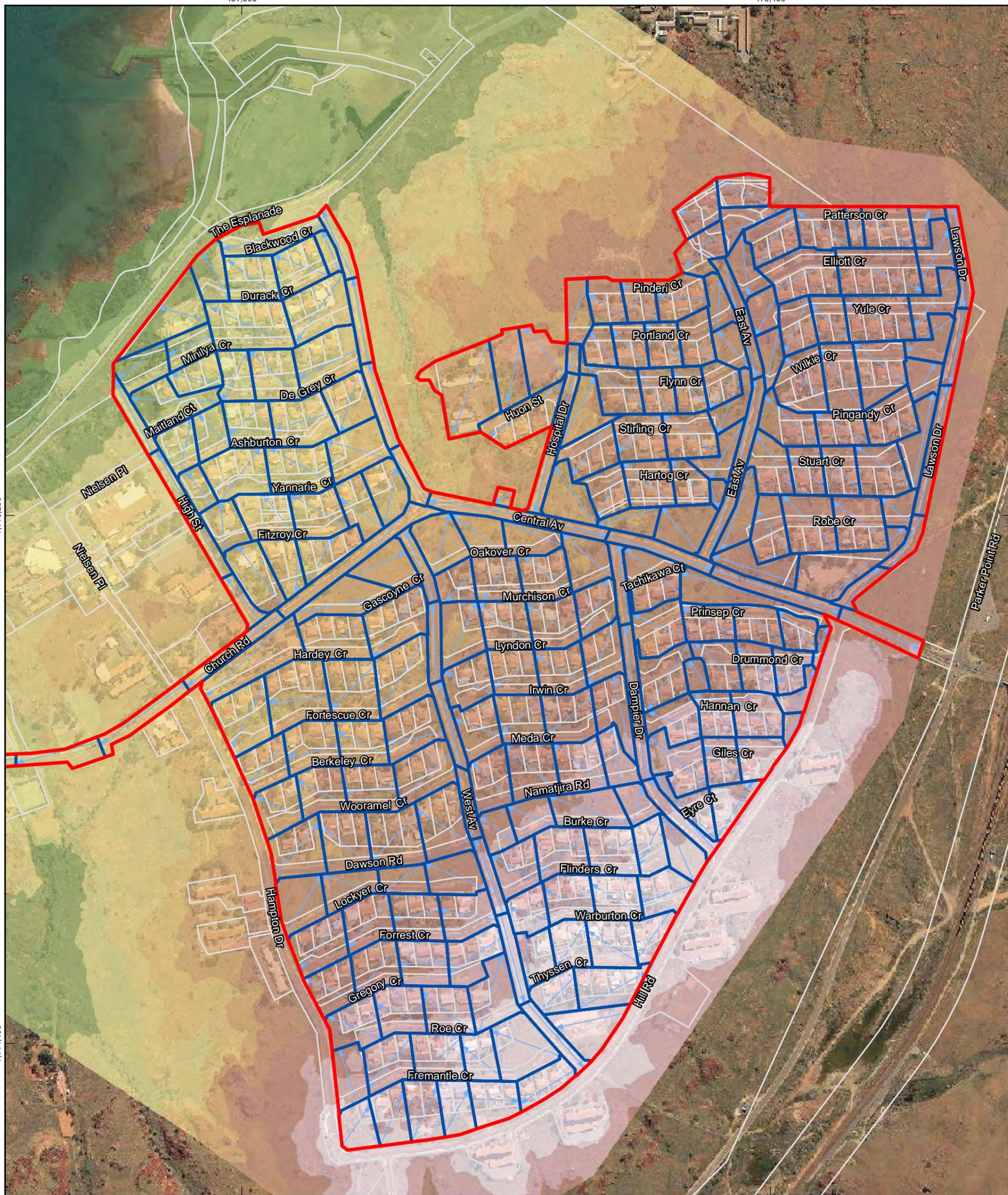
Table 2 presents a summary of each development block arranged by street.

Table 2 Study area precinct description

Road	Area (ha)	Description
Patterson Cr	0.24	Small section of Patterson Cr and associated lots; stormwater intercepted with catchpit and discharged to the north to an existing natural streamline via underground pipe.
Elliot Cr	0.25	Drains toward the E, over Lawson Drive and to a ponded area upstream of Lawson Drive.
Patterson Cr	0.81	Includes part of the duplex area and western section of Patterson Crescent; discharges to the north to an existing natural streamline, partially via underground pipework.
Elliot Cr (East)	0.58	Eastern section of the street; discharges to the ponded area upstream of Lawson Drive and over Lawson Drive in larger events.
Elliot Cr (west)	2.14	Quite a large section of Elliot Crescent, discharging partially via a ponded area across East Avenue and partially into a "sump" or stranded remnant drainage reserve near the centre of the street.
Yule Cr (East)	0.44	Small eastern section of Yule Crescent, draining to ponded area and over Lawson Drive.
Yule Cr (West)	2.21	Westward draining section of Yule Crescent; drains to ponded area and then via culverts and over-road flow over East Avenue; filling in centre but has some grade for drainage.
Wilkie Cr (East)	1.06	Eastward draining section of Wilkie Cr; considerable filling in central part of the original drainage reserve poorly drained.
Wilkie Cr (West)	0.87	Westward draining section of Wilkie Cr; considerable filling in central part.
Pingandy Cr (East)	0.67	Eastern section of Pingandy Crescent; central part of the original drainage reserve filled and poorly drained.
Pingandy Cr (West)	1.53	Western section of Pingandy Crescent; filling as for eastern section.
Stuart Cr (East)	0.95	Small eastern section of Stuart Crescent.
Stuart Cr (West)	1.65	Most of Stuart Crescent, draining to the west and over East Avenue via ponded areas and culverts under Stuart Crescent and East Avenue; filled area poorly drained.
Robe Cr (East)	0.73	Eastern part of Robe Crescent, draining to ponded areas and over Lawson Drive.
Robe Cr (West)	1.68	Western section of Robe Crescent, draining over East Avenue via ponded areas and a culvert.
Central Av (Central)	1.29	Playground area; drainage either west or east.
Central Av (East)	1.44	Reserve east of the playground; drains to ponded area then over East Avenue.

Figure 6 details the existing drainage system as developed based on supplied LiDAR elevation information received from Rio Tinto. The Horton stream order clarifies the region's expected overland flow and the subsequent consolidation of lower order flow into higher order major flow lines.

Figure 7 details delineated sub catchments. Current catchments are likely to have been similar to the existing condition but the drainage pathways are now incomplete due to the encroachment from fill at the rear of lots. Note that catchment boundaries and drainage flow paths are indicative only and will need to be confirmed as part of more detailed studies.

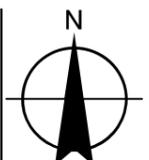


LEGEND

Study Area	Elevation (mAHD)	10.1 - 15	30.1 - 35
Subcatchment	-1 - 0	15.1 - 20	35.1 - 40
Cadastre	0.1 - 5	20.1 - 25	40.1 - 45
Catchment Direction	5.1 - 10	25.1 - 30	

Paper size : A4

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

Job Number | 61-31033
Revision | 0
Date | 06 Mar 2015

Subcatchments

Figure 7

\\ghdnet.internal\ghd\AU\Perth\Projects\61\31033\GIS\Maps\Working\6131033_G003_Rev0_Fig7.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2015 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805; GHD: Sub-Catchment - 20140711, Elevation (mAHD) - 20140625. Created by: mczekaj

2.5 Legislative considerations

All easement and drainage reserves under the control of local government are prepared under Section 195 of the Land Administration Act 1997. This gives local government powers under Section 167 of the Planning and Development Act 2005 and Local Government has the right to maintain function of the asset located within the easement/reserves, restrict what can be built within the easement/reserves, remove obstructions and identify liability, cost and obligations of successive registered proprietors.

As approved by the State Government, the transfer of assets and responsibilities from Hamersley Iron (HI) to the City of Karratha (City) results in drainage easement and reserves falling within Section 195 of the Land Administration Act 1997 the City of Karratha has rights under Section 167 of the Planning and Development Act 2005 to maintain function of the asset located within the easement/reserves.

Drainage design in all areas of the State of Western Australia is engineered to the same design guidelines as outlined in *Local Government Guidelines for Subdivisional Development Edition 2 – 2009*.

The following policies and guidelines are noted as requirements to be met for the provision for drainage infrastructure and flood protection works within urban built up areas.

2.5.1 Policies

The following policies contain requirements for City of Karratha which detail the provision of stormwater management to urban built up areas:

- State Water Plan, Department of the Premier and Cabinet, Perth, Western Australia, 2007;
- State Water Strategy, Department of Premier and Cabinet, Perth, Western Australia, 2003;
- State Planning Policy 1 State Planning Framework Policy, Western Australian Planning Commission, Perth, Western Australia, 2006;
- State Planning Policy 2 Environment and Natural resources, Western Australian Planning Commission, Perth, Western Australia, 2003;
- State Planning Policy 2.6 State coastal planning policy 2006, Western Australian Planning Commission, Perth, Western Australia,
- State Planning Policy 2.9 Water Resource 2006, Western Australian Planning Commission, Perth, Western Australia;
- State Planning Policy 3.4 Natural Hazard and Disasters 2006, Western Australian Planning Commission, Perth, Western Australia; and
- State Planning Policy 92 Urban stormwater Management 2008 Western Australian Planning Commission, Perth, Western Australia.

A description of the key policy statement related to flood management within Dampier is provided below.

Statement of planning policy no. 3.4: Natural hazards and disasters

The state government sets out its intention to plan for natural hazards in Statement of planning policy no. 3.4: Natural hazards and disasters (WAPC, 6006) (SPP 3.4). The specific requirements of this policy are to plan for hazards such as flood and severe storms.

In regards to flood hazards, the policy provides key statement that may affect development of the site, which can be summarised as follows:

- The 100 year ARI flood event should be used as the defined flood event.
- The floodplain if a defined flood event should be used as the areas over which controls on land use and development need to recognise impacts of flooding.
- A floodway in generally defined as the past of the floodplain where floodwaters are flowing fast and deep.
- Development on a floodplain is considered acceptable with regard to major flooding as long as it does not produce an adverse impact on surrounding development and has adequate level of flood protection.
- Development proposed within a floodway that is obstructive to major flooding is not acceptable as upstream level may increase.
- All habitable, commercial and industrial buildings should have their levels above the level of defined flood event.
- The Department of Water is the state government lead agency in floodplain mapping and floodplain management.

2.5.2 Guidelines

The following industry standards are referenced for stormwater system design:

- Better Urban Water Management 2008, Western Australian Planning Commission, Perth, Western Australia;
- Stormwater Management Manual for Western Australia, Department of Water, 2004-2007;
- Decision Process for Stormwater Management in WA, Department of Water;
- Australian rainfall and Runoff, 3rd Edition, Institution of Engineer, Canberra, Australian Capital Territory, 2001;
- Austrian Runoff Quality: A guide to water sensitive urban design, Institution of Engineers Australia, Melbourne, Victoria, 2006;
- Liveable Neighbourhoods: A Western Australian sustainable cities initiative, 4th edition, 2007 Western Australian Planning Commission, Perth, Western Australia; and
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council, Canberra, 2000.

2.5.3 Flood protection (managing storm events)

In accordance with the above policies and guidelines the drainage strategy for existing and new development (including infill development) must show the following requirements for flood protection:

- Minimum habitable floor levels of 0.5 metre above the adjacent 100 year ARI flood level is required where standing water is expected such as stormwater basins or trapped low points;
- In other parts of the catchment development can have a minimum habitable floor level 0.3 metre above the 100 year ARI event level, calculated for the local drainage system based on flowing stormwater which includes road reserves, drainage channels or swales.

- Climate change and its impacts on storm surge is advised to be considered in the determination of appropriate flood level;
- Proposed amendment including development does not detrimentally impact on the existing 100 year ARI flooding regime of the general area; and
- Accommodate flood events in drainage reserves, road reserves and public parkland.

2.5.4 Regional drainage principles

Due to the large volumes of water generated in cyclonic events, the priority for stormwater management in the North West region of WA has been the rapid removal of stormwater away from infrastructure to avoid flood related damages. Some town centres have addressed this issue well by constructing a drainage network designed for stormwater conveyance and less so detention. Others, such as Onslow, are constrained by site specific issues such as lack of relief and town layout and have been forced to construct a drainage network with limited function.

In the north of Western Australia, given favourable environmental conditions, the ideal drainage network is represented by utilising kerbed roads as the initial conveyor of stormwater, with kerb breaks located at topographic low points discharging stormwater to large open channels that discharge stormwater away from the urban zone. To date, there is evidence that treatment of stormwater in the North West region has not been practical or required for the protection of downstream ecosystems, due mainly to the intensity of major event rainfall and the use of overland flow as the principle conveyance method. Water Sensitive Urban Design (WSUD) measures for water quality improvement in this part of the State, relate to retaining or slowing frequent events in vegetated overland flow paths.

Drainage design guidelines provide sizing recommendations for drainage measures. These are provided in *Local Government Guidelines for Subdivisional Development Edition 2 – 2009*. Here, guidelines are provided for both urban and rural settings.

In accordance with the above policies and guidelines the drainage strategy for existing and new development (including infill development) most applicable to the Dampier townsite and are summarised below:

- The drainage system should be designed for the 100 yr ARI event using overland flow
- The top water level for the design shall be greater than 300 mm below the level of the road shoulder;
- Maximum flow velocities in open channels shall not exceed 2 m/s in lined open channels (can be arrested by the inclusion of drop structures);
- Mortared stone pitching shall be provided in open drains at all junctions and bends greater than 22.5°;
- Detention storage areas may be provided at suitable locations (can be on line) to reduce peak flow rates to the capacity of downstream facilities;
- Runoff from constructed impervious areas should be retained where possible within the lot or road reserve for the 1 yr ARI event; and
- Provision shall be made using storage facilities for peak 1 in 100 year storm event such that the floor level of all buildings shall be a minimum of 500 mm above the 100 year storm event given standing water; and
- Provision shall be made within flow paths for peak 1 in 100 year storm events such as within swales, over flow and road reserves that the floor level of all buildings shall be a minimum of 300 mm above the 100 year storm event or road reserve.

3. Existing Scenario Flood modelling

Hydrological and hydraulic assessment of the drainage network as defined using available high accuracy elevation (LiDAR) grid and supplied As-constructed survey information was undertaken to determine locations within the Dampier townsite where inadequacies exist within the current network and report expected top water levels during the 5 year and 100 year storm event.

3.1 Model setup

Mike URBAN is a two dimension flood drainage model which consists of two modules; a hydrologic module, and a hydraulic model. The hydrologic module characterises the generation of stormwater through the storage and transfer of rainfall and runoff to the collection system within the defined catchment area. The catchment area is a geographical feature which presents the hydrological urban catchments. The hydraulic module then simulates the routing of flows, over time, through the stormwater network conveyance system including the swale (defined through a two dimension surface grid), pipes and storage components.

The following sections summarise the key inputs parameters and assumptions made a part of the model build.

3.1.1 Soil type

The soils in the catchment are generally sands with high infiltration capacity. The soil type affects the volume of rainfall that will either infiltrate the soil profile or become runoff during a design storm event.

For the purposes of modelling surface infiltration rainfall losses, soils within the Mike URBAN Software Hydrological 'Model B: Kinematic Wave' runoff model are categorised as "Large Pervious", "Medium Pervious" or "Small Pervious". "Large Pervious" soils have greatest surface infiltration capacity whilst "Small Pervious" has the smallest. Note that these categories do not necessarily correspond to soakage capacity for stormwater soak-pits type devices, which utilise soil permeability at depth, rather than the surface.

For modelling purposes, soils within the study area are generally considered to be "Medium Pervious".

3.1.2 Land use

Land use classifications for the Dampier Town Site catchment were generated based on cadastre plans and building footprints, provided by the City.

Land use was classified as one of the three primary land use zones within the catchment:

- Bare, lawns, and parks;
- Buildings; and
- Roads and paved areas.

Table 3 summarises the Manning's 'M' values assigned to each land use zone, which were adopted for modelling purposes. The Manning's 'M' value is a roughness coefficient, and is the inverse of the commonly used Manning's 'n' ($M = 1/n$).

Table 3 Manning's M used for modelling

Land use type	Manning's 'M'
Bare, Lawn, parks	29
Buildings	50
Road, paved areas	70

3.1.3 Dampier town site asset data

Existing City of Karratha drainage assets (culverts) were provided for the purposes of drainage assessments. The total number of asset items (culverts) included in the supplied as built drawings is 81, as shown in Figure 8.

Detailed culvert information is available within Appendix A.

3.1.4 Overland flowpaths

The Catchment SIM software package was used to generate flowpaths within the catchment using the digital elevation model (DEM) provided from Rio Tinto Iron Ore. These flow paths are presented in Figure 6.

3.1.5 Imperviousness allowances

The land use within a catchment affects the quantity and quality of stormwater runoff. The study area is divided into 258 sub catchments (Figure 7) to estimate runoff generated throughout the study area.

Table 4 summarises the average pervious and impervious percentage determined for each land use types present within the sub catchments of Dampier Town Site area.

Table 4 Impervious allowances used for modelling

Type	Pervious percentage	Impervious percentage
Road	10	90
Residential Lots with road	60	40
Parks	90	10

3.1.6 Rainfall – Intensity-Frequency-Duration (IFD)

The intensity frequency duration (IFD) rainfall data used to generate rainfall hydrographs for the design storm events was sourced from the Bureau of Meteorology IFD program, in accordance with AR&R (1987), at the catchment. Table 5 summarises the IFD design rainfall depth for rainfall durations (5 minutes to 72 hours) for various return periods (5 and 100 years) adopted for modelling purposes.

Table 5 IFD design rainfall depth (mm)

DURATION	Return Period						
	1 Year	2 years	5 years	10 years	20 years	50 years	100 years
5Mins	6.6	8.9	13.3	16.2	19.8	24.8	28.9
6Mins	7.3	10.0	14.9	18.1	22.2	27.9	32.5
10Mins	10.0	13.6	20.5	25.0	30.8	39.0	45.5
20Mins	14.7	20.1	30.6	37.7	46.7	59.7	69.7
30Mins	17.9	24.6	37.8	46.8	58.0	74.0	87.5
1Hr	23.6	32.6	51.1	63.9	80.0	103.0	122.0

2Hrs	29.0	40.4	64.8	82.2	104.0	135.6	161.8
3Hrs	31.8	44.7	73.2	93.6	119.1	156.6	187.8
6Hrs	37.3	52.9	88.8	115.2	148.8	198.6	240.6
12Hrs	44.5	63.6	109.2	144.0	187.2	252.0	307.2
24Hrs	55.7	79.4	137.5	181.2	237.1	321.6	391.2
48Hrs	69.6	99.8	171.8	225.6	294.7	397.9	484.8
72Hrs	76.3	108.7	187.2	246.2	321.8	434.9	532.1

3.1.7 Model Calibration

There are no historic flood records which document flooding within the Dampier Town Site catchment. Therefore, it was not possible to perform a detailed model calibration.

Model runoff parameters are developed based on the selection of modelling parameters consistent with conditions found within Dampier as described in the sections above noting the soil types, roughness coefficients and rainfall intensity within Dampier.

An appropriate sensitivity analysis to match anecdotal evidence reported within the Dampier Drainage Assessment (GHD, 2010) noting the expected flood depths reported during actual storm events which assisted in the review of the modelled flood depth reported during similar design storm ARI as reported below.

Table 6 IFD design rainfall depth (mm)

Location	Anecdotal water depth (ARI)	Modelled water depth (ARI)
Pingandy Crescent	0.30 m (5 year)	0.34 m AHD (5 year)

3.2 Results

3.2.1 Flood Mapping

Flood mapping has been undertaken in order to identify the existing spatial extent and depths of flooding at key locations within the catchment to identify inadequacies in the existing system. Flood mapping is provided for the critical storm duration of 1 hour for both the 5 and 100 year ARI storm events.

The 5 year and 100 year ARI results for the existing scenario are shown in Figure 9 and Figure 10 respectively. Flow velocity for the existing scenario for both the 5 and 100 year ARI events is shown in Figure 11 and Figure 12.

The flood model indicates that in a 5 year ARI event, flooding and ponding is mostly contained within the drainage and road reserve, however there are certain instances where housing lots are anticipated to experience flood, particularly in blocks 1, 4a and 5a, as shown in Figure 9.

During the 100 year ARI the flooding extent significantly expands to include large portions of the road reserve and multiple housing lots as shown in Figure 10.

3.2.2 Flood impact

Flood impact or hazard areas, which are zones within a catchment whereby stormwater has the potential to be hazardous to property or people have been shown within Figure 9 and Figure 10 for the 5 and 100 year ARI storm respectively. Generally the flood hazard areas are comprised of overland flow or ponding areas. Overland flow is represented by shallow water depth along surface drainage paths.

The Overland flow will generally occur as a result of limited capacity within the culverts or drainage swale, forcing stormwater to overtop the swales. Where there is an operational and safe overland flowpath, the capacity of the drainage network can be balanced with overland flowpath capacity such that the overall conveyance capacity meets Level of Service requirements such as overland flow within the road reserve. If an operational and safe overland flow path is not available then the water is considered uncontrolled and overland through property or outside publicly held land holding is considered uncontrolled.

The flood modelling conducted has identified numerous specific locations within the study area where uncontrolled overland flow is occurring, a result of encroachments having a negative impact on the drainage reserve. Critical areas have been identified where multiple consecutive encroachments are located along the natural direction of flow, particularly at the downstream end of catchments. This results in flood water ponding upstream of the encroachments and being forced over the road reserve or across lots, creating a potential flood risk to the property owners.

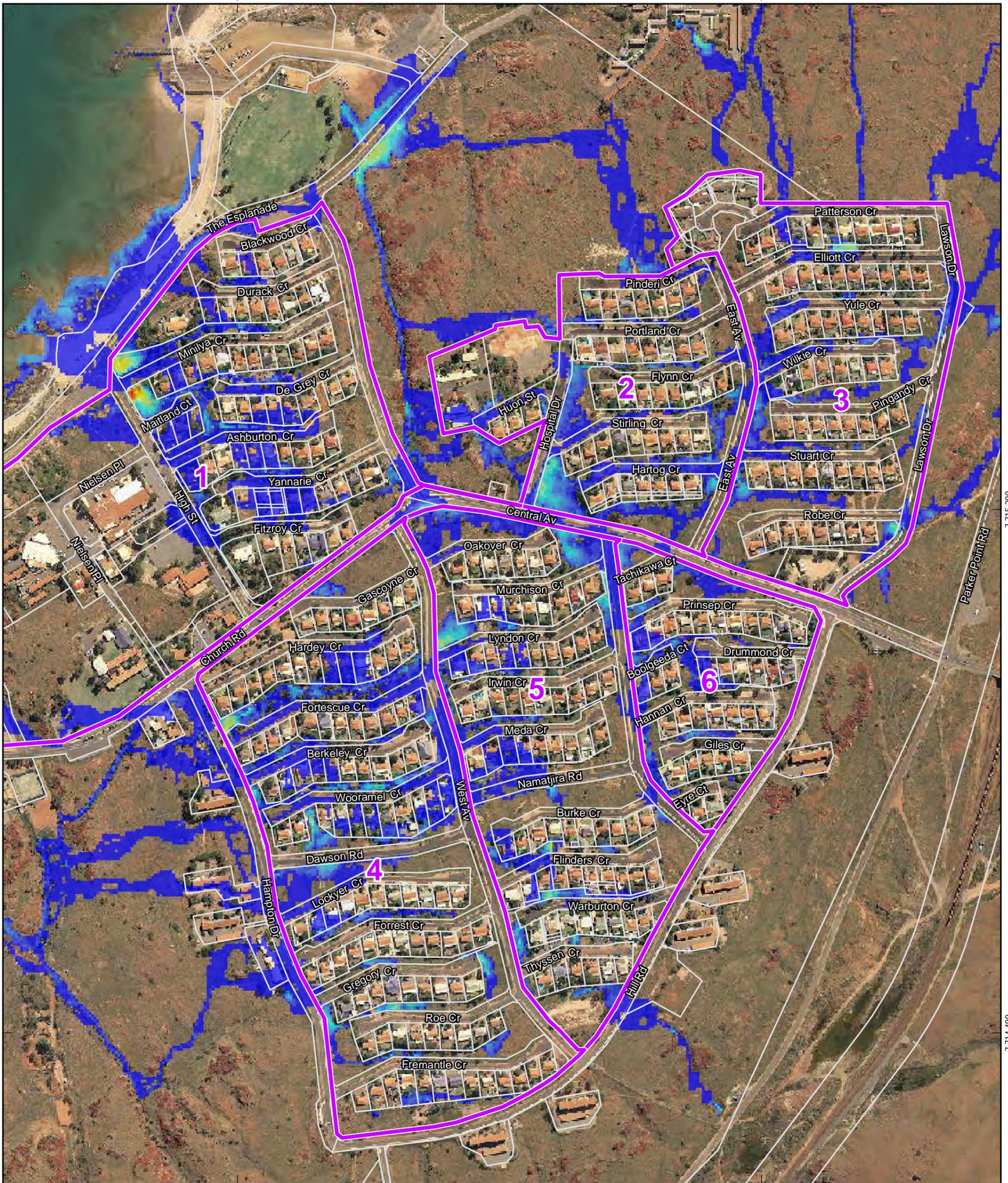
Section 3.3 details the impact of the encroachments on a block basis and provides recommendations on the removal mechanism for identified encroachment as either a planning based or maintenance based strategy to remediate the drainage reserve.

Not all the indicated flood areas are the result of encroachment and uncontrolled filling of the drains. Other reasons causing ineffective drainage can include:

- Insufficient capacity of drainage structures;
- Poor positioning of drainage structures; and
- Changes in the designed drainage paths due to vegetation, sedimentation or construction.

An indicated earlier within Section 3.1.6 the impact of rainfall has been considered. The original design undertaken during the 1960 was based on rainfall intensity different to the design requirements listed today. Analysis identified that particularly in the larger interval events such as the 100 years, the rainfall intensity had increased by as much as 64 %, with typical increases ranging from 30 – 50 %. The implications of this are that infrastructure constructed back in the 1960 was likely to have been under designed when compared to the same design guidelines today.

Combined with the impact of encroachments and the general loss of capacity within the swales as listed above (typically managed through maintenance) the existing results indicate that the current drainage system as it stands requires alteration and maintenance to ensure flooding and ponding of stormwater is reduced to acceptable levels and confined to appropriate locations within the drainage system. Options for drainage management and upgrade are discussed in Section 5.

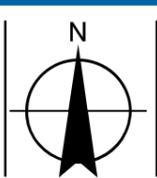


LEGEND

Cadastre	Flood Depth (m)	0.75 - 1	1.75 - 2
Block Boundary	0.002 - 0.25	1 - 1.25	2 - 2.25
	0.25 - 0.5	1.25 - 1.5	2.25 - 2.5
	0.5 - 0.75	1.5 - 1.75	

Paper size : A4

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



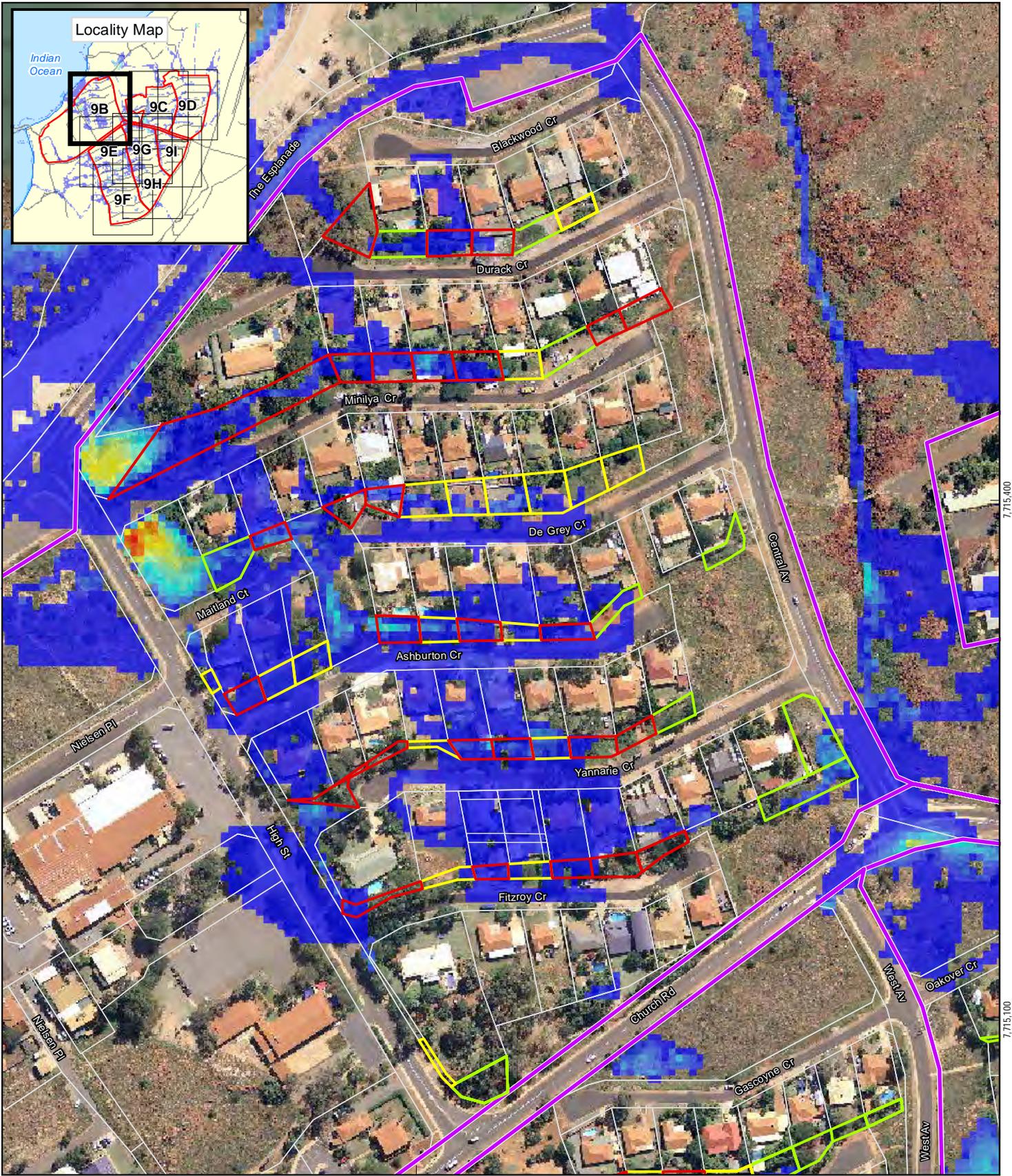
City of Karratha
Dampier Stormwater Management Study

Peak flood depth, existing
scenario, 5 year ARI

Job Number	61-31033
Revision	0
Date	06 Mar 2015

Figure 9A

\\ghdnet.internal\ghd\AU\Perth\Projects\61\31033\GIS\Maps\Working\6131033_G004_Rev0_Fig9A.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2015 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805; GHD: 5 year ARI - 20140729, Block Boundary - 20140805. Created by: mczekaj



7,715,400

7,715,400

7,715,100

7,715,100

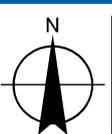
LEGEND

- Cadastre
 - Encroachment - High
 - Encroachment - Medium
 - Encroachment - Low
 - Block Boundary
- | | | | |
|------------------------|--------------|------------|------------|
| Flood Depth (m) | 0.002 - 0.25 | 0.75 - 1 | 1.75 - 2 |
| | 0.25 - 0.5 | 1 - 1.25 | 2 - 2.25 |
| | 0.5 - 0.75 | 1.25 - 1.5 | 2.25 - 2.5 |
| | | 1.5 - 1.75 | |

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



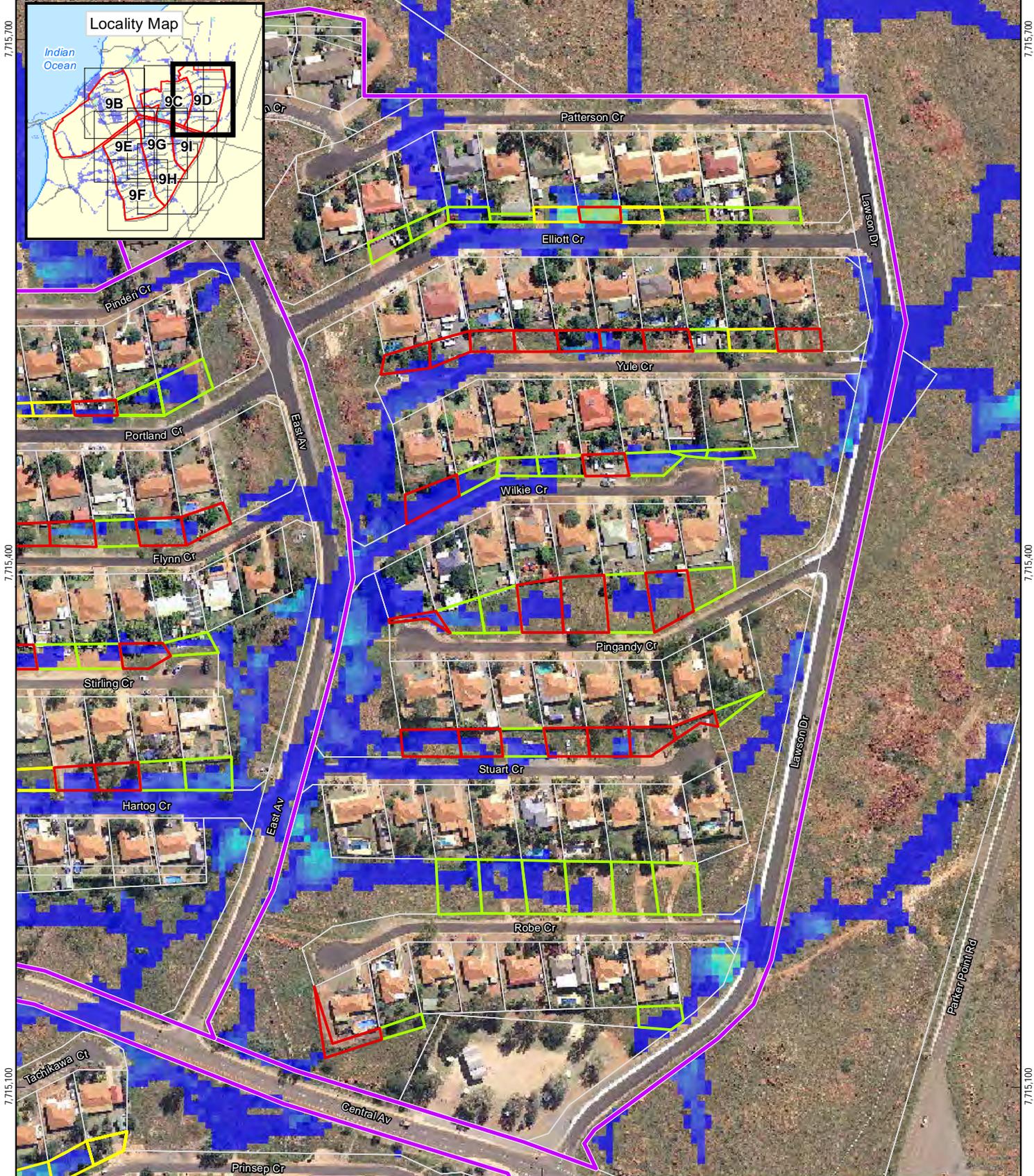
City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing
scenario, 5 year ARI - Block 1

Figure 9B

G:\61\31033\GIS\Maps\Working\6131033_G005_Rev0_Fig9B.mxd
239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD, City of Karratha and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczeckaj



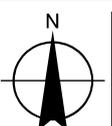
LEGEND

- Cadastre
- Block Boundary
- Encroachment - High
- Encroachment - Medium
- Encroachment - Low
- Flood Depth (m)**
- 0.002 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 2.25
- 2.25 - 2.5

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

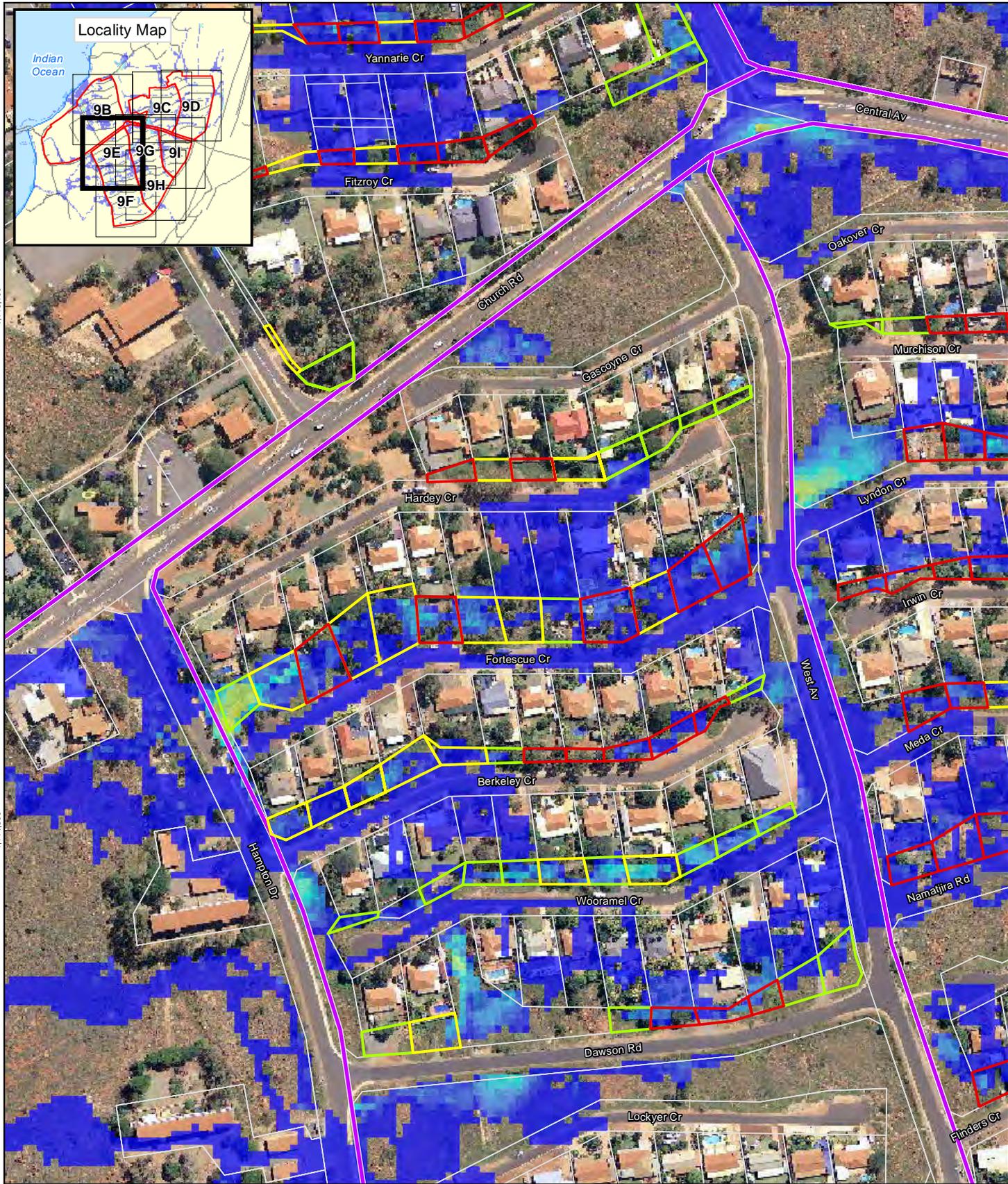


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing
scenario, 5 year ARI - Block 3

Figure 9D



7,715,100

7,715,100

7,714,800

7,714,800

LEGEND

- Cadastre
 - Encroachment - High
 - Encroachment - Medium
 - Encroachment - Low
 - Block Boundary
- | | | |
|------------------------|---|--|
| Flood Depth (m) | 0.75 - 1 | 1.75 - 2 |
| | 0.002 - 0.25 | 2 - 2.25 |
| | 0.25 - 0.5 | 1.25 - 1.5 |
| | 0.5 - 0.75 | 1.5 - 1.75 |

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

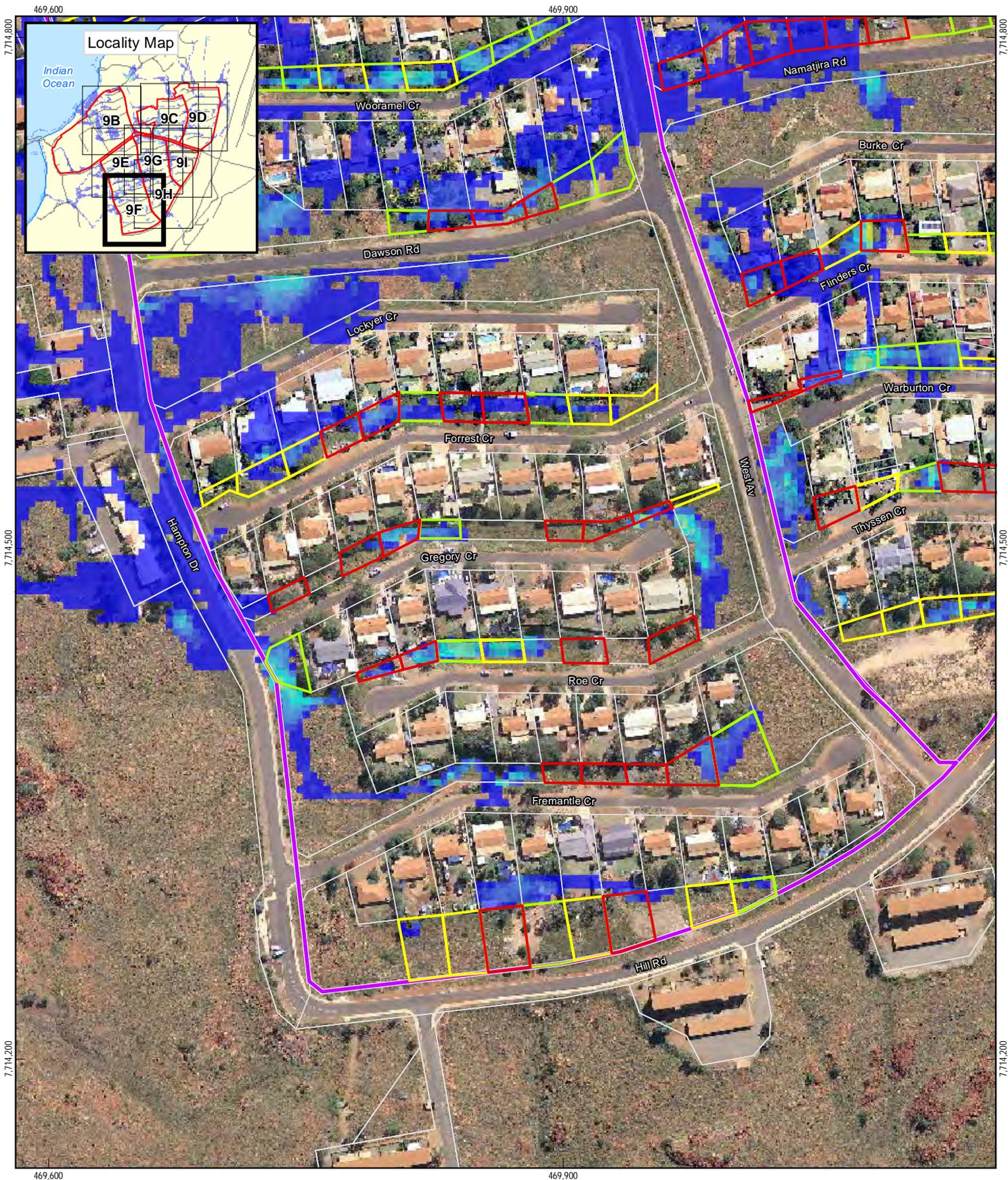


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 5 year ARI - Block 4a **Figure 9E**

G:\61131033\GIS\Maps\Working\6131033_G005_Rev0_Fig9B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD, City of Karratha and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



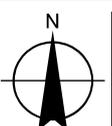
LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.75 - 1	1.75 - 2
Block Boundary	Encroachment - Medium	0.002 - 0.25	1 - 1.25	2 - 2.25
	Encroachment - Low	0.25 - 0.5	1.25 - 1.5	2.25 - 2.5
		0.5 - 0.75	1.5 - 1.75	

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

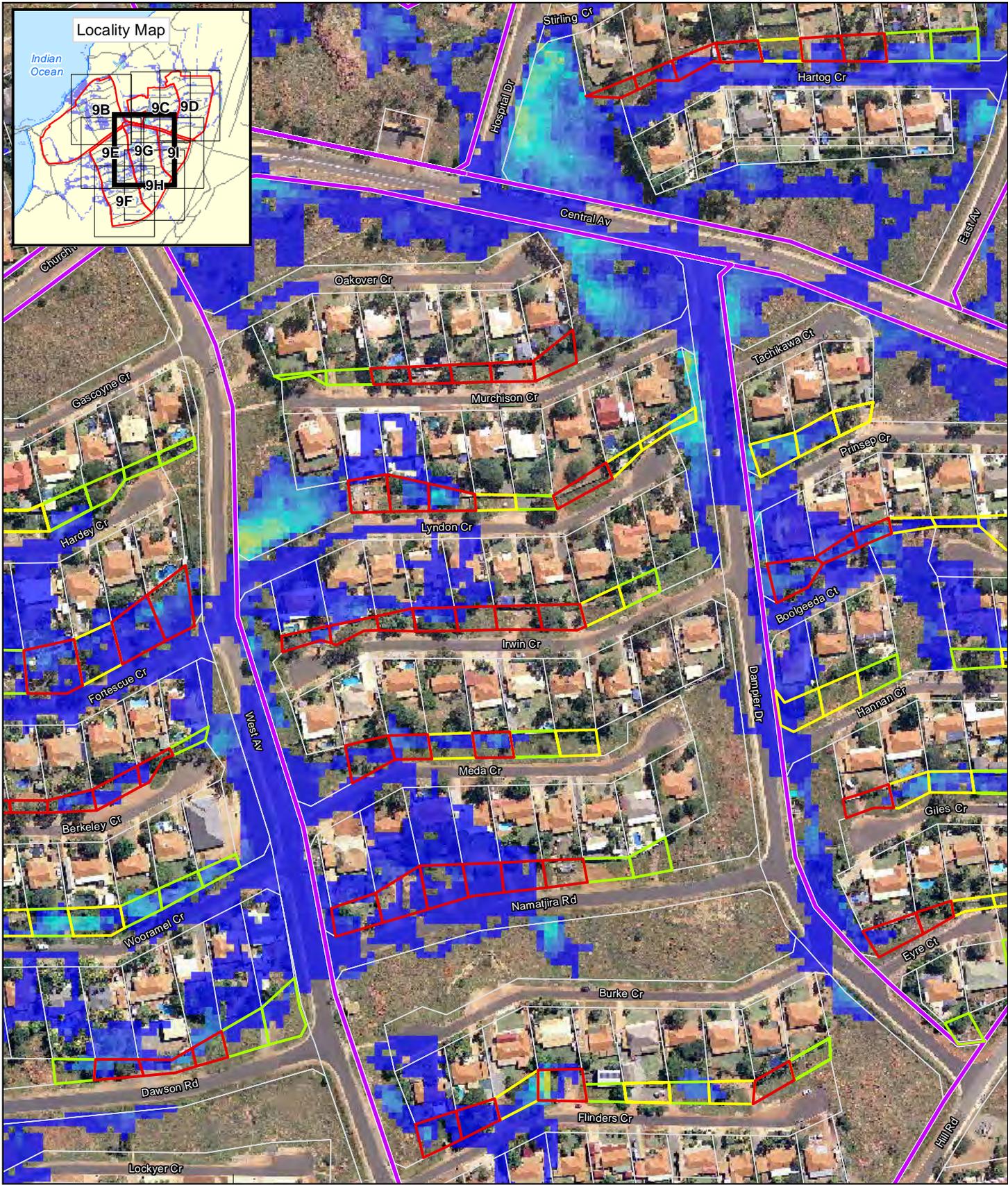


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing
scenario, 5 year ARI - Block 4b

Figure 9F



7,715,100

7,715,100

7,714,800

7,714,800

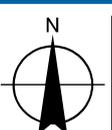
LEGEND

- Cadastre
 - Encroachment - High
 - Encroachment - Medium
 - Encroachment - Low
 - Block Boundary
- | Flood Depth (m) | |
|-----------------|--------------|
| | 0.002 - 0.25 |
| | 0.25 - 0.5 |
| | 0.5 - 0.75 |
| | 0.75 - 1 |
| | 1 - 1.25 |
| | 1.25 - 1.5 |
| | 1.5 - 1.75 |
| | 1.75 - 2 |
| | 2 - 2.25 |
| | 2.25 - 2.5 |

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

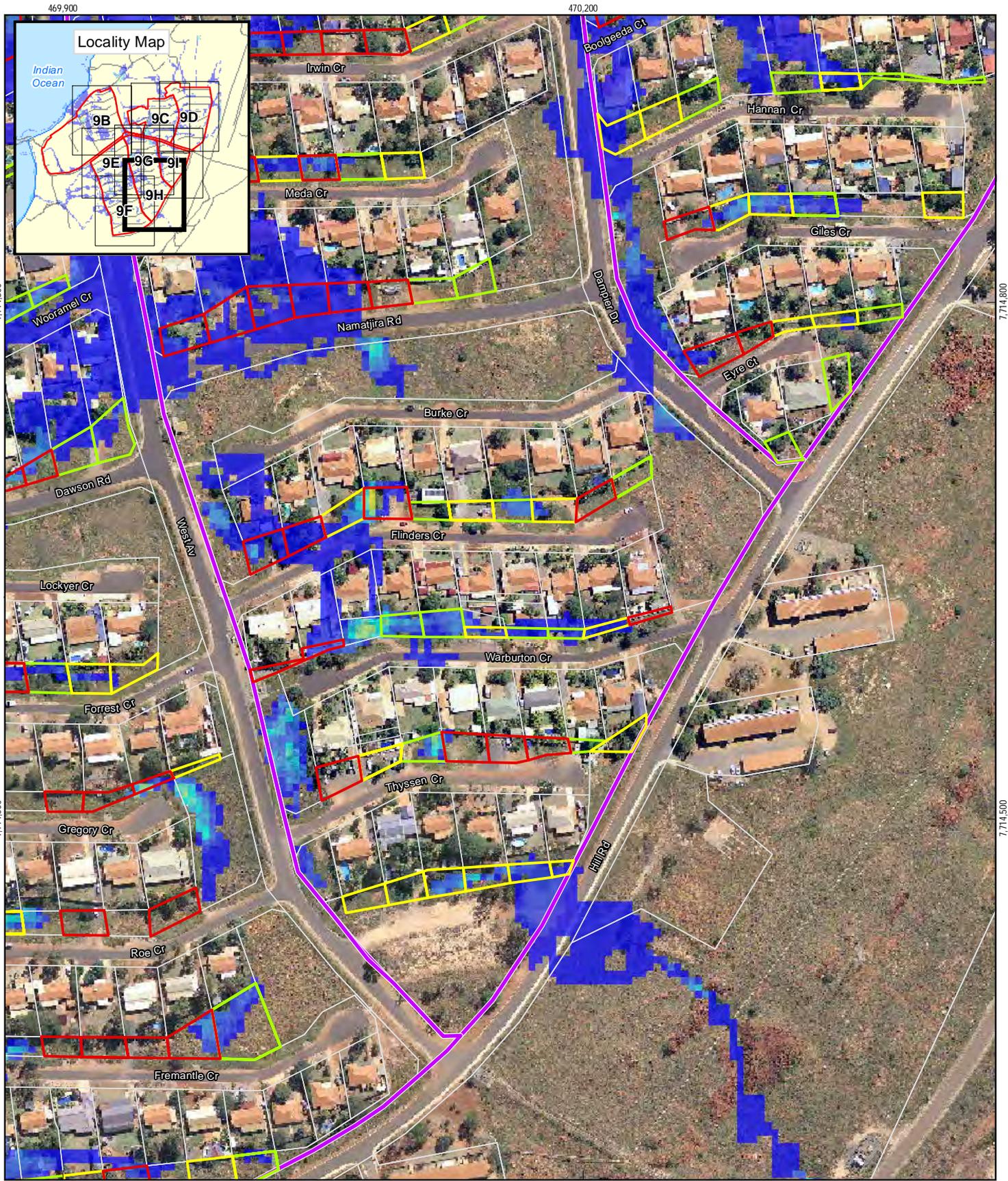


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 5 year ARI - Block 5a Figure 9G

G:\61131033\GIS\Maps\Working\6131033_G005_Rev0_Fig9B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD, City of Karratha and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



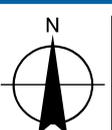
LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.75 - 1	1.75 - 2
Block Boundary	Encroachment - Medium	0.002 - 0.25	1 - 1.25	2 - 2.25
	Encroachment - Low	0.25 - 0.5	1.25 - 1.5	2.25 - 2.5
		0.5 - 0.75	1.5 - 1.75	

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

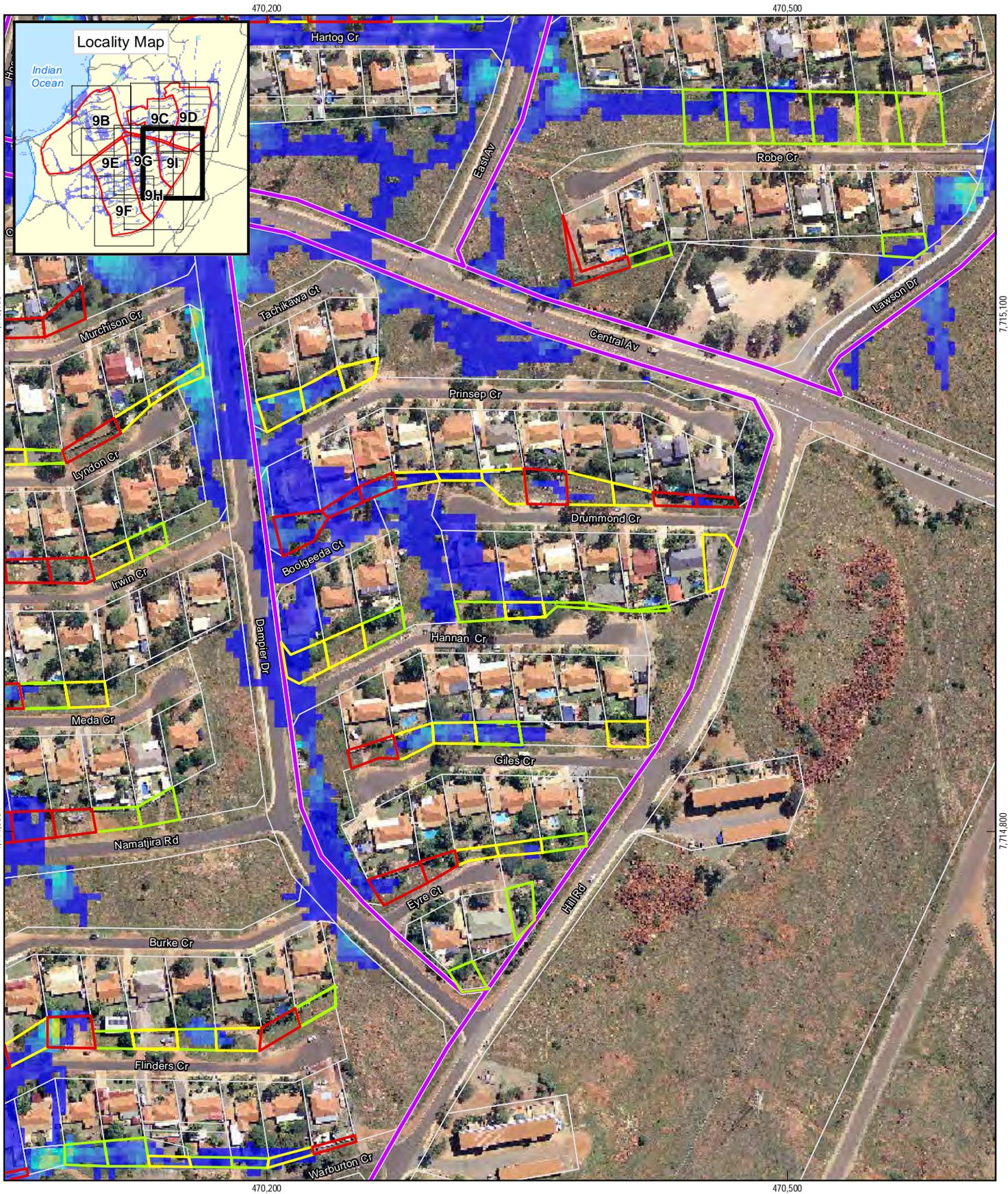


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

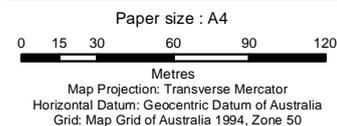
Peak flood depth, existing scenario, 5 year ARI - Block 5b **Figure 9H**

G:\61\31033\GIS\Maps\Working\6131033_G005_Rev0_Fig9B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014. Whilst every care has been taken to prepare this map, GHD, City of Karratha and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.75 - 1	1.75 - 2
Block Boundary	Encroachment - Medium	0.002 - 0.25	1 - 1.25	2 - 2.25
	Encroachment - Low	0.25 - 0.5	1.25 - 1.5	2.25 - 2.5
		0.5 - 0.75	1.5 - 1.75	

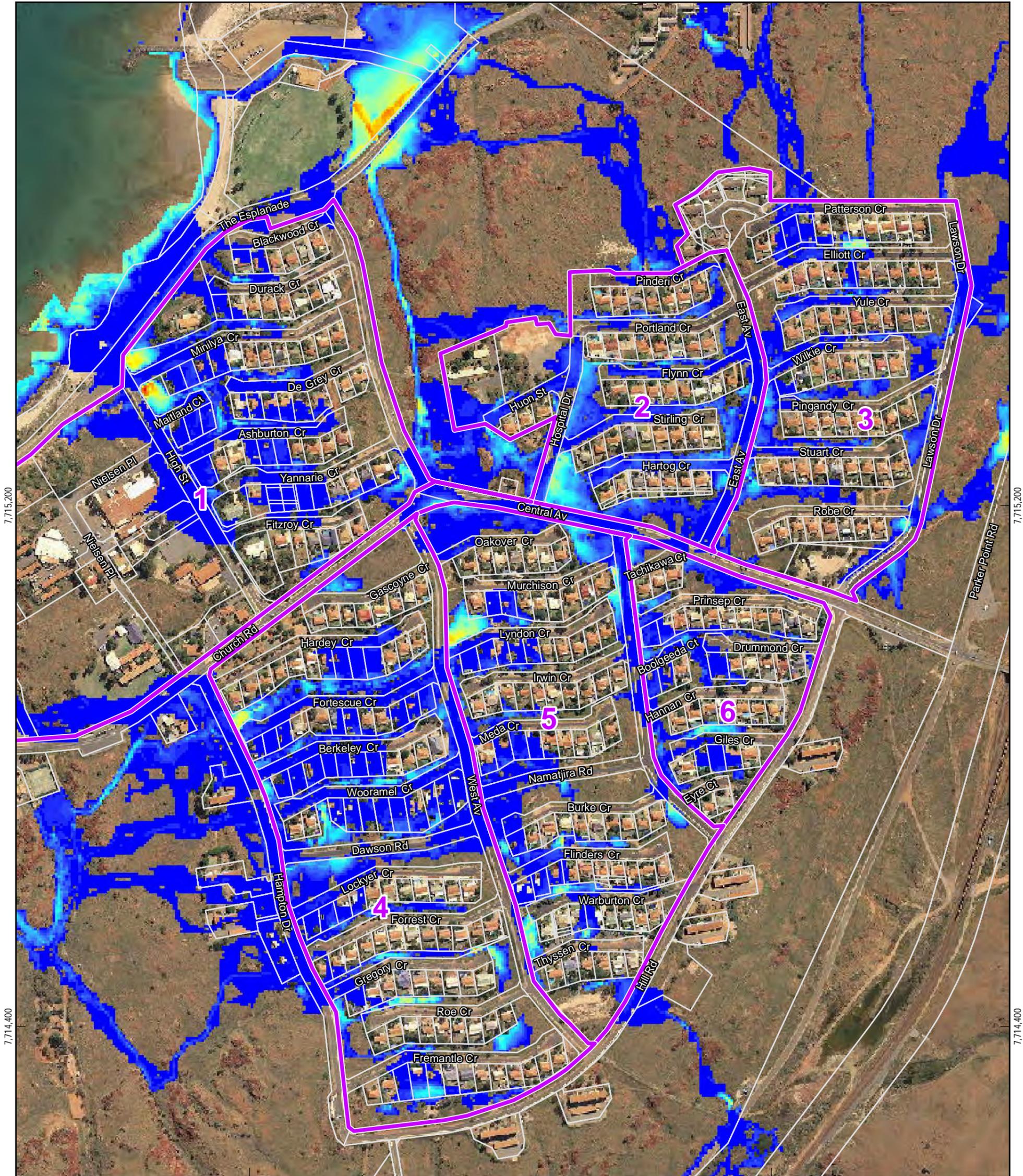


City of Karratha
Dampier Stormwater Management Study

Job Number | 61-31033
Revision | 0
Date | 10 Dec 2014

Peak flood depth, existing
scenario, 5 year ARI - Block 6

Figure 9I



7,715,200

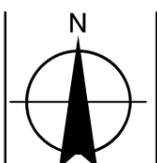
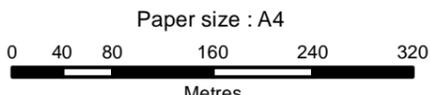
7,715,200

7,714,400

7,714,400

LEGEND

Cadastre	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
	0.51 - 0.75	1.51 - 1.75	2.51 - 2.75



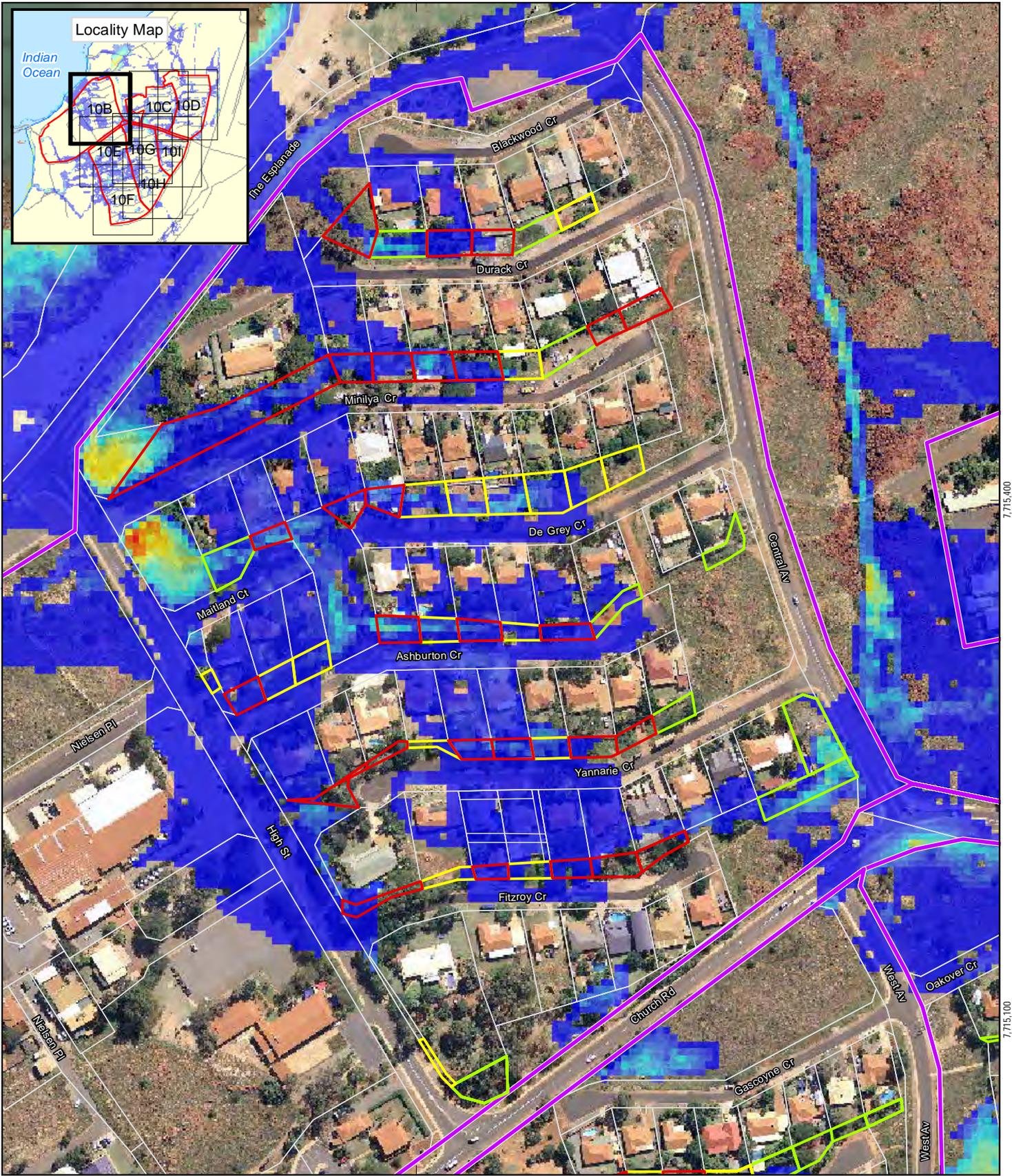
City of Karratha
Dampier Stormwater Management Study

Job Number | 61-31033
Revision | 0
Date | 06 Mar 2015

Peak flood depth, existing
scenario, 100 Year ARI

Figure 10A

\\ghdnet.internal\ghd\AU\Perth\Projects\61\31033\GIS\Maps\Working\6131033_G006_Rev0_Fig10A.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2015 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekej



7,715,400

7,715,400

7,715,100

7,715,100

LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

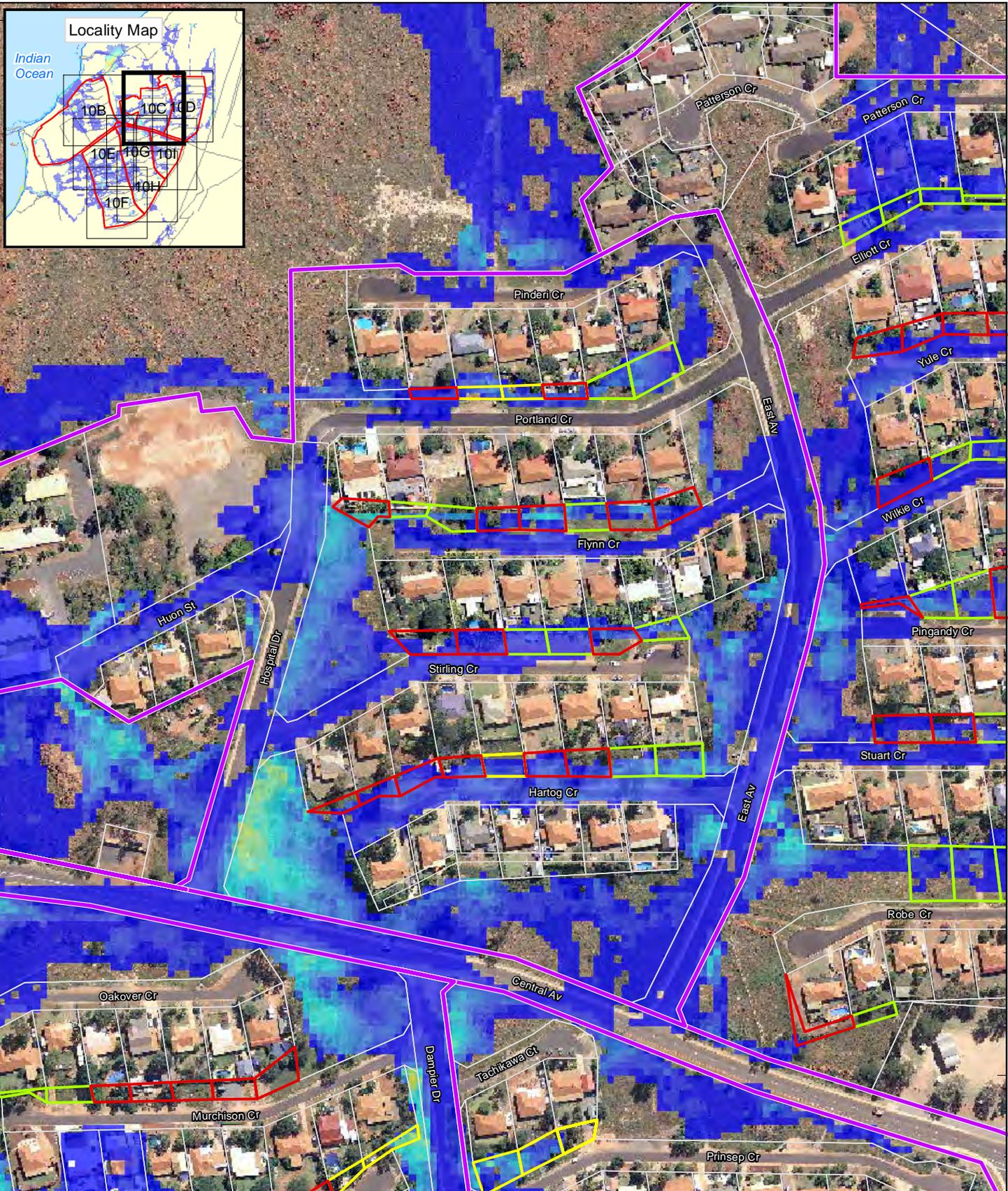


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 100 year ARI - Block 1 Figure 10B

G:\6131033\GIS\MapWorking\6131033_G007_Rev0_Fig10B.mxd
239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



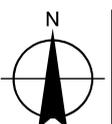
LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



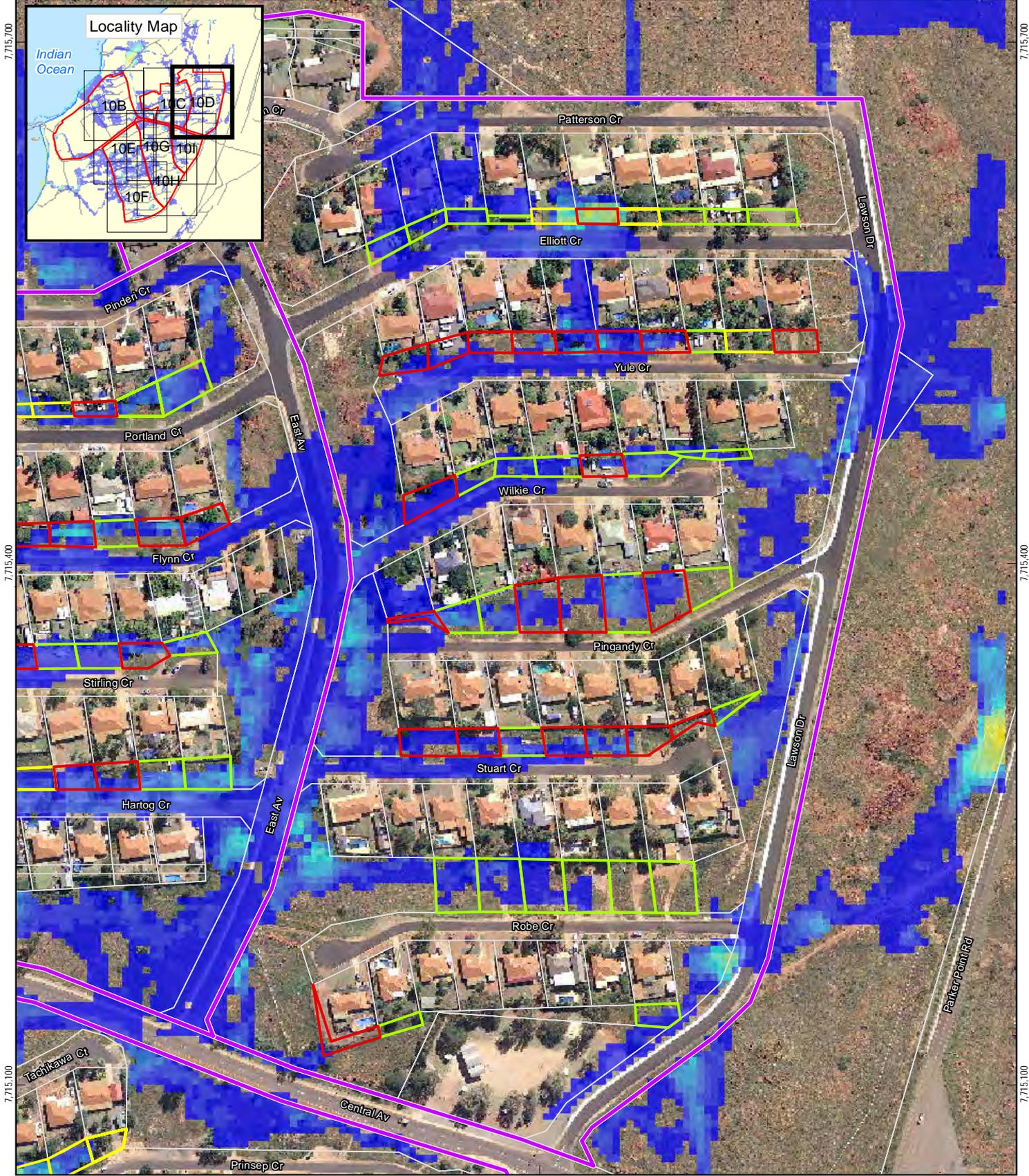
City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 100 year ARI - Block 2 Figure 10C

G:\61\31033\GIS\Maps\Working\6131033_G007_Rev0_Fig10B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



7,715,400

7,715,100

7,715,400

7,715,100

LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

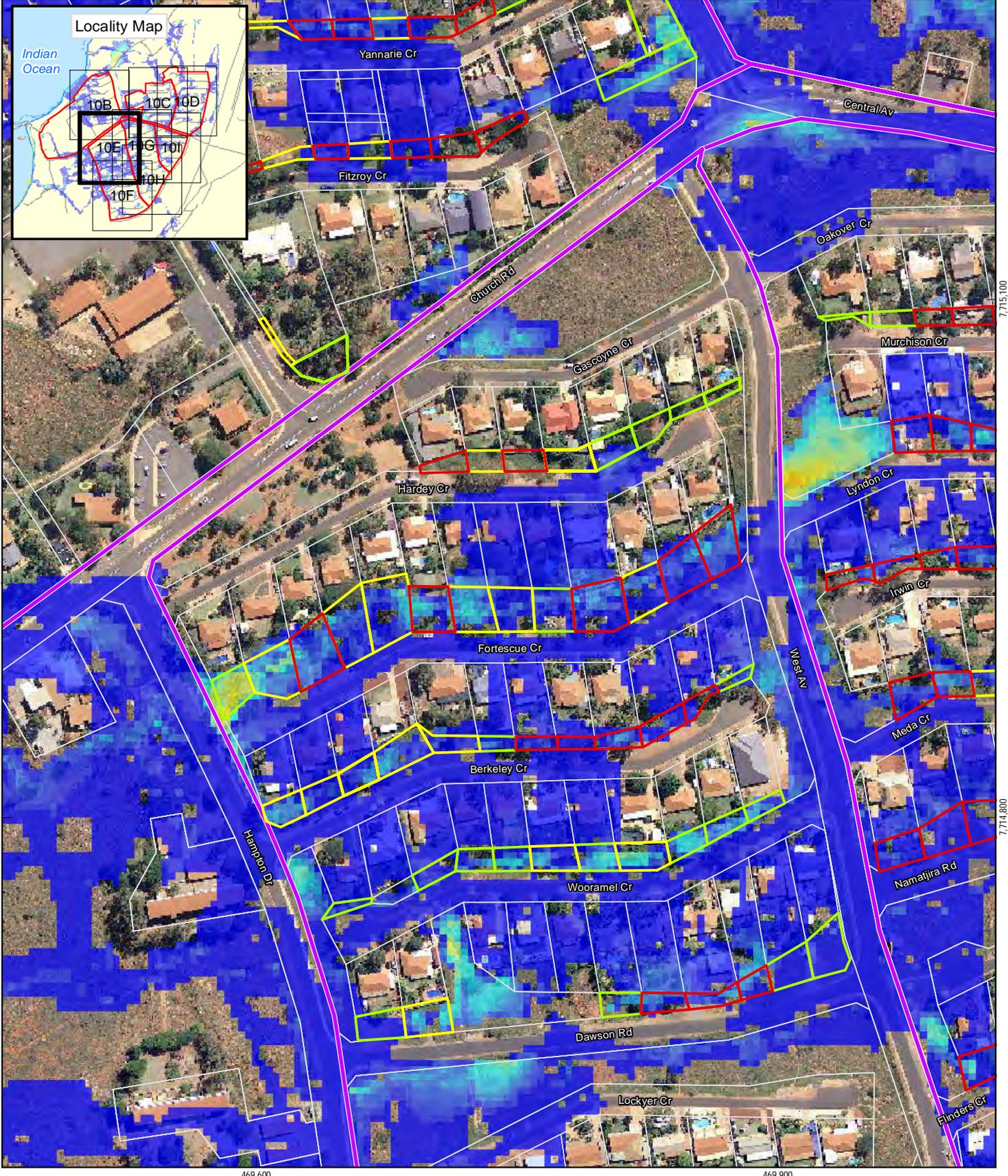
Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 100 year ARI - Block 3 Figure 10D

G:\6131033\GIS\Maps\Working\6131033_G007_Rev0_Fig10B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj

469,600

469,900



7,715,100

7,715,100

7,714,800

7,714,800

469,600

469,900

LEGEND

- Cadastre
 - Block Boundary
 - Encroachment - High
 - Encroachment - Medium
 - Encroachment - Low
- | Flood Depth (m) | |
|---|---|
| 0 - 0.25 | 1.76 - 2 |
| 0.26 - 0.5 | 2.01 - 2.25 |
| 0.51 - 0.75 | 2.26 - 2.5 |
| 1.01 - 1.25 | 2.51 - 2.75 |
| 1.26 - 1.5 | |
| 1.51 - 1.75 | |

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

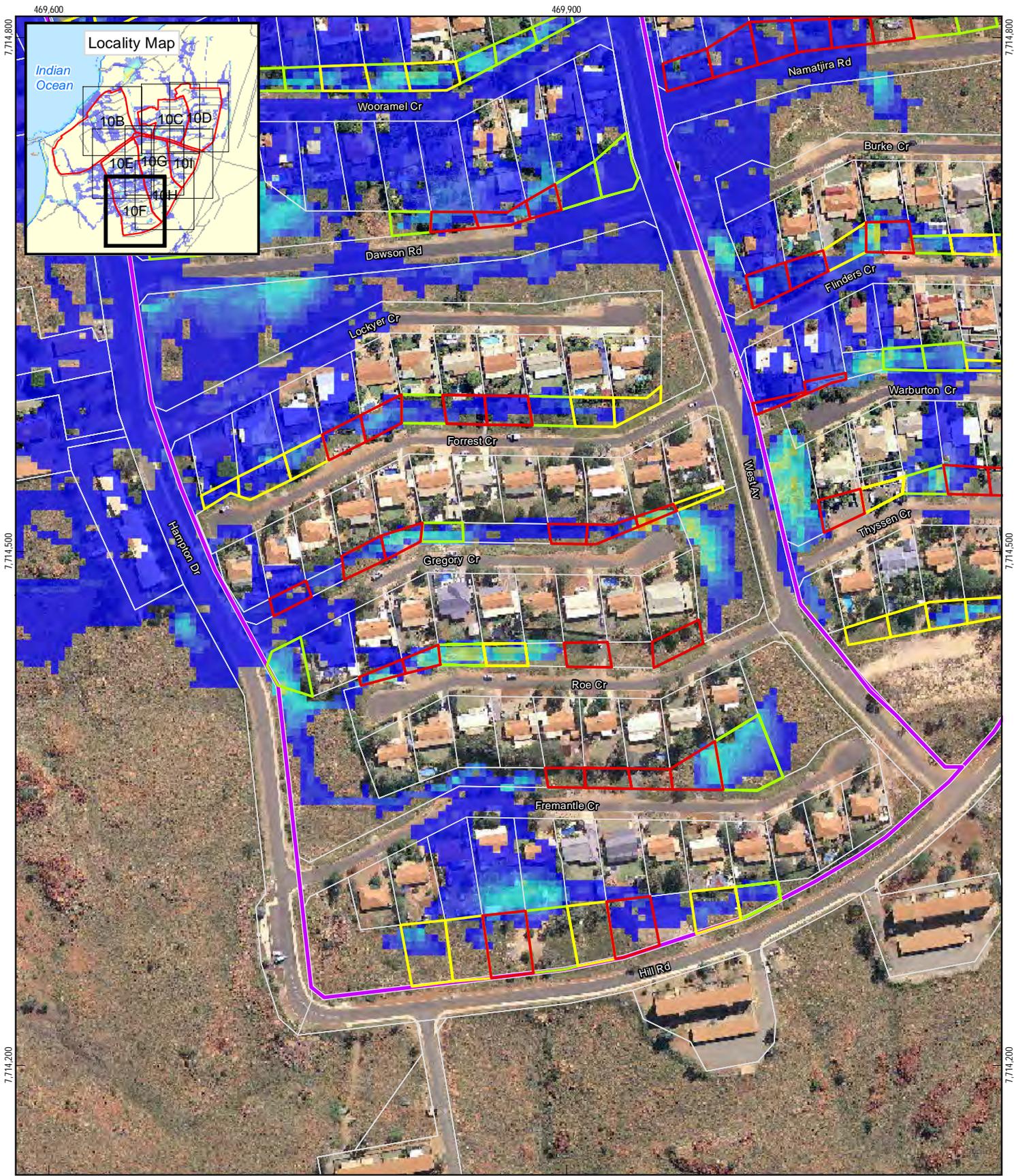


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 100 year ARI - Block 4a Figure 10E

G:\6131033\GIS\Maps\Working\6131033_G007_Rev0_Fig10E.mxd
239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



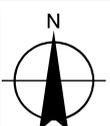
LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

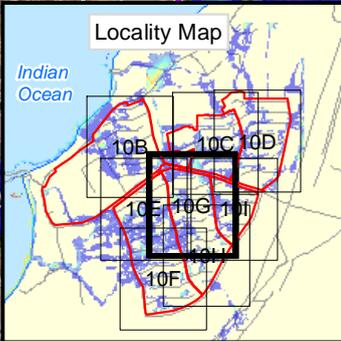
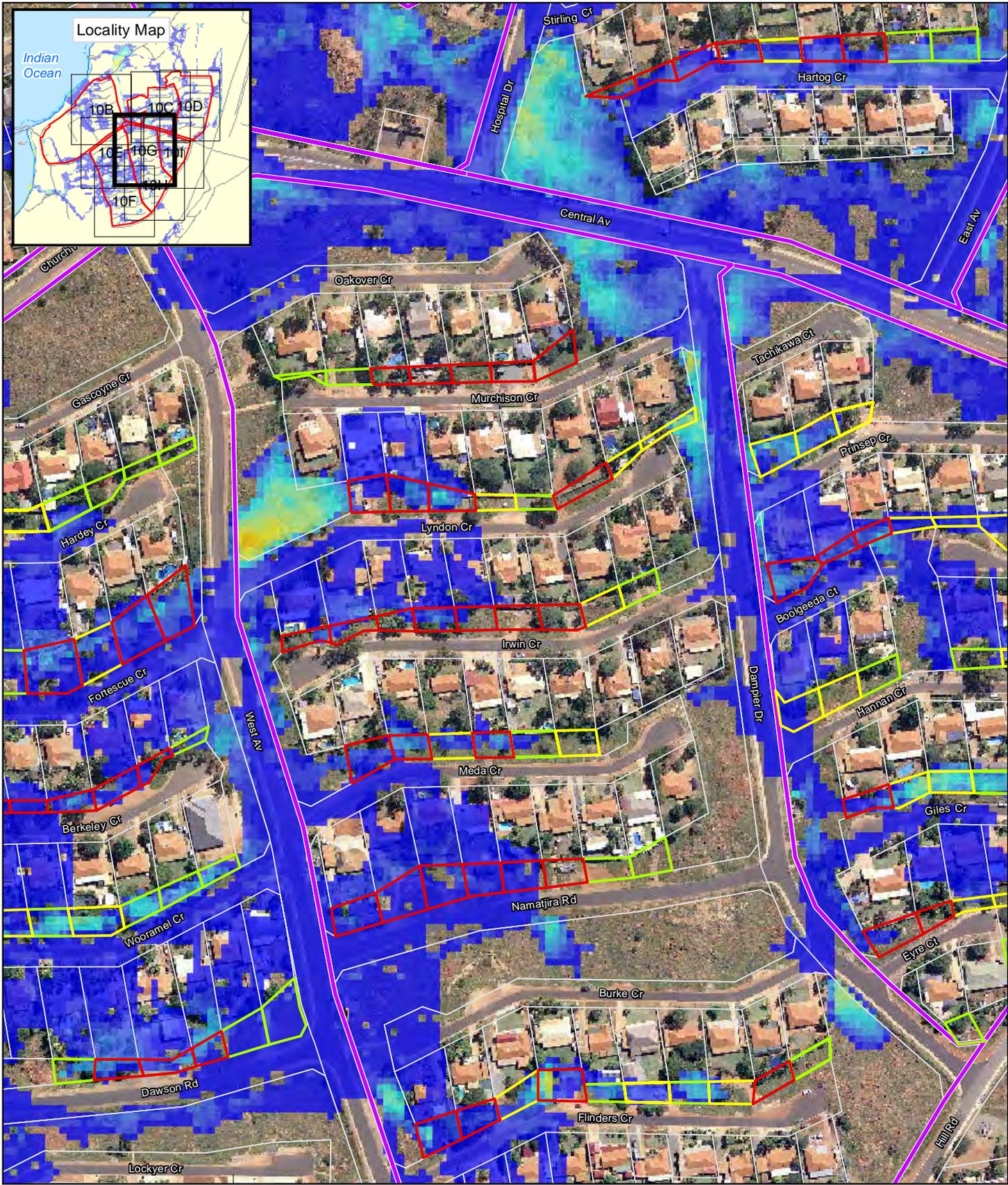


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

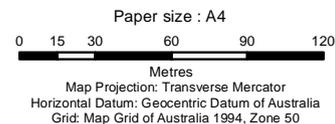
Peak flood depth, existing scenario, 100 year ARI - Block 4b Figure 10F

G:\6131033\GIS\Maps\Working\6131033_G007_Rev0_Fig10B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75



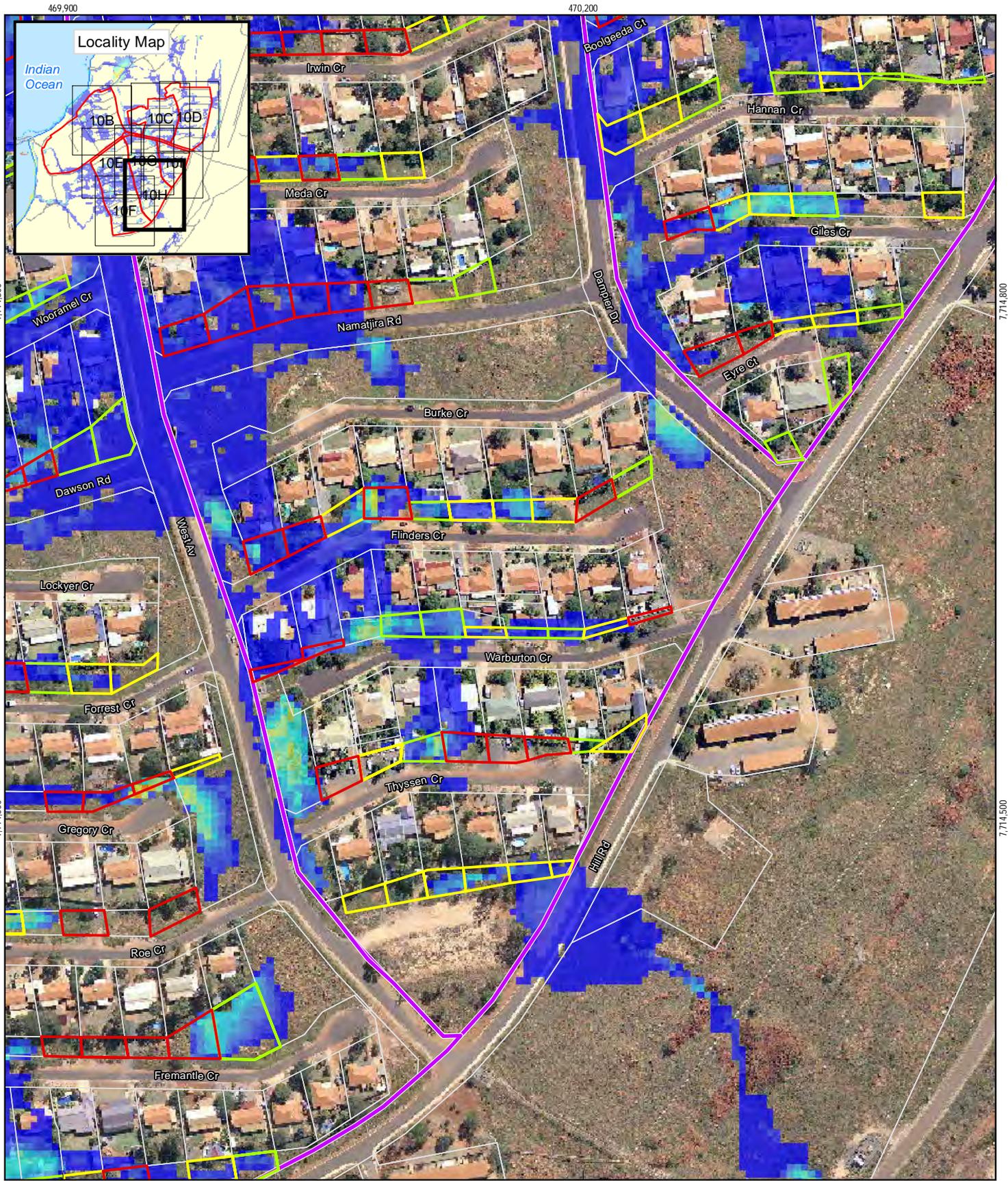
City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 100 year ARI - Block 5a Figure 10G

G:\6131033\GIS\Maps\Working\6131033_G007_Rev0_Fig10B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



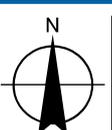
LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

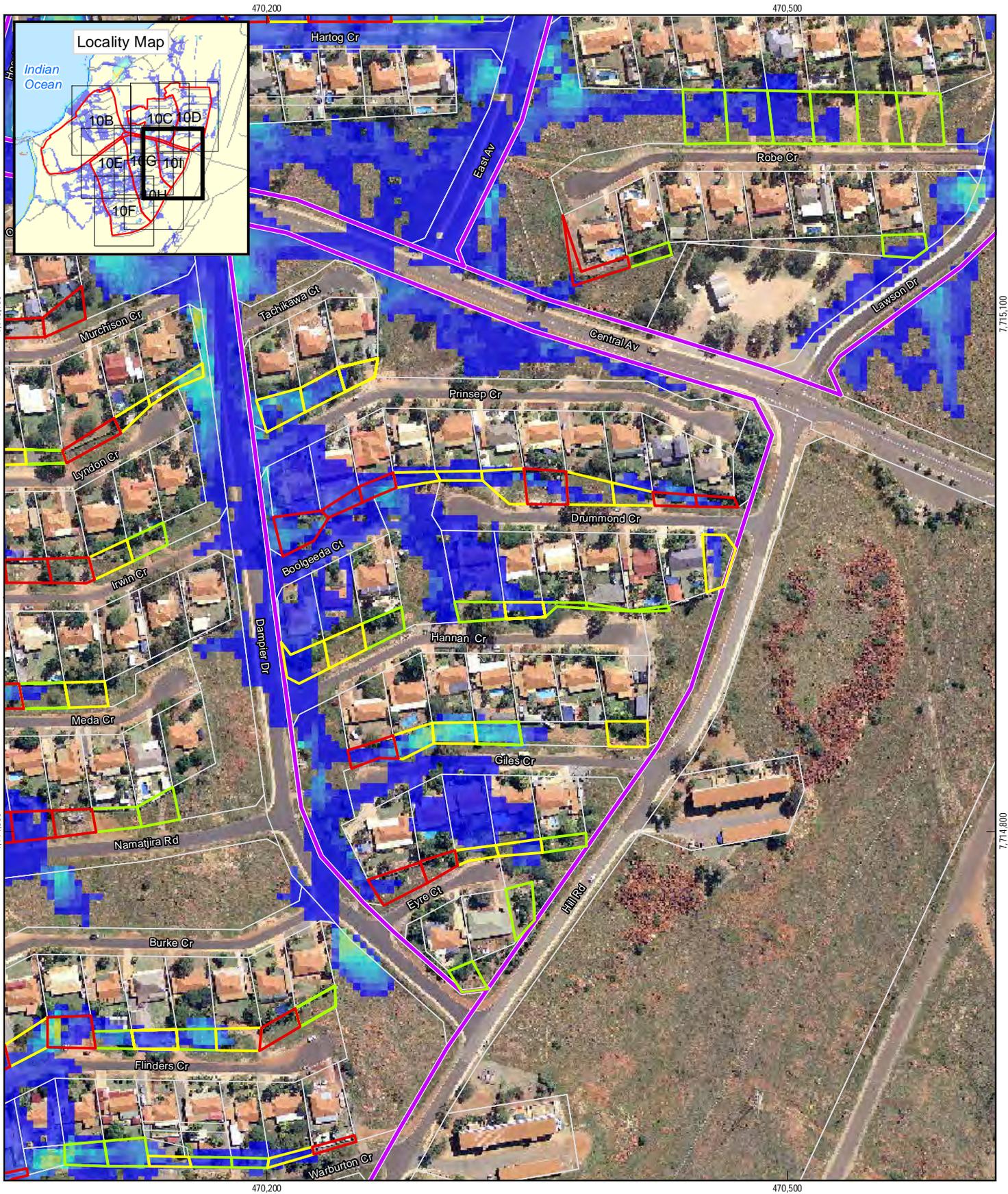


City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Dec 2014

Peak flood depth, existing scenario, 100 year ARI - Block 5b Figure 10H

G:\61\31033\GIS\Maps\Working\6131033_G007_Rev0_Fig10B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



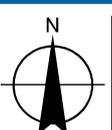
LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

Job Number | 61-31033
Revision | 0
Date | 10 Dec 2014

Peak flood depth, existing scenario, 100 year ARI - Block 6 Figure 10I

G:\61\31033\GIS\Maps\Working\6131033_G007_Rev0_Fig10B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj



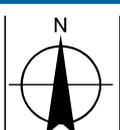
LEGEND

Cadastre	Velocity (m/s)	0.5 - 0.75	1.25 - 1.5	>3
Study Area	0 - 0.25	0.75 - 1	1.5 - 2	
	0.25 - 0.5	1 - 1.25	2 - 3	

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

Job Number	61-31033
Revision	0
Date	11 Dec 2014

Peak flood velocity, existing development, 5 year ARI

Figure 11

G:\61131033\GIS\Maps\Working\6131033_G012_RevA_Fig11.mxd
239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Velocity (m/s) - 20141211, Study Area - 20140805. Created by: AF, jcmatic



LEGEND

Cadastre	Flood Velocity (m/s)	0.5 - 0.75	1.25 - 1.5	>3
Study Area	0 - 0.25	0.75 - 1	1.5 - 2	
	0.25 - 0.5	1 - 1.25	2 - 3	

Paper size : A4

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

Peak flood velocity, existing development, 100 year ARI

Job Number	61-31033
Revision	0
Date	11 Dec 2014

Figure 12

G:\6131033\GIS\Maps\Working\6131033_G013_RevA_Fig12.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Velocity (m/s) - 20141211, Study Area - 20140805. Created by: AF, jcmatic

3.3 Encroachment impact

Previous drainage reviews of the Dampier townsite have acknowledged that as a result of infilling and property encroachment, parts of the drainage reserve no longer effectively conveys stormwater out of the study area. The results published as part of this review support these findings indicating the capacity of the existing drainage system is insufficient within instances of under sized swale due to encroachment, sedimentation, channel profile modification and undersized culverts.

A number of encroachments and those anticipated to have a negative impact on the drainage system are summarised for each block. In addition, critical areas have been identified where a significant flood risk to housing lots is expected.

3.3.1 Block 1

Forty six medium or high severity encroachments within the block have been identified, of which 33 are likely having a negative effect on the drainage system. All streets within the block are identified as having multiple consecutive high severity encroachments which are causing flooding and ponding of water in the western portion of the block.

3.3.2 Block 2

Nineteen medium or high severity encroachments within the block have been identified of which 12 are negatively impacting the drainage system. However, the flooding is predicted to be mostly contained by the existing drainage reserve and road reserves. The high severity encroachments are redirecting stormwater flow along the road reserve instead of drainage reserves, however the lots are sufficiently elevated above the predicted flood levels.

3.3.3 Block 3

Twenty five medium or high severity encroachments have been identified of which 12 are negatively impacting on the drainage system. Critical encroachments resulting in significant ponding and flooding of lots downstream have been identified on lot 324 on Patterson Crescent, and lots 334, 335 and 336 on Elliot Crescent. Remaining flood areas are anticipated to be contained by the road and drain reserves.

3.3.4 Block 4a

Almost all of the 15 high severity encroachments identified in block 4a are causing some level of inundation or flooding as a direct result of the encroachment. In total 31 medium or high severity encroachments have been identified of which 20 are negatively impacting the drainage system.

As a result of the various encroachments, it is estimated 30 of the lots are expected to experience flooding during the 100 year ARI event. Large portions of the road reserve and housing lots along Fortescue Crescent and Berkeley Cr are expected to experience inundation. The encroachments along the back of lots 73 – 77 on Fortesque Crescent are causing floodwater to flow across the road reserve in a south westerly direction flooding several more lots along Berkeley Crescent. The encroachments on lots 91-32 Dawson Road are causing significant flooding to the north along Dawson Road and Wooramel Crescent.

3.3.5 Block 4b

Of the 31 lots identified as having medium or high severity encroachments, 7 are anticipated to negatively impact the drainage system. Critical encroachments have been identified on lots 185 and 186 on Lockyer Crescent which are anticipated to cause significant flooding of lots and the road reserve northwest of these lots. Encroachments on lots 2,200, and 202, 203 are expected to cause flooding of the adjacent lot along the downstream flow path. A large area of ponding has

been identified between Fremantle Crescent and Hill Road around lot 220 and 221, which is the result of encroachments upstream on lots 223 and 224.

3.3.6 Block 5a

Thirty one lots have been identified as having medium or high severity encroachments of which 18 are anticipated to be negatively impacting the drainage system. Major areas of inundation are expected at the western end Lyndon Crescent which is caused by encroachments along the back of lots along the street. The other critical area identified is the inundation of a number of lots along Meda Crescent. High severity encroachments by all the lots along Meda Crescent are causing floodwaters to deviate from the natural drainage reserve flowing across lots in a north westerly direction.

3.3.7 Block 5b

Twenty three lots have been identified as having medium or high severity encroachments of which 11 are anticipated to be negatively impacting the drainage system. Encroachments on lots at the western end of Burke Crescent and Flinders Crescent are causing floodwaters to inundate lots in the area. This block also has subsurface drainage infrastructure running south to north which may be contributing the modelled flooding as a result of insufficient capacity by design or degradation of structures.

3.3.8 Block 6

Twenty six lots have been identified as having medium or high severity encroachments of which 8 are expected to negatively impact the drainage system. Majority of the floodwater is contained within the road or drainage reserves; however a few specific encroachments are resulting in inundation of lots. The largest area of ponding occurs around the intersection of Boolgeeda Court and Dampier Drive. There are encroachments on lots 132, 133, and 143 Prinmsep Crescent which may be contributing to the inundation anticipated in this area. Other critical encroachments have been identified on lots 144 and 152, 153 causing inundation of neighbouring properties.

3.3.9 Remediation mechanism

The remediation of the encroachment is an important element in ensuring the Dampier town site drainage system is operating at an acceptable level to maintain the required level of service. Review of the encroachment impacts above resulted in identification of encroachment which requires removal through drainage remediation in order to improve the level of service and reduce instances of overland flow and ponding within private property.

Lots shown within Figure 13 present an elevated flood risk during a 5 year ARI event and correspond to high or medium impact drainage encroachment with such encroachments considered high priority for remediation.

Remediation of the culverts as shown in Figure 14 has been identified as one of two mechanisms listed below:

- Planning based remediation - remediation requires legal input given the nature of the encroachment involves the removal of privately property which has been placed within the public owned drainage reserve; and
- Maintenance based remediation – remediation is achieved through reestablishment of swale with no impact on private property or adjacent private land holders.

The remediation mechanism was identified through review of the published June 2010 Dampier Drainage Block Encroachments Summary Report (GHD, 2010) as found in Appendix D.

Planning based solution were identified where a lot was identified as having a boundary or structure within the drainage reserve which was considered fixed such as a boundary fence, shed or pool. Survey is required to confirm the identified encroachment and the structures extent of impact into the drainage reserve. Reestablishment through civil works will be required upon resolution of the planning consideration.

Encroachments identified as unsuitable rear access ways or parking bays were considered maintenance solutions given the access way or parking bay could, in principle remain provided an appropriate drainage cross over is established for drainage conveyance (refer Section 5.2).

All other instance of encroachment including lack of drainage infrastructure (no swale), vegetation growth, debris and rubbish were considered maintenance based solutions requiring only reestablishment of the swale.

It should be noted drainage reserves identified as containing no remediation requirement or no encroachment impacts may require upgrade to facilitate overall drainage system improvement as noted in Section 5.2.



LEGEND

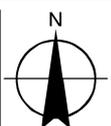
Cadastre	Lot with increased flood risk due to encroachment	Flood Depth (m)	0.75 - 1	1.75 - 2
Block Boundary	Encroachment - High	0.002 - 0.25	1 - 1.25	2 - 2.25
	Encroachment - Medium	0.25 - 0.5	1.25 - 1.5	2.25 - 2.5
	Encroachment - Low	0.5 - 0.75	1.5 - 1.75	

Paper size : A4

0 40 80 160 240 320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Mar 2015

Encroachment impact
5 year ARI

Figure 13

\\ghdne\Internal\gnd\AU\Perth\Projects\61\31033\GIS\Waps\Working\6131033_G014_Rev0_Fig13.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2015 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805; GHD: 5 year ARI - 20140729, Block Boundary - 20140805. Created by: mczekaj

It should be noted drainage reserves identified as containing no remediation requirement or no encroachment impacts may require upgrade to facilitate overall drainage system improvement



LEGEND

- Cadastre
- Encroachment - High
- Planning based consideration for remediation
- Block Boundary
- Encroachment - Medium
- Maintenance based primarily civil work required for remediation

Paper size : A4

0 40 80 160 240 320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
Dampier Stormwater Management Study

Job Number 61-31033
Revision 0
Date 10 Mar 2015

Preliminary encroachment
remediation strategy

Figure 13

\\ghdne\Internal\gnd\AUP\Perth\Projects\61\31033\GIS\Waps\Working\6131033_G015_Rev0_Fig14.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2015 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805; GHD: 5 year ARI - 20140729, Block Boundary - 20140805. Created by: mczekaj

4. Development scenario modelling

4.1 Development plan

The Dampier Redevelopment Land Use Plan Maps have been referred for future development assessment. Appendix B shows the redevelopment zone designations. The Dampier Redevelopment Land Use Plan provides information on the future probable development land use requirements and allowances, which will affect the imperviousness of the area and so the runoff. This study assumes the impervious coverage will not exceed the Dampier Redevelopment Land Use Plan values.

There are five main zoning designations within the Dampier Town Site Catchment:

- Special Purpose/ Tourism Use;
- Recreation Precincts;
- New Residential Redevelopment Precincts;
- Coastal Village Precincts; and
- Existing Neighbourhood Precincts.

4.1.1 Imperviousness allowances

The average estimated impervious areas for Existing Development (based on aerial photographs and future proposed development (based on Dampier Redevelopment Land Use Plan allowances) for residential and commercial catchments within the Dampier Town Site are summarised in Table 7. The redevelopment assumes 85% of existing lots within the Dampier two site are subdivided. These figures include an allowance for road imperviousness based on 90% imperviousness within the road boundaries.

Table 7 Impervious Allowances Used for Modelling

Type	Land use	Pervious percentage	Impervious percentage
New Residential Redevelopment Precincts	The Lookout (R30)	35	65
	Hill Road Ridge (R40)	25	75
	Hampton Views (R30)	35	65
	Beachside (R50 – R60)	25	75
Coastal Village Precincts	Commercial	20	80
Existing Neighbourhood Precincts	Change to R50 (assumes 85% existing lots subdivided)	25	75

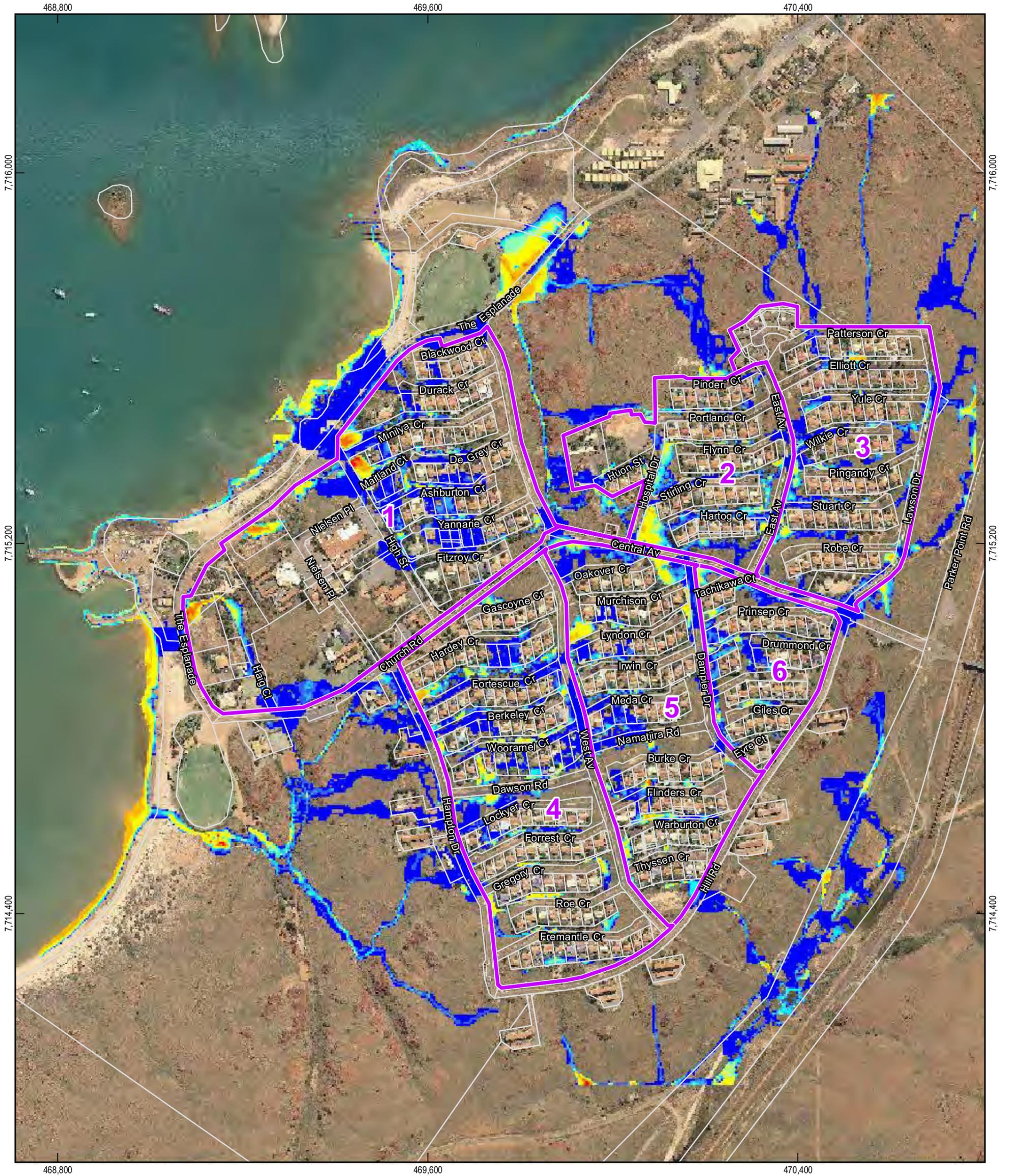
4.2 Results

The development scenario presents the results of a situation where intensification and expansion of the Dampier townsite has occurred with appropriate controls in place resulting in significantly increase runoff volumes. The model assumes the existing stormwater drainage network; including encroachment and culverts sizes are maintained.

The development scenario flood model indicates that in a 5 year ARI event, flooding and ponding is no longer contained within the drainage and road reserve as in the case of the existing scenario modelling. The additional impervious area and associated runoff has resulted in extended flood depths and floodable areas with a significant number of housing lots

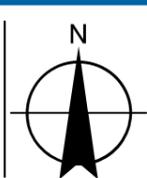
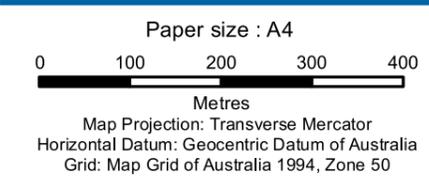
anticipated upon full redevelopment of the Dampier townsite to experience flooding, as shown in Figure 16.

In a 100 year ARI the flooding extent significantly expands to include large portions of the road reserve and multiple housing lots. As shown in Figure 17 the flood area encompasses a larger portion of lots than those identified within the existing scenario modelling (Figure 11).



LEGEND

Cadastre	Flood Depth (m)	0.75 - 1	1.75 - 2
Block Boundary	0.002 - 0.25	1 - 1.25	2 - 2.25
	0.25 - 0.5	1.25 - 1.5	2.25 - 2.5
	0.5 - 0.75	1.5 - 1.75	

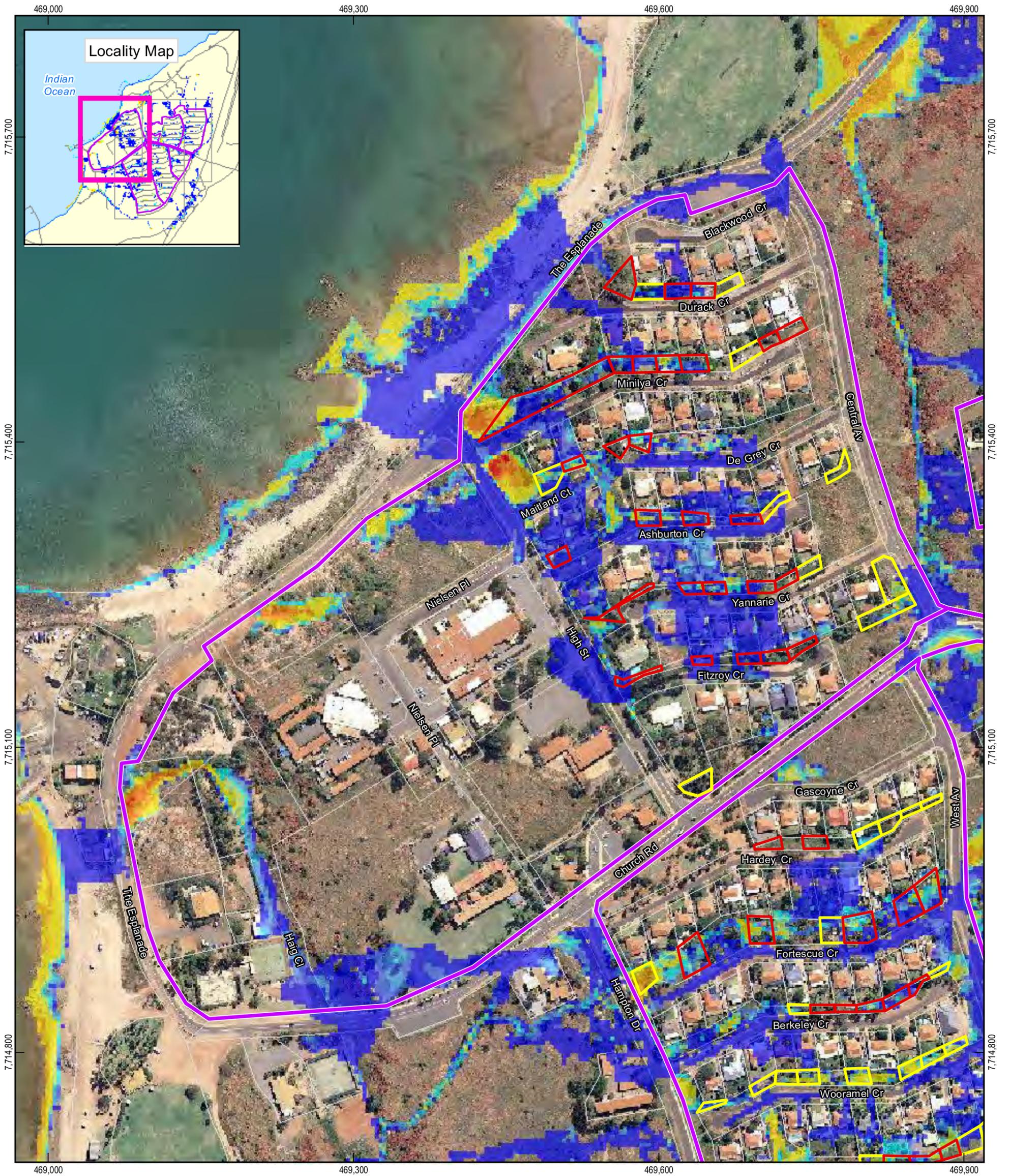


City of Karratha
Dampier Stormwater Management Study

Job Number	61-31033
Revision	0
Date	10 Dec 2014

Peak flood depth, development scenario, 5 year ARI **Figure 15A**

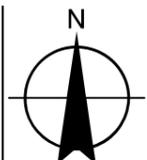
G:\61\31033\GIS\Maps\Working\6131033_G008_Rev0_Fig13A.mxd
 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate - Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20141014, Block Boundary - 20140805. Created by: AF, jcmatic



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.2 - 0.3	1.0 - 1.5
Block Boundary	Encroachment - Medium	0.002 - 0.05	0.3 - 0.4	1.5 - 2
	Encroachment - Low	0.05 - 0.1	0.4 - 0.5	2.0 - 2.5
		0.10 - 0.2	0.5 - 1	

Paper size a4
 0 15 30 60 90 120
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 50



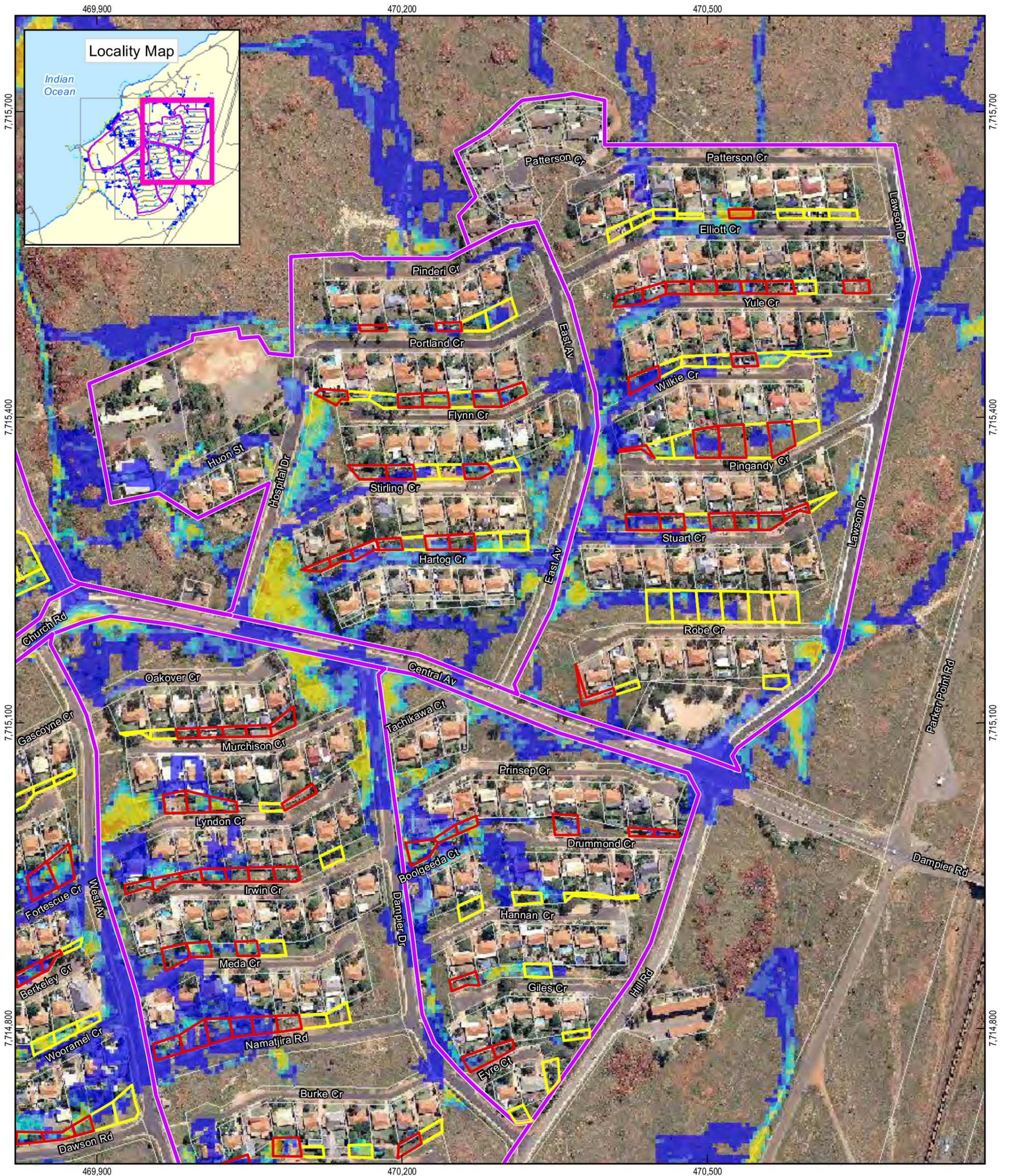
City of Karratha
 Dampier Stormwater Management Study

Job Number | 61-31033
 Revision | 0
 Date | 10 Dec 2014

Peak flood depth, development scenario 5 year ARI - Block 1

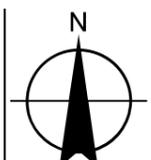
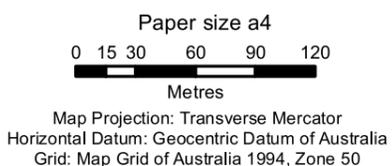
Figure 15 B

G:\61\31033\GIS\Maps\Working\6131033_G008_Rev0_Fig13B.mxd
 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014 . Whilst every care has been taken to prepare this map, GHD, City of Karratha and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj, jcmatic



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.2 - 0.3	1.0 - 1.5
Block Boundary	Encroachment - Medium	0.002 - 0.05	0.3 - 0.4	1.5 - 2
	Encroachment - Low	0.05 - 0.1	0.4 - 0.5	2.0 - 2.5
		0.10 - 0.2	0.5 - 1	



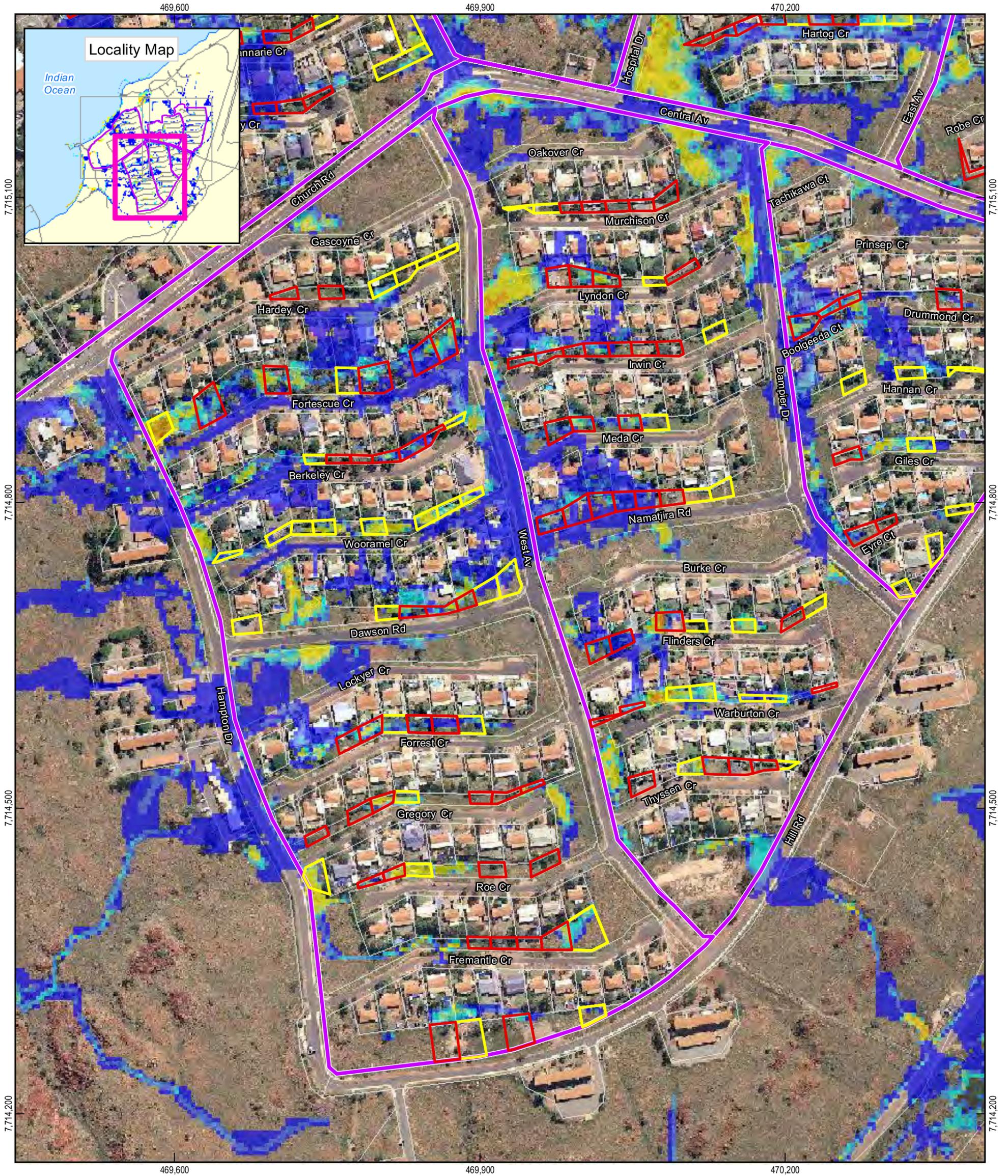
City of Karratha
 Dampier Stormwater Management Study

Job Number | 61-31033
 Revision | 0
 Date | 10 Dec 2014

Peak flood depth, development scenario 5 year ARI - Block 2

Figure 15 C

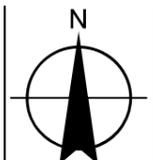
G:\61131033\GIS\Maps\Working\61131033_G008_Rev0_Fig13B.mxd
 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014 . Whilst every care has been taken to prepare this map, GHD, City of Karratha and Landgate make no representations or warranties about its accuracy, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj, jcmatic



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.2 - 0.3	1.0 - 1.5
Block Boundary	Encroachment - Medium	0.002 - 0.05	0.3 - 0.4	1.5 - 2
	Encroachment - Low	0.05 - 0.1	0.4 - 0.5	2.0 - 2.5
		0.10 - 0.2	0.5 - 1	

Paper size a4
 0 15 30 60 90 120
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 50



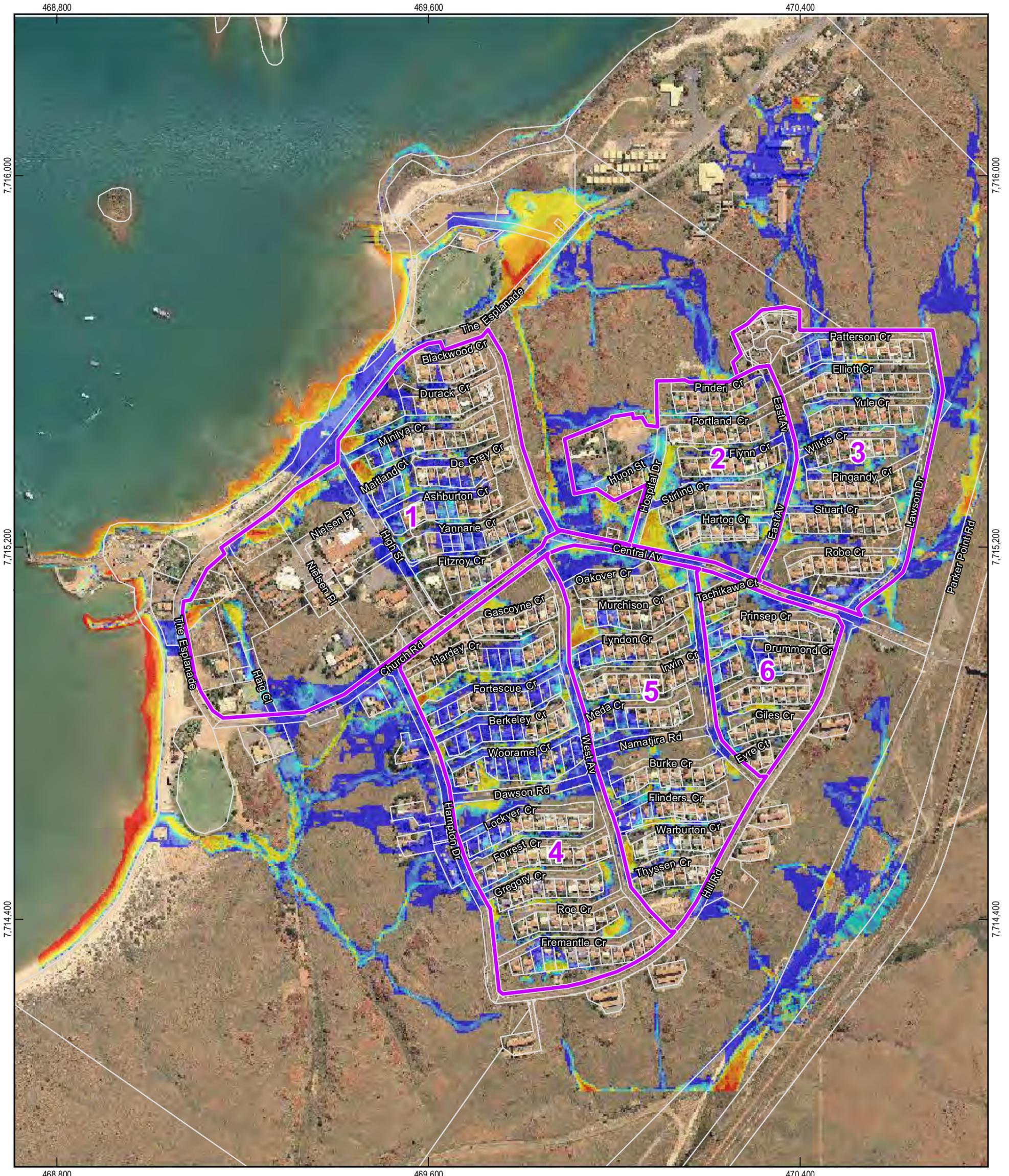
City of Karratha
 Dampier Stormwater Management Study

Job Number | 61-31033
 Revision | 0
 Date | 10 Dec 2014

Peak flood depth, development
 scenario 5 year ARI - Block 3

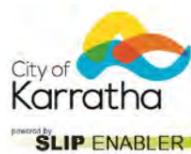
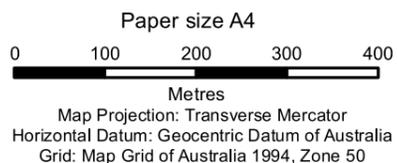
Figure 15D

G:\61\31033\GIS\Maps\Working\6131033_G008_Rev0_Fig13B.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014 . Whilst every care has been taken to prepare this map, GHD, City of Karratha and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekaj, jcmatic



LEGEND

Cadastre	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
	0.51 - 0.75	1.51 - 1.75	2.51 - 2.75



City of Karratha
Dampier Stormwater Management Study

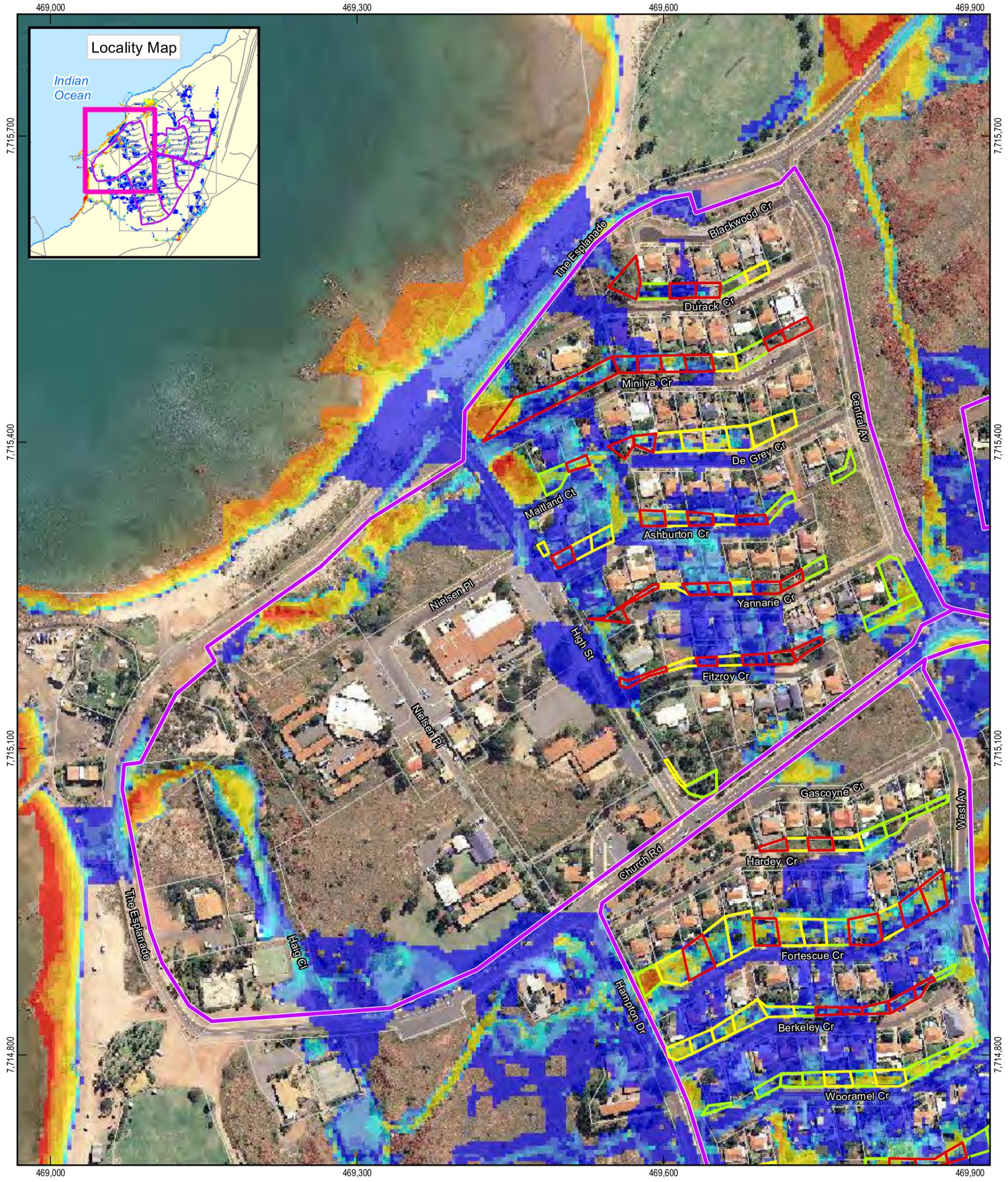
Job Number | 61-31033
Revision | 0
Date | 10 Dec 2014

Peak flood depth, development scenario, 100 year ARI

Figure 16A

G:\61\31033\GIS\Maps\Working\6131033_G009_Rev0_Fig14A.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2014 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

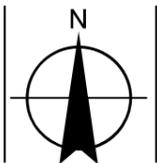
Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20141014, Block Boundary - 20140805. Created by: mczekaj, jcmatic



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size A4
 0 15 30 60 90 120
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 50

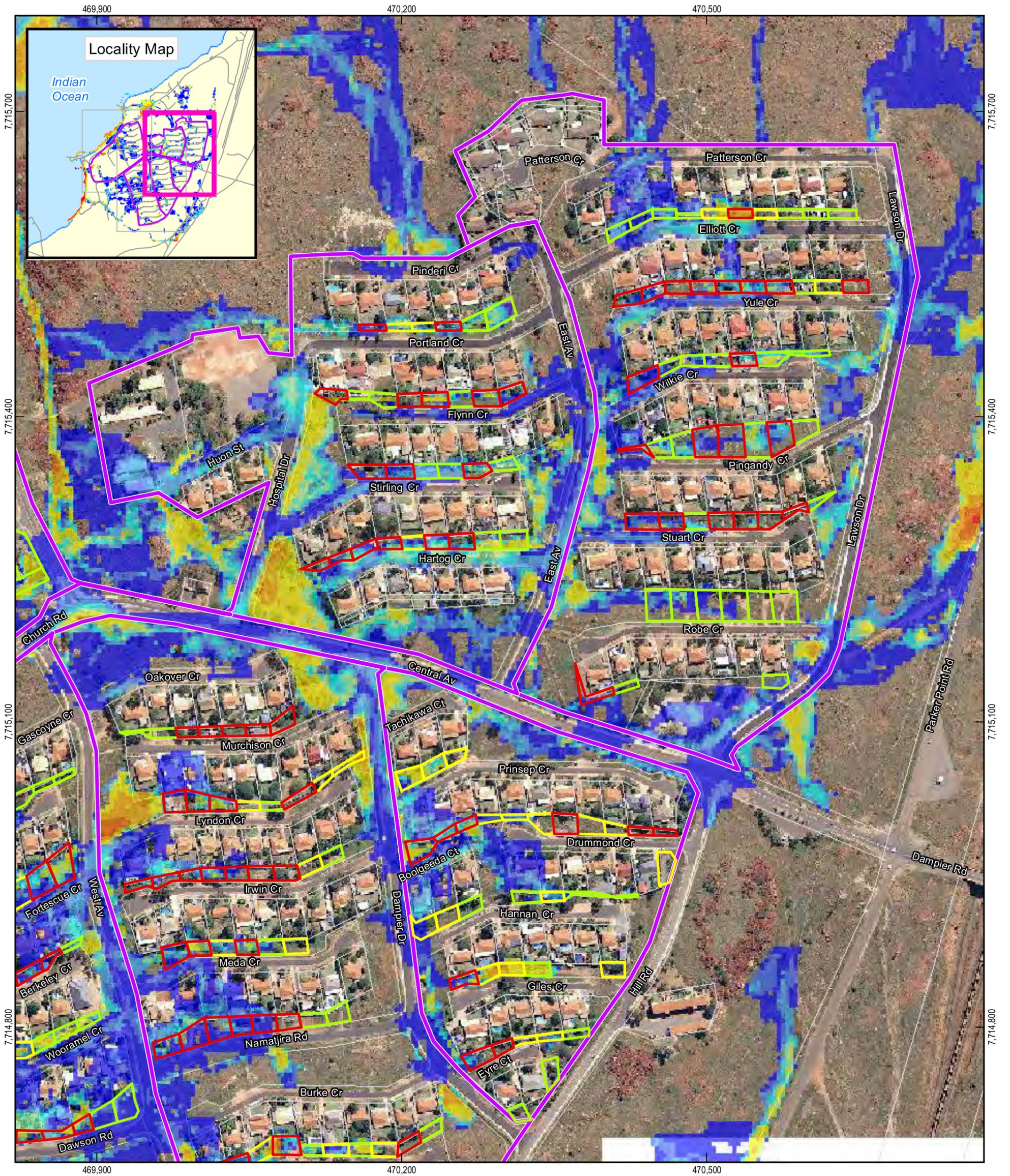


City of Karratha
 Dampier Stormwater Management Study

Job Number | 61-31033
 Revision | 0
 Date | 10 Dec 2014

Peak flood depth, development scenario 100 year ARI - Block 1 Figure 16 B

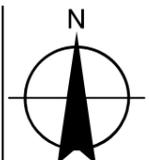
G:\61\31033\GIS\Maps\Working\6131033_G009_Rev0_Fig14B.mxd
 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate: Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekej, jcmatic



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size A4
 0 15 30 60 90 120
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 50

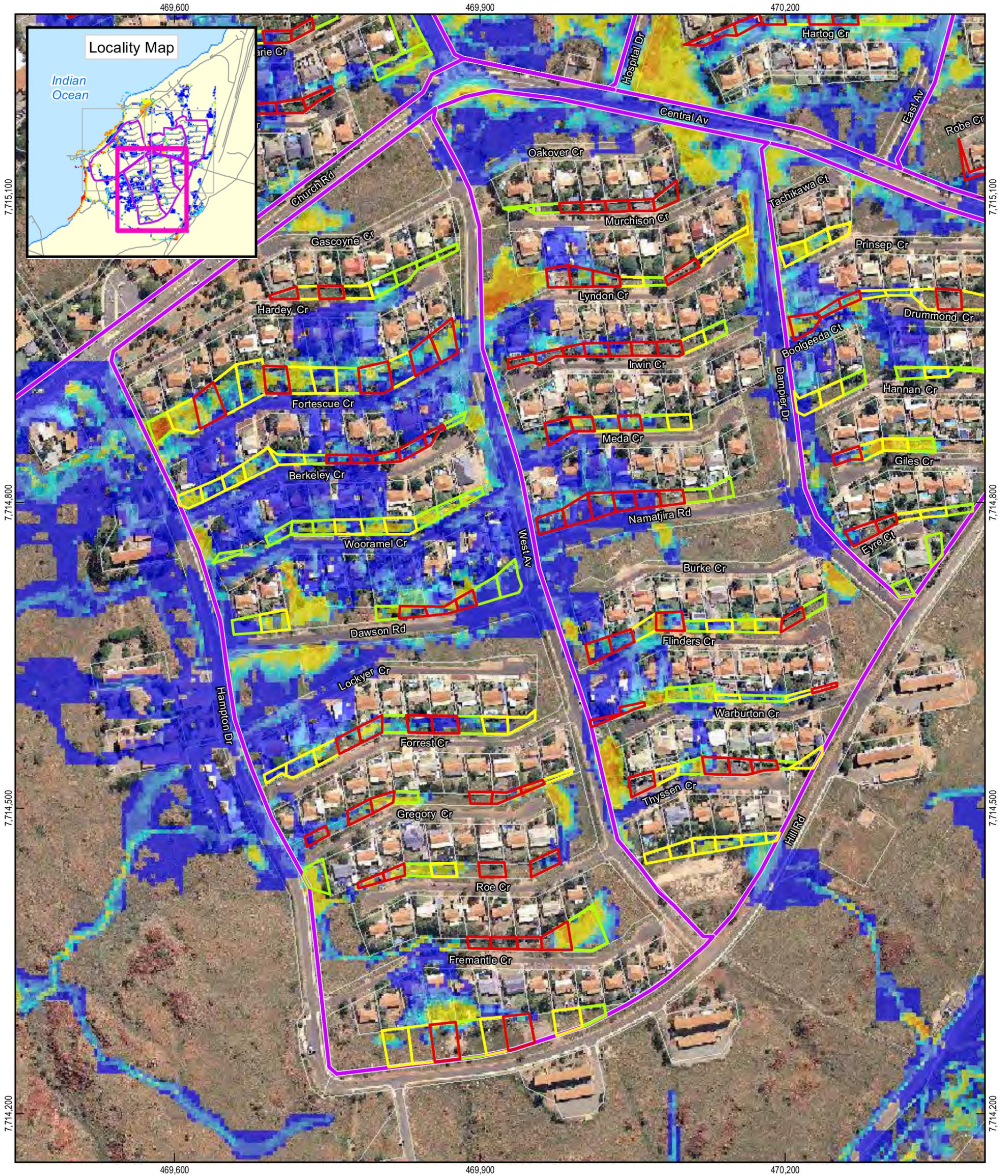


City of Karratha
 Dampier Stormwater Management Study

Job Number | 61-31033
 Revision | 0
 Date | 10 Dec 2014

Peak flood depth, development scenario 100 year ARI - Block 2 Figure 16C

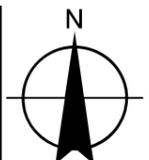
G:\61131033\GIS\Maps\Working\61131033_G009_Rev0_Fig14B.mxd
 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate - Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mccekaj, jcmatic



LEGEND

Cadastre	Encroachment - High	Flood Depth (m)	0.76 - 1	1.76 - 2
Block Boundary	Encroachment - Medium	0 - 0.25	1.01 - 1.25	2.01 - 2.25
	Encroachment - Low	0.26 - 0.5	1.26 - 1.5	2.26 - 2.5
		0.51 - 0.75	1.51 - 1.75	2.51 - 2.75

Paper size A4
 0 15 30 60 90 120
 Metres
 Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 50



City of Karratha
 Dampier Stormwater Management Study

Job Number | 61-31033
 Revision | 0
 Date | 10 Dec 2014

Peak flood depth, development scenario 100 year ARI - Block 3 Figure 16D

G:\61\31033\GIS\Maps\Working\6131033_G009_Rev0_Fig14B.mxd
 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
 © 2014. Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
 Data source: Landgate - Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mccekaj, jcmatic

4.3 Development Impacts

The impacts of further development and the intensification of existing housing density in built up areas on the existing drainage system is significant without appropriate controls in place to upgrade the existing stormwater systems capacity or manage the additional catchment runoff volumes.

The below text summaries the impacts on each development block where upon development no stormwater management strategy is implemented or no drainage upgrade undertaken.

Coastal Village and Beachside

The Coastal Village is zoned for R80 - R50 and Beachside is zoned for R50 - R60. Floodwater crossing Church Road flows along Haig Ct. Flooding along Haig Ct increased up to 100 mm and 200 mm for 5-year ARI and 100-year ARI respectively with proposed future development. Adequate culverts at crossing location of The Esplanade are required to convey additional drainage flows.

Block 1

The Block 1 area future development is zoned for R50. This would result in increased flooding in the area due to under capacity of culverts crossing The Esplanade and High Street. The encroachments identified in the area are going to aggravate flooding with proposed development. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively.

Block 2 and the lookout

The Lookout and Block 2 are zoned for R30 and R50 respectively for future development. Flooding in the area would increase with proposed development. The Central Avenue and Hospital Drive are under capacity and require upgrade. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively.

Block 3

The Block 3 area future development is zoned for R50. This would result in increased flooding in the area due to under capacity of culverts crossing the East Avenue. The 25 medium high severity encroachments identified in the area are going to aggravate flooding with proposed development. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively.

Block 4a and Hampton Views North

The Hampton Views and Block 4a are zoned for R30 and R50 respectively for future development. The existing development flood modelling identified 31 high or medium severity encroachments. Flood water from Hardey Cr is passing through Lots 62, 63, and 64 to Fortescue Cr drainage reserve. The culvert crossing the Hampton Drive at Fortescue Cr is under capacity. Hampton Views is currently flowing freely to the sea without any obstruction. However increased drainage East of Hampton views require passing through Hampton views. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively.

Block 4b Hampton Views South

Block 4b is zoned R50 for future development. The existing development flood modelling identified 31 high or medium severity encroachments. Flood water from Fremantle Cr is passing through Lots 219 and 220. The culvert crossing the Hampton Drive at Lockyer Cr is under capacity. Hampton Views is currently flowing freely to the sea without any obstruction. However

increased drainage East of Hampton views require passing through Hampton views. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively.

Block 5a and 5b

Blocks 5a and 5b are zoned for R50 for future development. The existing development flood modelling identified 31 high or medium severity encroachments. Flood water from Meda Cr is passing through Lots 126 and 127 to Namatjira Cr. Culverts crossing the West Avenue are under capacity and require upgrade with new development. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively.

Block 6

Block 6 is zoned for R50 for future development. The existing development flood modelling identified 26 high or medium severity encroachments. Flood water from Drummond Cr is passing through Lots 144 and 145 to Lots 132 and 133 of Princep Cr. Culverts crossing the Dampier are under capacity and require upgrade with new development. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively.

Hill Road Rise

Hill Road Rise is zoned R40 for future development. Stormwater from Hill Road Rise is currently flowing freely towards south-East. The flooding within the area can increase up to 50 mm and 100 mm for 5-year ARI and 100-year ARI respectively. The flood water from this area is crossing Parker Point Road. Culverts are required at crossing locations. In addition, this area requires onsite retention to attenuate additional drainage that is going to generate as a result of proposed development to prevent flooding east of the development

5. Stormwater management strategy

This section presents a stormwater management strategy for the Dampier townsite. Previous sections in this report set out a review of background material and identification of areas at risk of flooding and the impacts of redevelopment.

The intent of this section is to set out recommendations to both progress drainage improvements in Dampier to limit flood impact, free up excess land for redevelopment and provide recommendations for future development.

5.1 Objectives

The objectives of the strategy are to:

- Provide recommendations for upgrade the existing drainage network to ensure flooding is appropriately managed for existing and future development;
- Provide development assessment guidance;
- Identify areas surplus to drainage requirements that can be redeveloped for urban uses; and
- Identify potential implementation issues and management options.

5.1.1 Regional drainage principles

Drainage design in all areas of the State of Western Australia is engineered to the same design guidelines as outlined in *Local Government Guidelines for Subdivisional Development Edition 2 – 2009*.

Due to the large volumes of water generated in cyclonic events, the priority for stormwater management in the north west region of WA has been the rapid removal of stormwater away from infrastructure to avoid flood related damages. Some town centres have addressed this issue well by constructing a drainage network designed for stormwater conveyance and less so detention.

In the north of Western Australia, given favourable environmental conditions, the ideal drainage network is represented by utilising kerbed roads as the initial conveyor of stormwater, with kerb breaks located at topographic low points discharging stormwater to large open channels that discharge stormwater away from the urban zone.

Drainage design guidelines provide sizing recommendations for drainage measures. These are provided in *Local Government Guidelines for Subdivisional Development Edition 2 – 2009*. Here, guidelines are provided for both urban and rural settings. The rural guidelines outlined in this document are most applicable to the Dampier townsite and are summarised below:

- The drainage system should be designed for the 100 yr ARI event using overland flow
- Maximum flow velocities in open channels shall not exceed 2 m/s in lined open channels (can be arrested by the inclusion of drop structures);
- Mortared stone pitching shall be provided in open drains at all junctions and bends greater than 22.5°; and
- Detention storage areas may be provided at suitable locations (can be on line) to reduce peak flow rates to the capacity of downstream facilities
- Drainage design general principles are also provided in the same document and are applicable to both urban and rural settings. These are summarised below:

- Runoff from constructed impervious areas should be retained where possible within the lot or road reserve for the 1 yr ARI event;
- Provision shall be made using storage facilities for peak 1 in 100 year storm event such that the floor level of all buildings shall be a minimum of 500 mm above the 100 year storm event given standing water; and
- Provision shall be made within flow paths for peak 1 in 100 year storm events such as within swales, over flow and road reserves that the floor level of all buildings shall be a minimum of 300 mm above the 100 year storm event or road reserve.

5.1.2 Issues and constraints

The following general issues and constraints to implementation of drainage improvements and land amalgamation or redevelopment are identified:

- Dealing with private structures that have been constructed on public land;
- Requirements to maintain existing (non-approved) access after reinstatement of drainage flow paths;
- Possible contamination in material to be excavated to reinstate drainage flow paths;
- Possible geotechnical or stability issues associated with excavation of drainage works; and
- Requirement for upgrade of existing critical infrastructure, cost, disruption issues.

5.2 Recommended stormwater network upgrades

Stormwater network upgrades were identified from existing model outputs and identified encroachment impacts. Figure 9 and Figure 10 set out an assessment of areas with flood risk that can be used to prioritise stormwater network upgrades. This assessment marks areas ranked as high, medium and low encroachment onto drainage flow paths. Low indicates blockage to culverts or flow paths that could be rectified with maintenance. High means the drainage flow path is completely blocked. Medium is in between.

As much of the town's drainage flow path has some level of encroachment, improvement of the drainage system was sought by ensuring within the upgrade model all open drains were remediated by reestablishment of the original drain profile as discussed further in Section 5.2.1.

Improvement of drainage at roads that are flooded was also be considered as a high priority. Roads that overtop currently are a result of inadequate sizing or no cross drainage (culvert) provided. Locations requiring a new culvert or upgrade are identified in Section 5.2.2. Most road culvert crossing do not have any defined spillway or overland flow path that allows stormwater to drain in a controlled fashion. This is largely due to the shape of roads and continuity of kerbing. Where culverts are to be installed and upgraded is recommended the kerbing directly over the culvert crossing is removed so as to enable efficient overland via a defined overland flow path over the road should the culvert inlet surcharge.

Following open channel remediation, culvert upgrade and specification of new culverts the Dampier townsite flood impact is shown in Figure 17 and Figure 18 for the 5 year ARI and 100 year Ari respectively. The proposed upgrade ensure flood water are contained during the 5 year flood event within the drainage reserves and ensuring during 100 year ARI event water remains within the drainage and road reserves with limited to no impact on property.

5.2.1 Open drainage remediation

Reinstatement of the original drainage profile being a trapezoidal open channel maximum 1 in 3 side slope of depth of 1.5 m and maximum top width of 15 m is required in order to meet the required level of service.

Open channel should be surveyed to ensure positive grade from upstream to downstream with an appropriate tie to the culvert outlet invert achieved.

Locations of high velocity as shown in Figure 11 and Figure 12 as modelled for the existing scenario should be used as a reference to determine the potential needs for rock protection following drain remediation. Rock protection should be specified according the velocity exceeded. Open drain junctions and bends greater than 22.5° or locations of high turbulence such as culvert inlet or outlets should also provide an allowance for rock protection to minimise the impact of erosion.

5.2.2 Culvert improvement

The following culverts are identified as requiring upgrade or are noted as new culverts to service identified flow paths under roads.

Table 8 Culvert upgrades, locations and details

Name	Location	Description
New_336	Hampton Drive at the intersection of Lockyer Court	New Culvert 1 x 600mm diameter Class 4 RCP
New_318	Yule Court	New Culvert 1 x 600mm diameter Class 4 RCP
Link_319	Lawson Drive at the intersection of Lawson Drive	New Culvert 1 x 600mm diameter Class 4 RCP
New_334	Hampton Drive	New Culvert 600 x 1800 mm RBC (alternatively 4 x 600mm diameter Class 4 RCP)
New_335	Hampton Drive	New Culvert 600 x 1800 mm RBC (alternatively 4 x 600mm diameter Class 4 RCP)
New_323	West Avenue at the intersection of Dawson Road	New Culvert 600 x 900 mm RBC (alternatively 4 x 600mm diameter Class 4 RCP)
New_206	Hospital Drive	Additional culverts 2 x 600 x 1800 mm RBC (alternatively 7 x 600mm diameter Class 4 RCP)
New_332	Lawson Drive at the intersection of Robe Court	New Culvert 1 x 600mm diameter Class 4 RCP
New_333	Lawson Drive at the intersection of Robe Court	New Culvert 1 x 600mm diameter Class 4 RCP
Cul2_P1	Mirilya Court	Culvert upgraded to 1600mm x 1000mm RBC (or alternatively 2 x 1000mm diameter Class 4 RCP)

Cul4_P1	Maitland Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul5_P1	Nielsen Place	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul6_P1	Ashbourton Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul10_P1	Yannarie Court	Culvert upgraded to 1 x 600mm diameter Class 4 RCP
Cul18_P1	Huon Street	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul21_P1	East Avenue at the intersection of Wilkie Court	Culvert upgraded to 650mm x 450mm RBC (or alternatively 2 x 450mm diameter Class 4 RCP)
Cul25_P1	Patterson Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul29_P1	East Avenue and the intersection Hartog Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul34_P1	Dampier Drive at the intersection of Central Avenue	Culvert upgraded to 0mm x 0mm RBC (or alternatively x 0mm diameter Class 4 RCP)
Cul36_P1	Dampier Drive at the intersection of Prinsep Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul39_P1	Boolgeeda Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul40_P1	Boolgeeda Court	Culvert upgraded to 1 x 600mm diameter Class 4 RCP
Cul49_P1	Thyssen Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul57_P1	Berkley Court	Culvert upgraded to 1800mm x 600mm RBC (or alternatively 4 x 600mm diameter Class 4 RCP)
Cul59_P1	Hampton Drive at the intersection of Dawson Road	Culvert upgraded to 1 x 600mm diameter Class 4 RCP
Cul61_P1	Lot 62 Hardy Court	Culvert upgraded to 1 x 450mm diameter Class 4 RCP
Cul63_P1	Lyrdon Court	Culvert upgraded to 1 x 600mm diameter Class 4 RCP
Cul62_P1	West Avenue at intersection of Lyndon Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)

Cul64_P1	Ashbourne Court	Culvert upgraded to 1 x 600mm diameter Class 4 RCP
Cul65_P1	Hardy Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul67_P1	West Avenue at the intersection of Namatjira Road	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul68_P1	West Avenus at the intersection of Wooramel Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul69_P1	Wooramel Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)
Cul71_P1	Flinders Court	Culvert upgraded to 900mm x 600mm RBC (or alternatively 2 x 600mm diameter Class 4 RCP)

5.2.3 Cross over improvement

Existing cross over currently are not built informally resulting in some instance of complete blockage of the drainage reserve.

Following remediation of the drain profile property access (typically back of property access into garden and sheds) will require the installation of crossover. It is recommended the property access through a cross over is achieved through the provision of a typical cross over design requiring:

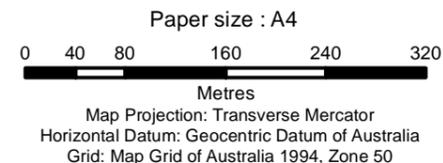
- The installation of a culvert minimum diameter equal to the downstream road culvert diameter;
- Installation of a Class 4 RCP for all crossovers;
- The requirement for cross over sag point corresponding to a location within the drain profile; and
- Finished cross over level below adjacent lot level.

A typical detail for cross over requirements is provided in Figure 19.



LEGEND

- Study Area
- Cadastre
- Block Boundary
- New Culvert
- Existing Culvert (no modification)
- Remediated Swale (15m top width)
- Upgrade Culvert



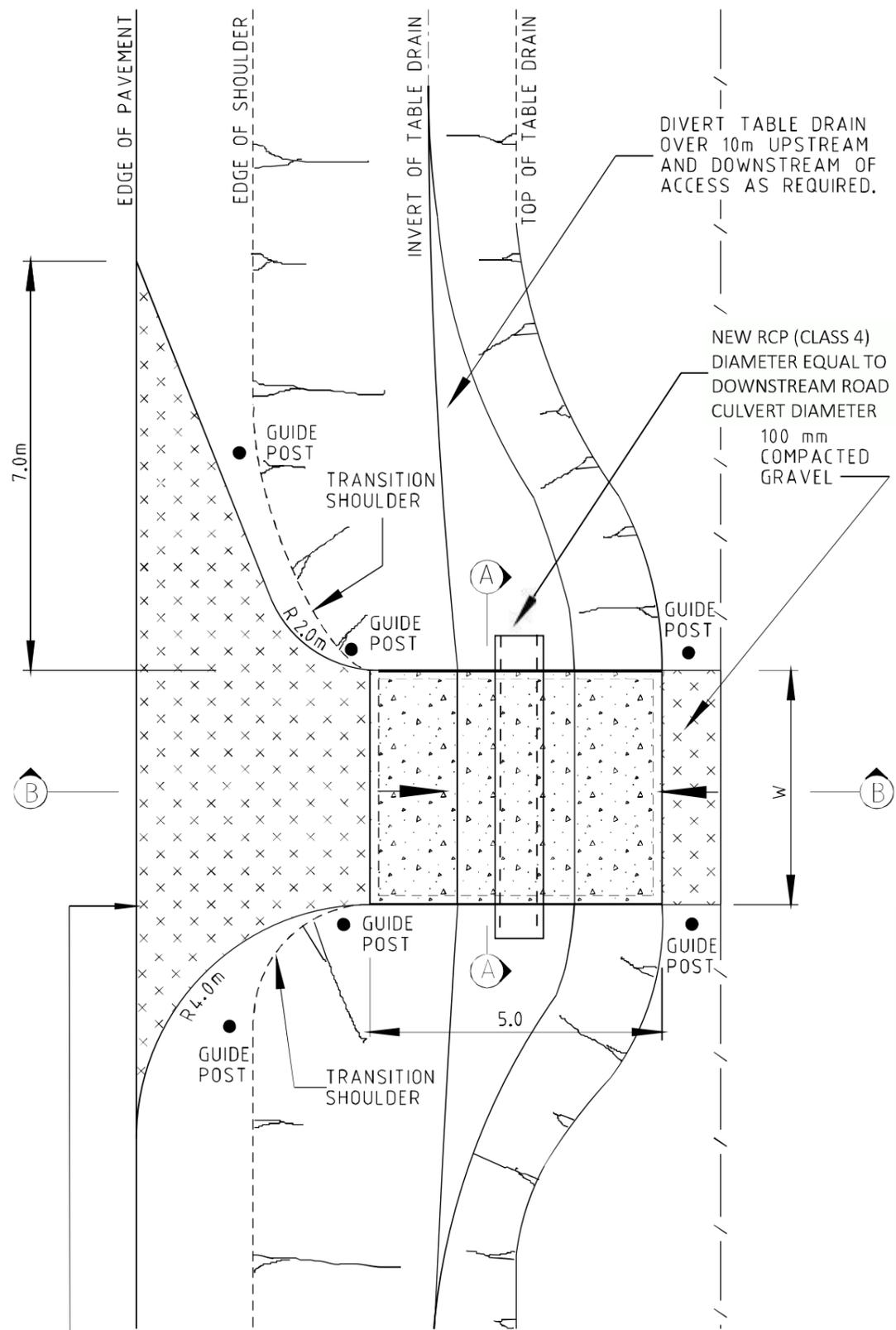
City of Karratha
Dampier Stormwater Management Study

Job Number | 61-31033
Revision | 0
Date | 06 Mar 2015

Culvert upgraded scenario

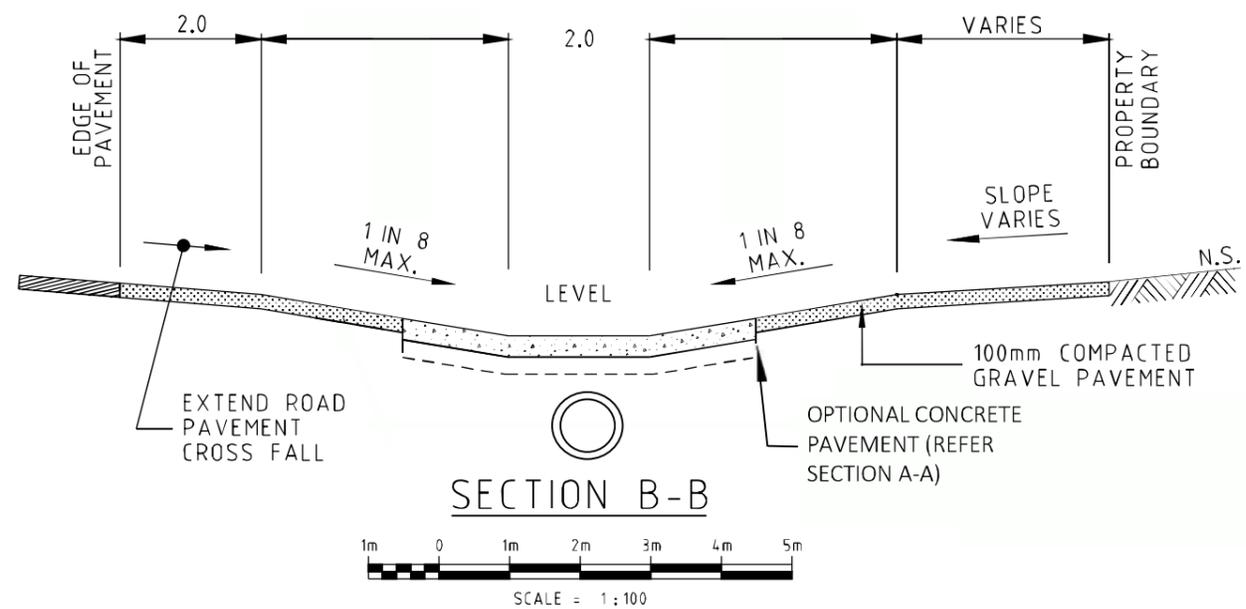
Figure 17

\\ghdnet.internal\ghd\AU\Perth\Projects\61\31033\GIS\Maps\Working\6131033_G015_Rev0_Fig17.mxd 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au
© 2015 . Whilst every care has been taken to prepare this map, GHD and Landgate make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Landgate - Cadastre - 20140805, Virtual Mosaic - 20140805, Road Names - 20140805, Encroachments - 20100817; GHD: Flood Depth (m) - 20140729, Block Boundary - 20140805. Created by: mczekej

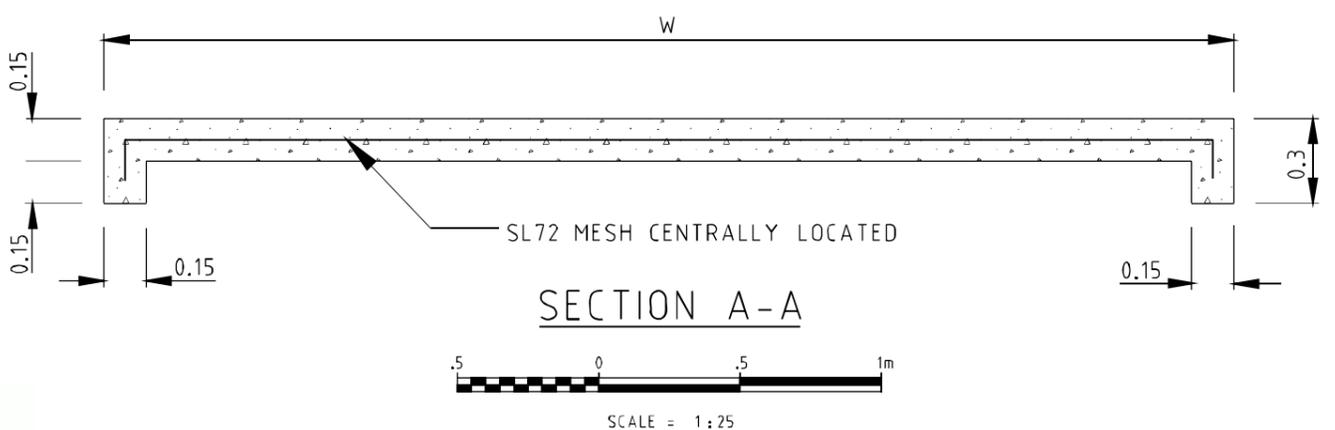


PLAN

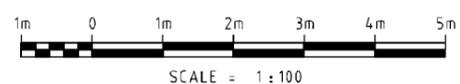
SAW CUT PAVEMENT ALONG EXISTING SEAL REFER NOTE 8



SECTION B-B



SECTION A-A



No.	DESCRIPTION	DATE	INIT.
1	ISSUED FOR REVISION		
AMENDMENTS			

DRAWN M.B. 2 MAR 2015	CHECKED
DATE	DATE
DESIGNED M.B. 2 MAR 2015	CHECKED M.B. 2 MAR 2015
DATE	DATE
DESIGN PROJECT LEADER	PROJECT OFFICER
	DATE

GHD CLIENTS | PEOPLE | PERFORMANCE

GHD House, 230 Adelaide Terrace Perth WA 6004
 PO Box Y3100 Perth WA 6832 Australia
 T 61 8 6222 8222 F 61 8 6222 8565
 E perma@ghd.com.au W www.ghd.com

CONCEPT DETAIL
DRAINAGE CROSS OVER

FIGURE 19

FILE No.	ASSET No.	SHEET No. OF	DRAWING No. 6131003-19	AMEND.	SHEET SIZE A3
----------	-----------	-----------------	---------------------------	--------	---------------------

5.2.4 Upgrade staging

Given the nature of the system defines being primarily a result of insufficient open channel capacity critical upgrade requirements are to re-established the open drainage system conveyance and available storage in order to minimise the impact of over land flow within property. As a result upgrade staging has been prioritised below:

- Removal of encroachments and reestablishment of drain profile complete within each drainage block working from downstream to upstream;
- Upgrade of culvert crossing working from downstream to upstream of the drainage network; and
- Installation of new culverts where required beginning from downstream to upstream.

Staging in general shall prioritise work at the downstream end of the drainage network. This minimises the associated risk of negatively impacting downstream locations by ensuring such location have the capacity to resolve the future flow requirements.

5.2.5 Cost estimate

The cost estimate for the upgrade of the full drainage system, to meet the shown flood depth are shown below in

Table 9 Overall cost estimate

Item	Quantities	Cost (Excl GST)
Preliminaries (traffic management, insurances, approvals, overhead etc)	1	\$658,000
Open Drainage (remediation including excavation to 15 m wide and depth to maximum 2 m)	15898 m	\$922,000
Culverts (including excavation, installation, pavement reinstatement)		
DN450	108 m	\$93,000
DN600	1140 m	\$1,423,000
Other (project management, contingency)	1	\$610,000
Total		\$3,706,000

The assumption built into development of this cost estimate are listed below

- Class A cost estimate based on initial concept design and unit cost based on typical North West Australia project examples assuming a 27% preliminaries cost and 25% other costs in line with recent examples completed in 2014;
- No provision for driveway crossovers;

- No realignment of existing services will be required; and
- Class 4 rubber ring concrete pipes are to be used with all pipes achieving at least 400 mm cover.

Further investigation into the relevancy of these assumptions will be required during detailed design. Cost estimate could vary by up to 50% from the estimate developed in this concept.

5.2.6 Upgrade timelines

Conceptual timelines for upgrade works have been provided below based on the upgrade priority, impact on downstream assets and balanced spend of approximately \$200,000 (in net present value terms) per financial year.

As a result three horizons were developed based on consultation with the City of Karratha being:

- Short term upgrade, identified as being high priority with drainage structures considered inadequate for design flows, resulting in flooding of nearby property. Short term upgrades have minimal impacts on downstream drainage assets and support upgrade of upstream drainage assets (0 to 5 year);
- Medium term upgrade, identified as being high priority with drainage structures considered inadequate for design flows, resulting in flooding of nearby property. Medium term upgrade have impacts on downstream drainage assets and require upgrade of downstream drainage assets before proceeding (5 to 10 years); and
- Long term upgrade, identified as being medium to low priority where the drainage assets are of sufficient capacity to continue to protect property from flooding (provided maintenance is undertaken) (10 to 20 years).

Indicative upgrades identified are summarised in Table 10 as horizon 1 or horizon 2. Location not considered within table 10 falls into the long term upgrade horizon. Culvert upgrades are identified only; it is assumed the required swale modification as described in Section 5.2.1 will be undertaken concurrently with the identified culvert upgrade, with adjacent swales both upstream and downstream of the culvert profiled to meet capacity requirements. Swale upgrades should extend to the nearest culvert.

Table 10 Indicative culverts upgrade timeline

Horizon	Upgrades	Location
1	Cul2_P1	Mirilya Court
	Cul4_P1	Maitland Court
	Cul5_P1	Nielsen Place
	Cul6_P1	Ashbourton Court
	New_334	Hampton Drive
	Cul59_P1	Hampton Drive at the intersection of Dawson Road
	New_336	Hampton Drive at the intersection of Lockyer Court
	New_206	Hospital Drive
2	Cul64_P1	Ashbourne Court
	Cul10_P1	Yannarie Court
	Cul21_P1	East Avenue at the intersection of Wilkie Court
	Cul29_P1	East Avenue and the intersection Hartog Court
	Cul34_P1	Dampier Drive at the intersection of Central Avenue

Cul36_P1	Dampier Drive at the intersection of Prinsep Court
Cul62_P1	West Avenue at intersection of Lyndon Court
Cul67_P1	West Avenue at the intersection of Namatjira Road
Cul68_P1	West Avenues at the intersection of Wooramel Court
New_323	West Avenue at the intersection of Dawson Road
Cul25_P1	Patterson Court

Flood management infrastructure/assets at risk from poor maintenance or where condition assessment of existing culvert show potential failure need to be identified and rectification works prioritised in conjunction with the nominated culvert upgrade timeline. Asset condition including the structural condition of the asset and the current maintenance condition (blockage) needs to be monitored with ongoing maintenance of the drainage system undertaken accordance with Section 6 of this document to maintain existing open drain and culvert capacity and reduce likelihood of blockage and the potential flooding of adjacent property.

5.3 Potential land amalgamation

The flood modelling indicated that there is potential for the City of Karratha to reclaim drainage reserves areas that are not required for drainage purposes and could be considered for redevelopment. These areas fall typically at the upper ends of catchments or above drainage pathways and flood-out zones as shown in Figure 20.

While not considered as part of this exercise further land may able to be reclaimed by constructing purpose built drain assets designed to minimise land take requirements such as pipe networks or controls which limit drainage through large undeveloped areas at the natural ground level.

Identification of this land does for potential amalgamation has not considered environmental, heritage, geotechnical issues or any potential servicing requirement (except for drainage) arising from the lands amalgamation.

Table 11 Summary of potential land amalgamation locations

Block	Summary of available land
Block 1	Drainage reserve along the eastern edge of the block along Central Avenue remains largely underutilised. These areas form the upstream of the catchment, with modelling indicating no ponding of stormwater during a 100 year ARI event.
Block 2	Most of the drainage reserves in Block 2 are being utilised in a 100 year ARI event, with the exception of the north west corner between Pinderi Crescent and Portland Crescent.
Block 3	Currently underutilised land for drainage reserve is located in the north western area of the block. However, if the critical encroachments impacting the draining system are rectified, it is likely that this drainage reserve will become useful in conveying and storing excessive stormwater flow. With this in consideration, it is still anticipated four lots currently reserved for drainage have the potential to be reclaimed at either end of Elliot Crescent.
Block 4a	There are portions of the drainage reserve along the north edge of the block along Church Road which remain underutilised. The area bound by Gascoyne Crescent and Church Road is largely redundant, however this area may be able to provide flood relief for the areas to the north east with the construction of culverts beneath the nearby intersection.

Block 4b	Unused areas of drainage reserve have been identified at the eastern end of Lockyer Crescent, as well as the south west corner of the block bounded by Hill Road and Hampton Drive.
Block 5a	The south eastern corner of block 5a currently has underutilised drainage reserve surrounding the intersection of Namatjira Road and Dampier Drive. All other drainage reserves are anticipated to experience some level of inundation during the 100 year ARI event.
Block 5b	This block has large areas currently allocated as drainage reserve which are not expected to experience any inundations during the 100 year event. Areas along the southern and eastern boundaries of the block have been identified as redundant drainage reserves.
Block 6	The eastern portion of this block is predicted to remain predominantly unaffected by floodwater levels. Areas allocated for drainage reserves along the eastern boundary are therefore considered to be redundant and potentially may be reclaimed.

5.4 Future development

Future development proposed for the townsite expansion is likely to impact on the hydraulic capacity of drainage control points such as road crossings, culverts and open drains. It is important that new developments are designed to ensure post development flows do not exceed pre development flows so additional pressures are not placed on these drainage points within the network.

Further, a drainage guiding document such as a District Water Management Strategy or Local Water Management Strategy is recommended for the Dampier townsite to provide drainage design recommendations that will ensure the responsible and proper management of stormwater should development proceed.

To assist in future land use planning, the following recommendations for the management of stormwater have been developed for the Dampier townsite and are detailed in the following sections.

5.4.1 General strategic approach

It is recommended that stormwater is managed upon redevelopment of the Dampier townsite using both structural and planning measures.

Structural

There should be appropriate design, construction and maintenance of critical infrastructure to support the additional impervious area. This includes:

- Identifying critical areas at risk of flooding, and definition overland flow routes to allow free drainage;
- Identify typical mitigation measures to manage risk of flooding;
- Design of appropriate drainage structures; and
- Specification of asset management requirements above the needs in this document to support larger catchment area.

Flood design standards need to be standardised. In accordance with current stormwater best practice (DoW 2008), it is recommended that the:

- 1-year ARI flow is managed for stormwater quality treatment;
- 5-year ARI flow is managed for conveyance at critical infrastructure; and
- 100-year ARI flooding is managed for protection of dwellings, critical infrastructure and emergency access.

Planning

An adaptive, risk based planning approach should be adopted. This involves planning, including undertaking design studies and modelling assessments, implementation, monitoring and updating of planning instruments and design methodologies over time as required to support redevelopment.

Initially, the City should undertake modelling and design studies for effective management of existing, future and residual flood risk based on the indented redevelopment.

The City should review development, building and land use controls in the planning scheme to support existing and future flood risk based on the indented redevelopment.

The planning scheme should provide for:

- Flood free access for all development; and
- Control of filling within the overland flowpaths, waterway corridors and floodplains, in particular with regard to cumulative impact.

Community education is recommended, particularly through collaborative partnerships to empower the community to maintain their own drainage reserve (keep it clean) to reduce damage to their properties during flood events.

5.4.2 Water quantity management

The post development annual discharge volumes and peak flows for the 100 yr ARI event are to be conveyed to the coastal plain by overland flow. To achieve the above principle the following criteria are recommended to be applied:

- Flood Management* - Manage the catchment runoff for up to the 1 in 100 year ARI event in the development area, unless otherwise indicated in an approved strategy or as negotiated with the relevant drainage service provider.
- Protect infrastructure and assets from inundation and flooding* - Urban development usually results in the removal of significant areas of vegetation and replacement of permeable areas with buildings, roads and paved areas. This results in increased volumes and flows of surface runoff, which has the potential to cause flooding and inundation.

5.4.3 Water quality management

Maintain surface and groundwater quality at pre-development levels and if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub catchment in which the development is located. To achieve the above principle the following criteria will be applied:

- Consideration for stormwater treatment should be given in areas at higher risk of contamination discharge (i.e. industrial and commercial areas) in the form of stormwater treatment or detention areas prior to discharge to the open drain network.
- Ensure that all runoff contained in the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the *Stormwater management manual* (DoW, 2004-2007) noting options considered appropriate for the North West of Australia.

6. Asset Management and Maintenance

The objective of this asset management and maintenance requirements for Dampier was to identify the key assets of the drainage network and provide management recommendations that will ensure the future operational efficiency of the drainage network through appropriate asset management and in particular its maintenance needs.

In the case of the Dampier townsite drainage network, the drainage infrastructure and drainage reserves represent assets, whilst business objectives are defined by the effective operation of the system.

6.1 Dampier Drainage Network Assets

The assessment of the Dampier drainage network identified the key drainage design features considered to be drainage assets and included the following:

- Kerbed roads;
- Kerb breaks;
- Un-kerbed roads;
- Open drains;
- Drainage reserves;
- Culverts / headwalls; and
- Vegetated POS / swales.

Particularly with respect to open drains, there was some variability with regard to their size. In order to provide a maintenance framework that is easy to follow, these drainage channels were grouped into three categories:

- Primary drain – large arterial drainage channels that receive flows from multiple channels and discharge to the away from the townsite;
- Secondary drain – medium sized drainage channels that convey flows from a small number of channels and discharge to primary drains; and
- Tertiary drain – small drainage channels located at the top of a catchment and convey low flows discharged from roads to secondary drains.

The assessment of the Dampier drainage network identified the key drainage design features considered to be drainage assets and included the following quantities:

Table 12 Drainage asset details

Asset Type	Quantity
Culverts	2352 m (82 unique culverts)
Open Drains	15898 m

6.2 Risk management

The identification, assessment and control of risks associated with the use of any asset including drainage are an important consideration in determining how the asset should be managed. The objectives of this risk management is to

- Outline the process which by the City will manage risk within this asset for the Dampier townsite, so that all risk can be identified in a consistent manner;
- Identify operational risk at a broad level; and
- Prioritise the risks to identify the highest risks that should be addressed in the short to medium term.

The key risk management criteria relating the City's drainage assets identified for the Dampier townsite include:

- Public health and safety;
- Financial risk (escalating costs through deterioration);
- Property damage;
- Legal compliance;
- Environmental compliance; and
- Reputation, political and public relations.

As part of the ongoing operating procedures the City of Karratha should undertake a review of the potential risks listed above. Drainage risks can be identified through a number of resources such as:

- Inspection;
- Industry information and trends; and
- Public and incident reports.

Following the identification of risk the likelihood and consequence of the events and other risk should be determined in line with the international standards on risk management. Table 13 summarises key identified risks, recommended treatment strategy and the residual risk for the Dampier townsite drainage system.

Table 13 Drainage risk register

Risk Details	Likelihood	Consequence	Treatment Strategy
On going deterioration of drainage assets	Possible	Medium	Ongoing maintenance and monitoring of drainage assets Condition survey of drainage assets
Accident caused by drainage infrastructure	Rare	Low	Ongoing maintenance and monitoring of drainage assets
Blockages / under performance of drainage assets	Possible	Medium	Annual cleaning by works department in accordance with recommend

			maintenance strategy
Recommended improvements not fully implemented	Possible	Medium	Dampier works staging identified and budget assigned for asset replacement and upgrade as required

6.3 Asset Capacity and performance

As part of this report GHD has undertaken a review of drainage catchments to identify system deficiencies and provide upgrades that could be undertaken to reduce the instance of flooding and the efficiency of stormwater disposal. The study has also identified opportunities to rationalise and combine drainage reserves to free excess land for other purposes.

Locations where deficiencies in service performance were identified are summarised below.

Table 14 Asset upgrade

Work required	Location
Drain renewal	All open drains
New culvert	Hampton Drive at the intersection of Lockyer Court, Yule Court, Lawson Drive at the intersection of Lawson Drive, Hampton Drive, West Avenue at the intersection of Dawson Road and Hospital Drive
Upgraded culvert	Mirilya Court, Maitland Court, Nielsen Place, Ashbourton Court, Yannarie Court, Huon Street, East Avenue at the intersection of Wilkie Court, Patterson Court, East Avenue and the intersection Hartog Court, Dampier Drive at the intersection of Central Avenue, Dampier Drive at the intersection of Prinsep Court, Boolgeeda Court, Thyssen Court, Berkley Court, Hampton Drive at the intersection of Dawson Road, Lot 62 Hardy Court, Lyrdon Court, West Avenue at intersection of Lyndon Court, Ashbourne Court, Hardy Court, West Avenue at the intersection of Namatjira Road, West Avenue at the intersection of Wooramel Court, Wooramel Court and Flinders Court

This report identified 32 recommendations with the highest priority being the reestablishment of the swale to original design profile of 15 m top drain width.

As the current life span of a number of drainage assets within the townsite is nearing full design life, therefore upgrade through culvert renewing programs (in line with the drainage system upgrade recommendations made in Section 5.2) provides the most suitable mechanism for culvert upgrade.

Section 6.4.1 summaries the impact of asset age in greater detail.

6.3.1 Asset selection

It is recommended the City consider cost benefit analysis in each asset carefully in particular in relation to the selection of culvert material. While upfront costs associated for reinforced concrete pipes are most significant (approximately 40%) then corrugated steel pipes, similar installation costs, lower ongoing maintenance costs and longer design life result within the coastal environment (reduced replacement time) results in an overall cost benefit for the reinforced concrete pipe.

Therefore it is recommend that the City consider the eventual phase out of all corrugated steel pipes within Dampier due to the limited design life associated with such a product and the greater accessibility of reinforced concrete pipes in north west Australia.

6.4 Life cycle management

The lifecycle management details how the City can manage and operate the assets while optimising the life cycle costs.

6.4.1 Drainage Network Condition Summary

The drainage network is constructed consistently throughout the townsite featuring open drains, culverts and detention areas as detailed previously.

The drainage condition assessment undertaken in 2010 and 2014 through site visits identified the drainage network is in poor condition with a number of drainage issues characterised. The main issues identified within the drainage network included drainage channels that required reestablishment through either encroachment or long term sedimentation, overgrown vegetation requiring maintenance and a number of culverts that are partially or fully blocked by sediment and debris.

6.4.2 Asset age

The age profile for the drainage infrastructure is based on As-constructed drawings and survey information supplied by the City. The year drainage assets first appear within the As-constructed drawings from 1960 is assigned as the asset age. It is evident that a majority of the drainage construction was undertaken 50 years ago.

The useful life of assets is represented in the below table, derived from typical life span identified by relevant Australian Standards.

Table 15 Asset useful life

Asset Category	Useful Life
Pipes and pits (concrete)	100 years
Pipe (corrugated steel)	50 years
Open drain / swale	100 years

The open drainage built within the Dampier town site should be performing adequately given its 50 years into its estimated 100 year design life. Modelling does show the sections of the open drainage are inadequate having lost capacity due to encroachment, sedimentation or increased channel roughness. Maintaining the drains ability to “self-clean” (maintain a suitable velocity to avoid siltation) is critical in achieving the expected design life for the drainage system. Refer to Section 6.4.3 for further details on the proposed asset management strategies proposed.

Given a number of culverts built are corrugated steel (43 culverts) which are approaching the end of their recommended useful design life the instances of asset replacement due to poor conditions or failure are expected to increase. The City has identified within the 2014 financial year two corrugated steel pipes culverts were replaced due to failure. The City should consider the culvert renewal as an opportunity to undertake the required culvert upgrades and minimise the duplicate costs potentially associated with initial replacement followed by future upgrade. Refer to Section 6.3 for further details on the proposed asset renewal strategies proposed.

It is recommend the City should consider the eventual phase out of all corrugated steel pipes within Dampier due to the limited design life associated with such a product given the impacts of the coastal environment in reducing that design life and the greater accessibility of reinforced concrete pipes in north west Australia.

6.4.3 Dampier Drainage Network Maintenance

The maintenance of the Dampier townsite drainage network relates to the maintenance of the drainage network assets including open drains, culverts, basins, safety fences and vegetated public open space. Of the drainage assets, the drainage reserves and drainage channels comprise approximately 50 % of the entire drainage network, which also includes the extensive road network within the townsite.

The intention with respect to maintenance of the drainage reserves and drainage channels was to use existing maps and the supplied GIS file detailing the classification of each drain reach together with maintenance recommendations developed herein to enable on ground inspections and maintenance to be carried out. The details regarding the recommended maintenance schedule are provided below.

This schedule recommends maintenance for key drainage network components and details the following:

- Requirements for immediate maintenance – highlights any immediate deficiencies within the drainage network that are likely to significantly impinge on flows;
- Inspection timing – provides recommended inspection intervals;
- Inspections type – outlines what issues to consider during the site inspection;
- Maintenance requirements – provides a general description of remediation options for drainage improvement.

The details associated with the above maintenance schedules are presented below in Table 16.

Table 16 Drainage network maintenance reference table

Immediate Maintenance	Inspection Timing	Inspection Type	Maintenance
N – none required	1 – After major events	1 – Inspection for damages i.e. structural damages to culverts	1 – Repair of damages i.e. replace culvert
Y – immediate maintenance required	2 – Every 12 months	2 – Inspection for blockages / sedimentation i.e. culvert blockages; sedimentation of drains	2 – Removal of blockages / sediment
	3 – Every 2 years	3 – Inspection for foreign items i.e. dumped goods	3 – Removal of foreign items

	4 – Every 5 years	4 – Inspection for overgrown vegetation	4 – Vegetation maintenance – cover maintained < 100 mm
			5 – Vegetation maintenance – cover maintained (< 300 mm with the exception of established trees

Based on the guiding information provided in Table 16, a maintenance schedule was developed that provides a simple approach that will enable City staff to maintain an efficient drainage network. The Karratha drainage network, whilst straightforward in its design, contains approximately 300 drain reaches. Consequently, it was necessary to develop a maintenance schedule that was not specific to each individual drainage asset, but rather specific to each drainage asset type. The Karratha drainage maintenance schedule is linked with the reference information in Table 16 and is presented below in Table 17.

Table 17 Karratha drainage network maintenance schedule

Drainage Asset	Immediate Maintenance	Inspection Timing	Inspection Type	Maintenance
Kerbed roads	N	4	1	1
Kerb breaks	N	2	1, 2	1, 2
Primary drain	Y	1, 2	2, 3, 4	2, 3, 4
Secondary drain	Y	1, 2	2, 3, 4	2, 3, 4
Tertiary drain	Y	2	2, 3, 4	2, 3, 4
Drainage reserve	Y	3	4	5
Culverts / headwall	Y	1, 2	1, 2	1, 2
Vegetated POS / Swale	N	3	2, 4	2, 4

6.4.4 Vegetation Maintenance

Vegetation maintenance is referred to throughout Table 17. Maintaining a level of vegetation cover in constructed features such as drainage reserves is important for increasing soil stabilisation and reducing erosion.

It was noted during the drainage inspection that some drainage channels displayed evidence of bank erosion. These drainage channels were predominantly bare, with no visible vegetation cover. Vegetation can act to inhibit stormwater flows and potentially lead to flooding in serious cases; however a balance of vegetation cover is required to ensure the optimal drainage system performance.

It is therefore recommended that appropriate vegetation be established in drainage channels and drainage reserves where there currently is none.

Established drainage channels are covered in native grasses, whilst small shrubs and trees occupy the drainage reserves. Given established drainage channels showed no signs of serious erosion, this level of vegetation cover is considered suitable in newly constructed drainage channels and reserves. GHDs Ecology team were consulted to identify a list of suitable groundcovers that were considered appropriate for establishment in Dampier's drainage reserves (Table 18).

Table 18 Recommended species for establishment in drainage reserves

Category	Species	Habitat	Image
Trees	<i>Corymbia hamersleyana</i> – 3 – 10 m;	Drainage lines	 <p><i>Corymbia hamersleyana</i> Photo: J. English & S. Wajon</p>
	<i>Terminalia canescens</i> (Joolal); 1 – 10 m	Variety of habitats	 <p><i>Terminalia canescens</i> Photos: J.R. Dixon & E. Wajon</p>
Shrubs	<i>Acacia ancistrocarpa</i> (Fitzroy Wattle); 1 – 3 m	Soft soils within creek lines	 <p><i>Acacia ancistrocarpa</i> Photo: B.R. Maslin</p>
Grasses	<i>Cymbopogon ambiguus</i> (scent grass)	Variety of habitats	 <p><i>Cymbopogon ambiguus</i> Photos: E. Davis & J. English</p>
	<i>Themeda triandra</i>	Variety of habitats	 <p><i>Themeda triandra</i> Photos: V. Ball & J. Siveton</p>

7. References

BoM (2011). Climate statistics. www.bom.gov.au.

Central Engineering Services (1968).

DoW (2008). Better Urban Water Management. State of Western Australia, West Australian Planning Commission: Perth.

GHD (2006). Dampier Stormwater Drainage Study. Engineering Report Number 2006/915. Unpublished report prepared for Pilbara Iron by GHD.

GHD (2010). Dampier Drainage Review. Unpublished report prepared for Rio Tinto Iron Ore by GHD.

JDA (2012). Dampier Coastal Vulnerability Study.

Scott and Furphy Engineers (1982). Report on Preliminary Inspection of the Stormwater Drainage System at Dampier Western Australia.

City of Karratha (2013). Draft Dampier Townsite Redevelopment and Revitalisation Strategy.

Appendices

Appendix A – Culvert Information

I HEREBY CERTIFY THAT THE DRAINAGE SYSTEM OF THIS PLAN OF DAMPIER DAMPIER OVAL IS IN ACCORDANCE WITH THE REQUIREMENTS OF APPROVAL NUMBERS 4, 5, 6 AND 9 OF THE SECOND, THIRD AND FIFTH REGULATIONS UNDER THE WATER SUPPLY ACT, 1904. DATED 21/1/88.

ISSUED BY: *[Signature]*
CHECKED BY: *[Signature]*
DATE: 21/1/88

LEGEND

- EXISTING STORMWATER PIPE
- PROPOSED STORMWATER PIPE
- ALIGNMENT OF OVERLAND FLOW
- DEPTH AND LEVEL OF WATER BODIED UP AT THE POINT OF OVERFLOW FOR THE YEAR FREQUENCY STORM AND FOR 50% GREATER INTENSITY THAN ONCE IN THE YEAR STORM.
- CALCULATED CHANNEL AND PIPE FLOWS (IN LITERS PER SECOND) RESULTING FROM THE YEAR FREQUENCY STORM AND 50% GREATER INTENSITY THAN ONCE IN THE YEAR STORM.
- PROPOSED CHANNEL OR CUT-OFF DRAIN STORM RUN OFF FLOWS OVER ROAD.
- USE THAT REQUIRE BREAKING/PILING TO REAR ACCESS.
- SEE:
 - ① DRAINAGE BASINMENT
 - ② WATER OR SURFACE ELEVATION
 - ③ OVERHEAD ELECTRICITY EQUIPMENT
 - ④ UNDERGROUND ELECTRICITY EQUIPMENT

2209-03-3	2209-03-4	2209-03-5
2209-03-6	2209-03-7	

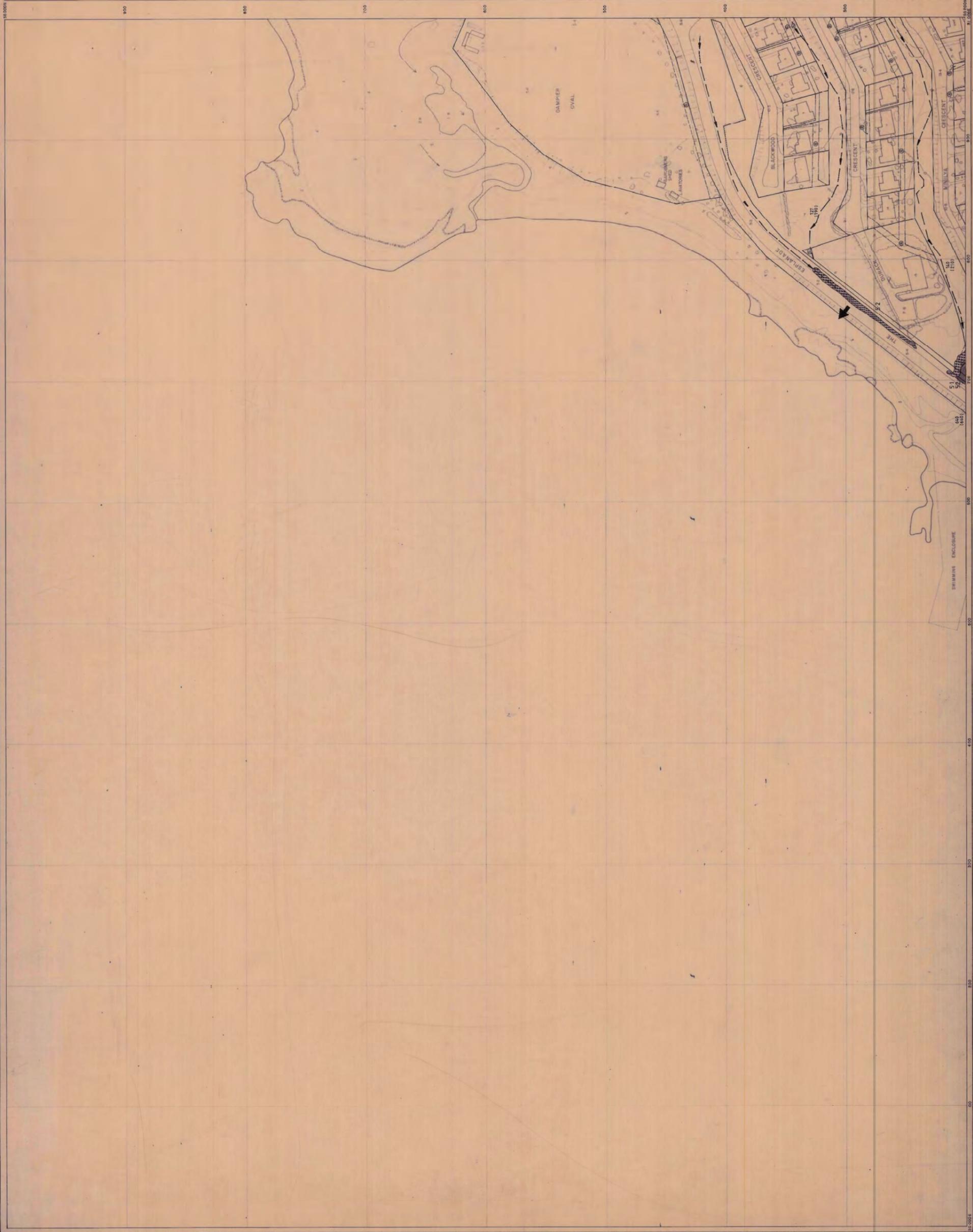
DATA TAKEN FOR SHIRE OF ROBEURNE ON 15.5.90

H.I. D&E. N^o 5-502215

HAMERSLEY IRON PTY. LTD.
DAMPIER DRAINAGE ANALYSIS
FLOWS AND ADDITIONAL WORKS

SCALE 1:1000
ISSUED BY: HARRIS T.J.
CHECKED BY: *[Signature]*

SCOTT & PUPPY PTY. LTD.
CONSULTING ENGINEERS
47 ORD STREET, WEST PERTH, WA, 6005
TELEPHONE 321 0582
AND 47 WILSONS CREEK, PERTH
WESTERN AUSTRALIA



"I HEREBY CERTIFY THAT THE DRAINAGE SYSTEM IS THAT SHOWN ON DRAWING DAMPER DRAINAGE ANALYSIS AND ADDITIONAL WORKS AND THAT THE SAME HAS BEEN DESIGNED AND CONSTRUCTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE ACT AND THE REGULATIONS MADE THEREUNDER AND IN ACCORDANCE WITH THE REQUIREMENTS OF THE ACT AND THE REGULATIONS MADE THEREUNDER AND IN ACCORDANCE WITH THE REQUIREMENTS OF THE ACT AND THE REGULATIONS MADE THEREUNDER."

SIGNED: *[Signature]*
DATE: *[Date]*

LEGEND

- EXISTING STORMWATER PIPE
- PROPOSED STORMWATER PIPE
- ALIGNMENT OF OVERLAND FLOW
- EXISTING AND LEVEL OF WATER BACKED UP AT CURBSIDE OR PONDING, FOR ONE IN FIVE YEAR PROBABILITY STORM AND FOR FIVE YEAR STORM.
- CALCULATED CHANNEL AND PIPE FLOWS ONE IN FIVE YEAR STORM AND ONE IN FIVE YEAR STORM AND ONE IN FIVE YEAR STORM AND ONE IN FIVE YEAR STORM.
- PROPOSED CHANNEL OR CUT OFF BRUSH
- STORM RUN OFF FLOWS OVER ROAD
- LOTS THAT REQUIRE BRUSHING/PILING TO REAR ACCESS.
- ALL
- DRAINAGE EASEMENT
- WATER OR SEWERAGE EASEMENT
- OVERHEAD ELECTRICITY EASEMENT
- UNDERGROUND ELECTRICITY EASEMENT

2209-03-2	2209-03-3
2209-03-4	2209-03-5
2209-03-6	2209-03-7

SEPIA TAKEN FOR SALES OF ROBEORNE ON 18-6-96

H.I. DRG. N° G-002-978
HAMERSLEY IRON PTY. LTD.

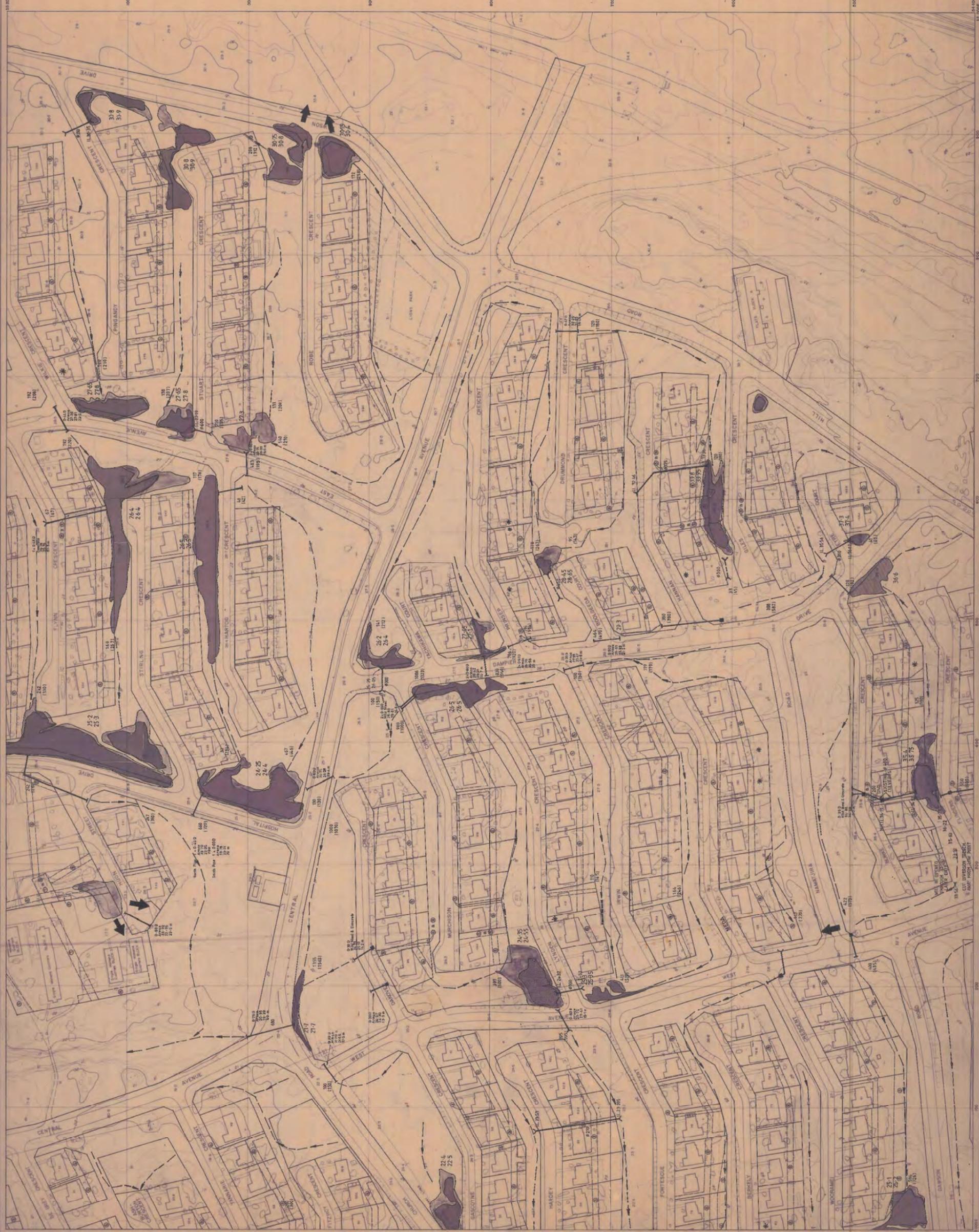
DAMPER DRAINAGE ANALYSIS
FLOWS AND ADDITIONAL WORKS

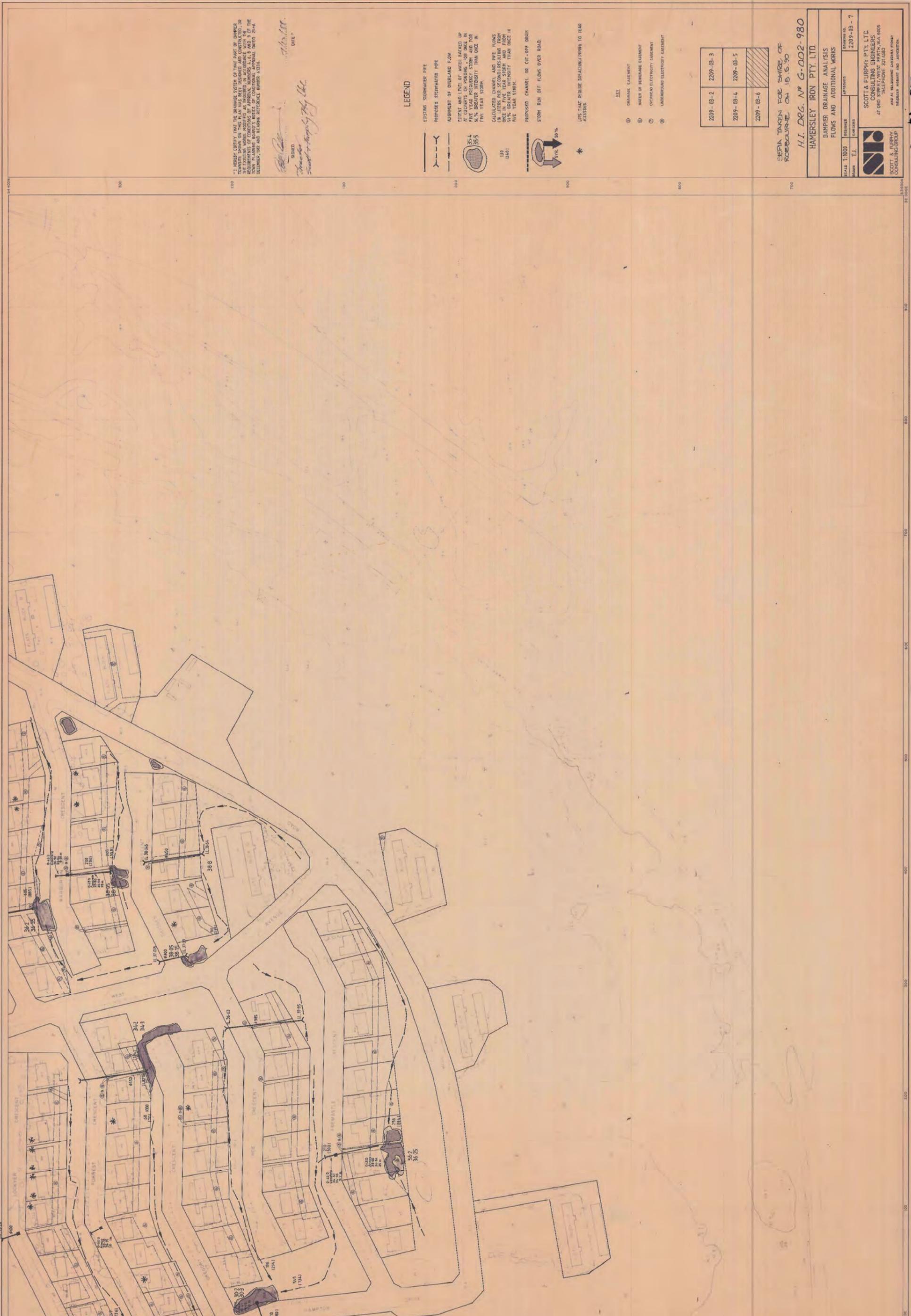
SCALE 1:1000

APPROVED

SCOTT & FURPHY GROUP

SCOTT & FURPHY PTY. LTD.
CONSULTING ENGINEERS
47 ORD STREET, WEST PERTH, W.A. 6005
AND 47 HANOVER ST. CANBERRA, ACT
NURSING, INTERIOR AND LANDSCAPE





I HEREBY CERTIFY THAT THE DRAINAGE SYSTEM OF THAT PART OF DAMPER
 WHICH IS SHOWN ON THIS PLAN AND WHICH IS TO BE CONSTRUCTED, OR
 THE EXISTING WORK WHICH IS TO BE RECONSTRUCTED, IS IN ACCORDANCE
 WITH THE REQUIREMENTS OF APPROVAL NUMBERS 1, 2, 3, 4, 5, 6, 7, 8, AND 9 OF THE
 DRAINAGE ACT, 1908, AND THE REGULATIONS MADE THEREUNDER, AND THAT THE
 EXISTING WORK AND REPAIRS REFERRED TO IN PARAGRAPH 1333A.

SIGNED
 [Signature]
 DATE

LEGEND

- EXISTING STEAMWATER PIPE
- PROPOSED STEAMWATER PIPE
- ALIGNMENT OF OVERLAND FLOW
- EXTENT AND LEVEL OF WATER BACKED UP AT CURBS OF PARADES, OR ONCE IN PARADES, IN FIVE YEAR STORM, OR ONCE IN FIVE YEAR STORM.
- UNCALCULATED CHANNEL AND ONE INCHES IN LITERS PER SECOND (RESISTANCE FROM ONCE IN FIVE YEAR STORM AND FROM ONCE IN FIVE YEAR STORM) THAT ONCE IN FIVE YEAR STORM.
- PROPOSED CHANNEL OR CUT-OFF DRAIN
- STORM RUN OFF FLOWS OVER ROAD
- LOTS THAT REQUIRE BRACKING/PURIN TO REAR ACCESS
- SEWER ELEMENT
- WATER OR SEWERAGE ELEMENT
- OVERHEAD ELECTRICITY ELEMENT
- UNDERGROUND ELECTRICITY ELEMENT

2209-03-2	2209-03-3
2209-03-4	2209-03-5
2209-03-6	

SEPIA TAKEN FOR SHIRE OF ROBEURNE ON 16.5.90

H.I. DRG. N° G-002-980
 HAMERSLEY IRON PTY. LTD.

DAMPER DRAINAGE ANALYSIS
 FLOWS AND ADDITIONAL WORKS

SCALE 1:500

DATE 11/11/90

PROJECT NO. 2209-03-7

SCOTT & FURPHY PTY. LTD.
 CONSULTING ENGINEERS
 47 ORD STREET, WEST PERTH, W.A. 6005
 TELEPHONE 221 0582

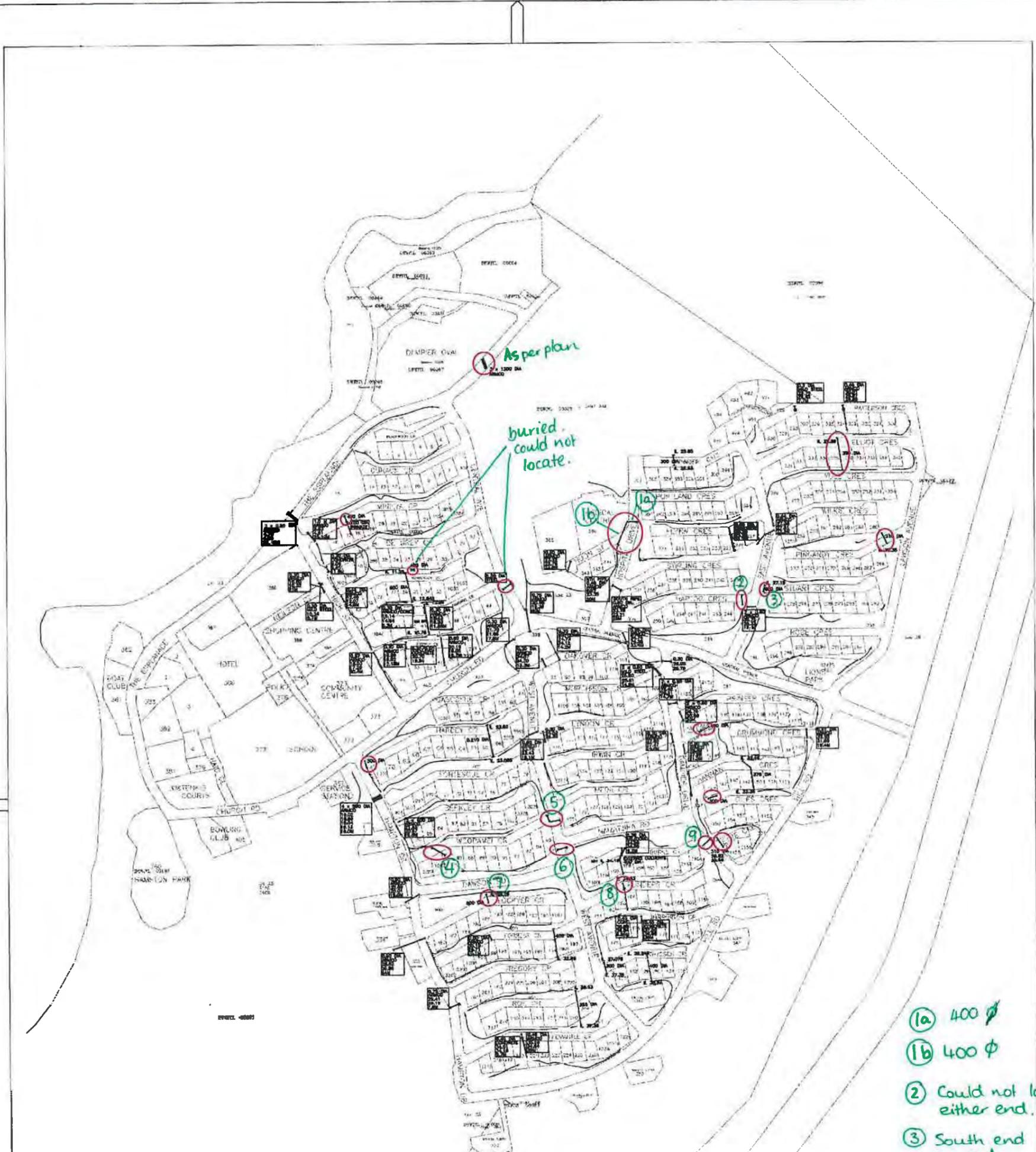
APP. IN RESUBMISSION CANTONMENT GROUP



ALL INFORMATION TO BE VERIFIED ON SITE

CULVERT INFORMATION TAKEN FROM
 HAMERSLEY IRON PTY LTD
 DAMPIER DRAINAGE ANALYSIS
 FLOWS & ADDITIONAL WORKS
 DWG No. D-01-02A TO D-01-07A
 CABINET 3 COPY MADE NOVEMBER 2002

SURVEY BOOKS	DATUM	DES CALC	NORTH POINT N	 SHIRE OF ROEBOURNE	DAMPPIER TOWNSITE DRAINAGE CULVERTS LOCATION PLAN AND DETAILS		
	DES REF				PROJECT FILE GDESIGN/DAMPPIER CULVERTS/LOCPLAN	SCALE 1:2500	DRAWING NUMBER E:259:001
		G.C. CHD					



- ①a 400φ
 - ①b 400φ
 - ② Could not locate either end.
 - ③ South end buried.
 - ④ 300φ North end blocked
 - ⑤ Wooramel: 600 wide box outlet, 400φ inlet.
West ave: 400φ inlet.
 - ⑥ 600φ
 - ⑦ As per plan
 - ⑧ Flinders: 600φ
 - ⑨ Burke: 400φ
Eyre: couldn't locate
- All others as per diameter on plan.

ALL INFORMATION TO BE VERIFIED ON SITE

CULVERT INFORMATION TAKEN FROM
HAMERSLEY IRON PTY LTD
DAMPER DRAINAGE ANALYSIS
FLOWS & ADDITIONAL WORKS
DWG No. D-01-02A TO D-01-07A
CABINET 3 COPY MADE NOVEMBER 2002

SURVEY POINTS	DATUM	DES. CALC.	NORTH POINT N	SHIRE OF ROEBOURNE	DAMPER TOWNSITE DRAINAGE CULVERTS LOCATION PLAN AND DETAILS	
	UIC REF				SCALE 1:2500	DRAWING NUMBER E:259:001

Appendix B - Site visit photos (2014)



Photo ref. DSC04525

Lot 15 Durack Crescent Culvert



Photo ref. DSC04529

Lot 15 Durack Crescent



Photo ref. DSC04531

Lot 15 Durack Crescent Culvert



Photo ref. DSC04516

Lot 33 Ashburton Crescent



Photo ref. DSC04517

Lot 53 Fitzroy Crescent



Photo ref. DSC04552

Lot 59 Gascoyne Crescent



Photo ref. DSC04570

Lot 68 Hardey Crescent



Photo ref. DSC04555

Lot 2071 Fortesque Crescent



Photo ref. DSC04556

Lot 1,071 Fortesque Crescent



Photo ref. DSC04560

Lot 1,079 Berkeley Crescent



Photo ref. DSC04571

Lot 184 Lockyer Crescent



Photo ref. DSC04572

Lot 185 Lockyer Crescent



Photo ref. DSC04573

Lot 186 Lockyer Crescent



Photo ref. DSC04574

Lot 186 Lockyer Crescent



Photo ref. DSC04582

Lot 195 Forrest Crescent



Photo ref. DSC04580

Lot 3,200 Forrest Crescent



Photo ref. DSC04577

Lot 202 Gregory Crescent



Photo ref. DSC04579

Lot 216 Roe Crescent



Photo ref. DSC04596

Lot 101 Oakover Crescent



Photo ref. DSC04597

Lot 111 Lyndon Crescent



Photo ref. DSC04598

Lot 1,116 Lyndon Crescent



Photo ref. DSC04601

Lot 124 Irwin Crescent



Photo ref. DSC04590

Lot 158 Burke Crescent



Photo ref. DSC04588

Lot 2160 Burke Crescent



Photo ref. DSC04587

Lot 173 Warburton Crescent



Photo ref. DSC04586

Lot 174 Warburton Crescent

www.ghd.com

