Mamre Road

Flood, Riparian Corridor and Integrated Water Cycle Management Strategy

August 2021

Sydney WATER

Acknowledgement of Country

Sydney Water respects the traditional 'Caring for Country' restorative approaches practiced over tens of thousands of years by Aboriginal people and play our part to improve the health of the landscape by recognising and nurturing all values of water in our environment.

In doing so, we acknowledge the traditional custodians and their ancestors of the lands and waters in Western Sydney where we are working and learning: the D'harawal and Dharug nations, as well as their neighbours the Gundungurra. Their lore, traditions and customs nurtured and continue to nurture the sweet waters in this area, creating wellbeing for all. We also pay our respects to Elders, past and present.

Executive Summary

This *Flood, Riparian Corridor and Integrated Water Cycle Management strategy* is a technical planning document that outlines how stormwater, water, wastewater, recycled water, trunk drainage and riparian zones should be managed to achieve the Western Parkland City vision and the objectives of the Industry and Employment SEPP as they relate to the Mamre Road precinct. Precinct development and planning undertaken according to this study is necessary to ensure safe, efficient, and sustainable outcomes for future business in the precinct. This study identifies opportunities within the Mamre Road precinct to deliver EES waterway health objectives and targets by considering:

- Recycled water, drinking water and wastewater services are available for development
- Land use is compatible with flood risk
- Flood management approaches are effective and consistent across the catchment
- Water sensitive urban design approaches achieve waterway health requirements in a flexible and cost-effective way
- Sufficient land is allocated for stormwater, riparian habitats and flood management on private lots and in the public domain

The report details how the integration of a regional approach to trunk drainage management with the planned recycled water network provides an innovative and efficient solution for meeting the NSW Government Waterway Health Objectives for the catchment as well as policy positions of Circular Economy and urban heat mitigation. Amended controls and clauses within the Mamre Road DCP will be drafted to reflect and support this outcome.

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1. Introduction

The Department of Planning and Environment (DPE) rezoned the Mamre Road Precinct (the Precinct) for primarily industrial purposes in June 2020.

On behalf of DPE, Sydney Water has developed this Flood, Riparian Corridor and Integrated Water Cycle Management strategy (the strategy) to inform the water servicing, and flood management for the Precinct. It is critical that Integrated Water Cycle Management (IWCM) is implemented in the Mamre Road precinct, and all Aerotropolis precincts, to ensure climate independent and sustainable water is available for greening and cooling, to protect waterways and to achieve the Government's vision of a Parkland City.

This final version of this strategy was prepared following public and government consultation and relevant feedback has been incorporated into this report.

1.1 Mamre Road Precinct

The Precinct is located approximately 40 km west of the Sydney CBD and 12 km southeast of the Penrith CBD. It is located entirely within the Penrith City Council Local Government Area (LGA). It is bordered by the WaterNSW Warragamba Pipeline to the north, Wianamatta South Creek and Kemps Creek to the west, Ropes Creek to the east and Mount Vernon to the south. The precinct has a gross site area of approximately 1002 ha.

1.2 Study Objectives

This Flood, Riparian Corridor and IWCM strategy has been prepared to support development of the Precinct whilst achieving the waterway health objectives established by DPE.

Controls prescribed by this study will inform the Precinct DCP and ensure that:

- Land use is compatible with flood risk
- Flood management approaches are effective and consistent across the catchment
- Stormwater management through water sensitive urban design (WSUD) contributes to the waterway health objectives (flow and quality) in a flexible and cost-effective way
- Sufficient infrastructure is identified, and land allocated for stormwater and flood management on private lots and in the public domain.

Water Servicing Strategy

The ultimate water demands for the Precinct have been compiled for toilet flushing, irrigation, urban cooling, drinking water, wastewater, stormwater and recycled water (recycled water being fit for purpose tertiary treated effluent).

The non-potable, irrigation and urban cooling demands have been used to inform the size of stormwater harvesting elements and effectiveness of stormwater volume reductions.

Flooding

An assessment of flood constraints associated with the land use change includes:

- defining flood behaviour within the Precinct's unnamed tributaries
- an assessment of flood behaviour post-development and the impacts the change in land use will have on local catchment flood behaviour, including impacts on existing infrastructure and lands outside the Precinct
- an assessment of the flood mitigation requirements for the Precinct.

Waterway Assessment

Waterways across the site have been ground truthed to determine the presence of riparian lands and those that are to be retained. An assessment has been developed for the Precinct that recommends the retention of waterways based on ground truthing and consultation with NSW Natural Resources Access Regulator (NRAR).

Waterway Health (Stormwater Quantity and Quality) Management

A management strategy for stormwater (low flows) is provided that demonstrates compliance with:

1. waterway health objectives and targets developed for the Wianamatta South Creek catchment by DPE
2. the *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* and
3. State Environmental Planning Policy (Industry and Employment) 2021 (Industry and Employment SEPP) Clause 2.44.

Wildlife Risk Mitigation

Farm dams and ponds can support large populations of water birds (eg duck, teal, swan, cormorant, pelican) that pose a risk to aircraft strike. Construction of the airport and changes to land use within the Mamre Road Precinct will alter many of these habitat sources.

Controls will be required to reduce the risk of new or existing permanent water bodies (wetlands), along with the revitalisation of natural water courses. Risk mitigation processes for infrastructure design and management as well as for development will be required

2. Predeveloped Site Conditions

The following section summarises the environmental constraints and context of the local environment that have informed the development of Flood, Riparian Corridor and IWCM strategy for the Precinct.

2.1 Land Use

The Precinct is zoned primarily IN1 - Industrial under the Industry and Employment SEPP as shown in Figure A-4.

At the at the time of preparation of this study, land use in the Precinct was mostly pasture, minor roads, sheds, out buildings and farm dams with pockets of intensive farming. The northern portion of the precinct includes Mamre Anglican School, Emmaus Catholic College, Trinity Primary School and several retirement villages.

2.2 Topography

The Precinct encompasses an area known as Mount Vernon and includes a prominent hill line that divides the Precinct with approximately one third draining east to Ropes Creek, one third to the main dam on Kemps Creek and one third below the Kemps Creek and Wianamatta South Creek confluence. Upper reaches are very steep with grades of 10 to 20 % while lower hill slopes are gentler approaching floodplains. Topography of the Precinct is presented in Figure A-5.

2.3 Waterways and Riparian Corridors

Reference to the 1:25000 topographic maps show ten minor tributaries crossing the Precinct. Many waterways are broad, poorly defined and highly impacted by land use. Farm dams have been formed along their reaches, some significant in size and volume. These farm dams account for approximately 30 ha in area which accounts for approximately 3% of the total Precinct area. As such, these structures likely play a significant part in the existing hydrology of the region, recharging groundwater and supplying baseflows to downstream waterways.

A waterway assessment has been carried out for the Precinct that recommends the retention of waterways based on ground truthing and consultation with NSW Natural Resources Access Regulator. The waterway assessment has been included in Appendix F.

2.4 Drainage Structures

The Precinct is crossed by Mamre Road which has 17 transverse drainage structures controlling runoff from undeveloped catchments upstream. Flow discharging from the transverse drainage structures is conveyed along a series of semi-natural channels that join Kemps Creek and Wianamatta South Creek around 200 m to 1 km to the west of the road corridor. Preserving the capacity of these culverts is a significant constraint to flood management within the precinct.

Access to the eastern portion of the Precinct is via Abbotts Road, Aldington Road and Bakers Lane which are crossed by six culverts located at local sags. These have significantly smaller catchments than the Mamre Road culvert crossings.

The northern edge of the Precinct runs along the WaterNSW Warragamba Pipeline and the Precinct drains to the north via four minor transverse drainage structures and the two main crossings of Wianamatta South Creek and Ropes Creek.

The Kemps Creek Dam (24.7 ha) is a significant hydrologic feature in the catchment. The dam likely contributes baseflow to the downstream reach by retaining wet weather flows and recharging the groundwater table. Anecdotally, Wianamatta South Creek is thought to become more perennial downstream of the Kemps Creek confluence (Pers Comm Tippler, 2019).

The Wianamatta South Creek Dam is another significant structure that has been partly demolished leaving a breach in the dam wall that allows the passage of stream flows. The base of the dam provides retention of water which has a significant capacity to retain stream flow and recharge groundwater.

2.5 Soils and Salinity

The Precinct is dominated by low permeability clays and alluvial soils in the floodplain comprising the following groups according to the Soil Landscapes of the Penrith and Wollongong 1:100,000 Sheet map and reports (Soil Conservation Service of NSW, 1990):

Luddenham (lu) 15,414 Erosional

Brown loam to clay loam over light to medium clay. Slopes 5-20%. Shallow on crests (<100 cm) to moderately deep (<150 cm) on lower slopes and drainage lines.

Low permeability, low available water capacity, low fertility, high erodibility, very low infiltration in B horizon, lateral water flow, water erosion hazard.

Infiltration rate - low

Blacktown (bt) 42,752 Residual

Shallow to moderately deep (>100 cm) hard setting mottled texture contrast soils. Brown loam over mottled brown light clay to grey plastic heavy clay.

Susceptible to ponding, waterlogging in A horizon, low infiltration rate in B horizon, lateral water flow, seepage, potential expression of salts.

Infiltration rate - low

South Creek (sc) 7,160 Alluvial

Very deep layered sediments over bedrock or relict soils. Brown sandy loam to clay loam over brown light to medium clay.

Low fertility, flood hazard, seasonal waterlogging, permanently high water tables (localised), low infiltration rate in B horizon, lateral water flow, seepage, potential expression of salts.

Infiltration rate - moderate

The Precinct soils are dominated by relatively low permeable saline clay soils. Groundwater recharge from over irrigation must be managed to reduce the mobilisation of natural salts in the catchment.

Land capability mapping commissioned by Sydney Water found that the Precinct has a moderate salinity risk, however it is likely that earthworks to form industrial lands will significantly alter the composition of the upper soil horizons (Aurecon, 2019).

2.6 Wianamatta-South Creek Floodplain

The Precinct accounts for 10 km^2 within the middle reach of the overall 627 km^2 Wianamatta South Creek catchment. Flood data for the catchment is defined by Penrith Council's flood study of South Creek.

The adopted 1% AEP flood extent of Kemps and Wianamatta South Creeks defines the western boundary of the Precinct. Areas of the Precinct that lie to the west of Mamre Road are flood prone and affected by the PMF.

3 Design Standards and Approach

The following sections compile the SEPP objectives and design standards that have informed the Integrated Water Cycle Management Study.

3.1 State Environmental Planning Policy (Industry and Employment) 2021

Clause 2.44 of the Industry and Employment SEPP requires that adverse impacts from stormwater on adjoining properties, riparian land, native bushland, waterways, groundwater dependent ecosystems and groundwater systems are avoided or minimised.

The SEPP requires that the following are considered prior to consent being granted for development:

(a) water sensitive design principles are incorporated into the design of the development, and

(b) riparian, stormwater and flooding measures are integrated, and

(c) the stormwater management system includes all reasonable management actions to avoid adverse impacts on the land to which the development is to be carried out, adjoining properties, riparian land, native bushland, waterways, groundwater dependent ecosystems and groundwater systems, and

(d) if a potential adverse environmental impact cannot be feasibly avoided, the development minimises and mitigates the adverse impacts of stormwater runoff on adjoining properties, riparian land, native bushland, waterways, groundwater dependent ecosystems and groundwater systems, and

(e) If the development will have an adverse impact on—

(i) the water quality or quantity in a waterway, including the water entering the waterway, and

(ii) the natural flow regime, including groundwater flows to a waterway, and

(iii) the aquatic environment and riparian land (including aquatic and riparian species, communities, populations and habitats), and

(iv) the stability of the bed, banks and shore of a waterway, and

(f) the development includes measures to retain, rehabilitate and restore riparian land.

For the considerations above the water sensitive design principles include:

(a) protection and enhancement of water quality, by improving the quality of stormwater runoff from catchments,

(b) minimisation of harmful impacts of development on water balance and on surface and groundwater flow regimes,

(c) integration of stormwater management systems into the landscape in a manner that provides multiple benefits, including water quality protection, stormwater retention and detention, public open space, habitat improvement and recreational and visual amenity,

(d) retention, where practical, of on-site stormwater for use as an alternative supply to mains water, groundwater or river water.

3.2 Mamre Road Precinct Development Control Plan 2021

The Mamre Road DCP is the principal DCP that applies to the precinct. The DCOP provides a structure plan for the development of the precinct along with controls to guide the design and delivery of new development. No other Penrith Council DCPs apply in this area. Some other Penrith Council guidelines and standards will continue to apply to development in the precinct, such as Council's engineering guidelines. The following provides a summary of relevant controls that apply to new development in accordance with the Mamre Road DCP.

2.6.1 Riparian Land

The Mamre Road DCP recognises that protection and restoration of creek health, ecology and biodiversity is a key policy for future development and delivery of the Blue-Green Infrastructure Network in the catchment. The DCP requires that waterways of Strahler Order 2 and higher will be maintained in a natural state, including the maintenance and restoration of riparian area and habitat, such as fallen debris. Where a development is associated with or will affect a waterway of Strahler Order 2 or higher, rehabilitation shall return that waterway to a natural state.

2.6.2 Integrated Water Cycle Management

Waterway objectives (flow and water quality) have been established for the protection of waterways in the Wianamatta-South Creek catchment in line with the NSW Government Risk-based Framework for considering Waterway Health Outcomes in Strategic Land-use Planning Decisions (2017). In addition, the NSW Government has prepared technical notes and guidance documentation on the modelling parameters and software packages that can be used to demonstrate compliance with these objectives.

The DCP requires that development applications demonstrate compliance with stormwater quality and flow during construction and operation phases at the lot or estate scale to ensure the NSW Government's waterway objectives are achieved. With the implementation of Sydney Water's proposed regional stormwater management system in the Mamre Road Precinct, development should only require the following key measures in order to achieve compliance:

- On site detention - Adequate stormwater systems shall be designed and constructed to ensure that, for all rainwater events up to and including the 1% AEP event, new developments and redevelopments do not increase stormwater peak flows in any downstream areas. On-site stormwater detention systems must release water after any rainfall event to maximise future capacity and therefore, cannot include rainwater tanks, water retention basins or dams. On-site stormwater detention systems are to be designed using a catchment wide approach.

- Gross pollutant traps
- Minimum permeability requirements as established in the DCP. Permeable ground surfaces are to be maintained as far as possible, and where suitable conditions exist, stormwater is to be infiltrated on-site. A minimum of 15% permeable surfaces are to be provided on site to comply with DCP provisions.
- Passively irrigated street trees, connected to the stormwater drainage system.

Development applications must include a Water Management Strategy (WMS) detailing the proposed Water Sensitive Urban Design (WSUD) approach, how the WMS complies with stormwater targets (i.e. MUSIC modelling), and how these measures will be implemented, including any proposed interim or temporary solutions, ongoing management and maintenance responsibilities. It is recommended that conceptual designs of the stormwater drainage and WSUD system be agreed with Sydney Water prior to lodgement of any development proposal.

2.6.3 Drainage

Appropriate drainage measures, including on-site stormwater detention will be required:

- Development will not overload trunk drains during peak storm events or cause localised flooding.
- All drainage will be designed to ensure that the intensity, quantity and quality of surface runoff is not detrimental to downstream properties and watercourses.

Naturalised trunk drainage paths are to be provided when the:

- Contributing catchment exceeds 15ha; or
- 1% AEP overland flows cannot be safely conveyed overland as described in Australian Rainfall and Runoff – 2019.

Where applied strictly in accordance with the controls in the Mamre Road Precinct DCP, naturalised trunk drainage paths can count towards the required contributions to canopy cover and site perviousness.

2.6.4 Recycled water

The Mamre Road DCP requires that, where a recycled water scheme is available, development must:

- Be designed in a manner that does not compromise waterway objectives, with stormwater harvesting prioritised over reticulated recycled water;
- Bring a purple pipe for recycled water to the boundary of the site, as required under Clause 2.39 of the Industry and Employment SEPP. Not top up rainwater tanks with recycled water unless approved by Sydney Water; and
- Design recycled water reticulation to standards required by the operator of the recycled water scheme.

Where no recycled water connection is available/provided, 80% of non-potable water demand must be provided from an alternative non-potable water source.

2.6.5 Flood Planning

The 1% AEP flood event is a tool for broadly assessing the suitability of land for development. It is not an assessment of flood risk, nor does reference to the 1% AEP flood event mean that properties and development above this level are not subject to flood risk.

Developments that may have a significant impact on the extent of flooding experienced by nearby or downstream properties may be asked to consider floods larger than the 1% AEP flood event.

Industrial Development

Floor levels shall be at least 0.5m above the 1% AEP flood or the buildings shall be flood-proofed to a least 0.5m above the 1% AEP flood.

Flood safe access and emergency egress shall be provided to all new developments.

Filling of Land

Council will not grant consent to filling of floodways or high hazard areas. The filling of other land at or below the flood planning level will generally not be supported; however, Council will adopt a merits-based approach where the following criteria are applied:

- Flood levels are not increased by more than 0.1m by the proposed filling;
- Downstream velocities are not increased by more than 10% by the proposed filling;
- Proposed filling does not redistribute flows by more than 15%;
- The potential for cumulative effects of possible filling proposals in that area is minimal;
- There are alternative opportunities for flood storage;
- The development potential of surrounding properties is not adversely affected by the filling proposal;
- The flood liability of buildings on surrounding properties is not increased;
- No local drainage flow/runoff problems are created by the filling; and
- The filling does not occur within the drip line of existing trees.

Rezoning of Land

Council will not support the rezoning of any land located in a floodway or high hazard area.

Council will generally not support the rezoning of rural land situated below the 1% AEP flood where the development of that land may require or permit the erection of buildings or works even if the surface of the land can be raised to a level above the 1% AEP flood by means of filling.

3.3 NSW Government Waterway Health Objectives

The NSW Government has developed numerical waterway health objectives for Wianamatta-South Creek by applying the Risk-based Framework for Considering Waterway Health Outcomes in

Strategic Land-use Planning Decisions (OEH/EPA, 2017). The waterway health objectives aim to achieve:

1. the protection, maintenance and/or restoration of waterways, riparian corridors, water bodies and other water dependent ecosystems that make up the 'blue' components of the Blue-Green Infrastructure Framework
2. a landscape-led approach to integrated stormwater management and water sensitive urban design if followed.

The numerical criteria presented in Table 3-1and Table 3 2 are referred to as water quality and flow objectives and apply to all urban developments on land in the Aerotropolis.

Table 3-1 Ambient water quality of waterways and waterbodies in the Western Sydney Aerotropolis.

Analyte	Concentration
*Total Nitrogen (TN, mg/L)	1.72
Dissolved Inorganic Nitrogen (DIN, mg/L)	0.74
Ammonia (NH3-N, mg/L)	0.08
Oxidised Nitrogen (NOx, mg/L)	0.66
Total Phosphorus (TP, mg/L)	0.14
Dissolved Inorganic Phosphorus (DIP, mg/L)	0.04
Turbidity (NTU)	50
Total Suspended Solids (TSS, mg/L)	37
Conductivity (S/cm)	1103
pH	6.20-7.60
Dissolved Oxygen (DO, %SAT)	43-75
Dissolved Oxygen (DO, mg/L)	8

Table 3-2 Stream flows objectives for waterways and water-dependent ecosystems based on average daily flow rates

Flow Objectives	Hydrologic characteristics of waterways in their current condition	Hydrologic characteristics of waterways at the tipping point for degradation
To be applied in Strahler ranked waterways as follows	1st-2nd order streams	3rd order streams or greater
Median daily flow volume (L/ha)	71.8 ± 22.0	1095.0 ± 157.3
Mean Daily Flow Volume (L/ha)	2351.1 ± 604.6	5542.2 ± 320.9
High spell (L/ha)		
90th percentile daily flow volume	2048.4 ± 739.2	10,091.7 ± 769.7
High spell- frequency (number/y)	6.9 ± 0.4	19.2 ± 1.0
High spell- average duration (days/y)	6.1 ± 0.4	2.2 ± 0.2
Freshes (L/ha)		
75th and 90th percentile daily flow volume	327.1 to 2048.4	2642.9 to 10091.7
Freshes - frequency (number/y)	4.0 ± 0.9	24.6 ± 0.7
Freshes - average duration (days/y)	38.2 ± 5.8	2.5 ± 0.1
Cease to flow (proportion of time/y)	0.34 ± 0.04	0.03 ± 0.007
Cease to flow-duration (days/y)	36.8 ± 6	6 ± 1.1

Waterway Health Targets for development.

The NSW Government has also developed the following stormwater targets to ensure stormwater management contributes to the waterway health objectives being achieved. New development must adopt these targets in designing stormwater and WSUD infrastructure.

A summary of how this study complies with these requirements is provided in Section 3.6.

These stormwater management targets replace the pollution load reduction and stream erosion index targets established in the Penrith DCP 2014.

Table 3-3 Stormwater Pollution reduction targets to achieve waterway health objectives

Stormwater quality targets	Operational Phase
Gross Pollutants (anthropogenic litter >5mm and coarse sediment >1mm)	90% reduction (minimum) in mean annual load from unmitigated development
Total Suspended Solids (TSS)	90% reduction in mean annual load from unmitigated development
Total Phosphorus (TP)	80% reduction in mean annual load from unmitigated development
Total Nitrogen (TN)	65% reduction in mean annual load from unmitigated development

Table 3-4 Flow targets to achieve waterway health objectives

Option 1: Mean Annual Runoff	Stormwater Flow Target
Mean Annual Runoff Volume (MARV)	<=2 ML/ha/year at the point of discharge to the local waterway
90%ile flow	1000 to 5000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5 to 100 L/ha/day at the point of discharge to the local waterway
10%ile flow	0 L/ha/day at the point of discharge to the local waterway
Option 2: Flow Duration Curve Approach	**Stormwater Flow Target**
95%ile flow	3000 to 15000 L/ha/day at the point of discharge to the local waterway
90%ile flow	1000 to 5000 L/ha/day at the point of discharge to the local waterway
75%ile flow	100 to 1000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5 to 100 L/ha/day at the point of discharge to the local waterway
Cease to flow	Cease to flow to be between 10% to 30% of the time

3.4 Draft South Creek Floodplain Risk Management Study

The *Draft South Creek Floodplain Risk Management Study* (Advisian, 2019) defines the Flood Planning Area (FPA) as land at or below the 1% AEP flood plus 0.5 m freeboard and proposes the flood related development controls for any development proposed within the FPA.

Current FPA extents are based upon the results of hydraulic modelling completed for Wianamatta South Creek and its tributaries as part of the *Updated South Creek Flood Study (*WorleyParsons, 2015) mapped to align with topographic elevations defined by the 2002 Aerial Laser Survey (ALS).

Where land below the FPA is currently zoned to permit urban development, Council will generally not support the rezoning of land to higher economic use or an increase in the density of development control 15(c).

FRMP Recommended Changes to the DCP

The FRMS recommends the following new standards to replace the current flood controls and these have been considered in the rezoning the Precinct:

- On the Precinct, flood hazard is not increased to greater than “low” based on current ARR criteria for hazard. Low hazard zones are defined in ARR as where the depth velocity product is (D.V) less than 0.4 m^2/s for children and less than 0.6 m^2/s for adults and should be applied depending on the type of development. Isolated areas of high hazard may be considered at Council’s discretion where people are prevented from entering the area i.e. dedicated flow paths. Hazard should never increase to exceed 0.8 m^2/s as this is the limiting working flow for experienced personnel such as trained rescue workers. Flood hazard should be assessed for the duration of the event and is not necessarily the flood hazard at the time of the peak flood level.
- Flood hazard on surrounding properties should not increase.
- The potential for cumulative effects of possible development proposals in that area is minimal.
- Where possible, any losses in floodplain storage are to be offset by compensatory cut at the same or a similar elevation.
- There is enough time to evacuate all persons from the site during all events up to and including the PMF.

3.5 Controlled activities on waterfront land - Guidelines for riparian corridors

The overarching objective of the controlled activities provisions of the Water Management Act 2000 (WM Act) is to establish and preserve the integrity of riparian corridors. Ideally the environmental functions of riparian corridors should be maintained or rehabilitated by applying the following principles:

- identify whether there is a watercourse present and determine its stream order in accordance with the Strahler System
- if a watercourse is present, define the riparian corridor (RC)/vegetated riparian zone (VRZ) on a map
- seek to maintain or rehabilitate a RC/VRZ with fully structured native vegetation

- seek to minimise disturbance and harm to the recommended RC/VRZ
- minimise the number of creek crossings and provide perimeter road separating development from the RC/VRZ
- locate services and infrastructure outside of the RC/VRZ. Within the RC/VRZ provide multiple service easements and/or utilise road crossings where possible
- treat stormwater runoff before discharging into the RC/VRZ.

3.6 Summary of Performance and Guidance

Key requirements of current policies relating to stormwater and flooding are summarised below in Table 1 with reference to the section of this report that specifically addresses those requirements

Table 3-5 Summary of IWCM compliance with existing requirements above

Existing Policy or Control	How this is to be achieved in the Precinct
Floor levels shall be at least 0.5m above the 1% AEP flood or the buildings shall be flood-proofed to a least 0.5m above the 1% AEP flood	Industrial land use zones are set outside of the 1% AEP flood extents of Ropes, Wianamatta South and Kemps Creeks. Overland flow paths have been mapped across the site to indicate areas where trunk drainage flow paths shall be provided. These demonstrate that development can be accommodated on lands outside high flood hazard land. Detailed design of trunk drainage channels including flood impact mapping will be required for development sites crossed by overland flow paths
Changes in floodplain storage and floodplain filling does not impact on flooding outside the precinct	Industrial land use zones are set outside of the 1% AEP flood extents of Ropes, Wianamatta South and Kemps Creeks to eliminate any risk of filling impacting 1% AEP flood levels outside of the precinct. Channelising overland flow paths through the precinct will reduce the flood storage within the precinct but on-site stormwater detention will compensate for changes in conveyance. Development within overland flow paths in the Ropes Creek catchment must provide evidence through detailed flood impact assessment that there are no local impacts on existing development on Bowood Road, Mt Vernon.
Flood safe access and emergency egress shall be provided to all new developments	Culvert upgrades are proposed on Mamre Road and local roads to facilitate egress. Works shall occur during Precinct road upgrades.
New developments do not increase stormwater peak flows in any downstream areas up to and including the 1% AEP event	A catchment wide approach has been used to size on-site stormwater detention for private industrial sites. This approach ensures no increase in peak flows on lands outside the Precinct and accounts for chanelisation of overland flow paths. This OSD approach can be applied to single sites or at an estate scale.

Existing Policy or Control	How this is to be achieved in the Precinct
Pollution reduction targets are achieved for new development	Pollution reduction targets will be achieved through a combination of: • water sensitive urban design on industrial lots. • biofiltration street trees on new and upgraded local roads • Regional wetlands • Regional stormwater harvesting
Changes to the natural flow regime (volume, flow rate and flow duration) shall be limited as far as practicable	A range of additional stormwater management measures are proposed to achieve reductions in stormwater runoff volumes and closely match the natural flow regime. These measures demonstrate the cost effectiveness of each measure in limiting changes in flow rate and flow duration and allow site designers to select measures that best suit their development. These measures are consistent with new stormwater targets established by DPE for Wianamatta South Creek and its tributaries. These measures have been developed by applying the Risk-based Framework and it is therefore appropriate that state significant development applications apply the same approach.

4 Land Use and Urban Form

The Precinct land zoning is shown in Figure A-4 (DPIE 2019). The paper identifies an opportunity to meet the shortfall of industrial land in Western Sydney by expanding the Western Sydney Employment Area. The Precinct will help alleviate the current shortfall in industrial land and provide approximately 780 ha of new industrial land.

4.1 Zoning

The Mamre Road Precinct structure plan provides for a new industrial zoned precinct which will become a warehousing industrial hub providing around 17,000 new jobs in Western Sydney. The Precinct preserves approximately 95 hectares of environmentally sensitive land, including Cumberland Plain Woodland.

Over 50 hectares of open space, recreation areas, cycle and walking paths will be included within the Precinct. Critical transport corridors are preserved and opportunities for an intermodal terminal are maintained. The total area of the Precinct is approximately 1000 ha and is zoned as outlined in Table 4-1.

Industrial land zoned IN1 will comprise allotments, local and estate roads and areas dedicated to flood conveyance. A suggested road layout has been provided by DPE. Flood modelling has informed the dedication of lands required for flood conveyance, listed as trunk drainage below.

Table 4-1 Summary of land use

Land Use and Zone		Area (Ha)	Percentage of Precinct
E2	Environmental Conservation	72.9	7%
SP2	Infrastructure	27.3	3%
RE2	Private Recreation	23.2	2%
RE1	Public Recreation	28.2	3%
IN1	General Industrial	850.0	
Total		**1001.6**	

4.2 Urban Form and Imperviousness

Urban form is an important consideration in IWCM as it defines many of the sources and opportunities for the generation and reuse of stormwater and wastewater and the need for management of residual discharges to the environment.

The Mamre Road DCP establishes a minimum perviousness target of 15%, and a maximum imperviousness of 85%. Trunk drainage, E2, RE1 and RE2 lands account for 15% of the total precinct area and contribute to the overall perviousness target for the precinct.

The combined verges, landscaping and building setbacks and some trunk drainage channels on the IN1 lands contribute to the remaining overall perviousness target for the precinct.

4.2.1 Roads

The DCP prescribes verge, pavements widths for road typologies with total imperviousness as follows:

- local roads - 84%
- distributer roads – 81%
- collector roads - 80%

Road verges are proposed to include passively irrigated street trees as outlined below in Section 5.2.1.

4.2.2 Large Format Industrial Sites

To calculate stormwater runoff contributions, the total perviousness and imperviousness for industrial land uses is provided in

Table 4-2. This includes an imperviousness split for DCP complying development and an ideal imperviousness.

A schematic of how imperviousness can be reduced on allotments is provided in the Western Parkland City Urban Typologies guidance document (Sydney Water, 2019).

Employment rates of 20 jobs/Ha are adopted for this land use type.

Table 4-2 Possible site coverage and imperviousness for Large Format Industrial and Logistics Centres

	Business as Usual Approach (Adopted for Flood Planning Modelling)		Adopted Imperviousness (Compliant with Mamre Rd DCP and adopted for IWCM Planning)	
For IN1 zoned lands*	**% of land zoning***	**% Imperviousness**	**% of land zoning***	**% Imperviousness**
Roof	40%	100%	40%	100%
Hardstand	16%	100%	16%	100%
Concrete/asphalt car parks and driveway cross overs	24%	100%	20%	100%
Landscaping and set backs	10%	0%	14%	0%
Roads	10%	85%	10%	85%
Sum total (excluding public open space, riparian lands and trunk drainage)		**90%**		**85%**

** Excludes all RE1, RE2, SP2, trunk drainage and Mamre Road*

4.2.3 Business Campus and Strata Industrial

Steeper areas of the catchment require terracing at more frequent intervals which may lead to smaller building footprints. A schematic and summary are provided in Figure 4-2 and Table respectively. Employment rates of 60 jobs/Ha are likely for this typology.

Table 4-3 Adopted imperviousness and site coverage for Business Campuses

	Business as Usual Approach (Adopted for Flood Planning Modelling)		Adopted Imperviousness (Compliant with Mamre Rd DCP and adopted for IWCM Planning)	
For IN1 zoned lands*	**% of land zoning***	**% Imperviousness**	**% of land zoning***	**% Imperviousness**
Roof	23%	100%	23%	100%
Hardstand	13%	100%	13%	100%
Concrete/asphalt car parks and driveway cross overs	36%	100%	24%	100%
Landscape	18%	0%	30%	0%
Public roads	10%	70%	10%	85%
Sum total (excluding public open space, riparian lands and trunk drainage)		**80%**		**69%**

** Excludes all RE1, RE2, SP2, trunk drainage and Mamre Road*

5 Integrated Water Cycle Management

The following section outlines Sydney Water's integrated water servicing strategy for the precinct. The water servicing strategy represents the overall, combined water demands for low and high-water users alike.

5.1 Regional Water Demands

Water planning for the precinct is based on a survey of Sydney Water's industrial customers across Western Sydney. Figure 5-1 shows a histogram spread of total water demands including high and low water users. Based on this, the median water demand rate for industrial lots is 12.5 kL/Nha/day and the weighted average is approximately 8.5 kL/Nha/d.

For planning regional infrastructure, the adopted water demand is adopted as 9.5 kL/day per hectare of industrial zoned lands. This water demand is also representative of business-as-usual industrial development, which is expected to be dominated by internal water demands with low associated irrigation rates.

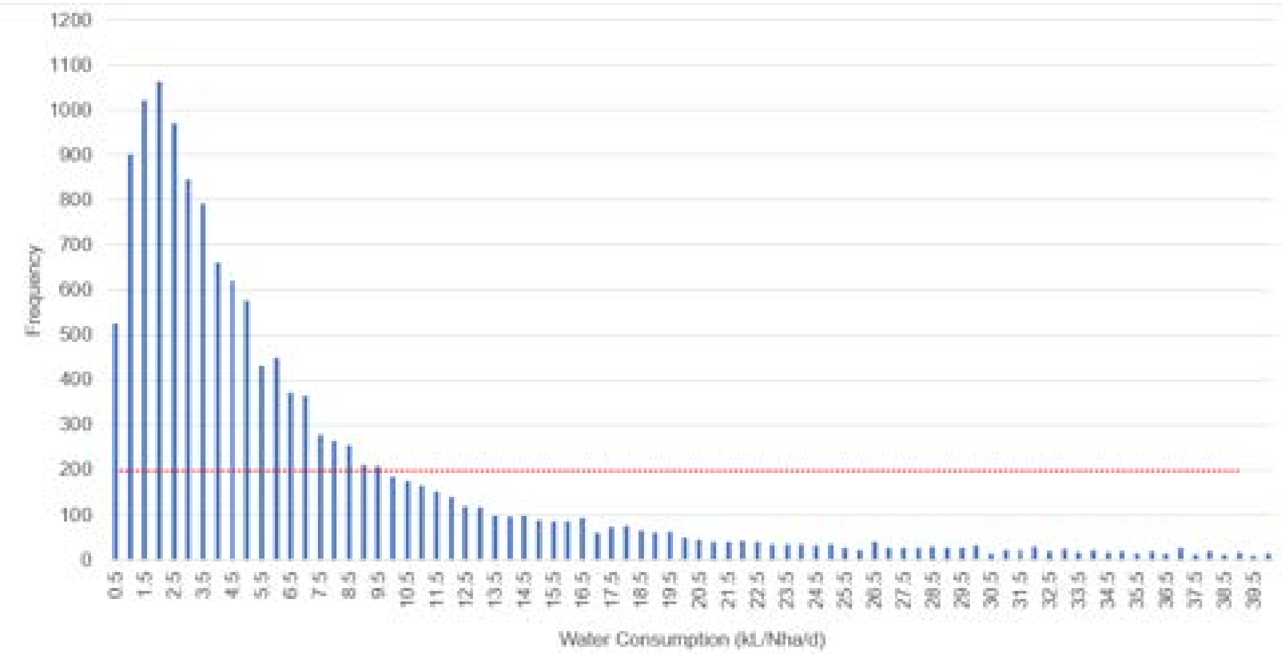

Figure 1 Histogram of total water consumption for industrial customers (median water user shown red dashed)

The spread of water demands shows a high proportion of low water users who use a fraction of the median water demand. A discussion on the risk of low water usage across the precinct is provided in Section 6.1.1 and 6.1.2.

Non potable water demands have been assumed to account for 50% of total potable water demands.

5.1.1 Non potable internal demands

For planning, internal non-potable water demands of 3.8 kL/day/Ha of industrial land have been adopted. Due to the number of low water users surveyed, a lower non-potable water demands of 0.3 kL/NHa/day was also adopted for sensitivity testing.

Data centres and other high-water users would increase total water demands to 10 kL/NHa/day which is associated with demand for higher quality non potable water.

Stormwater is prioritised for non-potable demands and supplemented with recycled water as required.

5.1.2 Irrigation

Irrigation demands have been adopted as follows:

- Private landscaped areas – 2.5 ML/yr/Ha of pervious area
- Road verges – 2.5 ML/yr/Ha of pervious area
- Public open space – 3.2 ML/yr/Ha of RE2 and RE1

Active transport routes, vegetated trunk drainage channels and public open space may feasibly be irrigated at 4.5 ML/Ha/yr according to a detailed land capability assessment study undertaken for the Aerotropolis (Aurecon, 2020).

Riparian corridors, wetlands and ponds may not be irrigated which reduces the total irrigation area.

Stormwater is prioritised for irrigation and supplemented with recycled water as required.

5.2 Servicing Strategies

5.2.1 Stormwater

Consultation with Penrith Council has indicated a preference for flood detention controls on each lot to manage flooding impacts, and a combination of on-lot and regional stormwater management infrastructure to manage waterway health (flow and quality) outcomes where there is appropriate funding.

An alternative approach is also presented where stormwater management is provided through a combination of private and public WSUD elements and centralised stormwater harvesting network delivered and managed by a Trunk Drainage Manager.

Drainage

Stormwater generated within the Precinct will be conveyed by a combination of minor and major drainage elements within public roads, natural trunk drainage channels and creek lines. Natural trunk drainage channels are recommended in order to fulfil the requirements of the Industry and Employment SEPP to integrate stormwater management systems into the landscape in a manner that provides multiple benefits, including water quality protection, stormwater retention and detention, public open space, habitat improvement and recreational and visual amenity.

In some cases, it will be necessary to use trunk drainage channels to safely convey stormwater from upstream catchments through land that is zoned as industrial. It will be cost effective to divert flows that exceed the capacity of low-cost stormwater pipes into these channels. This often coincides with a notional upstream catchment of 15 Ha as shown in Appendix G. There is some flexibility in the alignment of trunk drainage due to steeper site grades, but this must be balance with the earthworks.

The network of required natural trunk drainage channels is shown Appendix B.

Peak flow detention

At this time, it is expected that flood detention is required to preserve existing peak discharge at Mamre Road culverts and the precinct boundary. It is proposed that on-site stormwater detention basins on industrial lots compensate for discharges from roads. Detention controls for new developments are prescribed in Section 7.4.

Waterway quality objectives (flow and quality)

A WSUD strategy is required that achieves waterway health objectives and stormwater quality and quantity targets prescribed by the NSW Government outlined in Table 3-3 and Table 3-4.

Two strategies were detailed and tested to achieve the water quality objectives and targets (flow and quality):

- **On-lot approach** - A strategy that utilises mostly private, **on-lot stormwater management** measures to achieve the waterway objectives
- **Regional approach** - A strategy that uses a small amount of stormwater filtration (GPTs) on the industrial allotments and achieves the waterway objectives through a mix of **public infrastructure and centralised stormwater harvesting** in and around the precinct as well as assets located adjacent to the precinct.

Table 5-1 provides a summary of the treatment train elements in each approach.

Table 5-1 Treatment train functionality and scale

Stormwater management measures	Function	Description	On Lot Strategy	Regional / Precinct Strategy
Imperviousness	Low flow control	Retaining pervious areas within the Precinct provides base flow to waterways and opportunities to dispose of stormwater through irrigation. Pervious areas include landscaping on allotments, verges, trunk drainage corridors, riparian lands and public open space.	Minimum perviousness of 15% across roads and allotments Combined perviousness of 30% across entire precinct	Minimum perviousness of 15% across roads and allotments
Rainwater tanks	Storage Low flow control	Rainwater tanks provide an effective means of reducing stormwater volumes on development sites with high water demands but have limited effectiveness for low water users. Captured rainwater is suitable for internal and external non potable demands as well as irrigation of roof areas to dispose of stormwater and provide cooling benefits.	80 kL/NHa connected to 100% of roof area	Not required
Stormwater harvesting storage	Storage Low flow control	Pre-treated stormwater can be captured in above ground or below ground storages on the allotment or in public areas at the end-of-pipe.	Via private wetlands/ ponds or storages	Via wetlands on public lands
Passive irrigation of street trees or street scape	Low flow control	Regularly spaced, passively irrigated street tree pits provide an opportunity to irrigate landscape elements, reduce stormwater volumes and provide local microclimate benefits. Street trees are required to meet the canopy targets and must be irrigated with recycled water to better mitigate urban heat.	14 trees/NHa 9 m^3 / tree	14 trees/NHa 9 m^3 / treestora
Gross pollutant traps (GPT)	Pre-treatment / pollutant removal	Gross pollutant traps will provide pre-screening of stormwater prior to filtration discharge to Council-owned or trunk drainage elements.	Treatable flow 0.035 m^3/s/Ha on allotment	Treatable flow 0.035 m^3/s/Ha on allotment
Bioretention basins	Pre-treatment / pollutant removal	bioretention basins may provide pre-treatment and filtration of stormwater prior to stormwater harvesting storages.	0.6%* of allotment located in landscaped zone or flood detention basin	Not proposed
Constructed wetlands	Pre-treatment / pollutant removal Storage	Constructed wetlands provide pre-treatment to stormwater and a means of controlling stormwater discharged over several days. Wetlands are also important in the management of algal bloom risk as	5%* of allotment located in private lands	3%* of catchment located in public lands

Stormwater management measures	Function	Description	On Lot Strategy	Regional / Precinct Strategy
	Low flow control	recirculation of pond water through wetlands.		
Stormwater storage ponds	Storage Low flow control	Ponds provide a storage, amenity, and hydrologic function. While they are cheap to construct, they have a land take. Ponds require pre-treatment of stormwater and ideally are paired with a wetland to manage algal bloom risk.	As an alternative to wetlands on private lands	4%* of catchment prioritised in RE1, RE2 and Wianamatta-South Creek precinct
On-site-stormwater detention basins	Flood control	Flood detention is required to maintain existing peak flow rates at the Mamre Road culverts and the precinct boundary. On-site stormwater detention basins are considered for all private lands, in addition to other WSUD assets.	On lots in addition to rainwater tanks and wetlands	On lots
Vegetated trunk drainage swales	Stormwater conveyance Flood control	Vegetated channels and swales will be used to convey stormwater and flood flows from catchments greater than 15 Ha. At this catchment size, overland flow safety requires trunk drainage infrastructure. Culverts are significantly less cost effective than open channels and vegetated trunk drainage provides biodiversity, cooling, and public amenity benefits. Trunk drainage also contributes to the total perviousness target for the Precinct	Across precinct	Across precinct
Stormwater pit and pipe drainage networks	Stormwater conveyance Flood control	Drainage networks to convey minor stormwater flows will be required but are not considered in this study.	Across precinct	Across precinct

5.2.2 Recycled Water Servicing

Sydney Water will provide recycled water (tertiary treated effluent) to the Precinct from the Upper South Creek Advanced Water Recycling Centre (AWRC) which is planned for a site to the west of the Precinct.

Recycled water is a reliable, climate-independent source of non-potable water which plays an important role in substituting and conserving drinking water. Water balance analysis demonstrates that even with rainwater and stormwater harvesting, recycled water replaces significant volumes of drinking water, particularly in hotter drier conditions and is required in both the on-lot and regional approach.

For the regional approach, the recycled water reservoir and third pipe network will be utilised to distribute blended stormwater and recycled water, resulting in efficiencies for both systems. The regional approach will also free up developable land that would otherwise be required to meet the stormwater targets through on lot stormwater harvesting and treatment infrastructure.

Additionally, without recycled water, the size of the stormwater harvesting infrastructure (specifically wetlands and storage ponds) for either the regional or on lot approach, may need to increase in order to minimise potable top up during periods of dry weather. Such top up would also risk potential water restrictions in the event of broader metropolitan dry periods impacting the ability to maintain consistent greening and cooling outcomes in the precinct.

Below highlights the recycled water network required in Mamre Road Precinct. Detailed planning is underway to determine the optimum scheme plan including the integration of stormwater and recycled water to be delivered via one network.

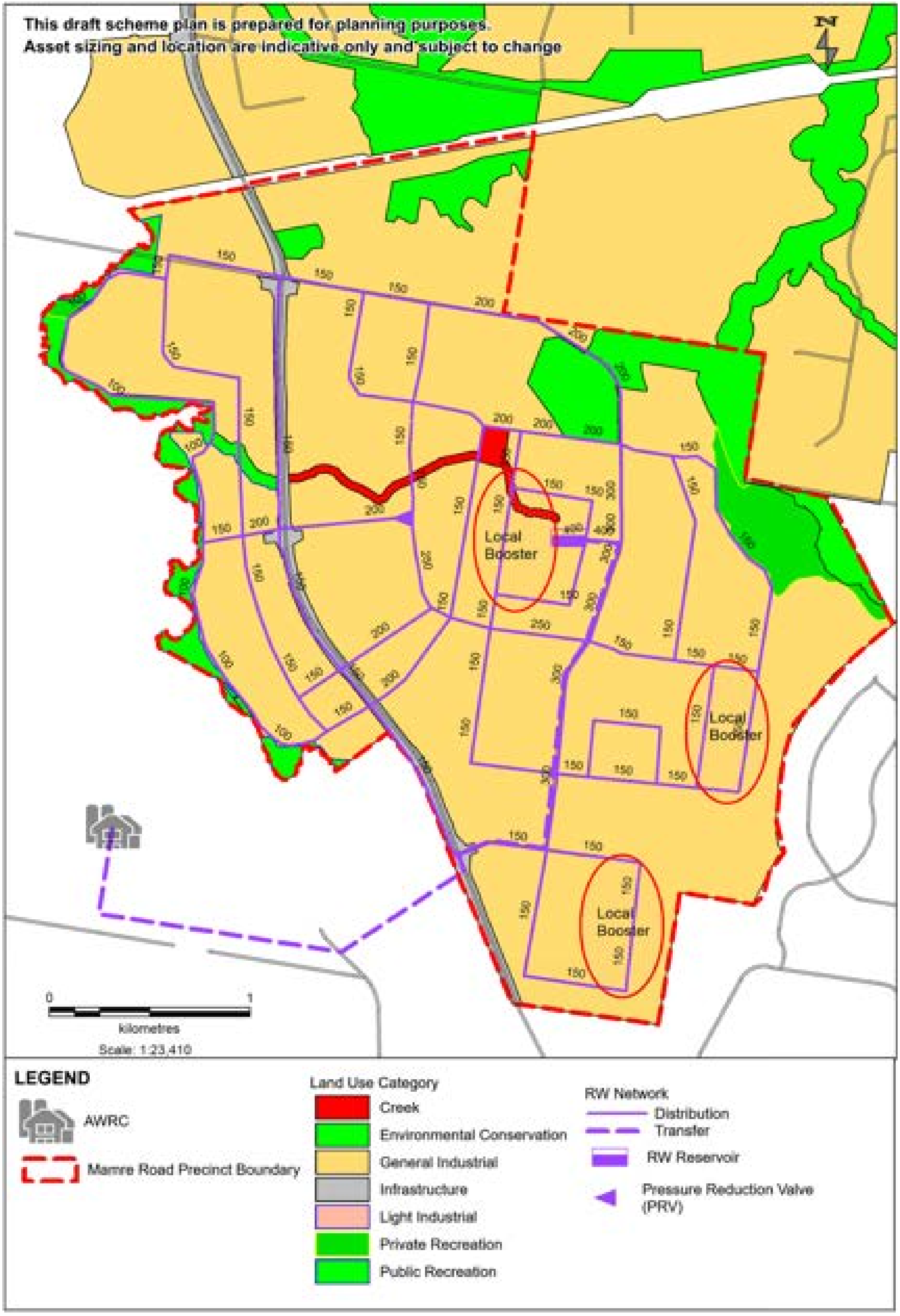

Figure 2 –Mamre Road Precinct Draft Recycled Water Scheme Plan (subject to final road layout)

Note: this has been prepared for planning purposes, it is indicative only and subject to change

5.2.3 Drinking Water Servicing

Existing drinking water servicing:

The Precinct is currently supplied via the Cecil Park reduced supply zone. There is very limited capacity in this system to supply the first stages of development.

Sydney Water is planning for staged delivery of trunk drinking water assets across the Western Sydney Aerotropolis (WSA) in line with DPE growth forecasts. This will enable flexible servicing for interim and staged delivery to meet anticipated development timeframes.

Interim drinking water servicing:

Interim servicing is required via extension of the Erskine Park elevated supply zone and the Cecil Park supply zone (via WP0184C).

Some pockets of the Precinct may require a booster pumping station, and this will be dependent on the staging and timing of the development, detailed hydraulic modelling and finished surface levels. Developers are also required to amplify some existing reticulation mains to provide adequate servicing of the precinct.

Upon finalisation of the DCP, Sydney Water can finalise the servicing scheme plan interim servicing.

Ultimate drinking water servicing:

Sydney Water's strategic servicing of the Precinct is linked to the Western Sydney Regional Master Plan and WSA Sub Regional plan. Ultimate drinking water supply for the precinct will be via the Cecil Park water supply zones, with utilisation of interim servicing links to adjoining supply zones for operational flexibility and reliability.

Figure 3 highlights the draft Drinking Water Scheme Plan for Mamre Road Precinct. Upon finalisation of the DCP, Sydney Water can finalise servicing the scheme plan for ultimate servicing.

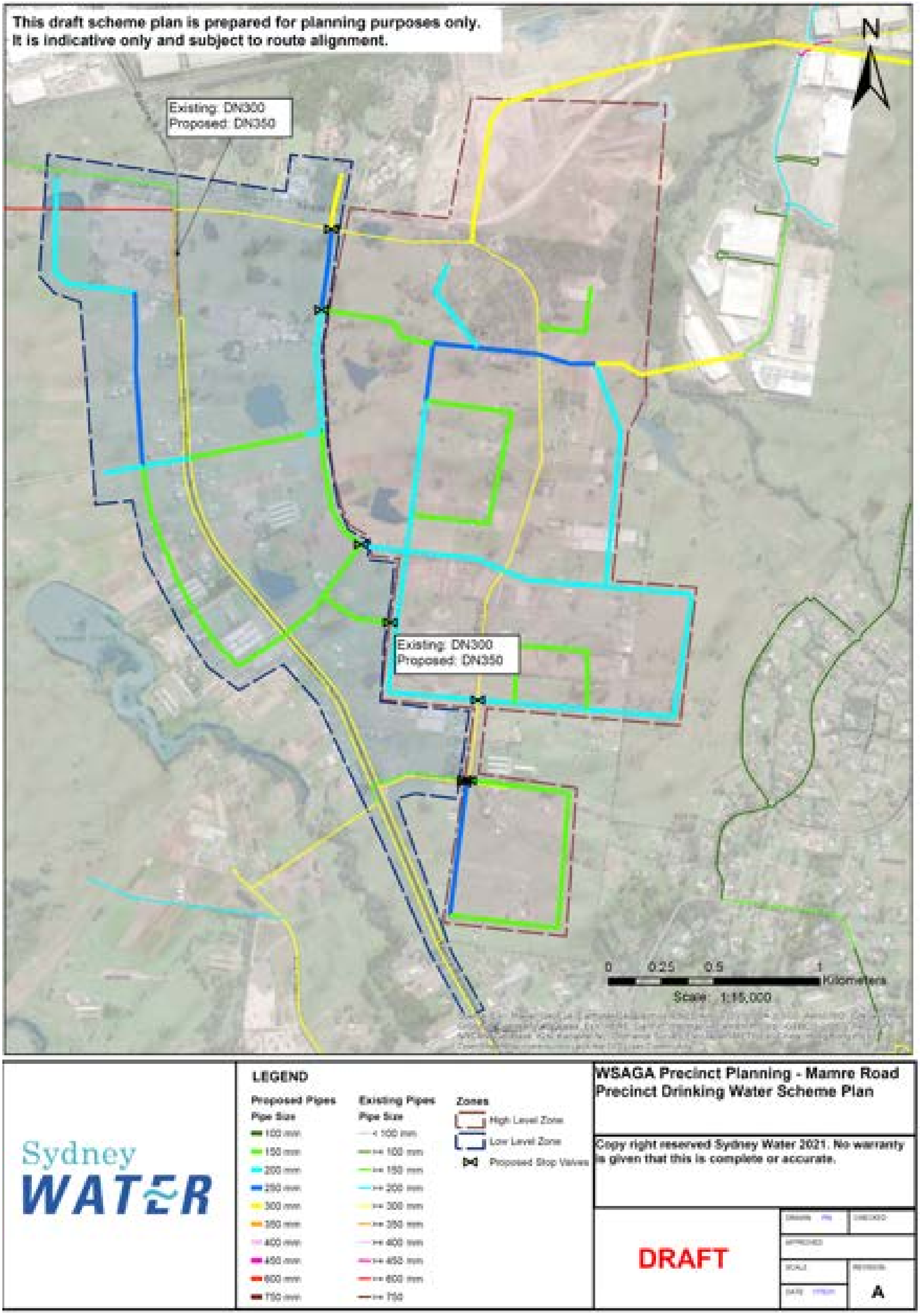

Figure 3 - Mamre Road Precinct Draft Drinking Water Scheme Plan (subject to final road layout)
(Note: this has been prepared for planning purposes, it is indicative only and subject to change

5.2.4 Wastewater Servicing

Existing wastewater servicing:

The eastern catchment of the Precinct drains by gravity to the St Marys wastewater system. This system has capacity to service the eastern catchment via a wastewater main extension. The eastern catchment can permanently drain to the St Marys system.

The western catchment is currently not serviced.

Sydney Water is planning for staged delivery of trunk wastewater assets across the WSA in line with DPE growth forecasts. This will enable flexible servicing for interim and staged delivery to meet anticipated development timeframes.

Interim wastewater servicing:

Sydney Water's interim wastewater servicing scheme for the western catchment of the Precinct is for two permanent wastewater pumping stations (WWPS) and deep gravity trunk mains to service the catchment. The western catchment can be pumped via a temporary pressure main to the St Marys wastewater system up to about 2026. The target delivery of this work is the second half of 2024. This interim solution is based on anticipated staged employment demand pre 2026 and connection will need to be managed to ensure capacity within the St Marys wastewater system.

Ultimate wastewater servicing:

Sydney Water's strategic servicing of the Precinct is linked to the draft Western Sydney Regional Master Plan and draft WSA Sub Regional plan. To fully service the Precinct the western catchment requires two permanent WWPS and deep gravity trunk mains, to be delivered as part of the interim servicing. A new pressure main will divert flows to the proposed Upper South Creek AWRC. The AWRC first stage completion is targeted for 2025/2026.

Figure 4**Error! Reference source not found.** highlights the draft Wastewater Scheme Plan for Mamre Road Precinct.

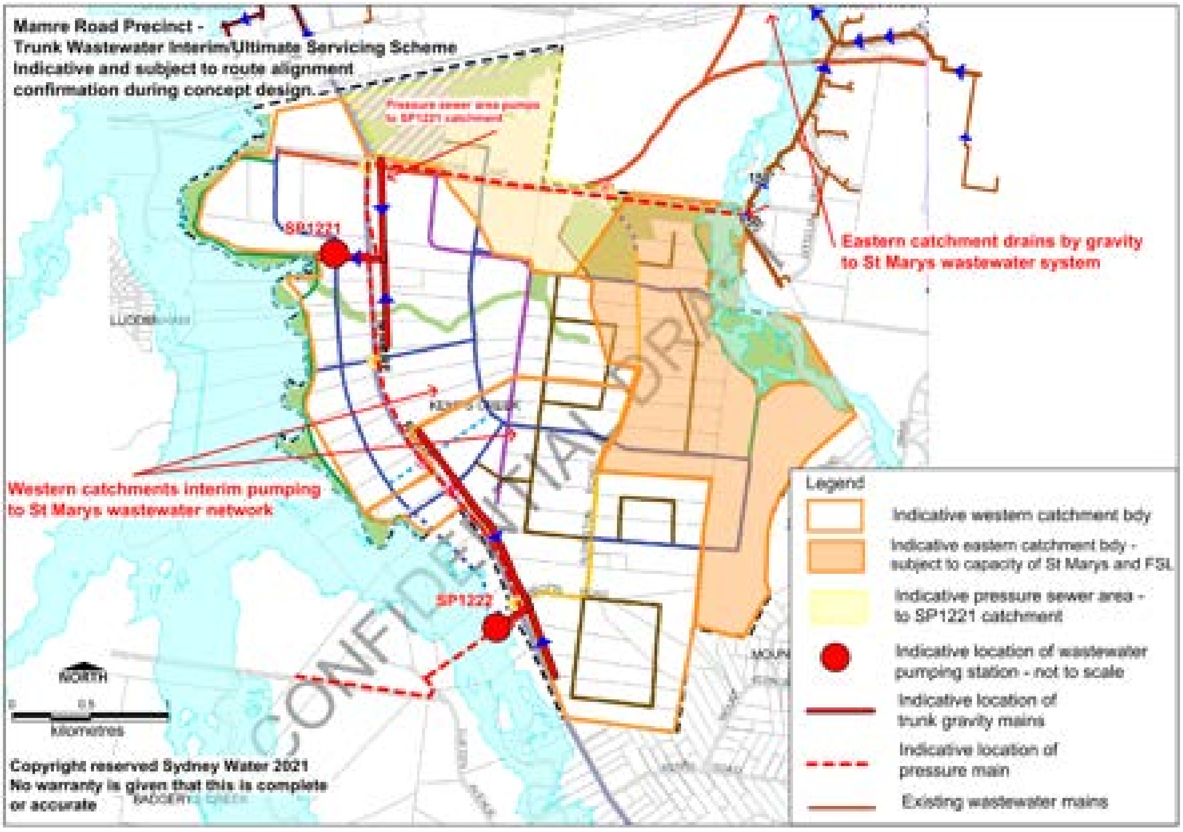

Figure 4 - Mamre Road Precinct Draft Wastewater Scheme Plan (subject to final road layout)
Note: this has been prepared for planning purposes, it is indicative only and subject to change

5.3 Prioritisation of Water Sources

Table 3-5 provides the hierarchy of water sources to supply industrial water uses and irrigation of gardens, verges and open space. Two water use hierarchies are provided which achieve the water quality objectives (flow) through the reuse, retention, and detention of low flows through a range of stormwater harvesting and WSUD measures:

On-lot approach – Prioritises the use of private rainwater tanks and wetlands to maximise the retention and reuse of stormwater on the on-lot.

Regional approach – Removes reliance on private rainwater tanks and prioritises the use of a centralised stormwater harvesting network which captures, filters and reticulates stormwater to industrial lots.

The adopted demands are also summarised which are applied to water balance modelling presented below.

Table 5-2 Water demands and water product prioritisation

End Use	On-lot stormwater management	Regional/Precinct Stormwater Harvesting	Adopted Demand
Potable indoor **(General industrial)**	1	1	4 kL/NHa/NHa
Non-potable indoor **(General industrial)**	1 2 3 4	1 2 3	Median - 3.8 kL/NHa/day Low - 0.3 kL/NHa/day
Non-potable outdoor **(General industrial)**	1 2 3 4	1 2 3	1 kL/NHa/day or 2.5 ML/Ha/yr * (Private gardens, verges, street scape)
Roof cooling irrigation **(General industrial)**	1 2		4.5 ML/ha/yr*
Open space irrigation **(RE1)**	1 2	1 2 3	3.2 ML/ha/yr *
Trunk Drainage irrigation	1 2	1 2 3	3.2 ML/ha/yr (ha of drainage channel) *
Streetscape and roadside verges	1 2 3	1 2 3	18 kL/yr/tree* Tree density is ≈ 14 trees/Nha
Sewage	1	1	30 EP/NHa 150 L/EP/day
Legend	Drinking water Rainwater	Stormwater Recycled Water	Sewerage

* indicates where the seasonal factor was applied

6 Water Quality Objectives (Flow and Quality)

6.1 Stormwater Balance Modelling

Water balance modelling has been undertaken to demonstrate the effectiveness of IWCM to achieve daily flow volume objectives for the precinct.

Water demands and hierarchies outlined in Table 6-1 were applied to Large Format Industrial and Business Campus typologies and water balance modelling was undertaken in MUSIC using a continuous hourly time series from 1993 to 2017. The time series gives an annual rainfall depth and evapotranspiration depth of 739mm and 1266mm respectively.

Two strategies were tested to determine the implementation options to achieve the waterway health objectives and targets (flow and quality):

1) **On-lot approach** - A strategy that utilises mostly private, **on-lot stormwater management** measures to achieve the waterway objectives
2) **Regional approach** - A strategy that uses a small amount of stormwater filtration (GPTs) on the industrial allotments and achieves the waterway objectives through a mix of **public infrastructure and centralised stormwater harvesting** at the Precinct boundary.

6.1.1 On-lot stormwater management approach

This approach prioritises the use of private rainwater tanks and wetlands to maximise the retention and reuse of stormwater on the on-lot. This scenario represents the on-lot approach.

A schematic for Scenario 1 (on-lot) is presented in Figure 5 and a cross section is presented in Figure 6

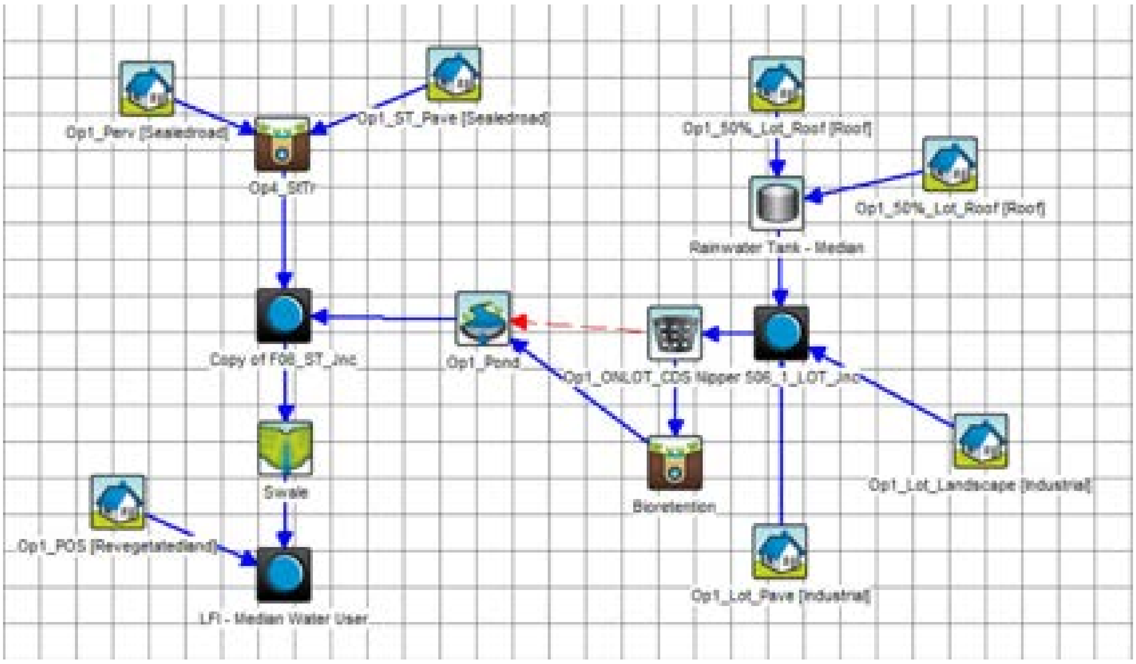

Figure 5 Option 1 treatment train structure showing on-lot measures

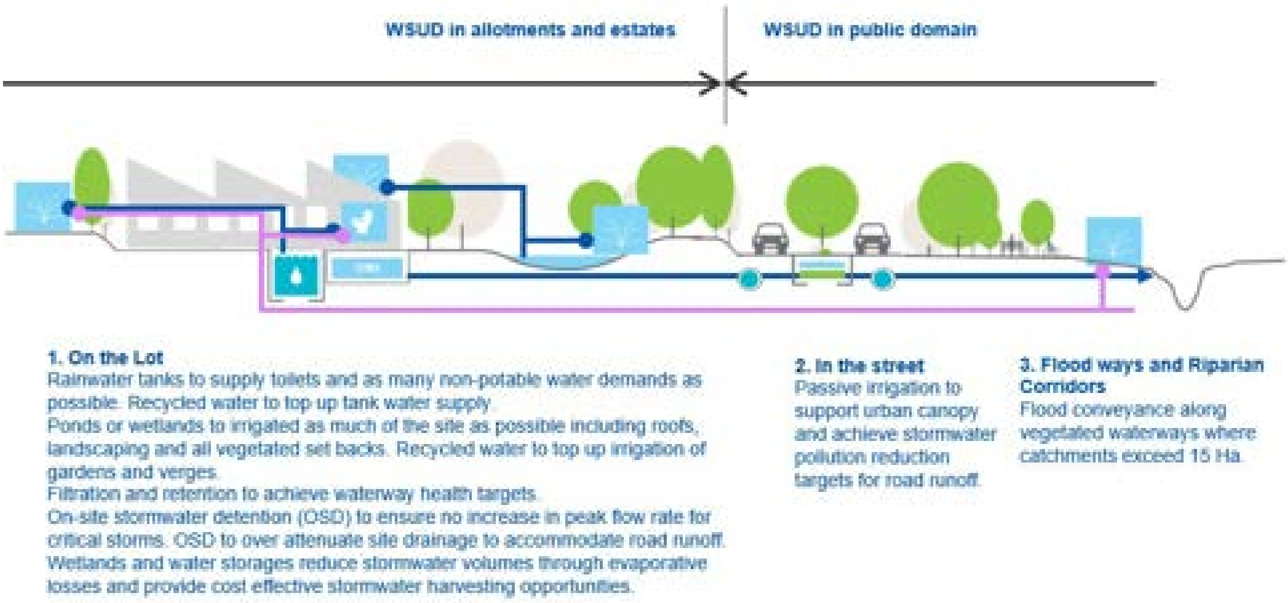

Figure 6 Schematic section for on-lot approach

In MUSIC software, the mean daily flow volumes are calculated and expressed as mean annual run-off volume (MARV) in megalitres of run-off per year (ML/year/NHa). This includes allowance for 15% of the precinct to remain as RE1, RE2, E2 and trunk drainage.

The MARV generated by each hectare of Precinct is presented as the stacked column graph on the left side of each graph. The volume of annual stormwater that 1st-2nd order and 3rd-4th order waterways receive is presented as the dark and pale green bars on the left-hand side. The grey bar above this represents the volume of run-off generated that exceeds the waterway flow objectives.

The potential stormwater volume reductions associated with the range of IWCM and WSUD approaches are presented as floating bars and the size of each bar represents the effectiveness (magnitude of flow reduction) of each measure.

Large Format Industrial land use, presented in Figure 7, is expected to be the dominant typology in the Precinct.

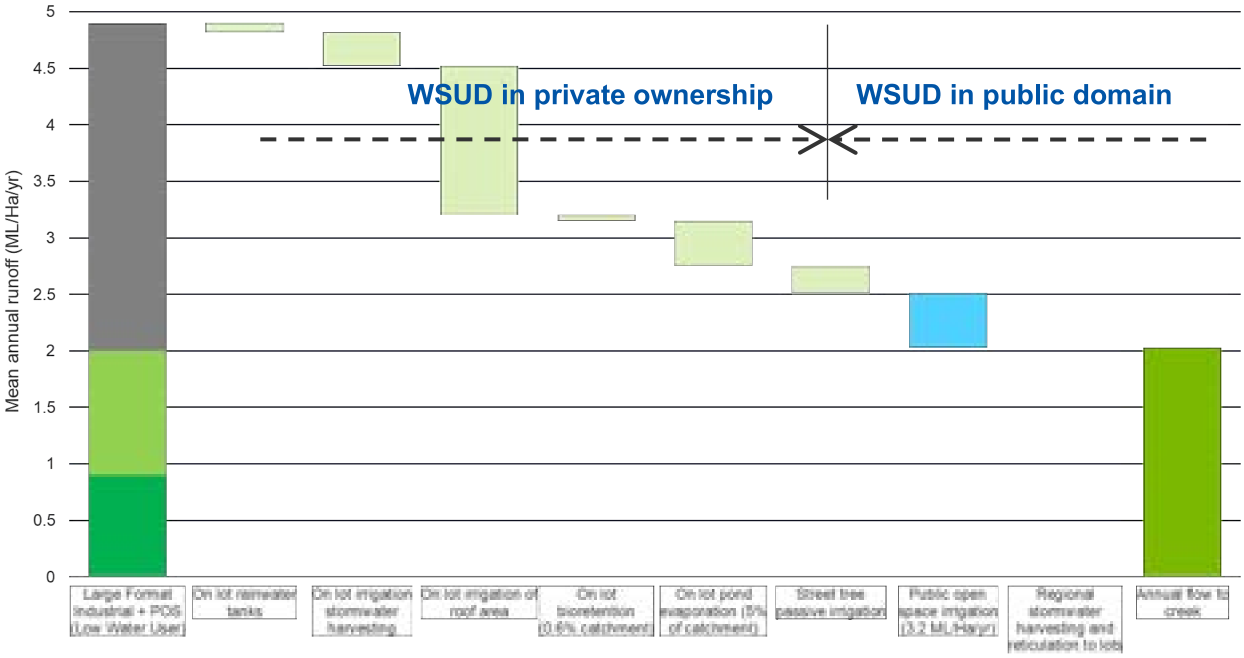

Figure 7 Effectiveness of on-lot approach on Large Format Industrial lots with low water use

Figure 7 shows that rainwater tanks are not highly effective on low water use sites. Irrigation of roof, gardens, verges and public open space contributes to achieving the mean daily or annual flow objectives. Under this scenario, additional stormwater harvesting for irrigation of public open space is required to achieve the objectives, which requires an additional level of governance and catchment coordination through Councils or a trunk drainage manager.

While no single measure will deliver the required flow reductions, the combined effect of all measures can deliver the mean daily or annual flow objectives for the Precinct. However, this would require significant on lot investment, maintenance and land take.

Figure 8 below presents water balance modelling for median water use Large Format Industrial development.

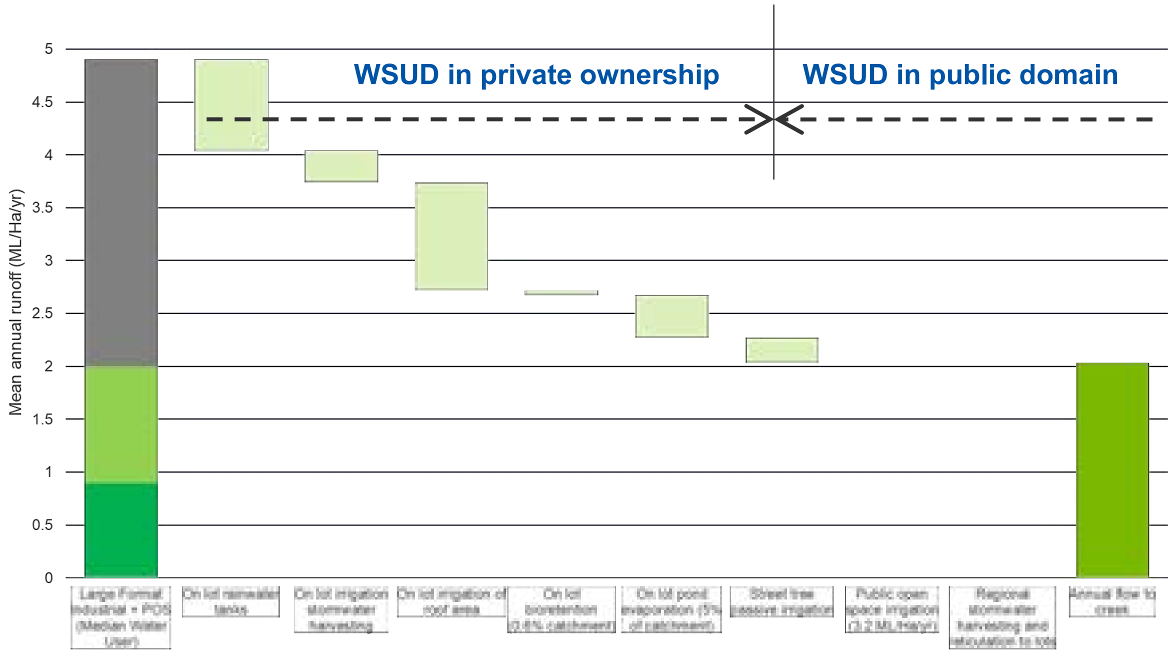

Figure 8 Effectiveness of on-lot approach on Large Format Industrial lots with median water use

Figure 8 also shows that median water users can achieve the flow objectives without reliance on stormwater harvesting for irrigation of public open space. In this scenario, achieving the objectives is still dependent on the combined effect of all IWCM measures on the lot functioning as intended. However this would require significant on lot investment, maintenance and land take.

This is also reliant on the adopted imperviousness rates of 85% across roads and allotments.

Figure 9 and Figure 10 below shows the on-lot water balance for low and median-water use on business campus typologies.

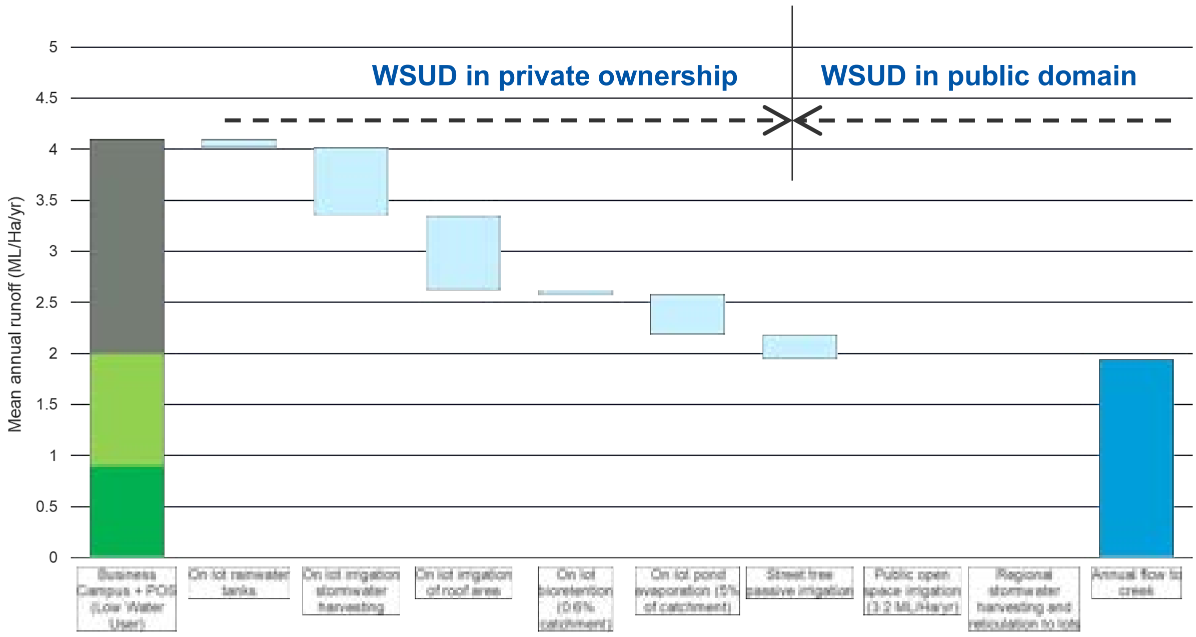

Figure 9 Effectiveness of on-lot approach on Business Campus lots with low water use

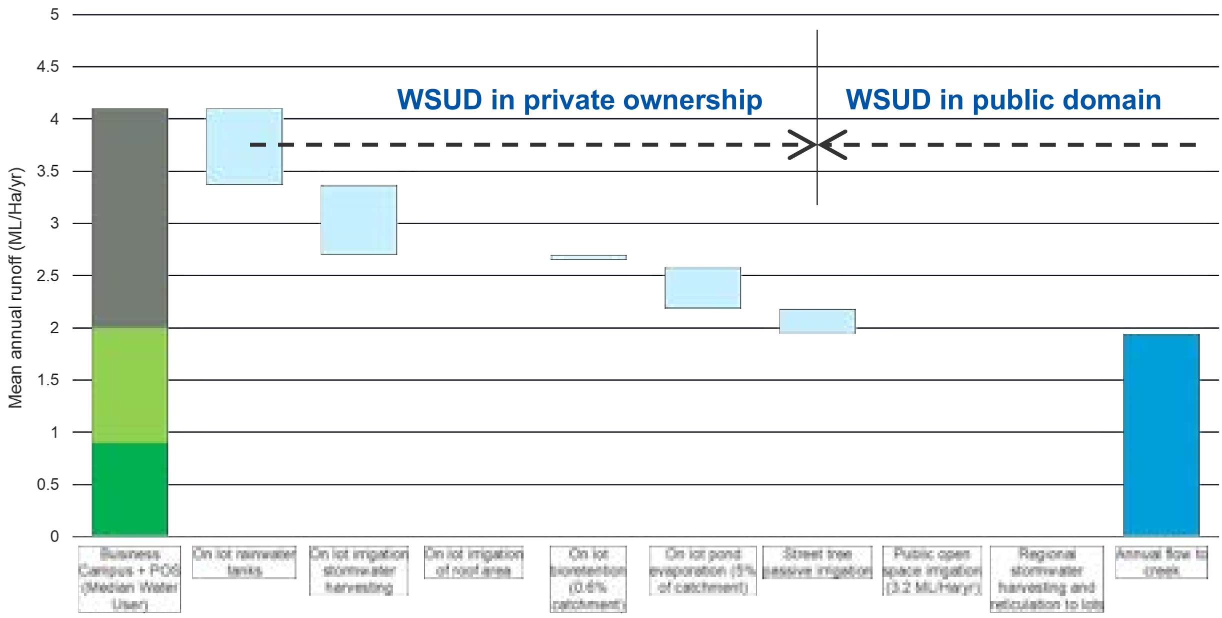

Figure 10 Effectiveness of on-lot approach on Business Campus lots with median water use

Figure 9 and Figure 10 above shows that business campus typologies can achieve the flow objectives but are still dependent on the combined effect of measures on the lot. The water balance shows that it is feasible to achieve the flow objectives on median and low water use sites alike based on a total imperviousness of 69% across lots and local roads. Low water users would still be required to irrigate roof areas to remove the additional water required to achieve the objectives.

Residual Risk

Achieving the flow objectives through on-lot measures is highly dependent is on imperviousness and water demands on the lot.

While the water balance shows that it is feasible to achieve the flow objectives on median and low water use sites, there is a risk of failure if on-lot measures are not designed or constructed correctly are abandoned or inadequately maintained. To manage the residual risk, it is recommended that Scenario 1 (on-lot) includes arrangements such as compliance officers to ensure or enforce compliance for on-lot WSUD and IWCM measures.

A regional approach mitigates this risk.

6.1.2 Regional stormwater harvesting

The regional approach removes reliance on private rainwater tanks and stormwater harvesting on the lot and utilises a centralised stormwater harvesting network to capture, filter and reticulate stormwater to lots across the precinct. This approach consolidates all stormwater and IWCM measures into a regional strategy that takes advantage of the third pipe (purple pipe) reticulation network. It also overcomes the risk of low water users occupying the precinct as a regional stormwater harvesting approach can buffer the difference between low and high median water demands more effectively than on-lot tanks and ponds.

A schematic for the regional approach is presented in Figure 11 and a cross section is presented in Figure 12.

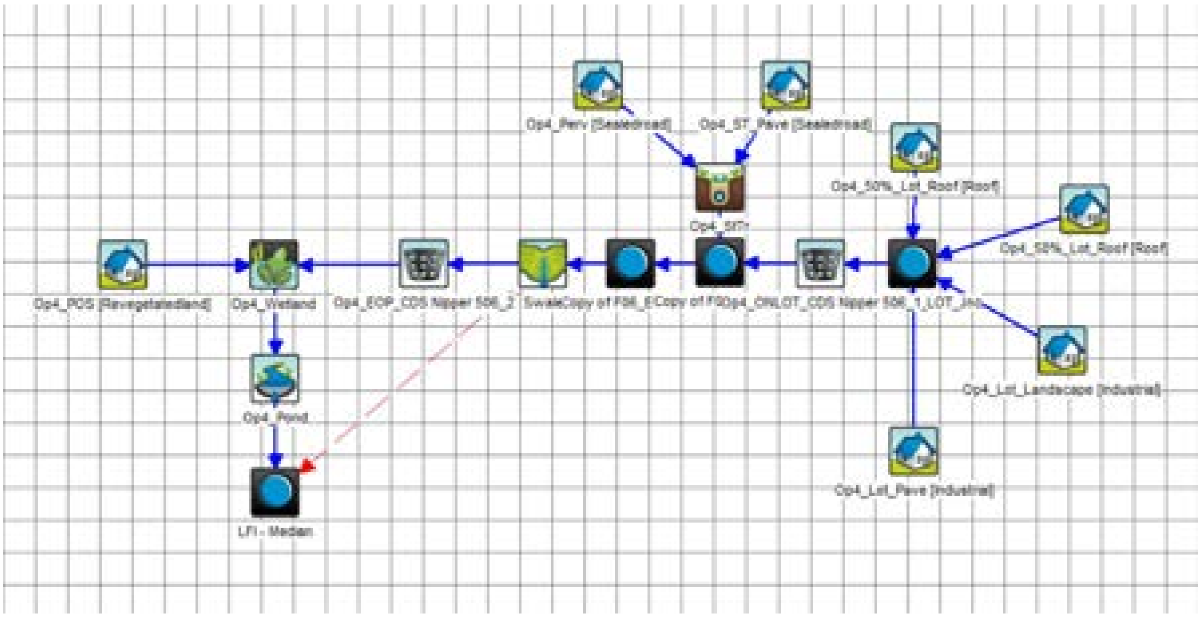

Figure 11 Regional approach treatment train structure

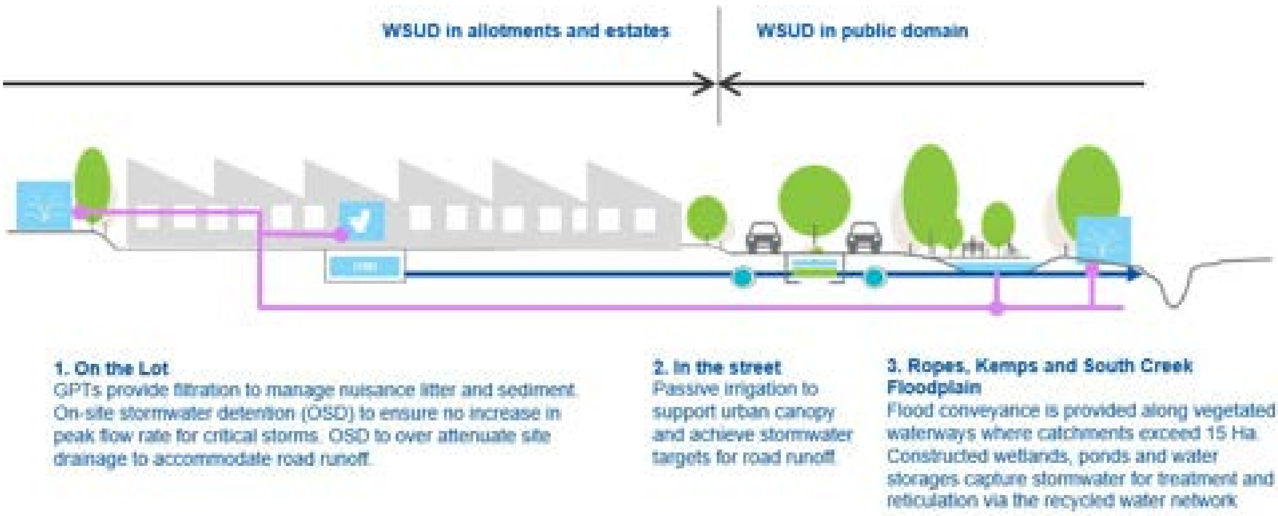

Figure 12 Schematic section for regional approach

MUSIC modelling results for the regional stormwater strategy is shown in Figure 13 and Figure 14.

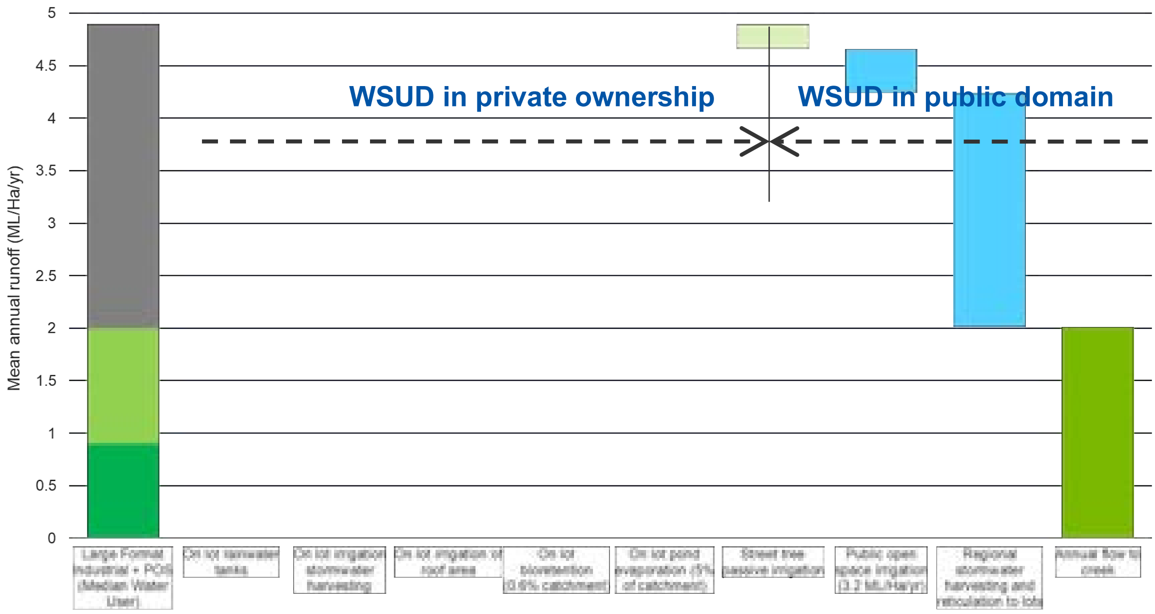

Figure 13 Effectiveness of regional stormwater harvesting with median water use on Large Format Industrial typologies

Figure 13 shows that median water usage on large format industrial lots combined with irrigation of public open space and passively irrigated street trees achieves the mean daily or annual flow objectives. The residual mean annual runoff volume is shown to drop below 2 ML/Ha/yr indicating some minor redundancy in the stormwater harvesting system that could be optimised during design.

The water balance below presents the water balance for Business Campus typologies and median water use is applied due to the regional reticulation approach.

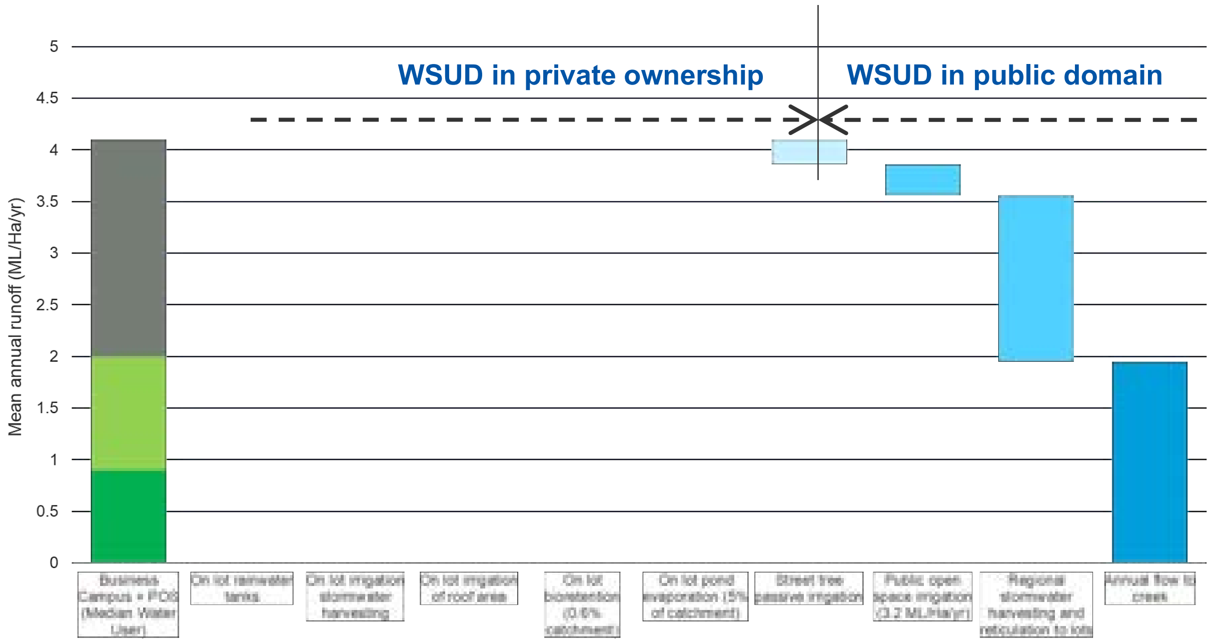

Figure 14 Effectiveness of regional stormwater harvesting with median water use on Business Campus typologies

Figure 14 above shows that business campus typologies can easily achieve the flow objectives through a regional stormwater harvesting approach with the residual stormwater discharge volume sitting below 2 ML/Ha/yr. This approach shows some potential to either optimise the footprint of stormwater harvesting wetlands or to potentially increase imperviousness in the catchment, if there is known to be extensive business campus typologies. This lends itself to the provision.

Residual Risk

The water balance for regional harvesting overcomes the risk that low water users in the Precinct do not result in sufficient reduction of stormwater volumes to achieve the mean daily and annual flow objectives. This is achieved by combining high and low water users into the same harvesting and reticulation system and using a stormwater harvesting network that has capacity to buffer the high and low water demands.

Regional harvesting is also shown to achieve the flow objectives by consolidating stormwater management elements and removing reliance on privately owned and maintained infrastructure.

This centralised management of water also provides a scale of WSUD assets that is more cost-effective for maintenance and management and allows integration with the recycled water network.

The regional harvesting requires the introduction of centralised and coordinated stormwater harvesting management on a scale that is not currently provided. To maximise economic benefits, flood fringe land within the adjacent Wianamatta Precinct should be the preference to locate regional wetlands and water storages.

6.2 Flow Duration Curves

Flow duration analysis has been undertaken using the mean annual runoff approach for Mamre Road developed by modelling utilises the Mamre Road template developed by DPIE EES having a mean annual rainfall depth of 691mm and potential evapo-transpiration of 1338 mm.

Table 6-1 Stormwater flow targets

Indices	Large Format Industrial		Business Campus		Target
	Result	Comply	Result	Comply	
MARV (ML/ha/yr)	1.90	Yes	1.29	Yes	< 2
90%ile	2307	Yes	1358	Yes	1000 to 5000 L/ha/day
50%ile	25	Yes	37	Yes	5 to 100 L/ha/day
10%ile	0	Yes	0	Yes	0 L/ha/day

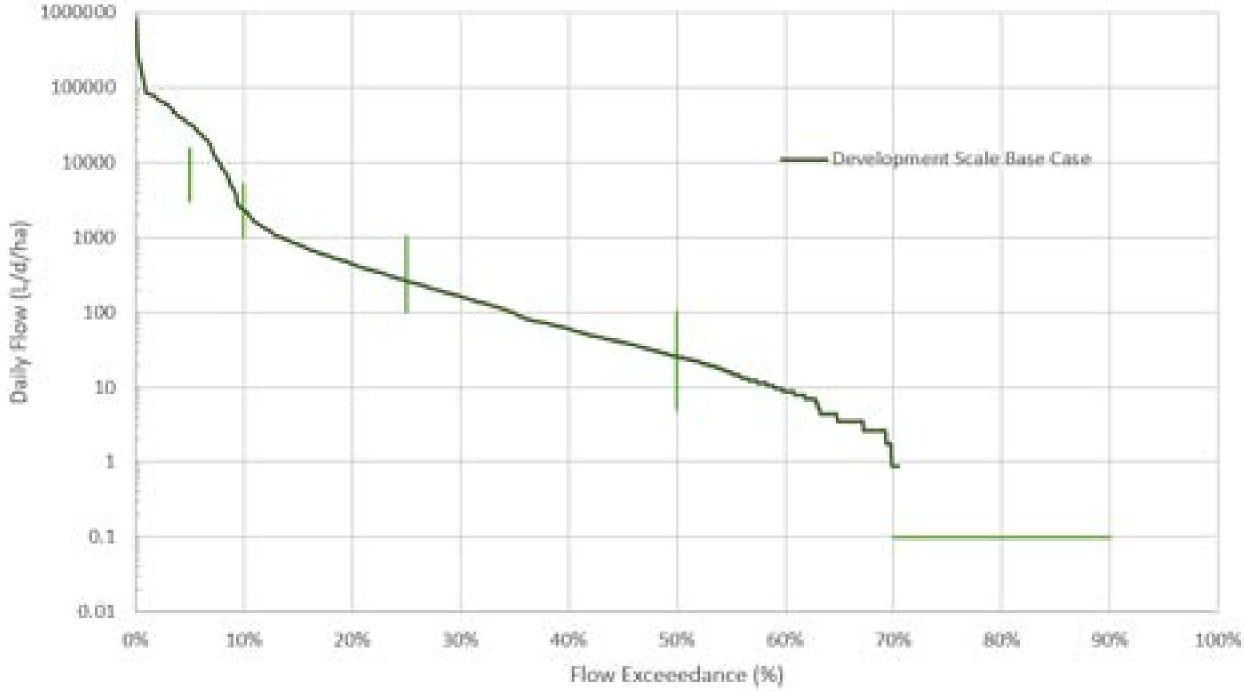

Figure 15 Flow duration curve for large format industrial typology and regional stormwater harvesting treatment train

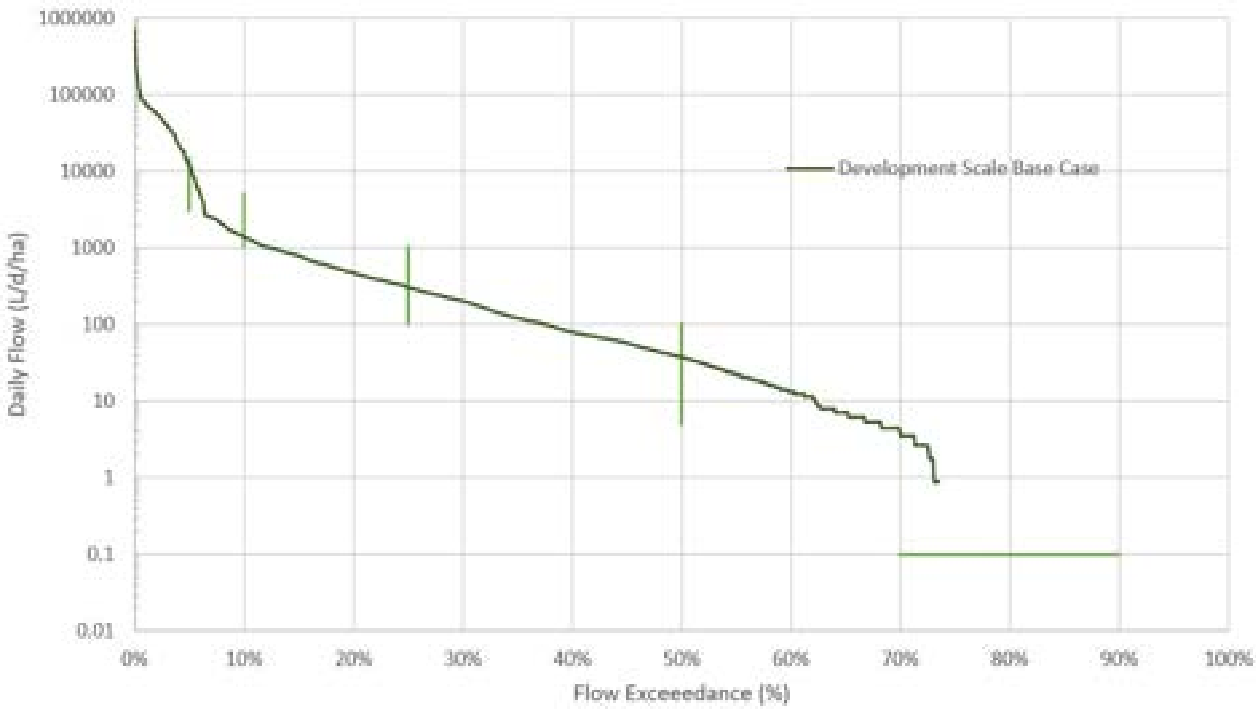

Figure 16 Flow duration curve for business campus typology and regional stormwater harvesting treatment train

6.3 Stormwater Pollution Load Reductions

Stormwater pollution reductions for the proposed treatment train have been determined using a 6-minute continuous time series. Pollutant load reductions for the on-lot approach and the preferred regional stormwater management approach are provided in Table 6-2 demonstrating that both strategies would achieve the required pollution reduction targets.

Table 6-2 Stormwater pollution reductions for regional and on-lot approaches

Parameter	Target	On Lot Approach			Regional Approach		
		Large Format Industrial	Business Campus	Comply	Large Format Industrial	Business Campus	Comply
Gross Pollutants (anthropogenic litter >5mm and coarse sediment >1mm)	90% reduction (minimum) in mean annual load from unmitigated development	99.9%	99.8%	Yes	99.9%	99.8%	Yes
Total Suspended Solids (TSS)	90% reduction in mean annual load from unmitigated development	94%	95%	Yes	95%	96.6%	Yes
Total Phosphorus (TP)	80% reduction in mean annual load from unmitigated development	82%	85%	Yes	84%	88%	Yes
Total Nitrogen (TN)	65% reduction in mean annual load from unmitigated development	78%	81%	Yes	75%	80%	Yes

6.4 Regional Stormwater Harvesting Schematic

The lowest risk approach to achieving stormwater flow objectives is via centralised open water bodies and wetlands connected to a precinct wide reticulation network.

Through master planning of the Wianamatta South Creek precinct, it will be possible to integrate regional wetlands and waterbodies and reduce the need for wetlands and open water to be distributed through the Precinct on developable land. For the catchments draining to the north and some in the south-west of the precinct however, it will still be necessary to locate stormwater storages within the industrial land as there are no open space areas at the boundary of the industrial and conservation lands. Suitable locations may be identified against the trunk drainage corridors.

A conceptual map of potential regional stormwater wetland/storage infrastructure is provided in Figure 17 for reference and consideration in the planning of the Wianamatta South Creek precinct.

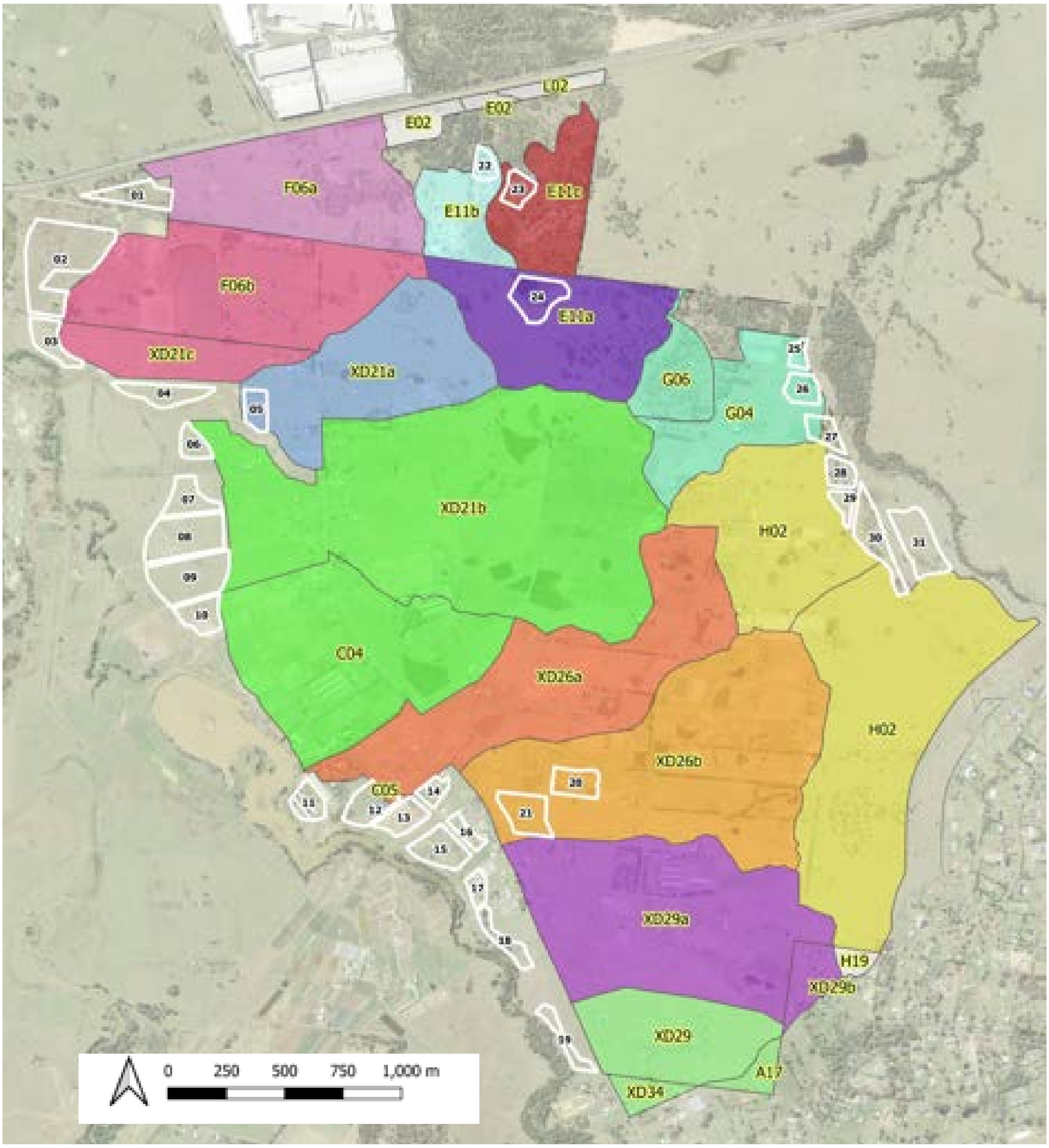

Figure 17 Proposed potential locations of wetlands and pond storages for centralised stormwater harvesting

Table 6-3 shows the contribution of wetlands achieves the approximate target of 7% of the precinct allowing for some balancing of flows during the design phase. It is noted that several water storages are shown to occupy land within the precinct due to restricted land over the downstream boundary. Basins 20 and 21 are provided as optional at this time as the combined wetland footprints.

Table 6-3 Notional regional wetlands and open water storage footprints

Catchment ID	Catchment Area (Ha)	Wetland ID	Wetland Footprints (Ha)	Total Wetland Area	% of Catchment
F06a	45.157	1	2.60	2.6	6%
F06b+XD21c	74.118	2	9.23	9.226	12%
extra	0	3	2.16	2.156	
XD21a	44.481	4	2.68	4.267	10%
		5	1.59		
C04+XD21b	212.891	6	1.38	17.054	10%
		7	2.43		
		8	5.43		
		9	5.60		
		10	2.22		
XD26a+C05	70.129	11	1.80	7.467	10%
		12	2.57		
		13	2.06		
		14	1.04		
XD26b	92.918	15	2.92	3.855	4%
		21	3.08		
		16	0.94		
XD29a+XD29b	81.075	17	1.01	2.642	3%
		21	3.08		
		18	1.63		
XD29+XD34+A17	33.311	19	1.35	1.351	4%
E11b	13.937	22	1.05	1.047	8%
E11c	21.586	23	1.45	1.446	7%
E11a	41.82	24	3.22	3.219	8%
G04+G06	40.22	25	0.74	3.908	10%
		26	1.62		
		27	1.55		
H02	129.805	28	1.39	9.834	8%
		29	0.90		
		30	3.44		
		31	4.10		
All Catchments	**994.366**			**75.326**	**7.6%**

A preliminary assessment of levels shows that diversions constructed within the culvert aprons at Mamre Road will be able to convey the desired volumes to those wetlands via gravity. A notional configuration is provided in Figure 18.

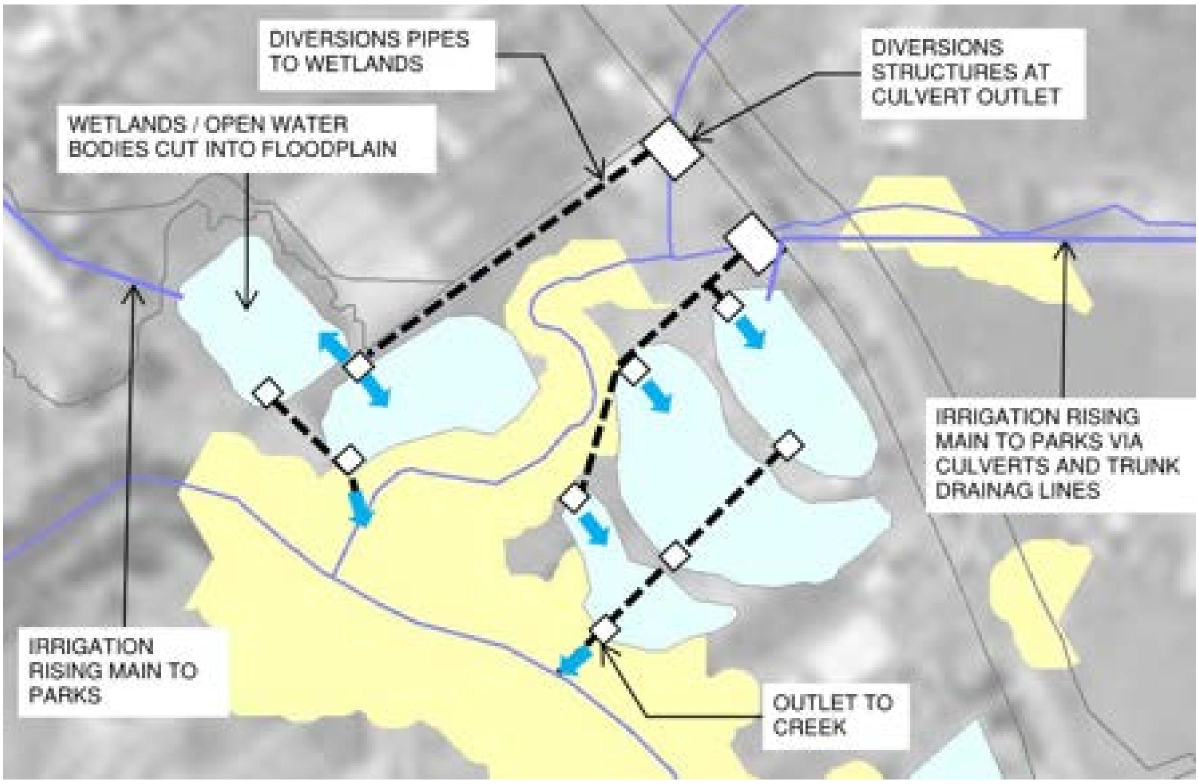

Figure 18 Notional stormwater diversion structures at Mamre Road and other similar culverts

6.5 Cost

Sydney Water has completed both a financial and economic analysis on the two options to determine the difference in the impact on the developer for each option, and to also quantify the total cost of each option for all stakeholders. Both analyses had similar outcomes in relation to the cost gap between the two options, however the economic analysis considers details such as power consumption, community benefit, impacts on creek integrity and the value of potable water offsets, which are beyond the scope of this document. As such, the following is a summary of the financial analysis only, which incorporates capital and operational costs as well as revenue from the sale of stormwater and recycled water.

Both options contain a similar cost for the implementation of recycled water. This cost includes the infrastructure required to transfer the treated recycled water from the Advanced Water Recycling Centre to the blending and storage reservoir located within the Mamre Rd precinct, and the third pipe network required to deliver the water to each lot in the precinct. The cost for this service is around $50k/ha.

For stormwater, the main costs are land, and to a lesser extent infrastructure. This cost is much higher for the on-lot option as the land used for on lot stormwater harvesting and reuse is valuable, developable land. The land used for the regional scale stormwater infrastructure is primarily within the flood plain (flood fringe), therefore the value of the land is significantly lower than the developable land.

There are several aspects within the financial analysis which have the largest influence over the financial gap between the two options. The two main aspects include whether land tax will be applicable to the regional scale option, and whether the loss of profit from the sale of improved land (i.e. developed land with buildings and services) should be included. The on-lot option is around $150 million more expensive across the entire precinct than the regional option if profit loss from land sale is not included (for Option 1) and land tax is included (for Option 2). When lost profit is included, and land tax is excluded, the margin extends to just under $530 million across the precinct.

It is clear from the financial analysis that the on-lot option will have a greater cost to stakeholders, especially developers.

7 Flooding

The Updated South Creek Flood Study (WorleyParsons, 2015) was completed for Penrith Council in conjunction with Liverpool, Fairfield and Blacktown Councils. The study utilises calibrated hydrologic losses and hydrodynamic modelling from the Flood Study endorsed to define flood planning levels throughout Penrith which includes the reaches of Ropes, Wianamatta South and Kemps Creek adjacent to the Precinct. These flood planning levels apply to new development at the boundaries of the Precinct.

For consistency, the hydrologic approaches adopted in the Penrith study have been adopted to generate new flood planning data within the Precinct.

Flooding constraints across the precinct and an assessment of flood impacts resulting from land use change, the channelisation of flow paths and the removal of farm dams has been assessed. This section describes the development of both the hydrologic and hydraulic models used to:

- Define flooding from the local catchments within the Precinct; and
- Determine flood impacts in the local catchments within the Wianamatta South, Kemps and Ropes Creek floodplains.

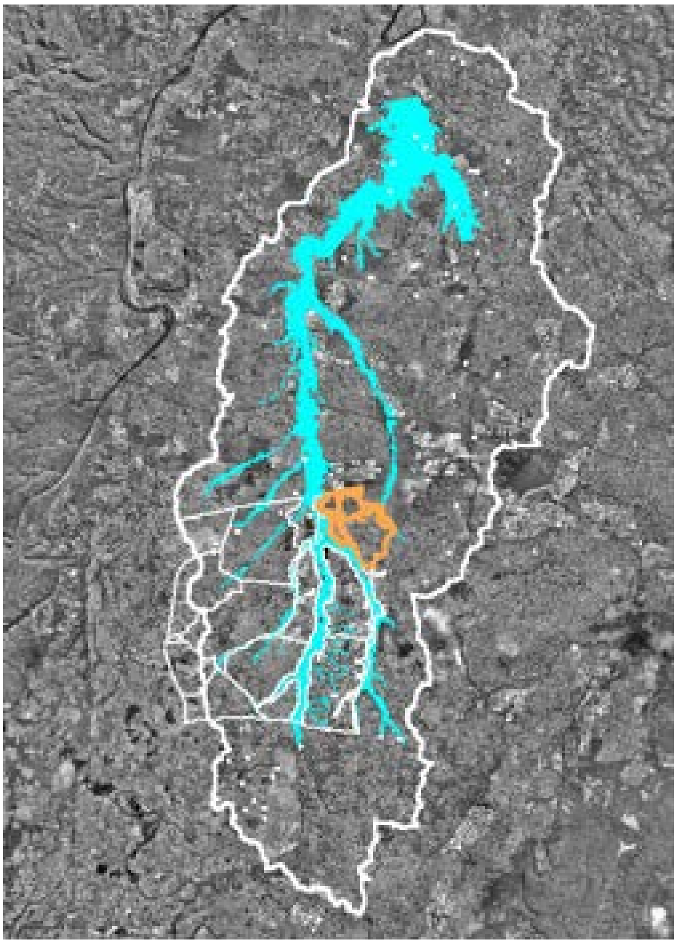

Figure 19 Location of Mamre Road in the context of the floodplain

7.1 Precinct Scale Hydrologic Model Development

A new precinct scale hydrologic model (XP-RAFTS) was used to simulate the distribution and volume of stormwater runoff generated at key locations within the Precinct under rural and post development conditions.

The model is used to simulate changes in 1% AEP flood hydrographs at the precinct boundaries. Pre and post development hydrographs are compared to the timing of regional hydrographs in the Wianamatta South and Kemps Creek hydrologic models to determine whether changes in the peak flow or timing of flows from the Precinct are likely to impact on existing flooding characteristics within the regional Wianamatta South, Kemps and Ropes floodplains.

7.1.1 Rainfall Data

The *Australian Rainfall and Runoff* (ARR) 1987 (ARR 1987) was adopted for floodplain management and planning in the Penrith LGA and has been adopted in this study for consistency and through consultation with the Western Sydney Planning Partnership Flood and Stormwater Management Technical Working Group.

Intensity frequency duration data adopted for the precinct was cross checked against values for Mount Vernon as adopted in the Penrith South Creek Flood Study update.

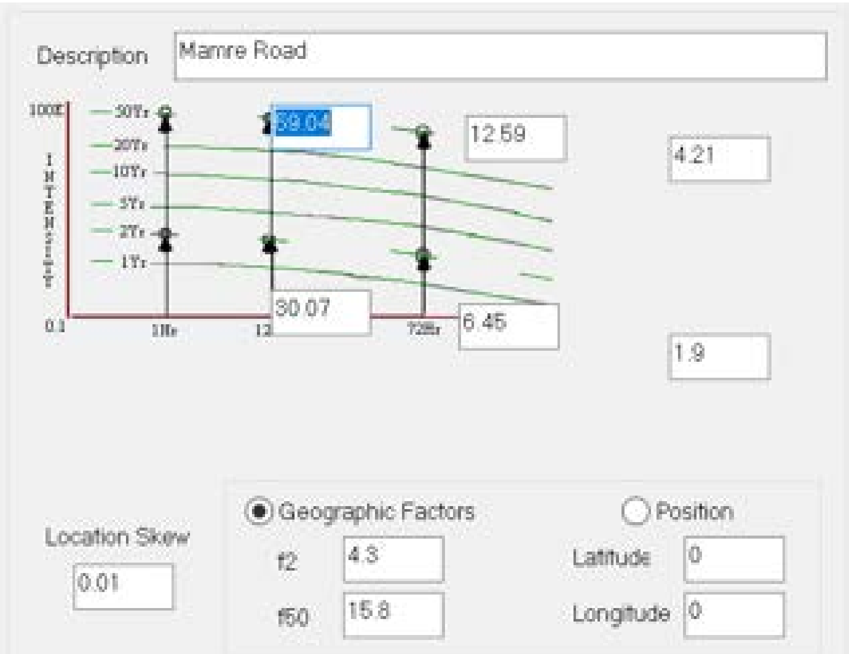

Figure 20 IFD parameters adopted in RAFTS modelling

Probable Maximum Precipitation

The Probable Maximum Precipitation (PMP) was calculated using *The Estimation of Probable Precipitation in Australia: Generalised Short Duration Method* (GSDM) (BoM 2003). This method is valid for catchments up to 1000 km^2 and storms up to 6 hours in duration. XP-RAFTS uses this method to produce PMP hyetographs based on the catchment's location, elevation, terrain roughness and moisture adjustment factor.

7.1.2 Sub-catchment Areas

Catchment boundaries were discretised using contours generated from LiDAR survey, topographic survey and survey of stormwater drainage systems through the upper and lower catchment areas. Additionally, catchments were discretised to represent areas of consistent land use, catchment slope, consideration of hydraulic controls, and size. Catchment mapping is shown in Figure A-6.

Changes in local sub catchment boundaries are likely following regrading of the Precinct for industrial land uses however changes to the Ropes or Wianamatta South Creek catchments will not be significant and have not been considered here.

Minimum sub catchment areas of 15 Ha were adopted to reflect the notional catchment size at which stormwater networks would generally be considered as trunk drainage systems.

Industrial Condition

The model structure was modified to represent local precinct roads and lots as separate nodes. This allows the simulation of on-lot flood detention basins to test how the detention strategy delivers compensatory flood detention for downstream roads that do not have a designated detention basin.

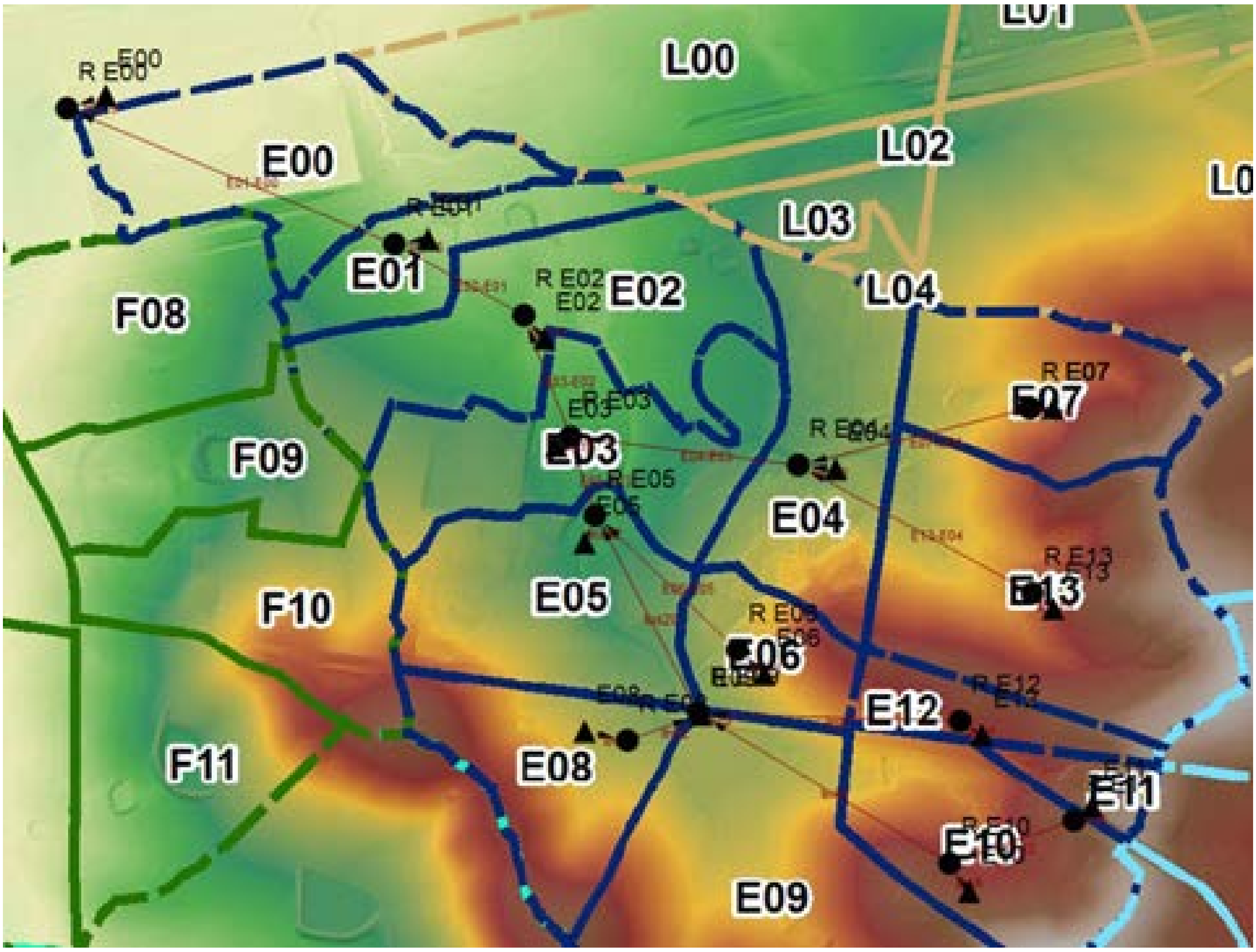

Figure 21 RAFTS model structure showing OSD and roads as separate nodes

7.1.3 Catchment Imperviousness

Rural Condition

Impervious land uses were delineated according to observed land use in aerial imagery for the existing scenario and based on rezoned land use for the developed scenario. Catchments with impervious surfaces were modelled as a second sub-catchment in XP-RAFTS.

Industrial Condition

In accordance with the urban form outlined in Section 4.2.1, a net total imperviousness rate of 80% was adopted for the IL2 lands accounting for:

- Industrial lots – 90% total imperviousness
- New roads (representing 7% of the catchment) – 80% total imperviousness
- Drainage reserves and riparian corridors – 10% total imperviousness

7.1.4 Catchment Roughness

Catchment roughness values were adopted as follows to be consistent with guidance:

- Rural lands and turf/vegetated areas– 0.04; and
- Developed areas with directly connected formal drainage – 0.02.

7.1.5 Slope

Average catchment grades were determined taking the streamflow lines from the highest part of the catchment to the catchment outlet. Rural catchment slopes were calculated using the equal area method from LiDAR survey.

New roads across the industrial precinct were modelled at existing sub catchment slopes while industrial lots are assumed to have a grade of 2% in accordance with typical practice.

7.1.6 Losses

Rainfall losses were adopted from the 1990 South Creek flood study which calibrated the hydrologic parameters to the 1986 and 1988 flood events. These losses were also adopted by the *Updated South Creek Flood Study* (Worley Parsons, 2015) and are therefore consistent with current flood planning data sets. Initial losses of 37.5 mm and 1 mm and continuing losses of 0.9 mm/hr and 0 mm/hr were adopted for pervious and impervious areas respectively.

Post development catchment conditions are likely to include significant earthworks with potential reductions in the capacity of urban landscape to infiltrate rainfall. For urban soils, initial losses of 10 mm and continuing losses of 0.9 mm/were adopted.

7.1.7 Catchment Lags

Where hydrologic model results rely on the routing of flows, an average channel flow velocity of 1 m/s has been adopted. This has been validated against TUFLOW velocity mapping which shows flood flow velocities range from 0.5 to 2 m/s. In other areas, flow routing is undertaken within the TUFLOW hydraulic model.

Farm dams and road crossings were not incorporated into the XP-RAFTS model of the predeveloped or developed catchment.

Hydraulic analysis and routing has been undertaken in a combination of XP-RAFTS and TUFLOW.

7.2 Precinct Scale Model Results

The local XP-RAFTS model was run for the 1EY, 5% AEP, 1%AEP, 0.2% AEP and PMF events for all durations between 15 minutes to 36 hours.

Model outputs were applied to a detailed local hydraulic model of the Precinct as outlined in Section 7.5.

The section below describes the changes in peak flows and timing at the Precinct boundary and the potential implications on regional flooding.

7.2.1 Western Catchments

The 1% AEP 9 hour duration ARR1987 event was determined to be critical for the rural catchment draining west to Wianamatta South and Kemps Creek. Hydrologic models of Wianamatta South Creek sourced from Council show the critical storm duration in the Wianamatta South Creek floodplain as being the 36 hour event, which was verified by the *Updated South Creek Flood Study* (Worley Parsons, 2015).

Following development of the Precinct, the XP RAFTS models predict a shift in timing of peak flows from the catchment to shorter duration storm events. Peak flow rates for storms are shown in Table 5 below.

7.2.2 Eastern Catchments

The 1% AEP 9 hour duration ARR1987 event was determined to be critical for the rural catchment draining to Ropes Creek.

The critical storm duration in the Ropes Creek floodplain is also determined to be the 9 hour event by testing a range of storm durations in the XP-RAFTS model used in the *Updated South Creek Flood Study* (Worley Parsons, 2015).

7.2.3 Northern Catchments

The Northern catchments flow directly to the WaterNSW Warragamba Pipeline, remnant high ecological value forest and the Western Sydney Employment Lands.

1% AEP 9 hour duration ARR1987 event is critical for this catchment under current conditions.

7.2.4 Peak Flows

The peak flow summary shown below demonstrates that the peak 1% AEP flow rates from the Precinct will increase significantly for short duration storm events and by small amounts in longer duration events that are critical to flooding in Wianamatta South and Kemps creek catchments (eg. 1% AEP, 36 hour event).

Table 7-1 Precinct scale hydrologic model results at Precinct boundaries

1% AEP Flow (m^3/s) Storm duration	Eastern Precinct Boundary		Northern Precinct Boundary		Western Precinct Boundary	
	Pre	Post	Pre	Post	Pre	Post
120 min	74.32	**183.08**	19.23	**49.01**	28.7	**55.12**
540 min	97.95	**107.24**	25.02	**26.65**	39.34	**39.7**
2160 min	65.57	**67.16**	15.23	**15.54**	26.66	**27.02**

Source: MR_Hydrology_D01.xp   MR_Hydrology_E01.xpLocal

Stormwater that discharges at the precinct boundaries must flow through existing development (to the north) or private lands to the east and west and therefore the increase in peak flows represents a potential flow impact on private land that must be managed.

7.3 Hydrologic Impacts

7.3.1 Local Impacts

Peak flows from the Precinct are sensitive to changes in rainfall loses associated with increased impervious surfaces and reduced capacity for water retention. Without stormwater detention within the Precinct, peak 1% AEP flows will increase in tributaries crossing the Precinct boundary, Mamre Road itself, and existing infrastructure to the north of the Precinct including the WaterNSW Warragamba Pipeline and Western Sydney Employment Area.

7.3.2 Detention Requirements

While peak flows in the Wianamatta South Creek floodplain are not sensitive to the presence of on-site stormwater detention in the Precinct, it is recommended on-site stormwater detention be provided within the Precinct on the basis that:

- On-site stormwater detention is necessary to attenuate peak flows of stormwater crossing the northern precinct boundary into existing industrial development and the southern precinct boundary into privately owned lands.
- On-site stormwater detention within the eastern catchments draining to Mamre Road itself preserves peak flow rates at the regional evacuation route and preserves the level of service of cross drainage structures and the flood immunity of the traffic lanes.
- On-site stormwater detention avoids potential staging or timing issues of runoff from developed sites entering lands that have not been rezoned or acquired by Council for drainage

7.4 On-site Stormwater Detention

A lot-based on-site stormwater detention (OSD) approach is proposed to preserve pre-development peak flowrates within the Precinct.

The approach to OSD was based on the following two guiding principles:

- To ensure that the Precinct has a negligible impact on existing flood behaviour; and
- To conserve stream stability in perennial streams.

Since the OSD would be located on individual lots within the commercial/industrial areas, runoff from the new road reserves would not be retarded and would be compensated for on the lot.

7.4.1 Modelling Approach

Predevelopment flow conditions were modelled using XP-RAFTS for the 50% and 1% AEP flood events using the ARR1987 rainfall data.

The models were then modified to reflect impervious rates and slopes outlined above. In accordance with general advice provided by the Planning Partnership Office, the role of water sensitive urban design has not been included in this assessment and a total imperviousness rate of 90% has been assumed for industrial lots.

Detention storages were then iteratively sized to determine the peak site storage requirement necessary to achieve the target 50% and 1% AEP discharges.

7.4.2 Detention Strategy

It is recommended that each industrial lot implements on-site stormwater detention as prescribed by Table .

Table 7-2 OSD requirements on industrial lots within Mamre Road Precinct

Zone	50% AEP SSR (m^3/ha)	50% AEP PSD (l/s/ha)	1% AEP SSR inclusive of 50% AEP SSR (m^3/ha)	1% AEP PSD (l/s/ha)
East Catchments draining towards Ropes Creek	190	40	393	150
North Catchment draining towards WaterNSW Warragamba Pipeline	190	40	393	150
West Catchments draining towards Ropes Creek	190	40	393	150

Demonstration of the effectiveness of the OSD approach for the Northern Catchment is shown below which indicates that there is a net 15% reduction in peak flows to correct for the effect of channelizing overland flow paths, which has been shown to increase flows rates (Appendix D) . This plot includes the peak critical hydrograph in Wianamatta South Creek that is associated with the 36-hour duration storm event which is provided here for reference to demonstrate the impact of the OSD on flows contributing to the floodplain at the time of the peak in the Wianamatta South Creek hydrograph.

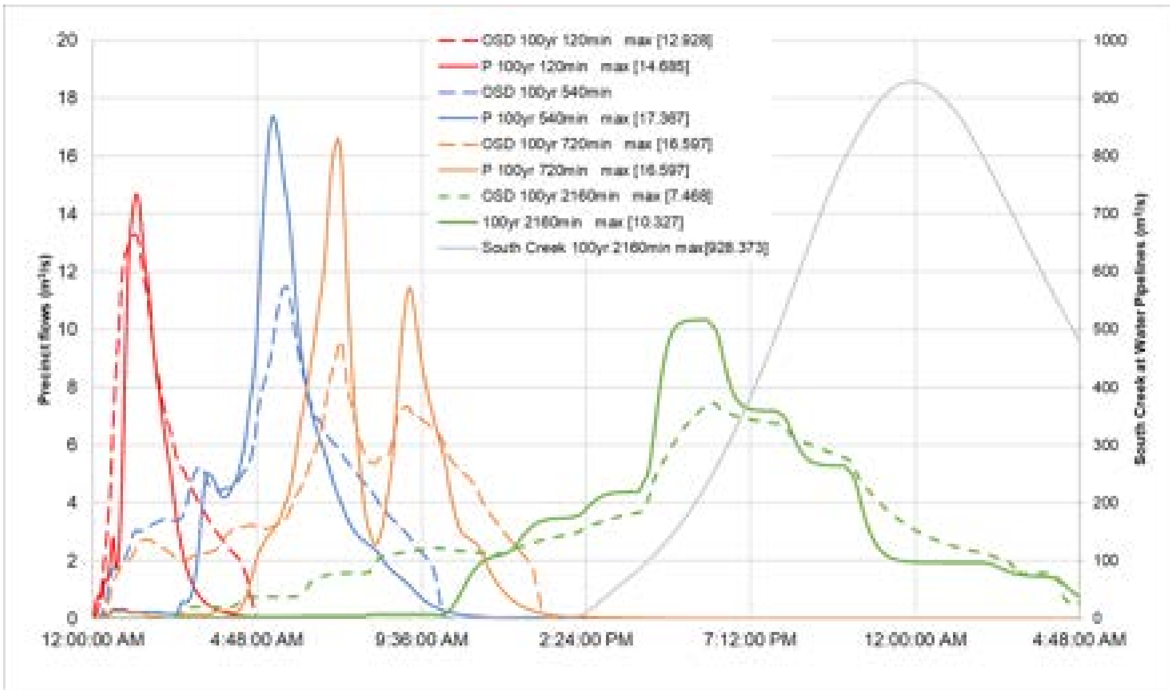

Figure 22 Performance of OSD basins for Northern catchments

7.5 Precinct Scale Hydraulic Model Development

A new precinct scale hydraulic model (TUFLOW) was used to quantify overland flow characteristics across the Precinct under rural and post development conditions and test the effectiveness and hydraulic impact of channelizing overland flows across through the Precinct to improve developable land outcomes.

Version 2018-03-AE (Single Precision) HPC module of TUFLOW was used for this project.

7.5.1 Existing Site Model Terrain, Model Extent and Grid Size

The terrain adopted in the TUFLOW model was created using a layered approach to add details where required from the sources of terrain made available during the model development process. Land and Property Information (LPI) NSW LiDAR dataset flown between 16 July 2019 to 18 July 2019 formed the basis for the model topography.

Design TINs obtained from Transport for NSW (TfNSW) were used to represent the strategic design for the Mamre Road upgrade. It is noted that this is a strategic design and may be revised by TFNSW in the future.

Several terrain modifications were made to realistically represent pre-developed site conditions in the model. These included:

- various road crests and kerbs were enforced in the terrain to ensure their potential hydraulic impact is captured
- the centreline of selected gullies and other small channels were enforced in the model topography to ensure appropriate representation of overland flow paths

- layered flow constrictions we applied to represent the two WaterNSW Warragamba Pipeline which were not captured in the LiDAR.

7.5.2 Post Development Model Terrain, Model Extent and Grid Size

The developed scenario proposes that trunk drainage corridors be provided to manage minor and major drainage from catchments exceeding 15 ha or where management of flood hazard necessitates. Terrain modification for the developed scenario included:

- the removal of all farm dams
- preserving 20 m wide overland flow paths to convey flood waters where riparian corridors don't exist
- providing low flow channels with 1 EY capacity treated with macrophytes, rip rap and rock drop structures as necessary with 4 m wide access tracks including all weather surface for maintenance vehicles and active cycle path.

The model extent is shown in Figure A-6 and Figure A-7 and includes the downstream watercourses of Kemps Creek, Wianamatta South Creek and Ropes Creek. The selected grid cell size provides a balance between the required resolution of model results with the computation time. A cell size of 3 m by 3 m has been adopted.

7.5.3 Culverts

Transverse culverts under Mamre Road, Aldington Road and Bakers Lane have been included in the model and are shown in Figure A-6 and Figure A-7 for pre-developed and developed scenarios respectively.

For the developed scenario, several culverts were upgraded to accommodate an upgrade to Mamre Road, Abbots Road, Aldington Road and Bakers Lane. Previous modelling from the TfNSW flood investigation (Lyall and Associates, 2017) have been adopted for Mamre Road.

7.5.4 Boundary Conditions

The internal source boundaries were applied as hydrographs from the XP-RAFTS model developed as part of this study (refer to Section 7.1). The delineated sub-catchments in the XP-RAFTS model were used as source area polygons, which were refined along the length of the Mamre Road and upstream of Aldington Way and Bakers Lane to ensure appropriate application of flows to the models.

The increase in impervious areas across the Precinct is predicted to generate peak flows that are more than double the existing peak flows requiring on-site stormwater detention to maintain peak discharges at road crossings, as has been assumed in the *Mamre Road Flooding and Drainage Investigation* (Lyall and Associates, 2017).

For the purposes of assessing flood risk across the Precinct, the existing rural peak flows were adopted as it was assumed each development site will preserve existing peak flood flows through on-site stormwater detention. On-site stormwater detention requirements for the Precinct are provided in Section 7.4.2.

For pre-developed conditions, initial water levels in dams have been set to represent full conditions to simulate peak flood levels for the Precinct.

7.5.5 Hydraulic Roughness

Hydraulic roughness in the 2D model domain is applied using GIS layers which define the extent of unique land uses. In the 1D model domain the adopted roughness value is applied to each element/conduit as one of its attributes. The Manning's "n" values adopted for the study area, including flow paths are shown in Table . The spatially varying roughness values for the model are shown in Figure A-6 and Figure A-7 for pre-developed and developed conditions respectively.

Table 7-3 Adopted hydraulic roughness coefficients

Land use	Adopted roughness value
Concrete pipes	0.012
Roads and hardstand	0.02
Grassed floodplain with sparse trees	0.05
Floodplain with dense trees	0.12
Vegetated riparian corridors	0.08
Rural residential / Environmental Living	0.06
Grassed floodways through industrial lands	0.05

7.6 Flood Mapping

Flood mapping for the Precinct is shown in Figure A-9 to Figure A-30 in Appendix A .

- Figure A-9 to Figure A-17 respectively show the 5% AEP, 1% AEP and 0.2% AEP peak flood depth, velocity and provisional hazard for pre-developed conditions within the precinct.
- Figure A-18 to Figure A-30 respectively show the 5% AEP, 1% AEP and 0.2% AEP peak flood depth, velocity and provisional hazard for developed conditions within the precinct.
- Flood impacts outside of the precinct for two OSD scenarios are shown in Figure A-27 and Figure A-28. These show relative flood level difference for the 1% AEP event in the local floodplain without OSD on lots (Figure A-27), and with OSD on lots in the northern catchments only (Figure A-28). These impacts also include selected draft wetland concepts in the floodplain.

7.6.1 Existing Flood Conditions Within the Precinct

Flooding associated with several unnamed tributaries across the Precinct have been mapped including the extents of modified agricultural drainage and diversions as well as transverse culverts at road crossings. Farm dams are prevalent across the Precinct and are assumed to be full at the onset of a design storm. The farm dams were assumed to behave like a bucket full of water whereby any water that enters the full bucket would immediately spill downstream.

Flood waters within the existing depressions are shallow and wide with velocities ranging from 0.1 to 1 m/s due to the poorly defined flow paths which have the effect of detaining flood flows and providing flood storage.

Flooding between Ropes Creek and Aldington Road creates a wide flow path within areas rezoned industrial which will constrain safe development of land on the western bank of Ropes Creek. The separation of Ropes Creek and its tributaries creates a “flood island” effect where two watercourses run parallel to each other which may present unsafe conditions for flood evacuation.

Flood water is shown to overtop Mamre Road, Abbotts Road, Aldington Road and Bakers Lane at several locations. At the WaterNSW Warragamba Pipeline overland flow crosses beneath the pipes despite there being several transverse culverts.

High hazard conditions are those creating danger to persons and emergency staff and potential damage to buildings. Low hazard may be possible for trucks to traverse if necessary, however would still provide difficulty for abled bodied persons to wade through safely (DIPN, 2015). Hazard categories can be calculated by the depth velocity product, the hazard calculated for this assessment is based on the Provisional Hydraulic Hazard Categories as per the *Floodplain Development Manual*, refer to Figure 23 (DIPN, 2015).

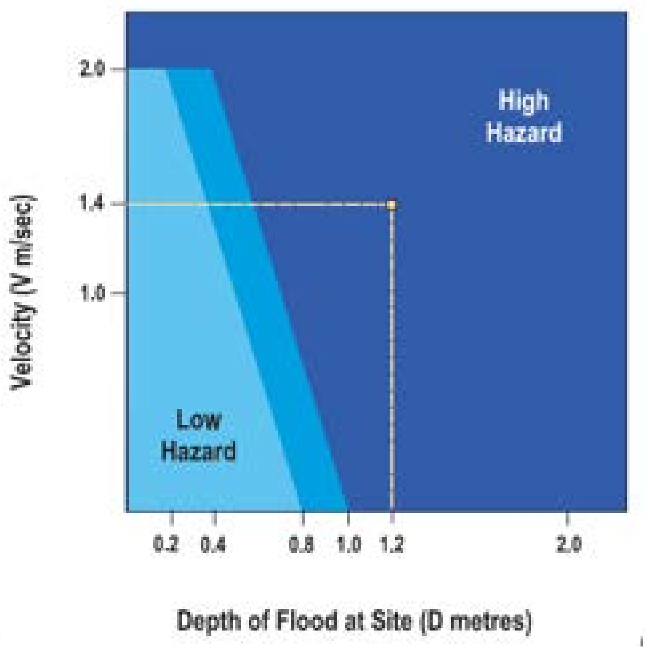

Figure 23 Provisional hydraulic hazard categories (DIPN, 2015)

Figure A-15 to Figure A-17 shows that areas of high hazard are mainly contained to farm dams due to their high depths. Most flow paths exhibit low hazard with some localised areas showing intermediate hazard.

The shallow but wide extent of flood waters may present a nuisance to development however it is expected to be manageable through the introduction of defined naturalised channels and the removal of farm dams. As outlined in Section 7.5.1, preliminary terrain modifications have been tested to control the flow paths within riparian corridors where possible and to limit hazard outside of roads and future workplaces.

7.6.2 Changes in Flood Behaviour Within the Developed Precinct

For most flow paths draining across the Precinct, naturalised channels are proposed to convey overland stormwater flows (refer to Section 6.10). This is an efficient and effective way to convey flood flows rather than allow major flows to form across private land or along roads. Channels presented in Figure 6-6 have been included in the precinct flood models and the results show that high hazard conditions form with flood waters reaching depths of up to 1 m and velocities of up to 2 m/s. It is therefore more appropriate that these types of channels be included where flooding is predicted, and no riparian corridor has been designated.

Channelising flows across the precinct is shown to increase the potential site discharge. Where existing peak 1% AEP discharges are preserved entering the trunk drainage channels, the peak flow rate will increase by 20% due to increased conveyance and reduced flood storage associated with channelization.

The relative difference in flood levels between the pre-development and the future scenarios shows that these differences are largely contained within the precinct boundary. Areas that are no longer inundated are the result of the channelisation of flows and removal of farm dams. Due to the channelisation of flows most stream reaches experience a flood level reduction of less than 0.5 m. This can be attributed to the relative difference in the underlying terrain rather than a reduction in flow or volume.

Increases, in excess of 0.1 m, are observed upstream of Mamre Road at crossings XD22, XD26, XD28, XD30 and XD31. The proposed upgrade of Mamre Road raises the road preventing flow from overtopping and thereby constricting flows to the transverse culverts.

The effect of channelising flood peak flow rates at selected locations are summarised in Table 7, Appendix D.

The results show that channelising flows may have an increase in flow rates at some boundaries to the Precinct which requires offsetting via on-site stormwater detention as described above in Section 7.4.

7.6.3 WaterNSW Pipelines

The WaterNSW Warragamba Pipeline along the northern boundary of the site are critical infrastructure that require protection from erosion and scour at the four locations where local stormwater generated from the Precinct crosses into the easement.

The 5% AEP flood produces very similar flow velocities in both pre-developed and developed scenarios. Similarly, 1% AEP velocities are not significantly different between existing and developed conditions.

While the duration of peak velocities may increase with increased flow durations associated with developed conditions in the catchment, the proposed Parkland mitigation strategy will result in twice the volume of stormwater runoff rather than four times the stormwater runoff which would be expected under business-as-usual stormwater management.

7.7 Evacuation

Hydraulic modelling demonstrates that the existing culvert capacity at Aldington Road and Bakers Lane is likely to be insufficient to provide 1% AEP flood immunity to those local roads. The culvert crossings are located in the sag points, and it is likely that both the road and the culverts will require upgrades to provide safe passage and acceptable freeboard in a 1% AEP event within the local catchments. As part of road upgrades, the road profile will most likely require raising to provide for new services in the road corridor to cross the culverts with sufficient cover.

Notional culvert upgrades for existing roads have been provided in Table to inform contribution plans. Note that no culverts have been modelled on the Ropes Creek tributary.

Table 7-4 Notional Road Culverts Upgrades in Existing Local Streets

	Bakers Lane BA01	Aldington Road AL01	Aldington Road AL02	Aldington Road AL03	Aldington Road AL04
Length (m)	24	32	16	13	22
Invert U/S (mAHD)	53.67	78.07	71.09	51.23	74.46
Invert D/S (mAHD)	53.48	77.21	70.8	51.07	73.96
Grade (%)	1%	3%	2%	1%	2%
Height (m)	0.9	-	-	1.52	-
Width / Diameter (m)	1.8	0.45	0.45	1.52	0.3
Number of cells	3	1	1	3	1

Lots within the eastern Precinct can access Aldington Road which steadily rises away from flood waters to land above the PMF. Vehicular evacuation is therefore possible.

Lots within the western Precinct can access Mamre Road which steadily rises away from flood waters to the South.

7.8 Upgrades to Existing Culverts

The *Mamre Road Flooding and Drainage Investigation Study* for RMS (now TfNSW) found that the majority of Mamre Road culverts (transverse drainage structures) within the Precinct have less capacity than required to convey the existing 10% AEP event. It is noted that the hydrology and road design adopted is likely to be revised at the next stage of planning and design by TfNSW and culverts may require a different capacity as a result of peak flow rates being revised should the ARR 2019 hydrologic methods be adopted.

The culverts may also require larger capacity than proposed if the Mamre Road is determined to be a regional flood evacuation route. This would require a 0.2% AEP flood immunity. Table and Table in Appendix C show the existing and developed culverts modelled for the Precinct.

7.9 Flood Impacts in Wianamatta South, Kemps and Ropes Creek Floodplains

Areas to the west of Mamre Road are outside of the 1% AEP flood extent but lie within the PMF extent. An assessment has been provided to show the potential impacts of flood events rarer than the 1% AEP event.

The results show an increase in level ranging from 0.01 m to 0.05 m within the PMF extent. This impact is relatively minor for such an extreme flood event and represents the upper limit of flood impacts to surrounding development. On this basis the potential flood impacts associated with filling the Precinct to the east of Mamre Road is considered acceptable and unlikely to have an impact on flood levels adjacent to the site.

The south eastern edge of the Precinct is affected by low hazard flooding. Industrial development in this location must provide overland flow paths that will not worsen flooding on existing housing to the south of the Precinct.

7.10 Trunk Drainage Channels

Flood mapping shows extensive flooding under pre-developed conditions that can be managed through the provision of 20 m wide overland flow paths to convey flood waters towards riparian corridors. Natural trunk drainage channels are recommended in order to fulfil SEPP requirements to integrate stormwater management systems into the landscape in a manner that provides multiple benefits, including water quality protection, stormwater retention and detention, public open space, habitat improvement and recreational and visual amenity. Trunk drainage channels are proposed to convey overland flow paths downstream of notional 15 ha catchments in order to:

- confine 1% AEP flood flows to designated flow paths rather than through private lands
- avoid the need for box culverts or stormwater pipes larger than 1200mm
- prevent unsafe conditions forming on steep local roads

The typical 20 m wide channel is shown in Figure 24 and includes:

- low flow channels with 1 EY capacity treated with macrophytes, rip rap and rock drop structures as necessary
- 4 m wide access track including all weather surface for maintenance vehicles and active cycle path.

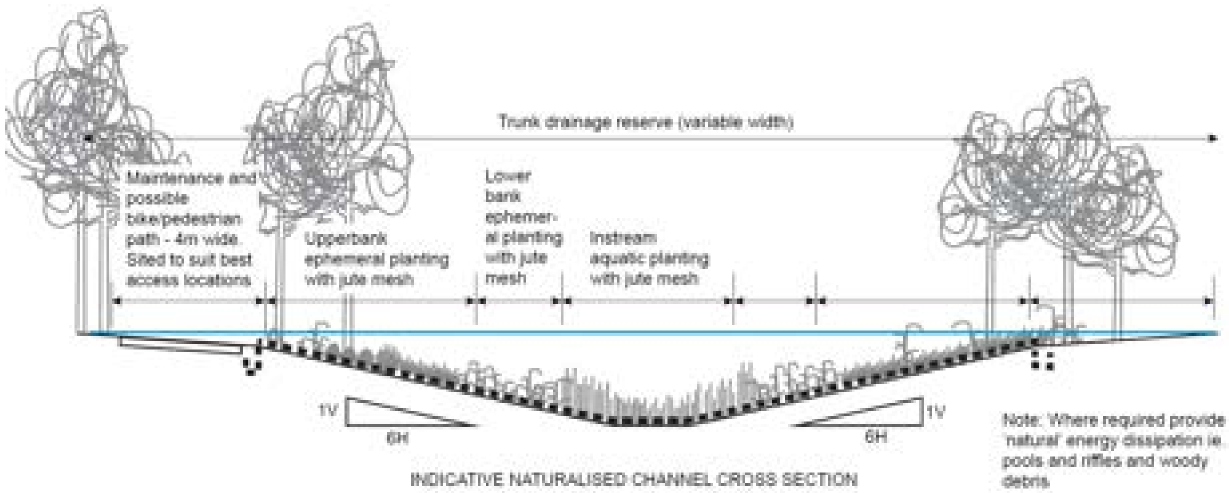

Figure 24 Overland flow path geometry

7.11 New Culverts for Local and Estate Roads

The provision of new public roads that cross riparian channels area will require new culverts sized appropriately to provide flood evacuation. Culvert locations have not been decided at this time. Hydrologic and hydraulic models developed in this study may be used to assist in the design of those structures.

7.12 Regional Stormwater Management Basins

Wetland and trunk drainage draft concept designs have been tested for flood impacts in the regional Wianamatta, Kemps and Ropes Creek floodplains.

Flood level difference for the 1% AEP event in the local floodplain without OSD on lots (Figure A-27), and with OSD on lots in the northern catchments only (Figure A-28).

The modelling shows the flood impacts associated with forming regional stormwater management wetlands and ponds within the floodplain can be mitigated by establishing the level of those assets to prevent flood conveyance loss.

Further refinement of the proposed wetlands and ponds will require additional flood modelling as the designs are progressed and refined.

8 Conclusion

This Flood, Riparian Corridor and Integrated Water Cycle Management Strategy outlines how stormwater, water, wastewater, recycled water, trunk drainage and riparian zones should be managed to achieve the Western Parkland City vision and the objectives of the Western Sydney Employment Area SEPP within the Mamre Road precinct.

Integrated Water Servicing

Sydney Water is providing recycled water to the Mamre Road Precinct from the Upper South Creek Advanced Water Recycling Centre (AWRC) which is planned at a site to the west of the Precinct. Detailed planning continues to be carried out on the servicing concepts and networks to deliver recycled water to Mamre Road.

Sydney Water is planning for staged delivery of drinking water and wastewater assets across the Western Sydney Aerotropolis Growth Area (WSAGA) in line with DPIE growth forecasts. This will enable flexible servicing for interim and staged delivery to meet anticipated development timeframes.

Ultimate drinking water supply for the precinct will be via the Cecil Park water supply zone, with utilisation of interim servicing links to adjoining supply zones for operational flexibility and reliability. Ultimate wastewater servicing will be via gravity for the eastern portion to the St Marys wastewater system and via a new pressure main to the AWRC.

To efficiently achieve the waterway health objectives and targets for development, it is recommended that stormwater is harvested via a system of precinct scale wetlands and storages. Harvested stormwater would be suitably treated and mixed with recycled water to service non-potable water demands across the precinct to achieve key greening and cooling outcomes.

This outcome should be noted in the in the completed precinct planning and facilitated by the Development Control Plan.

Riparian Corridors

A Waterway Assessment was undertaken in consultation with NRAR and DPIE that identifies waterways and their associated vegetated riparian zones to be protected across the Precinct. This assessment was used to update the rezoning within the precinct. These waterways as well as the system of natural trunk drainage channels provide important blue/green links through the precinct and have been incorporated into catchment perviousness calculations. It is recommended that these waterways and natural trunk drainage channels be managed by an appropriate trunk drainage authority.

Flooding

Hydrologic and hydraulic modelling demonstrates that precinct scale flooding can be managed by providing naturalised trunk drainage channels for catchments notionally 15 Ha and greater. The natural trunk drainage system flow paths will contain higher flood hazard conditions within designated flow paths. This approach has been demonstrated to increase peak flow rates by 20% which is to be offset by on-site stormwater detention.

On-site stormwater detention requirements on industrial lots have been sized to ensure no increase in peak flow rates at the Precinct boundary, WaterNSW pipelines, RMS Mamre Road culverts, existing downstream development and private lands outside the Precinct. The basins are sized to offset free discharge from new local roads and overland flow paths within trunk drainage corridors. Under this approach, no detention is required for new roads and no temporary detention is required making the staging of development simpler.

Waterway Health

The Mamre Road DCP adopts the NSW Government Waterway Health Objectives and development Targets for Wianamatta-South Creek established by DPIE (EES). This strategy tests both on-lot and regional approaches to achieving the new objectives and targets. It is recommended that a regional approach to achieving the targets is implemented via a system of precinct scale wetlands and stormwater storages integrated with the recycled water network. The regional approach provides a significantly more cost-effective approach by utilising the recycled water third pipe network to provide harvested stormwater back to the precinct for non-potable uses.

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Appendix A - Figures

Figure A-1 Site Locality

Figure A-2 Comparison of South Creek flood extents

Figure A-3 Previous land zoning

Figure A-4 Present day topography

Figure A-5 Industrial land zoning

Flood Constraint Mapping

Figure A-6 Hydrologic model catchment layout

Figure A-7 Hydraulic model configuration - existing conditions

Figure A-8 Hydraulic model configuration - developed conditions

Figure A-9 Flood depth - 5% AEP - existing conditions

Figure A-10 Flood depth - 1% AEP - existing conditions

Figure A-11 Flood depth – 0.2% AEP - existing conditions

Figure A-12 Flood velocity - 5% AEP - existing conditions

Figure A-13 Flood velocity - 1% AEP - existing conditions

Figure A-14 Flood velocity – 0.2% AEP - existing conditions

Figure A-15 Provisional flood hazard - 5% AEP - existing conditions

Figure A-16 Provisional flood hazard - 1% AEP - existing conditions

Figure A-17 Provisional flood hazard – 0.2% AEP - existing conditions

Figure A-18 Flood depth - 5% AEP - developed conditions

Figure A-19 Flood depth - 1% AEP - developed conditions

Figure A-20 Flood depth – 0.2% AEP - developed conditions

Figure A-21 Flood velocity - 5% AEP - developed conditions

Figure A-22 Flood velocity - 1% AEP - developed conditions

Figure A-23 Flood velocity – 0.2% AEP - developed conditions

Figure A-24 Provisional flood hazard - 5% AEP - developed conditions

Figure A-25 Provisional flood hazard - 1% AEP - developed conditions

Figure A-26 Provisional flood hazard – 0.2% AEP - developed conditions

Figure A-27 Flood level difference – 1% AEP developed model without OSD in Northern Catchment

Figure A-28 Flood level difference - 1% AEP developed model with OSD in Northern Catchment

Figure A-29 People hazard ZPA – 1% AEP developed conditions

Figure A-30 People hazard ZAEM – 1% AEP developed conditions

Water Servicing

Figure A-31 Mamre Road Existing Drinking Water

Figure A-32 Mamre Road Interim Drinking Water

Figure A-33 Mamre Road Ultimate Drinking Water

Figure A-34 Mamre Road Existing Waste Water

Figure A-35 Mamre Road Interim Waste Water

Figure A-36 Mamre Road Ultimate Waste Water

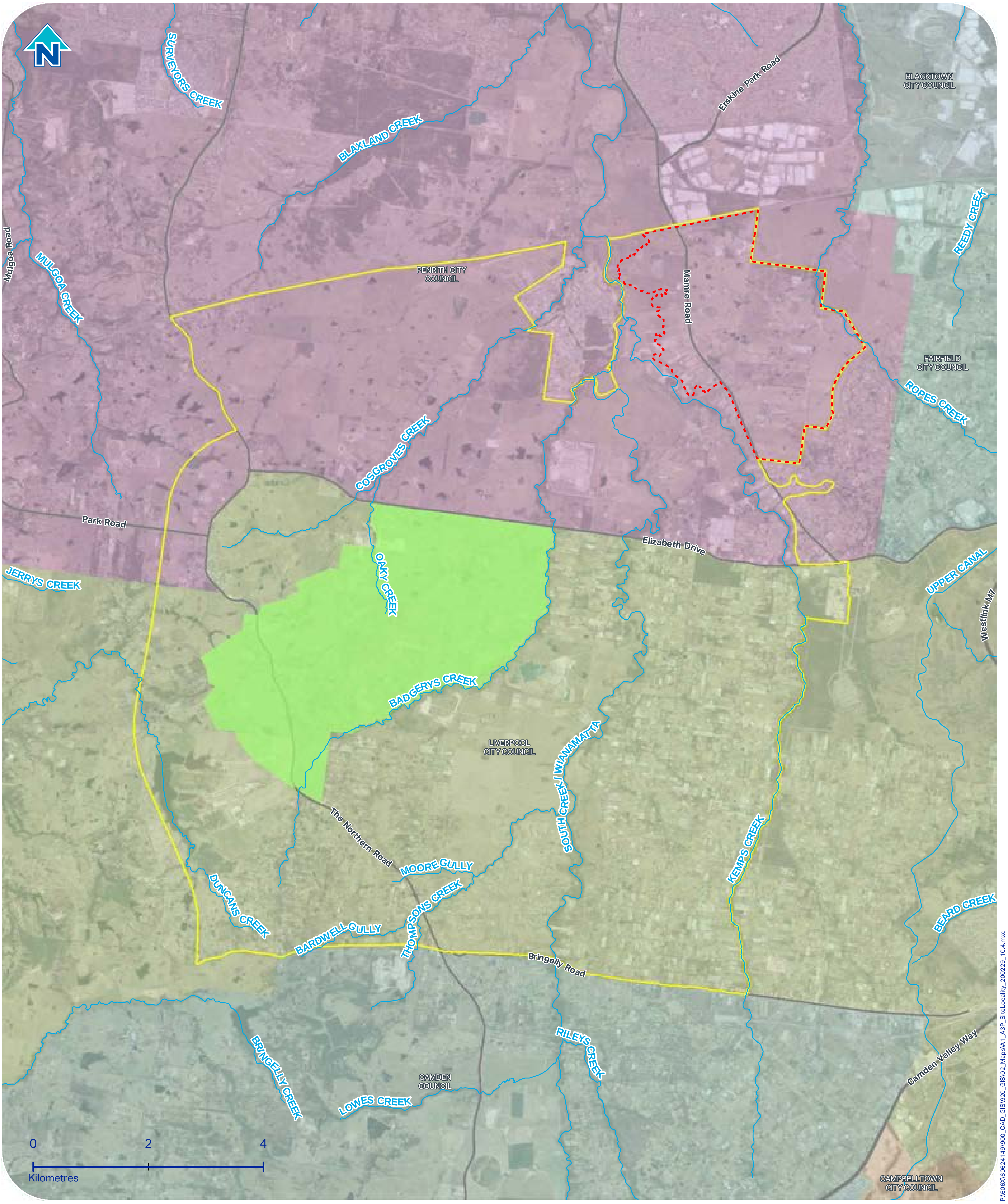

FIGURE A-1 SITE LOCALITY

LEGEND

Mamre Road Precinct
Aerotropolis Boundary
WSA Airport Precinct
Road
Watercourse

Local Government Area
BLACKTOWN CITY COUNCIL
CAMDEN COUNCIL
CAMPBELLTOWN CITY COUNCIL
FAIRFIELD CITY COUNCIL
LIVERPOOL CITY COUNCIL
PENRITH CITY COUNCIL

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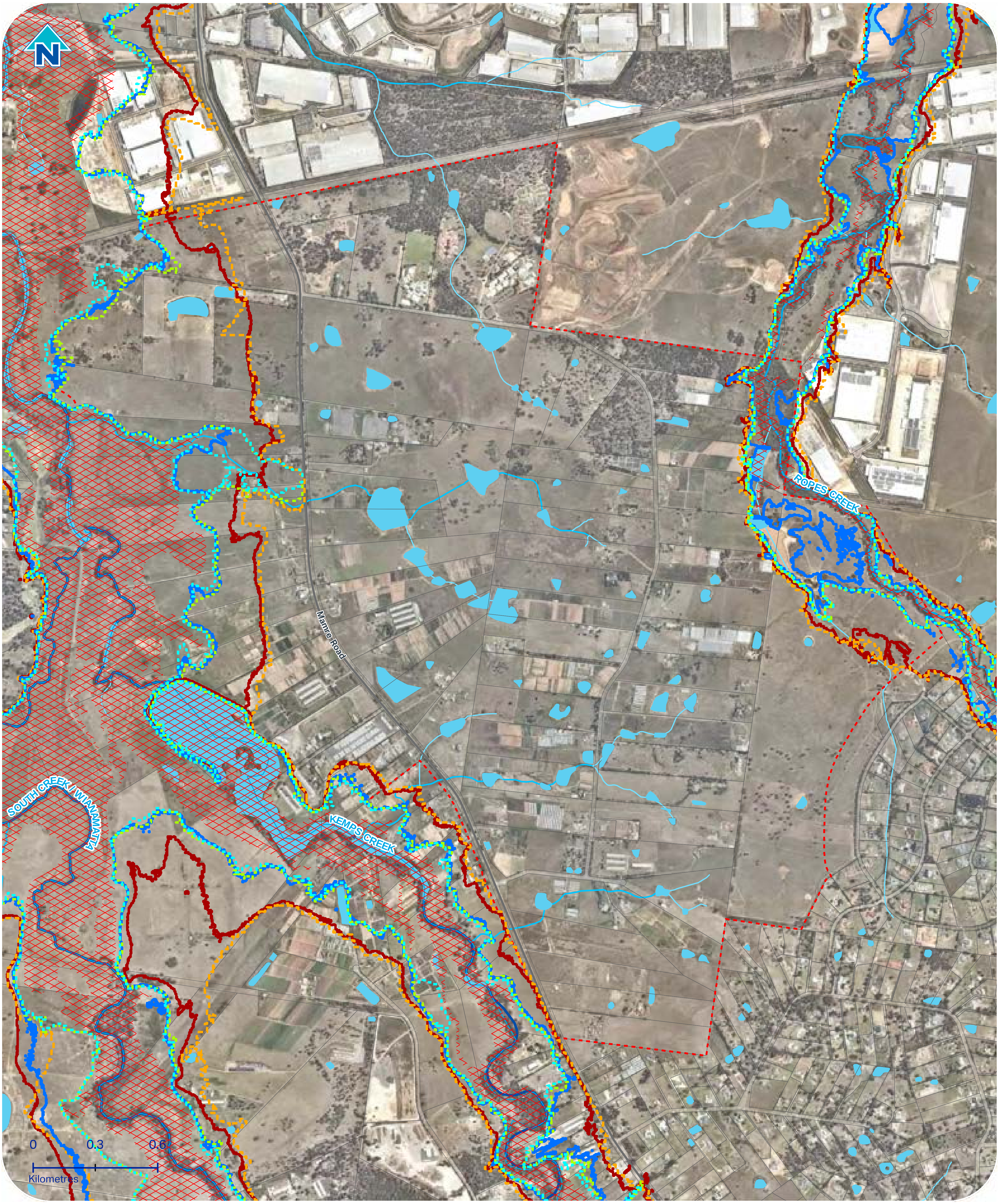
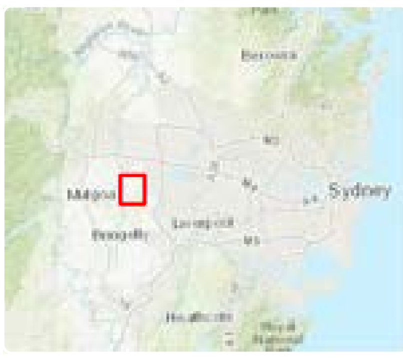


FIGURE A-2 COMPARISON OF SOUTH CREEK FLOOD EXTENTS

LEGEND

- Mamre Road Precinct
- Road
- Watercourse
- Water Body / Farm Dam
- 1st Order Strahler
- 2nd Order Strahler
- 3rd Order Strahler
- 4th Order Strahler
- 1% AEP ARR 2016 (Sydney Water 2019)
- 1% AEP ARR 1987 (Sydney Water 2019)
- 1% AEP ARR1987 (Worley Parsons 2015)
- PMF ARR 2016 (Sydney Water 2019)
- PMF ARR 1987 (Worley Parsons 2015)
- High Hazard



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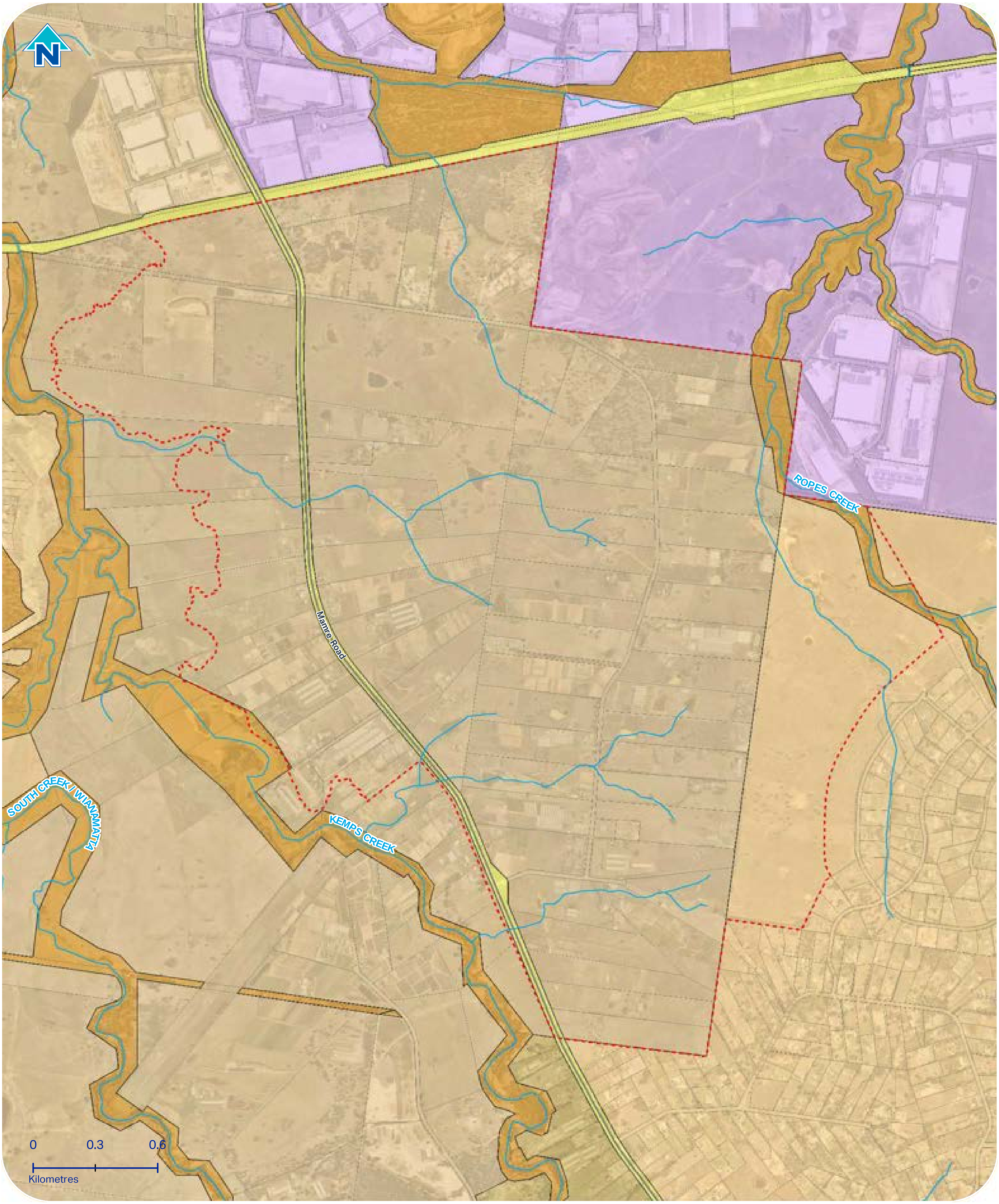

FIGURE A-3 PRESENT DAY LAND ZONING

LEGEND

- Mamre Road Precinct
- Road
- Watercourse
- Cadastre

ZONE

- E2 Environmental Conservation
- E4 Environmental Living
- IN1 General Industrial
- R2 Low Density Residential
- RU2 Rural Landscape
- RU4 Primary Production Small Lots
- SP2 Infrastructure

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Sydney WATER

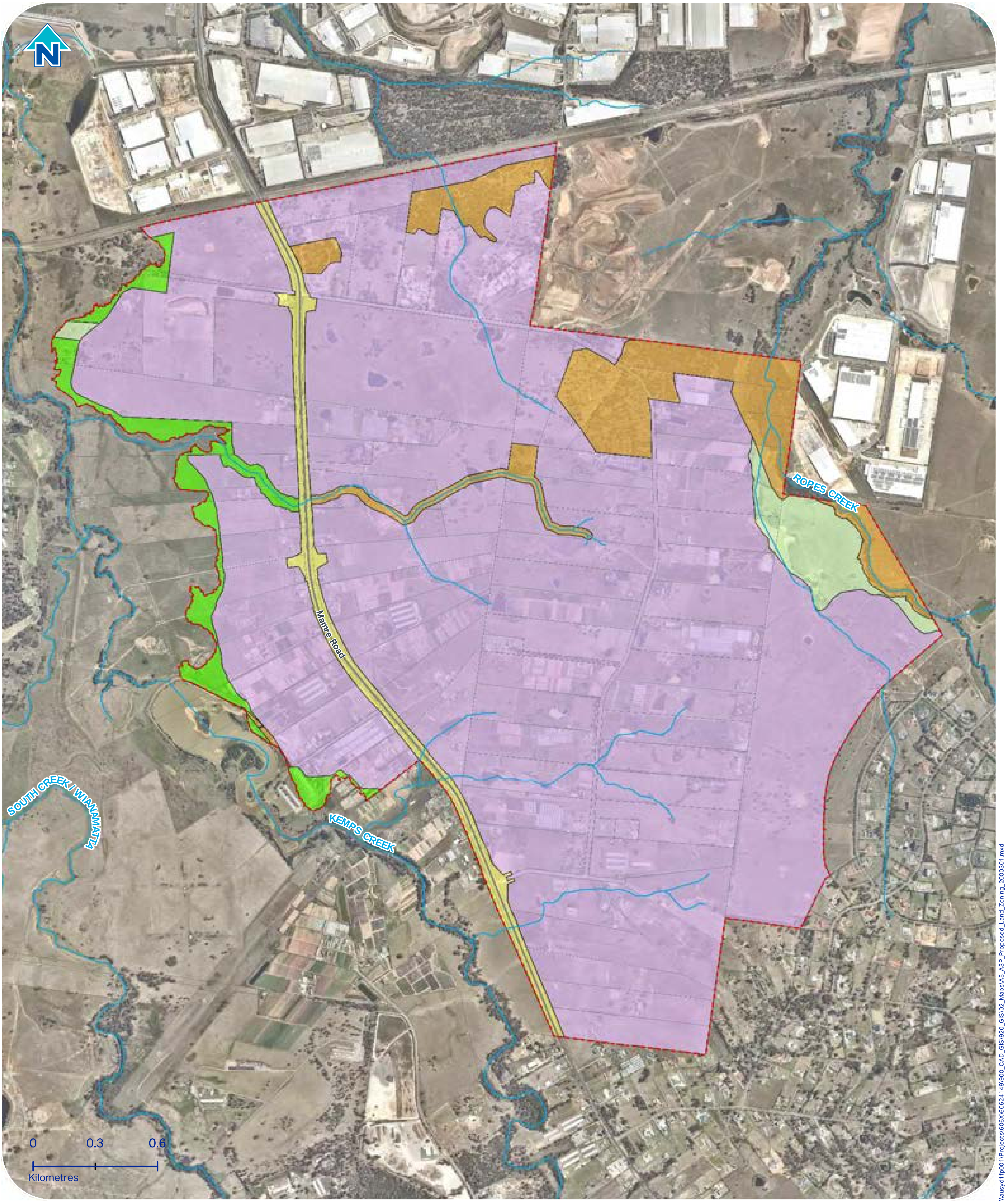
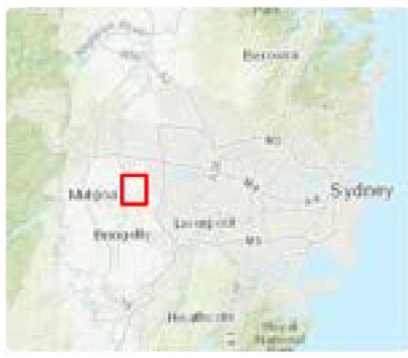


FIGURE A-4 PROPOSED LAND ZONING (DPIE, 2020)

LEGEND

Mamre Road Precinct
Road
Watercourse
Cadastre

ZONE
E2 Environmental Conservation
IN1 General Industrial
RE1 Public Recreation
RE2 Private Recreation
SP2 Infrastructure



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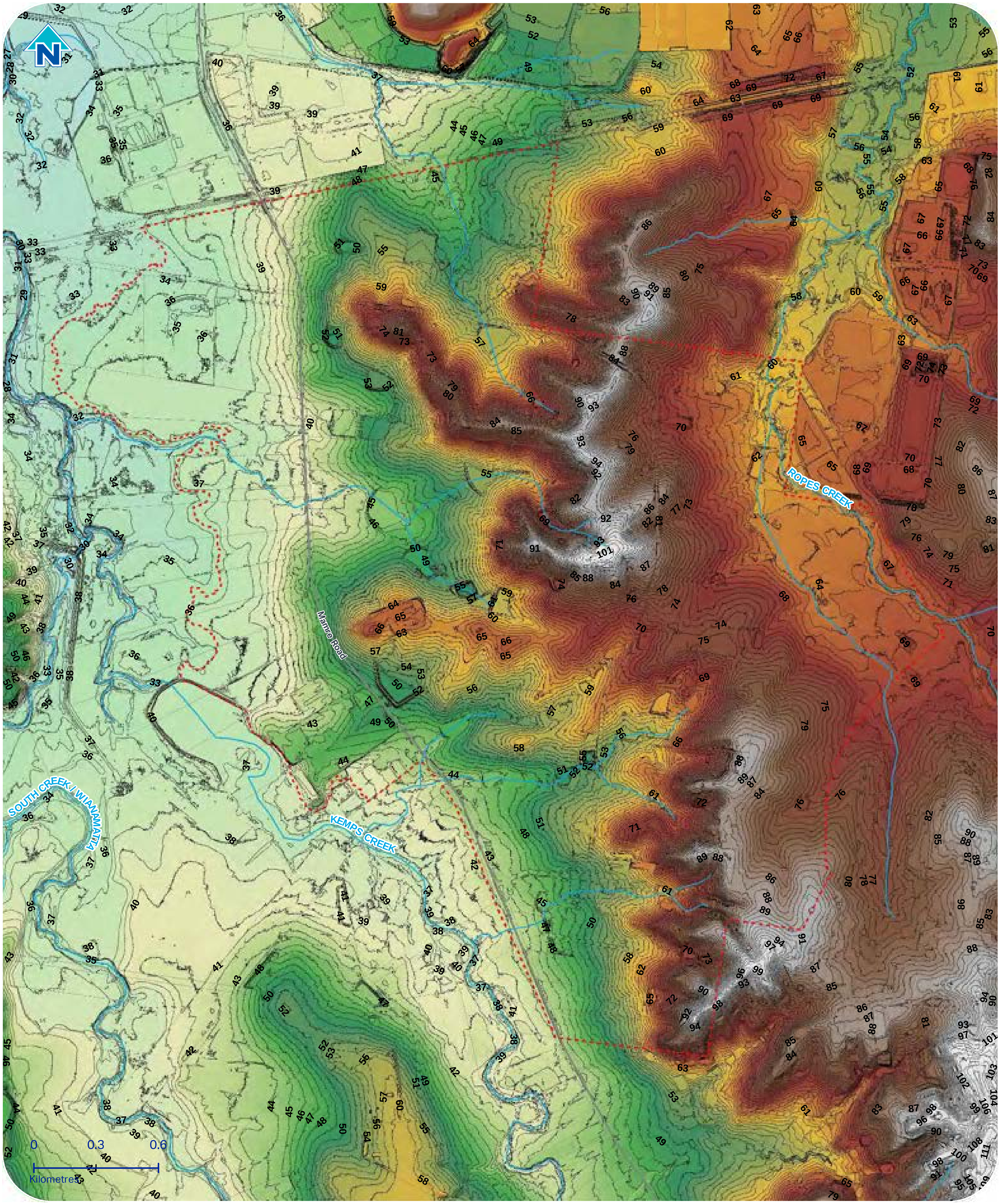

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FIGURE A-5 PRESENT DAY TOPOGRAPHY

LEGEND

Mamre Road Precinct
Road
Watercourse
Cadastre
1m Contour

2019LiDAR.tif
Value
High : 112.325
Low : 24.465

Map is indicative only and not to scale
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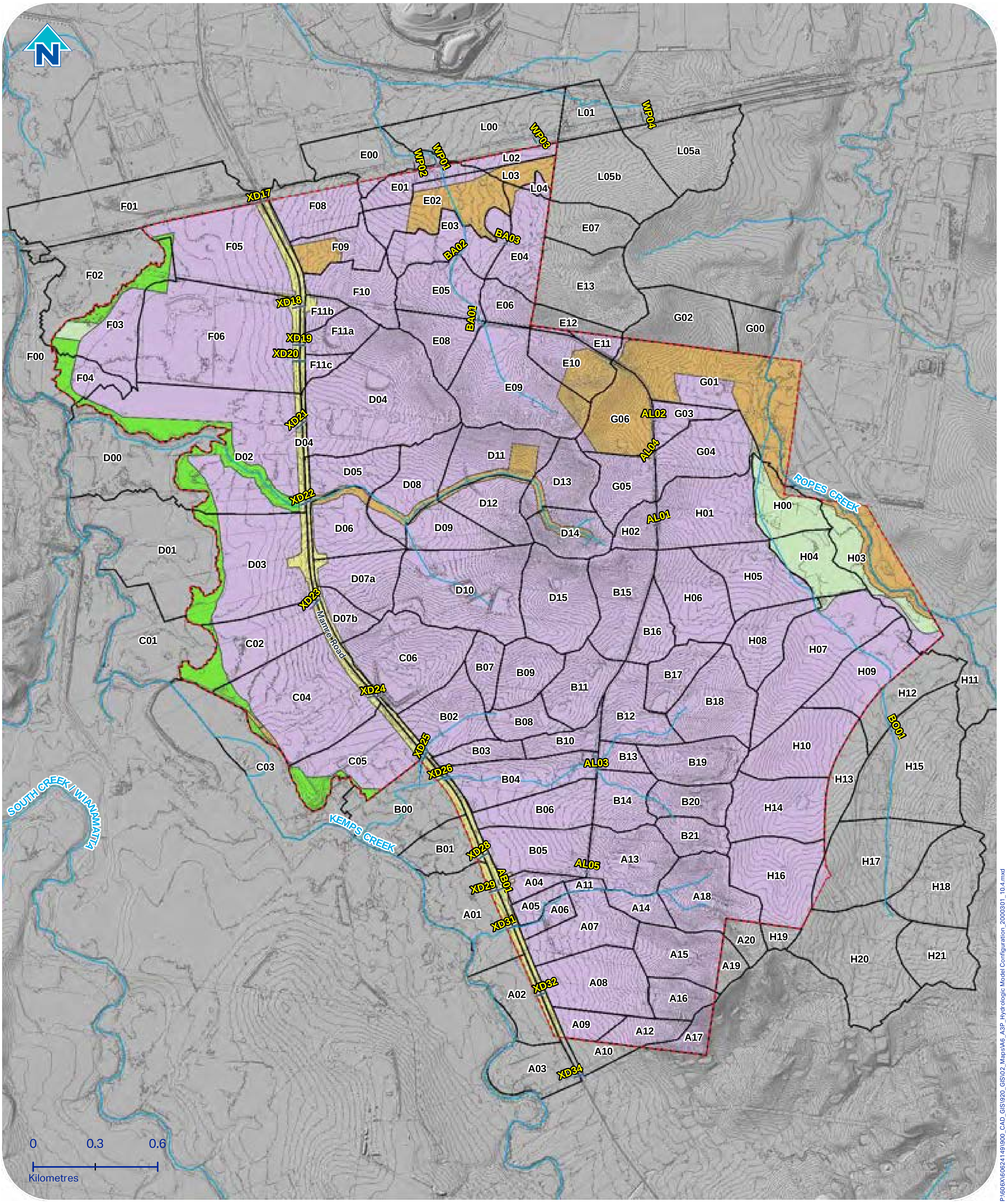


FIGURE A-6 HYDROLOGIC MODEL CATCHMENT LAYOUT

LEGEND

Mamre Road Precinct

Catchments

1m Contour

XY90 Modelled Pipes

Road

Watercourse

Cadastre

ZONE

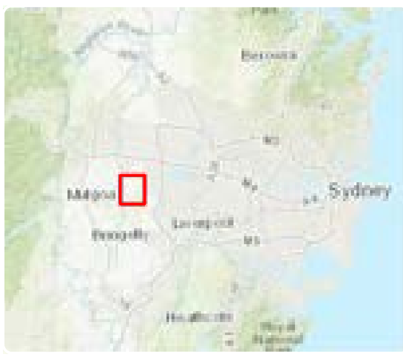
E2 Environmental Conservation

IN1 General Industrial

RE1 Public Recreation

RE2 Private Recreation

SP2 Infrastructure



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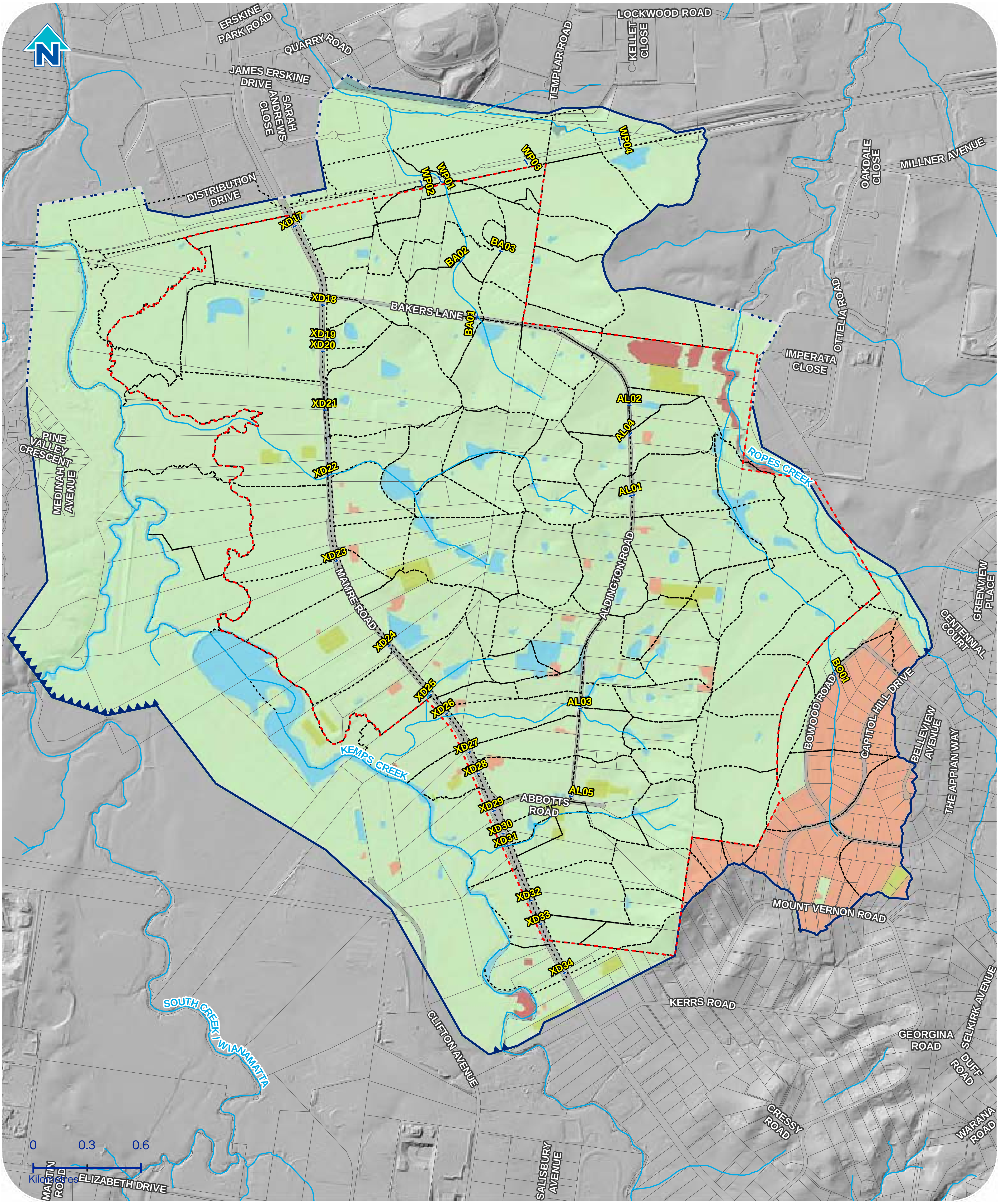

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FIGURE A-7 HYDRAULIC MODEL CONFIGURATION - EXISTING CONDITIONS

LEGEND

- Mamre Road Precinct
- Hydraulic Model Boundary
- XY90 Modelled Pipes
- Inflow Boundary
- Outflow Boundary
- Internal inflow boundaries
- Watercourse
- Cadastre
- Moderately vegetated creek channel
- Grassed floodplain and sparse trees
- Floodplain with dense trees
- Industrial Development/Intensive farming
- Roadways
- Water
- Rural Residential

Sydney WATER

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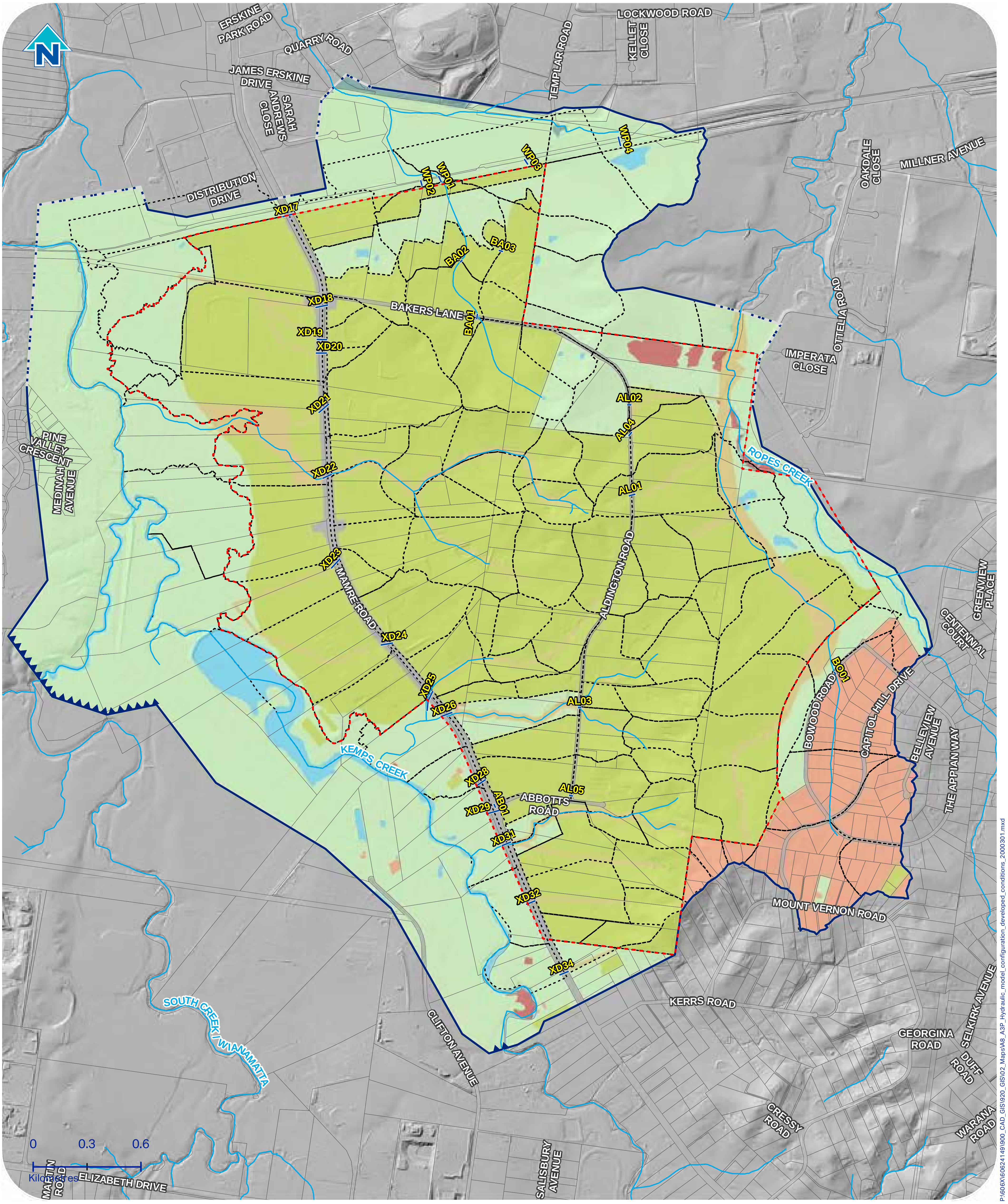

FIGURE A-8 HYDRAULIC MODEL CONFIGURATION - DEVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Hydraulic Model Boundary
- XY90 Modelled Pipes
- Inflow Boundary
- Outflow Boundary
- Internal inflow boundaries
- Watercourse
- Cadastre
- Riparian Corridor
- Moderately vegetated creek channel
- Grassed floodplain and sparse trees
- Floodplain with dense trees
- Industrial Development/Intensive farming
- Roadways
- Water
- Rural Residential

Sydney WATER

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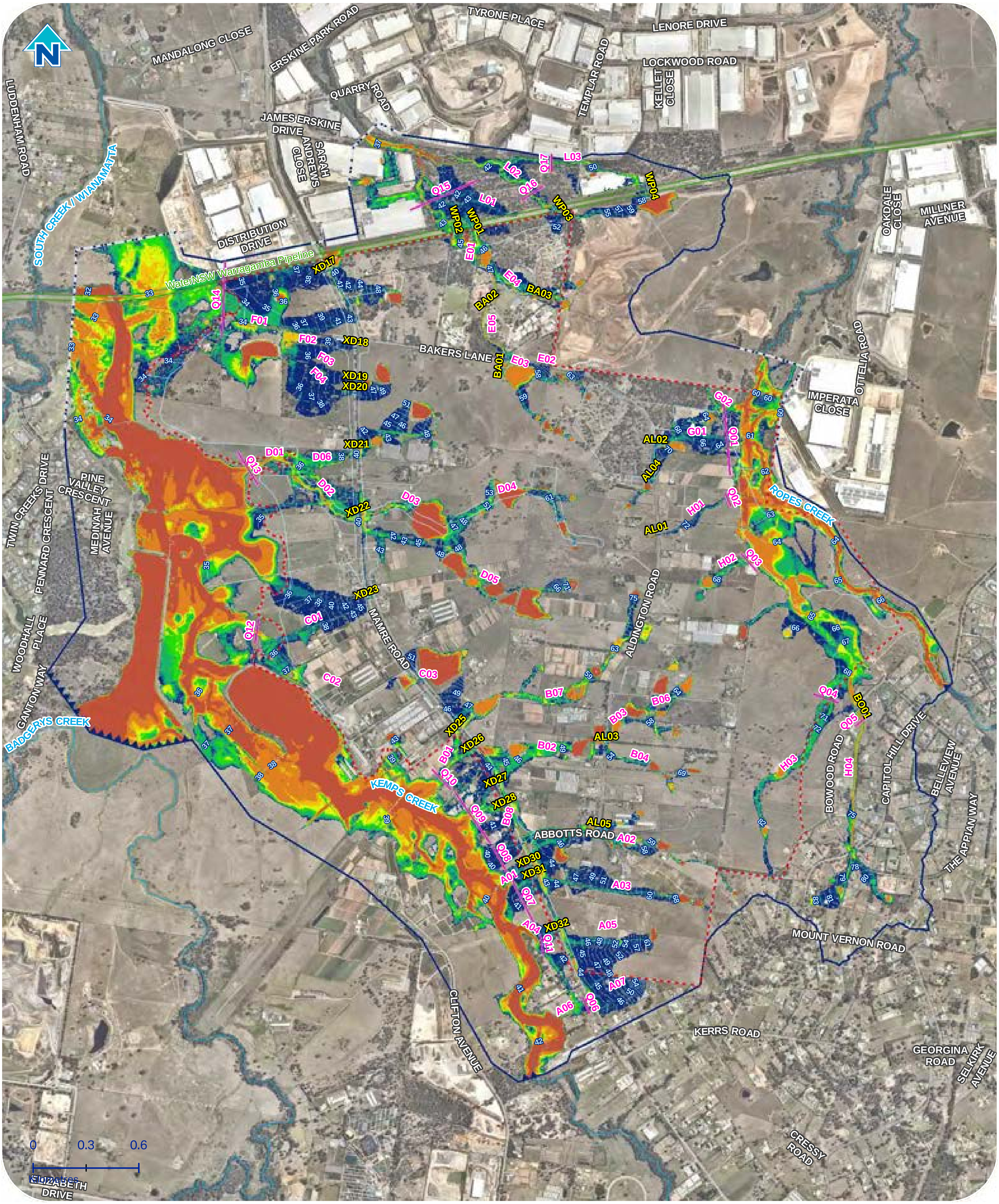

FIGURE A-9 FLOOD DEPTH - 5% AEP - EXISTING CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre
- X01 Reporting Location
- 99 1m Flood Level Contour (mAHD)

Depth (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

NOTE - ONLY 5% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 5% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

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Sydney Water does not guarantee accuracy, completeness or currency of this spatial information

Sydney WATER

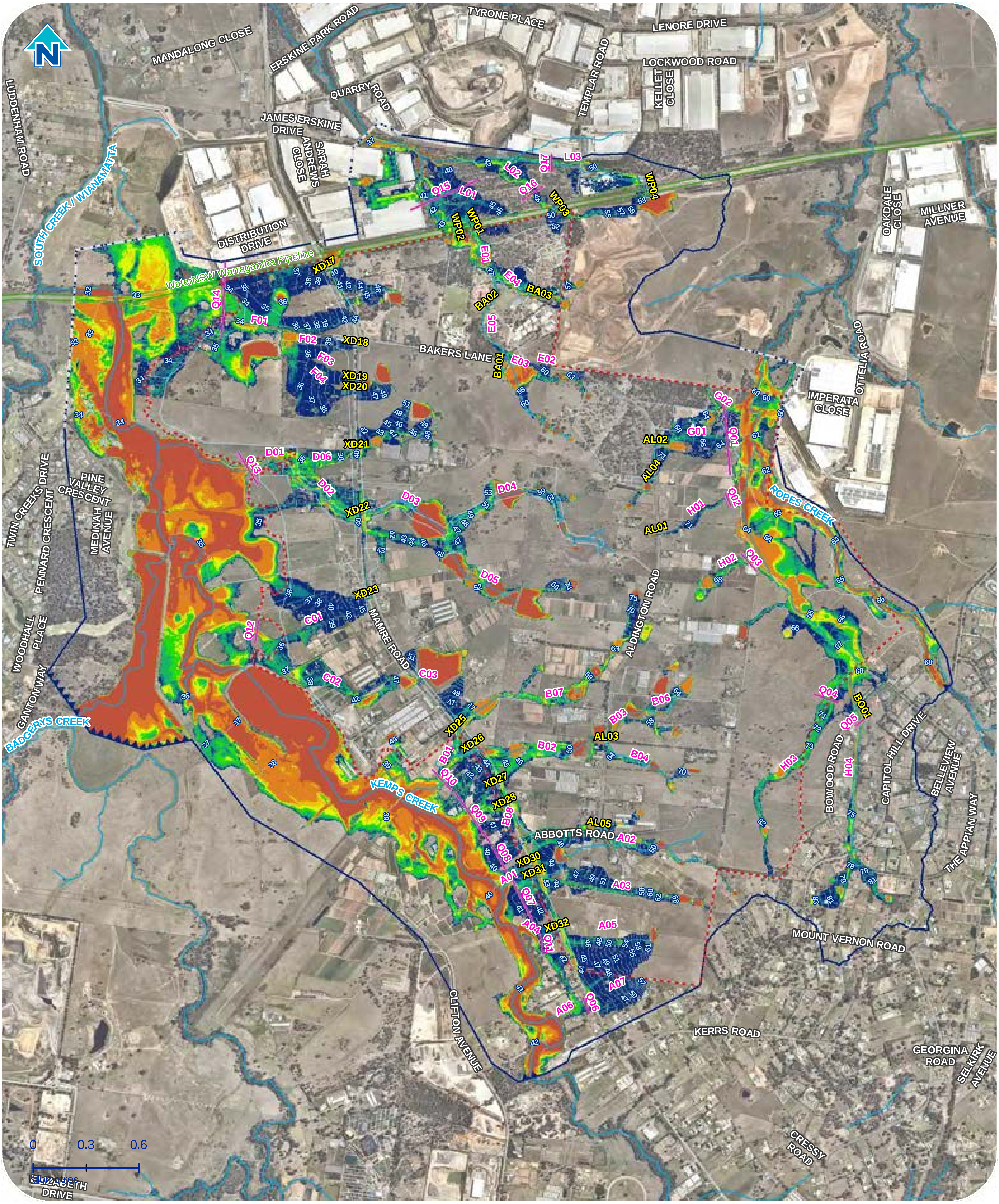


FIGURE A-10 FLOOD DEPTH - 1% AEP - EXISTING CONDITIONS

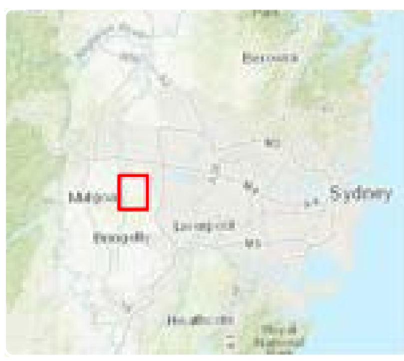
LEGEND

- Mamre Road Precinct
- Hydraulic Model Boundary
- XY90 Modelled Pipes
- Inflow Boundary
- Outflow Boundary
- Watercourse
- Cadastre
- Proposed Zoning Boundary
- X01 Reporting Location
- 99 1m Flood Level Contour (mAHD)

Depth (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



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Sydney WATER

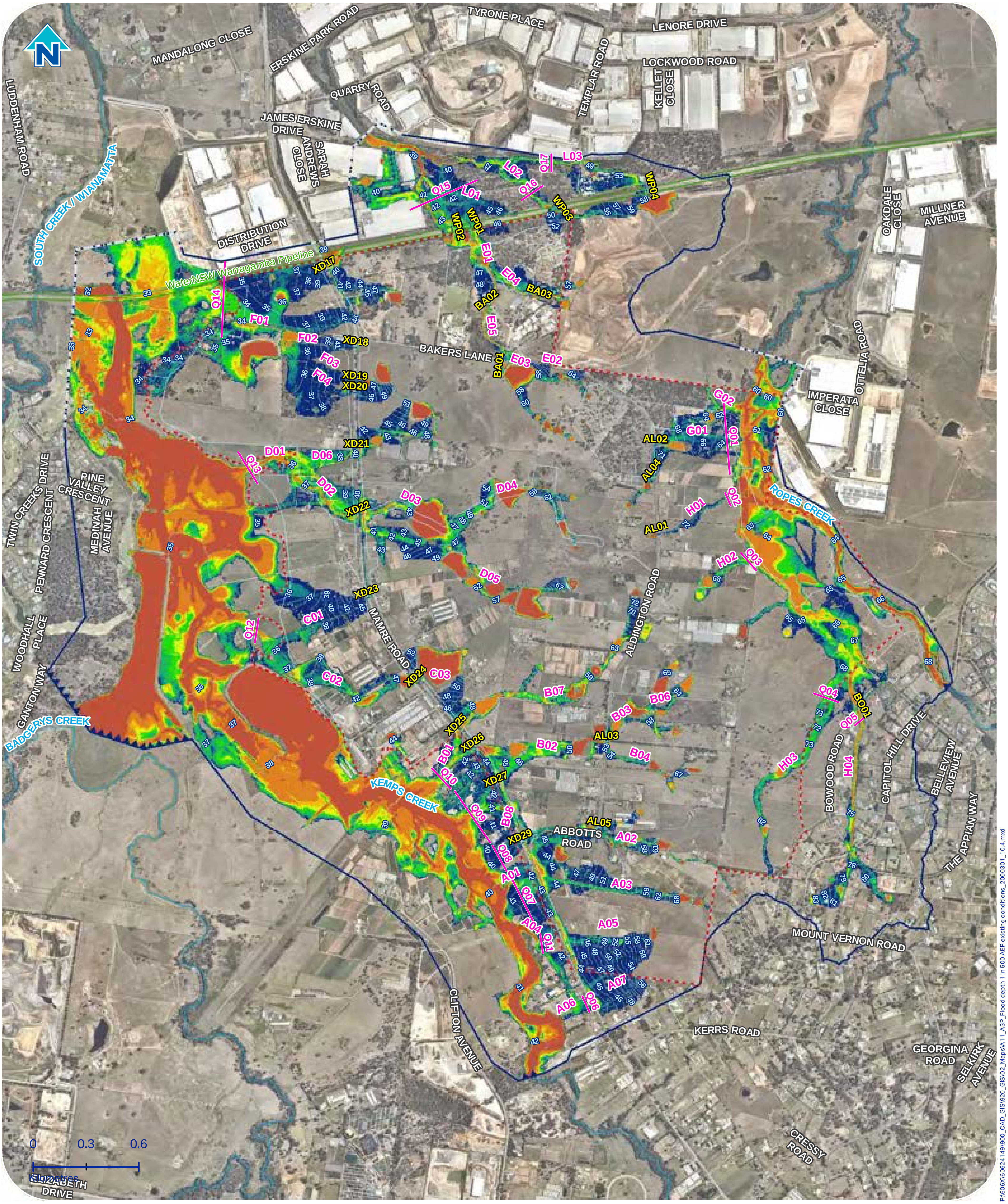


FIGURE A-11 FLOOD DEPTH - 1 IN 500 AEP - EXISTING CONDITIONS

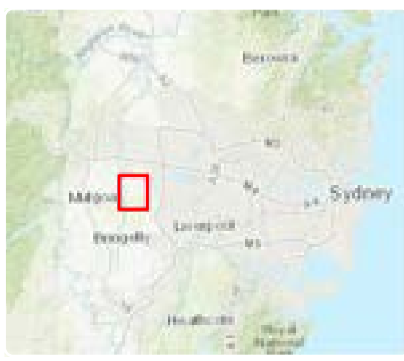
LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre
- X01 Reporting Location
- 99 1m Flood Level Contour (mAHD)

Depth (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

NOTE - ONLY 0.2 % AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 0.2% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



Map is indicative only and not to scale
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Sydney WATER

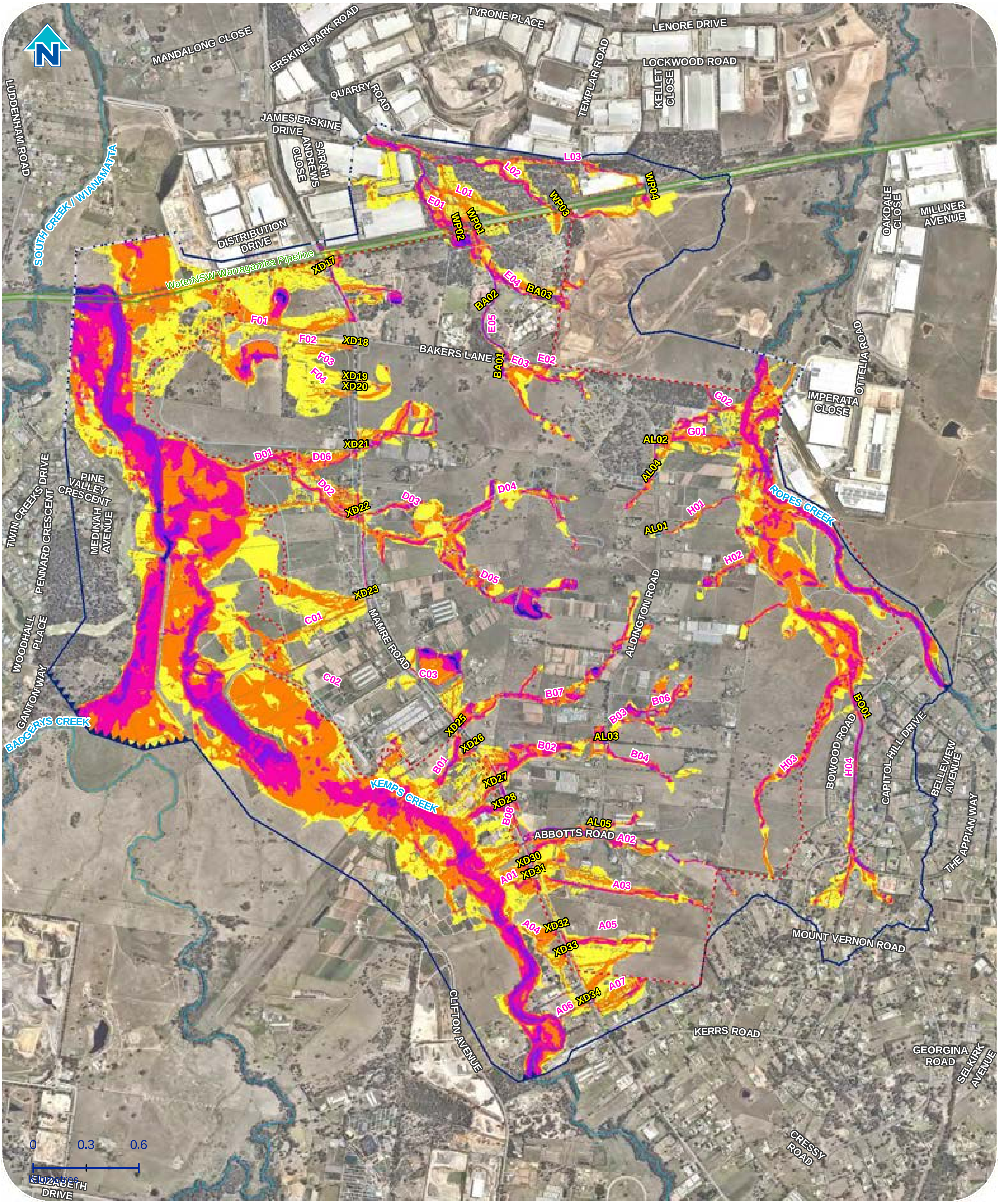

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FIGURE A-12 FLOOD VELOCITY - 5% AEP - EXISTING CONDITIONS

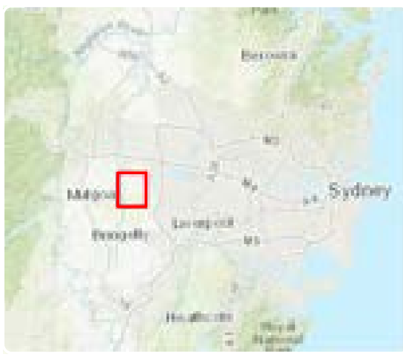
LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Peak Flood Velocity (m/s)

- <0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- >2
- X01 Reporting Location

NOTE - ONLY 5% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 5% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



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Sydney WATER

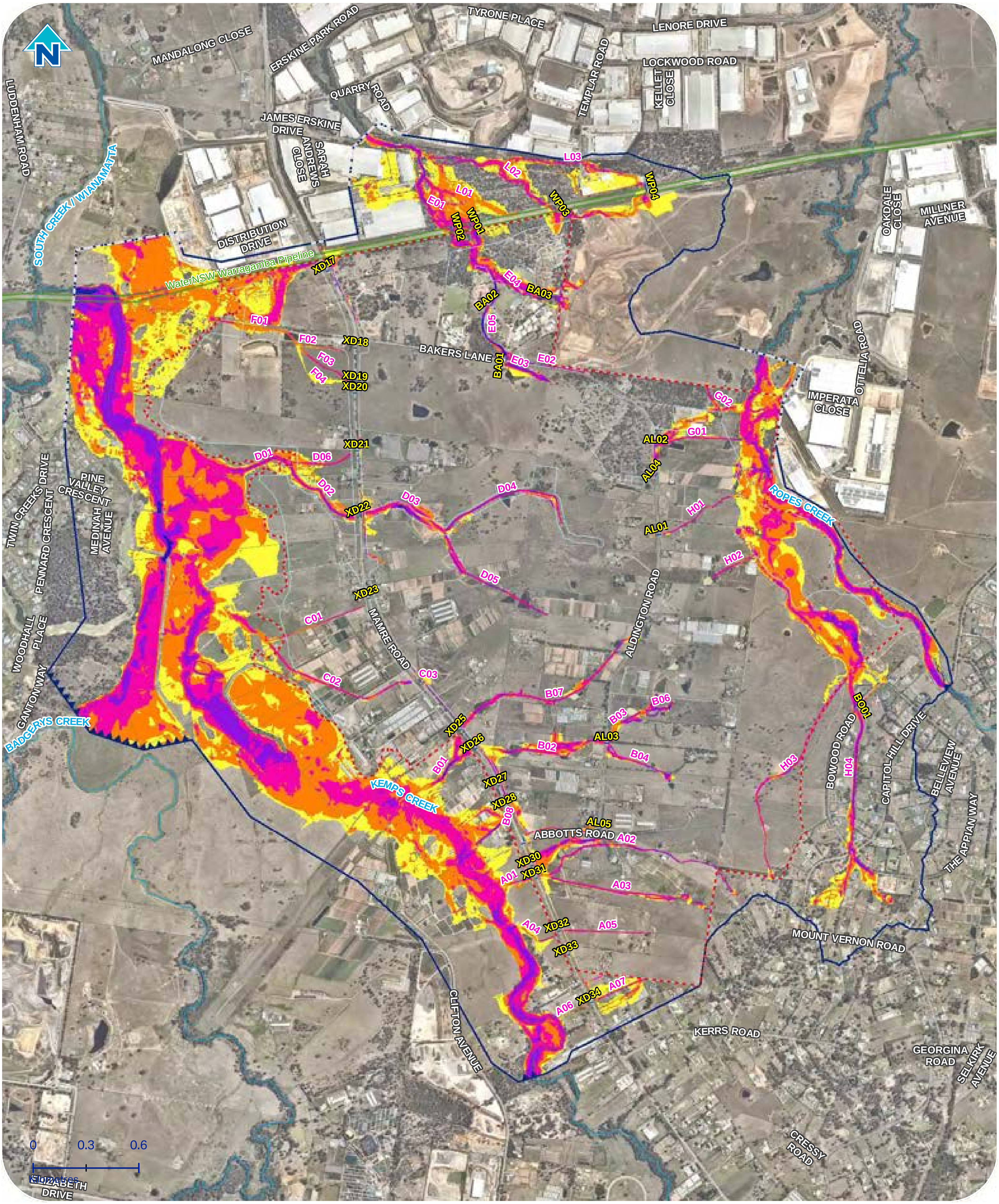

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FIGURE A-13 FLOOD VELOCITY - 1% AEP - EXISTING CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Peak Flood Velocity (m/s)

- <0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- >2
- X01 Reporting Location

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

Map is indicative only and not to scale

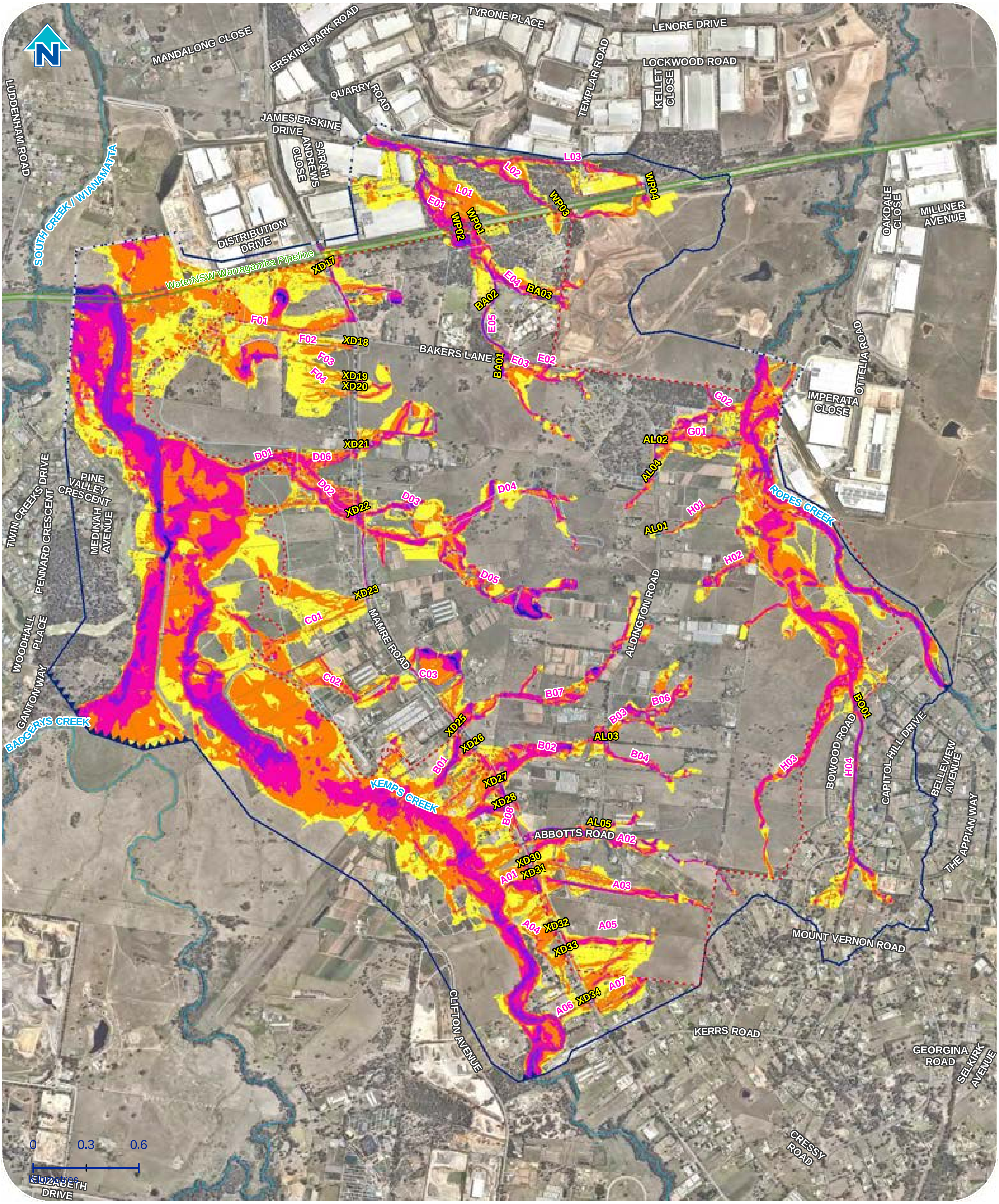

FIGURE A-14 FLOOD VELOCITY - 1 IN 500 AEP - EXISTING CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Peak Flood Velocity (m/s)

- <0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- >2
- X01 Reporting Location

NOTE - ONLY 0.2% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 0.2% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

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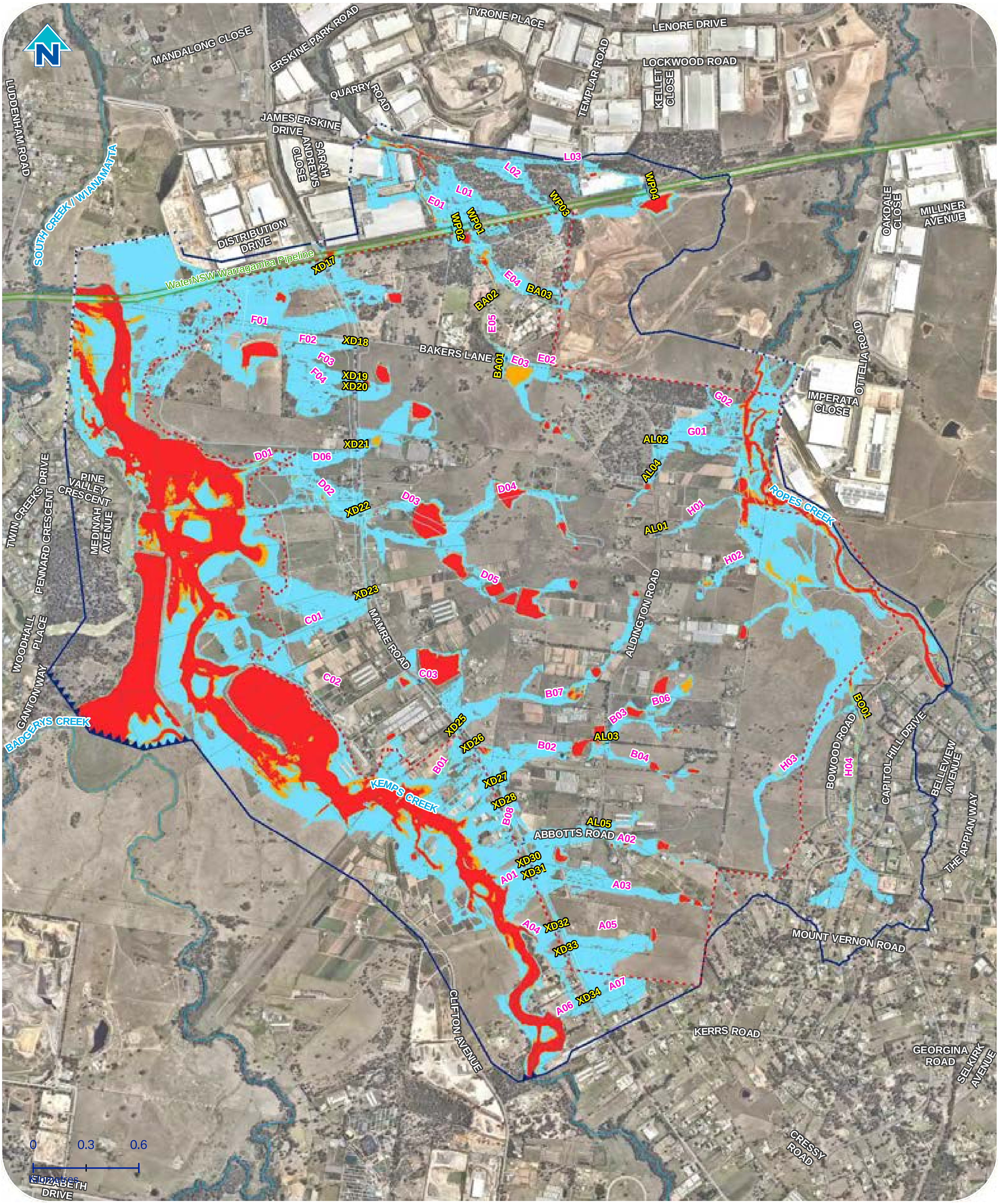


FIGURE A-15 PROVISIONAL FLOOD HAZARD - 5% AEP - EXISTING CONDITIONS

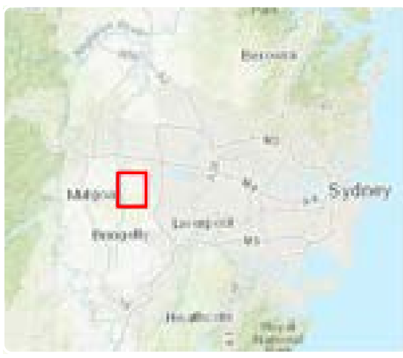
LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Provisional Flood Hazard

- Low
- Intermediate
- High
- X01 Reporting Location

NOTE - ONLY 5% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 5% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



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Sydney WATER

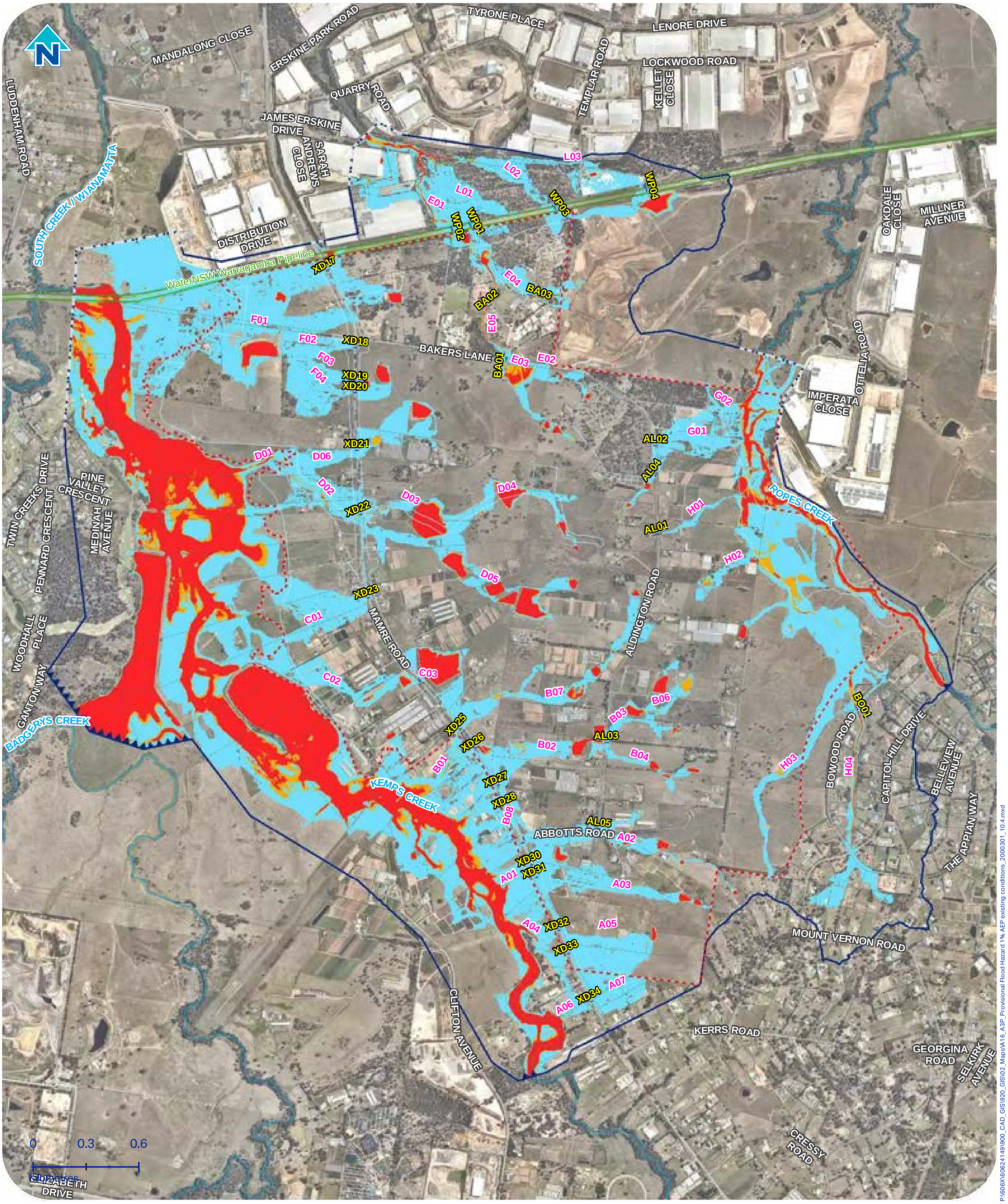

FIGURE A-16 PROVISIONAL FLOOD HAZARD - 1% AEP - EXISTING CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Provisional Flood Hazard

- Low
- Intermediate
- High
- X01 Reporting Location

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS
1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

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Sydney WATER

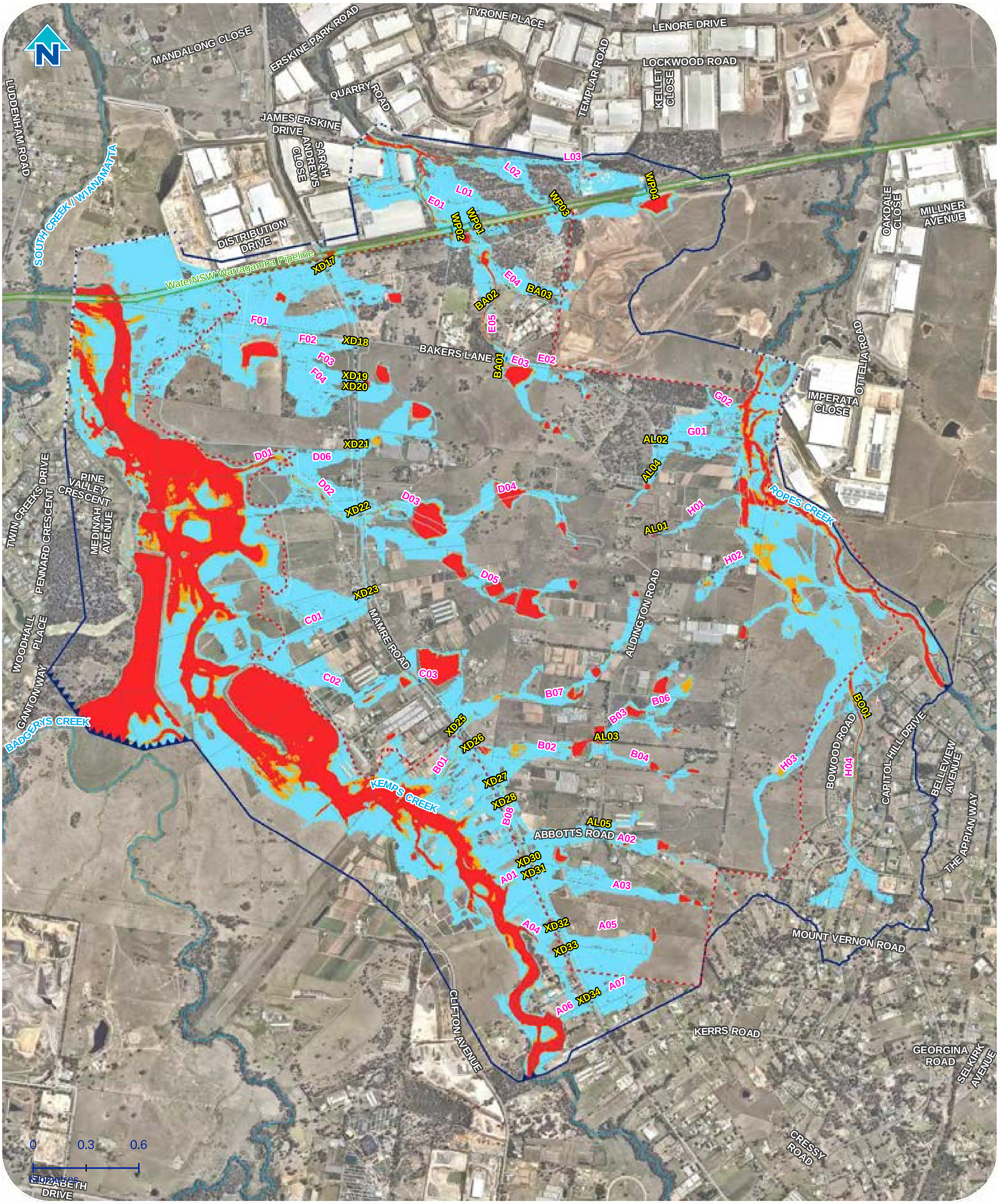

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FIGURE A-17 PROVISIONAL FLOOD HAZARD - 1 IN 500 AEP - EXISTING CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Provisional Flood Hazard

- Low
- Intermediate
- High
- X01 Reporting Location

NOTE - ONLY 0.2% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 0.2% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

Sydney WATER

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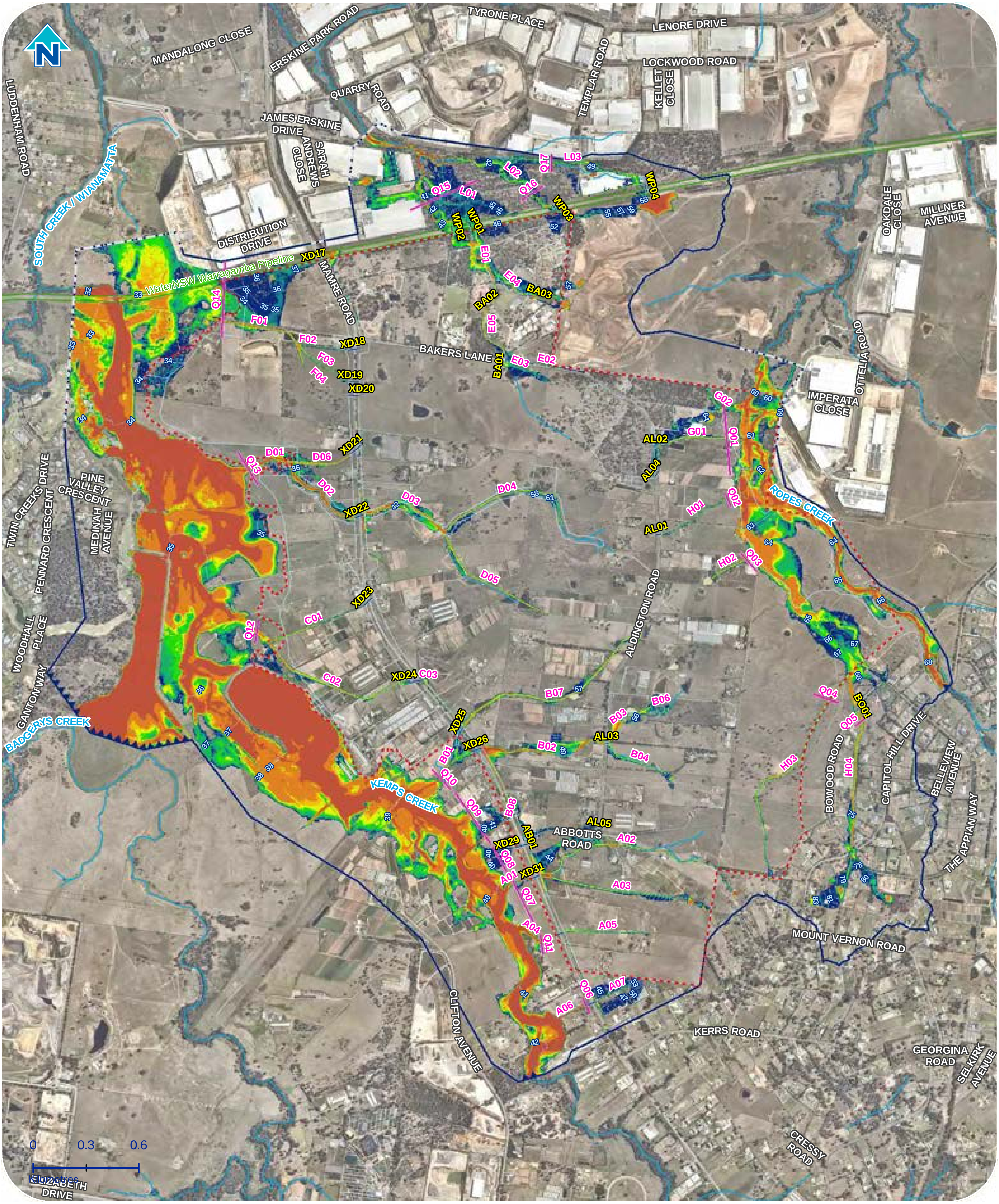

FIGURE A-18 FLOOD DEPTH - 5% AEP - DEVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre
- X01 Reporting Location
- 99 1m Flood Level Contour (mAHD)

Depth (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

NOTE - ONLY 5% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 5% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

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Sydney WATER

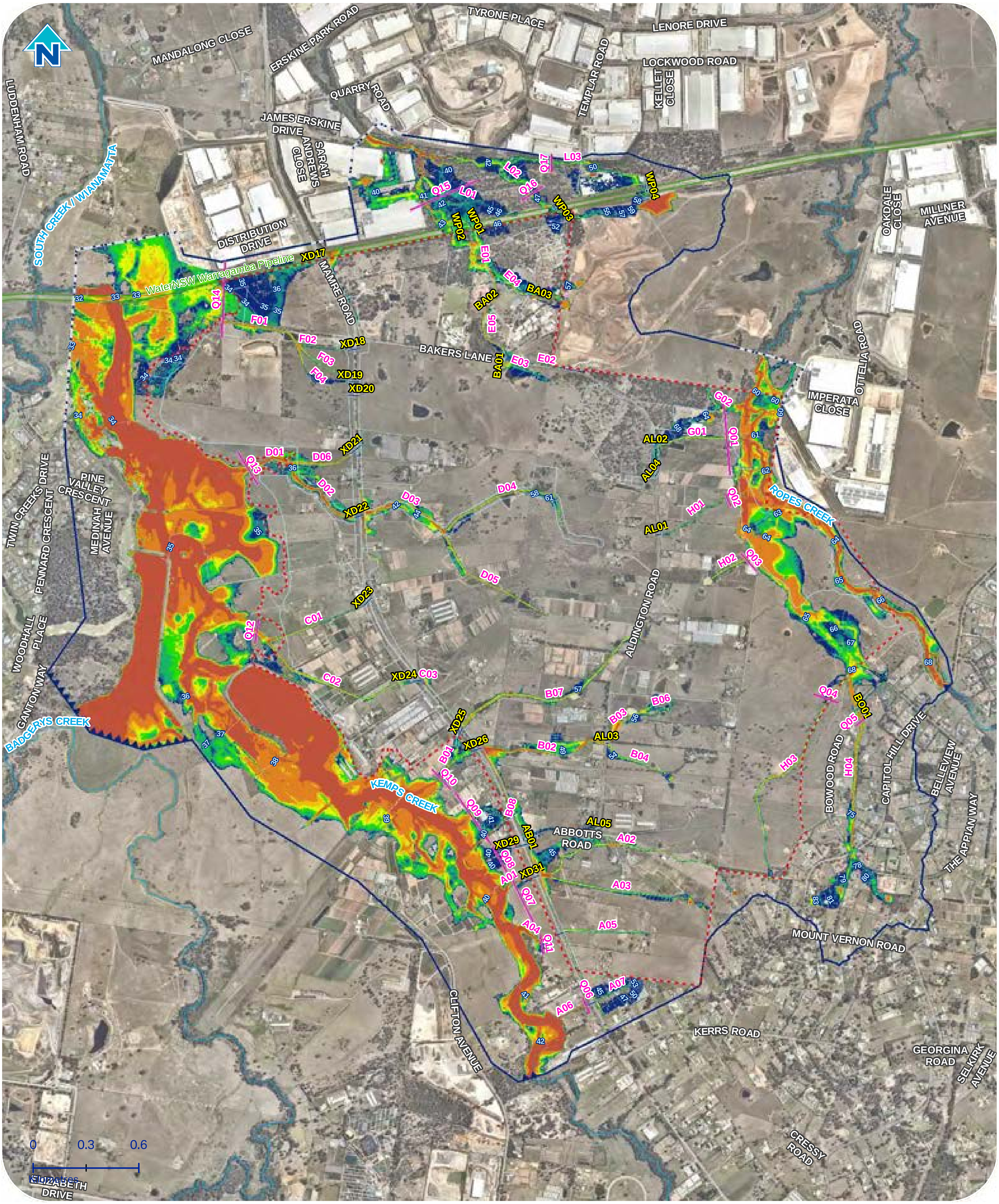

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FIGURE A-19 FLOOD DEPTH - 1% AEP - DEVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre
- X01 Reporting Location
- 99 1m Flood Level Contour (mAHD)

Depth (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

Sydney WATER

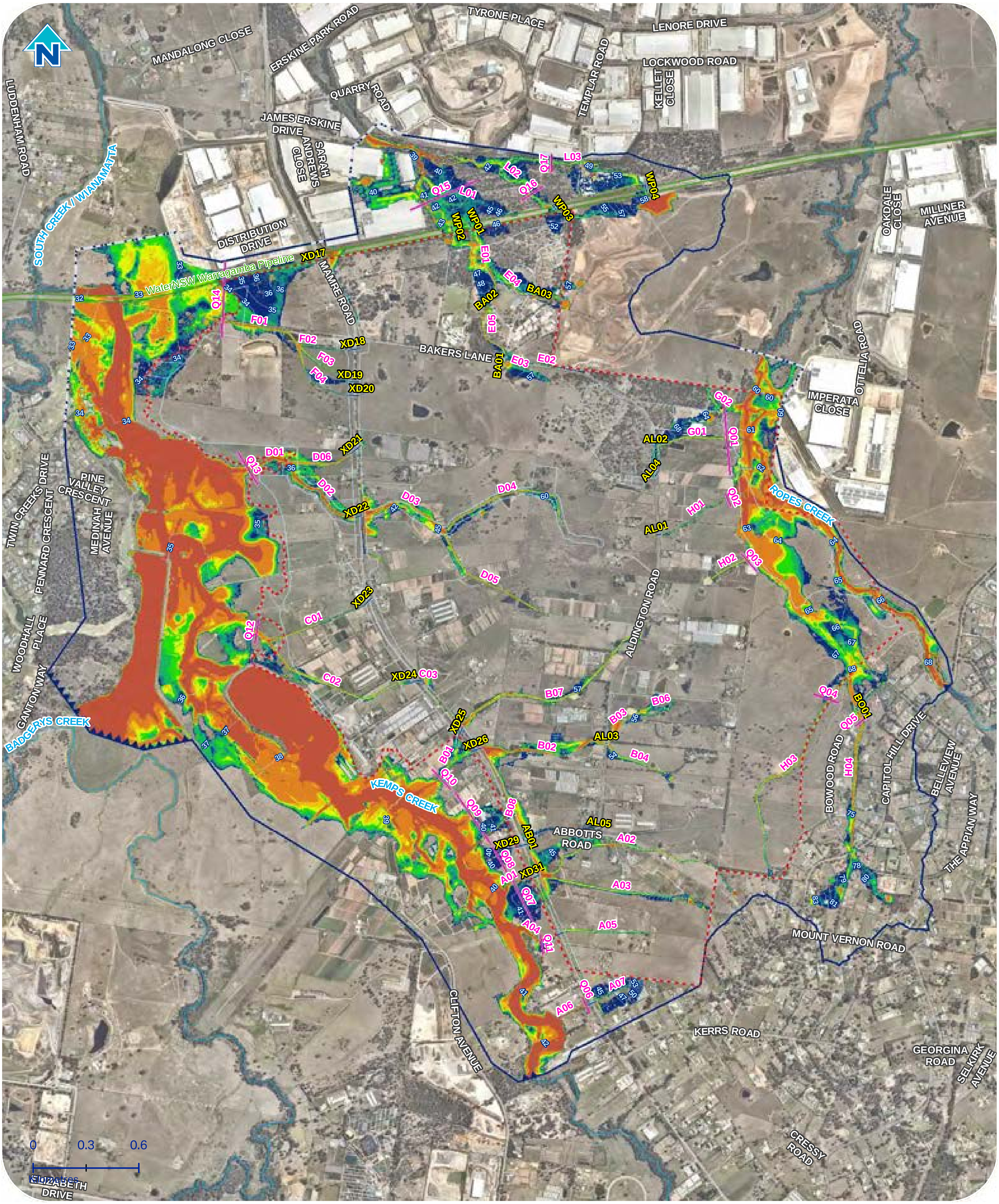

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FIGURE A-20 FLOOD DEPTH - 1 IN 500 AEP - DEVELOPED CONDITIONS

LEGEND

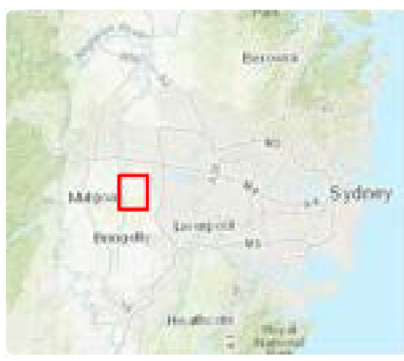
Mamre Road Precinct
Inflow Boundary
XY90 Modelled Pipes
Watercourse
Outflow Boundary
Hydraulic Model Boundary
Proposed Zoning Boundary
Cadastre

X01 Reporting Location
99 1m Flood Level Contour (mAHD)

Depth (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

NOTE - ONLY 0.2% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 0.2% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



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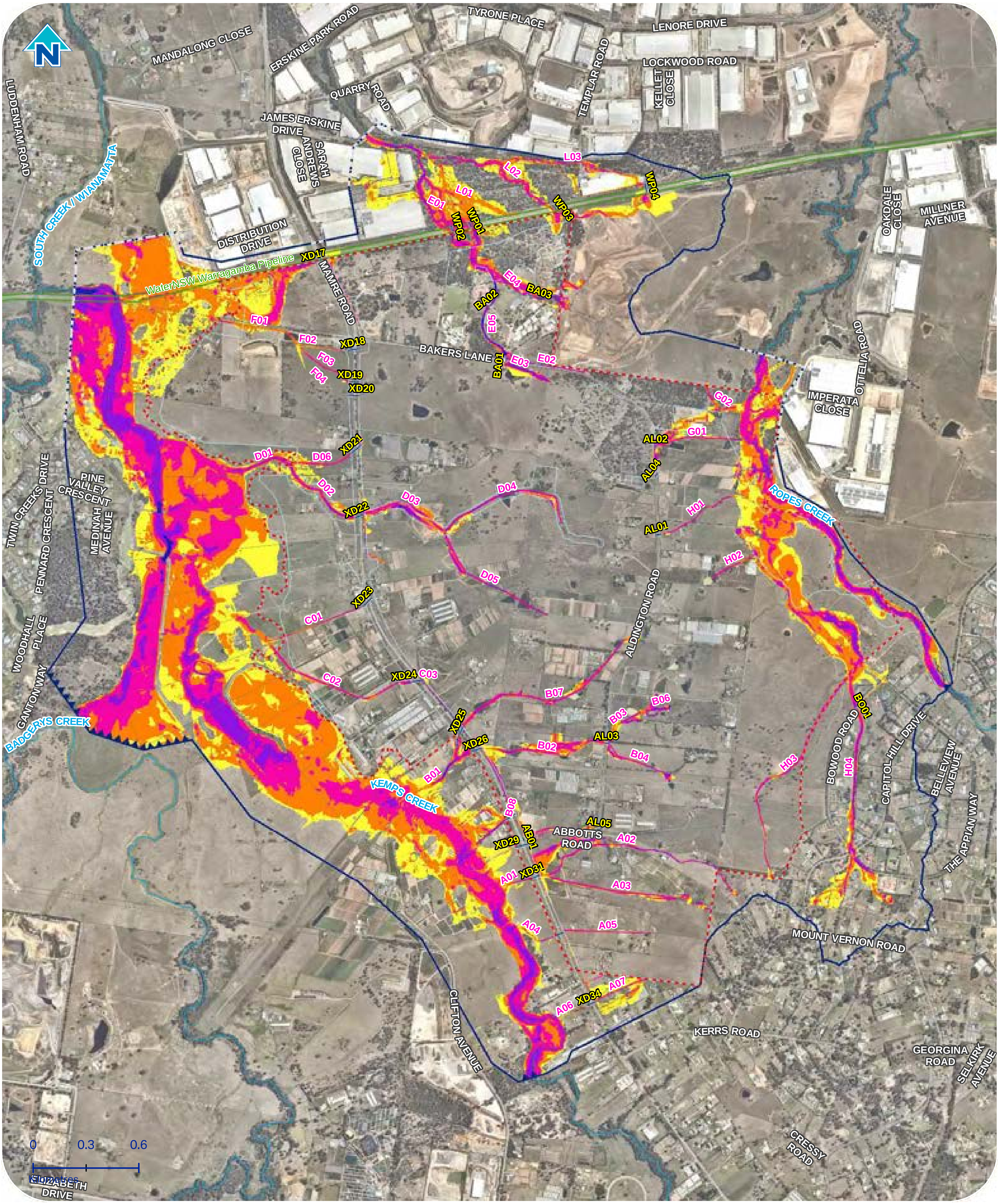

FIGURE A-21 FLOOD VELOCITY - 5% AEP - DEVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Peak Flood Velocity (m/s)

- <0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- >2
- X01 Reporting Location

NOTE - ONLY 5% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS
5% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

Sydney WATER

Map is indicative only and not to scale

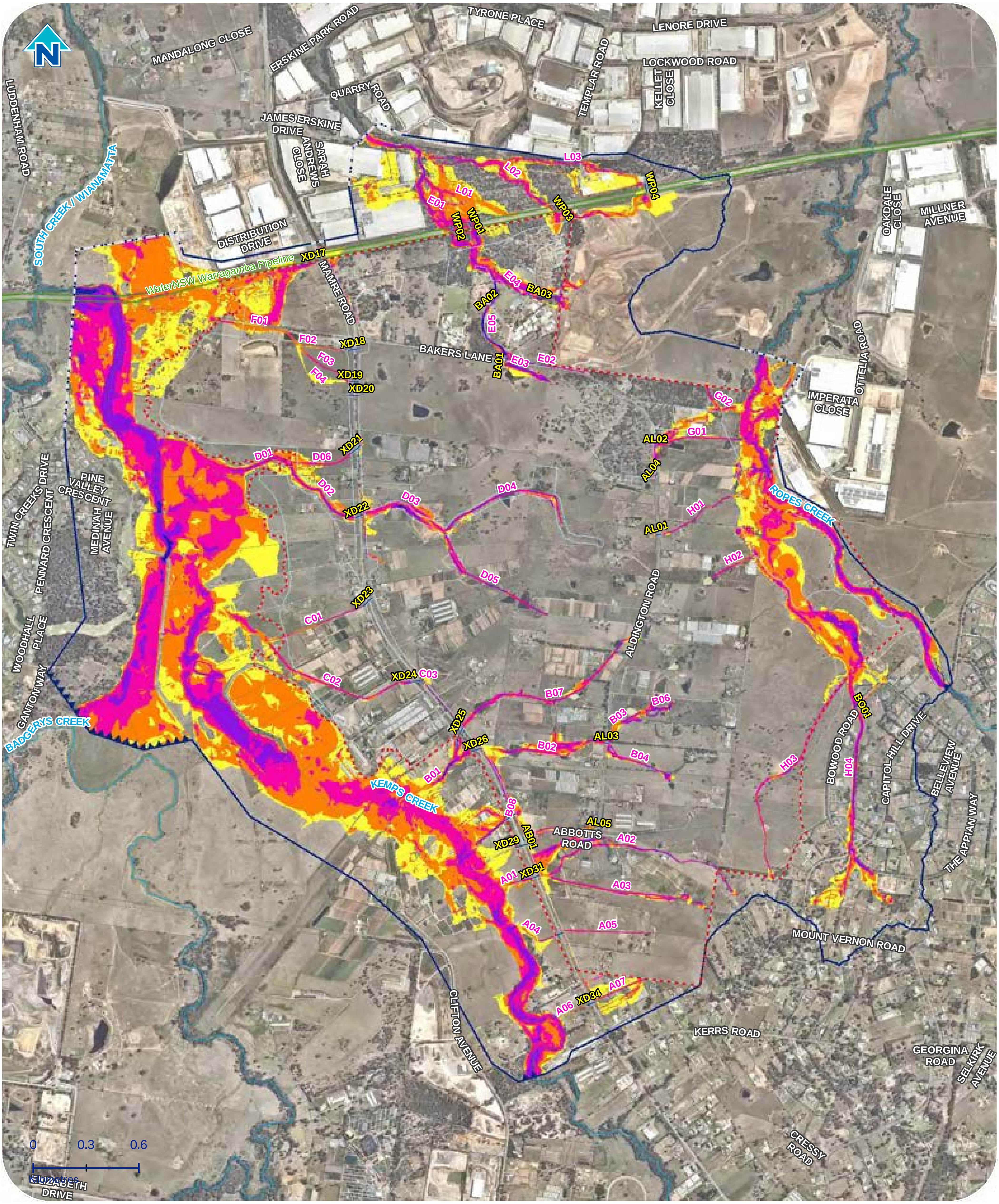

FIGURE A-22 FLOOD VELOCITY - 1% AEP - DEVELOPED CONDITIONS

LEGEND

Mamre Road Precinct
Inflow Boundary
XY90 Modelled Pipes
Watercourse
Outflow Boundary
Hydraulic Model Boundary
Proposed Zoning Boundary
Cadastre

Peak Flood Velocity (m/s)

<0.2
0.2 - 0.5
0.5 - 1
1 - 2
>2
X01 Reporting Location

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

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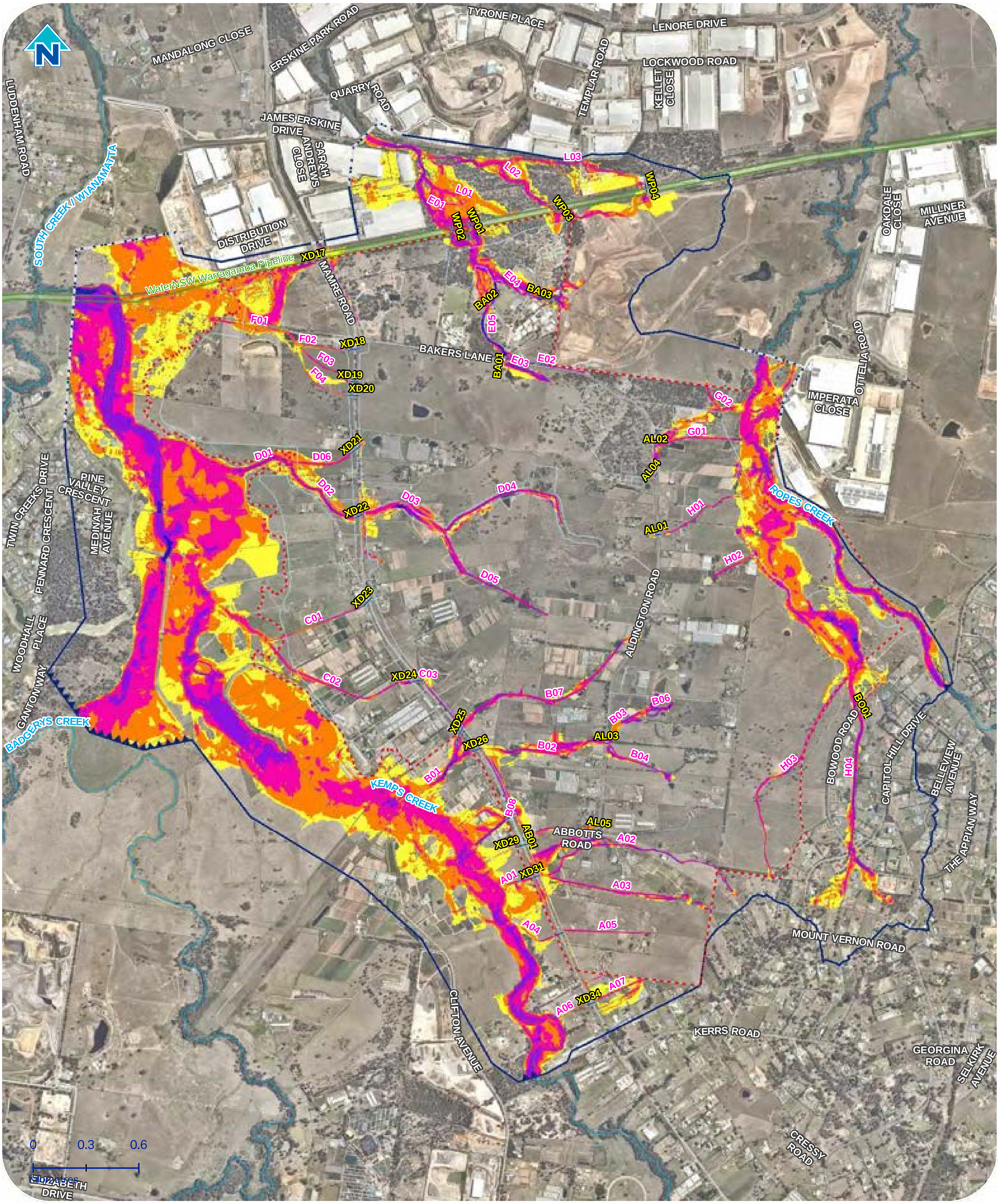


FIGURE A-23 FLOOD VELOCITY - 1 IN 500 AEP - DEVELOPED CONDITIONS

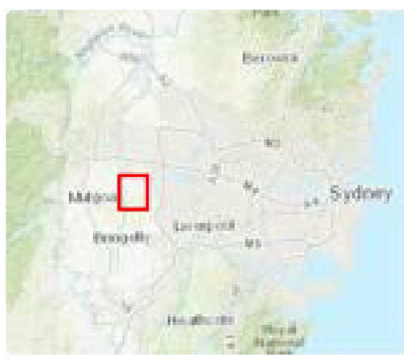
LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Peak Flood Velocity (m/s)

- <0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- >2
- X01 Reporting Location

NOTE - ONLY 0.2% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 0.2% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



Sydney WATER

Map is indicative only and not to scale

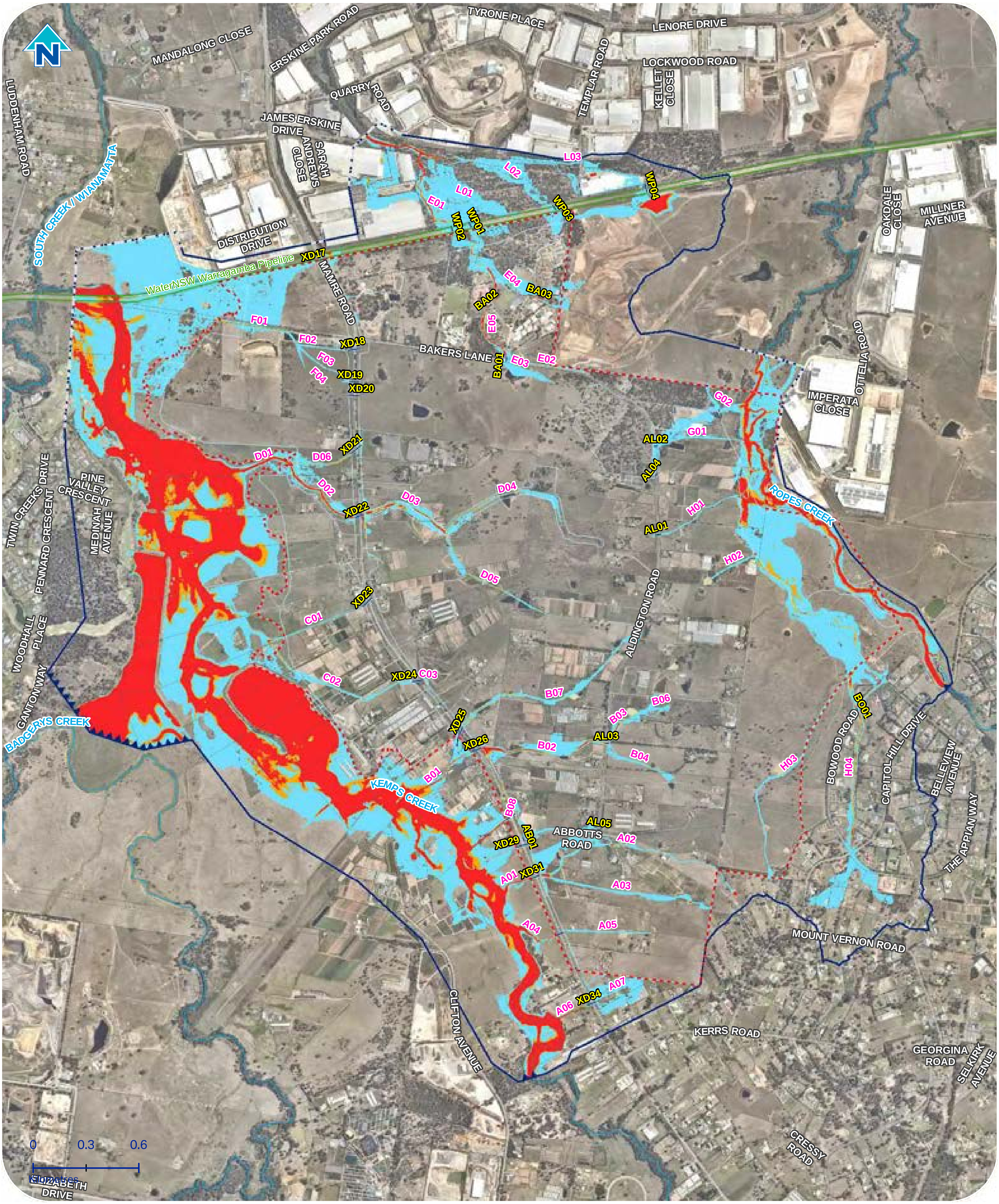


FIGURE A-24 PROVISIONAL FLOOD HAZARD - 5% AEP - DEVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Provisional Flood Hazard

- Low
- Intermediate
- High
- X01 Reporting Location

NOTE - ONLY 5% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 5% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

Sydney WATER

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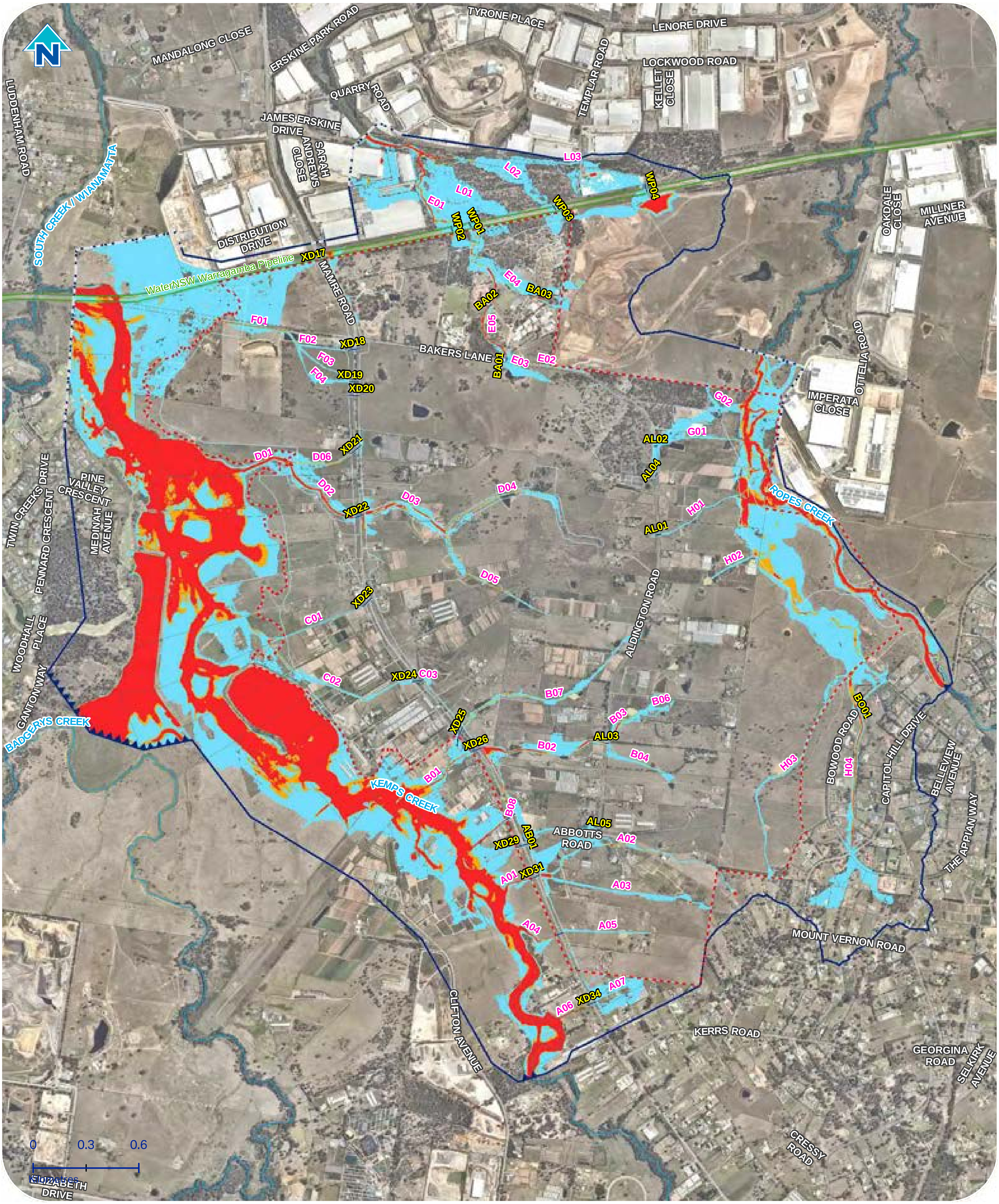

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FIGURE A-25 PROVISIONAL FLOOD HAZARD - 1% AEP - DEVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Provisional Flood Hazard

- Low
- Intermediate
- High
- X01 Reporting Location

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

Map is indicative only and not to scale

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Sydney WATER

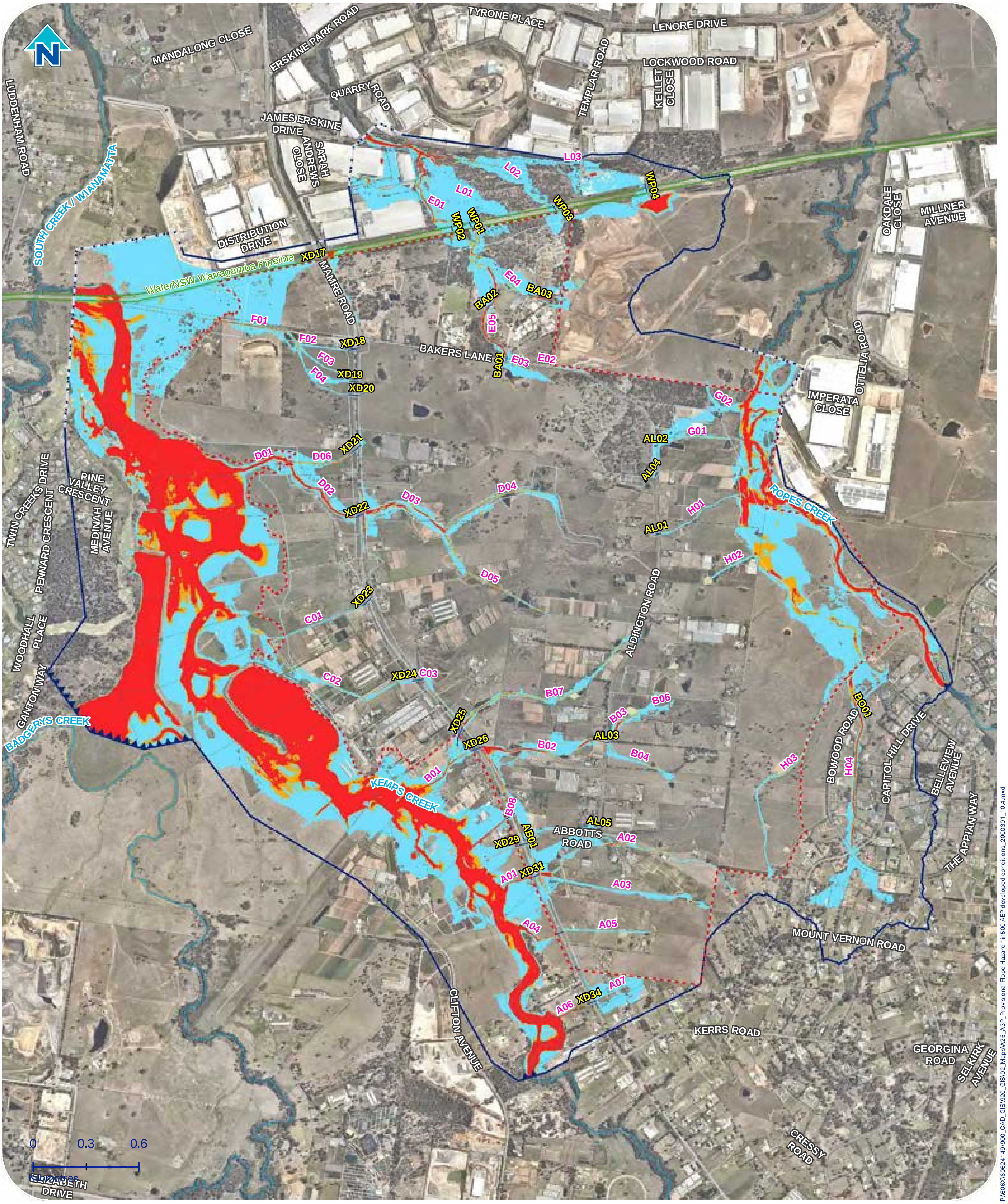

FIGURE A-26 PROVISIONAL FLOOD HAZARD - 1 IN 500 AEP - DEVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Inflow Boundary
- XY90 Modelled Pipes
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Provisional Flood Hazard

- Low
- Intermediate
- High
- X01 Reporting Location

NOTE - ONLY 0.2% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 0.2% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK

Map is indicative only and not to scale
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Sydney WATER

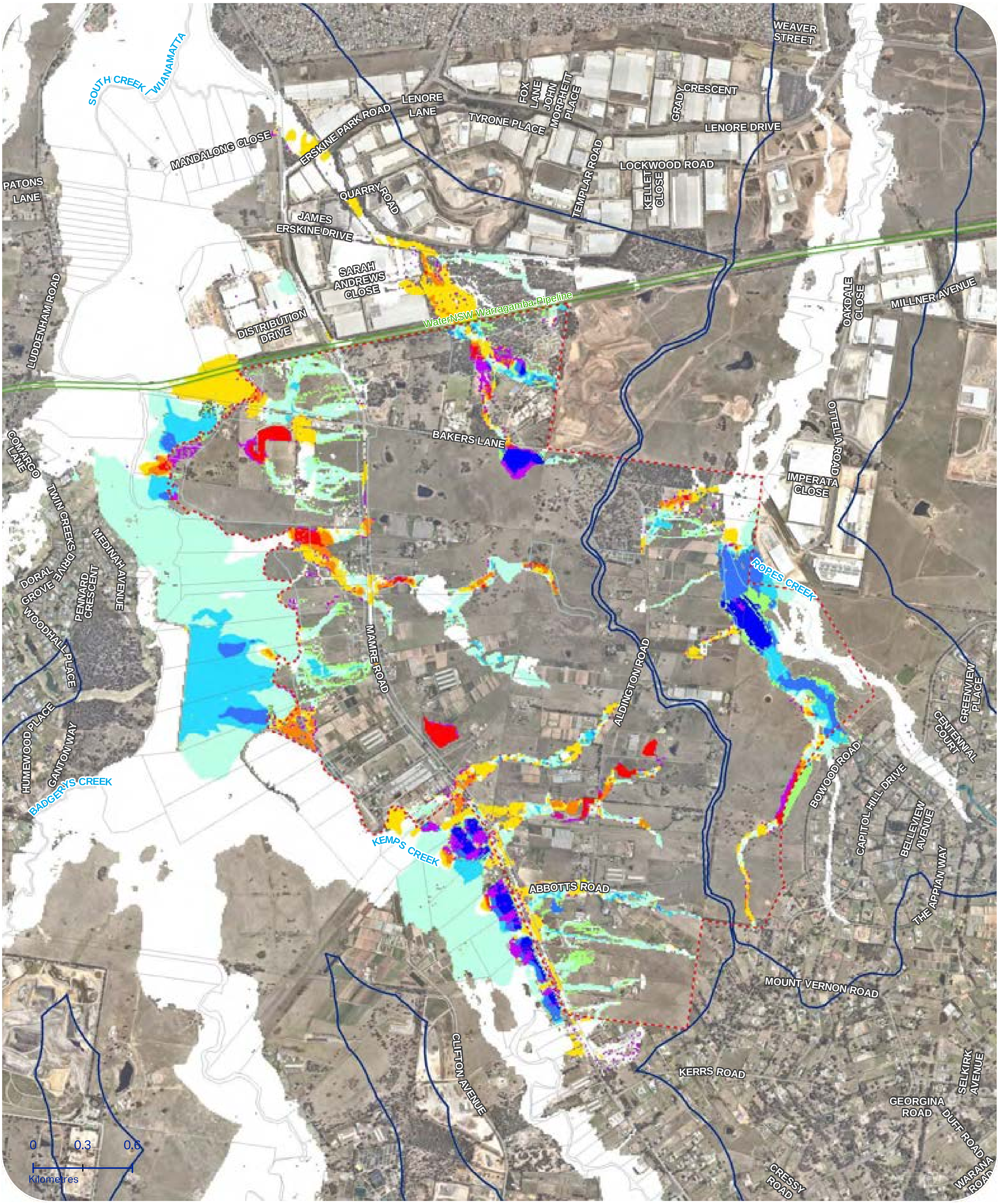


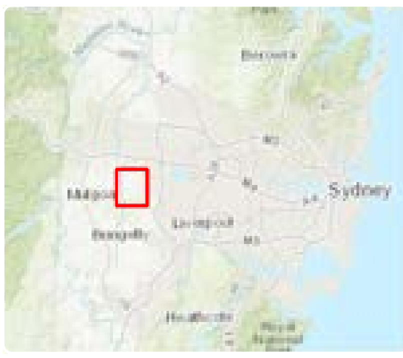
FIGURE A-27 FLOOD LEVEL DIFFERENCE - 1% AEP DEVELOPED MODEL WITHOUT OSD IN NORTHER CATCHMENT

LEGEND

- Mamre Road Precinct
- Watercourse
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Flood level difference (m)

- < -0.5
- -0.5 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- > 0.1
- Area no longer inundated
- New area of inundation



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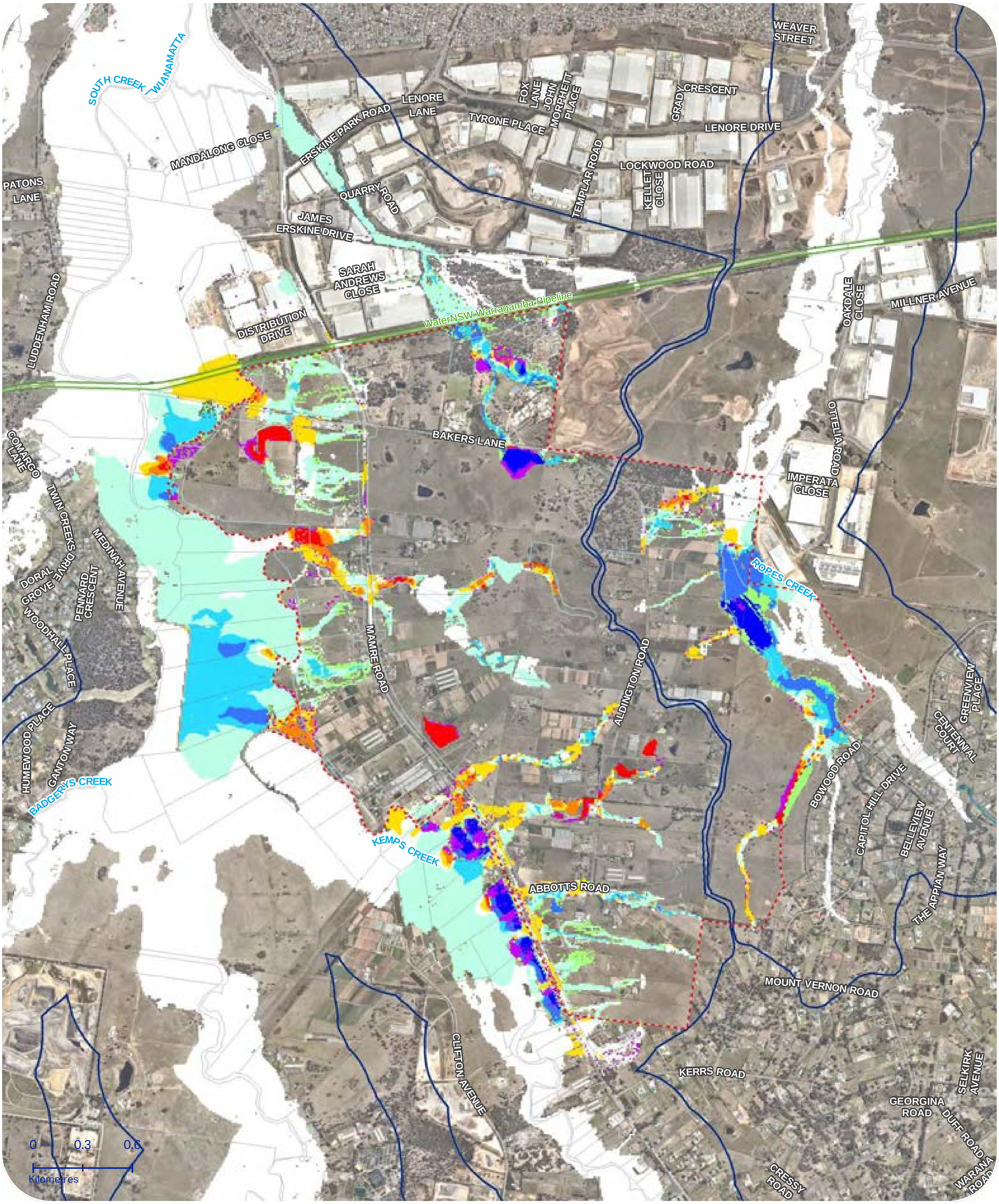

FIGURE A-28 FLOOD LEVEL DIFFERENCE - 1% AEP DEVELOPED MODEL WITH OSD IN NORTHER CATCHMENT

LEGEND

- Mamre Road Precinct
- Watercourse
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Flood level difference (m)

- < -0.5
- -0.5 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- > 0.1
- Area no longer inundated
- New area of inundation

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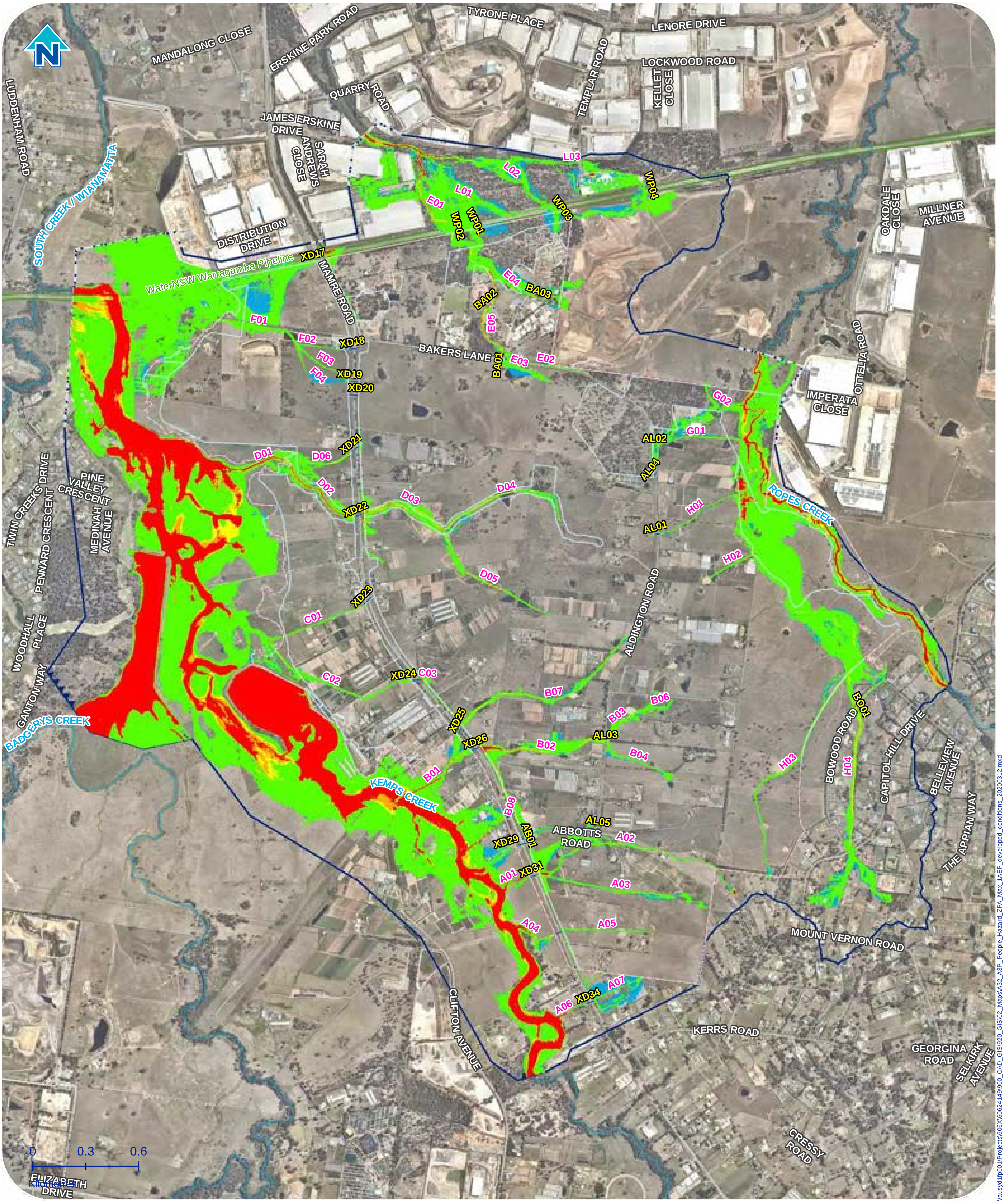


FIGURE A-29 PEOPLE HAZARD ZPA - 1% AEP - DVELOPED CONDITIONS

LEGEND

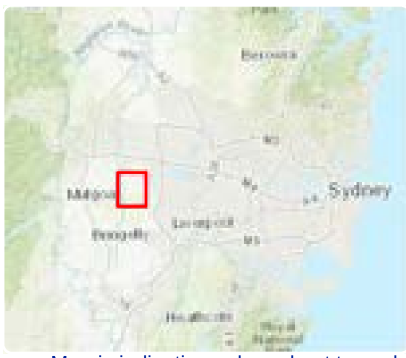
- Mamre Road Precinct
- Inflow Boundary
- Watercourse
- Outflow Boundary
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre

Hazard to Adults ZPA

- 0 = Safe (no hazard)
- 1 = Low Hazard
- 2 = Moderate Hazard
- 3 = Significant Hazard
- 4 = Extreme Hazard

- X01 Reach Names
- XY90 Pipe Network

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS
1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



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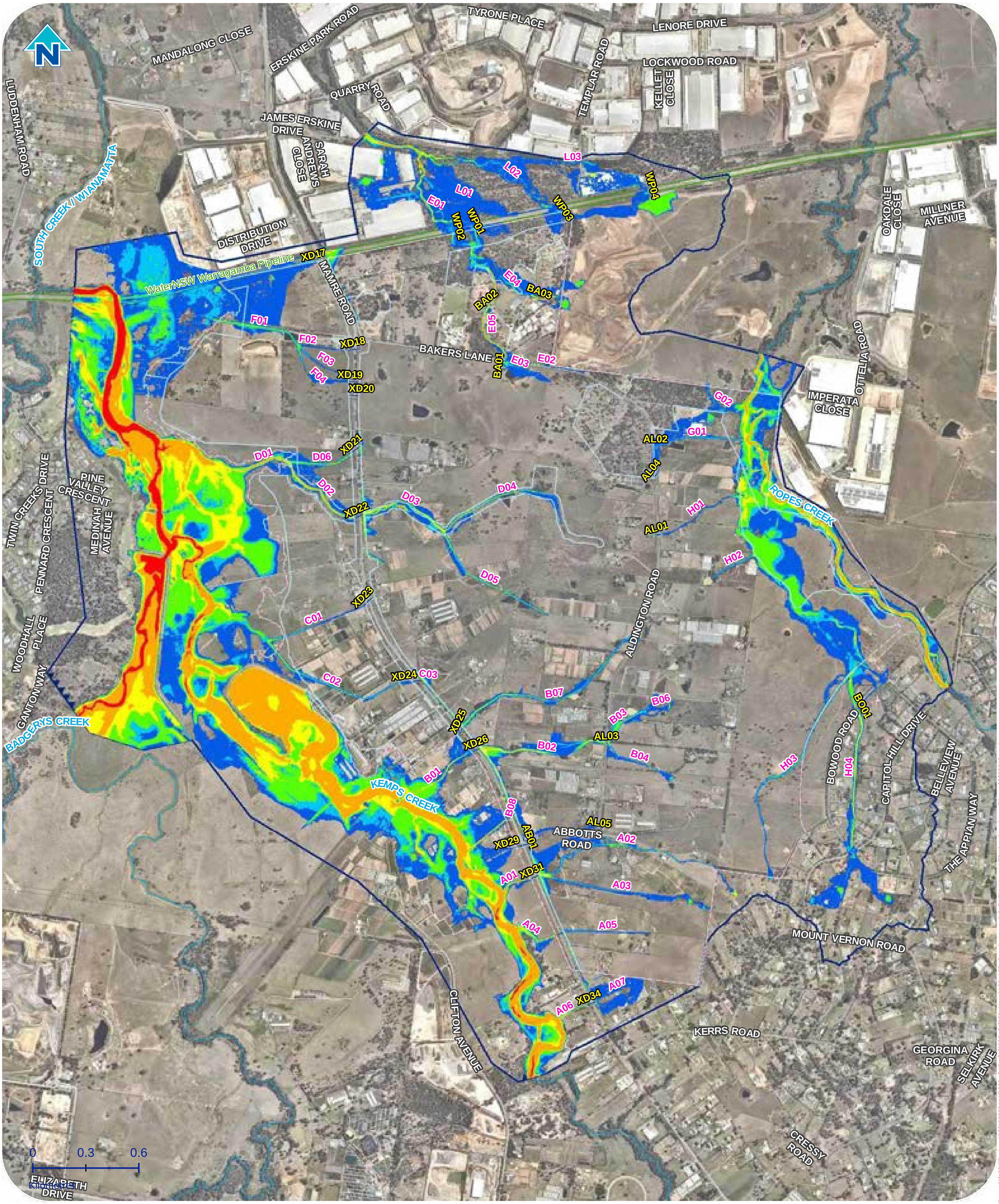

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FIGURE A-30 PEOPLE HAZARD ZAEM - 1% AEP - DVELOPED CONDITIONS

LEGEND

- Mamre Road Precinct
- Watercourse
- Hydraulic Model Boundary
- Proposed Zoning Boundary
- Cadastre
- Inflow Boundary

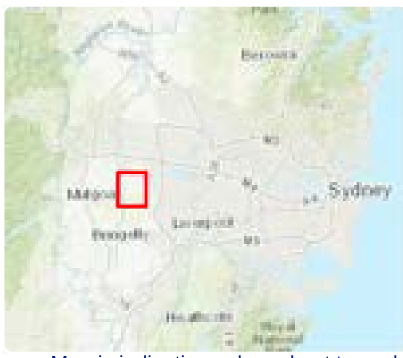
Hazard to Adults (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

X01 Reach Names

XY90 Pipe Network

NOTE - ONLY 1% AEP FLOODING IS SHOWN IN LOCAL CATCHMENTS 1% AEP IS NOT SHOWN IN SOUTH, KEMPS OR SOUTH CREEK



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• Appendix B - Regional Wetland and Trunk Drainage Concept

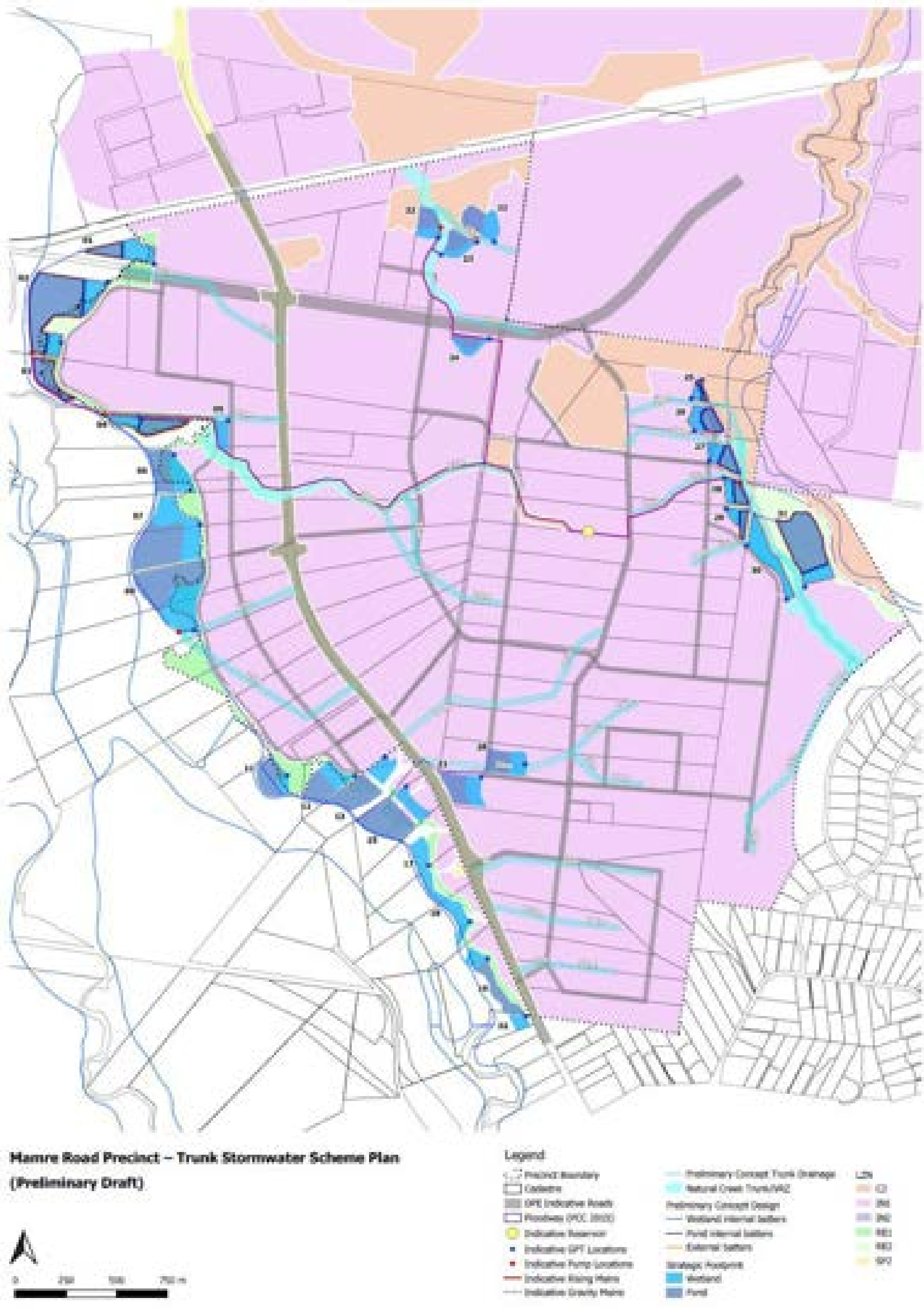

Figure 25 Wetland and Trunk Drainage Draft Concept - Locations and sizing are subject final investigation

• Appendix C - Adopted Culvert Sizes

Table 9-1 Existing Mamre Road Precinct culverts

Culvert Name	Dimension / Type (m)	Upstream Invert (mAHD)	Downstream Invert (mAHD)	Note
AB01	3x0.6 RCP	42.39	42.3	Assumed elevation based on available survey data and aerial imagery
AL01	1x0.3 RCP	78.07	77.21	Assumed elevation based on available survey data and aerial imagery
AL02	1x0.3 RCP	71.09	69.91	Assumed elevation based on available survey data and aerial imagery
AL03	2x0.6 RCP	51.93	51.8	Assumed elevation based on available survey data and aerial imagery
AL04	1x0.3 RCP	74.46	73.96	Assumed elevation based on available survey data and aerial imagery
AL05	2x0.3 RCP	49.96	49.73	Assumed elevation based on available survey data and aerial imagery
BA01	1x0.6 RCP	53.63	53.04	Assumed elevation based on available survey data and aerial imagery
BA02	3x1.8x0.6 RCBC	48.23	48.02	Assumed elevation based on available survey data and aerial imagery
BA03	2x0.525 RCP	51	50.8	Assumed elevation based on available survey data and aerial imagery
BO01	3x1.8x0.6 RCBC	68.07	68	Assumed elevation based on available survey data and aerial imagery
WP01	1x0.6 RCP	43.89	43.78	Assumed elevation based on available survey data and aerial imagery
WP02	1x0.6 RCP	43.33	43.21	Assumed elevation based on available survey data and aerial imagery
WP03	1x0.6 RCP	48.51	48.25	Assumed elevation based on available survey data and aerial imagery
WP04	1x0.6 RCP	54	51.6	Assumed elevation based on available survey data and aerial imagery
XD17	1x0.45 RCP	39	38.88	From L&A flooding investigation
XD18	1x0.525 RCP	44.07	43.56	From L&A flooding investigation
XD19	1x0.525 RCP	42.88	42.597	From L&A flooding investigation

Culvert Name	Dimension / Type (m)	Upstream Invert (mAHD)	Downstream Invert (mAHD)	Note
XD20	1x0.525 RCP	42.63	42.41	From L&A flooding investigation
XD21	2x0.6 RCP	38.95	38.9	From L&A flooding investigation
XD22	3x1.8x0.6 RCBC	39.58	39.2	From L&A flooding investigation
XD23	2x0.45 RCP	46.9	46.84	From L&A flooding investigation
XD24	2x0.6 RCP	47.77	47.72	From L&A flooding investigation
XD25	3x1.8x0.6 RCBC	43.34	43.28	From L&A flooding investigation
XD26	4x1.05 RCP	42.76	42.48	From L&A flooding investigation
XD27	3x0.45 RCP	43.14	42.95	From L&A flooding investigation
XD28	4x0.375 RCP	41.88	41.67	From L&A flooding investigation
XD29	2x0.6 RCP	42.25	42.04	From L&A flooding investigation
XD30	2x0.6 RCP	42	41.8	From L&A flooding investigation
XD31	2x0.525 RCP	42.38	42.31	From L&A flooding investigation
XD32	3x0.525 RCP	42.56	42.46	From L&A flooding investigation
XD33	2x0.6 RCP	42.72	42.52	From L&A flooding investigation
XD34	3x0.6 RCP	42.52	42.43	From L&A flooding investigation

Table 9-2 Developed Mamre Road Precinct culverts

Culvert Name	Dimension / Type (m)	Upstream Invert (mAHD)	Downstream Invert (mAHD)	Note
AB01	3x0.6 RCP	42.39	42.3	Assumed elevation based on available survey data
AL01	1x0.3 RCP	78.07	77.21	Assumed elevation based on available survey data
AL02	1x0.3 RCP	71.09	69.91	Assumed elevation based on available survey data
AL03	3x1.52x1.52 RCBC	51.23	51.07	Assumed elevation based on available survey data

Culvert Name	Dimension / Type (m)	Upstream Invert (mAHD)	Downstream Invert (mAHD)	Note
AL04	1x0.3 RCP	74.46	73.96	Assumed elevation based on available survey data
AL05	2x0.3 RCP	49.96	49.73	Assumed elevation based on available survey data
BA01	3x1.8x0.9 RCBC	53.67	53.48	Assumed elevation based on available survey data
BA02	3x1.8x0.6 RCBC	48.23	48.02	Assumed elevation based on available survey data
BA03	2x0.525 RCP	51	50.8	Assumed elevation based on available survey data
BO01	3x1.8x0.6 RCBC	68.07	68	Assumed elevation based on available survey data
WP01	1x0.6 RCP	43.89	43.78	Assumed elevation based on available survey data
WP02	1x0.6 RCP	43.33	43.21	Assumed elevation based on available survey data
WP03	1x0.6 RCP	48.51	48.25	Assumed elevation based on available survey data
WP04	1x0.6 RCP	54	51.6	Assumed elevation based on available survey data
XD17	1x1.65 RCP	38.15	37.78	From L&A flooding investigation
XD18	1x0.825 RCP	43.09	42.62	From L&A flooding investigation
XD19	1x0.75 RCP	42.23	41.98	From L&A flooding investigation
XD20	1x0.6 RCP	42.02	41.75	From L&A flooding investigation
XD21	3x1.05 RCP	38.6	38	From L&A flooding investigation
XD22	3x2.7x0.9 RCBC	39.06	38.8	From L&A flooding investigation
XD23	1x0.9 RCP	45.69	45.4	From L&A flooding investigation
XD24	1x0.825 RCP	46.91	46.6	From L&A flooding investigation
XD25	3x1.5x0.9 RCBC	42.87	42.6	From L&A flooding investigation
XD25b	1x0.375 RCP	42.64	41.95	From L&A flooding investigation
XD26	2x0.9 RCP	42.6	42.1	From L&A flooding investigation
XD28	3x1.5x0.9 RCBC	41.67	41.1	From L&A flooding investigation
XD29	1x0.9 RCP	41.93	41.59	From L&A flooding investigation
XD31	3x1.2x0.75 RCBC	41.6	40.8	From L&A flooding investigation
XD32	1x2.4x0.9 RCBC	41.64	41.1	From L&A flooding investigation
XD34	3x2.4x0.9 RCBC	42.46	42.2	From L&A flooding investigation

Appendix D - Peak Flow Rates

Table 9-3 Existing scenario peak flow rate (m^3/s)

Reporting Location	1EY	5% AEP	1% AEP	0.2% AEP	PMF
Q01	0.7	4.2	5.0	6.4	61.0
Q02	0.2	0.5	0.5	0.5	9.9
Q03	0.3	1.5	1.9	2.4	19.7
Q04	1.0	4.3	5.5	7.1	46.7
Q05	1.8	7.5	9.7	12.2	80.3
Q06	0.4	1.2	1.5	1.8	10.7
Q07	0.3	3.0	6.5	9.9	69.7
Q08	0.3	1.0	1.1	1.3	19.7
Q09	0.8	6.1	8.7	12.1	77.9
Q10	0.7	5.5	8.7	11.5	81.4
Q11	0.3	1.4	1.8	2.3	22.6
Q12	0.7	3.4	4.3	5.6	36.8
Q13	1.5	8.7	12.3	20.8	140.2
Q14	1.5	4.0	6.1	8.0	55.0
Q15	2.4	11.6	15.9	20.1	145.7
Q16	0.7	2.6	3.3	4.2	27.6
Q17	0.5	1.1	1.6	2.2	16.7

Table 9-4 Developed scenario peak flow rates (m^3/s) without OSD

Reporting Location	1EY	5% AEP	1% AEP	0.2% AEP	PMF
Q01	1.0	4.1	5.3	6.8	59.3
Q02	0.2	0.5	0.5	0.6	10.6
Q03	0.4	1.7	2.1	2.6	20.3
Q04	1.0	4.2	5.3	6.8	44.9
Q05	1.8	7.7	9.8	12.3	79.2
Q06	0.3	1.1	1.4	1.6	10.7
Q07	1.7	6.2	6.7	8.6	108.2
Q08	0.1	0.1	0.1	0.1	9.2
Q09	0.5	6.0	8.7	11.3	45.0
Q10	4.2	9.7	11.8	14.6	87.4
Q11	0.6	2.7	3.3	4.3	16.7
Q12	1.4	5.2	6.5	7.8	40.3
Q13	4.5	16.7	20.3	24.8	129.0
Q14	1.9	8.0	10.5	12.7	64.6
Q15	3.4	14.2	17.5	21.4	152.6
Q16	0.7	2.5	3.2	4.0	25.9
Q17	0.5	1.6	2.0	2.7	20.5

Appendix E - Summary of Adopted Parameters

An overview of the adopted design criteria and parameters for the urban form, hydrologic and hydraulic investigations are summarised in the Table below.

Item	Standard/Source	Adopted	Comment
Hydrology			
Pipe Drainage Network (Minor)	Design Guidelines for Engineering Works on Subdivisions and Developments, 1997	5% Annual Exceedance Probability	Minor drainage network capacity
Trunk Drainage Network (Major)	Design Guidelines for Engineering Works on Subdivisions and Developments, 1997	1% Annual Exceedance Probability	Flows exceeding minor drainage network capacity overflow to streets
ARR1987 Design Rainfall	Australian Rainfall and Runoff	ARR1987 for rainfall on grid ARR2019 for hydrologic – hydraulic modelling	Losses adopted from 2015 Worley Parsons XP RAFTS model
Rural Rainfall Losses	As endorsed by DPIE/OEH for new rezoning studies	**Node 9.06** Existing IL = 37.1mm Existing CL = 0.91 mm/h **Node 1.17** Existing IL = 33.9mm Existing CL = 0.91 mm/h	Taken from 2015 Worley Parsons XP RAFTS layers (node
Urban Rainfall Losses	As endorsed by DPIE/OEH for new rezoning studies	Pervious IL = 10mm Pervious CL = 2.5mm/h Imperv. IL = 1.0 mm Imperv. CL = 0.0 mm/h	Applied in flood modelling
Pervious Catchment Roughness (PERN)		Rural or landscaped 0.04 Urban impervious 0.02	
Hydraulics			
Flood impact	Recommended criteria under Draft South Creek Floodplain Risk Management Study	Peak flood levels not increased by more than 0.02 m (20 mm) outside of the development site	Represents a change from the current DCP which allows 100mm increase in flood afflux outside the Precinct which is not accepted as best practice

Item	Standard/Source	Adopted	Comment
Flood and Overland Flow			
Appropriate Safety Criteria for People	Stormwater Drainage Specifications for Building Developments	Max. Depth x Velocity = $0.4m^2s^{-1}$ Max. Depth = 0.8m Max. Velocity = $2.0ms^{-1}$	
Manning's Coefficient		Lots/Road/Paved Areas Only = 0.02 Rural = 0.04 South Creek in-bank areas = 0.06 to 0.08 South Creek over-bank areas = 0.045 to 0.10 Allotments = 0.10 Detention basin = 0.06	Consistent with *Mamre Road Flooding and Drainage Investigation*
Onsite Stormwater Detention			
Outlet control	Stormwater Drainage Specifications for Building Developments	1% AEP flood level at the discharge point Submerged outlets not approved	
OSD for industrial lots		On-site detention to match 50% and 1% AEP pre dev flow rates via 2-stage outlets	
OSD for roads		Council controlled basins where possible with on-lot measures to compensate for the shortfall	
Treatment Train Details			
Floodway		Inverts – match existing Base width – Varies Side batter – 1(V):4(H) Mannings – 0.06	
Rainwater tanks		At least 80 ML/NHa of industrial development	
Biofiltration street trees	Wianamatta Street Tree	Annual water demand – 18.25kL/tree	
Detention basing		Online if 2nd Order Side batter – 1(V):6(H)	

Appendix F - Mamre Road Waterway Assessment

CTENVIRONMENTAL
ECOSYSTEM MANAGEMENT AND MONITORING

Mamre Road Precinct Rezoning: Waterway Assessment

Kemps Creek and Mount Vernon

South Creek Catchment

Prepared for: Sydney Water

April 2020

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<tr><td>PROJECT NAME</td><td colspan="4">Mamre Road Precinct Rezoning: Waterway Assessment</td></tr>
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<tr><td>PREPARED FOR</td><td colspan="4">Sydney Water</td></tr>
<tr><td>AUTHOR/S</td><td colspan="4">Carl Tippler, Ben Green and Rani Carroll</td></tr>
<tr><td rowspan="2">REVIEW</td><td>Technical</td><td colspan="2">QA</td><td>Version</td></tr>
<tr><td>Peter Gillam (AECOM)</td><td colspan="2">Dan Cunningham
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Executive Summary

The purpose of this study was to determine the presence of mapped and potential unmapped waterways across the Mamre Road Precinct and to map the top of bank of waterways to determine appropriate Vegetated Riparian Zones (VRZ) as required by *NSW Water Management Act 2000.*

Field assessment involved a visual inspection of mapped waterways and inspection of gullies that have potential to be watercourses.

In the three weeks leading up to the field assessment, 438 mm of rain was recorded which resulted in easy identification of overland flow paths due to the amount of run-off generated.

Results of this assessment confirmed that all waterways assessed fit the definition of a river as defined by the *NSW Water Management Act 2000* and although some lacked bed and bank geomorphology, all had defined flow paths which formed broad and shallow drainage depressions, a typology which is typical of the Cumberland Plain.

An exception to this was the upper most section of Unnamed Trib South Creek 1 which was considered a topographical depression rather than a watercourse.

An unmapped 1st order watercourse was validated in the upper section of Unnamed Trib South Creek 1 and an unmapped wetland adjacent to Unnamed Trib Ropes Creek was validated by field assessment.

Watercourses assessed by this study had varied ecological value. Unnamed Trib Kemps Creek 1 and 2 had minimal ecological value due to a lack of native riparian vegetation and significant alteration of flow paths. Unnamed Trib South Creek 1 had some quality habitat patches in the form of wetland vegetation and remnant vegetation. The upper section of Unnamed Trib South Creek 2 had wetland and woodland habitats and Unnamed Trib Ropes Creek although highly modified had matrix of habitats which included wetlands and remnant woodland.

Recommendations from this assessment include;

1. Consider an alternative zoning for Unnamed Trib Kemps Creek 1 and 2.
2. Consider appropriately sized Vegetated Riparian Zones as per those required by the *NSW Water Management Act 2000*.
3. Consider an alternative zoning for Unnamed Trib Ropes Creek.
4. Consider extending the E2 Environmental Conservation on Ropes Creek to include the full extent of the 30 m Vegetated Riparian Zone.

Results of this study will inform the development of a Riparian Corridor Strategy for the Precinct.

Introduction

The Department of Planning, Industry and Environment (DPIE) have outlined amendments to the State Environmental Planning Policy (Western Sydney Employment Area) 2009 (WSEA SEPP) to rezone the Mamre Road Precinct (the Precinct) for primarily industrial purposes. DPIE has sought feedback on the proposed plan for the Mamre Road Precinct in the Western Sydney Employment Area (WSEA).

Sydney Water have been engaged to inform the water servicing, and flood management for the Precinct. In turn CTENVIRONMENTAL was engaged to undertake an assessment of waterways across the Precinct.

The Precinct is located approximately 40 km west of the Sydney CBD and 12 km southeast of the Penrith CBD. It is located entirely within the Penrith City Council Local Government Area (LGA). It is bordered by the Sydney Water Warragamba Pipeline to the North, South Creek and Kemps Creek to the West, Ropes Creek to the East and Mount Vernon to the South. The precinct has an approximate gross site area of 1002 Ha.

The focus of this assessment was four unnamed tributaries that flow to Ropes Creek (1), South Creek (2) and Kemps Creek (2) and a section of Ropes Creek (Figure 2).

Study Objectives

The purpose of this study was to determine the presence of mapped and potential unmapped waterways across the Precinct that are to be retained post rezoning and to map top of bank of waterways where present to enable determination of the appropriate Vegetated Riparian Zone (VRZ) for these waterways as required by *NSW Water Management Act 2000.*

Results of this study will inform the development of a Riparian Corridor Strategy for the precinct.

NSW Water Management Act 2000

The primary objective of the *Water Management Act 2000* (WM Act) is to manage NSW water in a sustainable and integrated manner that will benefit current generations without compromising future generations' ability to meet their needs.

Since 2018, the Water Management Act has been administered by Natural Resources Access Regulator (NRAR) and establishes an approval framework for activities within waterfront land which is defined as land 40 m from the highest bank of a river, lake, wetland or estuary.

The definition of a 'river' as per the Water Management Act is as follows;

a) any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved, and

b) any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows, and

c) anything declared by the regulations to be a river.

In relation to point (c) of the definition of 'river' in the Dictionary to the Act, the following are declared to be a river as per the *Water Management (General) Regulation 2018* (WM Regulation):

a) any watercourse, whether perennial or intermittent, comprising an artificial channel that has changed the course of the watercourse,

b) any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows.

The *Guidelines for Controlled Activities on waterfront land—Riparian corridors* (NRAR 2018) provides guidance to establish Vegetated Riparian Zones (VRZ) along watercourses which are based on the Strahler stream ordering system.

The VRZ is measured from the top of the creek bank and also includes the creek channel (Figure 1). The minimum required VRZ width for a first order stream is 10 m either side of the creek (measured from top of bank) plus the width of the creek channel. The maximum required VRZ is 40 m either side of the creek (measured from top of bank) plus the channel width and this is applied to 4th order and greater streams, wetlands, estuaries and tidal influenced waters (Table 1).

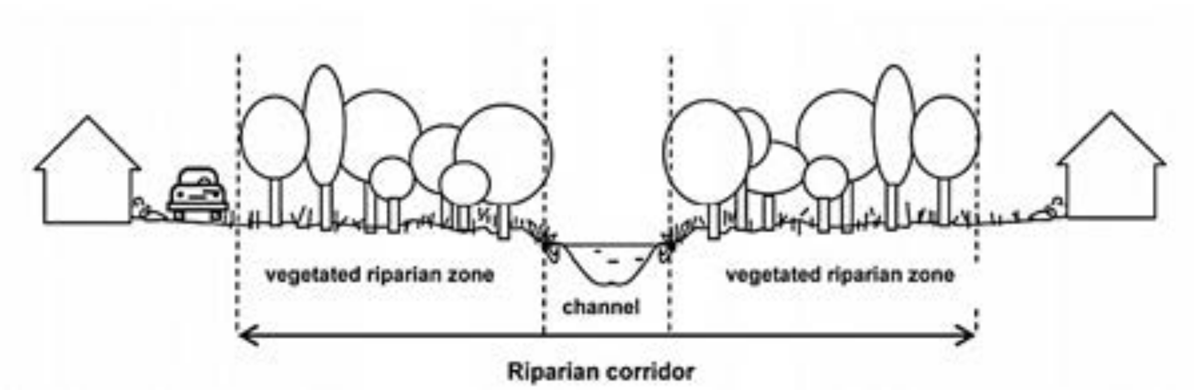

Figure 1: Vegetated Riparian Zone and watercourse channel comprising the riparian corridor (NRAR 2018).

Table 1: Required riparian corridor widths according to Strahler stream order (NRAR 2018).

Strahler steam order	VRZ WIDTH (m) (each side of watercourse)	Total Riparian corridor width (m)
1st order	10 m	20 m + channel width
2nd order	20 m	40 m + channel width
3rd order	30 m	60 m + channel width
4th order and greater, wetlands, estuaries and tidal influenced watercourse	40 m	80 m + channel width

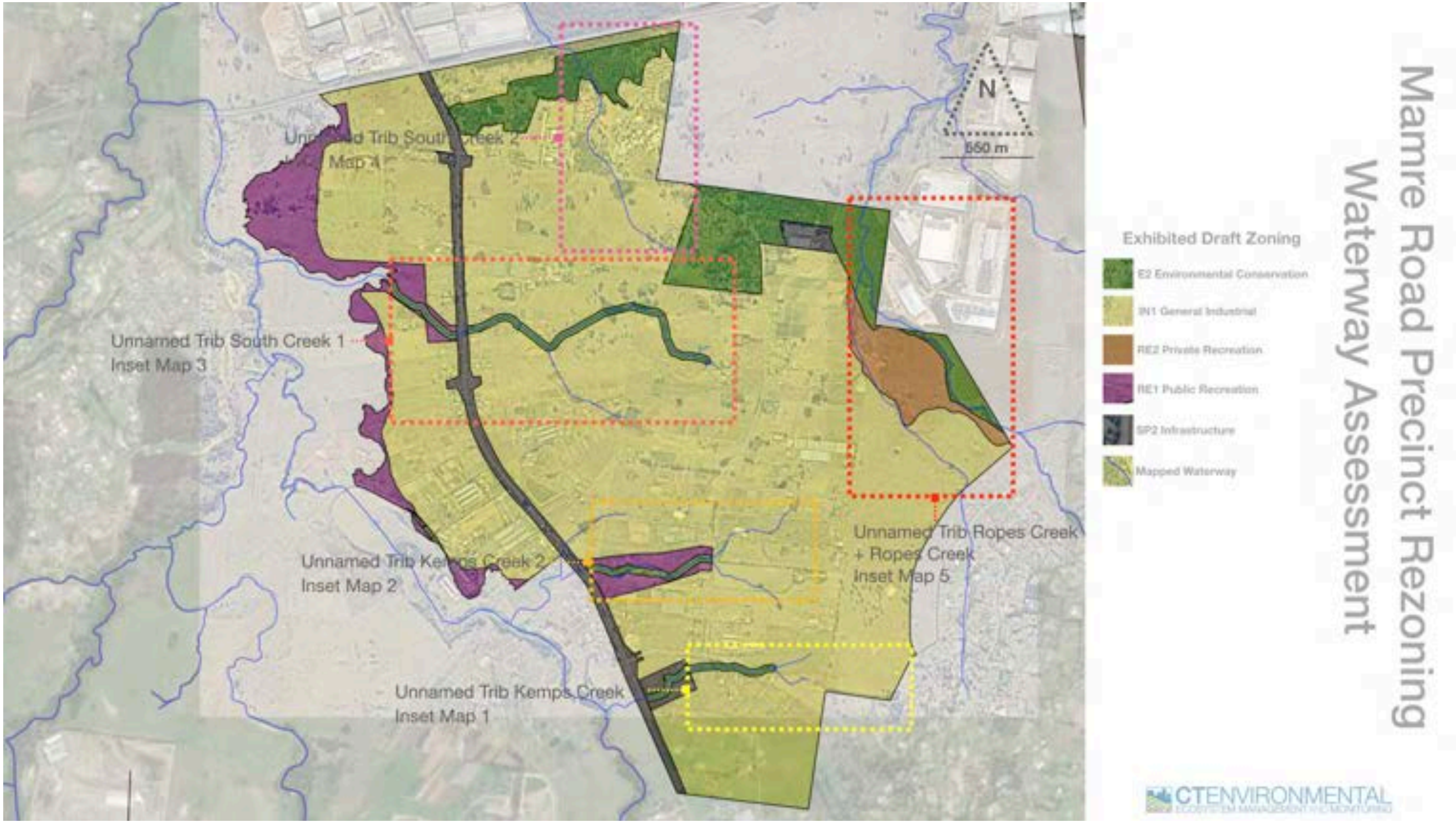

Figure 2: Waterways subject to assessment by this study are bordered by colour and labelled with the according inset map number.

Method

To undertake this study a combination of desktop review and field assessment was applied.

Desktop review

Prior to undertaking field assessment, a desktop review of spatial data, relevant policy and legislation and previous studies were reviewed. This included;

- NSW 1:25,000 topographic mapping of the Precinct area (SIX maps)
- Strahler stream order GIS data
- Proposed rezoning footprint of the Precinct
- NSW Water Management Act 2000 (WM Act)
- Guidelines for Controlled Activities on waterfront land—Riparian corridors (NRAR 2018)
- Aspect Industrial Estate State Significant Development Application - Riparian Assessment (Eco logical Australia 2019)
- 113 - 127 Aldington Road, Kemps Creek - Riparian Constraints Assessment (Eco Logical Australia 2019)

Field assessment

Field assessment of waterways across the Precinct was undertaken over a three-day period from February 25 -27, 2019. Assessment involved a visual inspection of mapped waterways across the site and inspection of gullies that have potential to be watercourses.

In the three weeks leading up to the field assessment 438 mm of rain was recorded at the Erskine Park reservoir weather station (BOM 2020). This rainfall resulted in easy identification of overland flow paths due to the amount of run-off generated.

To determine the presence of waterways within the Precinct, 1:25,000 topographic map for the area was loaded into the GIS field app iGIS and displayed on a field iPad. The CTENVIRONMENTAL undertook visual inspection of all mapped waterways across the Precinct by walking the length of each. Where access was not permitted visual inspection was undertaken using a MAVIC Pro 2 drone with 4k camera.

In the case where creek bed and bank were present, top of bank mapping was undertaken using a Trimble DGPS by walking along the route of the high point on the creek bank and recording the route on the GPS.

Results

Unnamed Trib Kemps Creek 1

Results of the inspection of Unnamed Trib Kemps Creek 1 validated the waterway is of 2nd order. Two first order watercourses were evident in the headwaters which run to the north and south of the house in the upper catchment (Figure 3). A clear flow path was evident below their confluence which validated the presence of a 2nd order watercourse. The flow path did not have defined bed and banks which is likely due to the buffering of flow velocity and erosion provided by three upstream farm dams (Figure 5).

However approximately 200 m below the confluence the waterway was heavily modified and formed into a drainage channel which was realigned to direct flows along a channel which runs parallel to Abbot Road and continues to Mamre Road (Figure 4).

Further inspection validated that the mapped lower section of this waterway was not present (Figure 5) and it was concluded that due to the lack of vegetation along the upper section of the headwaters and significant modification to a drainage channel of the lower section, the watercourse had minimal ecological value.

Figure 3: Upper headwater 1st order waterways on Unnamed Trib Kemps Creek 1.

Figure 4: Lower highly modified section of Unnamed Trib of Kemps Creek 1.

Figure 5: Unnamed Trib Kemps Creek 1. Field validated channel flow path and validated watercourses.

Unnamed Trib Kemps Creek 2

Field inspection of Unnamed Trib Kemps Creek 2 validated the waterway is of 2nd order. Two 1st order watercourses were evident in the headwaters which rise to the east of Aldington Road (Figure 6, Figure 7), both of which are significantly modified due to the construction of a series of farm dams along their flow paths(Figure 6, Figure 7). Native riparian vegetation was absent from both watercourses.

Figure 6: Northern 1st order watercourse above confluence point, east of Adlington Road, Unnamed Trib Kemps Creek 2.

Figure 7: Southern 1st order watercourse above confluence point, east of Adlington Road, Unnamed Trib Kemps Creek 2.

The lower section of this waterway which was proposed for E2 and RE1 zoning in the Exhibited Draft Mamre Road Precinct Zoning (DPIE 2020) in the draft was field validated as 2^{nd} order however this section is significantly modified and at the time of inspection was a series of farm dams linked by a drainage channel and diverted from the original flow path (Figure 10). The channel had a heavy infestation of the invasive weed, *Juncus acutus* (Figure 8).

The original flow path of this waterway, likely to have been a broad, swampy depression which meandered through the centre of the area shown in Figure 8, has been significantly modified to become a market garden and pig paddock and has been deeply furrowed to allow crop irrigation (Figure 9).

Field inspection of this watercourse validated that the mapped lower section was significantly modified to be a series of farm dams linked by a diversion channel. It was concluded that due to the lack of vegetation along the upper section of the headwater watercourses and significant modification to a drainage channel of the lower section, the watercourse had minimal ecological value.

Figure 8: View looking towards the east over the proposed E2 and RE1 zoning. Diversion channel can be seen running parallel to the track on the left.

Figure 9:Deeply furrowed section of the adjacent to the drainage diversion channel in the proposed E2 and RE1 zoning area.

Figure 10: Unnamed Trib Kemps Creek 2. Field validated channel flow path and validated watercourses.

Unnamed Trib South Creek 1

Field inspection of Unnamed Trib South Creek 1 validated the upper section of the waterway as 1st order which turns to 2nd order approximately 100 m downstream of the gully headwall (Figure 18)

The most eastern extent of the mapped 1st order stream was field validated as not fulfilling the definition of a river as per the *NSW Water Management Act 2000* and therefore was considered as a topographic feature in the landscape (i.e. a depression) rather than a watercourse (Figure 11).

The mapped watercourse section below this point and the most upper mapped 2nd order section had a defined bed and bank which was DGPS mapped (Figure 12). As a result, a 10 m Vegetated Riparian Zone measured from top of bank is required on the 1st order section which will increase to a 20 m Vegetated Riparian Zone for the 2nd order section (as per NSW Water Management Act 2000) (Figure 18)

Figure 11: Upper most section of mapped 1st order waterway which is considered by this assessment as not present.

Figure 12: Mapped upper 2nd order section with bed and bank evident.

Downstream of the creek section with defined bed and bank the flow path transformed to a broad and shallow depression. No bed and bank was evident for most of this section and it is likely the series of large farm dams within the drainage path has buffered the depression from high velocity flows and erosion (Figure 13).

Figure 13: Typical broad and shallow flow depression in 2nd order section of watercourse.

Field inspection validated the presence of an unmapped watercourse which forms an east – west flowing 1st order tributary (Figure 18).

At the time of inspection, a clear flow path was identified although no bed and bank was evident. This watercourse contained a small dam that was full of *Typha orientalis* and linked to a remnant patch of native bushland higher up in the valley headwall (Figure 14).

Figure 14: Field validate unmapped tributary with farm dam in foreground and native vegetation patch in the upper section.

Within the mid-section of this watercourse two large dams are present which have likely buffered this flatter section from high velocity flow and erosion. As a result, no bed and bank was evident however a broad and shallow drainage depression that contains overland flows when rainfall is sufficient to trigger dam overflow was apparent (Figure 15).

These large dams were found to contain a range of aquatic and riparian habitats which included fringing wetland vegetation, shallow marsh and standing dead trees. The dam pictured in Figure 15 has a dense stand of *Casuarina glauca* at the upstream end (top right corner) which provides habitat value.

Field validation of the unnamed 1st order tributary that flows to Unnamed Trib South Creek 1 from the south confirmed this watercourse is significantly modified and at the time of inspection was found to be a series of large farm dams that has likely lost all stream function and provides minimal habitat (Figure 16).

Figure 15: Mid-section of watercourse with large farm dam. Overland flow path is evident on downstream side of dam.

Figure 16: Mapped unnamed 1st order tributary modified to a series of farm dams. Photo looking downstream toward Unnamed Trib South Creek 1.

A defined bed and bank was evident in the section of watercourse which begins approximately 250 m upstream of Mamre Road and continues through to the western extent of the exhibited E2 zone. As a result, a 20 m Vegetated Riparian Zone is required as per the *NSW Water Management Act 2000* measured from top of bank on both sides of the channel (Figure 18).

Much of this section of waterway has undergone modification and appeared to be channelised and realigned with bed incision and bank erosion increasing as the waterway approached South Creek (Figure 17). There is a lack of native vegetation along the watercourse corridor in the proximity to South Creek and adjacent floodplain however given there is some habitat value in the upstream portion, including a series of farm dams, this waterway has potential to provide a valuable ecological corridor between South Creek and Ropes Creek.

Figure 17: Lower section of Unnamed Trib South Creek 1. Channel modification and erosion is evident.

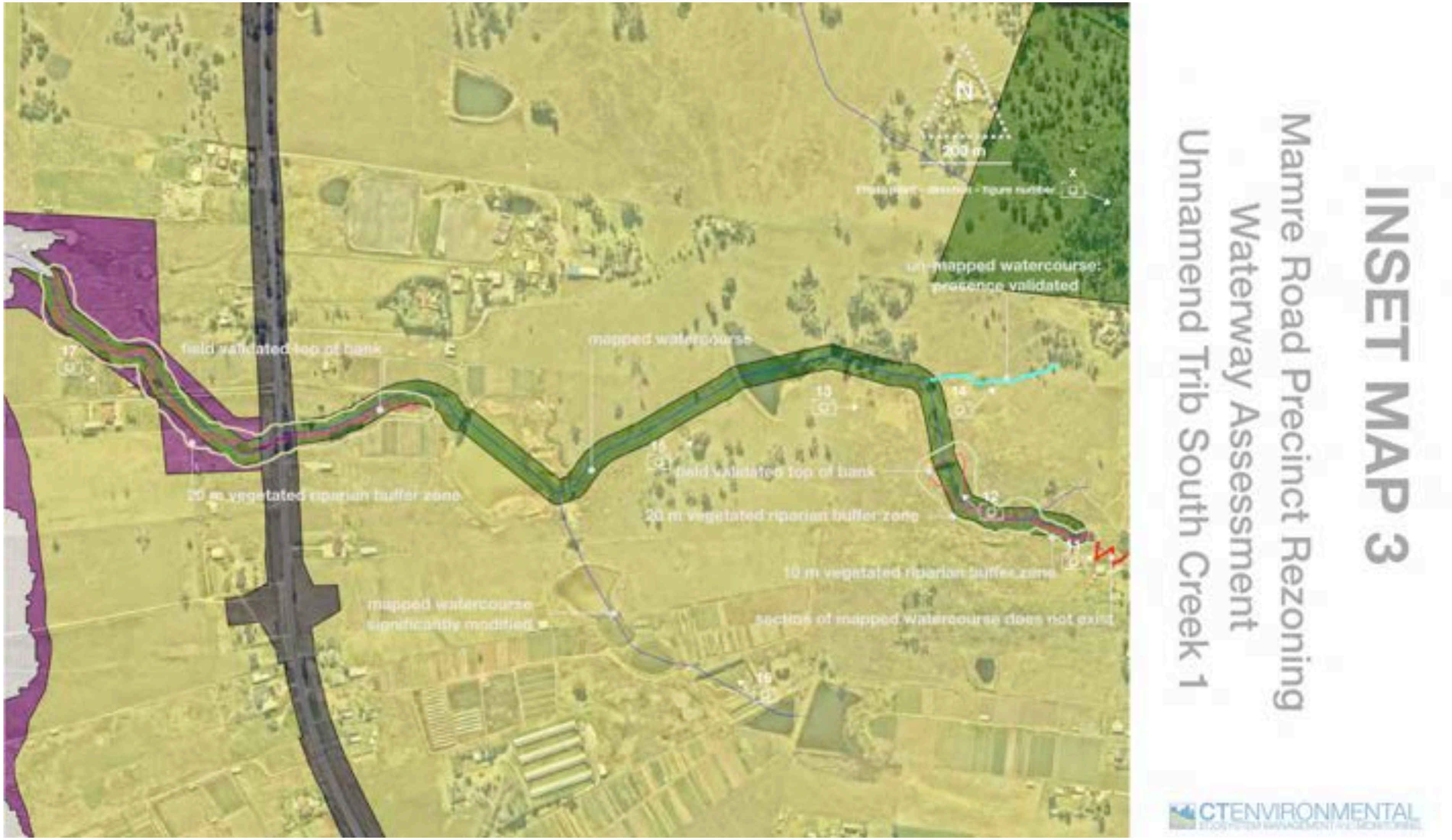

Figure 18: Unnamed Trib South Creek 1. Field validated channel flow path, validated watercourses, mapped top of bank and required Vegetated Riparian Zones.

Unnamed Trib South Creek 2

Field inspection of Unnamed Trib South Creek 2 validated the presence of a 1st order watercourse (Figure 24). The upper most section (south of Aldington Road) of this watercourse has been modified to a series of farm dams with overland flow paths providing links across a broad and shallow drainage depression (Figure 19). Fringing and emergent wetland vegetation and large native trees were present around all dams which provide habitat value for native fauna (Figure 20).

Figure 19: Upper section of Unnamed Trib South Creek 2 showing series of farm dams.

Figure 20: Emergent wetland vegetation and large native trees in upper section of Unnamed Trib South Creek 2.

Field inspection of the lower section of Unnamed Trib South Creek Trib 2 validated the presence of a defined bed and bank. As a result, a 10 m Vegetated Riparian Zone is required to be maintained on both banks (Figure 24) as per *NSW Water Management Act 2000.*

In this section the creek channel has been modified and realigned and a series of dams and diversions were observed at the northern most extent of the Precinct where the Sydney Water pipeline forms the boundary. The section of the channel within the grounds of the school had a heavy infestation of the invasive species *Juncus acutus* (Figure 21) and once the watercourse entered the patch of remnant bushland downstream this became a heavy cover of *Typha orientalis* (Figure 22).

Figure 21: Infestation of *Juncus acutus* in Unnamed Trib South Creek 2.

Figure 22: Thick cover of *Typha orientalis* in Unnamed Trib of South Creek 2.

The exit point of the watercourse was difficult to define due to the modified flow path of the lower section which included dams and diversion channels. On inspection it was apparent the watercourse exited the Precinct as a wide depression (Figure 23).

Figure 23: Flow path of Unnamed Trib South Creek 2 at the northern boundary of the Precinct.

Unnamed Trib South Creek 2 has high ecological value in the lower portion within the remnant bushland which is proposed to be rezoned as E2. The upper section of this waterway has ecological value as it provides wetland and woodland habitat and has potential to provide an ecological corridor between Ropes Creek and South Creek.

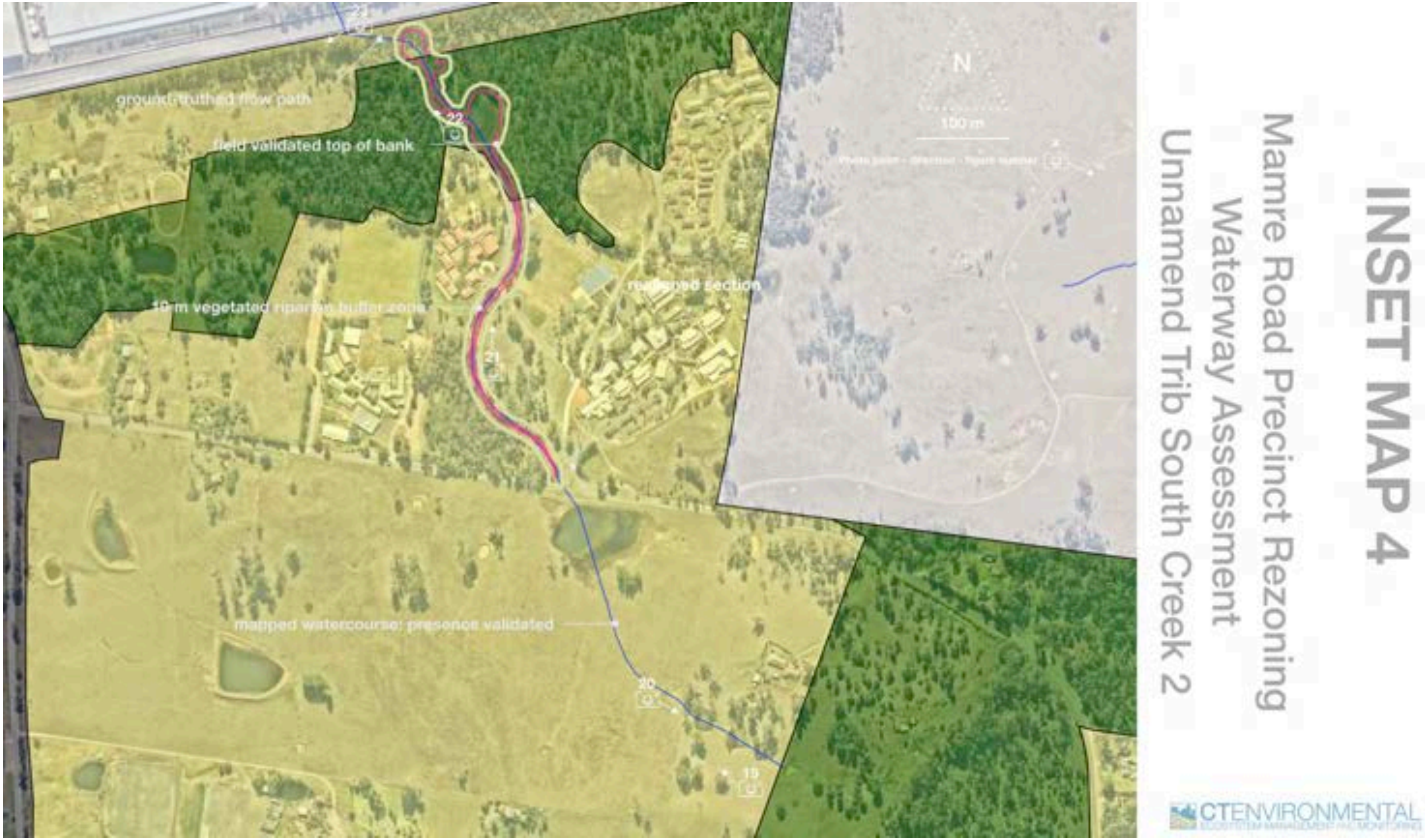

Figure 24: Unnamed Trib South Creek 2. Field validated watercourse, mapped top of bank and required Vegetated Riparian Zones.

Ropes Creek and Unnamed Trib Ropes Creek

Ropes Creek was field validated as a 3rd order stream and Unnamed Ropes Creek Trib was field validated as 1st order. Both waterways had a defined bed and bank and therefore top of bank was mapped (Figure 30). As a result a 30 m Vegetated Riparian Zone is required on Ropes Creek and 10 m Vegetated Riparian Zone is required on each bank of Unnamed Trib Ropes Creek (Figure 30) as per *NSW Water Management Act 2000*.

Field assessment recorded the presence of an unmapped wetland with an area of approximately 0.5 ha between Ropes Creek and Unnamed Trib Ropes Creek (Figure 25). This wetland had a thick cover of native wetland vegetation and lies in a shallow depression adjacent to a large online farm dam on Unnamed Trib Ropes Creek. The extent of the wetland was mapped and as a result a 40 m Vegetated Riparian Zone is required as per *NSW Water Management Act 2000* (Figure 30).

Figure 25: Unmapped wetland looking north towards Ropes Creek corridor.

The majority of the flow path of Unnamed Trib Ropes Creek has been modified to a series of farm dams (Figure 30). Where a channel exists between dams, heavy infestation of the invasive weed *Juncus acutus* was evident (Figure 26). However, at the time of assessment there was a diverse matrix of native fringing and emergent wetland plants within these farm dams and patches of *Casuarina glauca* scattered across the site (Figure 27).

In the lower section of the watercourse, upstream of the Ropes Creek confluence the flow path widened in places and root supported knick points were evident in a dense stand of Casuarina glauca which protects the channel from accelerated erosion (Figure 28).

Although modified, Unnamed Trib Ropes Creek provides a complex matrix of habitat which includes wetlands, emergent vegetation, riparian forest and creek channel. It is proposed this area is rezoned to a combination of Industrial, Private Recreation and Environmental Conservation. Given the habitat value of the online dams and wetland on and adjacent to this watercourse consideration should be given to zoning that offers protection of this waterway.

Figure 26: Unnamed Trib Ropes Creek with infestation of *Juncus acutus* and patch of *Casuarina glauca*.

Figure 27: Unnamed Trib Ropes Creek online farm dam with emergent and fringing wetland vegetation.

Figure 28: Widened channel upstream of Ropes Creek confluence.

Assessment of Ropes Creek validated the presence of a defined bed and bank which has undergone accelerated erosion due to land use change and the associated changes to stream hydrology. The banks of Ropes Creek are vegetated by dense stands of Casuarina glauca (Figure 29) however for a large portion of the creek this is restricted to a narrow strip which is less than the extent of the 30 m Vegetated Riparian Zone (Figure 30) as per *NSW Water Management Act 2000*.

The Ropes Creek corridor has ecological value as it contains endangered ecological communities and species and provides habitat and a movement corridor for native fauna species. The proposed rezoning has included the Ropes Creek corridor as Environmental Conservation. However, the extent of the proposed zoning does not include the full width of the 30 m Vegetated Riparian Zone and therefore consideration should be given to expand the Environmental Conservation zone to accommodate the full Vegetated Riparian Zone.

Figure 29:Ropes Creek corridor looking north west (downstream). Unnamed Trib Ropes Creek can be seen as a series of online dams to the left of the photo.

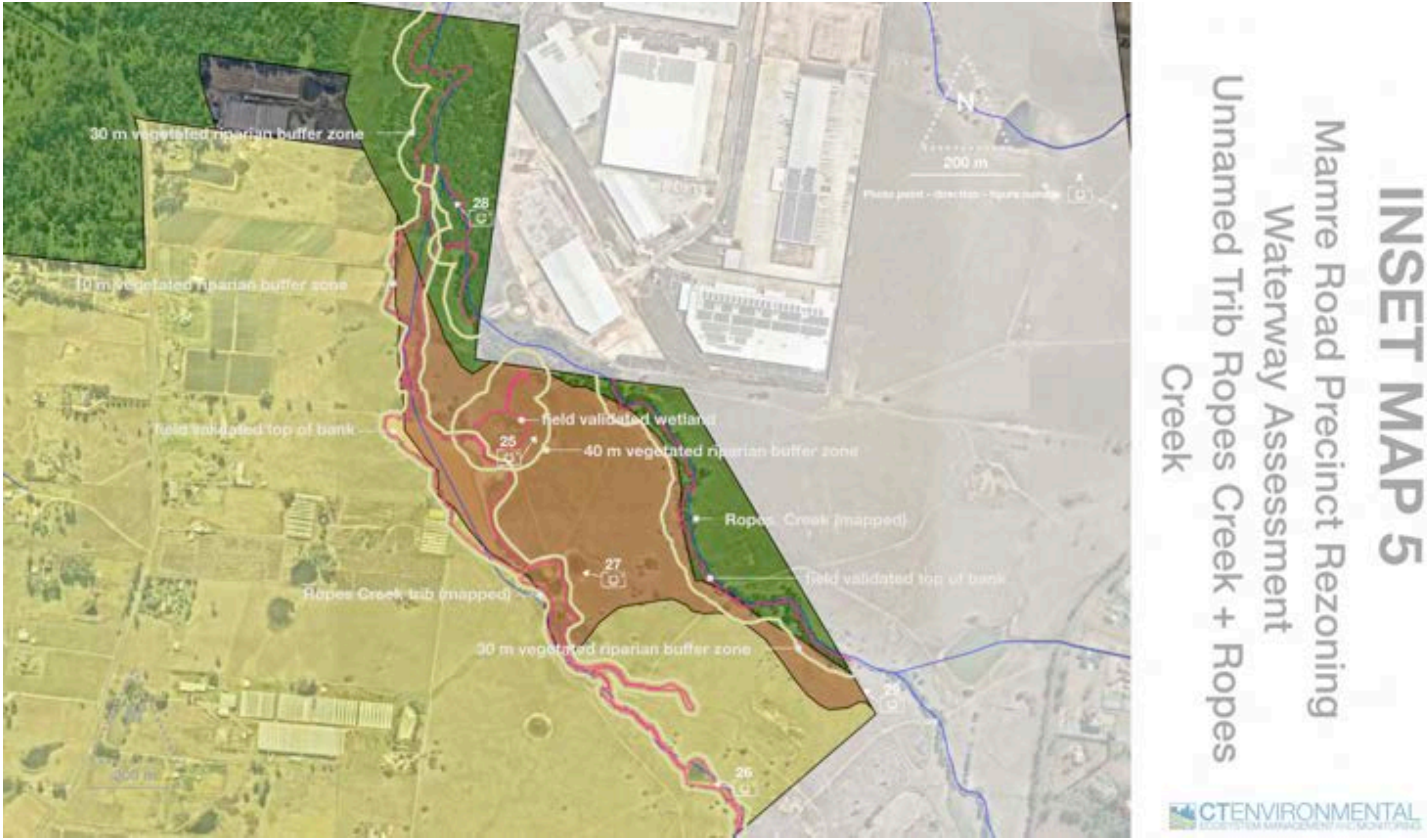

Figure 30: Ropes Creek and Unnamed Ropes Creek Trib. Field validated watercourse, mapped top of bank and required Vegetated Riparian Zones.

Conclusion and Recommendations

Results of this assessment have confirmed that all waterways assessed fit the definition of a river as defined by the *NSW Water Management Act 2000* which states;

The definition of a 'river' is as follows;

a) any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved, and

b) any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows, and

c) anything declared by the regulations to be a river.

Although some watercourses lacked a defined bed and bank geomorphology, all had defined flow paths which were broad and shallow drainage depressions, a typology which is typical of the Cumberland Plain.

An exception to this was the upper most section of Unnamed Trib South Creek 1 which on inspection was considered more a topographical depression than a watercourse.

In addition to those watercourses that were mapped on the 1:25,000 topographic maps, an unmapped 1st order watercourse was validated in the upper section of Unnamed Trib South Creek 1. An unmapped wetland adjacent to Unnamed Trib Ropes Creek was also validated by field assessment.

Watercourses assessed by this study had varied ecological value. Unnamed Trib Kemps Creek 1 and 2 were found to have minimal ecological value due to a lack of native riparian vegetation and significant alteration of flow paths.

Unnamed Trib South Creek 1 was found to have some quality habitat patches in the form of wetland vegetation and remnant vegetation and has potential to become an ecological corridor linking Ropes Creek and South Creek.

The upper section of Unnamed Trib South Creek 2 was found to have wetland and woodland habitats and has the potential to form an ecological corridor which links the downstream high-quality remnant bushland patch to Ropes Creek which has high ecological value.

Unnamed Trib Ropes Creek although highly modified was found to have a matrix of habitats which includes wetlands, emergent and fringing wetland vegetation and remnant woodland. This watercourse has potential to enhance the ecological value of the Ropes Creek corridor if managed accordingly.

Results of this study have informed the following recommendations which include;

1. Consider an alternative zoning for Unnamed Trib Kemps Creek 1 and 2. These watercourses have minimal ecological value due to the significant modification of the upper catchments and flow paths

however an alternative zoning may offer protection to these creeks under a future development scenario and facilitate potential creek restoration/realignment to be undertaken in accordance with Natural Resource Access Regulator (NRAR) Guidelines.

2. Consider appropriately sized Vegetated Riparian Zones as per those required by the *NSW Water Management Act 2000*. This includes 10 m buffers on each bank of 1^{st} order streams, 20 m buffers on each bank of 2^{nd} order streams, 30 m buffers on each bank of 3^{rd} order streams and 40 m buffer around the perimeter of wetlands. Where defined bed and bank is absent, the extent of overland flow paths could be considered as a substitute for top of bank.
3. Consider an alternative zoning for Unnamed Trib Ropes Creek. The current proposal is for this waterway to become zoned as Industrial and Private Recreation. Given the diverse range of habitat found on this watercourse consideration of an alternative zoning may enhance the ecological value of the Precinct and maintain an efficient drainage corridor which could include retaining the farm dams and re-engineering them as online stormwater treatment to improve both water quality and hydrology. The adjacent wetland should also be incorporated into this alternate zoning.
4. Consider extending the E2 Environmental Conservation on Ropes Creek to include the full extent of the 30 m Vegetated Riparian Zone. The current proposed rezoning has a portion of the 30 m Vegetated Riparian Zone located within the Private Recreation zone and therefore this area may become under private ownership which may result in difficulties managing the riparian corridor. Consideration to extend the E2 zone to incorporate this area will provide benefit to biodiversity and future management of the area.

References

Bureau of Meteorology (BOM) (2020) Daily rainfall Erskine Park Reservoir (accessed March 6, 2020).

Eco logical Australia (2019) Aspect Industrial Estate State Significant Development Application - Riparian Assessment

Eco Logical Australia (2019) 113 - 127 Aldington Road, Kemps Creek - Riparian Constraints Assessment.

Natural Resource Access Regulator (2018) Guidelines for Controlled Activities on waterfront land—Riparian corridors.

Spatial Information Exchange (SIX Maps) (2020) NSW 1:25,000 topographic mapping

Appendix G Vegetated Trunk Drainage Sizing

Factors Considered for the Commencement of Naturalised Trunk Drainage within the Aerotropolis Precincts.

Naturalised trunk drainage has increasingly become a part of greenfield development. It is often adopted when considering the safe and economic conveyance of overland flows (often referred to as pluvial flows). This discussion paper will consider controlling influences such as existing creeks, catchment size and safety when choosing the point to initiate trunk drainage. The economics are not considered, in this paper, as there are many individual issues that will control the economics of a pluvial system.

The rainfall data used is based on Bureau of Meteorology (BOM), from ARR Hub, for areas adjacent to South Creek within the Aerotropolis precincts. The charts produced have utilised this data in a "smoothed" format to provide an indication of appropriate trunk drainage initiation point and will require appropriate hydrologic and hydraulic modelling to produce formalised designs. The conclusions drawn from this data will be generally appropriate for areas in western Sydney but may not be suitable for areas with greater or lesser rainfall.

Natural Constraints

Pluvial flows innately follow the depressions in the topography and in a natural or rural landscape, this can be quite dendritic. Urban development tends to tame these flow paths to suit the efficacy of the urban landscape. This urban taming needs to be considered carefully, and if well thought out will utilise the form of the landscape to its advantage in locating pluvial drainage systems. This may be an iterative process but locating roads, paths and parkland in the natural depressions can greatly assist in safely directing excess flows to the trunk drainage system.

A major constraint that needs to be taken into account is the existing stream structure and the Strahler Order of these streams. This information can be obtained through the Natural Resources Access Regulator (NRAR) or from 1:25,000 topographic maps that indicate the appropriate stream categorisation. Generally, streams of Strahler Order 2 and above will require protection while Order 1 streams can often be realigned with an appropriate Controlled Activity approval. Trunk drainage systems will often commence at, or upstream of the Order 1 streams, with the use of naturalised channels enhancing the stream structure and contributing to the parklands objectives of the Aerotropolis.

Flowpath Safety

Location of flowpaths and trunk drainage channels should consider the safety of people, vehicles and structures whilst complying with the approval authorities' requirements. Australian Rainfall and Runoff 2019 (ARR 2019) provides guidelines for safe flows by relating hazard ratings to flow velocities and depth. Councils will often have a gutter flow width that is related to the design standard of the street stormwater drainage system. Typically, the street systems are designed to either a 5% or 10% AEP while the pluvial overland flows are considered to the 1% AEP standard. Although the design standard for these systems are set, there needs to be an understanding of the hazard from flows greater than the standard with an allowance for safe failure of these systems.

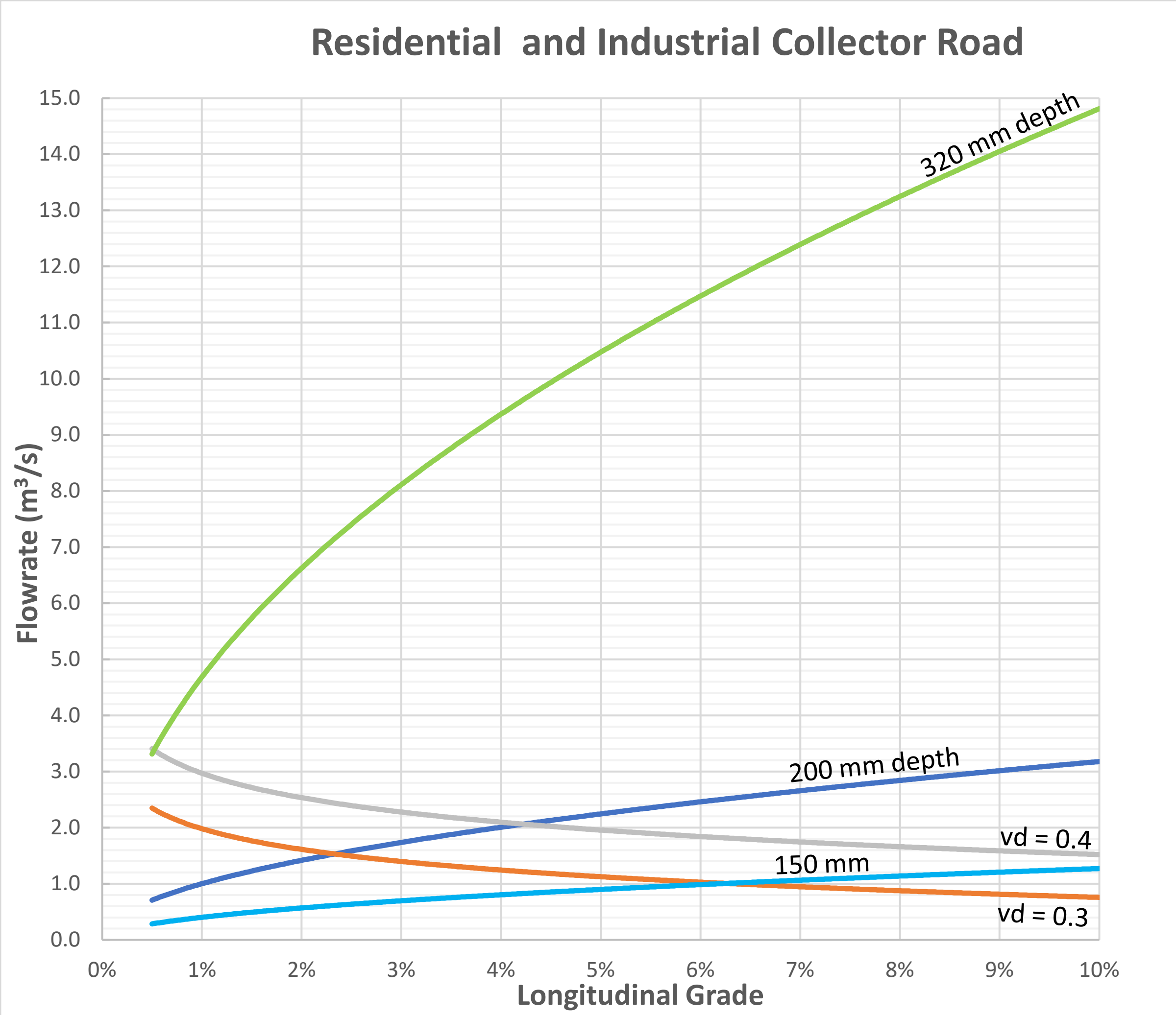

Figure 1 - Flow capacity for full carriageway width flow

ARR 2019 (Book 9 Ck 5 Sect 5.6.2) suggests a maximum street flow depth of 200 mm and a velocity depth product of 0.3 m^2/s for parked vehicles and 0.4 m^2/s for pedestrians. This is shown in Figure 1 and is related to typical residential and industrial collector road profiles.

This figure is indicative of the potential full width flowrates for collector roads as shown in Figure 2 and Figure 3. The 320 mm depth is about the maximum depth that can be achieved in these sections while keeping flows in the road reserve. These flows are above those that can be safely conveyed under the ARR 2019 guidelines, but this curve can be of assistance to assess fail safe solutions for flows greater than the design standards. Other considerations would include whether the vehicle access to a property is lower than the standard kerb height and the potential 200 mm depth of flow. The 150 mm depth curve has been included to show typical “gutter full” situations.

These curves were produced using Mannings formula with a slight increase in the typical Mannings ‘n’ to allow for the potential of parked vehicles and increased vegetation in line with the parkland’s objectives. These should be seen as a tool to establish a starting point for investigation and design To accurately assess the hazards in a design case the peak flow from the upstream catchment should be hydraulically modelled in the proposed road cross-section and assessment made of the topography adjacent to the road reserve to ensure that flows will be contained as intended.

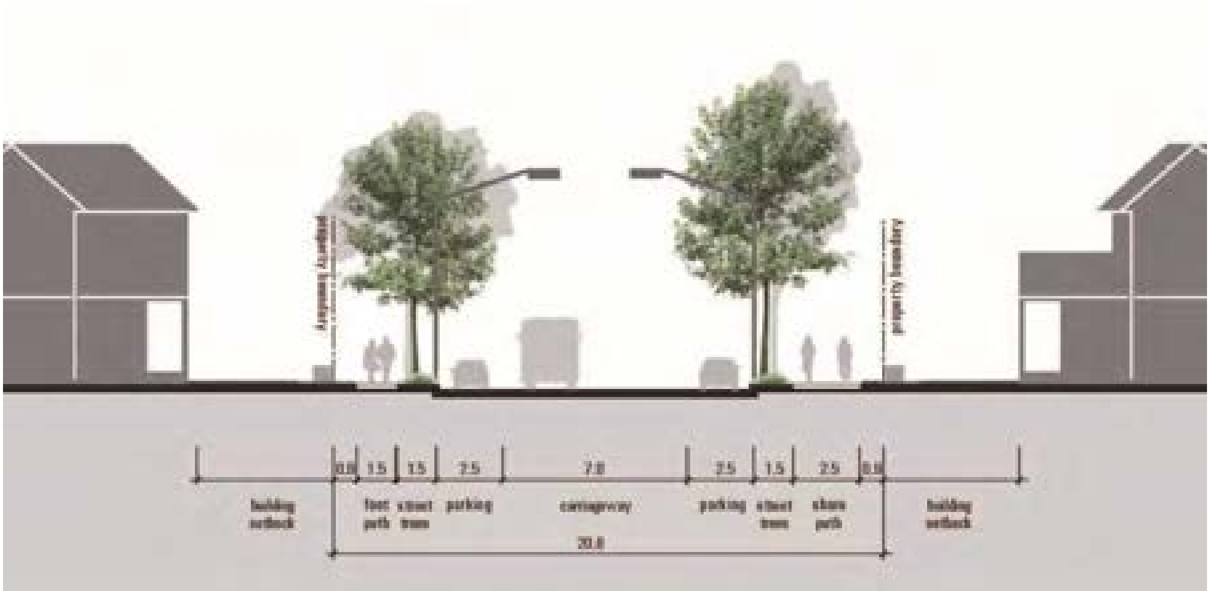

Figure 2 - Example of Residential Collector Road

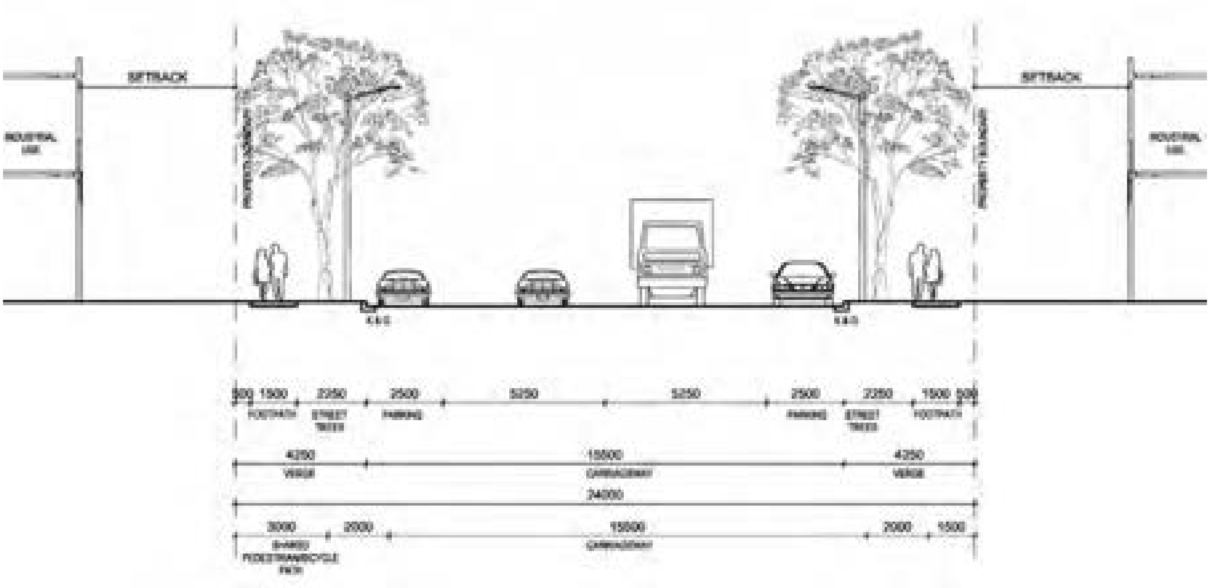

Figure 3 - Example of Industrial Collector Road

Catchment Flows

The flows presented in the Figures 4, 5 and 6 were modelled using the RORB hydrologic model, considering catchment sizes of 10ha, 15ha, 20ha and 25ha. Each catchment was assessed with a range of imperviousness from 0% to 100%.

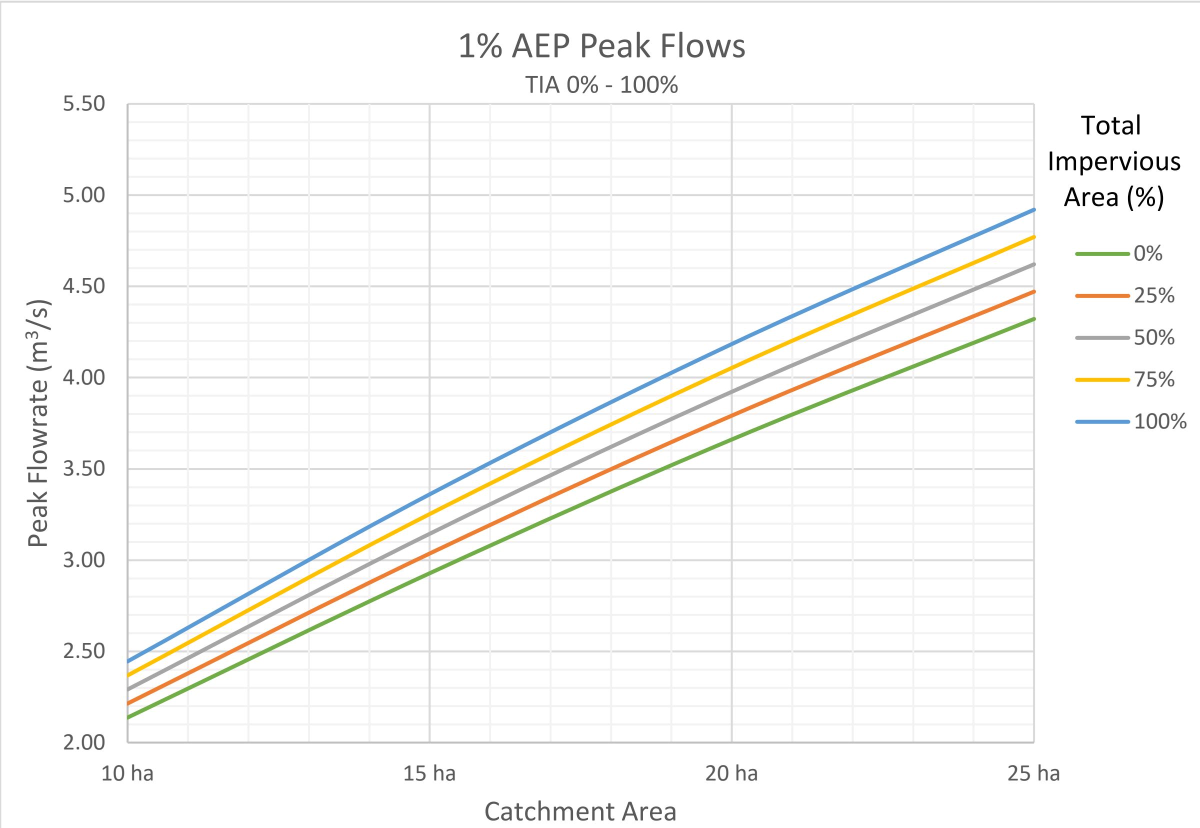

Figure 4 - Peak 1% AEP Flows for Varying TIA

The peak flow from a catchment will vary depending on the total impervious area (TIA) and the effective impervious area (EIA). The principles for this are described in ARR 2019 and for modelling purposes EIA was considered to be 66.6% of TIA.

Figure 4 shows the peak 1% AEP flowrate for the four catchment areas with a range of imperviousness from 0% to 100%. This range was shown for completeness, but the parklands objectives suggest that the imperviousness will be more mid-range and less than current business-as-usual. The modelling makes no assessment of possible site retention/detention of stormwater but is a raw discharge flowrate. These curves can be refined if DPIE-EES guidelines suggest stormwater flows are retained onsite but will be dependent on what design standards are adopted for any retention.

Figures 5 and 6 show the potential flowrates within the road sections with a reduction for flows conveyed in the street drainage system. Typically, the street drainage systems will have a 5% or 10% AEP design standard. Figure 5 shows the 1% AEP flowrate minus the 10% AEP flow and Figure 6 shows the 1% AEP flowrate minus the 5% AEP flow. Design standards for the roadway drainage are available from the local council and may also include allowances for blockage of pit and pipe systems.

An alternative to conveying pluvial flows through the roads and stormwater drainage is the possibility for flowpaths within large lots. This may be an approach suitable for large industrial developments but will require an assessment of the flows and how they can be conveyed in a safe manner to a trunk drainage or creek system. These pluvial flowpaths should be designed considering the guidelines in ARR 2019 and the approval authority requirements.

Discussion

From Figure 1 it can be seen that, depending on the road grade the safe flow rates vary between 0.76 m^3/s to 1.53 m^3/s using the ARR 2019 guidelines. It also indicates that maximum gutter full flows will range between 0.4 m^3/s and 1.2 m^3/s. Also, from the Figures 5 and 6 it can be seen that, for street drainage systems designed to convey 5% AEP flows, trunk drainage should commence when about 10 – 16 ha of catchment contribute flows. While for 10% AEP drainage systems the commencement point for trunk drainage is about 10 – 12.5 ha. This assists in providing safe conveyance of pluvial flows through urban streets

As mentioned previously these are raw numbers that may be influenced by various factors relating to development and on-lot stormwater treatment but give a generalised point to initiate trunk drainage.

Other factors to consider are the location of roads and where they cross topographical depressions. Parklands can influence the placement of trunk drainage as well as the potential location for stormwater quality/quantity basins. All these parts of urban infrastructure can give good initiation points to commence trunk drainage and terminate the street drainage system. Naturalised channels have an advantage for the Aerotropolis precincts as they will assist in the parklands objectives by providing green infrastructure as well as assisting evapotranspiration and cooling the landscape.

Conclusion

The information provided in the charts are an indicative tool for concept assessment and in no way replace detailed investigation and design. While the issues controlling the initiation of trunk drainage are varied, a maximum point of commencement can be seen to be about where 15 ha of catchment contribute flows and the street drainage system is designed for a 5% AEP peak flowrate. This drops to 12 ha of contributing catchment where the street drainage system is designed for a 10% AEP peak flowrate.

Adopting a 5% AEP design standard for street drainage conveying significant pluvial flows may be seen as an acceptable way of considering the initiation point for trunk drainage.

This is suitable as a general planning tool and does not replace detailed investigation and design.

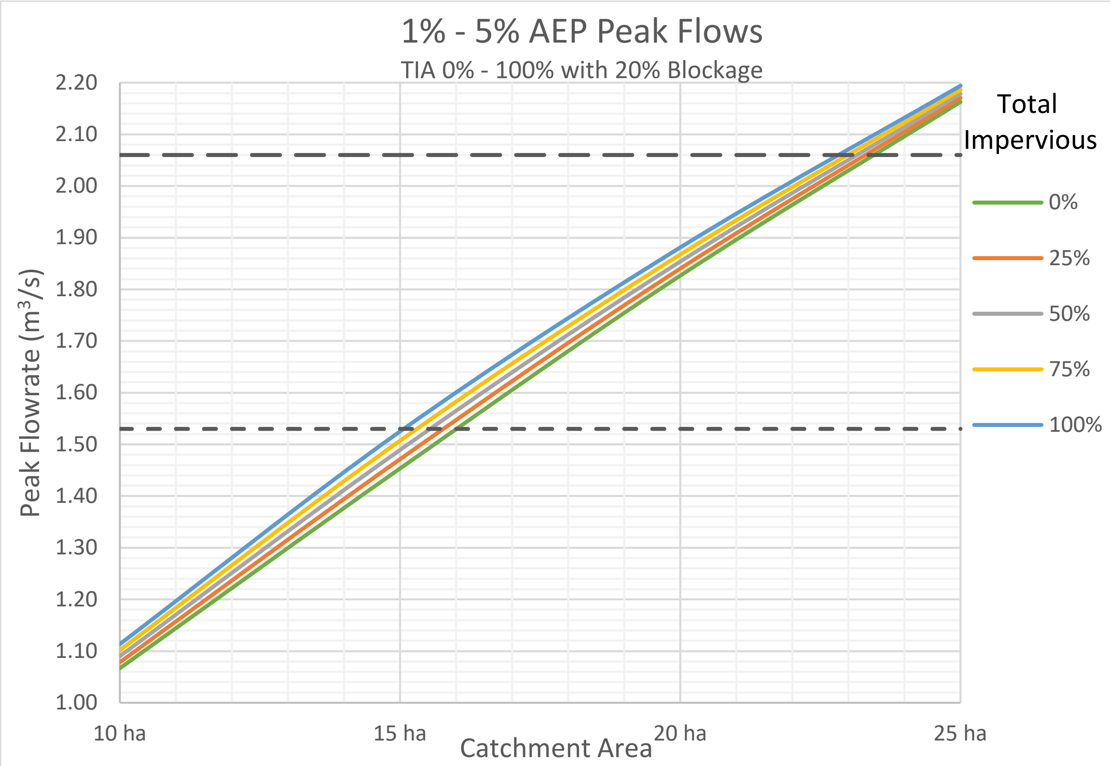

Figure 5 - 1% AEP Street Flows Reduced by 10% AEP Street Drainage

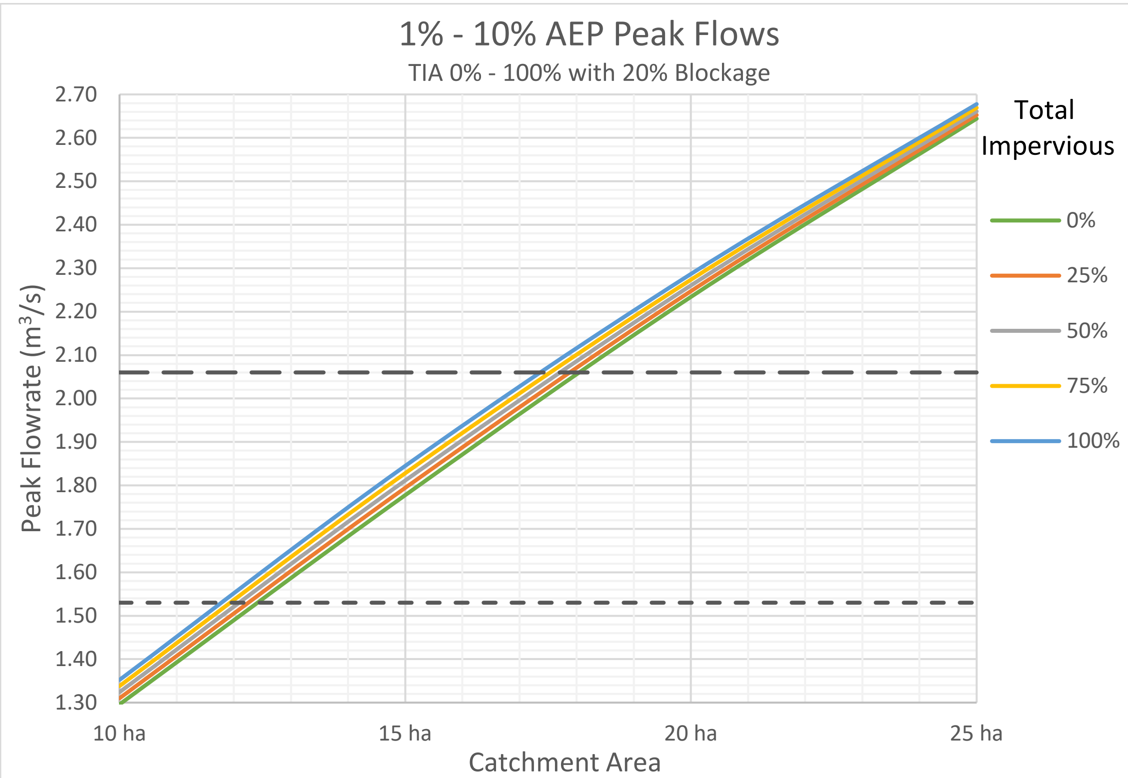

Figure 6 - 1% AEP Street Flows Reduced by 5% AEP Street Drainage