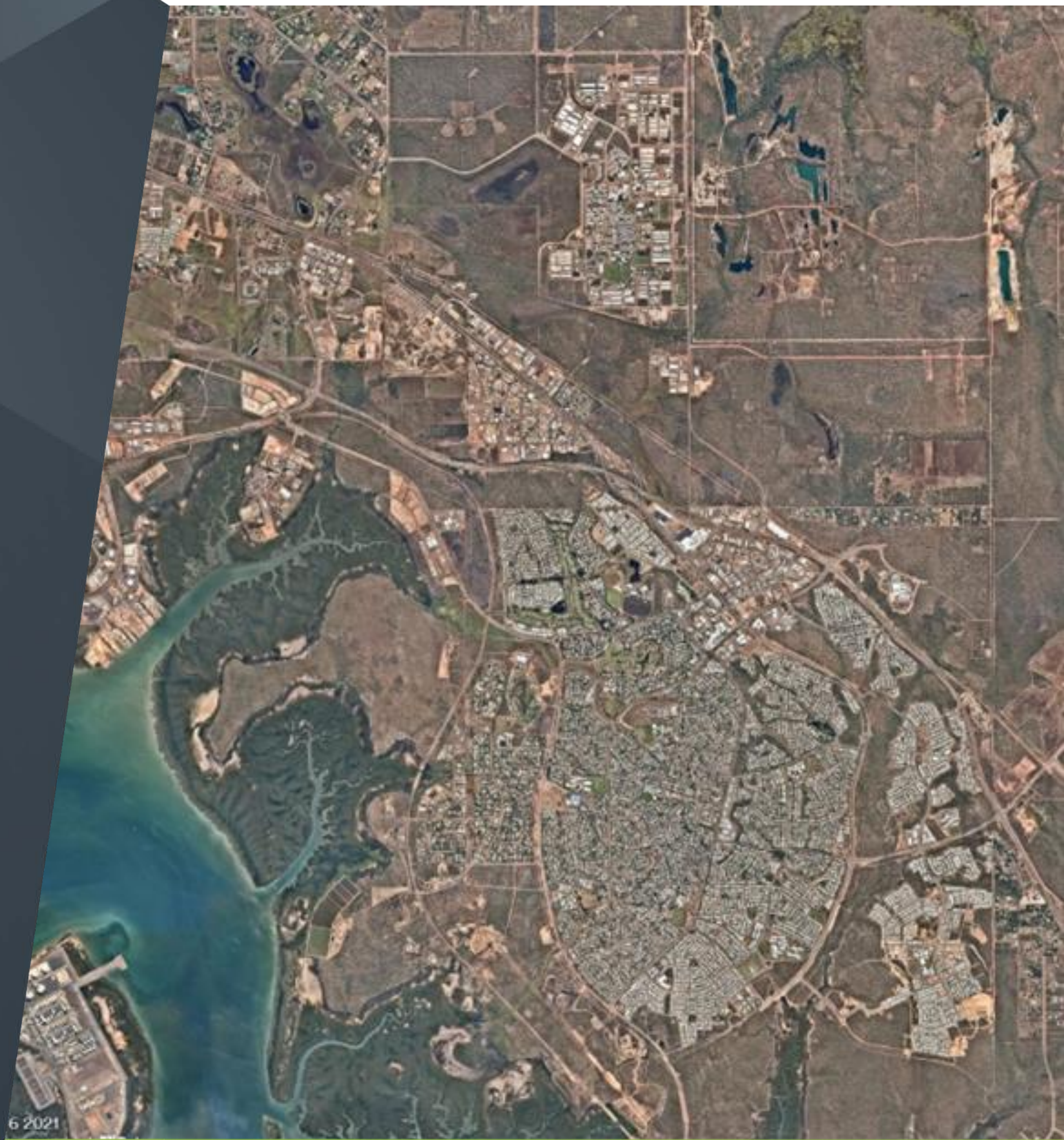
Greater Holtze Development

Holtze Stormwater Management Plan

Department of Infrastructure, Planning and Logistics

7 September 2022



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A	7 Sep 2022	Final Report	Geoff MacKenzie (Project Manager)

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1 Introduction

This Stormwater Management Plan has been prepared by Byrne Consultants to support the Holtze Subdivision Referral. This report provides a description and relevant concepts for the stormwater management required for the development.

The site includes the Palmerston Regional Hospital (PRH), which is to be further developed with an increased footprint in the south portion of the development site. The Northern area (north of Linco Road alignment) will consist of mainly residential lots with some commercial areas available for other uses.

1.1 Definitions and Abbreviations

AEP	:	Annual Exceedance Probability
CoP	:	City of Palmerston
LSC	:	Litchfield Shire Council
DIPL	:	Department of Infrastructure, Planning and Logistics
GPT	:	Gross Pollutant Trap
NT	:	Northern Territory
PRH	:	Palmerston Regional Hospital
TCSD	:	Transport and Civil Services Division
TN	:	Total Nitrogen
TP	:	Total Phosphorous
TSS	:	Total Suspended Solids
WSUD	:	Water Sensitive Urban Design

1.2 Site Description

1.2.1 The Site

The site is bounded by Stuart Highway to the southwest, the south boundary of existing lots on Wallaby Holtze Road, to the north, and Taylor Road to the east.

PRH is located northeast of the Stuart Highway with access to Linco Road. Aside from the Hospital Development, the remainder of the site is forest and bushland.

The site extent and location is shown in Figure 1.1 – Holtze Site Plan. Refer to Appendix A.

1.2.2 Topography

The site features its highest point immediately north of the PRH.

The principal area to be developed for residential living in Holtze is north of Linco Road. The land slopes in this area vary between 0.5% at the highest point to 2.0% in the steeper areas, with levels varying between RL 46 AHD to RL 37 AHD.

The area to the south of Linco Road falls towards the Stuart Highway. Existing slopes vary between about 3% and 15%, with levels varying between RL 46 AHD to RL 20 AHD.

The site topography is also shown in the form of 1m contours shown in Figure 1.1 – Holtze Site Plan. Refer to Appendix A.

1.2.3 Geotechnical Conditions

Geotechnical Investigations on the hospital site have previously been conducted by Douglas Partners and Golders, which are documented in the following report(s):

- Doc No 78175-1 - Report on Geotechnical Investigation – Proposed Road extension
- Doc No 1416828-002-R-Rev0 - Geotechnical Investigation - Wallaby Holtze Road Water Main Extension

2 Stormwater Management in General

2.1 General

The aim is to provide an efficient stormwater drainage system for the development which provides the required flooding protection without any significant effect on the receiving environment at the point of discharge.

The two key Water Sensitive Urban Design (WSUD) Principles to achieve this are as follows.

- Manage stormwater drainage to ensure both upstream and downstream drainage is not adversely affected.
- Protect the baseline water quality to ensure there is no risk to public health and mitigate stress placed on the ecosystems downstream.

2.2 Managing Stormwater Flows

Urban developments have major impacts on stormwater catchment characteristics by altering land use, significantly reducing stormwater infiltration, and decreasing the time of stormwater concentration. Under current urban development guidelines, it is common practise for detention systems to be installed within a new development so that post-development peak flows at the point of discharge are limited to the peak flows experienced pre-development. Generally, detention basins take the form of dry or wet basins as discussed later in Stormwater Quality Management Devices.

The following design methods are adopted to quantify the hydrology and hydraulics for the proposed stormwater systems. Different methods of calculation are required depending on the size of the catchment as detailed in the following sections.

2.2.1 Small catchments

This methodology is generally used for design of the stormwater system within the development area.

Design Methods:

- Stormwater discharge flows for small catchments are calculated using the Rational Method.
- Time of Concentration for Overland Flow is calculated using the Kinematic Wave Theory (urban catchments) or Bransby-Williams and Horton's Methods (small rural catchments).
- Design Rainfall Intensity is calculated using Intensity-Frequency-Distribution data sourced from the Bureau of Meteorology.
- The hydraulic gradeline method is then used to assess the flow characteristics within piped systems and basic stream flow calculations used to assess flows in open drains and swales.

2.2.2 Large Catchments

This method is used to create stormwater flow models for larger catchments and has been used to create flood models for Greater Holtze as detailed later in this report.

- The hydrologic model of the study zone is developed using the XP-RAFTS hydrologic modelling software package. The XP-RAFTS hydrologic model is used to estimate design discharge hydrographs for a range of storm durations for the 20% Annual Exceedance Probability (AEP), 10% AEP and 1% AEP design flood events.

- The XP-RAFTS estimates of peak design discharges are validated by comparing to an alternative estimate of peak design discharges. The Rational Method was adopted as the preferred alternative design discharge methodology.

These flows are then entered into a "TuFlow" model which utilises the existing topography to estimate stormwater flow depths and water levels for each flow path.

2.2.3 Design Standards

The relevant standards include:

- Australian Rainfall and Runoff (IEAust)
- Stormwater Drainage Design in Small Urban Catchments (ARRB Report No. 34)

2.3 Stormwater Quality Management

Urban Developments affect the quality of stormwater runoff, and stormwater quality management is essential to prevent issues with discharge of stormwater to the existing environment.

Stormwater treatment is required to prevent contamination such as gross pollutants, sediment and hydrocarbons leaving the development and entering drainage systems and waterways.

The location and design of treatment devices for stormwater quality improvement should also consider public safety, community health and access for cleaning and maintenance.

Stormwater quality treatment is often installed out outlets of drainage systems, and can be incorporated with the design of a detention system.

2.3.1 Water Sensitive Urban Design

WSUD is an approach to urban planning and design philosophy which aims to overcome some of the deficiencies associated with conventional developments. This is achieved by integrating the total water cycle into new urban development and redevelopment areas from the strategic planning phase through to the design and construction phase.

WSUD promotes an approach to urban development that responds to the site's natural features, protects natural ecosystems on site and downstream and optimises the use of water as a precious resource.

The principles of WSUD are:

- Protect existing natural features and ecological processes.
- Maintain natural hydrologic behaviour of catchments for specified storm events.
- Protect water quality of surface and ground waters.
- Reduce demand on the reticulated water supply system.
- Reduce wastewater discharges to the natural environment.

- Integrate water into the landscape to enhance visual, social, cultural and ecological values.

2.3.2 Water Quality Objectives

The key references regarding stormwater quality requirements are Darwin Harbour Strategy and The NT Subidivison Guidelines. Overall the Darwin Harbour Strategy is considered the higher requirement level, and therefore it is adopted for this development.

2.3.2.1 Darwin Harbour Strategy

The protection of the receiving ecosystems and the enhancement of water conservation within this development will be achieved by implementing Water Quality Management in line with the Darwin Harbour Strategy (Darwin Harbour Advisory Committee, 2010). This Strategy has been prepared by the Darwin Harbour Advisory Committee and is not mandated by law. However, it provides guiding principles which are contributing to ongoing reform of legislation enforced by the Northern Territory Environment Protection Authority.

The Darwin Harbour Strategy includes the following relevant objectives:

- 1.4 - Water quality and ecological health of the marine, freshwater and terrestrial catchment environments in the region are to be maintained or, if quality and health have been negatively affected through human activity, improved where possible; and
- 1.10 - Stormwater collection systems are to be designed and managed to minimise pollution of receiving waters, protect the structure of waterways, optimise the protections of property, and where and when possible, provide grey water for reuse and ensure public health and safety.

Darwin Harbour WSUD objective performance targets for stormwater from developed areas are as follows:

- 80% Reduction in the mean annual load of Total Suspended Solids (TSS)
- 60% Reduction in the mean annual load of Total Phosphorus (TP)
- 5% Reduction in the mean annual load of Total Nitrogen (TN)
- 90% Reduction in the mean annual load of Gross Pollutants

These Water Quality Objectives are adopted for this development.

2.3.2.2 Northern Territory Subdivision Guidelines Strategy

The NT Subdivision Guidelines include the following relevant objectives/best management practices:

- Preservation of natural hydrological flow regimes, including managing sub-catchment flow directions, discharge rates and volumes;
- Retention of natural Waterways, where practicable to do so; and
- Selection of stormwater drainage infrastructure to slow down flows, maximise groundwater recharge, and filter out nutrients and other pollutants.

The NT Subdivision Guidelines WSUD objective performance targets for stormwater from developed areas are as follows:

- 85% Reduction in the mean annual load of Total Suspended Solids (TSS)
- 60% Reduction in the mean annual load of Total Phosphorus (TP)
- 35% Reduction in the mean annual load of Total Nitrogen (TN)
- 90% Reduction in the mean annual load of Gross Pollutants

2.3.3 Stormwater Quality Management Devices

A wide range of drainage solutions are available to the designer for the implementation of **WSUD** across a development. Each of these features performs in a different way in the removal of a specific pollutant, and some features are more suitable for a region than others.

Treatment options are discussed hereunder.

2.3.3.1 Gross Pollutant Trap

A Gross Pollutant Trap (GPT) is a sediment trap incorporating a litter or trash rack and generally remove coarse litter and sediment greater than 5 millimetres. They are designed to screen and trap litter and debris before it enters watercourses. Some GPTs also remove some suspended sediments through rapid sedimentation. They are the most effective, efficient means to remove gross pollutants.

GPTs are used in conventional drainage systems either in stormwater drainage pipes, at outfalls and in open channels; and are best suited as close to the source as possible. It is therefore proposed that GPTs are considered at the point of discharge from piped systems and detention basins as part of a water quality strategy for the overall catchment.

2.3.3.2 Porous Paving

Porous paving allows water to pass through it into the sub-surface course or filter back to the stormwater drainage systems. It provides the opportunity for infiltration and groundwater recharge. Porous paving offers a primary level of filtration by the removal of some coarse sediments. It also helps to reduce peak stormwater discharge from paved areas, contributing to stormwater attenuation. Porous pavements have some limitations as they can only support light traffic loads, they are prone to clogging with sediment and hydrocarbon spills may cause ground contamination concerns.

The application of porous pavements is considered inefficient and unnecessarily costly in Darwin due to high intensity, short duration rainfall events and the presence of clayey soils or weathered rock, limiting the chance of infiltration.

2.3.3.3 Grassed Swales

Grassed Swales not only provide flow paths for stormwater within a development but also provides some infiltration, treatment of nutrients and removal of TSS. Capitol cost of construction is relatively low, but periodic maintenance is required in the form of grass cutting and desilting.

2.3.3.4 Wetlands

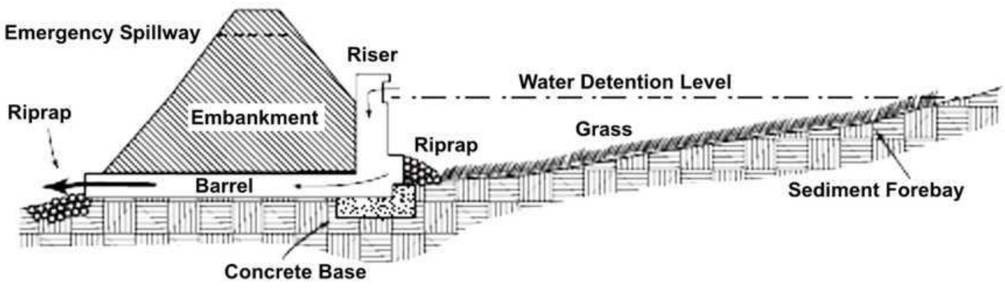
Wetlands are primarily designed to treat stormwater and are very effective at pollutant and nutrient removal through sedimentation, subsurface infiltration, and biological uptake processes. Wetlands provide a diverse ecosystem that includes many plant and animal species. They are typically shallow, except for intermittent deep pools, and have dense vegetation.

Unfortunately, Darwin's tropical climate normally renders this style of treatment unsuitable for the following reasons:

- Darwin has distinct 'Wet' and 'Dry' seasons meaning that additional water is required to be delivered to keep vegetation live for at least 6-8 months of the year, requiring bores or connection to the public water supply
- Wetlands creates a biting midge issue unless the water is maintained relatively deep at the perimeter
- Costly maintenance and operation costs

2.3.3.5 Detention Basins

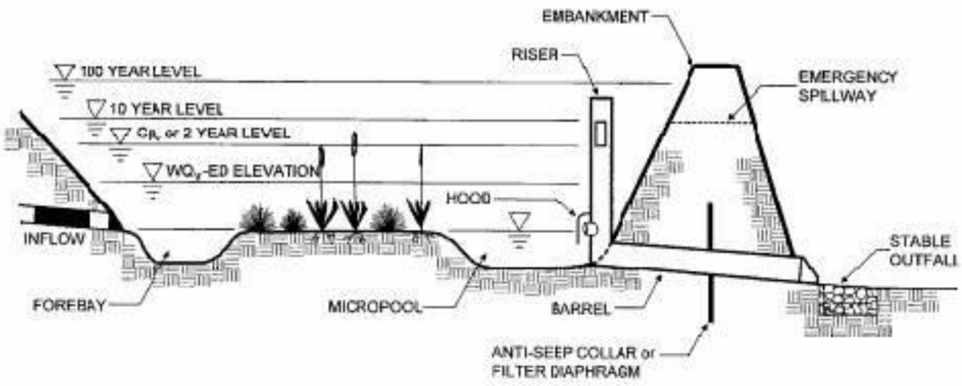
Dry basins are designed to be free draining, so they only remain flooded during a rainfall event and drain completely over time. A dry basin can provide some very effective removal of pollutants and nutrients from stormwater due to the time of retention in this tropical climate, depending on the configuration.



A conceptual section through a 'dry' detention basin

Wet basins contain a permanent pond of water. Unlike wetlands, wet basins are relatively deep (to minimise evaporation and the chance of breeding biting insects) and typically have minimal vegetation.

The depth of these systems poses some concerns with safety, constructability, and groundwater contamination. The application of wet basins in urban areas requires careful consideration of nutrient build-up from fertilisation etc. which can create algae blooms and have adverse biological impacts.



A conceptual section through a 'wet' detention basin

Both dry and wet basins are effective at removing coarse sediment, whilst wet basins offer additional benefits of removing some soluble pollutants as well.

Aside from water quality control, the primary function of detention basins is to attenuate peak flows so peak flows experience pre-development are not exceeded.

2.3.3.6 Health and Safety

The NT Department of Health provides guidance on design of water features under their publication Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions *in the Top End of the NT* (Dept. Health, Aug 2014). The following design principles are recommended to prevent creation of biting insect habitats:

- Detention Basins should be constructed as 'dry' basins, with the basin designed to completely drain within at least 5 days on initial water ponding.
- Detention Basins require a low flow invert or pipe from inlet to outlet to prevent low flow ponding.
- 'Wet' Basins should be constructed with steep sides (45° or greater) and be relatively deep (1.8m) to prevent the establishment of marginal semi-aquatic vegetation.
- Open drains should need to be designed with a suitable grade (minimum 0.50% desirable) and generally provided with low flow provisions to prevent localised ponding.
- In addition to biting insects, the following safety issues need to be considered:
- Facilities that may hold water for short or long periods of time shall be designed with public safety as a primary consideration. Fencing may be required and should be assessed on a case by-case basis.
- Safety signage for basin perimeters and overflow structures should be provided.
- Accesses should be provided to allow machinery access to conduct routine maintenance such as desilting or weed or mosquito management.
- Controlled overflow structures are required for major storm events with appropriate erosion protection.

2.3.4 Verification of Treatment Options

To establish the effectiveness of stormwater treatment options to meet the requirements of the Water Quality Objectives (WQO), the adopted system of treatment is modelled using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). This model uses inputs such as:

- meteorological data
- catchment soil properties
- catchment pollutant load
- treatment device configuration inputs

The model will then predict the pollutant Load reductions, which can be compared to the WQO for verification.

3 Stormwater Management at Holtze

3.1 The Proposed Development

All proposed works for the Holtze Residential land release take place north of the catchment divide, approximately 500m from the Stuart Highway.

Future development in the southern catchment may include some residential or commercial development, or extension of the health precinct footprint, but no details are available at this stage.

3.2 The Catchments

The north-eastern sub-catchment predominantly falls east towards Kowandi, and discharges to the existing northbound drainage system in Kowandi. A portion of the north-western sub-catchment falls to the north towards Wallaby Holtze Road.

The southern sub-catchment, south of Linco Road, falls towards the Stuart highway, and ultimately discharges to Mitchell Creek via systems managed by the Transport and Civil Services Division (TCSD) and City of Palmerston (CoP).

The footprint of the Holtze site crosses 3 separate sub-catchments, as shown in Figure 3.1 – Stormwater Catchments. Refer to Appendix A.

3.3 The Stormwater System for the Development

3.3.1 Controlling Stormwater Discharge

The residential development area will feature an underground stormwater drainage system discharging east towards Kowandi and north towards Wallaby Holtze Road.

At this stage it is likely that there will be 3 points of discharge for this development, that will each require temporary outfalls, detention, and treatment.

The outfalls and detention/treatment structures are considered temporary at this stage as future development beyond the current scope may require relocation and re-configuration of the detention and treatment systems.

South of Linco Road, stormwater treatment and detention structures will be required for any future development.

The final location, detail and structure of the treatment devices will depend on final grading and stormwater design within the development, the catchment area, the outfall conditions, and the land area available for such devices.

The preliminary location of outfalls and detention/treatment devices are shown in Figure 3.2 – Conceptual Stormwater Outfall Locations. Refer to Appendix A.

3.4 The Receiving Stormwater System

Receiving stormwater systems are shown in Figure 3.3 – Area Stormwater Flow Paths. Refer to Appendix A.

3.4.1 North of Linco Road

Both northern sub-catchments for Holtze, ultimately discharge into the Howard River Catchment system.

The receiving stormwater system to the East of Holtze, within Kowandi, features a series of paperbark swamps and low areas, and generally falls to the north with an average slope of approximately 0.2% (2m per km).

The receiving stormwater system to the northwest of Holtze features some swamps and generally falls to the north, traversing the Robertson Barracks Training Area to the East of Thorngate Road.

3.4.2 South of Linco Road

The sub-catchment south of Linco Road ultimately discharges to Mitchell Creek via two culverts crossing the Stuart Highway.

3.4.3 Previous Studies

Water & Environment Pty Ltd (WRM) were commissioned by DIPL to undertake flood mapping and mitigation studies in the Elisabeth River and Howard River catchments. As Holtze-Kowandi has been identified as a future development site, WRM has provided preliminary modelling results for flooding in this area under existing conditions.

A copy of the memo from WRM is included in Appendix B - WRM Memo – Modelling for Holtze-Kowandi.

3.4.4 The Effect of the Holtze Development on Receiving Drainage Systems

3.4.4.1 South of Linco Road

Development in the Holtze southern sub-catchment will increase the total volume of stormwater runoff discharging to Mitchell Creek.

However, peak flows are mitigated, and stormwater quality is managed by the installation of detention basins and water quality treatment for each individual development area as development proceeds, as is the case with Stage 1 of the Palmerston Regional Hospital.

3.4.4.2 North of Linco Road

The residential development in the Holtze northern sub-catchment will increase the total volume of stormwater runoff discharging to the existing northbound drainage systems.

However, peak flows are mitigated, and stormwater quality is managed by the installation of detention basins and water quality treatment for each individual sub-catchment.

With the construction of Holtze, there will be an increase in total volume of runoff in both affected northbound systems, but the practical effect will be negligible as this development will decrease permeability of the surface only over a small portion of the total catchment area affecting these drainage systems, so no noticeable increase in flooding is predicted with the construction of this development in Holtze.

4 References

- Northern Territory Subdivision Development Guidelines August 2020.
- Evaluating Options for Water Sensitive Urban Design – A National Guide City of Palmerston, 2015.
- Subdivision and Development Guidelines Darwin Harbour Advisory Committee, 2010.
- Darwin Harbour Strategy Department of Health, Aug 2014.
- Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions in the Top End of the NT Department of Transport, 2015.
- Water Pollution Prevention and Control Best Management Practices. http://water.epa.gov

Appendix A Figures

FIGURE 1.1
HOLTZE SITE PLAN

FIGURE 3.1
STORMWATER CATCHMENTS

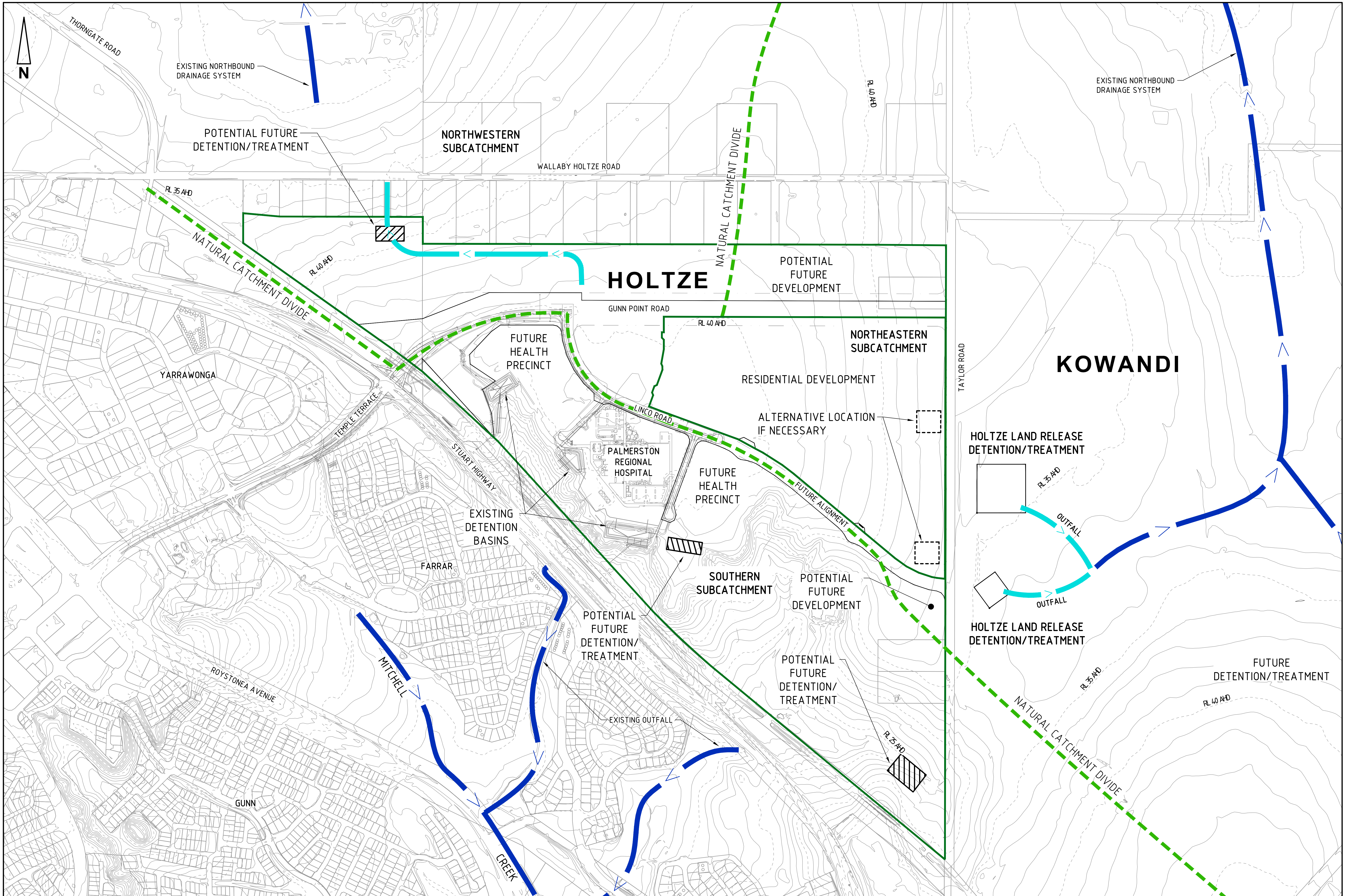


FIGURE 3.2
CONCEPTUAL STORMWATER OUTFALL LOCATIONS

FIGURE 3.3
AREA STORMWATER FLOW PATHS

Appendix B WRM Memo – Modelling for Holtze-Kowandi

wrm water + environment

Memorandum

Date	14 July 2020	Pages	11
Attention	Ken Gardner		
Company	Department of Infrastructure, Planning and Logistics		
Job No.	1582-01-F		
Subject	Existing conditions flood modelling results for the Holtze-Kowandi area (study zone 8)		

Dear Ken,

This memo presents an overview of model development and preliminary modelling results for existing conditions flooding for the above study zone.

Background

The Department of Infrastructure, Planning and Logistics (DIPL) have requested WRM Water & Environment Pty Ltd (WRM) to undertake flood mapping and mitigation studies for eight (8) study zones located in the Elizabeth River and Howard River catchments. Note, these studies assess the impacts of flooding from local catchment runoff only, rather than riverine flooding.

It is understood that the Holtze-Kowandi area has been identified as a future development site and consequently DIPL wishes to understand any potential issues which might impact future development.

This memo presents preliminary modelling results for flooding in the Holtze-Kowandi area (study zone 8) under existing conditions.

Drainage characteristics

Figure 1 shows local drainage features in the vicinity of the Holtze-Kowandi study area. The study area is drained by several minor or unnamed drainage features. The eastern portion of the study area drains north to the Howard River, while the remainder of the study area drains north, directly to the Beagle Gulf.

There do not appear to be any existing flood studies covering the Howard River. However, it appears unlikely that that the Holtze-Kowandi study area would be impacted by riverine (Howard River) flooding.

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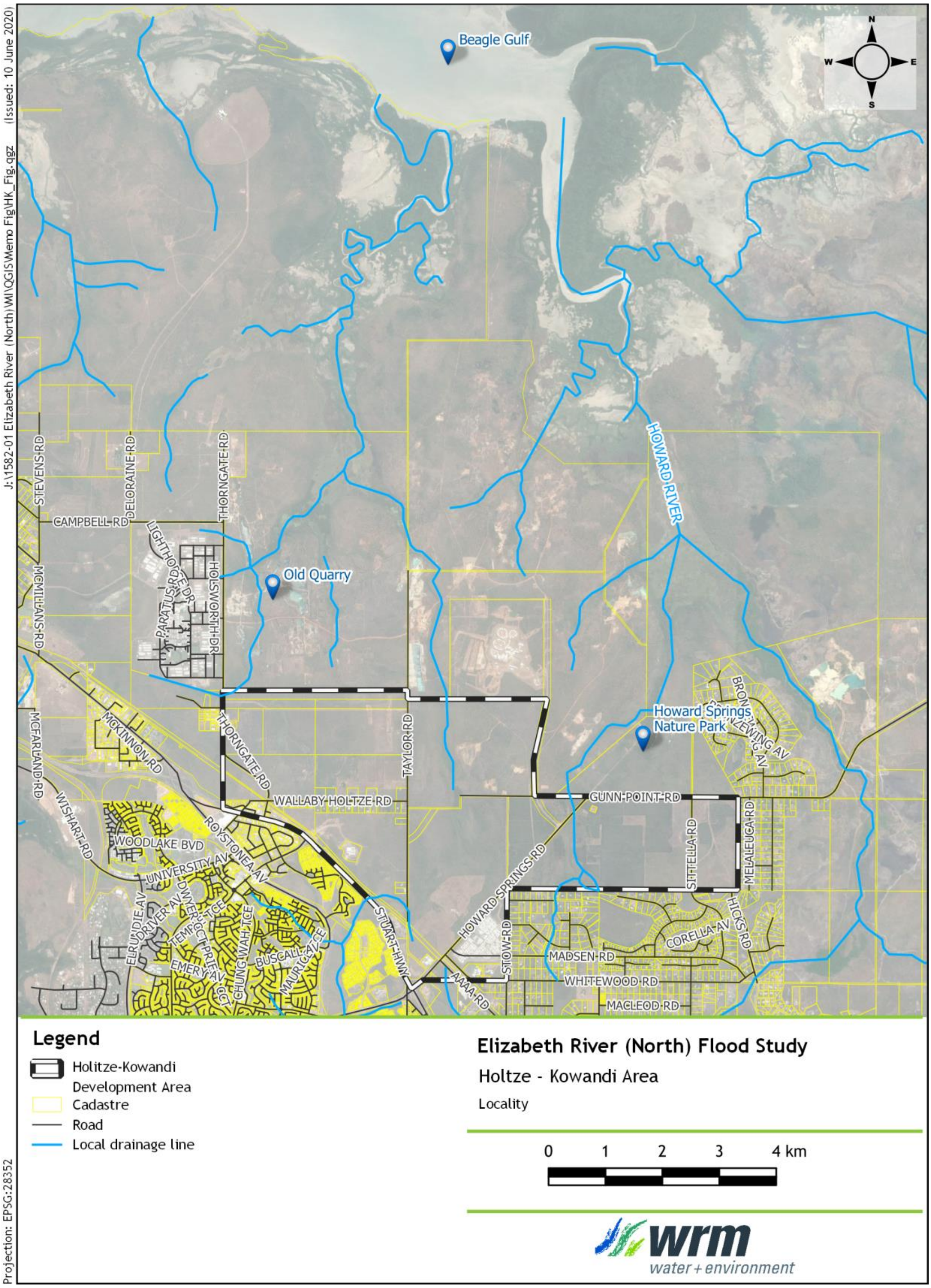

Figure 1 - Local drainage features, Holtze-Kowandi study area (Zone 8)

Model development and validation

The Holtze-Kowandi study zone is located north of Palmerstone, along the northern side of the Stuart Highway and is predominantly in the Howard River catchment.

A hydrologic model of the study zone was developed using the XP-RAFTS hydrologic modelling software package. Figure 2 shows the adopted XP-RAFTS hydrologic model configuration. The XP-RAFTS hydrologic model was used to estimate design discharge hydrographs for a range of storm durations for the 20% Annual Exceedance Probability (AEP), 10% AEP and 1% AEP design flood events.

The XP-RAFTS estimates of peak design discharges were validated by comparing to an alternative estimate of peak design discharges. The Rational Method was adopted as the preferred alternative design discharge methodology for this study.

The XP-RAFTS model validation was done for three key locations (Holtze-Kowandi catchments 1 to 3 shown in Figure 2). Table 1 to Table 3 show a comparison between XP-RAFTS predicted peak design discharges and Rational Method estimates of peak design discharges for the validation locations in the study area. Model validation results show a good agreement between the Rational Method and XP-RAFTS estimates of peak design discharges, with the two estimates agreeing within 10%.

Table 1 - Peak design discharge validation, Holtze-Kowandi catchment 1

Design event	Peak design discharge estimate (m^3/s)		
AEP (%)	XP-RAFTS	Rational Method	Difference (%)
20%	72.3	68.1	6%
10%	88.2	82.6	7%
1%	149	138	8%

Table 2 - Peak design discharge validation, Holtze-Kowandi catchment 2

Design event	Peak design discharge estimate (m^3/s)		
AEP (%)	XP-RAFTS	Rational Method	Difference (%)
20%	52.2	49.8	5%
10%	63.3	60.0	5%
1%	104	98.5	6%

Table 3 - Peak design discharge validation, Holtze-Kowandi catchment 3

Design event	Peak design discharge estimate (m^3/s)		
AEP (%)	XP-RAFTS	Rational Method	Difference (%)
20%	108	101	7%
10%	126	122	3%
1%	203	199	2%

A hydraulic model of the study zone was developed using the TUFLOW hydraulic modelling software package. Figure 3 shows the adopted TUFLOW model configuration.

Design discharge hydrographs estimated using the validated XP-RAFTS hydrologic model were input to the TUFLOW model for a range of storm durations, for the 20% AEP, 10% AEP and 1% AEP design flood events. As the model area is well clear of the Howard River, a 'normal flow' type boundary condition was adopted based on the downstream channel slope.

Modelling results

Figure 4 to Figure 6 show preliminary predicted flood extents and peak flood levels and depths in the Holtze-Kowandi area for the 20% AEP, 10% AEP and 1% AEP design flood events under existing conditions.

Preliminary model results show:

- There are three main flow paths (flow path A, B & C) drain in the Holtze-Kowandi catchments;
    - Flow path A drains east-southeast towards and across Thorngate Road, then drains north to the east of Thorngate Road towards the Old Quarry (shown in Figure 1) before joining flow path B, continuing to drain north and discharging into the Beagle Gulf;
    - Flow path B drains north, across Gunn Point Road towards the Old Quarry before joining with flow path A;
    - Flow path C drains north east, across Howard Springs and Gunn Points Road before discharging to the Howard River approximately 3.1 km north (downstream) of the study area.
- Flooding is generally confined to an area within about 200 m of the main flow paths or to low-lying areas within existing wetlands;
- An area of extensive ponding, reaching depths of up to about 1.7 m is observed on the northwest part of the Holtze-Kowandi area (see location P1) for the 1% AEP design event. Model results show that this area drains northwest to Thorngate Road and discharges to flow path A;
    - Ponding depths of up to about 1.5 m is observed at location P1 for the 10% AEP design event and up to 1.3 m for the 20% AEP design event. Model results indicate that in the 20% AEP design event, flows draining northwest to Thorngate Road are generally confined to the local drainage channel east of Thorngate Road;
- Another area of ponding of up to a depth of 1.8 m is observed at the centre of the Holtze-Kowandi area (see location P2), south of Gunn Point Road for the 1% AEP design event. The ponding depths decrease to about 1.6 m for the 10% AEP design event and about 1.5 m for the 20% AEP design event;
- A number of other areas of confined ponding are observed south of Gunn Point Road and Howard Springs Road (see locations P3, P4, P5 and P6). Maximum ponding depths in these areas range between about 1.1 m and 2.3 m for the 1% AEP event.

Model results show that future development in the area east of Taylor Road would have to make allowance for existing drainage paths (e.g. design of flood ways etc.)

Model results also show that future development in the area west of Taylor Road and north of Wallaby Holtze Road would have to either accommodate (incorporate into trunk drainage concept) or remove (fill in and reclaim) the existing wetland (see location P1).

Please do not hesitate to contact us if you have any queries or require any clarifications.

For and on behalf of

WRM Water & Environment Pty Ltd

Sharmil Markar

Director

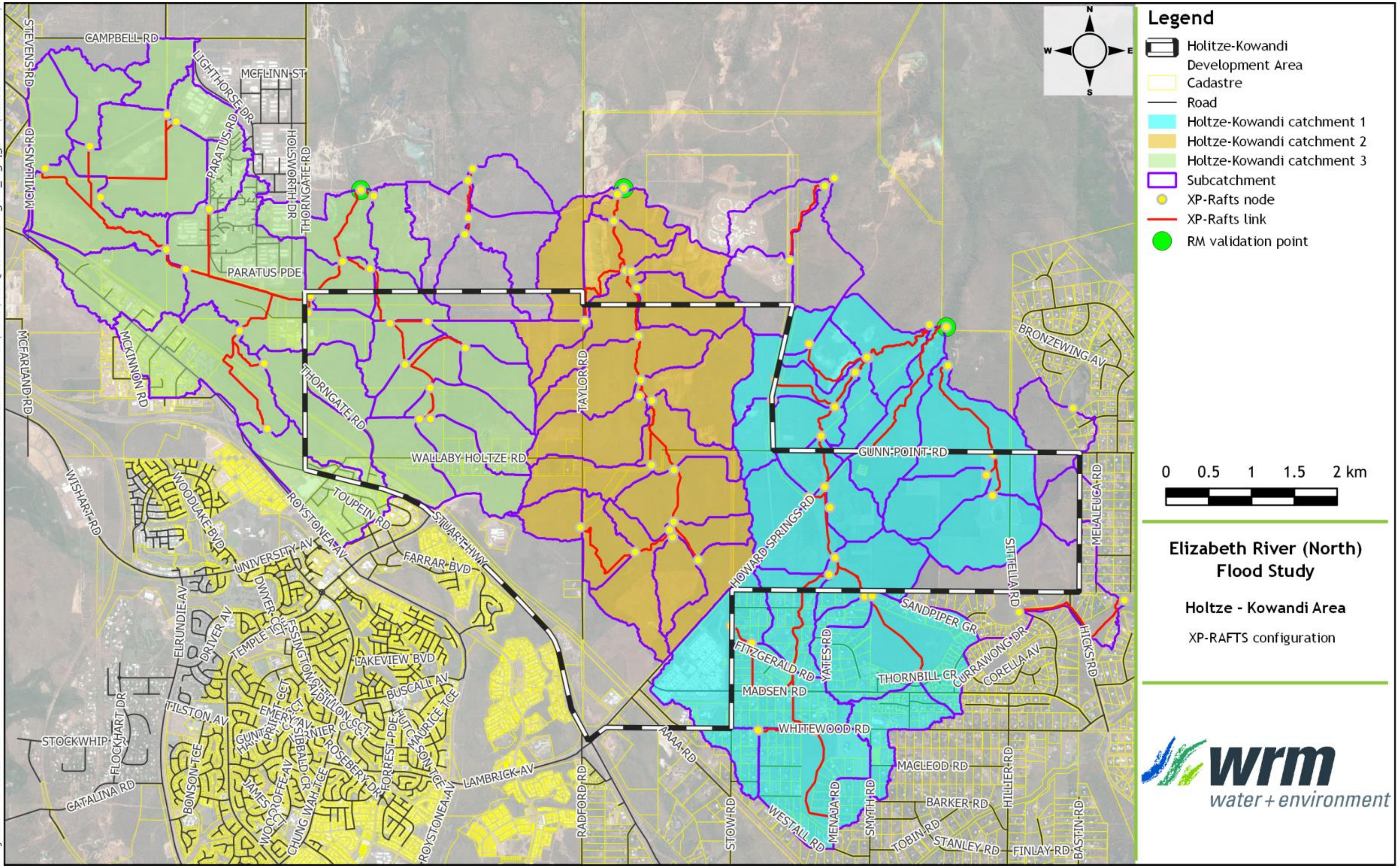

Figure 2 - Holtze-Kowandi study area and XP-RAFTS model configuration

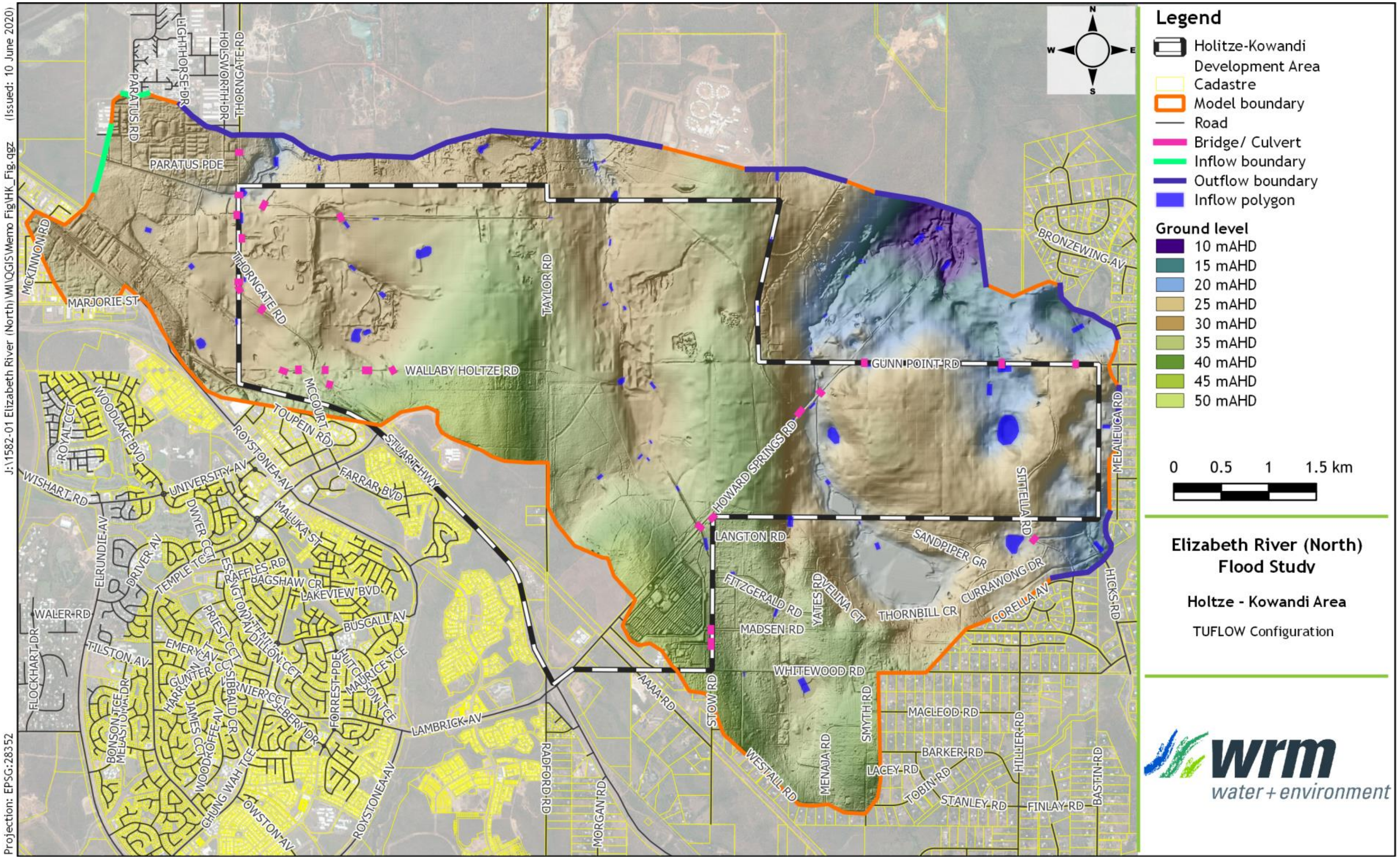

Figure 3 - Holtze-Kowandi study area TUFLOW model extents

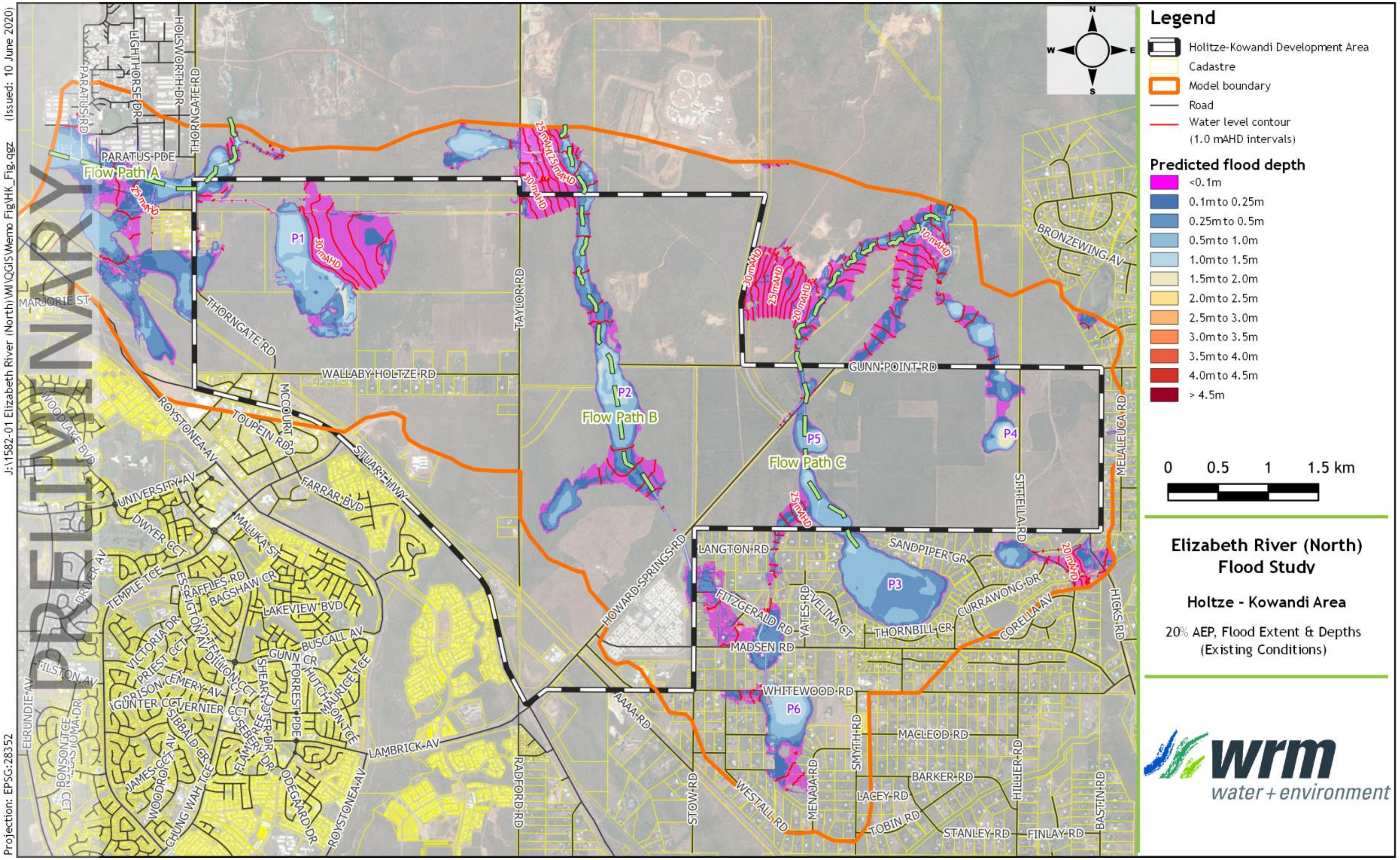

Figure 4 - Preliminary flood extents and peak flood levels and depths under existing conditions, 20% AEP design event, Holtze-Kowandi study area (Zone 8)

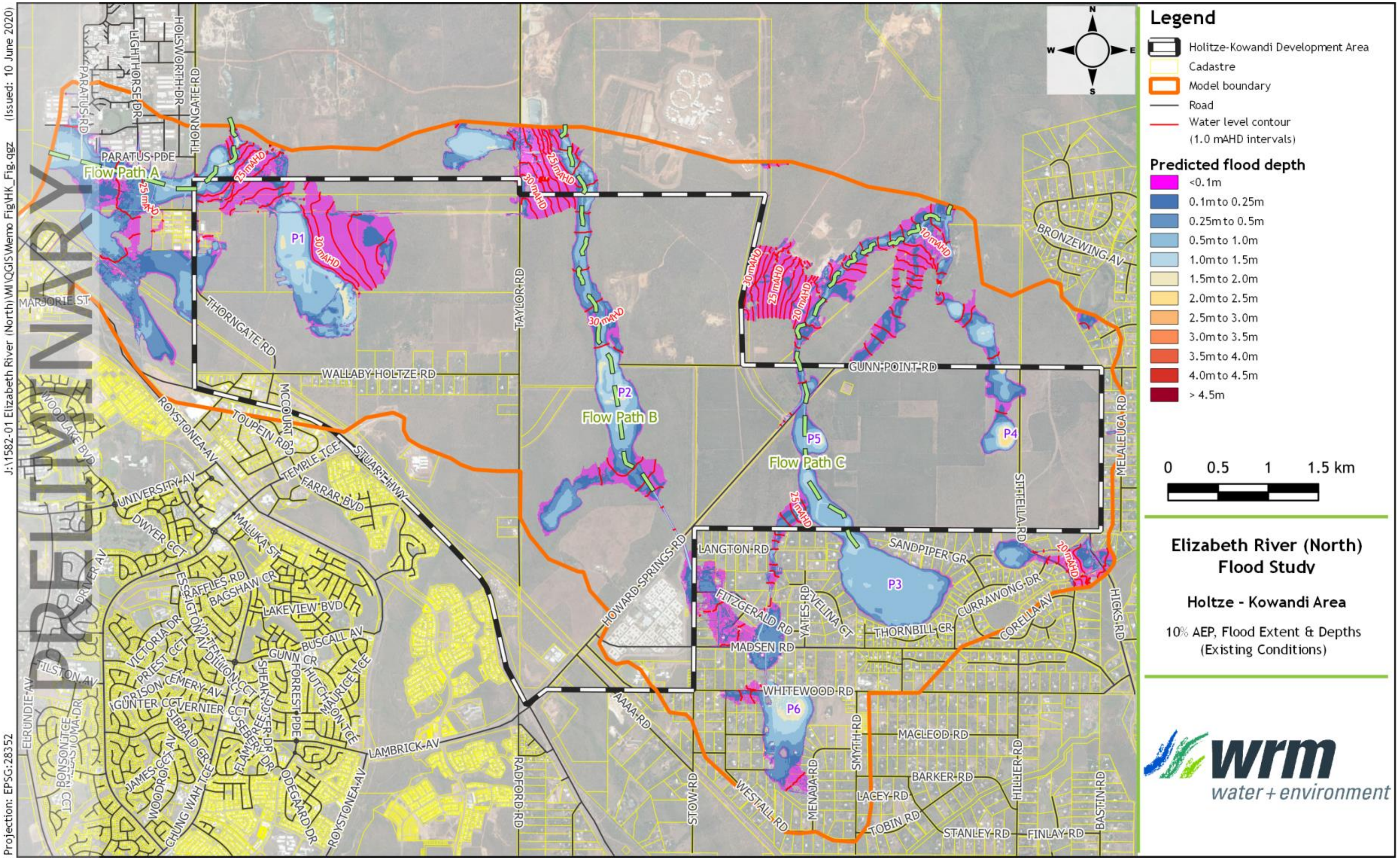

Figure 5 - Preliminary flood extents and peak flood levels and depths under existing conditions, 10% AEP design event, Holtze-Kowandi study area (Zone 8)

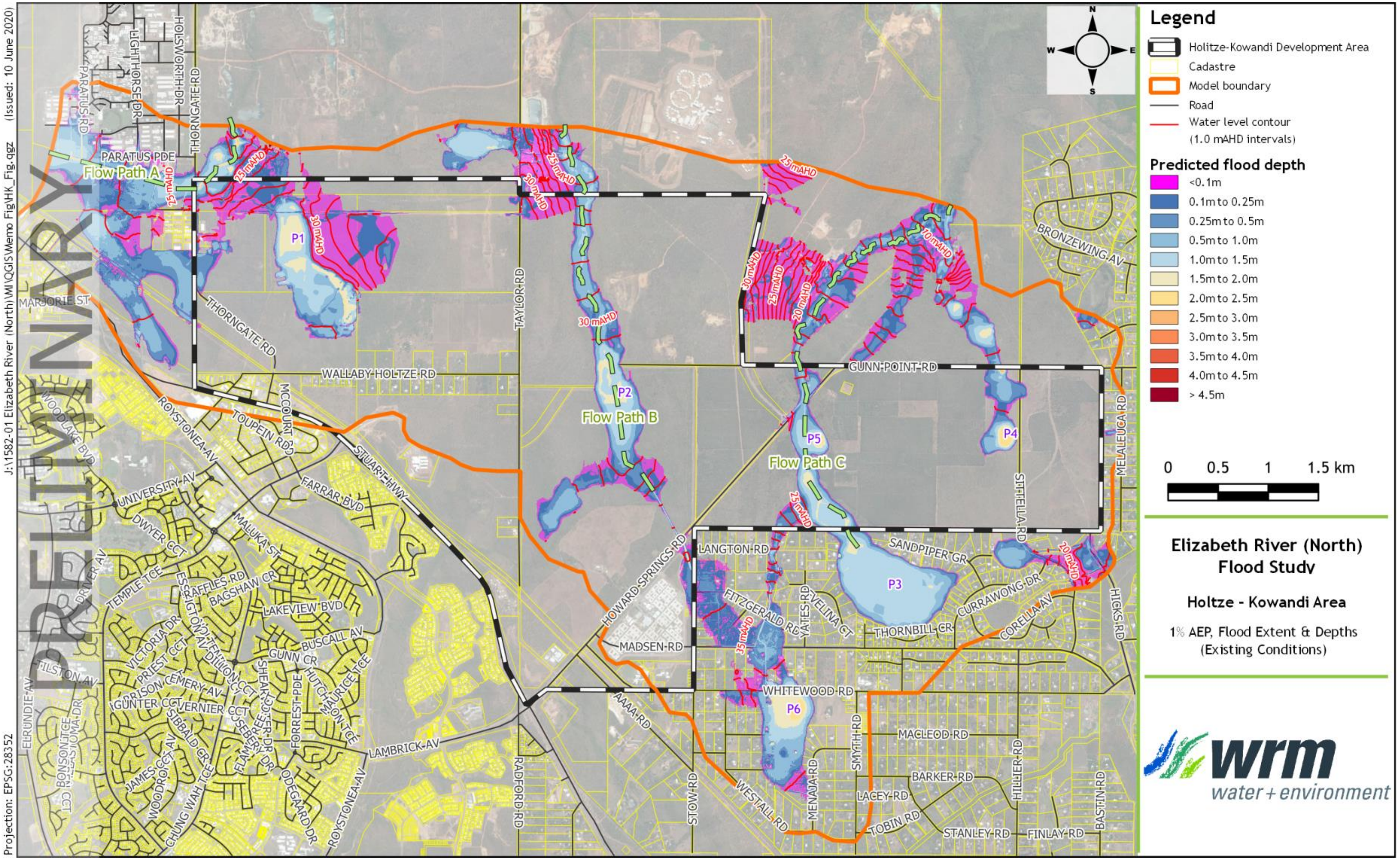

Figure 6 - Preliminary flood extents and peak flood levels and depths under existing conditions, 1% AEP design event, Holtze-Kowandi study area (Zone 8)

Memorandum

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