NORTHROP

ENGINEERING REPORT

Kings Hill – Master Plan

Kings Hill Development Pty Ltd

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EXECUTIVE SUMMARY

The Proposal is described as a Concept Development Application for future Residential Subdivision and Stage 1 Subdivision Works (Initial Site Preparation Works).

Kings Hill is an identified urban release area under part 6 of the Local Environmental Plan. Zoning across the site varies, and includes B2 local centre, part B4 mixed use, part E2 environmental conservation, part R1 general residential and part RE1 public recreation.

The proposed development includes subdivision of the site into approximately 1900 residential lots, 6 mixed use lots, 1 local centre, parks and a school site. The development is within Port Stephens Council Local Government Area (LGA)

This report supports a Development Application (DA) pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The site is subject to the controls contained within the Port Stephens *Local Environmental Plan 2013* (Port Stephens LEP) and the *Port Stephens Development Control Plan 2010* including DCP *Section D14 Kings Hill – Raymond Terrace Specific Area*.

The purpose of this report is to describe the physical infrastructure proposed as part of the development, and how compliance with the associated legislation is achieved. This document is to be read in conjunction with the Development Application as a whole, however the following specific items are addressed in detail within:

- Site Earthworks;
- Road Network;
- Stormwater Management and Flooding;
- Sediment and Erosion Control;
- Essential Services; and
- Construction Management Plan Framework.

1.1.1 Site Earthworks

It is expected that reshaping of the existing topography will be required to overcome a number of constraints, mostly attributable to the excessive slope of the site. The finished surface level will be designed to:

- Minimise the extent of earthworks;
- Balance the cut and fill to minimise haulage between precincts; and
- Balance the cut and fill to negate the need for export or import of material from site.

Detailed bulk earthwork plans will be provided at Precinct level development applications.

1.1.2 Road Network

The proposed road network has been designed to incorporate major circulation routes for private vehicles, public transport, cyclists and pedestrians as well as local roads for access to local neighbourhoods and residential lots. Perimeter roads, to facilitate firefighting access, have also been integrated into the network.

The main access point to the site is from ae new grade separated interchange on the pacific highway. The collector roads provide linkage to precincts, community facilities, the local centre and school.

Detailed road design details will be provided at Precinct level development applications.

1.1.3 Stormwater Management Conclusions

Based on the above assessment it has been shown that the URA can be developed generally in accordance with Landcom's Stretch Targets, PSC DCP and the *BMT WBM Guidelines* prepared for the site through the introduction of a number of stormwater management devices. These devices include gross pollutant traps, bio-filtration basins, retention basins and detention basins. Preliminary locations and sizing of devices have been included in the above report and shown in the attached figures.

The purpose of this study is to provide a guiding Stormwater Strategy on a master plan scale. Information provided in this study should guide but not be solely relied upon when submitting future individual Development Applications. It is noted that future applications may differ from this report due to changes to the masterplan and road layout, catchment areas and best design practices evolving as the development and stages are rolled out. Additional stormwater management options such as vegetated swales, rain gardens integrated into the streetscape, wetlands and proprietary products used for conveyance and treatment should be considered.

An additional level of detail will be provided with the stormwater strategy submitted for each precinct, at precinct level development application.

1.1.4 Wetland Impact Assessment

The proposed development is located upstream of Irrawang Swamp and Coastal Wetland 803. Alluvium were engaged to undertake an assessment of the impact of the proposed development on both of the downstream water bodies and provide recommendations on water quality and quantity measures to be implemented into the stormwater management strategy. The assessment determined that the major risks to the wetlands, including increases in periods of increased inundation depth and reductions in seasonal drying patterns are unlikely to occur.

1.1.5 Essential Services

Each lot will be provided with potable water, wastewater, electricity and telecommunications. A sewer and wastewater servicing strategy has been conditionally approved by Hunter Water Corporation (HWC).

Servicing strategies and detail design in collaboration with the relevant authority will progress in line with the detailed design of each precinct.

1.1.6 Sediment and Erosion Control

Staging, stabilisation and erosion and sediment control will be managed during construction activities to minimize sediment runoff from the site. Concept sediment and erosion control plans will be provided with precinct level development applications. Detailed erosion and sediment control plans will form part of the Contractors construction management plan provided as part of the construction certificate.

1.1.7 Construction Management Plan Framework

Prior to issue of a Construction Certificate for any Precinct or Stage, it is proposed that a Construction Management Plan (CMP) be prepared. The CMP is to give consideration to the items contained within this report as a minimum. The approved CMP is to be implemented throughout construction activities, overseen by the nominated delegate.

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1 INTRODUCTION

Northrop Consulting Engineers have been engaged by Kings Hill Development Pty Ltd (KHD) to prepare an Engineering Report to support the Development Application (DA) for the proposed future residential subdivision and Stage 1 subdivision works (Initial Site Preparation works).

The purpose of this report is to describe the physical infrastructure proposed as part of the development, and how compliance with the associated legislation is achieved. This document is to be read in conjunction with the Development Application as a whole, however the following specific items are addressed in detail:

- Site Earthworks;
- Road Network;
- Stormwater Management and Flooding;
- Sediment and Erosion Control;
- Essential Services; and
- Construction Management Plan Framework.

Kings Hill is an identified Urban Release Area (URA) under part 6 of the Local Environmental Plan. Zoning across the site varies, and includes B2 local centre, part B4 mixed use, part E2 environmental conservation, part R1 general residential and part RE1 public recreation.

The proposed development includes subdivision of the site into approximately 1900 residential lots, 6 mixed use lots, 1 local centre, parks and a school site. The development is within Port Stephens Council Local Government Area (LGA).

This report supports a Development Application pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The site is subject to the controls contained within the Port Stephens *Local Environmental Plan 2013* (Port Stephens LEP) and the *Port Stephens Development Control Plan 2010* including DCP *Section D14 Kings Hill – Raymond Terrace Specific Area*.

1.1.1 Project Overview

The Proposal is described as a Concept Development Application for future Residential Subdivision and Stage 1 Subdivision Works (Initial Site Preparation Works). The area to which the Proposal applies is shown in Figure 1.1 as indicated by the subject site boundary; a boundary that reflects the zone boundary (R1, B2 and B4) and additional lands as indicated in the Statement of Environmental Effects. Refer to the Statement of Environmental Effects for further details on the Proposal.

1.1.2 Site Description

The land owned by KHD is currently vacant land located within the Port Stephens Council LGA approximately 5km north of Raymond Terrace, within Lot 41 DP 1037411 and Lot 4821 DP 852073 as shown in Figure 1-1. The site covers approximately 538Ha. For the purposes of this study, this area has been divided into several separate "Precincts" as shown on drawing DA-08-C2.00 included in Appendix A.

The investigation covers the entire development, herein known as the “subject site”. The subject site is spread across two lots. The northern lot 4821 DP852073, consisting of Precincts 1 & 2, saddles lot 4822 and is bound to the east by the Pacific Highway, to the north by Six Mile Road and to the south and west by existing properties. The southern lot 41 DP1037411, consisting of Precincts 3, 4, 5, 6 & 7, is bound to the east by the Pacific Highway, to the west by Newline Road and to the north and south by adjacent properties.

Access to the site is currently via unsealed fire roads, accessed via Newline Road, the Pacific Highway and Six Mile Road.

Figure 1 - 1 Kings Hill Location Plan

The elevation within the subject site ranges from 5m AHD to 130m AHD within the upper reaches of the catchment. Existing slope varies from approximately 1% to 30%. Drawing DA-08-C2.00 in Appendix A shows the topography and slope within the development.

Numerous ephemeral watercourses are located within the subject site. These have been classified in accordance with the Strahler system and in liaison with the Department of Industry (DI) - Water. Riparian corridors have been designated in accordance with the Department’s *Guidelines for Riparian Corridors on Waterfront Land*. The location of the classified watercourses and associated riparian zone within the subject site are included on drawing DA-08-C7.00 in Appendix A.

The condition of many of the existing watercourses appear to be eroded and in a state of degradation. The watercourses within Precincts 3 (south of the East West Link road), 4, 5, 6, 7 currently drain to the south into the Irrawang Swamp. Watercourses from Precinct 1, 2 & 3 (north of the East West Link Road) currently drain underneath the Pacific Highway via existing drainage culverts to Grahamstown Dam.

Throughout the upper reaches of the catchment vegetation is generally densely wooded while in the lower reaches, vegetation ranges from medium density woodlands to grazing land with sparse vegetation and pastoral grasses.

The Wallalong and Ten Mile Road soil landscapes are expected across the subject site. These consist generally of sandy loam topsoil underlain by either medium or heavy clay, or bedrock. The topsoil layer is generally highly erodible with relatively impermeable substrate. The clay layers are considered to have a moderate to high shrink swell potential and are highly dispersive.

2 PROPOSED DEVELOPMENT

The proposed development includes subdivision of the site into approximately 1900 residential lots, 6 mixed use lots, 1 local centre, parks and a school site.

The development has been separated into 7 Precincts, generally in line with the Figure DAC Section D14 of the DCP. Two main collector roads link each of the Precincts, denoted as the east-west link road (EWL) and the north-south link road (NSL). Access to all areas of the proposed development will be via one of these roads.

The main access to the site will be via a new grade-separated interchange on the Pacific Highway proposed as part of the development, under a separate approval.

It is expected that works associated with the development will include the following:

- Site earthworks;
- Internal road network;
- Stormwater infrastructure; and
- Essential services

Each of the above are described in detail in subsequent sections of this report.

It is noted that this report does not intend to provide detailed design solutions to all issues. Rather, it presents the feasibility of solutions suitable for a Master Plan, with the intent to develop these further at Precinct level Development Application.

In addition to the concept development consent, this submission also seeks approval for Stage 1 subdivision works (Initial Site Preparation works). Concept Erosion and Sediment Control and Construction Management frameworks are described in subsequent sections of this report.

3 SITE EARTHWORKS

Earthworks and regrading will be required across the majority of the site for the provision of access, drainage and the creation of residential lots. Detailed levels and cut/ fill plans will be determined at Precinct Development Application stage.

Earthworks which will change the natural surface topography and the management thereof are discussed in the following sections.

3.1.1 Proposed Cut/ Fill Areas

The main areas of cut/ fill are expected to include the following:

- Most roads will involve some adjustment to existing surface levels, however in general the design principle is to maintain an overall cut/fill balance in the road design. It is expected that the roads will vary from either cut or fill and therefore earthworks batters from the edge of the road reserve will extend into adjacent lots by a distance which will be relative to the height of cut or fill at the road centre line. Due to the steep nature of the site, it is expected that retaining walls or vegetated batters with grades up to 1:3 will be required, particularly around the perimeter roads;
- Above ground detention and water quality basins will require adjustments to existing surface levels, both cut and fill, to achieve the necessary embankment heights and floor depths/ grades within the basins. Basins will generally be located at the downstream end of each precinct, which typically has flatter grades, so batters will be minimised where possible;
- Development areas along existing watercourses may require filling to ensure building areas are located above the expected 100-year ARI flood level;
- The removal of dams from within the site will require appropriate earthworks, however this will serve to return these areas to the natural or proposed topography;
- Any proposed re-alignments of ephemeral watercourses will require the filling of existing gullies and creation of new watercourses by cut and fill to achieve the desired cross-sectional shape. Wherever possible, natural stream forms will be adopted, including the provision of pool and riffles, a meandering low flow channel, natural erosion protection (e.g. rock rip rap), the introduction of rock bars at regular intervals to act as bed control structures and dense "three storey" indigenous riparian vegetation planting along the core riparian zones;
- Some filling of development lot areas may occur to smooth out any localised surface high or low points which might affect the development lot. This would assist with ensuring that surface runoff occurs in a sheet flow manner rather than concentrating into small gullies which may produce erosion problems and drainage issues for newly constructed buildings; and
- Landscaping of open spaces may involve some shaping and regrading of the natural surface; however, it would be expected that this would be minor and not impact on existing vegetation.

3.1.2 Earthworks and Spoil Management

All earthworks required as part of the development will be detailed at Precinct level Development Application and go through the appropriate approvals process, including any necessary controlled activity permits for works within defined watercourses.

Management of the earthworks operations will be based on protocols which will respect the relevant authorities consent conditions and the approved Construction Management Plan (CMP). The CMP for each substage of the development will detail erosion and sediment control requirements, waste management minimisation measures and general requirements for earthworks management.

In relation to specific earthworks and spoil management, the following outlines the minimum expected protocols that would be included in the CMP:

- Only undertake earthworks operations in the areas as defined on the approved plans, i.e. no works to be within designated no-go areas;
- Ensure erosion and sediment controls are in place prior to commencing clearing operations;
- Initial tree/ vegetation clearing to be undertaken in accordance with the environmental requirements of the CMP;
- Re-use of cleared trees and vegetation for protection of disturbed areas or other landscaping purposes (mulching);
- Classify and separate spoil into various groups such as VENM, ASS soils, topsoil and other various waste classifications as may be appropriate including stockpiling as appropriate;
- Maximise the reuse of suitable materials on site in preference to importing fill or disposal to landfill;
- Attempt where possible to maximise the reuse of fill materials unsuitable for engineering purposes for alternative non-structural uses such as landscaping;
- Stockpiles of spoil material awaiting reuse on site or off-site disposal should be located and managed in line with the following;
    - Locate stockpiles within proposed road reserves or areas of future development. These should be identified and approved prior to the commencement of construction and be shown on the sediment and erosion control plans;
    - Locate away from native vegetation and not within the drip line of any trees proposed to be retained;
    - Locate on areas of shallow grade and away from areas of concentrated water flow;
    - Locate away from sensitive areas such as creeks and existing residences;
    - The stockpile should be accessible for the purpose of dust suppression;
    - Provide sediment fences down-slope and earth bank up-slope to divert water from impacting on the stockpile; and
    - Long term stockpiles should be protected from wind and rain erosion by covering with geo-textile or stabilised with hydro-seeding or similar.
- Dispose of materials off site in accordance with the approved waste management plan; and
- Revegetation and restoration of areas as soon as works are completed in accordance with the approved sediment and erosion control plan.

4 ROAD NETWORK

4.1 Existing Road Network

Access to the site is currently via Pacific Highway, Newline Road and Six Mile Road. There are a number of existing unsealed access trails throughout the site constructed to facilitate fire management and maintenance. Due to the erratic nature of the existing trails, it is unlikely that any will be retained within the development footprint. Instead, a new sealed road network is proposed, as described below.

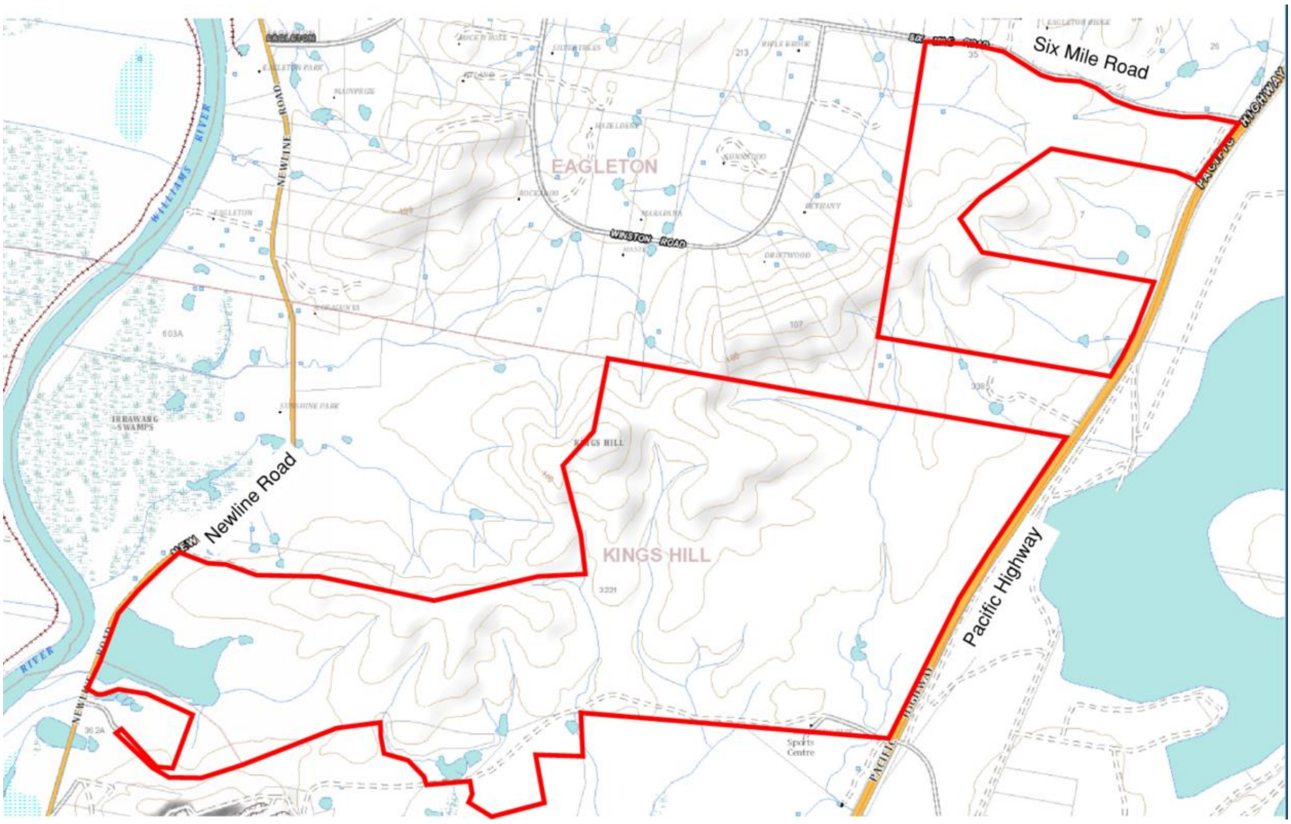


Figure 4-1 – Existing Road Network

4.2 Proposed Interfaces with Existing Road Network

A new grade-separated interchange with the Pacific Highway is proposed as the primary access point to the site. This intersection is currently being designed by RMS as part of a separate process. A copy of the concept design drawings for the intersection, prepared by Arcadis, have been lodged to Roads and Maritime Service (RMS). The internal road networks have been coordinated with the proposed interchange, as shown in drawing DA-08-C3.00 in Appendix A.

The internal road network will consist of collector roads, local streets, perimeter roads and laneways. Two collector roads, denoted as the East-West Link (EWL) and the North-South Link (NSL), will provide the main link between existing road networks, precincts, commercial areas and the local centre, generally in line with Figure DAC of DCP D14, shown below in Figure 4-2. The EWL will link the new interchange at the Pacific Highway to a new roundabout on Newline Road. THE NSL will link the EWL with Six Mile Road to the north. All other internal roads will be accessed via the EWL and NSL. Drawing DA-08-C3.00 in Appendix A shows an indicative road hierarchy and layout, while drawing DA-08-C3.10 shows the proposed road typical section. Collector Road Type 1 generally matches the Major Collector Shown in Figure DA in Part D14 of the DCP.

As noted in the Kings Hill Traffic Study prepared by GHD 2019, the EWL will consist of 4 lanes from the interchange for approximately 750m into the site. This is reflected on drawing DA-08-C3.00 and the typical sections on drawing DA-08-C3.10.

The road network will include an 8m wide perimeter road at the interface of the development footprint and retained vegetation in line with NSW Rural Fire Service's Planning for Bush Fire Protection. Refer to drawing DA-08-C3.10 and DA-08-C3.11 in Appendix A for typical road sections.

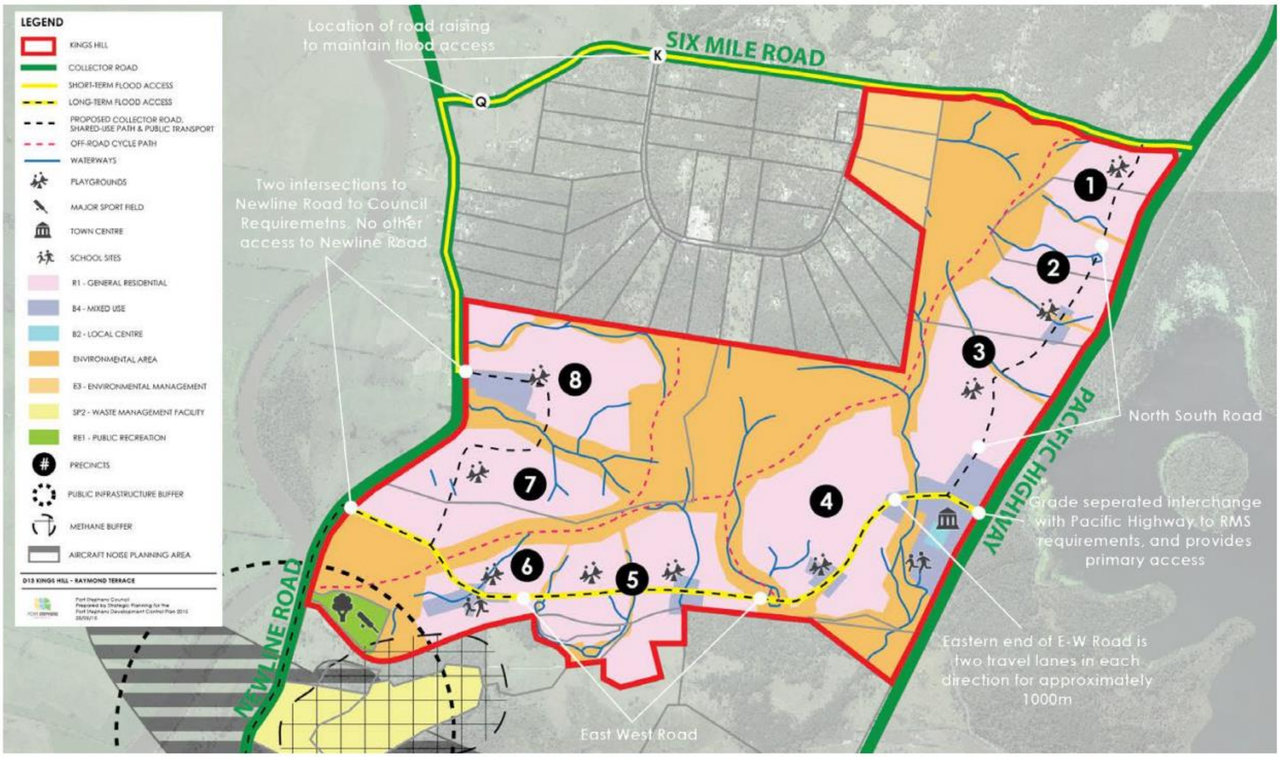


Figure 4-2 – DAC: Kings Hill - Raymond Terrace Locality Control Map

4.3 Proposed Road Characteristics

The roads within the subject site are to be designed in accordance with Port Stephens Council DCP, best practices for traffic management, pedestrian/cyclist safety and amenity as well as the urban design philosophies of the overall development.

Roads have been classified into several types to highlight differences in their vehicle or pedestrian usage, adjacent land uses and general urban design treatment. A summary of the main road classifications is provided below:

- Collector Road Type 1 – 27.0m road reserve with 3.0m wide median, 3.5m wide travel lanes (two lanes in each direction), 2.5m shared cycle / pedestrian path and 2.5m pedestrian path;
- Collector Road Type 2 - 27.0m road reserve with 3.0m wide median, 3.5m wide travel lanes, 3.5m parking/cycle, 2.5m shared cycle / pedestrian path and 2.5m pedestrian path;
- Collector Road Type 3 - 23.0m road reserve with 13.0m carriageway for two-way traffic and parking, 2.5m shared cycle / pedestrian path and 1.20m pedestrian path;
- Local Streets - 16.5m road reserve with 8.0m carriageway for two-way traffic, 1.20m pedestrian path;
- Perimeter Roads – 17.0m road reserve with 8.0m carriageway for two-way traffic, 1.20m pedestrian path. The perimeter road is to accommodate a koala fence and 1.5m maintenance access, as noted in the Species Impact Statement. Road width will be 19.5m where parking is also provided; and
- Laneway - 11.5m road reserve with 6.0m carriageway for two-way traffic, 1.20m pedestrian path. The laneway is intended for areas of excessive grade, to provide lot access to one side of the road only, with a retaining wall or batter on the other side.

An indicative road hierarchy layout and typical cross-sections for the development are contained Appendix A. The proposed construction phasing of the trunk collector road is shown in drawing DA-08-C2.00.

Figure 4-3 – Internal /External Road Interface

4.4 Engineering Requirements

4.4.1 Flood Free Access

The proposed EWL is to provide long-term flood free access to the development, linking the Pacific Highway and Newline Road, as shown in the Locality Controls Map DCP Section D14 Figure DAC, presented in Figure 4-2.

This Figure also shows a collector road providing connectivity and a bus route to Precinct 8, which sits outside of KHD footprint. As noted in D1.10 of *Port Stephens Design Specifications* the absolute maximum grade for a collector road is 12%. Based on survey of the site, the existing grade at this location has been calculated as approximately 20%. Therefore, a change in level, either filling or cutting to a depth of approximately 8m would be required to provide a compliant road longitudinal grade. This will also have knock-on effects to grading of the surrounding local streets and allotments.

Instead, it is proposed that the existing Newline Road be upgraded to provide flood free access to Precinct 8. Preliminary investigation undertaken by Northrop has identified that Newline Road would need to be raised to approximately RL4.2m AHD to provide immunity to the 1% AEP, for a length of approximately 785m. A preliminary cost investigation has determined that the cost of both options are similar, however upgrade of Newline Road will provide increased amenity to a larger proportion of the community. Refer to Appendix B for additional details.

4.4.2 Service Vehicle Access

The road layout, particularly junctions and any turning heads, will be designed to ensure access for service vehicles, including garbage trucks and emergency vehicles such as fire trucks and ambulances.

4.4.3 Public Transport

In accordance with the Locality Controls Map DCP Section D14 Figure DAC, presented in Figure 4.2 above, the proposed EWL and NSL collector roads will provide the public transport routes through the site. As mentioned in Section 4.4.1, connectivity to Precinct 8 would be via Newline Road.

The location and type of bus stops will be determined in accordance with Council's Design Development Specification and consultation with Council and Newcastle Transport as the lot layout is developed.

4.4.4 Pedestrian and Cycle Connectivity

In accordance with the Locality Controls Map DCP Section D14 Figure DAC, presented in Figure 4-2 above, convenient and safe off-road pedestrian and cycle routes through the site will be provided, linking the precinct centres, school, community facilities and open space. 2.5m shared pedestrian and cycle paths will be provided on the EWL and NSL collector roads and through the linear park adjacent the Pacific Highway. 1.2m footpaths will be provided to all other roads, including perimeter roads to provide pedestrian connectivity throughout the site. The proposed pedestrian and cycle network is shown on drawing DA-08-C3.00 in Appendix A.

Existing unsealed fire access tracks are proposed outside of the development footprint and would provide off-road recreational cycle paths.

4.4.5 Design Requirements

The detailed design for new roads within the development will be carried out based on the relevant guidelines contained within:

- The Port Stephens Council DCP, including Section D14 Kings Hill – Raymond Terrace specific area;
- Port Stephens Council's Planning and Design Specifications; and
- AUSTROADs Guide to Traffic Engineering Practice for detailed design of intersections and roundabouts, as well as general horizontal and vertical road design.

The documents referred to above will set out the following road design requirements;

- Road cross falls and superelevation;
- Maximum and minimum longitudinal grades;
- Design speeds;
- Horizontal and vertical curve details;
- Intersection/ roundabout geometry and setout;
- Traffic control devices;
- Footpaths and cycleways; and
- Signposting/ linemarking.

4.4.6 Materials and Technical Specifications

Technical specifications for roads and infrastructure will be based on Port Stephens Councils *Planning and Design Specifications*.

4.4.7 Pavement Design

Pavement design will be based on the requirements of Council's *Development Design Specification – D2 – Pavement Design* for all internal development roads. Pavement design will be undertaken by geotechnical engineers as part of the detailed infrastructure design following site investigation and laboratory testing.

4.4.8 Proposed Road Grades

The road hierarchy plan includes collector roads, local streets, perimeter roads and laneways. The minimum longitudinal grade will be 0.5% while the maximum grades will be as follows:

- Collector / bus route – 12%
- Local streets / perimeter roads / laneways – 25%

Detailed design plans will be provided at precinct level development application.

4.4.9 Block Dimensions

As noted in Chapter C, Part C1.1 'Subdivision' of Council's DCP2014, a maximum block depth of 80m and maximum block length of 160 is permissible. An indicative road layout is shown on drawing DA-08-C3.00, however detailed design of the local road network, incorporating maximum block length of 160m will be undertaken at Precinct stage DA.

5 STORMWATER MANAGEMENT AND FLOODING

5.1 Background

This report aims to assess the proposed development with respect to the *Kings Hill Urban Release Area Water Management Strategy Guidelines* prepared by BMT WBM for PSC and the requirements outlined in the PSC DCP, specifically Section D14.D relating to stormwater. The intent of the study is to demonstrate how stormwater will be practically integrated and managed to comply with the *BMT WBM Guidelines* and the PSC DCP, and further refine the water management strategy for the development. Also considered, is the management of the stormwater impacts of the development on the Irrawang Swamp, and addressing the concerns raised by Hunter Water Corporation in their referral response dated 9th January 2019. It is expected that the strategy will be further refined at subsequent precinct level development application.

This study includes the development of the masterplan by integrating a broad catchment and regional approach, therefore identifying the most ideal position for stormwater devices such as detention basins and water quality treatment devices. In doing so, a development where stormwater can be efficiently integrated into the lot design to provide visual amenity as well as achieve the requirements stipulated in the DCP can be achieved.

Contained herein is a description of the surrounding area, the subject site and the proposed development. Also discussed are the water management objectives, which have guided the design, and a summary of the water quality and quantity modelling which was undertaken as part of the assessment.

5.1.1 Previous Studies

Kings Hill Urban Release Area Water Management Strategy Guidelines (BMT WBM)

The *Kings Hill Urban Release Area Water Management Strategy Guidelines* developed by BMT WBM provides the Development Control Plan (DCP) guidelines for the development as well as preliminary hydrology and hydraulics for the upstream portion of the site. An XP-RAFTS model was developed for the hydrology and an unsteady TUFLOW analysis was undertaken for the hydraulics.

5.1.2 Relevant Legislation and Guidelines

A number of legislative policies and guidelines relate to the proposed development of the Kings Hill URA. Notably, the following guidelines have been considered in relation to the stormwater assessment:

- **Port Stephens Local Environmental Plan (Kings Hill, North Raymond Terrace) 2010**

The *Port Stephens Local Environmental Plan* (LEP) for the Kings Hill development outlines the permitted or prohibited development for the Kings Hill area. More specifically, the Kings Hill LEP outlines the land zoning in the area and the type of development that is permitted with or without consent.

- **Port Stephens Council Development Control Plan – Specific Areas, Kings Hill – Section D14**

The *Port Stephens Council Development Control Plan* (DCP) provides the specific requirements for the URA identified under Part 6 of Port Stephens LEP. This document outlines the requirements and controls for the development of the land and ensures a logical and cost-effective sub-division design is prepared.

- **Australian Rainfall and Runoff 2016**

Australian Rainfall and Runoff (AR&R) is a document originally published in 1987 by the Institution of Engineers, Australia (IEAust) which has recently been revised and re-released in 2016. The document provides designers with the best available information on design stormwater and flood estimation and is widely accepted as a design guideline for all flood and stormwater related design in Australia.

- **Australian Runoff Quality**

Australian Runoff Quality (ARQ) is a guideline that was published by IEAust in 2005. The document provides information regarding the current best practice when considering Water Sensitive Urban Design (WSUD) measures for developments, including preventative measures, source controls, conveyance controls and end of line controls. Additionally, it provides guidance for water quality modelling and stormwater harvesting and re-use.

- **The Water Management Act 2000**

The *Water Management Act 2000* is the overlying statutory framework for managing water in NSW. The *Act* aims to maintain the health of natural water systems by encouraging ecologically sustainable development. The *Water Management Act* provides guidance for riparian setbacks for any controlled activity occurring within 40 metres of a defined water course such as a river, lake or estuary.

- **The NSW MUSIC Modelling Guidelines 2015**

The *NSW MUSIC Modelling Guidelines* were prepared by BMT WBM and provides information regarding modelling stormwater quality in the Software Package called MUSIC (Model for Stormwater Improvement Conceptualisation). The guidelines provide the recommended variables and parameters to enter when setting up a MUSIC model.

- **Landcom's Water Sensitive Urban Design Guidelines**

Landcom is the NSW Government's land and property development organisation. Landcom's Water Sensitive Urban Design Book 1 – Policy (2009) spells out aspirational water quality treatment targets, being pollutant load reductions of 90% for total suspended solids, 85% for total phosphorus and 65% for total nitrogen.

5.1.3 Available Data

- LiDAR Elevation Data;
- Detailed Survey at various locations undertaken by DeWitt Consulting;
- Kings Hill Urban Release Area Water Management Strategy Flood Study (BMT WBM, 2016);
    - 1% AEP (1 in 100 year ARI) Flood Extent;
    - 20% AEP (1 in 5 year ARI) Flood Extent; and
    - Probable Maximum Flood (PMF) Extent.

5.2 Stormwater Management Objectives

The following stormwater management objectives were adopted from the DCP and the *BMT WBM Guidelines.* Generally, targets are geared toward minimising the change to the natural water cycle on the receiving environments. This is achieved through water quality treatment objectives, retention and frequency control.

5.2.1 Retention Objectives

The *BMT WBM Guidelines* suggest retaining 15mm runoff from the directly connected impervious roof, road, driveway and other paved landscaping areas to minimise the increase in runoff volume. As such, it is proposed that 5,000 litre rain tanks are provided for each dwelling. Additionally, a series of retention basins have been proposed to accommodate the required storage volume throughout the development.

The BMT WBM Guidelines states that the necessary retention volume will need to be "*harvested and used; infiltrated at appropriate locations or slowly released to the receiving environments over a period not exceeding 24 hours".* As such, it is possible that the necessary retention requirements may be incorporated into the bio-filtration basins as part of the storage volume between the top of the filter media and the high flow outlet provided the basins have a discharge rate that ensures the storage volume is released "over a period not exceeding 24 hours". This has been discussed further in Sections 5.6.5 and 5.6.6 below.

5.2.2 Detention Objectives

Hunter Water Corporation (HWC), in their referral response dated 9th January 2019, stated that on-site detention should be provided to limit post development flows to pre-developed flows for all storm events up to 1% AEP, for catchments flowing into Irrawang Swamp. *The BMT WBM Guidelines* state that for catchments discharging directly into Irrawang Swamp, detention may not be required.

The storage volume required to reduce post-developed flows to pre-development conditions up to 1% AEP, particularly on the steep slopes experienced on the Kings Hill site were found to be excessive. Instead, and in consultation with Alluvium, it was determined that a more appropriate outcome would be to limit the more frequent flows, up to and including the 40% AEP, to pre-developed flow rates. This is intended to retain the existing flow rates for the regular rain events, while rain events that occur less frequently than 40% AEP are not expected to have sufficient regularity to impact the day-to-day hydrological conditions within the wetland. Therefore, detention for catchments flowing directly to the Irrawang Swamp has been provided to limit peak post developed flows to pre developed flows for events up to the 40% AEP.

Although runoff from the eastern catchment will discharge into the Irrawang Swamp via a diversion channel, runoff will first need to pass below the Pacific Highway to reach the proposed diversion swale. Site investigations have shown that the existing infrastructure below the Pacific Highway is in good condition, and therefore to avoid upgrading this infrastructure, detention has been proposed in this area to limit peak post-developed discharge to peak pre-developed discharge.

5.2.3 Water Quality Treatment Objectives

The stormwater treatment targets stated in the *BMT WBM Guidelines* for the Kings Hill development are reproduced in Table 5-1 below. HWC have stated that the Landcom stretch water quality targets should be adopted for any part of the development draining directly or indirectly into the Irrawang Swamp. These targets are also included in Table 5-1. The stretch targets have been achieved for all discharge points from the proposed development for each pollutant type excluding Phosphorous. It is reasoned that an 85% reduction in Phosphorus is not feasible for this development due to the impractical land take of bio-filtration. This is discussed further in Section 5.6.6 below.

Table 5-1 – Water Quality Treatment Targets

Pollutant Type	BMT WBM Guidelines Removal Target	Landcom Stretch Water Quality Targets
Total Nitrogen	50%	65%
Total Phosphorous	65%	85%
Total Suspended Solids	85%	90%

5.2.4 Drinking Water Catchment

Northrop Consulting Engineers have undertaken hydrological and hydraulic investigations for the Kings Hill URA. The site is located adjacent to Grahamstown Dam which is the Hunter Valley's largest drinking water supply. As outlined in the *BMT WBM Guidelines*, HWC has confirmed that stormwater runoff from the eastern catchment of the development area will need to be diverted away from Grahamstown Dam.

A flood study for the proposed stormwater diversion channel was completed by Northrop in 2016. The study was revised in 2017, adopting the latest 2016 AR&R rainfall intensities and temporal patterns. Copies of the following reporting are including in Appendix C:

- Flood Study for Proposed Stormwater Diversion Channel, Kings Hill Urban Release Area (29/02/2016);
- Revised Flood Modelling re: Proposed Stormwater Diversion Channel, Kings Hill Urban Release Area (26/10/2017); and
- Response to Council comments re: Proposed Stormwater Diversion Channel, Kings Hill Urban Release Area (26/10/2017).

The investigations concluded that, from a hydraulic perspective, the proposed channel has no significant impact on the adjacent highway, Grahamstown Dam, or downstream properties in a 1% AEP event. Furthermore, the capacity of the channel is sufficient to convey a peak 0.2% AEP event.

RMS are in the process of designing the channel, in collaboration with the interchange. The channel is expected to be owned and managed by two separate parties, being Port Stephens Council for the extent adjacent the Pacific Highway, and HWC for the extent within Hunter Water land. Maintenance of the channel will be required by both parties to ensure ongoing performance of the channel. A preliminary Operational Maintenance Plan is enclosed in Appendix I.

5.2.5 Minor and Major Drainage Design

The minor stormwater system will be designed to cater for the requirements of the DCP at the time of detailed design. This is currently 0.2 EY (Exceedances per Year, equivalent to the 5-year ARI) storm event, however it is understood that Council intends to adopt 10%AEP. A detailed analysis will be provided in the Precinct level Development Application or Construction Certificate documentation for each stage as they are rolled out.

The major system will cater for the 1% AEP (equivalent to the 1 in 100yr ARI). Flow from upstream of the proposed development will be diverted to a trunk drainage system or natural watercourse to minimise the impact on proposed lots.

Creek crossing along the main Collector road are proposed to be designed to cater for the 1% AEP plus a freeboard of 500mm to ensure safe evacuation routes are available for residents in the event of a major storm.

5.2.6 Flooding

As shown in the Port Stephens Council Flood Hazard Mapping 2016, the proposed development footprint is clear of the High Hazard Floodway area. Part of the Irrawang swamp within the site is mapped as High Hazard Flood Storage, however this is clear of the proposed development footprint. Some existing waterways within the site are mapped as flood prone land subject to further investigation and covered by the flood planning level. In accordance with the NSW Government 2005 Floodplan Development Manual and PSC DCP, all habitable floor levels will be constructed above the Flood Planning Level (FPL). All areas of fill are outside of the mapped flood storage area, so are not expected to impact regional flood levels.

The FPL for regional flooding is expected to be sourced from Council. Local major flow channels within the development, will be determined as part of the detailed design, based on post-developed catchments.

The remainder of the site is mapped as flood free or minimal risk flood prone land.

5.2.7 Irrawang Swamp and Coastal Wetland 803 Objectives

HWC have outlined requirements for the management of stormwater quantity and quality discharging from the proposed development into the Irrawang Swamp, both directly and indirectly, as discussed in sections 5.2.2 and 5.2.3 above. HWC have requested a detailed investigation to be carried out to assess the environmental impacts of the discharge on the Irrawang Swamp. Alluvium were engaged to complete the assessment and their report is appended to this report in Appendix E.

As noted in Section 7 of the report, the analysis undertaken indicates that the major risks to the wetland, including increases in periods of increased inundation depth and reductions in seasonal drying patterns are unlikely to occur. The report proposes a number of measures are put in place to manage water quantity and quality from development areas, including:

- Reducing stormwater runoff during frequent smaller rainfall events;
- Implement measures including disconnecting impervious areas, oversized BASIX rainwater tanks, infiltrating biofiltration systems, stormwater retention and harvesting systems;
- Ensuring that the majority of future runoff passes through appropriately sized stormwater retention/detention measures to protect ephemeral watercourses from erosion; and
- Management of stormwater runoff quality to prevent coarse sediment, dissolved nutrients, fine sediment and other diffuse source stormwater pollutants from impacting on the wetland ecology. This includes effective measures (including regular inspections) in the subdivision construction, building construction and post development phases.

These measures have been incorporated into the propose Stormwater Management Plan.

5.3 Methodology

The necessary requirements outlined in the PSC DCP were assessed via the following:

- An initial desktop study of the proposed site including the review of topographic maps, existing infrastructure on site, existing documents as well as guidelines and planning instruments relevant to the site;
- The classification of onsite watercourses in accordance with the Water Management Act 2000. Suitable buffers from watercourses have been determined in accordance with the guidelines presented by the Department of Industry – Water, including the potential use of these buffers for stormwater management devices and public amenity;
- The determination of local catchments based on the master plan layout, catchment features and a combination of available detailed survey and LiDAR elevation data;
- Determine retention volumes for each catchment generally based on the BMT WBM Guidelines including the potential location for each basin within the development. A number of basins have been proposed, of which the extent and form of these devices have been determined with due consideration to the actual topography and the current masterplan;
- A one-dimensional XP-STORM hydrological model has been used to estimate the pre-developed to post-developed peak flow requirements for stormwater entering Irrawang Swamp from the southern portion of the development area;
- The XP-STORM hydrological model was also used to estimate likely peak flows including bypassing flows for proposed water quality devices; and
- The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) has been used to quantify runoff volumes as well as sediment volume, nutrient and gross pollutant loads typical for the type of proposed development in each catchment.

5.4 Catchment Characteristics

5.4.1 Catchment Boundaries

The portion of the URA owned by KHD has been divided into catchments for the purposes of hydrological modelling. The catchments are based on preliminary development layouts, local catchment features and a combination of available detailed survey/ LiDAR elevation data. The catchments have then been further divided into a series of land uses based on the land zoning and information provided in the masterplan. The land use types include:

- Upstream Catchments (Forest);
- Urban Residential;
- Commercial/ High Density Residential; and
- Parkland.

The assumed impervious fraction used for each land use defined above is shown in Table 5-2.

Table 5-2 – Assumed Impervious Percentage per Land Use

Land Use	Percentage Impervious (%)
Upstream (Forest)	0
Urban Residential	60
Commercial / High Density Residential	80
Parkland	5

5.4.2 Creek Classification

An assessment of the natural creeks and streams within the subject site was conducted in conjunction with DI – Water in 2015. The aim of the assessment was to determine the necessary creek order to determine whether modifications to existing creeks are permissible under the *Water Management Act 2000*. The stream order of each watercourse was classified in accordance with the Strahler system.

Riparian corridor widths have been adopted from DI – Water's document "*Controlled activities on waterfront land – Guidelines for riparian corridors on waterfront land"*. The required Vegetated Riparian Zone (VRZ) offsets for either side of the classified watercourses are reproduced below in Table 5-3.

Table 5-3 – Stream Classifications and Riparian requirements

Stream order	Vegetated Riparian Zone Width (m)	Total Riparian Corridor Width (m)
First	10	20m + Channel width
Second	20	40m + Channel Width
Third	30	60m + Channel Width

A Request for Information was received from the Natural Resources Access Regulator dated 3rd April 2019. Drawing DA-08-C7.00 included in Appendix A has been prepared to address this request.

5.5 Water Quantity Modelling

A one-dimensional XP-STORM hydrological and hydraulic model has been developed to estimate the pre-developed to post-developed peak flow requirements for stormwater entering Irrawang Swamp from the western portion of the development area. The following provides a description of the hydrological and hydraulic modelling undertaken as a response to Hunter Water's letter dated 9th Jan 2018 and titled *DA 16-2018-772-1 – Concept Development Application for Torrens Title Subdivision – 1900 Lots (including residential, 6 mixed use lots, 1 Local Centre, Parks and a School Site) and Stage 1 Subdivision works for site preparation and clearing.*

5.5.1 Hydrology

The Australian Rainfall and Runoff 2016 (ARR 2016) guidelines were used for this study. Through conversation with the site Ecologists, it has been confirmed that Irrawang Swamp is expected to be sensitive to very frequent rainfall events up to the 0.5 EY (1 in 2 year) event rather than infrequent events (i.e 1 in 100 year), thus rainfall depths for the 4EY (3 month event), 1EY and 0.5EY events have been considered in the hydrological model. This rainfall data was obtained from the Bureau of Meteorology (BOM).

The hydrological model was developed using Laurenson hydrology with a typical storage non-linearity exponent of -0.285 for all design storm events.

Losses have been represented using the initial and continuing loss model. All catchments in the existing case model are assumed to be 100% pervious and have been modelled with an initial loss of 17mm and continuing loss rate of 2.7mm/hr. These losses were obtained from the ARR Data Hub. For the developed case model, impervious areas within the development footprint were modelled with an initial loss of 1mm and continuing loss rate of 0mm/hr, while pervious areas were modelled with an initial loss of 5mm and continuing loss rate of 2.5mm/hr. All catchments outside the development footprint were modelled with an initial loss of 17mm and continuing loss rate of 2.7mm/hr.

A series of catchments for both the pre and post developed scenarios have been digitised for the subject site including the upstream catchment as shown in Appendix D - Figures A1 and A2 respectively. It is important to note that the naming system used for the catchments in the detention model is different to that used in the water quality model. This was done as several of the large catchments in the water quality model needed to be split into further sub-catchments for the detention model. The following Table 5-4 and Table 5-55-5 provide a description of the pre and post developed catchment characteristics respectively.

Table 5-4 – Pre-Developed Catchment Characteristics

Catchment	Area (ha)	Roughness (n)	Percentage Impervious (%)	Loss Model (mm)	Vectored Slope (%)
E01	3.117	0.08	0	IL17 CL2.7	11
E02	0.868	0.08	0	IL17 CL2.7	13
E03	3.353	0.08	0	IL17 CL2.7	9
E04	1.236	0.08	0	IL17 CL2.7	18
E05	2.321	0.08	0	IL17 CL2.7	17
E06	5.455	0.08	0	IL17 CL2.7	15
E07	4.455	0.08	0	IL17 CL2.7	1
E08	1.000	0.08	0	IL17 CL2.7	9

E09	1.822	0.08	0	IL17 CL2.7	6
E10	4.623	0.08	0	IL17 CL2.7	1
E11	6.714	0.08	0	IL17 CL2.7	12
E12	4.067	0.08	0	IL17 CL2.7	9
E13	2.935	0.08	0	IL17 CL2.7	6
E14	8.541	0.08	0	IL17 CL2.7	9
E15	1.338	0.08	0	IL17 CL2.7	8
E16	12.489	0.08	0	IL17 CL2.7	13
E17	5.456	0.08	0	IL17 CL2.7	17
E18	6.101	0.08	0	IL17 CL2.7	5
E19	1.051	0.08	0	IL17 CL2.7	13
E20	0.637	0.08	0	IL17 CL2.7	13
E21	4.346	0.08	0	IL17 CL2.7	15
E22	6.926	0.08	0	IL17 CL2.7	13
E23	2.661	0.08	0	IL17 CL2.7	9
E24	10.325	0.08	0	IL17 CL2.7	12
E25	7.867	0.08	0	IL17 CL2.7	12
E26	6.799	0.08	0	IL17 CL2.7	12
E27	14.879	0.08	0	IL17 CL2.7	11
E28	5.106	0.08	0	IL17 CL2.7	22
E29	28.972	0.08	0	IL17 CL2.7	12
E30	10.600	0.08	0	IL17 CL2.7	7
E31	12.536	0.08	0	IL17 CL2.7	6
E32	12.866	0.08	0	IL17 CL2.7	7
E33	1.620	0.08	0	IL17 CL2.7	7
E34	7.886	0.08	0	IL17 CL2.7	4
E35	3.221	0.08	0	IL17 CL2.7	4
E36	5.485	0.08	0	IL17 CL2.7	3
E37	36.015	0.08	0	IL17 CL2.7	9
E38	9.109	0.08	0	IL17 CL2.7	3
E39	6.532	0.08	0	IL17 CL2.7	3

Table 5-5 – Post-Developed Catchment Characteristics

Catchment	Area (ha)	Roughness (n)	Percentage Impervious (%)	Loss Model (mm)	Vectored Slope (%)
D01	3.314	0.018	0	IL5 CL2.5	11
D01	4.971	0.035	100	IL1 CL0	11
D02	2.967	0.018	0	IL5 CL2.5	9
D02	0.691	0.035	100	IL1 CL0	9
D03	0.572	0.018	0	IL5 CL2.5	17
D03	0.567	0.035	100	IL1 CL0	17
D04	0.930	0.018	0	IL5 CL2.5	17
D04	1.394	0.035	100	IL1 CL0	17
D05	11.183	0.080	0	IL17 CL2.7	15
D06	4.459	0.080	0	IL17 CL2.7	1
D07	0.137	0.018	0	IL5 CL2.5	9
D07	2.596	0.035	100	IL1 CL0	9
D08	0.663	0.018	0	IL5 CL2.5	5
D08	0.994	0.035	100	IL1 CL0	5
D09	4.622	0.080	0	IL17 CL2.7	1
D10	2.062	0.018	0	IL5 CL2.5	13
D10	3.092	0.035	100	IL1 CL0	13
D11	2.877	0.018	0	IL5 CL2.5	9
D11	5.738	0.035	100	IL1 CL0	9
D12	0.535	0.018	0	IL5 CL2.5	5
D12	0.803	0.035	100	IL1 CL0	5
D13	0.675	0.018	0	IL5 CL2.5	8
D13	1.012	0.035	100	IL1 CL0	8
D14	0.780	0.018	0	IL5 CL2.5	7
D14	1.370	0.035	100	IL1 CL0	7
D15	1.349	0.018	0	IL5 CL2.5	12
D15	2.148	0.035	100	IL1 CL0	12
D16	0.648	0.080	0	IL17 CL2.7	10
D17	0.732	0.080	0	IL17 CL2.7	24
D18	1.833	0.080	0	IL17 CL2.7	20
D19	0.939	0.080	0	IL17 CL2.7	11
D20	2.228	0.080	0	IL17 CL2.7	5
D21	1.450	0.018	0	IL5 CL2.5	13

D21	2.174	0.035	100	IL1 CL0	13
D22	0.927	0.080	0	IL17 CL2.7	6
D23	2.033	0.018	0	IL5 CL2.5	13
D23	3.050	0.035	100	IL1 CL0	13
D24	3.251	0.080	0	IL17 CL2.7	17
D25	1.738	0.018	0	IL5 CL2.5	15
D25	3.608	0.035	100	IL1 CL0	15
D26	4.066	0.018	0	IL5 CL2.5	10
D26	6.099	0.035	100	IL1 CL0	10
D27	1.935	0.080	0	IL17 CL2.7	13
D28	2.104	0.018	0	IL5 CL2.5	10
D28	3.155	0.035	100	IL1 CL0	10
D29	2.554	0.080	0	IL17 CL2.7	12
D30	5.106	0.080	0	IL17 CL2.7	22
D31	14.876	0.080	0	IL17 CL2.7	11
D32	3.705	0.080	0	IL17 CL2.7	12
D33	3.803	0.018	0	IL5 CL2.5	12
D33	7.160	0.035	100	IL1 CL0	12
D34	1.803	0.018	0	IL5 CL2.5	7
D34	2.713	0.035	100	IL1 CL0	7
D35	6.488	0.080	0	IL17 CL2.7	7
D36	8.423	0.080	0	IL17 CL2.7	7
D37	6.553	0.018	0	IL5 CL2.5	6
D37	9.829	0.035	100	IL1 CL0	6
D38	28.972	0.080	0	IL17 CL2.7	12
D39	4.271	0.080	0	IL17 CL2.7	24
D40	13.556	0.018	0	IL5 CL2.5	9
D40	21.198	0.035	100	IL1 CL0	9
D41	13.556	0.018	0	IL5 CL2.5	9
D41	21.198	0.035	100	IL1 CL0	9
D42	4.829	0.018	0	IL5 CL2.5	4
D42	4.972	0.035	100	IL1 CL0	4
D43	1.551	0.018	0	IL5 CL2.5	4
D43	1.704	0.035	100	IL1 CL0	4
D44	2.106	0.018	0	IL5 CL2.5	3

D44	8.422	0.035	100	IL1 CL0	3
D45	3.365	0.018	0	IL5 CL2.5	3
D45	5.047	0.035	100	IL1 CL0	3

As shown above in Table 5-5, the post developed catchments take into account the additional hardstand areas for the proposed subdivision. The impervious fractions included in Table 5-2 were used to calculate the impervious areas in Table 5-5.

5.5.2 Hydraulics

The catchments in the hydrological model were connected to the hydraulic model via a series of nodes, each positioned at the low-point of their corresponding catchment. The nodes are connected to links which simulate the natural topography along watercourses. In some locations, watercourses are undefined, so dummy trapezoidal channels have been used to convey flows along links.

The developed case model was built using the existing case model and includes storage nodes which simulate the proposed detention basins located upstream of several discharge points across the site boundary.

5.5.3 Existing Runoff Regime

The existing scenario was split into 39 different catchments, named E01 to E39 as presented in Table 5-4 and Appendix D – Figure A1. Run-off from these catchments drains towards Irrawang Swamp which is located south of the site. Two culvert crossings have been identified under Newline Road at the outlet of catchment's E01 and E02. This includes a 450mm RCP at the outlet of catchment E01 and a 225mm RCP at the outlet of catchment E02.

5.5.4 Developed Runoff Regime

The developed scenario has been split into 45 different catchments named D01 to D45 as presented in Table 5-5 and Appendix D – Figure A2. Runoff from these catchments generally drains to the same outlet locations as the existing catchments, however some regrading is assumed, resulting in different pre-post catchment sizes draining to each outlet location. Detention basins are proposed at 12 different locations across the site as presented in Appendix D – Figure A3. Basins have been numbered 1-12. The discharge from these detention basins has been modelled and measured at 12 locations across the site. Each of these discharge points is presented in Appendix D – Figure A3.

Five of the 12 proposed detention basins will be offline (not within a classified watercourse), while seven will be online (within a classified watercourse). Offline detention basins include; Basin 1 - 3, 11 and 12, while online basins are basins 4 - 10 as presented in Appendix D – Figure 3. These online detention basins are proposed to be located along 1st and 2nd order streams within the site boundary which is allowable in accordance with the NSW Guidelines for Riparian Corridors on Waterfront Land, 2012.

The major properties of each modelled detention basin are presented below in Table 5-6. Each detention basin was modelled with outlet culverts at two different levels, ensuring no overtopping of basin banks occurs in any design storms up to and including the 0.5 EY event.

Table 5-6 – Modelled Detention Basins

Basin	Basin Area (Ha)	0.5EY depth (m)	Volume (m3)	Lowflow Outlet Pipe(m)	Highflow Outlet Pipe (m)	Lowflow Outlet Invert (mAHD)	Highflow Outlet Invert (mAHD)
1	0.1657	1.682	2787	0.15	2x 0.15	10.055	10.825
2	0.0731	0.964	704	0.15	2x 0.15	6.003	6.430
3	0.0693	0.997	690	2x 0.15	3x 0.15	10.799	11.220
4	0.5120	0.997	5104	3x 0.3	4x 0.3	5.513	5.940
5	0.2000	0.982	1964	2x 0.3	3x 0.3	16.063	16.450
6	0.4852	1.005	4876	2x 0.525	3x 0.45	6.800	7.282
7	0.2000	1.079	2158	3x 0.45	4x 0.45	12.888	13.500
8a	0.2000	0.517	1034	0.45	-	13.755	-
8b	0.3000	1.252	3756	0.45	0.45	13.447	14.01
9	0.1960	1.226	2402	2x 0.225	3x 0.225	9.564	10.120
10	1.0150	1.439	14605	2x 0.375	3x 0.375	13.121	13.700
11	0.2106	1.438	3028	3x 0.15	2x 0.225	12.680	13.356
12	0.1682	1.605	2699	0.15	3x 0.15	30.144	30.900

All basins have been modelled with vertical walls rather than battered walls for modelling simplicity. Detailed modelling or basin staged storage relationships will be done in more detail at construction certificate stage to reflect the actual shape of each basin.

Detention's basins 1 – 3 and 11 – 12 are proposed to be cut into the existing topography at the downstream end of their corresponding upstream catchments. Stormwater from upstream catchments will be directed to each basin through catchment regrading and a variety of methods including; urban swales, road gutters, pipe networks and overland flow.

Detention basin 4 is proposed on a first order watercourse and receives stormwater inflows from catchment's D08, D10 – D14, and D18 – D20. It has been assumed that catchment's D07 and D15 bypass basin 4. This will result in a higher detention volume than if they were directed through the basin and is therefore considered a conservative approach to detention modelling. This assumption has been made as both catchments naturally grade away from basin 4 and will therefore result in less catchment regrading. The flow out of this basin is measured at the point labelled "Bulk West Discharge Point" in Appendix D – Figure A3 which also includes outlet flow from basin 3 and the bypassing catchments which drain to the same point.

Detention basin's 5 – 9 are proposed within existing watercourses/gullies and detention shall occur within each channel behind the main collector road. Culverts running underneath the collector road shall control outlet flows from each basin. Catchment's D25 and D34 do not naturally grade to any of the above basins, so it has been assumed that re-grading of these catchments will occur in the developed scenario. Stormwater from catchment D25 shall be directed to basin 6 and stormwater from catchment 34 will be redirected to basin 8.

Detention basin 10 is proposed at the low point of catchment's D40 and D41. Catchment D43, shown in Appendix D – Figure 3 is proposed to be re-graded to direct flows back to detention basin 10.

5.5.5 Water Quantity Results

The effectiveness of the proposed detention system was assessed using the one-dimensional XP-STORM model. The results for the site outlet location are shown in Table 5-7 below.

Table 5-7 – Pre to Post Development Peak Flow Results

Discharge Point	Design Storm	Pre-Developed (m3/s)	Post Developed (m3/s)
Basin 1	4EY	0.041	0.040
	1EY	0.143	0.123
	0.5EY	0.248	0.156
Basin 2	4EY	0.041	0.033
	1EY	0.143	0.136
	0.5EY	0.246	0.185
Bulk West	4EY	0.485	0.446
	1EY	1.696	1.376
	0.5EY	2.839	1.995
Basin 5	4EY	0.213	0.174
	1EY	0.673	0.508
	0.5EY	1.026	0.722
Basin 6	4EY	0.322	0.290
	1EY	0.968	0.819
	0.5EY	1.537	1.239
Basin 7	4EY	0.508	0.418
	1EY	1.562	1.285
	0.5EY	2.421	1.873
Basin 8a and 8b	4EY	0.635	0.617
	1EY	2.135	1.958
	0.5EY	3.426	3.162
Basin 9	4EY	0.097	0.076
	1EY	0.286	0.268
	0.5EY	0.435	0.303
Basin 10	4EY	0.405	0.345
	1EY	1.253	0.962
	0.5EY	1.904	1.277
Basin 11	4EY	0.098	0.090
	1EY	0.291	0.260
	0.5EY	0.435	0.323

Discharge Point	Design Storm	Pre-Developed (m3/s)	Post Developed (m3/s)
Basin 12	4EY	0.043	0.039
	1EY	0.166	0.148
	0.5EY	0.278	0.188

These results show that pre to post detention requirements can be achieved through the inclusion of 12 detention basins.

5.5.6 Collector Road Creek Crossings

An XP-RAFTS model has been used to estimate the flows at the location where major creeks cross the main Collector road in the vicinity of the subject site. These locations have been shown in the DA-08-C4 drawing series included in Appendix A.

A two dimensional XP-STORM model was also developed using equivalent modelling variables, such as Manning's roughness, initial and continuing loss and rainfall in order to compare the results with the XP-RAFTS model. The results show that both models are generally in good agreeance, however to remain conservative the greatest peak flow determined by each model has been recorded in Table 5-8 below.

Table 5-8 – Collector Road Creek Crossings

Crossing	1% AEP (m3/s)	0.2EY (m3/s)
A	2.50	1.44
B	10.25	6.07
C	6.25	3.75
D	10.60	6.43
E	10.81	6.45
F	15.14	8.67
G	6.13	3.70
H	30.48	16.38
I	9.13	5.12
J	6.95	3.96
K	5.75	3.28
L	4.50	2.52

It is recommended that the results be reviewed and confirmed, based on the ultimate catchment size and characteristics prior to specifying infrastructure at each location.

5.6 Water Quality Modelling

Stormwater quality is proposed to be managed through a treatment train approach to meet the stretch water quality targets as requested by HWC. Modelling has been undertaken using the Model for Urban Stormwater and Conceptualisation (MUSIC) V6.3 to estimate the efficiency of the proposed treatment train. A short description of the catchments, the catchment parameters used in the models, treatment devices and results are included herein.

5.6.1 Water Quality Catchments

A total of 22 sub-catchments have been digitized for the subject site for water quality modelling purposes. DA-08-C4 drawing series included in Appendix A. They have then been further divided into a series of land uses based on the land zoning and information provided in the masterplan, including Upstream Catchments (Forest), Urban Residential – Roof, Urban Residential - Excluding Roof, Commercial / High Density Residential and Parkland. The impervious fraction used for each land use is based on Table 5-2.

The majority of upstream catchments are to be diverted around the urban zones and into the main water courses. Where this is not possible, the additional area has been included in the stormwater modelling. The catchment characteristics are shown in Table 5-9 below.

Table 5-9 – Sub-Catchment Characteristics

Catchment	Upstream Catchment (ha)	Residential Area (ha)	Commercial / High Density Residential Area (ha)	Parkland Area (ha)	Total Area (ha)	Percentage impervious (%)
C01	-	8.289	0	0	8.289	60
C02	-	4.192	0	2.931	7.123	37
C03	-	13.915	2.850	2.735	19.499	55
C04	-	4.479	1.027	0.142	5.648	62
C05	5.003	1.618	0.069	0.000	6.690	15
C06	-	8.706	0.000	0.316	9.021	58
C07	-	19.773	0	0.290	20.063	59
C08	-	8.050	2.911	0.000	10.961	65
C09	-	20.902	0	2.388	23.290	54
C10	-	5.084	2.252	2.465	9.801	51
C11	-	10.940	0.251	0.528	11.720	58
C12	4.377	33.025	1.721	0.000	39.123	54
C13	-	8.049	0.178	0.188	8.414	59
C14	-	22.349	8.939	0.413	31.701	65
C15	-	0.000	10.528	0.000	10.528	80
C16	0.636	1.540	0.000	0.000	2.177	42
C17	-	3.0563	0.000	0.270	3.327	56
C18	-	10.903	1.4124	0.790	13.106	59
C19	-	11.027	0.0672	0.000	11.094	60
C20	-	5.480	0.3265	0.079	5.885	60
C21	-	4.930	0	0.236	5.167	57
C22	-	8.246	0	1.045	9.291	54

Residential roof area catchments were included as part of the Urban Residential catchments based on the following assumptions:

- The number of lots in each catchment was approximated by dividing the total residential area by the anticipated lot yield; and
- The roof area for each lot was assumed to be 250m2.

Additional external catchments outside the development footprint have been defined and included in the MUSIC modelling provided to Alluvium for the purposes of assessing the impacts of the development on the Irrawang Swamp.

5.6.2 Water Quality Modelling Methodology

A MUSIC meteorological template was prepared by Alluvium and used to set up rainfall and PET data for the modelling. It incorporated six-minute time step pluviograph data from the Williamtown RAAF station for a continuous period between 1989-2008, along with PET data obtained from the SILO database covering the same period. The data provided in MUSIC-link only covers a 5 year period and is therefore considered insufficient for this assessment.

The source nodes used to represent the different sub-catchments were the Urban Residential node for the Urban and Parkland catchments, the Urban Residential Roof node for the assumed roof catchments, the Urban Commercial node for the Commercial/High Density Residential catchments and the Forest node for the upstream catchments.

Effective Impervious Area (EIA) factors have been adopted for the model in accordance with the *NSW MUSIC Modelling Guidelines* (2015). An EIA factor of 0.6 has been applied to the typical Urban catchments and a factor of 0.8 has been applied to the Commercial/High Density Residential catchments.

The rainfall runoff parameters have been adopted from the PSC MUSIC-link for Raymond Terrace, Sensitive Catchment Clay Soils Zone C. This is consistent with the soil types found across the site in with the geotechnical report prepared by Douglas Partners. The parameters are reproduced in Tab le 5-10 below.

Table 5-10 - MUSIC rainfall-runoff parameters

Source Node	Non-Urban Catchments (Upstream Catchments)	Urban Catchments (Developed Footprint)
Rainfall Threshold (mm)	1.0	1.0
Soil storage capacity (mm)	120	120
Initial storage (%)	30	30
Field capacity (mm)	85	85
Infiltration capacity coefficient – a	150	150
Infiltration capacity coefficient – b	3.5	3.5
Initial depth (mm)	10	10
Daily recharge rate (%)	25	25
Daily baseflow rate (%)	5	5
Daily deep seepage rate (%)	0	0

The pollutant generation parameters were adopted from the *2015 NSW MUSIC Modelling Guidelines*, based on large areas of interest, and are reproduced in Table 5-11 and Table 5-12 Below.

Table 5-11 – Base-flow Pollutant Generation Parameters

	TSS (log mg/L)		TP (log mg/L)		TN (log mg/L)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Upstream Catchments (Forest)	0.78	0.13	-1.220	0.130	-0.520	0.130
Urban Residential	1.200	0.170	-0.850	0.190	0.110	0.120
Parklands (Residential)	1.200	0.170	-0.850	0.190	0.110	0.120
Commercial/ High Density Residential	1.200	0.170	-0.850	0.190	0.110	0.120

Table 5-12 – Storm-flow Pollutant Generation Parameters

	TSS (log mg/L)		TP (log mg/L)		TN (log mg/L)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Upstream Catchments (Forest)	1.600	0.200	-1.100	0.220	-0.050	0.240
Urban Residential	2.150	0.320	-0.600	0.250	0.300	0.190
Parklands (Residential)	2.150	0.320	-0.600	0.250	0.300	0.190
Commercial/ High Density Residential	2.150	0.320	-0.600	0.250	0.300	0.190

Four MUSIC models were developed to simulate the main discharge locations for the development as follows:

- Model 1: Kings Hill West A – includes sub-catchments C02-C05 which drain to a small wetland referred to as Coastal Wetland 804;
- Model 2: Kings Hill South – includes sub-catchments C06-C15 (excluding C14) which drain to the northern end of Irrawang Swamp;
- Model 3: Kings Hill East – includes sub-catchments C14-C20 (excluding C15) that will enter the Irrawang Swamp from the east via the proposed diversion channel; and
- Model 4: Kings Hill West B – includes sub-catchments C01 which drains towards Newline Road and doesn't enter any wetlands.

MUSIC schematic diagrams for the four models are included in Appendix F.

5.6.3 Water Quality Treatment Devices

The *BMT WBM Guidelines* advocate a number of stormwater treatment devices including swales, constructed wetlands, infiltration basins, media filters and permeable paving, depending on the treatment scale. These devices were investigated as part of the design process, however many were not integrated for a number of reasons;

- In general, slopes within the development footprint are generally too steep to accommodate road side swales. Further consideration is expected for the feasibility of swales during the more detailed design processes;
- Soil properties do not lend themselves to infiltration, especially concentrated at locations immediately downstream of roadways and other infrastructure; and
- It is the preference of the DI - Water to have water quality treatment devices offline which reduces the potential for constructed wetlands to be incorporated as part of the development.

Bio-filtration basins in combination with Gross Pollutant Traps (GPTs) are considered the most efficient and economical treatment devices for the Kings Hill development at a precinct scale. Rain water tanks at a lot scale have also been included as the first step in the treatment train.

5kLrain water tanks were modelled as lumped nodes in MUSIC, based on the assumption of 8 tanks per hectare in the residential catchments. The following reuse demands were adopted, based on rates provided in the *NSW MUSIC Modelling Guidelines* (2015) for a dwelling with 2 occupants:

- 151L/day/dwelling for all outdoor uses; and
- 325L/day/dwelling for all internal uses.

A generic Humegard GPT node has been modelled upstream of the bio-filtration basins for each catchment. An approved equivalent GPT may be used if deemed necessary following further detailed assessment. Bio-filtration has been considered downstream of the GPTs for a number of reasons:

- They can be placed offline therefore satisfying the requirements outlined by DI – Water;
- They have minimal standing water within the basin, typically emptied shortly following precipitation events, therefore reducing environments that are susceptible to pest species such as mosquitoes and algae;
- They are typically used as an end of line treatment device and are therefore ideal for the proposed development due to steep grades in upstream reaches of the development;
- They have a greater treatment efficiency per square metre when compared to wetlands and are therefore highly effective at removing suspended solids, nutrients and gross pollutants from stormwater;
- They have the ability to satisfy both water quality and quantity requirements for the development due to retention capacity within the basins; and
- They can be aesthetically pleasing if properly designed with the potential to be easily integrated into the development masterplan within parks and surrounding residential zones.

Bio-filtration basins are typically designed as an offline treatment option for runoff prior to discharging downstream. They are commonly designed to allow water to enter, pond and infiltrate through a filter system and exit through an underdrain and pit and pipe network. A typical 500mm extended detention zone has been adopted to allow sufficient treatment time while stormwater percolates through the filter media. A typical basin is shown in Figure 5-1 below.

Figure 5-1 – Photo of a bio retention basin (Source: waterbydesign)

The filter media installed in the basins are highly susceptible to scour and erosion. Therefore, it is expected that flows from the minor events are to enter the basins and flows from the major event will bypass. This will be achieved by a "splitter pit" immediately upstream of the bioretention basin. Flows up to and including the 1 in 2-year event, deemed "low flows" will be diverted to the bioretention basin, while larger flows will be directed to the downstream detention basin, channel or existing creek. Suitable scour protection will be implemented at all outlets, designed to prevent scour. During construction, it is important to ensure that the majority of the upstream catchment is stabilized prior to installing the filter media to ensure the filter media does not become inundated by sediment.

Typical modelling parameters have been adopted to generally be inline *NSW MUSIC Modelling Guidelines (2015)* and are outlined in Table 5-13 below.

Table 5-13 – Bio-filtration basin parameters (Typical)

Filter depth (m)	0.6
Saturated hydraulic conductivity (mm/hr)	100
Total nitrogen content in filter (mg/kg)	400
Orthophosphate content in filter (mg/kg)	35
Base lined?	Yes
Underdrain?	Yes
Vegetated with effective nutrient removal plants?	Yes
Submerged Carbon Zone Present?	No

5.6.4 Street Scale and Lot Scale Water Quality Treatment Measures

MUSIC modelling has been completed at a masterplan scale, with the exception of the rain water tanks, with the assumption that all runoff from each sub-catchment will reach its respective bio-filtration basin and GPT. During the detailed design process, it may become apparent that street scale and lot scale water quality treatment, in addition to the rain water tanks, will be more suitable in some scenarios.

5.6.5 Retention

The preliminary retention volume required is based on the impervious area for each sub-catchment shown in Table 5-14. The DA-08-C4 drawing series included in Appendix A provides an indicative location for each retention basin.

Table 5-14 – Retention Volume

Catchment	Total Impervious (ha)	Retention volume required (m^3)	Retention Volume Provided (m^3)
C01	4.97	746	912
C02	2.66	399	790
C03	10.77	1615	2077
C04	3.52	527	634
C05	1.03	154	744
C06	5.24	786	1008
C07	11.88	1782	2135
C08	7.16	1074	1192
C09	12.66	1899	2467
C10	4.97	746	1071
C11	6.79	1019	1271
C12	21.19	3179	4091
C13	4.98	747	926
C14	20.58	3087	3331
C15	8.42	1263	1147
C16	0.92	139	261
C17	1.85	277	386
C18	7.71	1157	1415
C19	6.67	1000	1206
C20	3.55	533	659
C21	2.97	446	583
C22	5.00	750	1017

It is proposed to provide the required retention volume as extended detention above the bio-retention water quality treatment basins. The proposed extended detention depth is 0.5m, which, as can be seen in Table 5-14 provides sufficient retention volume in line with the *BMT WBM Guidelines.*

5.6.6 Water Quality Results

The bio-filtration basin sizes required to achieve the treatment targets results are outlined in below in Table 5-15. The filter media area in each basin is equivalent to 2% of the catchment area. An estimated land take is also provided based on a typical rectangular bio-filtration basin with an extended detention depth of 0.5m. An additional allowance has been provided for the external battering based on the estimated land slope at each location. These values are an estimate only and the actual land take will depend on actual topography and road design.

Table 5-15 – Bio-filtration Basin Sizes

Catchment	Filter area (m^2)	Surface Area (m^2)	Estimated High Flow Bypass (m^3/s)	Estimated Land Slope at Device (%)	Approximate Land Take (m^2)
C01	1658	1825	0.820	12.0	4144.0
C02	1425	1580	0.275	12.0	4624.0
C03	3900	4154	1.438	11.0	10292.0
C04	1130	1268	0.451	8.0	3039.0
C05	1338	1488	0.132	7.0	3260.0
C06	1840	2016	0.670	18.0	5393.0
C07	4012	4269	1.483	10.0	9993.0
C08	2192	2383	0.911	9.0	5576.0
C09	4658	4935	1.597	10.0	11400.0
C10	1960	2141	0.629	6.0	4201.0
C11	2344	2542	0.540	4.0	4276.0
C12	7825	8183	2.710	4.0	12540.0
C13	1683	1851	0.626	10.0	4704.0
C14	6340	6662	2.171	4.0	10331.0
C15	2106	2294	1.049	2.0	3379.0
C16	435	522	0.167	16.0	1453.0
C17	665	772	0.167	19.0	2570.0
C18	2621	2830	0.769	2.0	4086.0
C19	2219	2411	0.805	5.0	4375.0
C20	1177	1318	0.324	4.0	2413.0
C21	1033	1166	0.339	5.0	2333.0
C22	1858	2034	0.588	4.0	3517.0

The stormwater basins shown in the DA-08-C4 drawing series in Appendix A have been split the following categories, as follows:

- Combined Bio-retention and retention basins; and
- Detention Basins.

These basins are based on a preliminary estimate for the most efficient basin layout and are subject to change following 3D surface modelling using actual topography.

Each bio-filtration basin has been designed to meet the required reduction targets, with the exception of Phosphorous. The combined treatment train effectiveness for the four separate MUSIC models is shown below in Table 5-16.

Table 5-16 – Treatment Train Effectiveness

Pollutant	Source	Residual	Reduction (%)
MODEL 1 RESULTS (Kings Hill West A)			
TSS (kg/yr)	25800	2570	91
TP (kg/yr)	54	10.7	80.2
TN (kg/yr)	463	143	69.1
MODEL 2 RESULTS (Kings Hill South)			
TSS (kg/yr)	122000	9280	92.4
TP (kg/yr)	228	41.7	81.7
TN (kg/yr)	1970	572	71
MODEL 3 RESULTS (Kings Hill East)			
TSS (kg/yr)	70700	5380	92.4
TP (kg/yr)	134	24.7	81.6
TN (kg/yr)	1160	335	71
MODEL 4 RESULTS (Kings Hill West B)			
TSS (kg/yr)	6740	403	94
TP (kg/yr)	13.4	2.32	82.6
TN (kg/yr)	118	32.3	72.7

Table 5-16 above shows that the stretch treatment targets are achieved for all pollutants, with the exception of Phosphorus. However, an assessment of the proposed bio-filtration basin sizes reveals that to achieve an 85% reduction in Phosphorous would involve an unreasonable size of filter media. The graph shown below in Figure 5-2 show the treatment effectiveness for filter media areas ranging from 1-5% of the catchment area for MUSIC Model 2. The graphs highlight that increasing the filter media area from 2% to 5% (which equates to almost triple the area) has a minimal impact on treatment. As such, a filter area of 2% of the catchment size has been adopted.

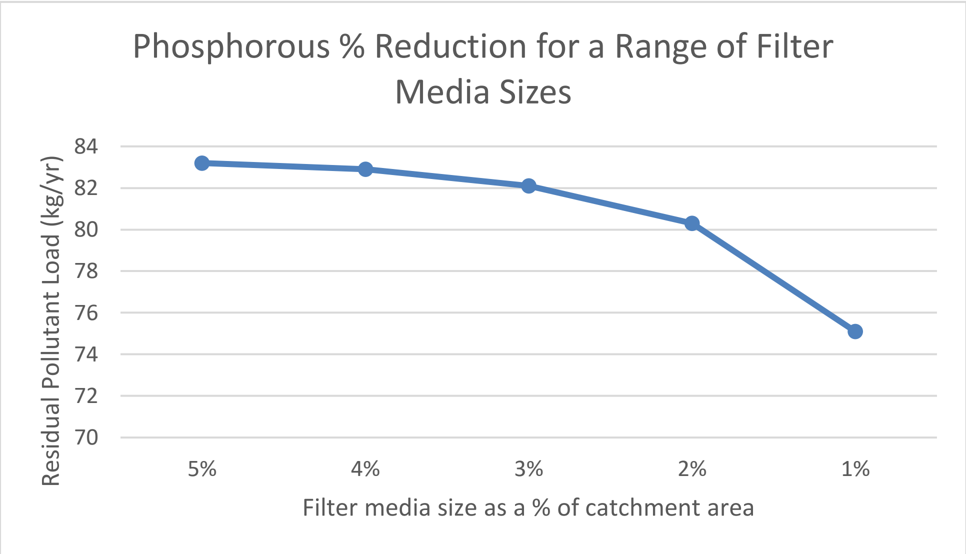


Figure 5-2 – MUSIC Model 2 Phosphorus Percentage Reduction for a range of Filter Media Sizes

5.6.7 Point of Discharge

Discharge from the site will be per existing drainage channels or culverts as shown on drawing DA-08-C4.00 in Appendix A to existing receiving water bodies.

5.6.8 Other Pollutants

The proposed land use is predominantly residential with small isolated pockets of commercial zoning. Residential land uses are generally not known major generators of hydrocarbons, metals and chemical residues and will therefore be removed by the implemented treatment train consisting of gross pollutant trap and bio retention basins.

Any commercial developments will be subject to separate Development Application. If additional treatment for pollutants is required, such as oil/ water separator or proprietary product, this will be defined at the relevant development application stage.

5.7 Maintenance

The following details the components of the stormwater system which will require continual monitoring and regular maintenance. The importance of regular inspections and maintenance are fundamental in ensuring the system is functioning as designed. A summary of the items to be considered during monitoring with the associated consequences and recommended actions to be taken are provided below in Table 5-17. It is recommended that all of these inspections be undertaken at three monthly intervals for the first year of operation. Any major problems encountered during this time should be documented and conveyed to the owner to seek appropriate action. It is also recommended that inspections take place as soon as possible after any heavy rain or major storm events. Table 5-17 outlines the potential issues which may occur within the system. These issues have been separated into general site items and device specific monitoring. The general items listed would be visually apparent during day to day activities. If an issue is identified, appropriate action should be taken immediately. Waiting until the next scheduled monitoring inspection is not advised.

A detailed maintenance strategy will be provided at construction certificate stage of each sub-precinct. This will include timeframes for maintenance operations and details of product specific requirements for any proprietary products.

Table 5-17 – Monitoring and Maintenance Summary

Item to be Monitored	Monitoring Task	Purpose of Monitoring	Maintenance Action
GENERAL			
Sub-soil drains	• Ensure that sub soil pipes are not blocked to prevent filter media and plants from becoming waterlogged.	• If the sub soil pipes become blocked, percolation of water through the system may be reduced, resulting in poor treatment performance and permanent waterlogging of the plants and filter media.	• Flush sub soil drains.
Sediment build up	• Check for built up of sediment in pre-treatment devices. • If sediment build up is noted, identify source of sediment.	• If sediment accumulates in the detention basin, percolation of water into the media may be reduced, resulting in poor treatment performance.	• Once sediment source is identified and stabilised, remove accumulated sediment by flushing the system to a sucker truck and removing from site.
Erosion or Scour	• Check for erosion and scour around the structures. • If scour is noted check for source of scour.	• Erosion impairs filtration systems by preventing uniform distribution of flow from the detention basin. • If left untreated, small concentrations of erosion can quickly spread over large areas becoming costly to repair.	• Once source of damage is identified and rectified, infill any holes with appropriate filter media. • Provide energy dissipation if required. • Replace any damaged plants to meet the design plant schedule.
Litter (Organic)	• Check for litter in and around treatment areas.	• Organic litter can provide an additional source of nutrients to the filtration systems. • Accumulated organic matter can also cause offensive odors and can reduce percolation of water into the filter media.	• Address source of organic litter with appropriate action. • Remove litter.
Litter (Anthropogenic)	• Check for litter in and around treatment areas and structures.	• Litter can potentially block the inlet and outlet structures resulting in flooding, as well as detract from the system's visual amenity.	• Address source of litter with appropriate action. • Remove litter.

Item to be Monitored	Monitoring Task	Purpose of Monitoring	Maintenance Action
Weeds and Invasive Plants	• Identify the presence of any rapidly spreading weeds or invasive plants.	• The growth of weeds can impair a systems performance by: • Shading and out-competing plant species that are important for water treatment or filter stability. • Weeds can spread to downstream environments, compromising ecosystem health. • Weeds can compromise the visual amenity of the storm water system.	• Hand remove weed species or spot spray with a herbicide. Application of herbicide should be restricted.
Plant Condition	Assess plants for; • Disease • Pest infection • Stunted growth • Senescent plants	• During dry periods plants help maintain structure and porosity of the filter media. • During rainfall events above ground vegetation helps to retard and distribute flows and provides scour protection. Below ground the roots provide an important media for trapping or absorbing pollutants as they percolate through the media.	• Maintenance action will depend on the cause of die-back or poor plant health. Once the problem is rectified, infill planting may be required; especially if more than 1 m^2 of plantings have died. Infill planting must be as per the original planting specification.

Item to be Monitored	Monitoring Task	Purpose of Monitoring	Maintenance Action
DEVICES			
Inlet and Outlet Pits	• Ensure inflow areas and grates over pits are clear of litter and are in good/safe condition. • Check for dislodged or damaged pit covers and ensure general structural integrity.	• If the pits become blocked it is likely to cause the basins to not function correctly. • Dislodged or damaged pit covers can be a safety hazard.	• Remove debris and repair any structural damage as required.
Retention Basins	• Check for built up of sediment in pre-treatment trash racks.	• If sediment accumulates in the detention basin, the orifice controlled outlet may become restricted meaning that detained water will not discharge from the device as intended.	• Remove all sediment from the upstream trash racks. Remove accumulated sediment by flushing the system to a sucker truck and removing from site.
Bio-filtration Gardens *	• Check for a healthy coverage of macrophytes. • Take note of any water logging, die back or scour.	• Die back may have occurred during extend periods of water logging or drought. If this has occurred optimal pollutant removal is not being achieved.	• Re-plant as required if die back has occurred. Infill planting must be as per the original planting specification.

Item to be Monitored	Monitoring Task	Purpose of Monitoring	Maintenance Action
Filter Media **	• Check for sediment accumulation on media surface. • Visually inspect for erosion damage. • Ensure ponding is not evident for more than 24 hours after storm events. • Check for organic and anthropogenic litter accumulation.	• If sediment accumulates on the bio-filtration media surface, percolation of water into the media may be reduced, resulting in poor treatment performance. • Erosion impairs bio-filtration systems by changing the bed profile and preventing uniform distribution of flow across the media. • Litter can potentially block the inlet and outlet structures resulting in flooding, as well as detract from the system's visual amenity.	• Once sediment / erosion source is identified and stabilised, remove accumulated sediment and replace top 100mm of filter media as required from the bio-filtration system with appropriate filter media. • Lightly spread and compact replaced filter media using hand tools. • Replace any damaged plants as per the original plant specification. • Remove litter and address the source.
Trash Racks	• Check for built up of sediment, debris and litter in devices. • Ensure inflow areas are clear of litter and are in good/safe condition. • Ensure the trash collection chamber or basket is not full.	• If the rack become clogged the flow and storage capacity of the storm water system will be reduced which may result in damage to storm water assets. • If the trash collection chamber becomes full, the rack will be unable to collect further Gross Pollutants from the site runoff.	• Remove all litter, sediment and debris from the device. • Contact the appropriate authority within Council to repair structural damage.

* It is likely that plants within the bio-filtration systems will require irrigation during the establishment phase. Irrigation should be applied directly to the surface of the filter media. The use of ag pipes for irrigating is not recommended as it encourages the creation of a short-circuit pathway/preferential flow path through the filter material and effects the long-term pollutant removal effectiveness of the filter media.

**Once the Filter Media has been constructed, protection should be provided from sediments from the catchment. A sediment fence should be constructed for the full perimeter of the Filter Media and should remain in place until the whole catchment has been fully developed and revegetated. Full development of the catchment includes the construction and landscaping of all buildings within the catchment.

6 ESSENTIAL SERVICES

6.1 Potable Water

6.1.1 Regional Infrastructure

The water supply authority responsible for the proposed development area is Hunter Water Corporation (HWC). Potable water supply to the site will be generally in accordance with the *Kings Hill Development Water Servicing Strategy Revision H* prepared by SMEC. HWC granted conditional approval for the strategy in August 2019. This correspondence is included in Appendix G.

6.1.2 Internal Infrastructure

A potable water service connection will be provided to each allotment, with sufficient capacity for water supply and firefighting. Internal reticulation will be designed and constructed in accordance with WSAA and HWC guidelines.

6.2 Wastewater

6.2.1 Regional Infrastructure

The authority responsible for wastewater collection within the proposed development area is Hunter Water Corporation (HWC). Collection of wastewater from the site will be generally in accordance with the *Kings Hill Development Wastewater Servicing Strategy Revision G* prepared by SMEC. HWC granted conditional approval for the strategy in February 2014. This correspondence is included in Appendix G.

6.2.2 Internal Infrastructure

A gravity wastewater connection will be provided to each allotment, connected to the trunk wastewater infrastructure proposed in the Kings Hill Development Wastewater Servicing Strategy. Internal reticulation will be designed and constructed in accordance with WSAA and HWC guidelines.

6.3 Electricity

The energy supply authority responsible for network supply to the proposed development area is Ausgrid. Preliminary electrical servicing advice has been provided by Connect Infrastructure Design. A copy of this advice is included in Appendix H.

6.4 Telecommunications

The development is proposed to be serviced by the NBN.

7 SEDIMENT AND EROSION CONTROL

Water quality and soil erosion control are a primary consideration during clearing and construction activities. Each Precinct and Construction Certificate will require the design and implementation of detailed Sediment and Erosion Control Plans or Water and Soil Management Plan depending on the size of sub-stages.

The site contains numerous tributaries of Grahamstown Dam and Irrawang Swamp. Therefore, the prevention of sediment and other pollutants into this system is an important consideration during construction. Sediment runoff is considered a significant contributor to high nutrient levels in wet weather conditions. These elevated nutrient levels often promote excessive growth of algae which can release toxic compounds into the water killing aquatic organisms as well as restricting fish migration, fishing and recreational activities. The direct build-up of sediment in creeks also has several negative impacts on aquatic plant and fish life, as well as reducing the storage and conveyance properties of the watercourse.

Various best practice guidelines exist to assist in preparing management plans for water quality and erosion control, such as *Managing Urban Stormwater: Soils and Construction, Volume 1* (Landcom 4th Edition, reprinted 2006) and *Volume 2* (DECCW 2008).

There are also several pieces of legislation which may need to be considered in the preparation and implementation of appropriate construction water quality and erosion control measures, such as;

- Protection of the Environment Operations Act 1997;
- Fisheries Management Act 1994;
- Soil Conservation Act 1938; and
- Water Management Act 2000.

The above referenced documents would be expected to form the basis for the preparation of Precinct specific designs. However, key measures to be included are outlined below;

- A Soil and Water Management Plan shall be prepared for the subdivision construction works (as part of the CMP) and submitted to the relevant authorities for approval. This would be submitted at the Construction Certificate application. All construction activities are to be undertaken in accordance with the approval soil and water management plan;
- Implementation of erosion and sediment controls prior to significant construction or site disturbance commencing;
- Regular inspections and maintenance of erosion and sediment controls;
- Maximise the retention of riparian and mature native or threatened vegetation;
- Frequent monitoring of turbidity downstream of the construction works;
- Creation of designated no-go areas to minimise site disturbance;
- Minimise areas of earthworks or trenches open at any one time;
- Progressive revegetation of disturbed areas;
- Regular cleaning of public roads which are used by construction traffic; and
- Construction of temporary surface drains to minimise the flow of clean runoff into the construction site. Where possible, surface flows should also be directed away from material stockpiles and open trenches.

8 CONSTRUCTION MANAGEMENT PLAN FRAMEWORK

The following framework is intended to guide the future preparation of detailed Construction Management Plans (CMPs) prepared for each Precinct of the development. These plans are envisaged as a requirement of each Precinct prior to a Construction Certificate. The framework identifies key environmental issues to be considered, potential impacts due to construction activities and suggests management measures which should be included in the CMPs prepared by contractors.

This framework has been prepared to specifically cover the subdivision and infrastructure construction aspects of the development, built form on individual allotments will be considered under another framework.

8.1 Roles and Responsibilities

A key component for the successful implementation in any CMP is ensuring that the project personnel are aware of their roles and responsibilities. All project personnel have a role to play in ensuring the construction site is a safe workplace and that the key environmental objectives are also met.

These roles and responsibilities have been outlined below.

8.1.1 Developer

The developer would normally have an in-house project manager as well as an external contract manager during the construction stage. The contract manager would be expected to check on the status of the site CMPs and undertake checks or formal audits, which may be carried out by the developers own environmental or QA team. The developer and contract manager would also be involved in liaison with government authorities and in providing specific advice or directions in regard to specific environmental requirements for the site.

8.1.2 Government Authorities

Several government agencies will have a role to play during the construction process to cover various aspects of the development. Agencies that may be involved are Port Stephens Council, DECCW (comprising various sub-agencies such as National Parks, DI - Water, EPA etc.) and potentially NSW Work Cover.

8.1.3 Subdivision Infrastructure Contractor

The subdivision contractor will have several representatives who will be involved in the preparation, implementation and ongoing responsibilities for the construction management plan.

- Construction / Project Manager: would have overall responsibility for the site management plans and ensuring that these are implemented and communicated to all site personnel and sub-contractors. The site manager reporting to the construction manager will undertake most of these tasks on a day to day basis;
- Environmental representative: The contractor may have a specialist environmental representative involved on the project depending on the nature and complexity of the environmental issues to be managed during the construction process;
- Site Manager: The site manager will be responsible for ensuring that the requirements of the CMP are being undertaken on site on a day to day basis; including ensuring inductions are undertaken and running weekly site toolkit meetings as required;

- Sub-contractors: All sub-contractors would be expected to go through a site-specific induction, or, if responsible for a significant subcontract, may also have their own construction management plan which would be expected to include those key requirements of the overall site CMP; and
- Site personnel: All site personnel would be expected to go through a site-specific induction process which would train them in the relevant site specific OH&S and environmental issues.

8.2 Key CMP Considerations

8.2.1 Air Quality

The construction of the subdivision infrastructure has the potential to impact on the air quality in the local area due to construction activities such as:

- Soil disturbance due to movement of vehicles / machinery;
- Vehicle / machinery exhaust emissions;
- Wind disturbance of material stockpiles or areas of exposed ground; and
- Uncovered material loads being delivered to site.

Statutory requirements for air quality would fall under the Protection of the Environment Operations Act 1997 and it would also be expected that conditions on air quality during construction would be included in the development consent and / or the construction certificate.

Strategies to limit the impacts on air quality during construction which should be included in the contractor's CMP are outlined below:

- Limiting areas of the site available to the movement of machinery (i.e. designated no-go areas);
- Limiting of the actual area of exposed soil on the site at any one time, ensure disturbed areas are treated as quickly as possible prior to moving on to the next area (i.e. staging of works, re-vegetation / mulching etc.);
- Areas designated for vehicle movement or disturbance (i.e. earthworks areas) should be regularly watered by tanker. Stockpiles which are not covered should also be wet down regularly to prevent dust movement;
- Areas adjacent or near to existing residences or workplaces should be dealt with more stringently during periods of high wind, i.e. minimising work in sensitive areas for short times or applying more dust suppression measures;
- All trucks to / from the site should be covered;
- Long term stockpiles should be covered or vegetated;
- Wash bays or shakedown facilities should be provided at all entry and egress points to ensure vehicles do not track material onto public roads;
- Regular street cleaning should be undertaken to remove any material tracked or blown onto nearby public roads; and
- Undertake regular visual monitoring on site and ensure communication with sensitive receptors so that problems are identified and resolved quickly.

8.2.2 Ecological

The CMP shall include various protocols and management measures to protect existing flora and fauna on the site during the construction phase.

The general strategies to be included in the CMP prepared by the contractor should include the following along with any additional specific requirements of the construction consent conditions or ecological consultants;

- Areas of ecological (e.g. areas of trees or individual trees) or heritage significance shall be clearly fenced to prevent unauthorized disturbance by construction works and vehicles;
- Construction areas adjacent to any proposed conservation areas shall be given special consideration, including the potential provision of buffer zones between the conservation area and any construction works. Special attention shall also be given to ensure no contaminated / sediment laden runoff is able to enter conservation areas from adjacent construction areas through provision of erosion and sediment control structures, bunding/diversion channels or restriction of construction vehicle access;
- Works adjacent to or within watercourses will need to be undertaken in accordance with consent conditions imposed by DECCW (DI Water). Typically, all possible measures shall be undertaken to prevent erosion or contamination/ sedimentation of watercourses or unnecessary destruction of aquatic flora or fauna. All watercourses shall be fenced off to prevent access with appropriate vegetated buffer zones also in place. Construction zones upstream of watercourses shall have appropriate sediment and erosion control measures in place, offline of the watercourse, to prevent sedimentation occurring;
- Where possible, any required works within watercourses shall not be undertaken when rain is forecast to occur;
- Monitoring of the effectiveness of management measures in relation to watercourses and conservation areas shall be regularly undertaken by the contractor, with written records of inspections kept on site, detailing any failures of the management measures and actions taken to remedy the situation. Watercourses should be checked after each rainfall event to check for sedimentation or erosion, and where found, corrective action and repairs undertaken immediately;
- A protocol for dealing with injured animals found on site shall be included in the CMP, i.e. contact numbers for local WIRES representative;
- A procedure for tree removal in approved construction areas shall be prepared by an appropriately qualified ecologist and included in the CMP. This procedure should consist of the following as a minimum;
  - A pre-clearing survey shall be undertaken by appropriate ecological consultant to determine potential habitat trees. These trees should be examined for the presence of fauna;
  - Where detected, animals should be given time to leave or removed by the ecologist;
  - Following clearing activities, the area should be examined for injured animals. Should any injured animals be discovered, the local WIRES representative should be called; and
  - The loss of tree hollows should be offset by the placement of nest boxes, the number and location to be advised by the ecologist.

8.2.3 Site Safety & Emergency Response Plan

Various statutory requirements would normally be incorporated into the CMP by the contractor, including the following:

- Occupational Health and Safety Act 2000;
- Occupational Health and Safety Regulation 2001; and
- Protection of the Environment Operations Act 1997.

All construction personnel would need to have completed the General Construction Industry Health and Safety Induction training but would also be required to undergo the site-specific induction for the site which would be the responsibility of the principal contractor. The site induction would include all relevant safety issues as well as any site-specific environmental requirements of the site, such as the protection of specific flora or fauna and their habitat.

The site OH&S and emergency response plan would form part of the overall CMP and would be included in the induction undertaken by all construction personnel; this would be expected to include the following as a minimum;

- Roles and responsibilities;
- Emergency contact phone numbers including prioritized list of contact names;
- Procedures for incident reporting and investigation;
- Emergency evacuation points;
- Identification of site specific risks;
- Identification of site specific environmental requirements;
- Work method statements;
- Safe operation of equipment and maintenance procedures;
- Storage and handling of hazardous materials and material safety data sheets; and
- Standard forms for reporting and recording various site activities.

8.2.4 Waste

The construction of the subdivision infrastructure would be expected to generate waste materials such as concrete, cleared vegetation, demolition material, sanitary/domestic wastes, packaging, oils and greases, timber and plastics.

Waste is a major issue for all Local Council's with recovery, recycling and reuse a key element in minimizing waste in landfills and the drain on new resources.

The waste hierarchy established under the CMP, that ensures that resource management options are considered against the following priorities;

1. Avoidance, including action to reduce the amount of waste generated by households, industry and all levels of government;
2. Resource Recovery, including reuse, recycling, reprocessing and energy recovery, consistent with the most efficient use of the recovered resources; and
3. Disposal, including management of all disposal options in the most environmentally responsible manner.

A requirement of each stage of the development will be the completion of a Waste Management Plan (WMP). The WMP will form part of the CMP and generally follow the layout required by Port Stephens Council's proforma for Waste Management.

All Contractors engaged on the Project will be required to prepare a Waste Management Plan specific to the stage of works under construction. This requirement will be included in the Contractor's Construction Management Plan.

The Contractors site specific management plan will be regularly audited by KHD's Contract Manager and the plan assessed at the completion of each stage to determine potential improvements in successive construction stages.

8.2.5 Construction Noise

For the purposes of this project application, reference is made to the document *Construction Noise Guideline* (DECCW, 2009), which has been prepared by DECCW in consultation with the NSW Department of Planning, RMS, WorkCover, NSW Health and various local councils.

The guideline is specifically aimed at managing noise on construction sites regulated by DECCW; however, it is expected that even where local councils are responsible for managing noise from a particular construction activity, the local council may seek guidance from DECCW. The "Construction Noise Guideline" is therefore also expected to be used as a point of reference for council.

The general steps for managing noise impacts from construction are;

1. Identify sensitive land uses;
2. Identify construction hours;
3. Identify noise impacts; and
4. Select and apply the best work practices.

The above steps are briefly discussed below in order to provide an overall direction for noise management for the construction of the development, however the contractor as part of the CMP will finalise the management measures for noise during construction and undertake any monitoring or further investigations required.

8.2.5.1 Sensitive Land Uses

There are a number of sensitive land uses within close proximity to the proposed development, including existing residential dwellings, Riding for the Disabled NSW as well as fauna. After construction of the first Precinct, subsequent stages of development will also need to consider existing stages.

8.2.5.2 Construction Hours

The recommended standards hours for construction work are shown below in Table 8-1. There are some situations where construction work may need to be undertaken outside of these hours, and this may be acceptable, subject to prior approval by the relevant authority.

Table 8-1 - Standard Hours for Construction

Work Type	Recommended standard hours of Work(1)
Normal Construction	Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or Public Holidays
Blasting	Monday to Friday 9am to 5pm Saturday 9am to 1pm No blasting on Sundays or public holidays

Note: (1) Subject to relevant authority conditions of consent.

8.2.5.3 Noise Impacts

In order to determine the impacts of construction noise for the development, it is required to select an assessment method (quantitative or qualitative) appropriate for the construction works.

The quantitative assessment method involves predicting noise levels and comparing them with the levels in the DECCW guidelines. Guidance levels are given for airborne noise at sensitive land uses, ground-borne noise and sleep disturbance. The qualitative method for assessing noise is a simplified way to identify the cause of potential noise impacts and avoids the need to perform complex predictions by using a checklist approach to assessing and managing noise.

At this stage it has been assumed that a qualitative approach is satisfactory, the work areas in close proximity to existing residential development would not be long term construction areas, i.e. works in those areas will occur intermittently and for relatively short periods at any one time. All significant construction works would also be expected to occur during normal construction hours as outlined above and would not be expected to require high noise generating equipment such as rock drilling, jack hammering, rock breaking or impact piling.

Based on a qualitative assessment approach, the work practices outlined in the following section should be part of the contractor's overall CMP for noise management as a minimum. Additional detailed assessment may be required as a result of consent conditions by the relevant authority or due to specialist construction activities being identified as required in close proximity to the existing residential developments.

8.2.5.4 Work Practices

In order to reduce the potential impacts of construction noise at the site, the following work practices would be expected to be employed by the contractor;

1. Universal Work Practices

   - Regularly train workers and contractors to use equipment in ways to minimise noise;
   - Ensure site managers periodically check the site and nearby residences for noise problems so that solutions can be quickly applied;
   - Keep vehicle operators informed of designated vehicle routes, parking locations, acceptable delivery hours or other relevant practices; and
   - Avoid mobile plant clustering near residences and other sensitive land uses.

2. Consultation and Notification

- Provide information to neighbours before and during construction through media such as letterbox drops, meetings or individual contact;
- Maintain good communication between the community and project staff;
- Provide a toll-free contact phone number for enquiries during works;
- Have a documented complaints process, including an escalation procedure so that if a complaint is not satisfied there is a clear path to follow;
- Implement all feasible and reasonable measures to address the source of the complaint; and
- Keep a register of any complaints, including details of the complaint such as date, time, person receiving complaint, complainants contact number and name, description of the complaint, time of verbal response and timeframe for written response.

3. Plant and Equipment

- Regularly inspect and maintain equipment to ensure it is in good working order;
- Where possible and feasible, select plant for particular work based on lowest noise rating; and
- Operate in a quiet and efficient manner.

4. Site Planning

- Restrict areas in which mobile plant can operate so that it is away from residences and other sensitive land uses at particular times;
- Locate site vehicle entrances away from residences and other sensitive land uses;
- Use natural landform as a noise barrier – place fixed equipment in site low points or behind earth berms; and
- Note the presence of any large reflecting surfaces on and off site that might increase noise levels, and avoid placing noise producing equipment in locations where reflected noise will increase noise exposure.

5. Work Scheduling

- Where possible, provide respite periods for particularly noisy construction operations;
- Schedule activities to minimise noise impacts; and
- Organise deliveries and access to less sensitive times of the day.

8.2.6 Construction Vibration

Vibration can occur as a result of construction activities, particularly compaction of roads or earthworks areas. If vibration is excessive and sensitive buildings are located close to the source of vibration, damage to buildings can occur.

Vibration and its associated effects are normally classified as continuous, impulsive or intermittent as defined below;

- Continuous – vibration continues uninterrupted for a defined period.
- Impulsive – vibration is a rapid build up to a peak followed a damped decay.
- Intermittent – this vibration can be defined as interrupted periods of continuous or repeated periods of impulsive vibration.

Vibration is not expected to be a significant issue; however, the CMP will contain management and complaint handling procedures to ensure that any issues with vibration are identified quickly and remedial actions taken before damage occurs.

The following management measures are to be included in the CMP, with reference made to the DECCW document titled *"Assessing Vibration: A Technical Guideline";*

- Prior warnings are to be provided to potentially effected premises where vibration levels are expected to be in excess of the nominated levels, including how long the activity is expected to occur;
- If vibration complaints are received, the following control measures may need to be implemented;
  - Choose alternative lower-impact equipment or methods wherever possible;
  - Scheduling the use of vibration causing equipment at the least sensitive time of the day;
  - Routing, operating or locating high vibration sources far away from sensitive receptors;
  - Sequencing operations so that vibration causing activities do not occur simultaneously; and
  - Restricting the use of roads near sensitive areas for construction traffic, alternatively limit vehicle speeds or ensure road surface is maintained and kept smooth.

Vibration monitoring is not expected to be required during construction, however should complaints be received or the contractor unsure in regard to the impacts of a particular construction activity, independent monitoring should be undertaken.

Monitoring would be undertaken in accordance with DECCW requirements and a report completed including the following information as a minimum;

- Relevant guideline or policy that has been applied;
- Details of any background measurements that have been undertaken;
- Details of instruments and methodology used for measurements (including calibration details);
- Site map showing location of vibration sources, measurement locations and receivers;
- Vibration criteria;
- Vibration predictions for the proposed activity;
- A discussion of the proposed mitigation measures, the vibration reduction likely and the feasibility of these measures; and
- Compliance measurement.

8.2.7 Hazardous Materials

The following strategies should be incorporated into the CMP to ensure that no hazardous materials cause soil contamination or adversely impact on human health or the local environment in any other way;

- Emergency procedures should be well defined to cater for hazardous material spills, spill kits should be kept on site and all spills should be cleaned up immediately;
- Chemicals should be stored in appropriately labelled containers in designated areas away from sensitive areas. Storage and refueling areas should be bunded to prevent migration of any spills that may occur; and

- The storage of hazardous materials on site should be minimised where possible. Records should be kept on site of all hazardous material types, including material safety data sheets and quantities.

8.2.8 Traffic Management

It is recognised that an increase in heavy vehicles in the area due to the construction of the subdivision may have impacts on the existing road network. These potential impacts include;

- Increased traffic noise;
- Damage to the existing road pavements if not designed for heavy vehicles;
- Additional traffic delays at intersections or generally on the roads due to slow vehicles; and
- Tracking of construction materials and soil on the existing road network.

It is envisaged that the primary construction access to the site will be off Newline Road as this provides the main point of access for the Kings Hill site.

The CMP prepared by the contractor for the construction works would be required to include a construction traffic management plan covering the following issues:

- Authority requirements and consents/licenses;
- Consideration of risks and incident management;
- Identify main site access points;
- Consideration of vehicle access routes for workers/visitors to site offices and trucks to material / machinery delivery areas. Include consideration of parking requirements for workers vehicles on the site;
- Consider impacts to the existing road networks and any temporary road diversions;
- Consider access to other properties and how this will be maintained during construction. If required, consider communication strategy to affected properties;
- Identify speed zones through construction areas;
- Consider staging of the construction and changing traffic control requirements;
- Review possible types of traffic control devices and signage requirements; and
- Prepare drawings showing the adopted traffic control devices, traffic control staging, road diversions (if any), main access routes for different vehicle categories and all signage requirements.

The site inductions carried out by all construction personnel should include the key points from the traffic management plan to ensure that all persons are aware of the main vehicle access points and routes through the site as well as the key areas of risk.

9 CONCLUSION

9.1.1 Site Earthworks

It is expected that reshaping of the existing topography will be required to overcome a number of constraints, mostly attributable to the excessive slope of the site. The finished surface level will be designed to:

- Minimise the extent of earthworks;
- Balance the cut and fill to minimise haulage between precincts; and
- Balance the cut and fill to minimise the need for export or import of material from site.

Detailed bulk earthwork plans will be provided at Precinct level development applications.

9.1.2 Road Network

The proposed road network has been designed to incorporate major circulation routes for private vehicles, public transport, cyclists and pedestrians as well as local roads for access to local neighbourhoods and residential lots. Perimeter roads, to facilitate fire fighting access, have also been integrated into the network.

The main access point to the site is from the new grade separated interchange on the pacific highway. The collector roads provide linkage to precincts, community facilities, the local centre and school.

Detailed road design details will be provided at Precinct level development applications.

9.1.3 Stormwater Management Conclusions

Based on the above assessment it has been shown that the URA can be developed generally in accordance with the Landcom Water's Stretch Targets, PSC DCP and the *BMT WBM Guidelines* prepared for the site through the introduction of a number of stormwater management devices. These devices include gross pollutant traps, bio-filtration basins, retention basins and detention basins. Preliminary locations and sizing of devices have been included in the above report and shown in the attached figures.

The purpose of this study is to provide a guiding Stormwater Strategy on a master plan scale. Information provided in this study should guide but not be solely relied upon when submitting future individual Development Applications. It is noted that future applications may differ from this report due to changes to the masterplan and road layout, catchment areas and best design practices evolving as the development and stages are rolled out. Additional stormwater management options such as vegetated swales, rain gardens integrated into the streetscape, wetlands and proprietary products used for conveyance and treatment should be considered.

An additional level of detail will be provided with the stormwater strategy submitted for each precinct, at precinct level development application.

9.1.4 Wetland Impact Assessment

The proposed development is located upstream of Irrawang Swamp and Coastal Wetland 803. Alluvium were engaged to undertake an assessment of the impact of the proposed development on both of the downstream water bodies and provide recommendations on water quality and quantity measures to be implemented into the stormwater management strategy. The assessment determined that the major risks to the wetlands, including increases in periods of increased inundation depth and reductions in seasonal drying patterns are unlikely to occur.

9.1.5 Essential Services

Each lot will be provided with potable water, wastewater, electricity and telecommunications. A sewer and wastewater servicing strategy has been conditionally approved by Hunter Water Corporation.

Servicing strategies and detail design in collaboration with the relevant authority will progress in line with the detailed design of each precinct.

9.1.6 Sediment and Erosion Control

Staging, stabilisation and erosion and sediment control will be managed during construction activities to minimize sediment runoff from the site. Concept sediment and erosion control plans will be provided with precinct level development applications. Detailed erosion and sediment control plans will form part of the Contractors construction management plan provided as part of the construction certificate.

9.1.7 Construction Management Plan Framework

Prior to issue of a Construction Certificate for any Precinct or Stage, it is proposed that a Construction Management Plan (CMP) be prepared. The CMP is to give consideration to the items contained within this report as a minimum. The approved CMP is to be implemented throughout construction activities, overseen by the nominated delegate.

9.2 DCP D14 Compliance Summary

The purpose of this report is to describe the physical infrastructure proposed as part of the development, and how compliance with the associated legislation is achieved. This document is to be read in conjunction with the Development Application as a whole, however the following specific items have been addressed in this report.

Table 9-1 Port Stephens Council DCP Section D14 Compliance

Objective – Structure Planning and Precinct Planning (D14.A)		**How Objective is Addressed**
D14.11 & D14.12	Servicing	The *Kings Hill Development Water Servicing Strategy Revision H* and the *Kings Hill Development Wastewater Servicing Strategy Revision G* prepared by SMEC has been conditionally approved by Hunter Water Corporation. In addition, liaison with Ausgrid and NBNCo has been undertaken to confirm electrical and telecommunication services can be provided to the site.
Objective – Traffic and Transport (D14.B)		**How Objective is Addressed**
D14.13 & D14.14	Transport Movement Hierarchy	The proposed road hierarchy plan is shown on drawing DA-08-C3.00 in Appendix A, showing the major circulation routes for private vehicles, public transport, cyclists and pedestrians.
D14.15 & D14.16	Collector Roads	As shown on drawing DA-08-C3.00, internal collector roads linking precincts, community facilities, the local centre and school, generally in accordance with the Locality Controls Map at Figure DAC. It is proposed to orientate allotments and dwellings to face and have access from the collector roads, however this level of information will be provided at a Precinct level development application.
D14.71	East-West Road 4 Lane Section	A traffic investigation has been undertaken by GHD on behalf of Council and confirmed the need for 4 lanes for approximately 750m into the site. This is reflected in the proposed design.
D14.22 & D14.23	Public Transport	Designate public transport routes have been provided generally in line with Locality Controls Map. A bus route has not been provided linking the EWL and adjacent Precinct 8 due to excessive grades, refer to section 4.4.1. The location of bus stops will be determined at Precinct level DA.
D14.24	Paths	Pedestrian and cycle paths have been provided generally in line with the Locality Controls Map.
D14.25	Pedestrian Path	A pedestrian path is to be provided on one side and a shared path on the other of all collector roads, B2/B4 roads and within 400m and providing primary frontage to a school or major community facility.

Objective – Drainage and Water Quality (D14.D)		How Objective is Addressed
D14.30	Eastern Catchment & Grahamstown Dam	The Kings Hill Urban Release Area Eastern Channel Flood Study completed by Northrop Consulting Engineers, included in Appendix C, details the diversion of flows from the eastern catchment away from Grahamstown Dam. This shows that stormwater from development areas up to 0.2% AEP design flood event is prevented from discharging into Grahamstown Dam via a diversion channel on the eastern side of the Pacific Highway.
D14.31 & 14.32	Water Management Strategy	The purpose of this report is to provide a stormwater drainage plan in accordance with the guidelines outlined in the *Kings Hill Urban Release Area Water Management Strategy Guidelines* completed by BMT WBM in 2013. Section 6 of this report addresses drainage and water quality management for the entire catchment. The proposed stormwater control measures for each sub-catchment are shown on drawings DA-08-C4.00 to 4.03, however additional details will be provided at precinct level development applications.
Objective – Natural Resources (D14.E)		
D14.35	Riparian Corridors	The riparian extents for existing streams have been determined in accordance with DI Water's *Guidelines for riparian corridors on waterfront land.* Drawing DA-08-C7.00 shows the calculated riparian extents. A controlled activities approval will be obtained, where necessary, in accordance with the Water Management Act 2000 at Construction Certificate phase.

APPENDIX A -
Design Drawings

KINGS HILL URBAN RELEASE AREA,

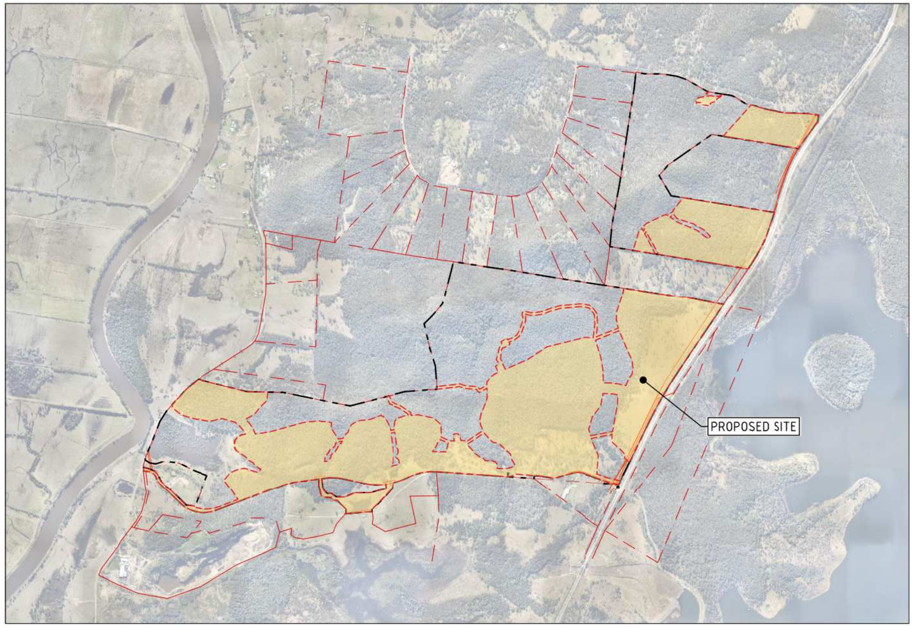
KINGS HILL,

N.S.W. 2324

DEVELOPMENT APPLICATION

- MASTERPLAN -

NORTHROP



DRAWING INDEX

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
E	ISSUED FOR APPROVAL	JB	SC	CP	10.05.19
F	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
G	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
H	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
I	ISSUED FOR APPROVAL	JB	SC	CP	25.11.18
J	ISSUED FOR APPROVAL	WC	SC	CP	06.12.19

CLIENT
KINGS HILL DEVELOPMENTS

DRAWING NOT TO BE USED FOR CONSTRUCTION UNLESS VERIFICATION SIGNATURE HAS BEEN ADDED

PLANNER
JW PLANNING

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PROJECT
KINGS HILL
DEVELOPMENT APPLICATION
MASTERPLAN

DRAWING TITLE
COVER SHEET, DRAWING INDEX AND LOCALITY PLAN

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C0.00

REVISION
J

DRAWING SHEET SIZE = A1

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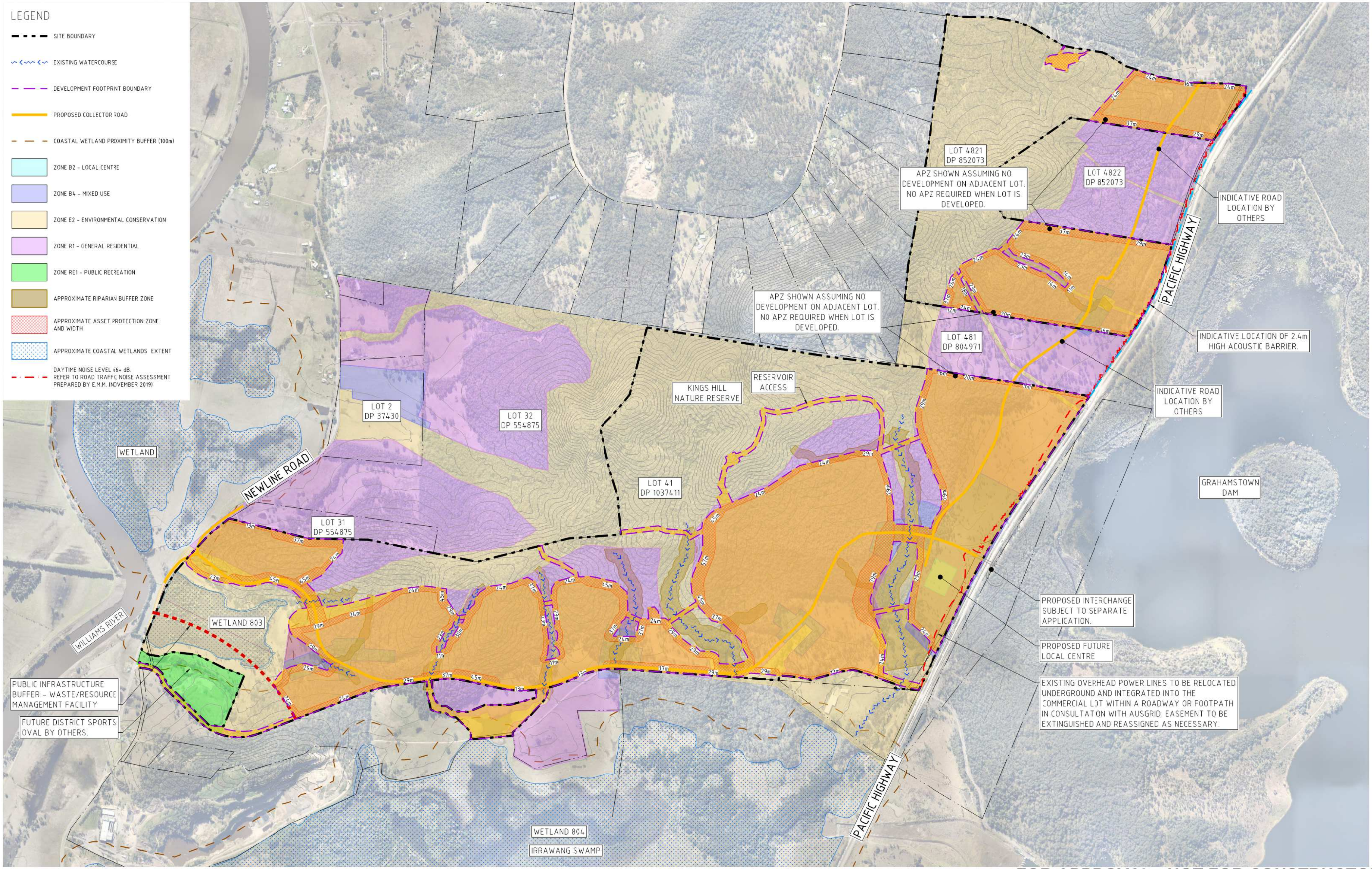

VERIFIER: B.CLARK
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FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
G	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
H	ISSUED FOR APPROVAL	JB	SC	CP	28.05.19
I	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
J	ISSUED FOR APPROVAL	WC	SC	CP	25.11.19
K	ISSUED FOR APPROVAL	JB	SC	CP	28.11.19
L	ISSUED FOR APPROVAL	JB	SC	CP	06.12.19

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PROJECT
KINGS HILL
DEVELOPMENT APPLICATION
MASTERPLAN

DRAWING TITLE
SITE CONSTRAINTS PLAN

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C1.00

REVISION
L

DRAWING SHEET SIZE = A1

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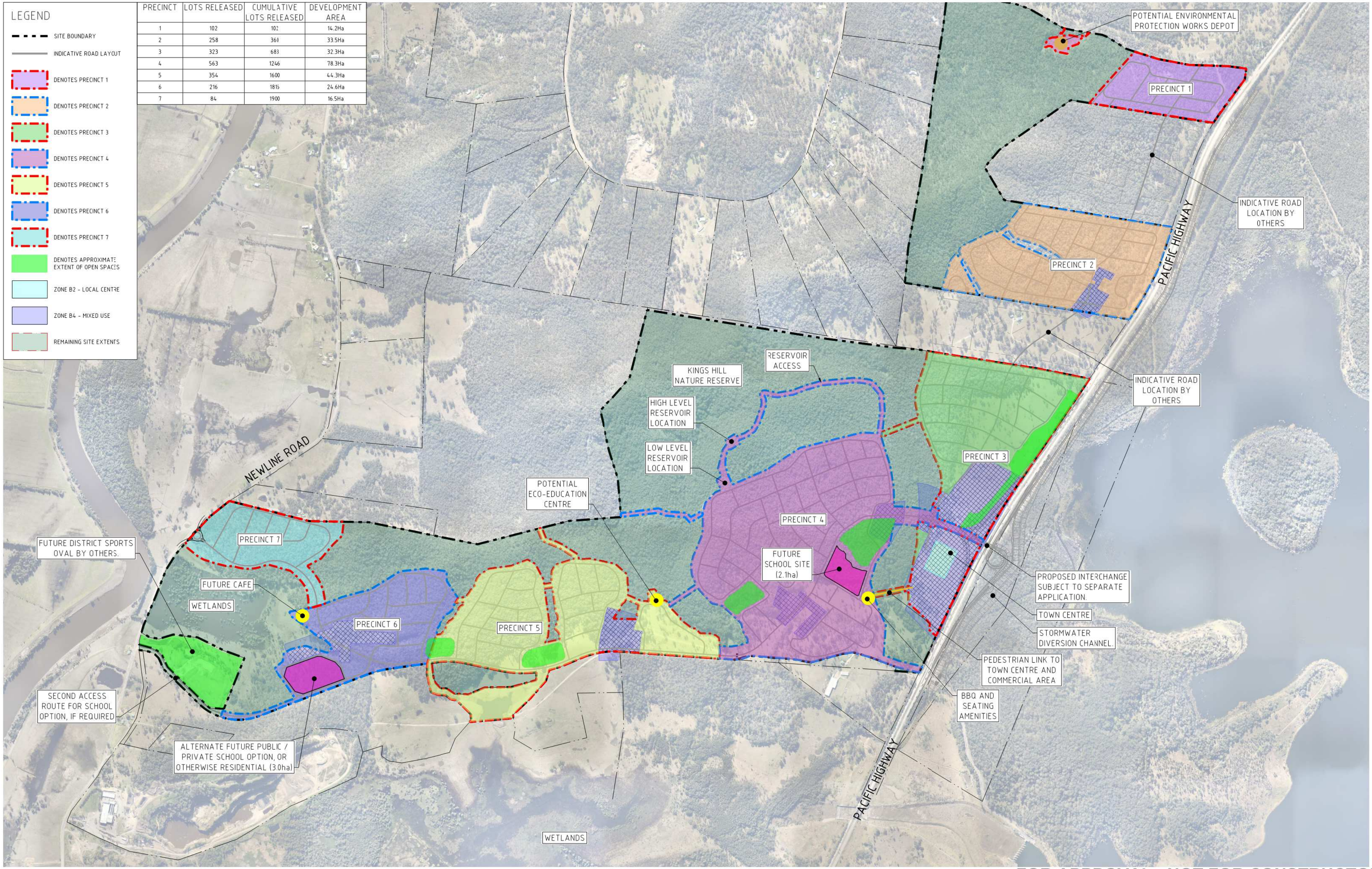

LEGEND

- SITE BOUNDARY
- INDICATIVE ROAD LAYOUT
- DENOTES PRECINCT 1
- DENOTES PRECINCT 2
- DENOTES PRECINCT 3
- DENOTES PRECINCT 4
- DENOTES PRECINCT 5
- DENOTES PRECINCT 6
- DENOTES PRECINCT 7
- DENOTES APPROXIMATE EXTENT OF OPEN SPACES
- ZONE B2 - LOCAL CENTRE
- ZONE B4 - MIXED USE
- REMAINING SITE EXTENTS

PRECINCT	LOTS RELEASED	CUMULATIVE LOTS RELEASED	DEVELOPMENT AREA
1	102	102	14.2Ha
2	258	360	33.5Ha
3	323	683	32.3Ha
4	563	1246	78.3Ha
5	354	1600	44.3Ha
6	216	1816	24.6Ha
7	84	1900	16.5Ha

DRAWN: J.BEVITT
DESIGNED: P.BURL
JOB MANAGER: C.PIPER
VERIFIER: B.CLARK

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REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
I	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
J	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
K	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
L	ISSUED FOR APPROVAL	WC	SC	CP	25.11.19
M	ISSUED FOR APPROVAL	JB	SC	CP	28.11.19
N	ISSUED FOR APPROVAL	JB	SC	CP	06.12.19

CLIENT
KINGS HILL DEVELOPMENTS
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PLANNER
JW PLANNING

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SCALE 1:8000@ A1 — 0 100 200 300 400m

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Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
PROPOSED PLAN OF SUBDIVISION

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C2.00

REVISION
N

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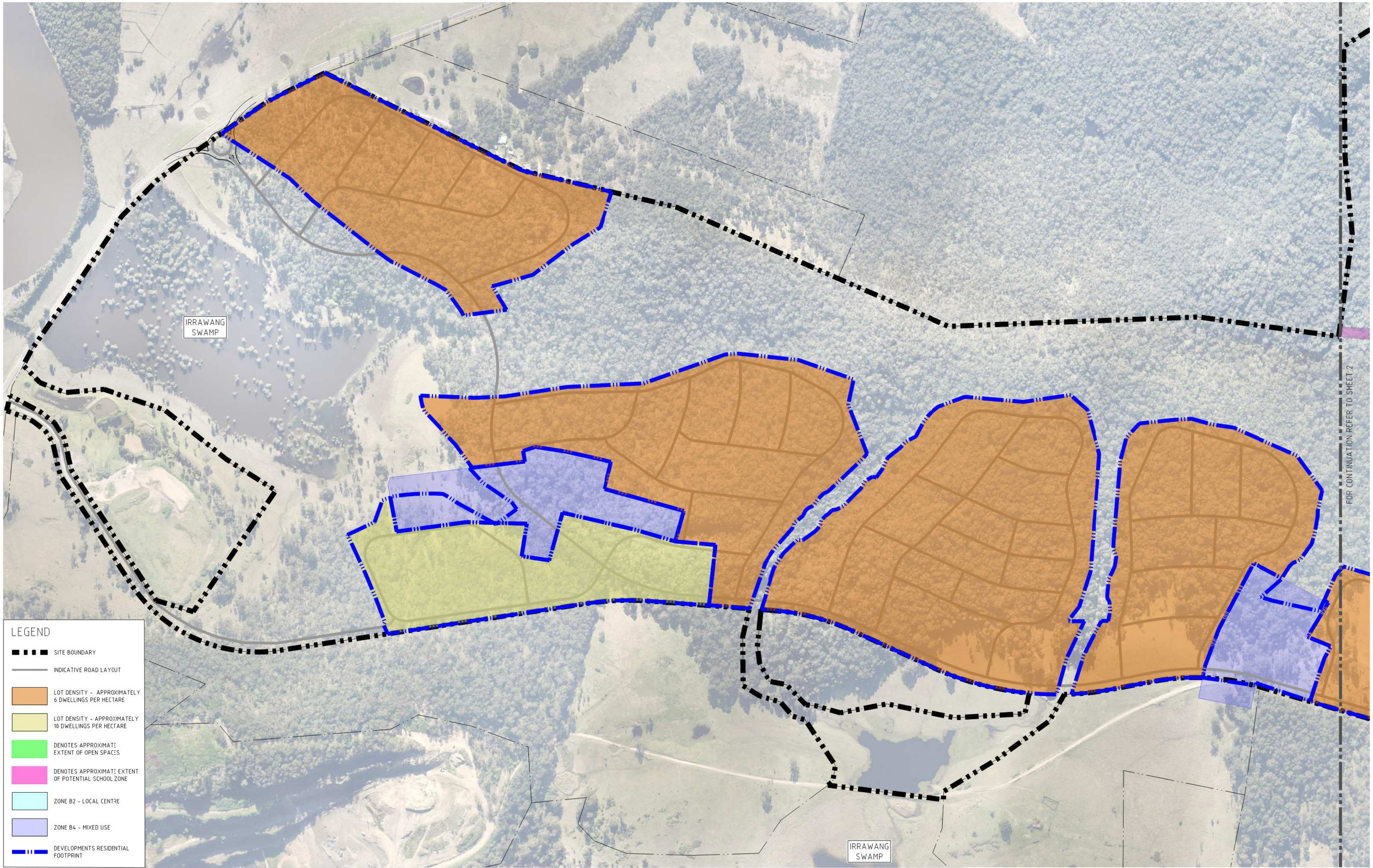

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
PROPOSED PLAN OF SUBDIVISION - SHEET 1

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C2.01

REVISION
H

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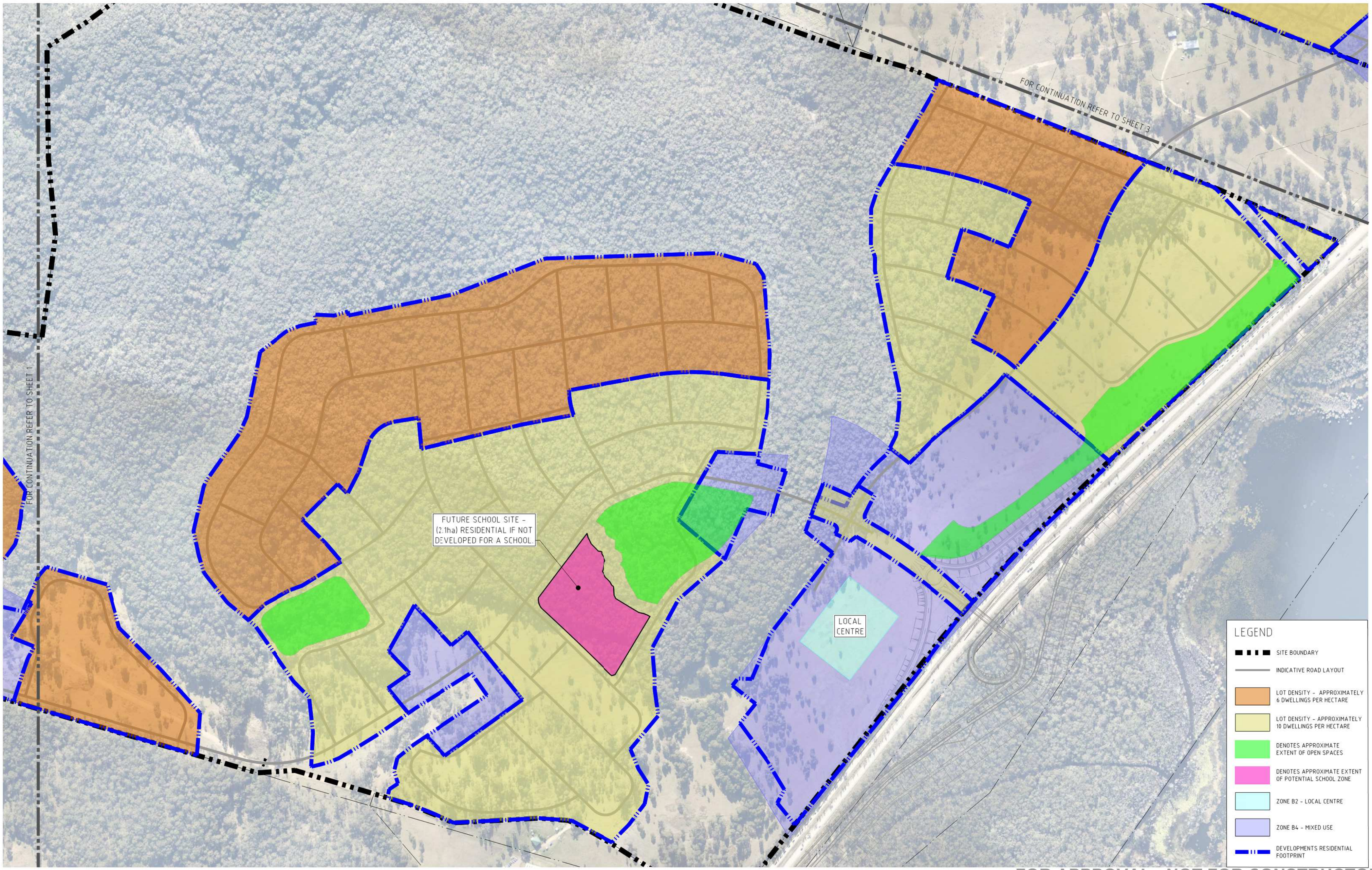

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VERIFIER: B.CLARK

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
PROPOSED PLAN OF SUBDIVISION - SHEET 2

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C2.02

REVISION
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DRAWN: J.BEVITT
DESIGNED: P.BURL
JOB MANAGER: C.PIPER
VERIFIER: B.CLARK

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
PROPOSED PLAN OF SUBDIVISION - SHEET 3

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C2.03

REVISION
H

DRAWING SHEET SIZE = A1

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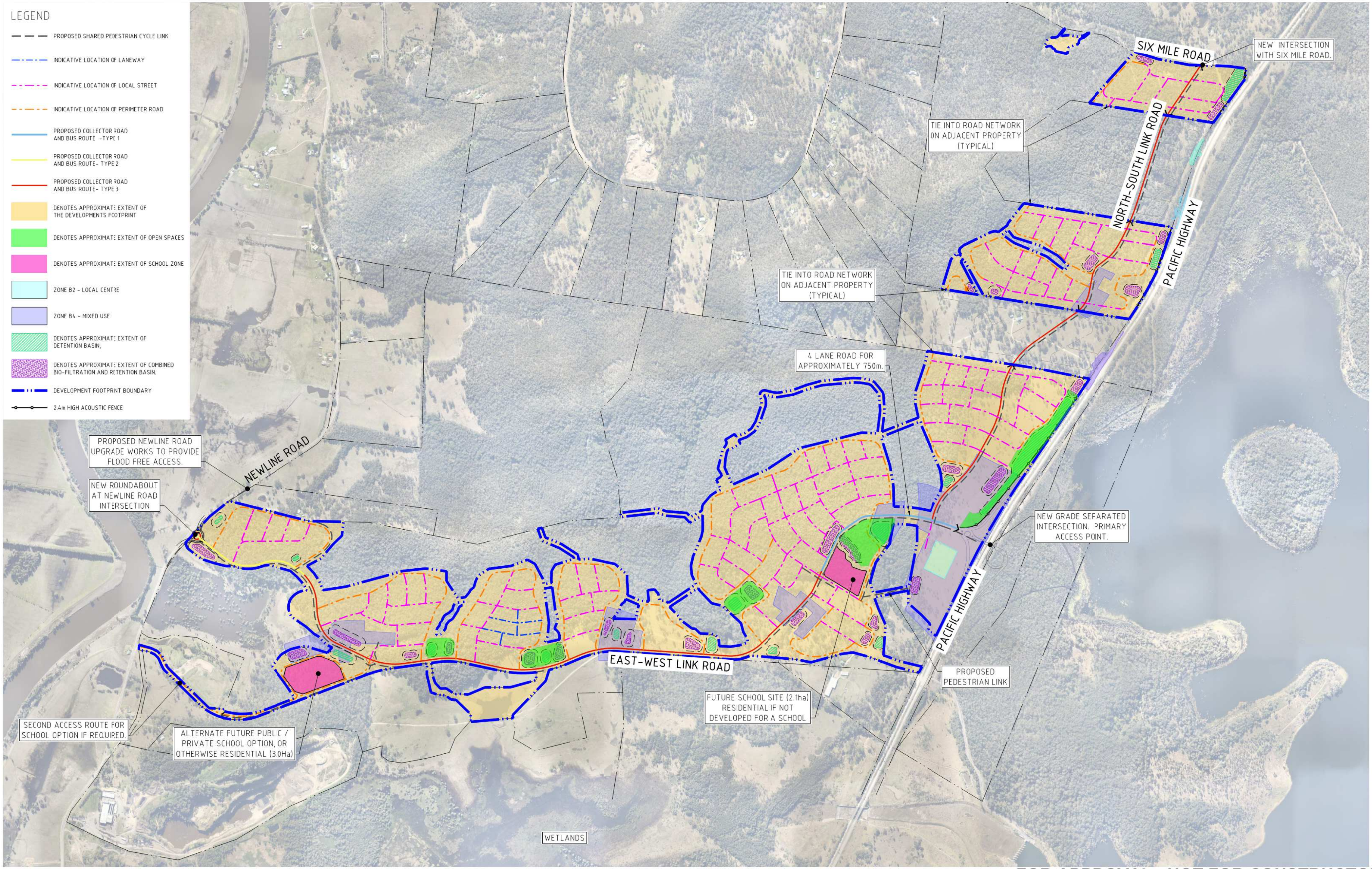

DRAWN: J.BEVITT
DESIGNED: P.BURL
JOB MANAGER: C.PIPER
VERIFIER: B.CLARK

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J	ISSUED FOR APPROVAL	WC	SC	CP	28.11.19
K	ISSUED FOR APPROVAL	JB	SC	CP	2.12.19

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
ROAD HIERARCHY AND PEDESTRIAN CONNECTIVITY PLAN

JOB NUMBER **NL120526**
DRAWING NUMBER **DA-08-C3.00**
REVISION **K**
DRAWING SHEET SIZE = A1

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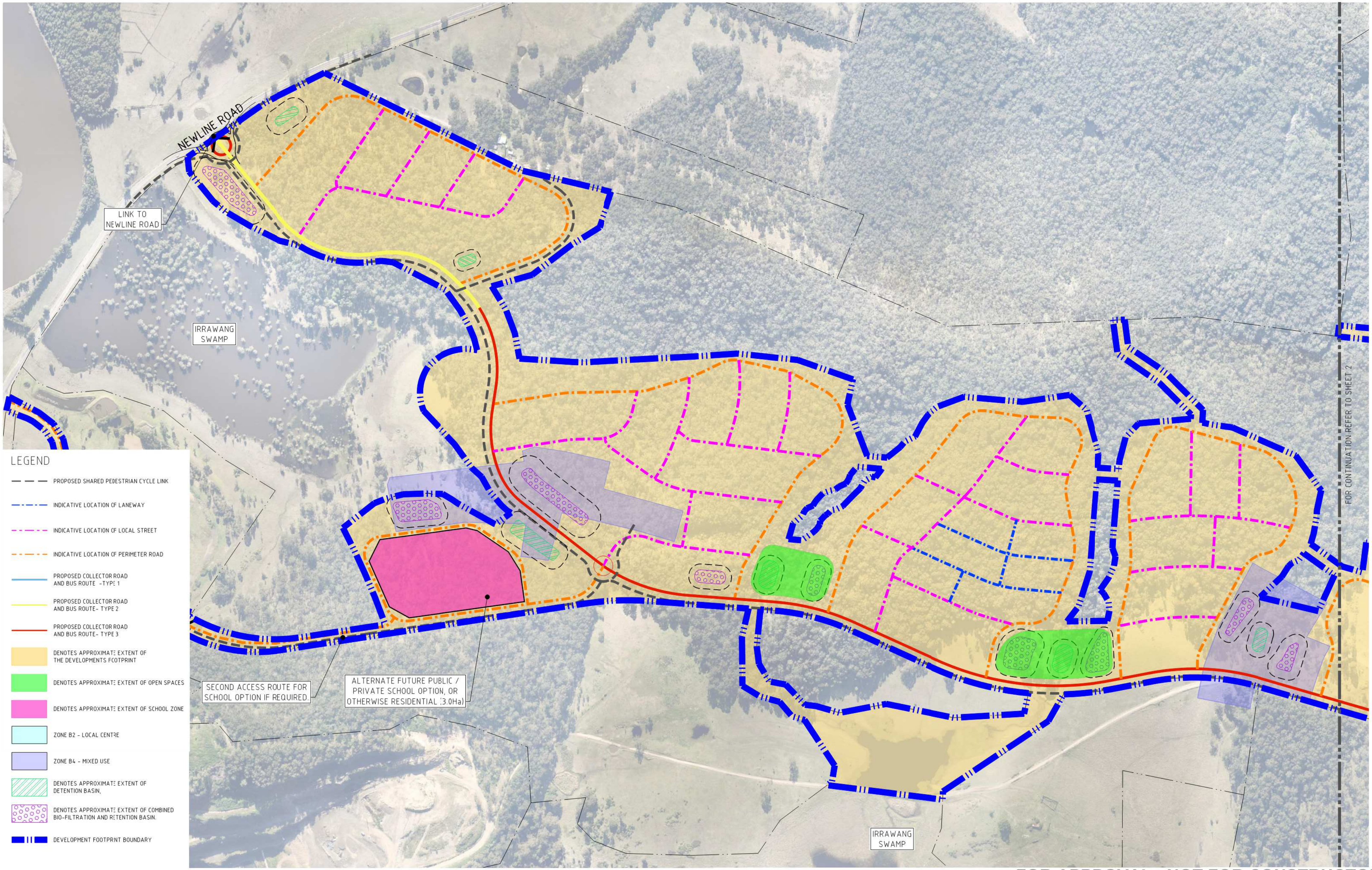

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
ROAD HIERARCHY AND PEDESTRIAN CONNECTIVITY PLAN - SHEET 1

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C3.01

REVISION
I

DRAWING SHEET SIZE = A1

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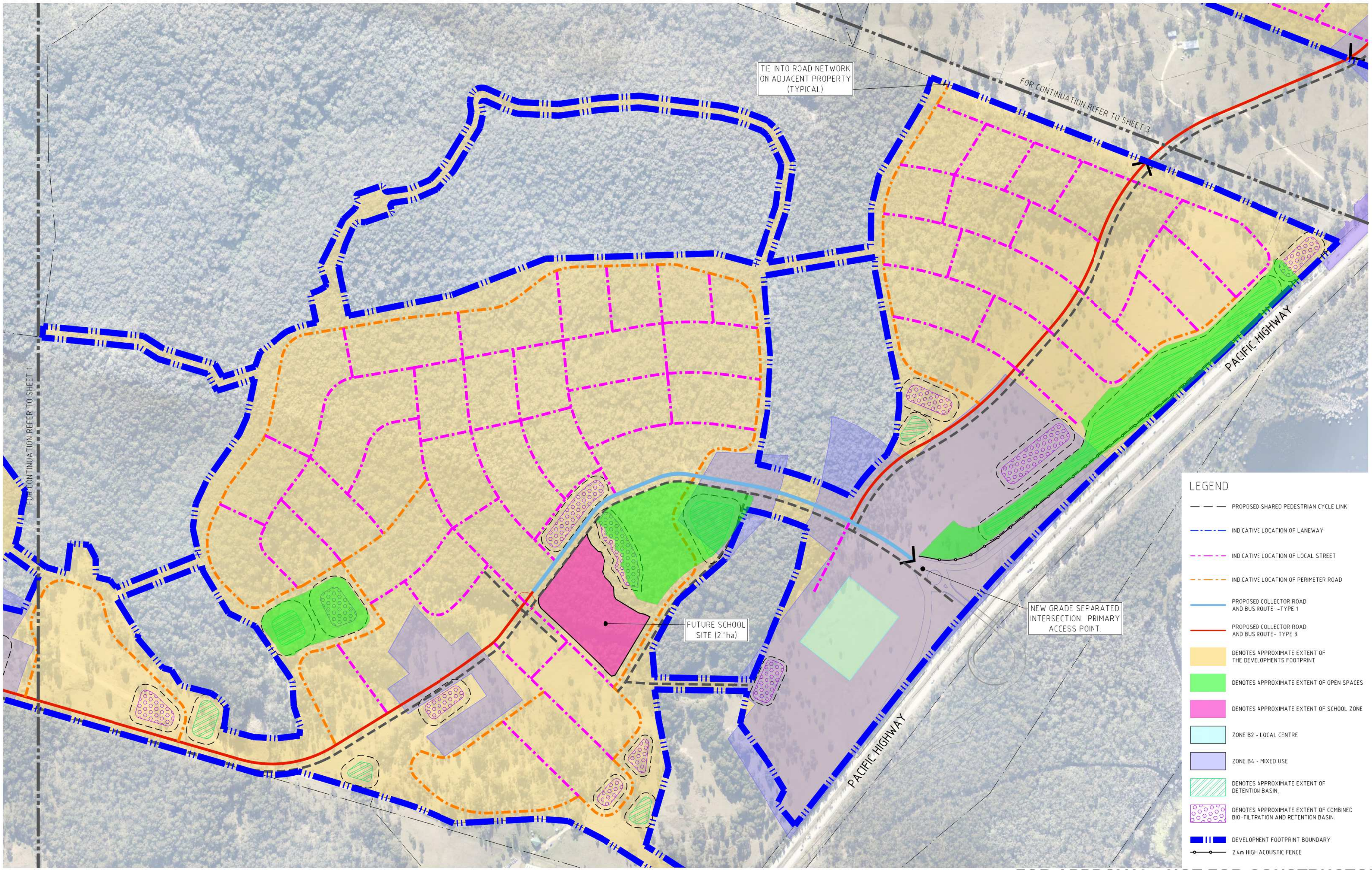

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
ROAD HIERARCHY AND PEDESTRIAN CONNECTIVITY PLAN - SHEET 2

JOB NUMBER **NL120526**

DRAWING NUMBER **DA-08-C3.02**

REVISION **J**

DRAWING SHEET SIZE = A1

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VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
ROAD HIERARCHY AND PEDESTRIAN CONNECTIVITY PLAN - SHEET 3

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C3.03

REVISION
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DRAWING SHEET SIZE = A1

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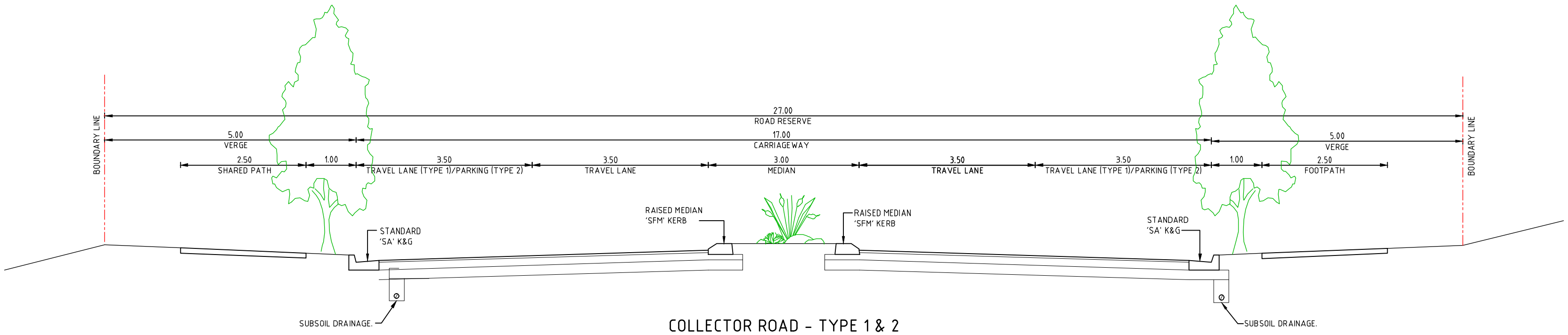
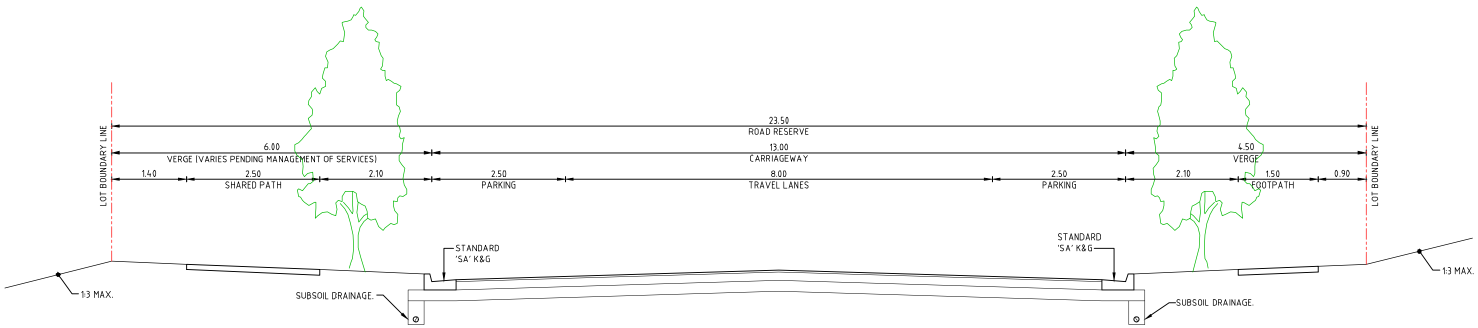
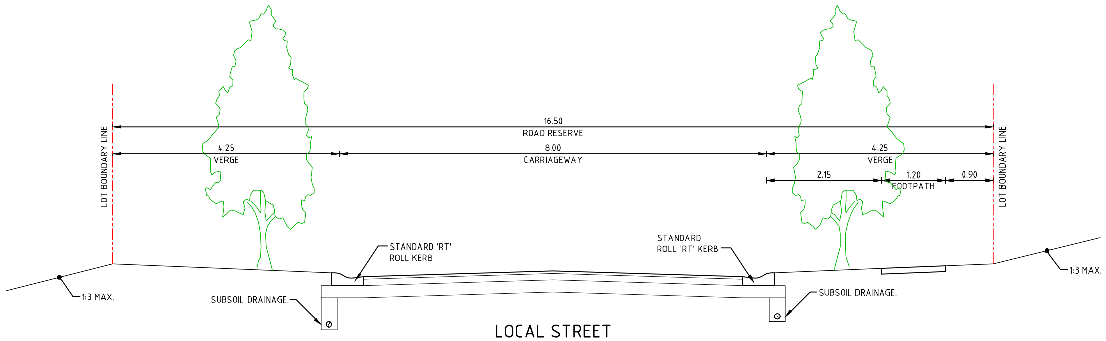


COLLECTOR ROAD - TYPE 1 & 2
TYPICAL SECTION



COLLECTOR ROAD - TYPE 3
TYPICAL SECTION



LOCAL STREET
TYPICAL SECTION

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

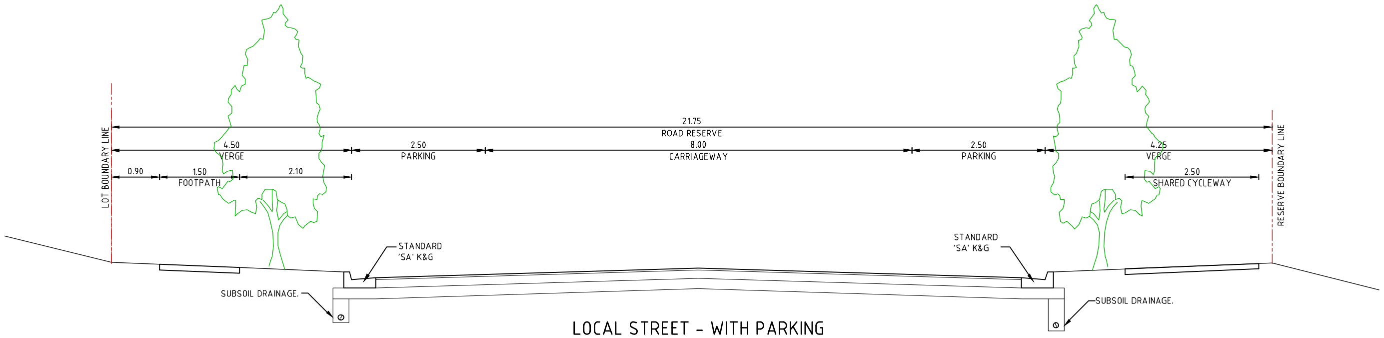
DRAWING TITLE
INDICATIVE TYPICAL ROAD CROSS SECTIONS - SHEET 1

JOB NUMBER
NL120526

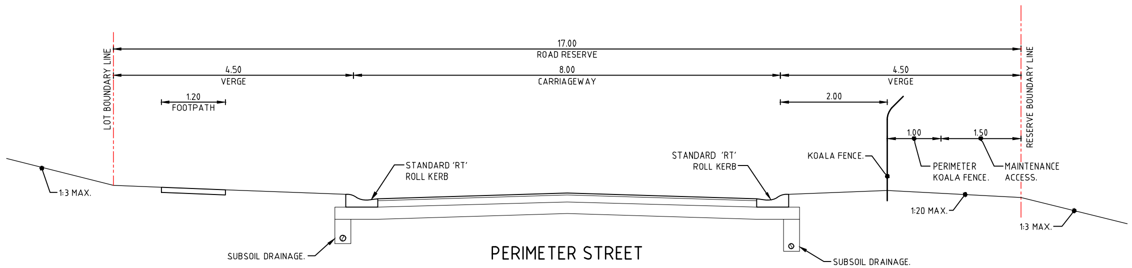
DRAWING NUMBER
DA-08-C3.10

REVISION
G

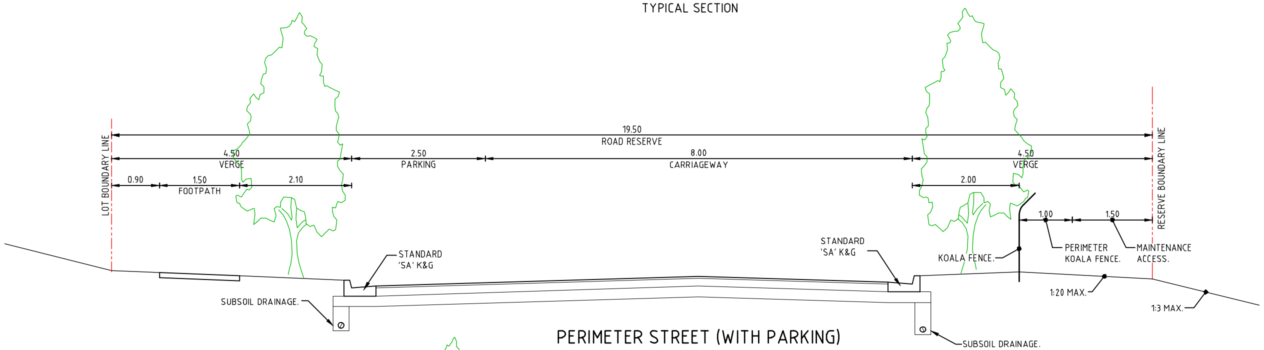
DRAWING SHEET SIZE = A1



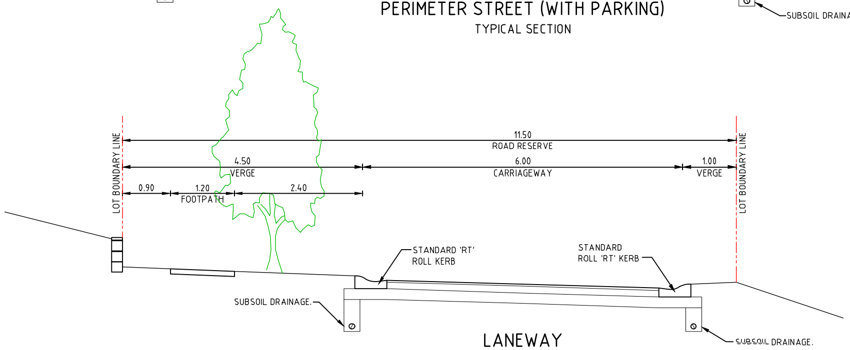
LOCAL STREET - WITH PARKING
(ADJACENT SCHOOL)
TYPICAL SECTION



PERIMETER STREET
TYPICAL SECTION



PERIMETER STREET (WITH PARKING)
TYPICAL SECTION



LANEWAY
TYPICAL SECTION

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DRAWN: J.BEVITT
DESIGNED: P.BURL
JOB MANAGER: C.PIPER
VERIFIER: B.CLARK

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PROJECT
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DRAWING TITLE
INDICATIVE TYPICAL ROAD CROSS SECTIONS - SHEET 2

JOB NUMBER
NL120526

DRAWING NUMBER
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DRAWING SHEET SIZE = A1

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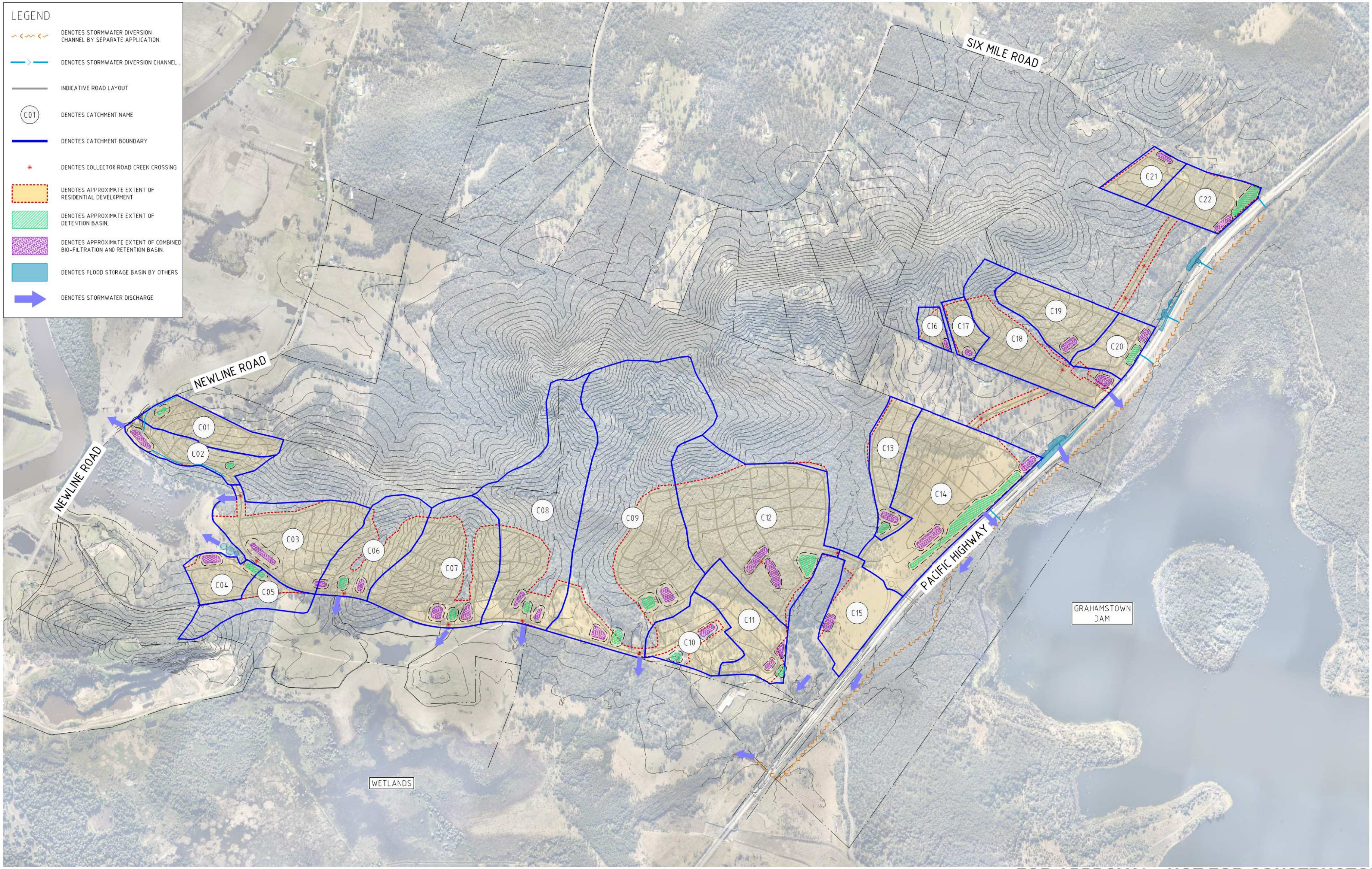

DRAWN: J.BEVITT
DESIGNED: P.BURL
JOB MANAGER: C.PIPER
VERIFIER: B.CLARK

FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
D	ISSUED FOR APPROVAL	WC	SC	CP	06.02.19
E	ISSUED FOR APPROVAL	JB	SC	CP	10.05.19
F	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
G	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
H	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
I	ISSUED FOR APPROVAL	JB	SC	CP	25.11.19

CLIENT
KINGS HILL DEVELOPMENTS

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PLANNER
JW PLANNING

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SCALE 1:8000@A1
0 100 200 300 400m

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Ph (02) 4943 1777 Fax (02) 4943 1577
Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
STORMWATER MANAGEMENT PLAN - OVERALL SITE

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C4.00

REVISION
I

DRAWING SHEET SIZE = A1

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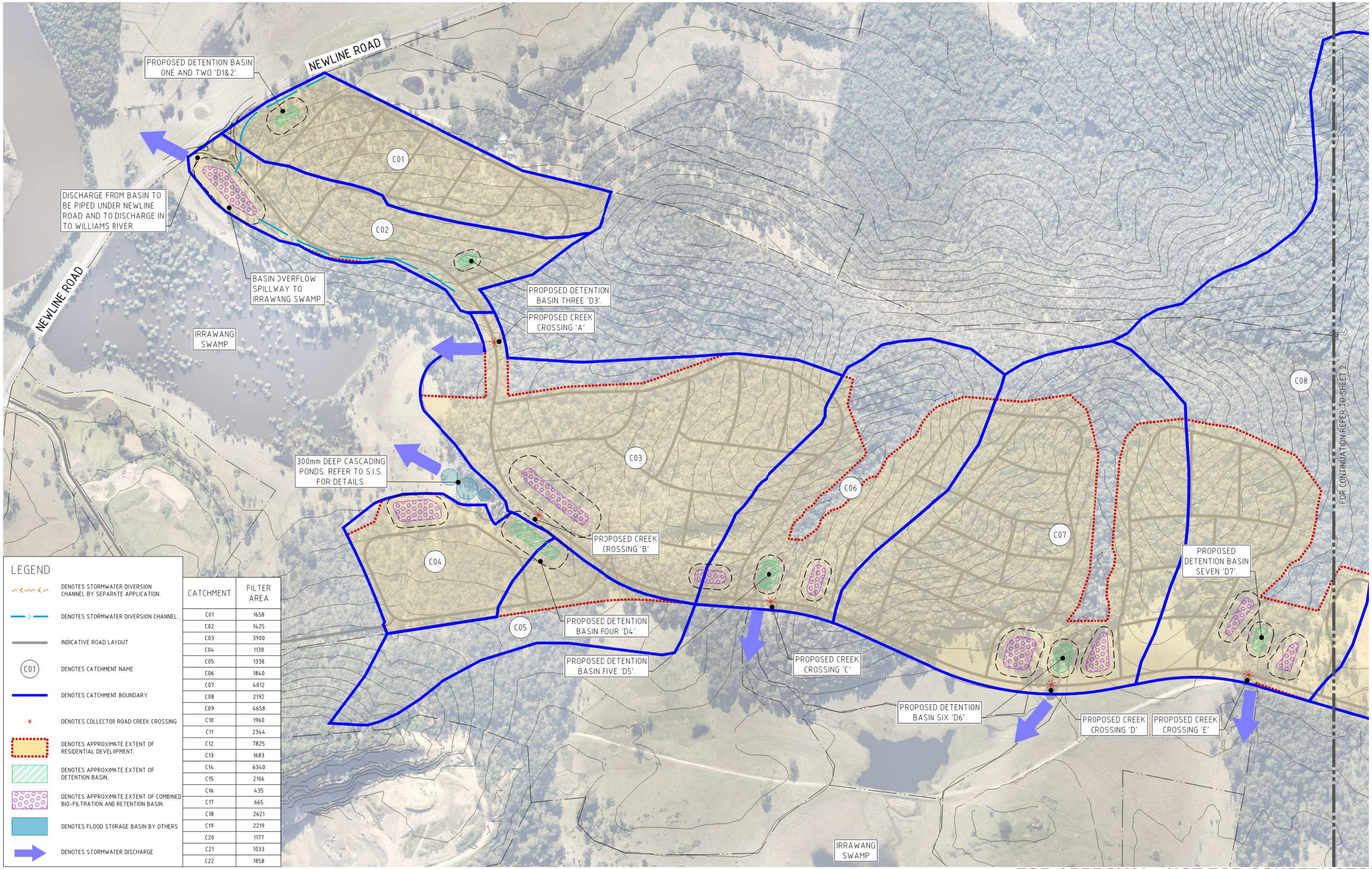

LEGEND

- DENOTES STORMWATER DIVERSION CHANNEL BY SEPARATE APPLICATION.
- DENOTES STORMWATER DIVERSION CHANNEL .
- INDICATIVE ROAD LAYOUT
- C01 DENOTES CATCHMENT NAME
- DENOTES CATCHMENT BOUNDARY
- DENOTES COLLECTOR ROAD CREEK CROSSING
- DENOTES APPROXIMATE EXTENT OF RESIDENTIAL DEVELOPMENT.
- DENOTES APPROXIMATE EXTENT OF DETENTION BASIN.
- DENOTES APPROXIMATE EXTENT OF COMBINED BIO-FILTRATION AND RETENTION BASIN.
- DENOTES FLOOD STORAGE BASIN BY OTHERS
- DENOTES STORMWATER DISCHARGE

CATCHMENT	FILTER AREA
C01	1658
C02	1425
C03	3900
C04	1130
C05	1338
C06	1840
C07	4012
C08	2192
C09	4658
C10	1960
C11	2344
C12	7825
C13	1683
C14	6340
C15	2106
C16	435
C17	665
C18	2621
C19	2219
C20	1177
C21	1033
C22	1858

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

FOR APPROVAL - NOT FOR CONSTRUCTON

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G	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
H	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
I	ISSUED FOR APPROVAL	JB	SC	CP	25.11.19

CLIENT
KINGS HILL DEVELOPMENTS

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PLANNER
JW PLANNING

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SCALE 1:3000@ A1
0 25 50 75 100 125 150m

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
STORMWATER MANAGEMENT PLAN - SHEET 1

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C4.01

REVISION
I

DRAWING SHEET SIZE = A1

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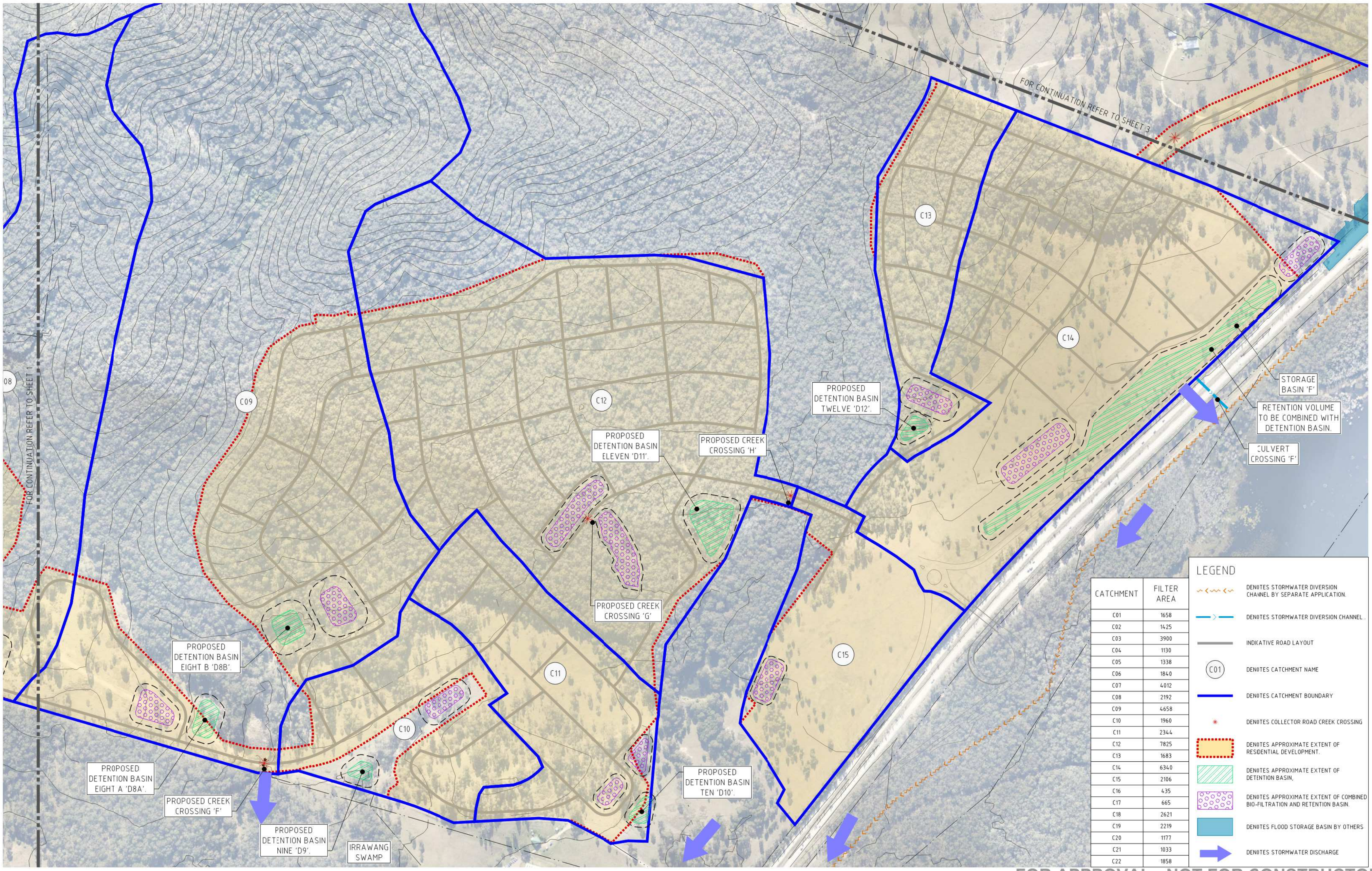

CATCHMENT	FILTER AREA
C01	1658
C02	1425
C03	3900
C04	1130
C05	1338
C06	1840
C07	4012
C08	2192
C09	4658
C10	1960
C11	2344
C12	7825
C13	1683
C14	6340
C15	2106
C16	435
C17	665
C18	2621
C19	2219
C20	1177
C21	1033
C22	1858

FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
D	ISSUED FOR APPROVAL	WC	SC	CP	06.02.19
E	ISSUED FOR APPROVAL	JB	SC	CP	10.05.19
F	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
G	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
H	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
I	ISSUED FOR APPROVAL	JB	SC	CP	25.11.19

CLIENT
KINGS HILL DEVELOPMENTS

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SCALE 1:3000@ A1 — 0 25 50 75 100 125 150m

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
STORMWATER MANAGEMENT PLAN - SHEET 2

JOB NUMBER **NL120526**

DRAWING NUMBER **DA-08-C4.02** REVISION **I**

DRAWING SHEET SIZE = A1

Y:\YEAR 2012 Jobs\NL120526\0 - Drawings\CIVIL\#CAD\C - DA\08 - CONCEPT DA_NOV 2018\NL120526_DA-08-C4.00_SW.dwg

CATCHMENT	FILTER AREA
C01	1658
C02	1425
C03	3900
C04	1130
C05	1338
C06	1840
C07	4012
C08	2192
C09	4658
C10	1960
C11	2344
C12	7825
C13	1683
C14	6340
C15	2106
C16	435
C17	665
C18	2621
C19	2219
C20	1177
C21	1033
C22	1858

FOR APPROVAL - NOT FOR CONSTRUCTON

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
D	ISSUED FOR APPROVAL	WC	SC	CP	06.02.19
E	ISSUED FOR APPROVAL	JB	SC	CP	10.05.19
F	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
G	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
H	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
I	ISSUED FOR APPROVAL	JB	SC	CP	25.11.19

CLIENT
KINGS HILL DEVELOPMENTS

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PLANNER
JW PLANNING

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0 25 50 75 100 125 150m

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
STORMWATER MANAGEMENT PLAN - SHEET 3

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C4.03

REVISION
I

DRAWING SHEET SIZE = A1

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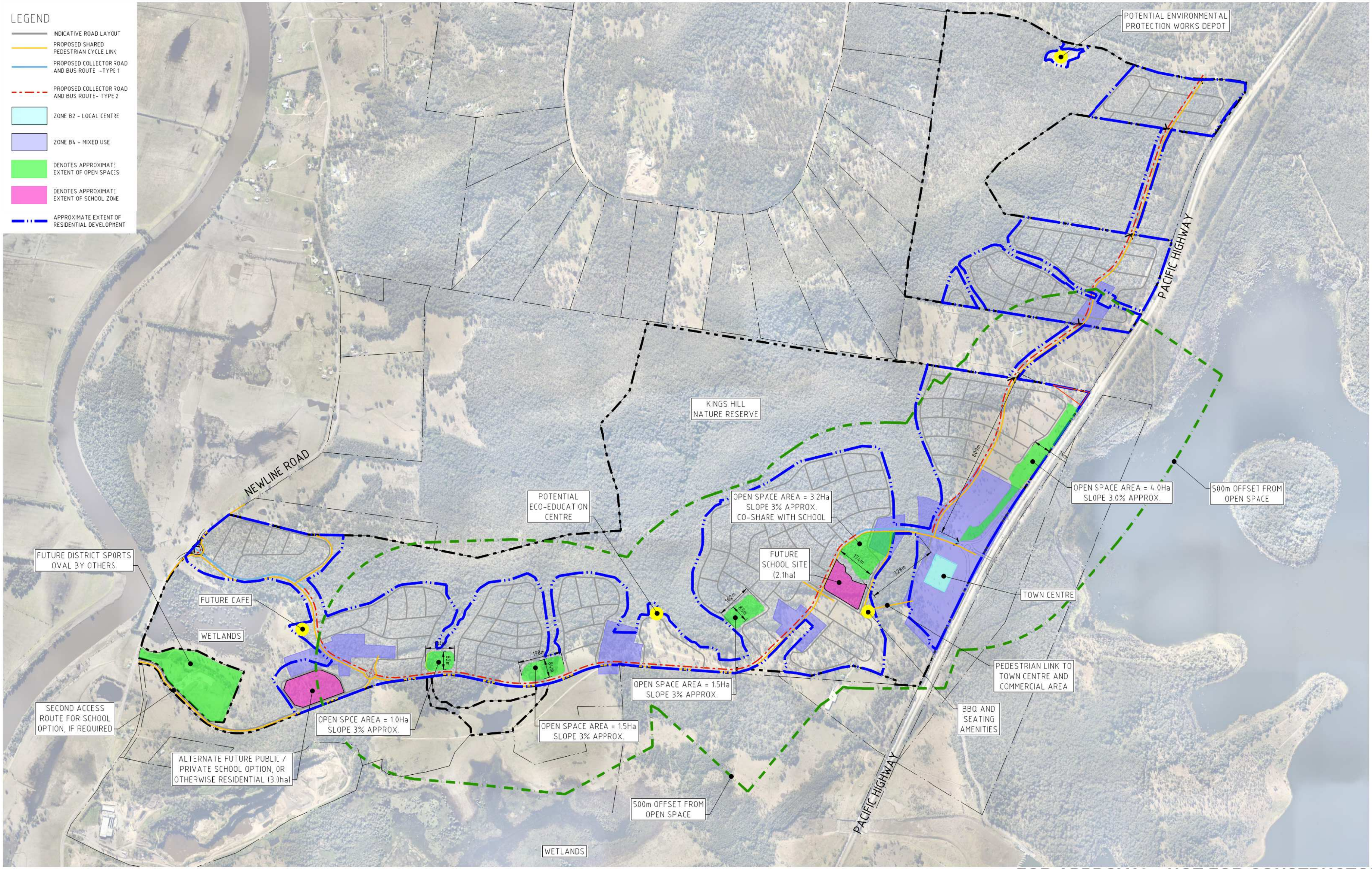

DRAWN: J.BEVITT
DESIGNED: P.BURL
JOB MANAGER: C.PIPER
VERIFIER: B.CLARK

FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
E	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
F	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
G	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
H	ISSUED FOR APPROVAL	JB	SC	CP	25.11.19
I	ISSUED FOR APPROVAL	WC	SC	CP	28.11.19
J	ISSUED FOR APPROVAL	JB	SC	CP	06.12.19

CLIENT
KINGS HILL DEVELOPMENTS
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PLANNER
JW PLANNING

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SCALE 1:8000@ A1
0 100 200 300 400m

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
PUBLIC SPACE AND CONNECTIVITY

JOB NUMBER **NL120526**
DRAWING NUMBER **DA-08-C5.00**
REVISION **J**
DRAWING SHEET SIZE = A1

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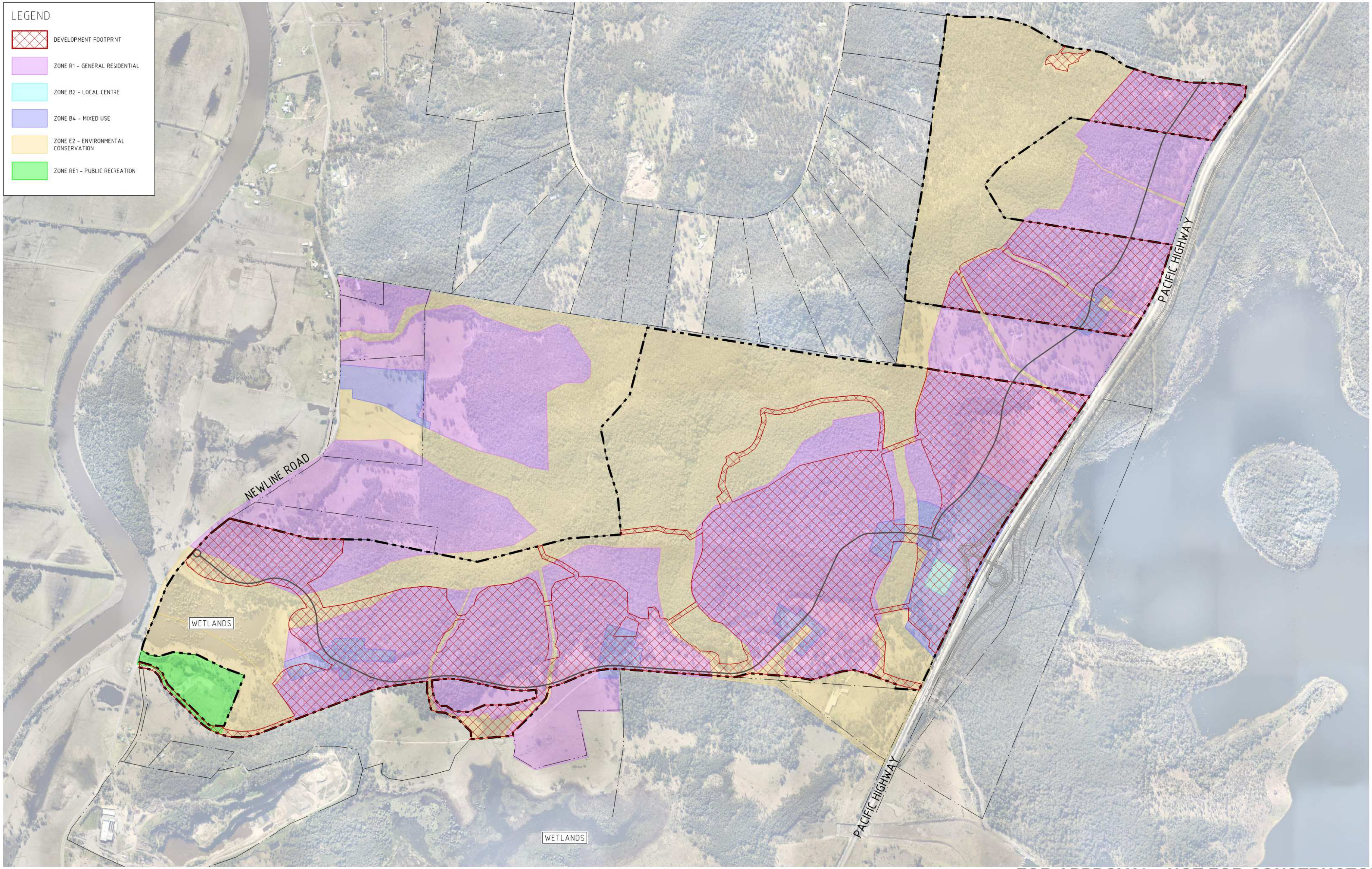

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
B	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
C	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
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E	FOR INFORMATION	JB		CP	25.11.19
F	ISSUED FOR APPROVAL	RG		CP	28.11.19
G	ISSUED FOR APPROVAL	JB	SC	CP	06.12.19

CLIENT
KINGS HILL DEVELOPMENTS

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SCALE 1:3000@ A1
0 25 50 75 100 125 150m

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
DEVELOPMENT PLAN 1

JOB NUMBER
NL120526

DRAWING NUMBER
DA-08-C6.00

REVISION
G

DRAWING SHEET SIZE = A1

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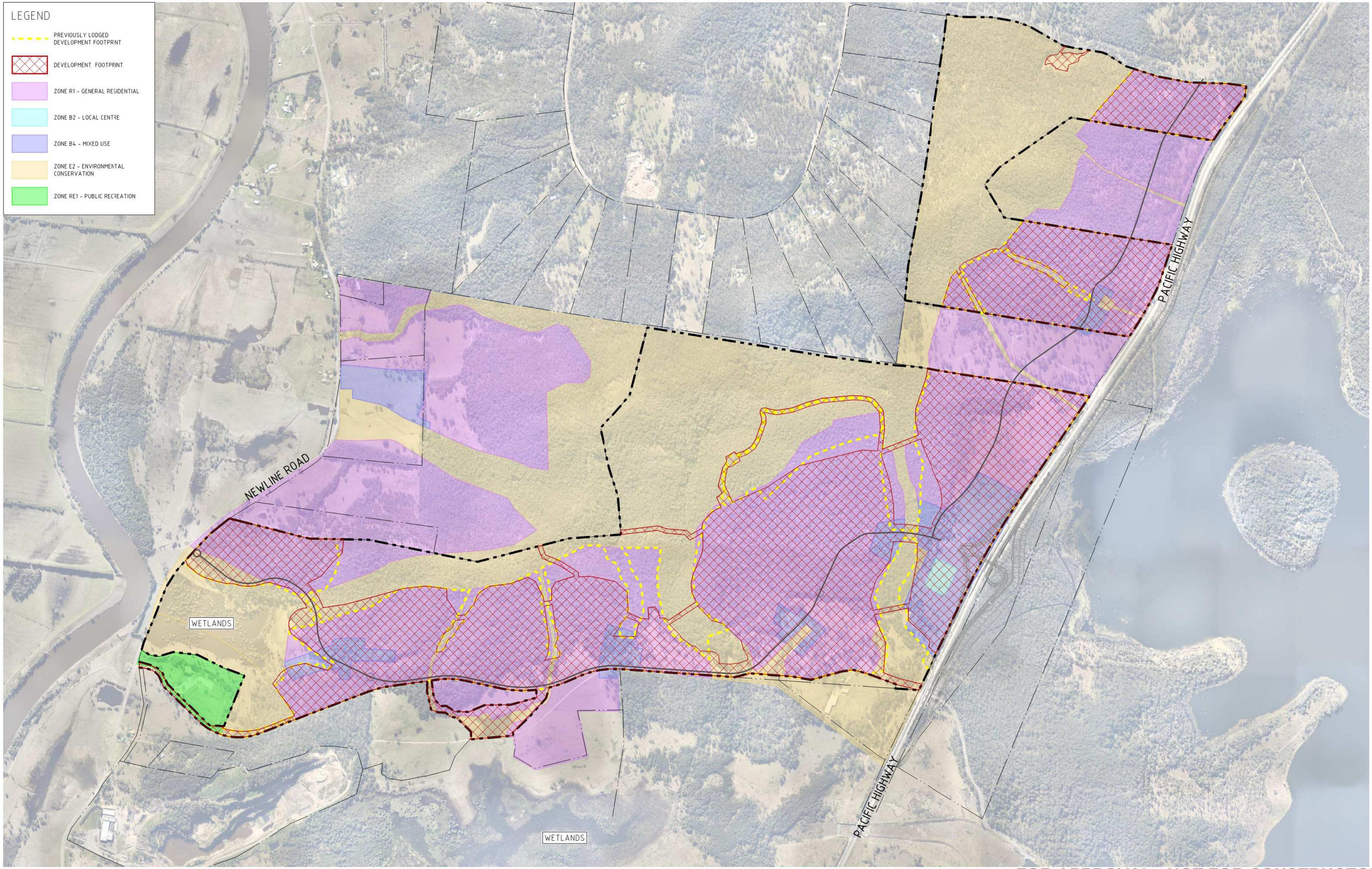

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

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F	ISSUED FOR APPROVAL	RG		CP	28.11.19
G	ISSUED FOR APPROVAL	JB	SC	CP	06.12.19

CLIENT
KINGS HILL DEVELOPMENTS

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SCALE 1:8000@ A1 0 100 200 300 400m

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PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
DEVELOPMENT PLAN 2

JOB NUMBER **NL120526**

DRAWING NUMBER **DA-08-C6.01** REVISION **G**

DRAWING SHEET SIZE = A1

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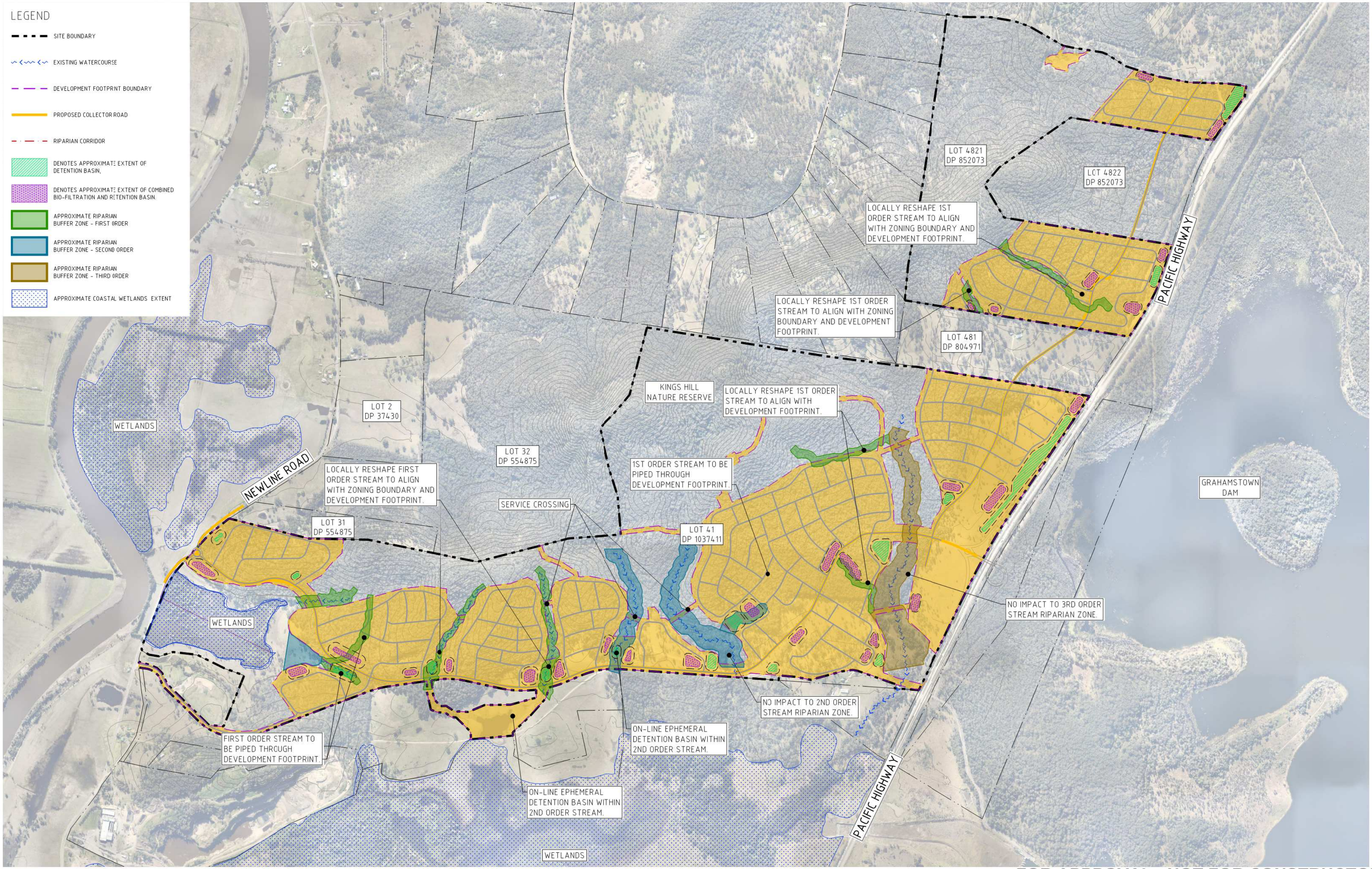

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

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REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
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C	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19
D	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
E	ISSUED FOR APPROVAL	JB	SC	CP	28.11.19
F	ISSUED FOR APPROVAL	JB	SC	CP	06.12.19

CLIENT
KINGS HILL DEVELOPMENTS

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JW PLANNING

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Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
RIPARIAN BUFFER PLAN

JOB NUMBER **NL120526**
DRAWING NUMBER **DA-08-C7.00**
REVISION **F**
DRAWING SHEET SIZE = A1

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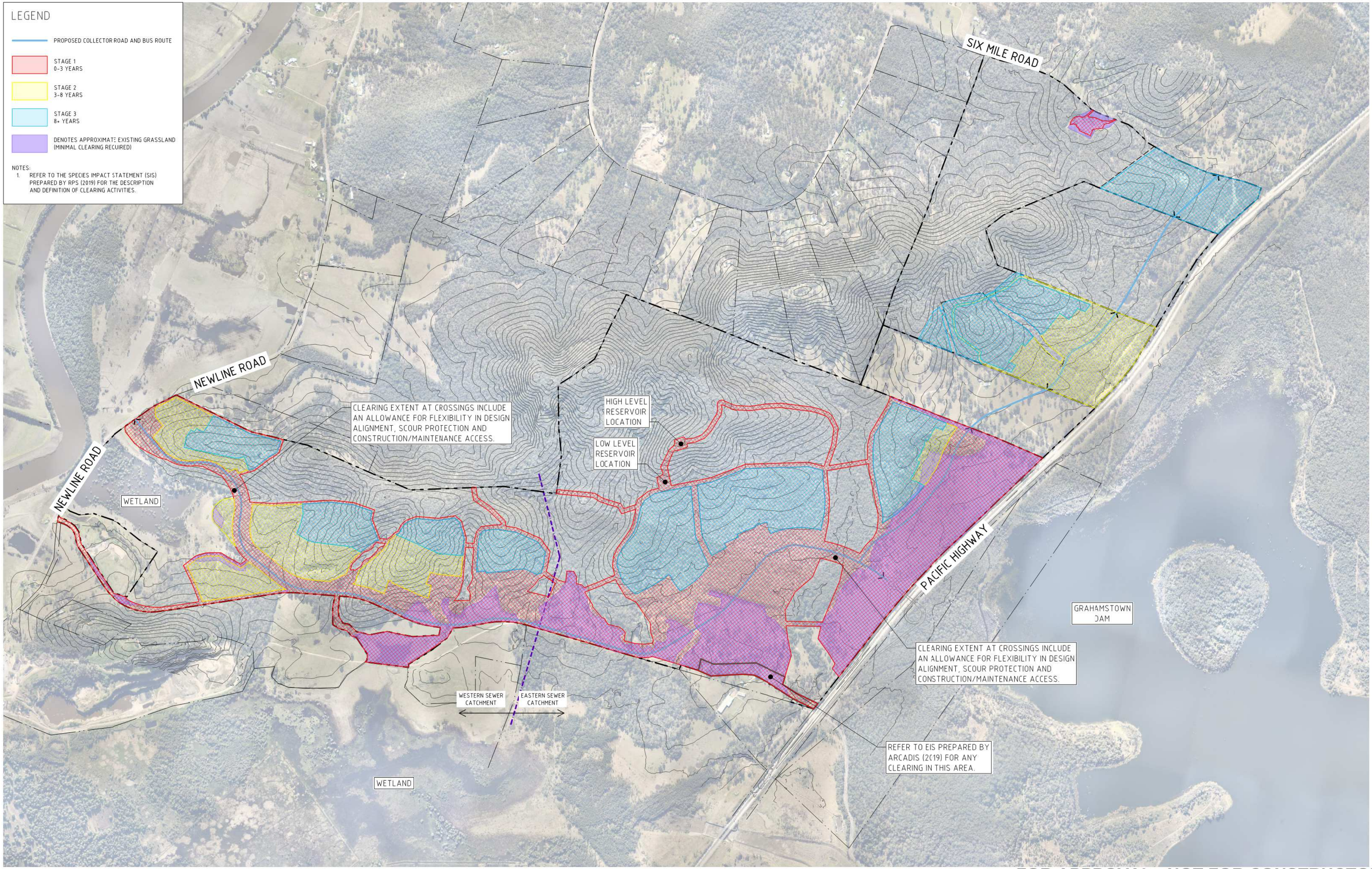

VERIFIER: B.CLARK
JOB MANAGER: C.PIPER
DESIGNED: P.BURL
DRAWN: J.BEVITT

FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
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C	ISSUED FOR APPROVAL	JB	SC	CP	22.05.19
D	ISSUED FOR APPROVAL	JB	SC	CP	22.11.19
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F	ISSUED FOR APPROVAL	JB	SC	CP	28.11.19
G	ISSUED FOR APPROVAL	JB	SC	CP	06.12.19

CLIENT
KINGS HILL DEVELOPMENTS

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JW PLANNING

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SCALE 1:8000@ A1 0 100 200 300 400m

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Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
DEVELOPMENT CLEARING AND STAGING

JOB NUMBER		
NL120526		
DRAWING NUMBER	REVISION	
DA-08-C8.00	G	
DRAWING SHEET SIZE = A1		

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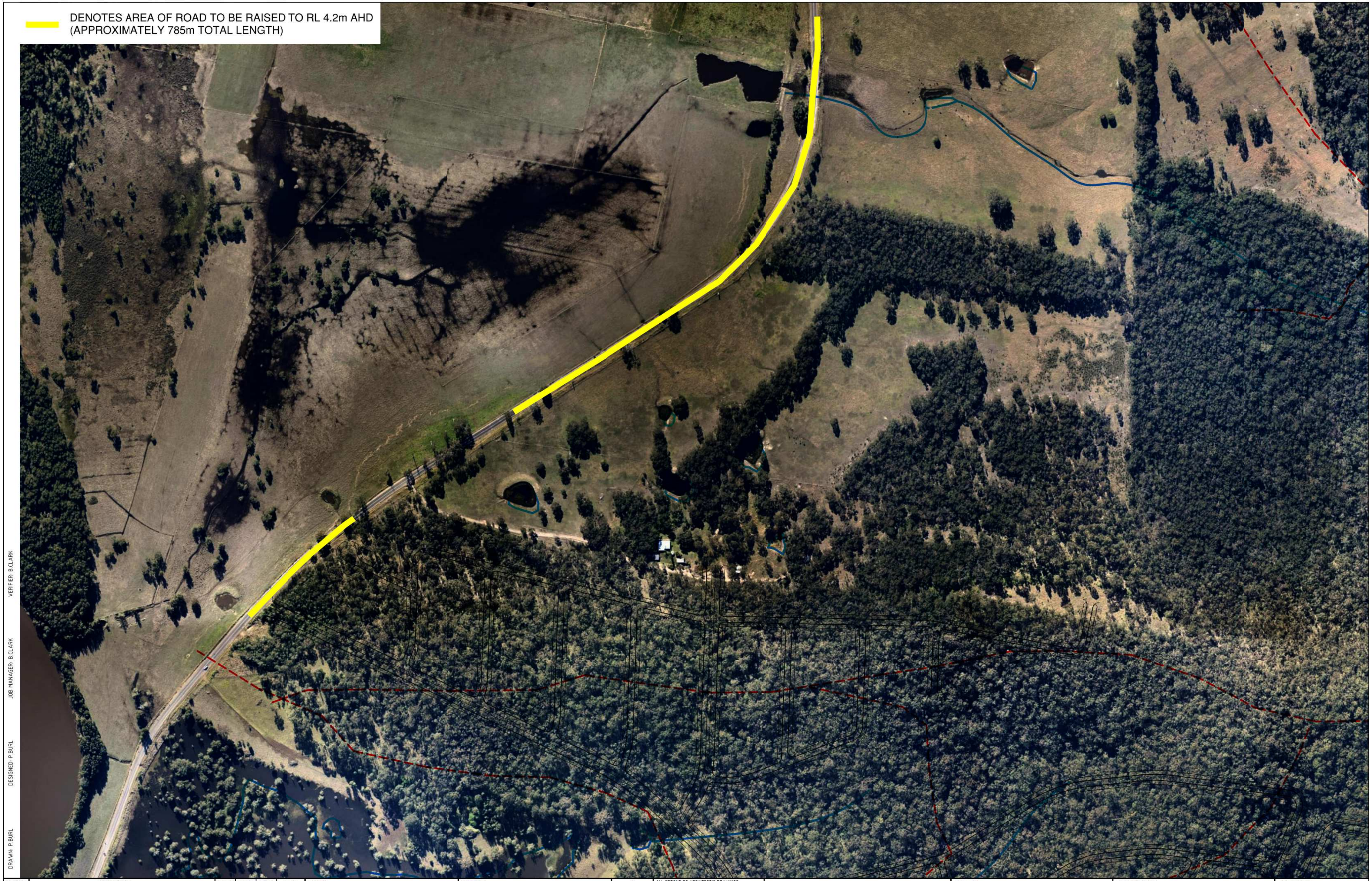
APPENDIX B -
Proposed Extent of Newline Road Upgrade



VERIFIER: B.CLARK
JOB MANAGER: B.CLARK
DESIGNED: P.BURL
DRAWN: P.BURL

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
1	INFORMATION	JH	B.C.	B.C.	24.10.16

CLIENT
KINGS HILL DEVELOPMENTS

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PLANNER
JW PLANNING

ALL SETOUT TO ARCHITECT'S DRAWINGS, DIMENSIONS TO BE VERIFIED WITH THE ARCHITECT AND ON SITE BEFORE MAKING SHOP DRAWINGS OR COMMENCING WORK.
NORTHROP ACCEPTS NO RESPONSIBILITY FOR THE USABILITY, COMPLETENESS OR SCALE OF DRAWINGS TRANSFERRED ELECTRONICALLY.

0 20 40 60 80 100m
PLAN
SCALE 1:2000 @ A1

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Suite 4, 215 Pacific Hwy, Charlestown NSW 2290
P.O. Box 180, Charlestown NSW 2290
Ph (02) 4943 1777 Fax (02) 4943 1577
Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
KINGS HILL URBAN RELEASE AREA

DRAWING TITLE
NEWLINE ROAD FLOOD FREE ACCESS

JOB NUMBER
NL120526

DRAWING NUMBER
NLR01

REVISION
1

DRAWING SHEET SIZE = A1

DRAWN: P.BURL
DESIGNED: P.BURL
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
1	INFORMATION	JH	B.C.	B.C.	24.10.16

CLIENT
KINGS HILL DEVELOPMENTS

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PLANNER
JW PLANNING

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0 20 40 60 80 100m
PLAN
SCALE 1:2000 @ A1

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Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
KINGS HILL URBAN RELEASE AREA

DRAWING TITLE
NEWLINE ROAD FLOOD FREE ACCESS

JOB NUMBER
NL120526

DRAWING NUMBER
NLR01

REVISION
1

DRAWING SHEET SIZE = A1

APPENDIX C -
Flooding Investigations

Level 1, 215 Pacific Highway Charlestown NSW 2290
PO Box 180 Charlestown NSW 2290
T (02) 4943 1777 F (02) 4943 1577
E newcastle@northrop.com.au

NL120526_[B15]

26th October 2017

Kings Hill Development
C/- APP Corporation
Mr Adam Smith
PO Box 1573
NORTH SYDNEY 2060

Dear Adam,

Re: Revised Flood Modelling re: Proposed Stormwater Diversion Channel, Kings Hill Urban Release area – Kings Hill, Raymond Terrace

We are writing regarding Council's request for additional information dated the 01 August 2017. The purpose of this correspondence is to provide a summary of the changes made to the previously submitted Flood Impact Assessment for the "Proposed Stormwater Diversion Channel – Kingshill Urban Release Area" (NL120526_E02_[A]) dated the 29th of February 2016 and to present the revised flood modelling results for the aforementioned site.

Below is a summary of the changes made to the original flood model including any modifications to the original model parameters.

Catchments and Hydrology

Due to the increased number of events for consideration as part of the Australian Rainfall and Runoff (AR&R) 2016 ensemble approach and to aid in the reduction of run times, a one-dimensional XP-STORM model was developed in order to determine the critical storm events for the stormwater network.

To build the one-dimensional model, a series of sub-catchments were digitised based on the site topography and the catchment outlet locations. The pre and post developed catchments are shown in the attached Figures B1[B] and B3[A] respectively.

For the pre-developed scenario, only the catchments upstream of the Pacific Highway have been considered, as a free outfall outlet condition has been assumed downstream. This is considered conservative, particularly when estimating the volume of the upstream flood storage basins as it yields a lower pre-developed water level on the western side of the Pacific Highway. By eliminating any tailwater conditions a greater head difference is observed between the inlet and outlet of the culverts, resulting in greater flow through the culvert, lowering the water level at the inlet and within the existing storage basins.

In comparison, the developed scenario includes all contributing catchments including the Kings Hill Urban Release Area (URA) as well as the Pacific Highway and the proposed eastern channel. Tailwater conditions in this case are governed by the flow through the eastern channel and as such, less flow is expected through the culverts with a higher water level within the storage basins on the western side of the Pacific Highway.

Prepared	LG	23/10/2017
Reviewed	GB	23/10/2017
Admin	LD	25/10/2017

Shown below in Table 1 is a summary of the variables and parameters used to determine the sub-catchment hydrology including the sub-catchment area, vectored slope, the existing Manning's surface roughness and the pre and post-developed impervious fractions.

Table 1– One-dimensional XP-STORM Sub-Catchment Data

Sub-catchment	Area (ha)	Vectored slope (%)	Existing Case Manning's Roughness	Pre-Dev Impervious Fraction (%)	Developed Impervious Fraction (%)
A01	14.14	5.8	0.080	3.8	37.7
B01	6.62	8.9	0.120	4.7	61.2
C01	8.04	12.6	0.120	0.0	14.1
C02	7.28	9.4	0.120	0.0	23.9
C03	5.86	11.0	0.120	0.0	55.4
C04	8.44	7.0	0.120	0.0	53.3
C05	9.07	5.1	0.120	3.8	56.8
D01	6.10	18.5	0.120	0.0	35.6
D02	8.58	7.4	0.120	0.0	56.1
D03	15.21	7.2	0.120	6.8	59.0
E01	7.23	14.0	0.120	0.0	1.8
E02	5.79	12.5	0.080	0.0	47.7
E03	10.11	8.4	0.060	0.0	55.7
E04	18.86	5.8	0.060	7.8	59.7
F01	30.68	4.8	0.060	5.4	61.4
S01	0.50	2.0	0.050	-	80.0
S02	0.77	0.4	0.050	-	0.0
S03	0.42	0.4	0.050	-	0.0
S04	1.00	1.9	0.050	-	60.2
S05	1.27	0.9	0.050	-	25.6
S06	1.28	2.5	0.050	-	13.2
S07	0.89	2.5	0.050	-	1.9
S08	3.90	0.7	0.050	-	26.3
S09	3.55	1.4	0.050	-	20.6
S10	2.98	0.8	0.050	-	0.0
S11	7.31	1.3	0.050	-	6.8
S12	20.44	2.0	0.050/0.120	-	1.7
S13	17.53	1.7	0.050	-	3.6

Each sub-catchment was divided into specific land-use areas including the Kings Hill URA, the upstream undisturbed forest, the creek lines, the Pacific Highway and the proposed eastern channel.

For developed areas, including the Pacific Highway and Kings Hill URA, a typical Manning's roughness of 0.015 and 0.030 has been used for impervious and pervious surfaces respectively, while a roughness of 0.050 has been used for the eastern channel. The roughness values used for the existing and developed case forested areas vary and are shown in Table 1 above. The varying Manning's roughness for the forested areas are based on the BMT WBM values used for the "Kings Hill Urban Release Area Water Management Strategy Guidelines, 2013".

For the developed areas a typical impervious percentage of 60% has been assumed, while 80% has been assumed for the Pacific Highway. All other areas have been assumed to be 100% pervious. Losses have been represented using the initial and continuing loss model. In this case, 0mm has been adopted for initial and continuing loss for impervious areas while an initial loss of 0mm and a continuing loss of 2.5mm/hr was used for the pervious surfaces.

As previously mentioned, the latest ARR 2016 rainfall IFDs have been used for this revision of the modelling. The rainfall IFDs were obtained from the Bureau of Meteorology (BOM) for a location over Kings Hill. These rainfall intensities were then used with the 2016 temporal patterns to develop the new rainfall hyetographs.

The latest 2016 ARR rainfall IFDs do not provide intensities for storm durations less than 1 day for events greater than the 1% Annual Exceedance Probability (AEP) design storm event. As an alternative, a multiplication factor of 1.344 is recommended by the 2016 AR&R guidelines as a method to determine the 0.2% AEP rainfall intensities. This factor was applied to the 1% AEP IFD in order to obtain the intensities for the 0.2% AEP design storm event. The same temporal patterns that were used for the 1% AEP were also used for the 0.2% AEP design storm event.

In order to maintain consistency between the one dimensional and two-dimensional models the rainfall on grid extent previously considered was no longer used. Instead the same one-dimensional hydrology was applied directly to the grid of the latest two-dimensional model.

Hydraulics and the 1-D Network

The culvert details have been based on detailed survey and design levels and have been linked directly to the two-dimensional grid. The downstream Irrawang Spillway has been modelled as a 5.3m wide by 5.6m high concrete lined channel as it passes under the Pacific Highway, then narrowing to 2m wide by 4m high prior to the outlet of the spillway. This is consistent with what was observed during site investigations.

Blockage has been considered during the design of both the proposed flood storage basins as well as during the design of the eastern channel. As suggested by Council, a blockage factor of 0% has been assumed for the culverts crossing under the Pacific Highway while for the Hunter Water Corporation (HWC) Access Road culvert crossing, a blockage factor of 50% has been applied. Due to the shallow grade in the base of the proposed eastern channel, a bottom up blockage has been assumed with the settlement of sediment considered the most conservative likely blockage mechanism.

In comparison, based on the latest 2016 AR&R guidelines, a blockage factor of 0% for the 1% AEP and 15% for the 0.2% AEP design storm events are considered acceptable for the HWC access road due to the limited availability of debris in the upstream catchment. The Pacific Highway is expected to block large debris from the development site. The availability, mobility and transportability has been assessed as LMM, resulting in a low debris potential. Shown below in Table 2 are the AEP adjusted value results based on AR&R 2016 blockage guidelines.

Table 2–AR&R 2016 Assumed Blockage Results

Design Storm Event	Debris Potential*		Sediment Potential#	
1% AEP	Low	0%	Low	0%
0.2% AEP	Medium	0%	Low	15%

* Based on AR&R 2016 Blockage Guidelines, Table 6.6.6
# Based on AR&R 2016 Blockage Guidelines, Table 6.6.8

For the existing scenario, a free outfall head boundary was entered downstream of the culvert outlets. For the developed scenario, an outlet head boundary was entered downstream of the Irrawang Spillway with a tailwater level of 4.59m AHD for both the 1% AEP and 0.2% AEP design storm events.

Results

The results presented below have been divided into four sections including the following:

- Sub-catchment peak flow results for the 1% AEP design storm event;
- Revised modelling for the design of the eastern channel based on the 0.2% AEP design storm event;
- Revised modelling for the design of the flood storage basins located upstream of the culvert crossings based on the 1% AEP design storm event; and
- Comparison between the one-dimensional XP-STORM model used in this study and the BMT WBM XP-RAFTS model used in the "Kings Hill Urban Release Area Water Management Strategy Guidelines, 2013".

The comparison of the one-dimensional BMT WBM XP-RAFTS model and the one-dimensional XP-STORM model used in this study has been undertaken in order to gauge the accuracy of the model used in this study as well as the effect that the latest 2016 rainfall has on the design of the eastern channel and flood storage basins.

Sub-catchment Peak Flows

The individual and cumulative peak flow results for the 1% AEP design storm event for each sub-catchment is shown in the below Table 3. The results are based on the median peak flow event in accordance with the AR&R 2016 guidelines.

Table 3–Sub-Catchment Median Peak Flow Results

Sub-Catchment	Pre-Developed Individual Peak Flow (m3/s)	Pre-Developed Cumulative Peak Flow (m3/s)	Post-Developed Individual Peak Flow (m3/s)	Post-Developed Cumulative Peak Flow (m3/s)
A01	3.55	3.55	5.49	5.49
B01	1.69	1.69	4.23	4.23
C01	2.33	2.30	2.56	2.43
C02	1.96	1.94	2.57	2.37
C03	1.71	3.73	3.50	4.37
C04	1.96	3.82	4.74	5.09
C05	1.73	9.17	5.28	12.98
D01	2.14	2.06	3.02	2.84
D02	2.03	3.64	5.15	5.97
D03	2.91	6.36	8.84	12.52
E01	2.20	2.19	2.22	2.19
E02	2.28	4.27	3.55	4.53
E03	3.79	7.74	6.04	9.44
E04	5.05	12.53	10.18	17.45
F01	7.38	7.38	16.75	16.75
S01	-	-	0.34	0.65
S02	-	-	0.16	0.70
S03	-	-	0.10	0.79
S04	-	-	0.56	2.34
S05	-	-	0.39	5.75
S06	-	-	0.31	13.21
S07	-	-	0.17	13.28
S08	-	-	0.97	20.34
S09	-	-	0.78	26.58
S10	-	-	0.63	26.09
S11	-	-	1.63	25.28
S12	-	-	2.49	26.80
S13	-	-	4.16	20.18

Eastern Channel

To demonstrate the existing channel has adequate capacity, the maximum 0.2% AEP design storm event was considered for the capacity of the channel without the additional flood storage basins. The AR&R 2016 guidelines suggest the median should be considered however in this case, the channel is shown to have capacity to support the maximum event without the additional flood storage upstream of the Pacific Highway.

The one-dimensional model was used to determine the critical event along the length of the channel. The revised 0.2% AEP flood depth, elevation and velocity results for the eastern channel are shown in the attached Figures E4 to E6. The below Table 4 presents the critical event and peak flows at various locations along the channel. These locations are shown in the attached Figure H1.

Table 4– Eastern Channel Critical Storm and Peak Flows

Location (Refer to Figure H1)	0.2% AEP Critical Event (Max)	Peak Flow Rate (m3/s)
A	20 min TP9	1.00
B	20 min TP9	3.46
C	1-hour TP1	9.16
D	1-hour TP1	20.70
E	1-hour TP10	27.71
F	1-hour TP10	38.07
G	1-hour TP10	34.26
H	1-hour TP10	35.64
I	12hr TP9	33.74
J	12hr TP9	33.69

The critical event was shown to vary along the length of the channel with the latest 2016 rainfall intensities and temporal patterns considered. As shown in Table 4 above, the 20-minute duration is shown to be critical in the upstream reaches of the channel, transitioning to the 1-hour event midway along and the 12-hour event shown to be critical in the lower reaches due to the additional storage volume downstream of the HWC Access Track.

A comparison between the previously submitted results and the latest results is shown in the attached Figure F3. These results show an increase in the order of 670mm directly upstream of the HWC Access Track which is expected to be a result of the introduction of 50% blockage and the latest 2016 rainfall intensities. Other elevation changes include an increase of up to 200mm in the channel between Culverts A and B and an increase of up to 500mm between Culverts B to F. These changes are also expected to be a result of the change in the design rainfall from the AR&R 1987 to the latest 2016 data and how the catchment responds to the new design temporal patterns.

A sensitivity test was performed with 50% blockage applied to the culverts beneath the Pacific Highway. The results show an increase in the water level on the western side of the Pacific Highway and generally a decrease in the eastern channel. These results suggest that by increasing the blockage in these culverts, greater detention is provided upstream of the Highway.

The results of the sensitivity test show that a decrease of up to approximately 150mm is observed in the channel, located adjacent to the outlet to Culvert B as well as up to approximately 110mm on the upstream side of the HWC Access Track. A slight increase of up to 5mm is observed downstream of Culvert E as flow spills over the Pacific Highway in this location, however this increase is shown to dissipate by the time it reaches the outlet of Culvert F.

Overall the results show that the channel has sufficient capacity to support design flows up to the maximum 0.2% AEP without any additional flood storage on the upstream side of the Pacific Highway.

Flood Storage Basins

For the estimation of the additional flood storage required upstream of the Pacific Highway, the median 1% AEP design storm event was considered. The one-dimensional model was also used to determine the critical storm event for each storage area. The two-dimensional model was then run with the critical event to determine the pre and post developed water levels. Table 5 presents the results for the pre-developed scenario including the critical event and water level. The estimated road spill level and freeboard is also provided.

Table 5– Culvert Crossings Existing Water Levels

Culvert Storage Areas	Critical Event (Median)	Water Level (mAHD)	Estimated Road Spill Level (mAHD)	Freeboard to the Pacific Highway (m)
A	3hr TP9	21.52	22.0	0.48
B	45min TP6	19.18	20.4	1.22
C	45min TP2	19.13	19.2	0.07
D	45min TP2	17.79	18.2	0.41
E	45min TP9	16.3	16.2	-0.1
F	1hr TP4	14.25	15.3	1.05

The basin design philosophy was based on the water level on the upstream side of the Pacific Highway. In order for the basins to comply, the following design criteria had to be met.

- If the water level was below the 1% AEP plus a 500mm freeboard during the pre-developed case, then the developed water level must not breach the 1% AEP plus 500mm.
- If the existing freeboard was between greater than the 1% AEP plus 500mm, then the developed water level must not increase in the post-developed scenario.

The approximate location of the proposed storage basins is shown in the attached Figure H1. These areas are based on the developed water level and existing topography. It is anticipated these extents will change leading into detailed design as the final lot layout and design surface is developed. The estimated pre and post developed storage volumes are shown in Table 6 below.

Table 6– Culvert Crossings Upstream Storage Capacities

Culvert	Estimated Pre-Developed Storage (m^3)	Estimated Post Developed Storage (m^3)	Change (m^3)
A	9370	13092	+3722
B	22	3056	+3034
C	1829	7806	+5977
D	3927	5962	+2035
E	1745	6568	+4823
F	14970	17283	+2313

The volumes presented above are based on the volume between the highest water level and the surface topography and as such, freeboard has not been considered. It is anticipated that when the final basin locations are determined, the additional volume required to accommodate freeboard will be provided.

The post-developed water level upstream of the Pacific Highway is shown in Table 7 below. Also provided are the peak flow rates for each culvert crossing beneath the Pacific Highway for both the one and two-dimensional models.

Table 7– Culvert Crossings Post-Developed Water Levels

Culvert Storage Areas	Critical Event (Median)	Water Level (mAHD)	1D Pipe Flow (m^3/s)	2D Pipe Flow (m^3/s)
A	6hr TP1	21.46	0.44	0.44
B	45min TP6	19.02	1.36	1.34
C	45min TP9	19.04	3.28	3.20
D	45min TP9	17.76	7.36	6.70
E	45min TP6	16.29	1.47	1.28
F	1hr TP4	14.34	7.42	7.15

The results presented in Table 7 shows the aforementioned design criteria can be met with the provision of additional flood storage presented in Table 6.

It is noted that, although Storage B had sufficient freeboard to the Pacific Highway, reducing the water level in this location assisted in reducing the volume required for the downstream basins (Storage C and D). There is significant interaction between Storage Areas B through to E and as such it may be possible to provide greater flood storage in some areas in order to reduce the water level in other areas. It is anticipated, this will be further refined at a later stage.

Model Comparisons

A comparison of the one-dimensional models has been developed in order to compare that latest models used in this study with the XP-RAFTS model developed by BMT WBM during the development of the “Kings Hill Urban Release Area Water Management Strategy Guidelines, 2013”. Only the existing case, 1% AEP critical design storm event has been considered to simplify the comparison. Below is a summary of the main differences in the models:

Model 1 – BMT WBM 1D 1987 XP-RAFTS

- Original BMT WBM XP-RAFTS Hydrologic Model
- Based on AR&R 87 rainfall and initial losses

Model 2 - Northrop 1D 1987 XP-STORM

- AR&R 87 Northrop 1D XP-STORM hydrologic and hydraulic model
- Changed Losses to match BMT WBM (IL15CL2.5)
- Changed Rainfall to match BMT WBM 1987 Rainfall Hyetograph’s
- Maintained existing catchment areas and vectored slopes

Model 3 - Northrop 1D 2016 IFDs and Losses (Critical Median)

- AR&R 2016 Northrop 1D XP-STORM hydrologic and hydraulic model used in this study
- Allows for pre-burst rainfall by assuming 0 initial loss over pervious catchments
- Includes latest 2016 rainfall IFDs and temporal patterns

Shown below in Table 8 are the results for the peak flow generated from each model. The flows shown below can be considered as the peak flow rate generated by the catchment prior to reaching the storage areas.

Table 8– Model Comparisons

Storage Areas upstream of Culverts	Model 1 WBM 1987 XP-RAFTS (Critical) (m^3/s)	Model 2 Northrop 1D 1987 XP-STORM (Critical) (m^3/s)	Model 3 Northrop 2016 IFDs and Losses (Critical Median) (m^3/s)
A	0.68 (2hr)	2.18 (2hr)	3.55 (45min, TP6)
B	1.35 (6hr)	1.03 (2hr)	1.69 (45min, TP6)
C	5.02 (2hr)	5.88 (2hr)	9.17 (45min, TP2)
D	7.02 (2hr)	4.20 (2hr)	6.36 (45min, TP2)
E	6.13 (2hr)	8.35 (2hr)	12.53 (25min, TP9)
F	4.80 (2hr)	4.56 (2hr)	7.38 (45min, TP6)
Combined	25.0	26.2	40.68

The difference between Models 1 and 2 are a likely the result of slightly different catchment boundaries and vector slopes.

The results for Models 1 and 2 show a relatively close correlation, with a difference in the total peak flow of just 1.2m3/s. A comparison of the data between the two models indicates this is likely due to a larger contributing catchment for Model 2 as LiDAR in the area suggests an additional catchment area to the north and south drains to this culvert when compared to Model 1. Similarly, the peak flows for the D and E catchments appear to be reversed, however when combined a similar peak flow rate for both culverts D and E is observed, therefore again some differences between catchment areas are likely. The remaining catchments, including B, C and F appear to produce similar results when Models 1 and 2 are compared.

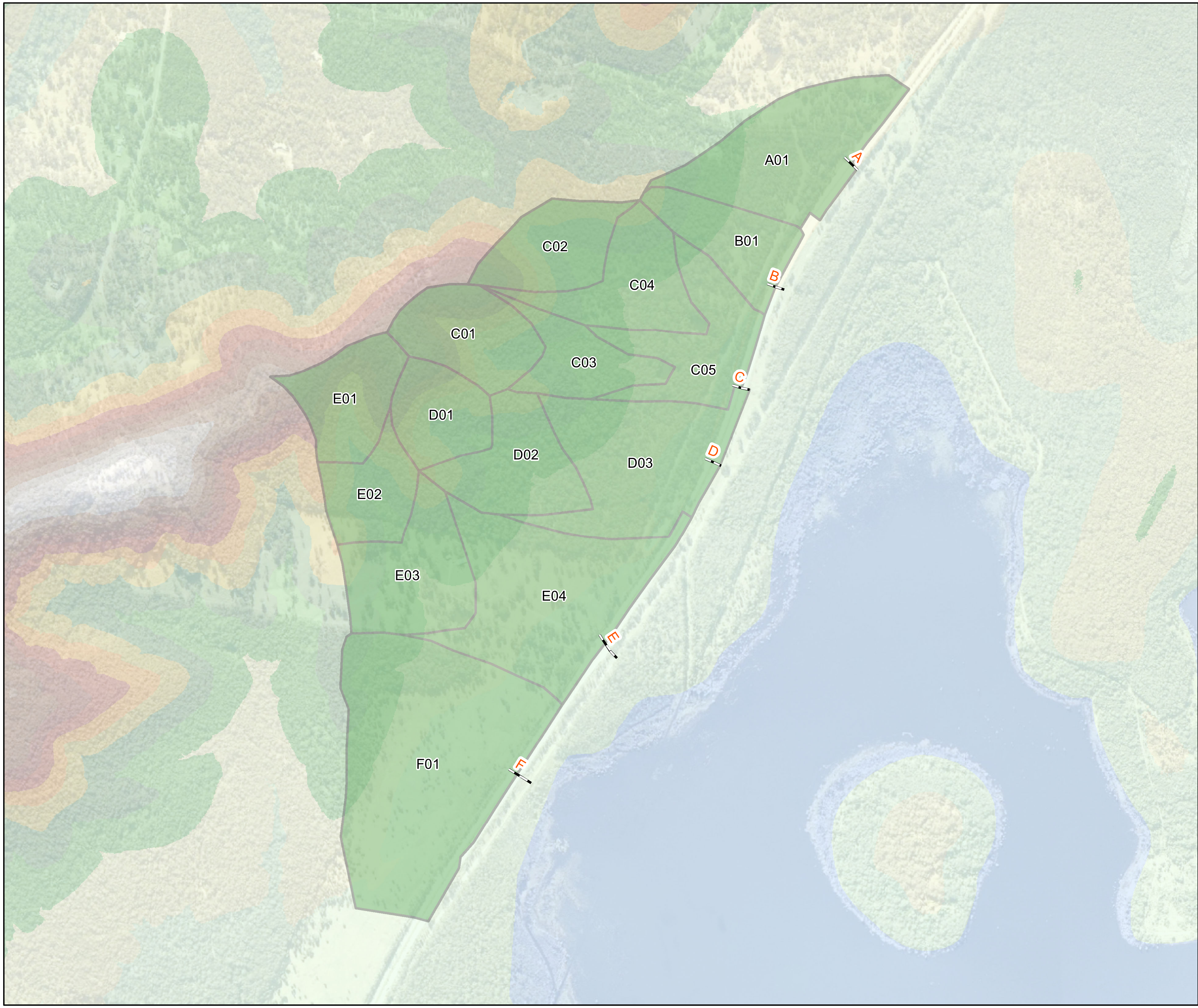
The results for Models 2 and 3 show an increase in combined peak flow by approximately 155%. The cause of this increase is due to the introduction of the 2016 rainfall and temporal patterns as well as the allowance for pre-burst rainfall by setting the initial loss to 0mm/hr.

Conclusion

The results presented above shows an increase in flow as a result of the introduction of the 2016 AR&R rainfall, however the previous design of the eastern channel has sufficient capacity to support the increase. Furthermore, approximate basin sizes and locations have been provided in order to prevent any significant impact on the Pacific Highway as a result of the development. We note these are subject to change as part of the future subdivision design.

As such we believe we have satisfied Councils request for additional information. We trust this is what you require. Should you have any queries, please feel free to contact the undersigned on (02) 4943 1777.

Prepared by:	Reviewed by:
Laurence Gitzel	**Angus Brien**
Civil/Environmental Engineer	Civil Engineer
BEng (Environmental)	*BEng (Civil)*



Legend

Culverts

Catchments

Elevation (m AHD)

- 0.0 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0
- 40.1 - 50.0
- 50.1 - 60.0
- 60.1 - 70.0
- 70.1 - 80.0
- 80.1 - 90.0
- 90.1 - 100.0
- 100.1 - 110.0
- 110.1 - 120.0
- 120.1 - 130.0
- 130.1 - 140.0

Figure B1

1D Pre-Developed
Catchment Boundaries

Date 20 October 2017

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 150 300 450 Meters

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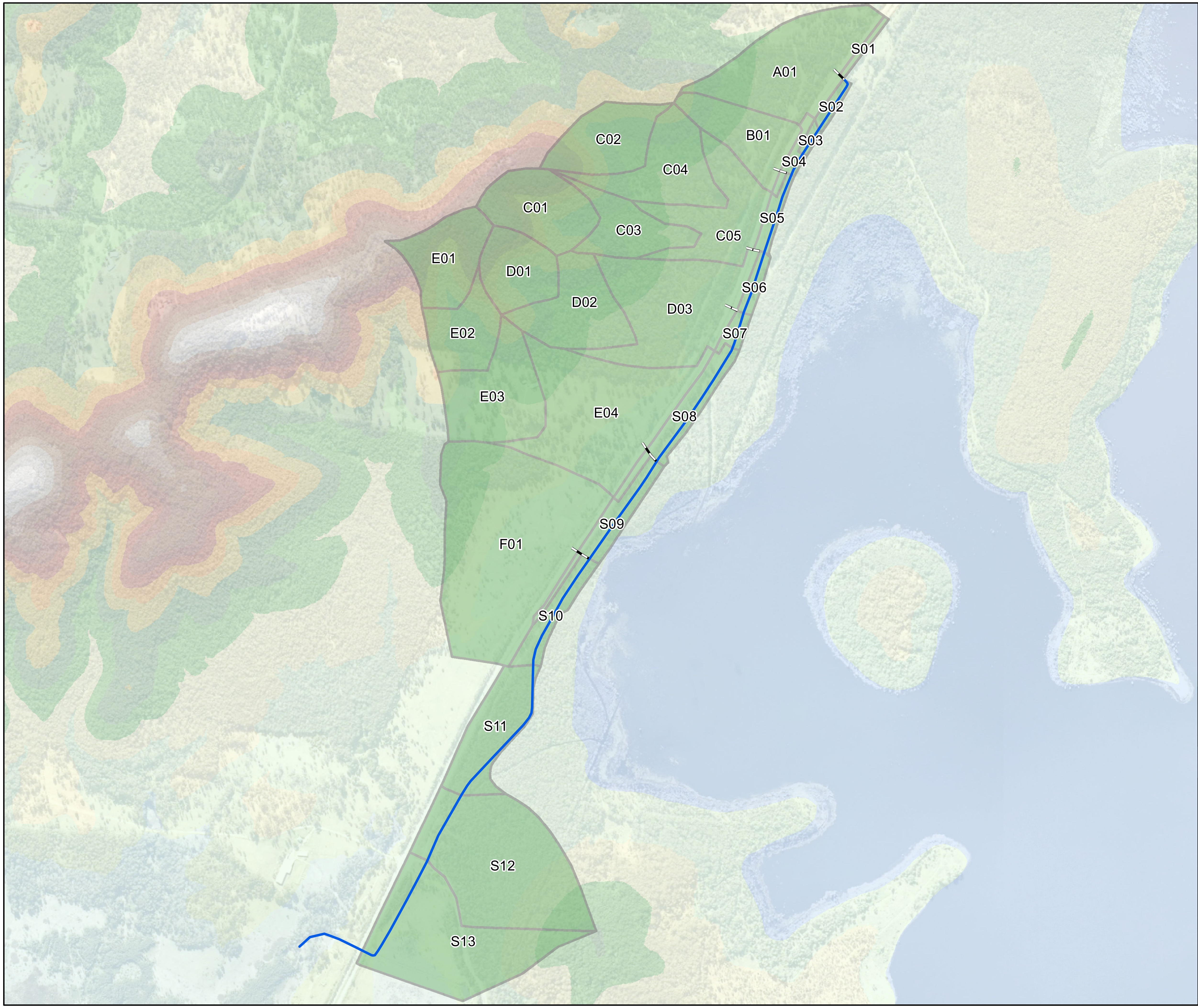

Legend

Culverts

Channel

Catchments

Elevation (m AHD)

0.0 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
100.1 - 110.0
110.1 - 120.0
120.1 - 130.0
130.1 - 140.0

Figure B3

1D Post-Developed
Catchment Boundaries

Date 20 October 2017

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 200 400 600 Meters

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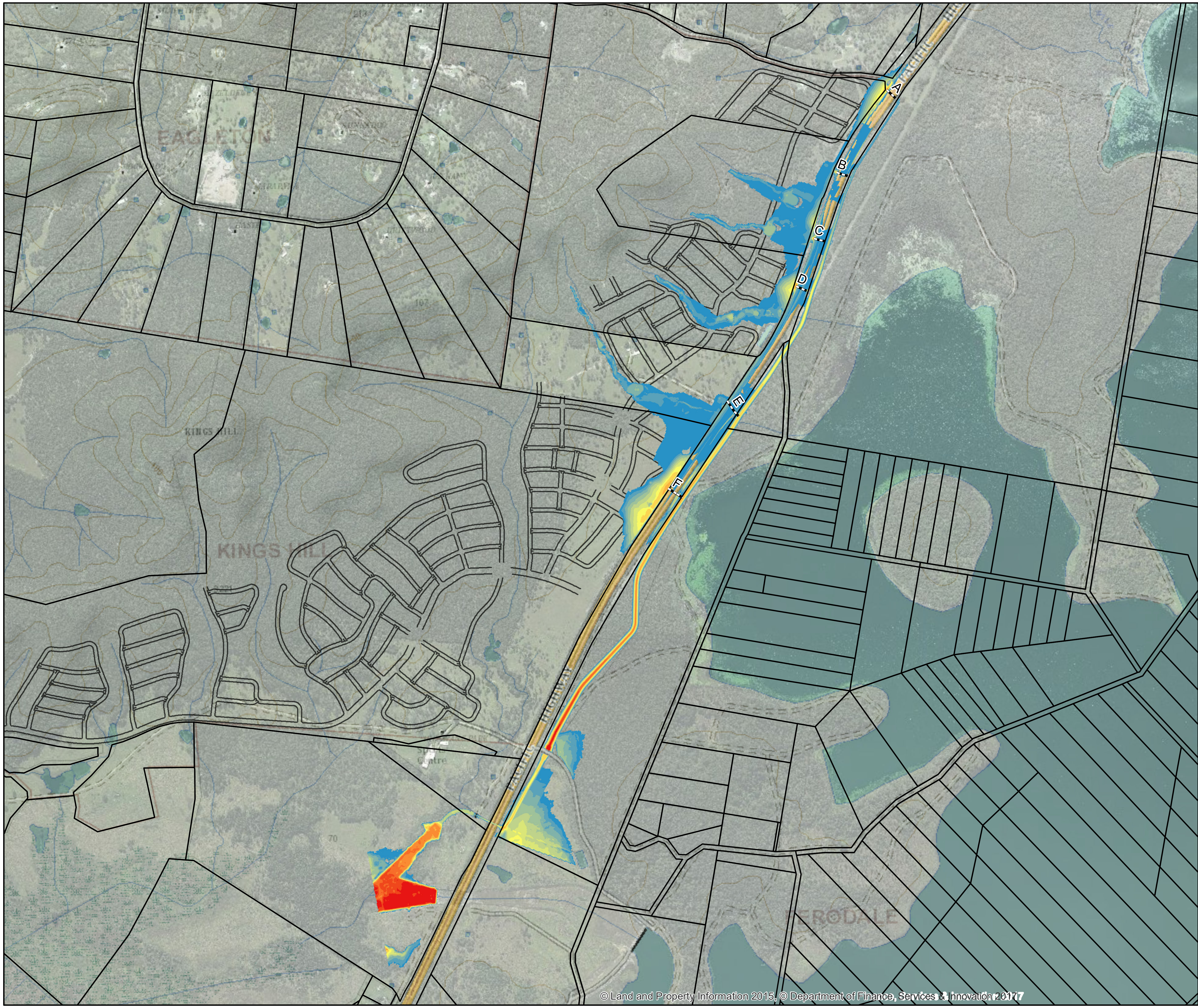

Depth (m)

	0.00 - 0.25
	0.26 - 0.50
	0.51 - 0.75
	0.76 - 1.00
	1.01 - 1.25
	1.26 - 1.50
	1.51 - 1.75
	1.76 - 2.00
	2.01 - 2.25
	2.26 - 2.50
	2.51 - 2.75
	2.76 - 3.00
	>3.00

Figure E4

0.2% AEP Developed Depth

Date 20 October 2017

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** B

N

0 230 460 690 Meters

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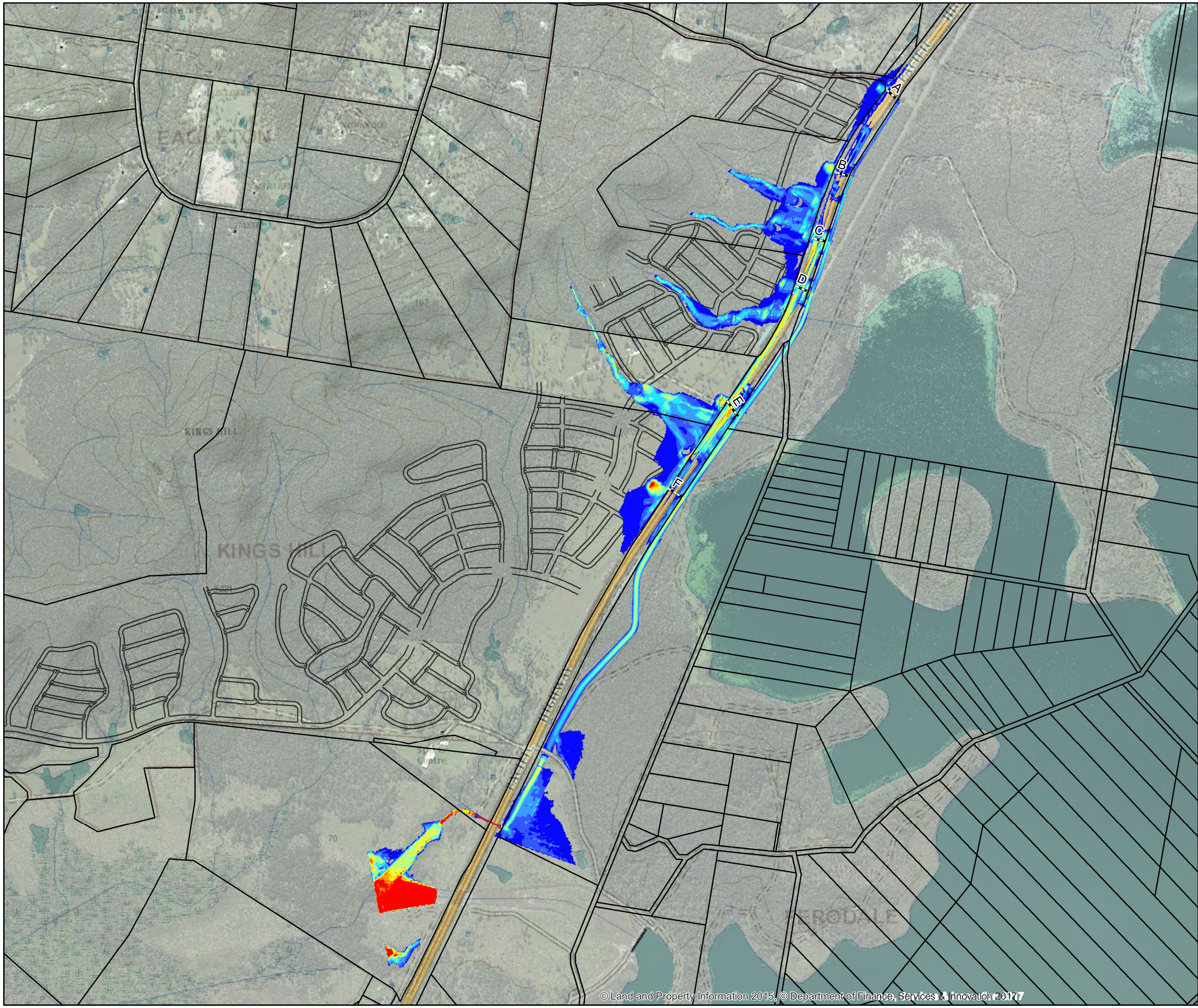

Velocity (m/s)

- 0.00 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.25
- 1.26 - 1.50
- 1.51 - 1.75
- 1.76 - 2.00
- 2.01 - 2.25
- 2.26 - 2.50
- >2.50

Figure E5

0.2% AEP Developed Velocity

Date 20 October 2017

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** B

N

0 230 460 690 Meters

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Elevation (mAHD)

4.6 - 10.0	15.6 - 16.0
10.1 - 10.5	16.1 - 16.5
10.6 - 11.0	16.6 - 17.0
11.1 - 11.5	17.1 - 17.5
11.6 - 12.0	17.6 - 18.0
12.1 - 12.5	18.1 - 18.5
12.6 - 13.0	18.6 - 19.0
13.1 - 13.5	19.1 - 19.5
13.6 - 14.0	19.6 - 20.0
14.1 - 14.5	20.1 - 25.0
14.6 - 15.0	25.1 - 50.0
15.1 - 15.5	50.1 - 125.0

Figure E6

0.2% AEP Developed
Depth

Date 20 October 2017

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** B

N

0 230 460 690 Meters

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email newcastle@northrop.com.au ABN 81 094 433 100

Difference (m)

	<-1.00
	-0.99 - -0.75
	-0.74 - -0.5
	-0.49 - -0.3
	-0.29 - -0.2
	-0.19 - -0.1
	-0.09 - -0.05
	-0.04 - 0.05
	0.06 - 0.1
	0.11 - 0.2
	0.21 - 0.3
	0.31 - 0.5
	0.51 - 0.75
	0.76 - 1
	>1.00

Figure F3

0.2% AEP Revisions B vs A
Elevation Comparison

Date 20 October 2017

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690 Meters

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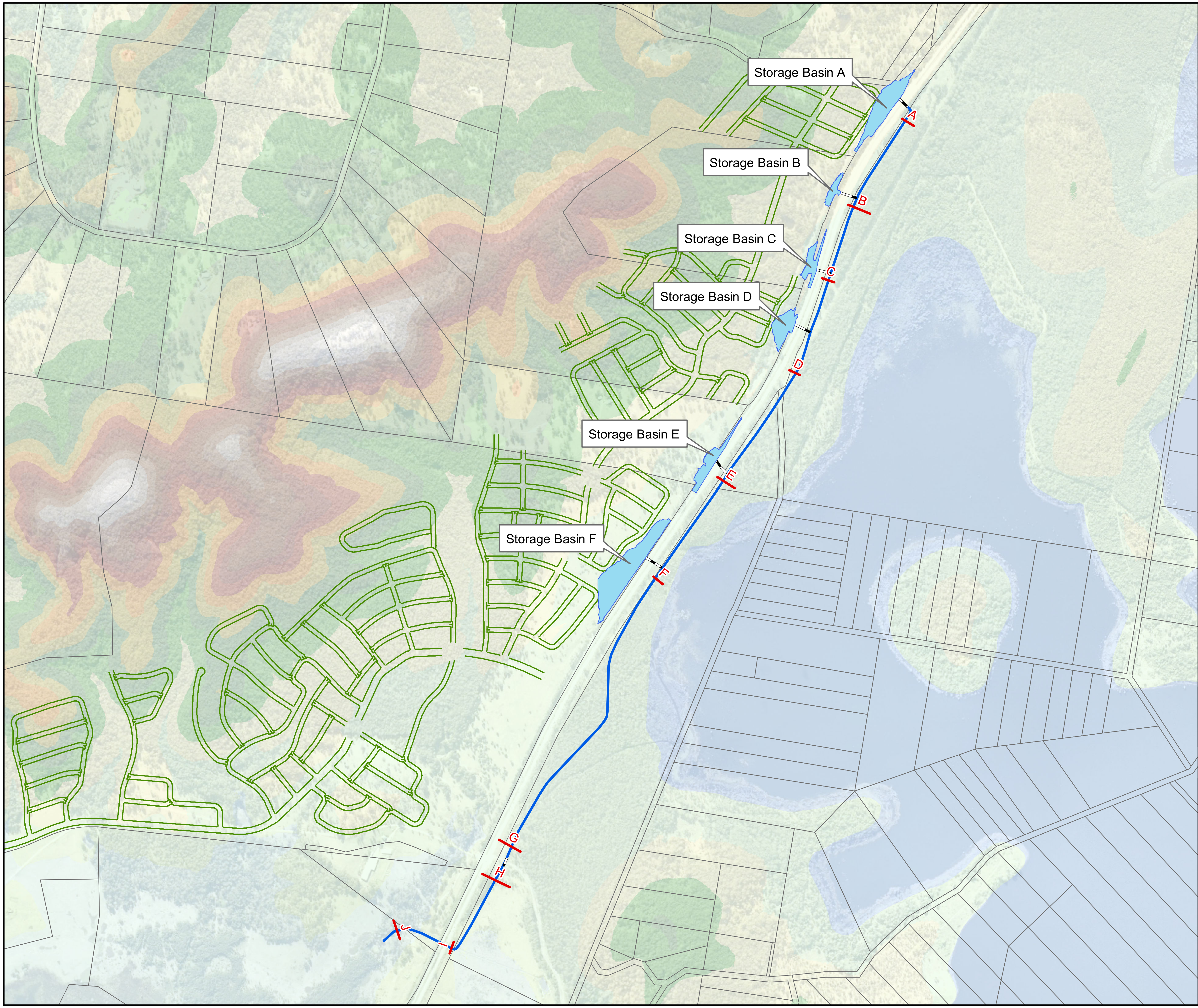

Legend

Flow Line Locations
Flood Storage Basins
Culverts
Channel

Figure H1

Flood Storage Basins
and Peak Flow Line Locations

Date 20 October 2017

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 200 400 600 Meters

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NL120526_[B16]

26th October 2017

Kings Hill Development
C/- APP Corporation
Mr Adam Smith
PO Box 1573
NORTH SYDNEY 2060

Dear Adam,

Re: Response to Council comments re: Proposed Stormwater Diversion Channel, Kings Hill Urban Release area – Kings Hill, Raymond Terrace

We are writing regarding Council's request for additional information dated the 01 August 2017. The purpose of this correspondence is to provide a response to Council's comments with respect to stormwater management for the aforementioned site.

Our response to Council's queries are as follows:

Review of Flood Study for Proposed Stormwater Diversion Channel Kings Hill Urban release area –prepared by Northrop dated 23 September 2015

Item 1

Council's Comment

"The report must include a catchment plan (sub-catchment plan) and the area contributing runoff to each culvert. This should provide information on how this system works and some understanding of how flow magnitude and flow characteristics of each sub-catchment contributing run-off to the diversion channel."

Response

Please find attached letter B15 which outlines the extent of changes made to the previous revision of modelling including both the pre-developed (Figure B1) and post developed (Figure B3) catchments. The sub-catchment properties including catchment area, vectored slope, Manning's roughness and assumed impervious fractions are presented in Table 1 of the attached letter B15, while the peak flow results for each sub-catchment, both pre and post development are shown in Table 3.

Item 2

Council's Comment

"Section 2.3 Development proposal (page 5 para 3) states that modifications have been made to the outlets pipes (pipes under Highway) with cut off swales and detention basins to lessen the impact on Highway and neighbouring properties. But it doesn't specify the locations and sizes of the detention basins used in the model to achieve this. Documentation of this information is important as potential future development of Kings Hill will require this information in order to design their sub-division and control flows across the culverts."

Prepared	LG	23/10/2017
Reviewed	GB	23/10/2017
Admin	LD	25/10/2017

Response

Please find attached Figure H1 which shows the approximate locations of the proposed storage basins. In addition, Table 6 of the attached letter shows the preliminary pre and post-developed storage capacities for each storage area. It is anticipated these storage areas will be further refined as the developed surface and final lot layout is finalised. Further information is provided in the attached letter B15.

Item 3

Council's Comment

"Section 5 – The hydrological model indicates that Design Rainfall has been estimated using the IFD data from Beresfield and ARR temporal patterns. It is not clear why Beresfield data was used instead of Raymond Terrace data. Also, it is believed that ARR 87 was used for IFD data. It should be noted that Council is in the process of adopting current Australian Rainfall and Runoff Guidelines (ARR 2016) and therefore, hydrological/hydraulic calculations and designs shall be prepared in accordance with the approaches outlined in the current Australian Rainfall and Runoff Guidelines (ARR 2016) and use the current Hydrologic Soil Mapping data for Port Stephens available from Council. Other current Australian published design guides may also be applied to particular design situations. Use of ARR-87 may under-estimate the catchment design flows and capacity of the diversion channel. Council require the modelling and design to be reviewed taking into account ARR 2016"

Response

The latest 2016 AR&R rainfall intensities and temporal patterns have been adopted for this revision of modelling as requested by Council. The rainfall IFDs were obtained from the Bureau of Meteorology (BOM) for a location over Kings Hill. Further details regarding the hydrologic and hydraulic modelling is included in the attached letter B15.

Item 4

Council's Comment

"Determination of critical Storm using RAFT model. Critical storm duration may vary from sub-catchment to sub-catchment. Smaller sub-catchments may have critical storms of shorter duration and larger sub-catchments may critical storms of longer duration. Also it may be different for the western side of the highway to the eastern side of the highway. If any detention system is introduced to the western side of highway (as mentioned in the section 2.3) then the critical storm duration may be different with and without a detention system. The critical storm duration of the upstream side of the diversion channel (northern end) may be different to the downstream side (southern end) of the diversion channel. This requires further modelling to identify the critical storm duration for each sub-catchments– western side of highway, with and without detention system and upstream and downstream of diversion channel. It is recommended that a variety of storm durations are run through the hydraulic model to determine the peak flows at various sections in the diversion channel. For example, upstream of the diversion channel may have 1hr critical storm duration for peak flows and the downstream channel may have longer critical storm duration. This may change the required cross-section of the diversion channel upstream (north) and downstream (south) as well as the details of the water management infrastructure on the western side of the Highway. Running a model for single critical storm duration may not be sufficient to determine the actual peak flows along the channel at a given point."

Response

Due to the increased number of events for consideration as part of the latest 2016 AR&R rainfall and temporal patters, a one-dimensional XP-STORM model was developed. The critical event determined by the one-dimensional model was then used in the two-dimensional model using the same catchment hydrology as the one-dimensional model. The full suite of storm durations was run in the one-dimensional model, ranging from the 10 minute to the 7 day storm durations for both the

1% AEP and 0.2% AEP design storm events. As such, up to 400 storm events were considered in order to determine the critical event for both the 1% and 0.2% AEP design storm events.

It was determined that each storage area, upstream of the Pacific Highway had a different critical event while four different storm events were determined to be critical along the length of the eastern channel. Further details are provided in the attached letter B15, which outlines which design storms were determined to be critical along both the channel and at each storage area.

Item 5

Council's Comment

"Section 6.8 – Blockage – The main purpose of this exercise is to obtain an optimum design for the stormwater diversion channel and therefore, all culverts (under the highway) must be assumed to have zero blockages. There is no sensitivity analysis necessary for the culverts to design the diversion channel. However sensitivity analysis is necessary for the diversion channel design (25% blockages or 50% blockages, etc). The diversion channel may be blocked with fallen trees and branches and therefore, a sensitivity analysis should be undertaken."

Response

As discussed during a meeting with Council, a blockage factor of 0% has been applied to the culverts beneath the Pacific highway with 50% applied to the HWC Access Track located within the eastern channel. A sensitivity test, with 50% blockage applied to the culverts across the Pacific Highway during the 0.2% AEP design storm event was also considered. The results of the sensitivity test shows that generally a reduction in the water level is expected in the eastern channel as a result. Further details are provided in the attached letter B15.

Item 6

Council's Comment

"Section 6.9 – Post developed basin and swale- Introduction of post development basins and swale along the western side of highway may change the critical storm duration and critical flows through the culverts. This may change the flows within the proposed diversion channel and as a result the cross-section of the channel, and hence the conveyance capacity may change. Require further RAFT modelling (with the detention basins) be undertaken to identify the correct critical storm duration for the channel design."

Response

A worst case scenario has been considered in the design of the eastern channel. The maximum 0.2% AEP design storm event with no additional flood storage has been considered in the results presented in the attached Figures E4 to E6.

The latest 2016 AR&R guidelines suggest that the median event should be considered, while the absence of additional flood storage will reduce the detention effects on the western side of the Pacific Highway. In light of this the results indicate the eastern channel still has sufficient capacity to convey the 0.2% AEP design storm event.

As mentioned previously, a one-dimensional model was developed in order to determine which the critical events for both the storage basins as well as the eastern channel. Further details are provided in the attached letter B15.

Item 7

Council's Comment

"Section 7 Results – The report assumed 2hr as critical storm duration for 1% AEP and 0.2% AEP storm events. But as explained in item No 4 of this memo, the critical storm duration may change at various locations such as western side of the highway, eastern side of the highway and upstream and downstream of the channel. Introduction of post development basins may also change the

critical storm duration. Therefore, several runs of the XP-Storm model are required for various storm durations and the diversion channel must be designed based on these results. Running a model for only a 2hr duration storm event may not provide an accurate design for whole length of the diversion channel."

<u>Response</u>

As mentioned previously, a one-dimensional model was developed in order to determine the critical event for both storage basins and the channel. Further details are provided in the attached letter B15.

Item 8

<u>Council's Comment</u>

"Section 7 Results- Table 5 – Comparison of XP-Raft Model result and XP-Storm Model Result – There is no proper explanation on the reason between the large variation of the results for outlets C, E and F. Flow reaching culvert E has been decreased approximately 5 times and culvert F has been increased by approximately 2 times. There is no correlation between the two models and therefore it is hard to compare."

<u>Response</u>

Please find attached letter B15 which shows in Table 6 the pipe flow results from both the one-dimensional and two-dimensional models. The results show a much closer correlation between the one and two-dimensional models to what was previously submitted.

Item 9

<u>Council's Comment</u>

"Section 7.3 – Post development flood behaviour – the report does not provide details concerning:

- *the basins locations,*
- *size of the basins,*
- *outlet from the basins,*
- *how the outlet of the basins are proposed to be connected to the culverts,*
- *how the introduction of the basins change the dynamic of water flow,*
- *how the introduction of the basins change the critical duration of the storm/s,*
- *what the cumulative impact/benefits of the basins on diversion channel"*

<u>Response</u>

The basin locations are presented in the attached Figure H1 with the size of each basin shown in Table 5 of the attached letter B15. Each storage area is proposed to be directly connected to the culverts crossing the Pacific Highway (i.e. the culverts are the outlet for each storage area). The size of these culvert crossings are shown in the below Table 1

Table 1– Pacific Highway Culvert Crossings

Culvert Crossing	Culvert Size	Pre-Developed Pipe Flow (m3/s)	Post-Developed Pipe Flow (m3/s)
A	1x450mm RCP	0.56	0.44
B	1x900mm RCP	1.70	1.36
C	4x600mm RCP	3.73	3.28
D	3x1050mm RCP	8.39	7.36
E	2x600mm RCP	1.29	1.47
F	4x1050mm RCP	10.64	7.42

Also shown in Table 1 is a comparison between the pre and the post developed pipe flow during the 1% AEP design storm event in the one-dimensional model. These results show a decrease in the peak flow through the majority of the culverts as a result of the introduction of the flood storage basins and the eastern channel. This increase is to be expected as the pre-developed case has been modelled assuming a free outfall condition, permitting greater flow through the culverts. In the developed scenario, this is not the case as the tailwater conditions are controlled by the flow through the eastern channel.

Culvert E is shown as an outlier in that, it is showing an increase in the flow capacity through the culvert during the developed case when compared to the pre-developed case. This is due to the change in the inlet conditions at the upstream end of the culvert. During a site visit it was noted that this culvert is a grated inlet with an industrial type grate 1.4m long by 0.8m wide and therefore has been modelled as such in the pre-developed case. For the developed scenario, it is proposed to carve out and remove this grate and provide additional flood storage in this area. As such the new inlet conditions will include a headwall and not the grated inlet.

It is noted during the investigation that there is significant interaction between Basins B to E during both the developed and pre-developed scenarios. The two-dimensional model suggests that overflow from upstream basins (falling from Basin B to Basin E) ran along the road reserve and discharged into the downstream basins. As such there is the potential to reduce the size of some basins if the storage volume is increased upstream. It is anticipated that further investigation will be conducted at a later stage.

The critical event was found to vary from basin to basin and when storage volumes were changed, often the same storm duration was critical, however the temporal patter that produced the median results would change. The final pre and post critical events are presented in the attached letter B15 in Tables 5 and 7 for the pre and post developed scenarios respectively.

Item 10

<u>Council's Comment</u>

"Section 7.3 – Post development flood behaviour- Table 6- This table must include peak flows from culverts and cumulative peak flows along the diversion channel (just d/s of each culverts). There is no information available in the report regarding design flows (at various section of the channel)."

<u>Response</u>

Table 4 in the attached letter B15 shows the results of the 0.2% AEP design storm event at various locations along the eastern channel including just downstream of each of the culverts. Figure H1 shows the location where each peak flow rate has been recorded.

Table 7 of the attached letter B15 shows the results for the 1% AEP design storm event for each of the culverts crossing the Pacific Highway during the developed scenario for both the one-dimensional and two-dimensional models.

Furthermore, Table 3 shows the 1% AEP design storm peak flow results for each sub-catchment during both the pre and post developed scenarios.

Item 11

Council's Comment

"Section 7.3 – This section must incorporate an additional table showing sub-catchment areas, sub-catchment flows (before and after development), u/s of the detention basin, d/s of the detention basin, d/s of the culverts and along the channel etc."

Response

Table 1 in the attached letter B15 shows the sub-catchment properties and variables used for the revised modelling, while Table 3 shows the individual and cumulative peak flow results for both the pre and post developed scenarios for each sub-catchment during the 1% AEP design storm event.

Item 12

Council's Comment

"Section 7.3 – Table 7 – Flood maps show that all basins are submerged during the 1%AEP and 0.2% AEP storm events. Also, some of the figures indicate that the flood level resulting from 0% blockages in the culverts is higher than 50% blockages. It is not clear in the report how this is happening. Storage capacity on the western side of highway (with basins and without basins) should provide sufficient information on why the reduction of water level is happening. Require a detailed explanation as to why and how this is happening."

Response

It is not clear as to the location of where this is occurring, however updated basin extents and locations have been provided in the attached Figure H1 with estimated volumes provided in Table 6 of the attached letter B15.

Item 13

Council's Comment

"Section 8 – Upstream Development – This section indicates that the manning n=0.03 was used for a mixture of pervious and impervious area. But, in fact most of the upstream developments will have low grasses and paved areas directly connected to the drainage system. Paved areas manning's n is 0.015 and turf grass growing where average depth of flow is equal to the vegetation is 0.025 - 0.05. An even lesser value is applicable, if the depth of water is more than the average vegetation height. Therefore, use of manning, n=0.03 for the development scenario would result in lesser flows reaching the culverts. It is required to separate pervious and impervious areas in the modelling and use appropriate Manning's "n" values separately."

Response

The impervious and pervious catchments have been separated and the suggested values have been used as requested. Please refer to the attached letter B15 for a detailed explanation of the revised Manning's roughness and other catchment variables used in the one and two-dimensional models.

Item 14

Council's Comment

"Section 8.4 Sensitivity analysis – The report states that 50% blockages were applied to the outlet culverts. The diversion channel must be designed with zero blockages on the culverts and not 50% blockages on the culverts. Sensitivity analysis must be applied on the channel blockages and spillway blockage and not on the culvert blockages."

Response

Blockage has been applied based on discussions with Council. The diversion channel has been designed based on 0% blockage in the culverts beneath the Pacific Highway and 50% blockage in the culverts across the HWC Access Track. A sensitivity has also been undertaken with 50% blockage applied to the culverts beneath the Pacific Highway. A detailed explanation of the results is presented in the attached letter B15.

ARCADIS – Drainage Diversion Channel – Detailed Design

Item 1

Council's Comment

"Condition of the existing disused spillway – The condition of the spillway is unknown. It is important to find out the condition of the spillway for its structural integrity and potential use as a stormwater conveyance structure. This is a very old disused spillway (more than 50 years) and therefore, the internal walls and retaining structures may be reaching the end of their life expectancy and may require structural improvements."

Response

Response is to be provided by others.

Item 2

Council's Comment

"It is not clear from the report how this spillway was modelled – was it modelled as a channel, broad crested weir, Ogee type of spillway or something else. Spillways generally are made up of four components: a control structure, discharge channel, terminal structure, and entrance/outlet channels. Control structures regulate the flows and therefore, use of actual characteristics of the spillway is important for determining the water levels and flow rates within the channel. Discharge channels, also known as waterways, convey flow that passes through the control structure down to the dam, in this case, the proposed channel. The actual type of spillway must be identified and this should be used in the modelling."

Response

The downstream Irrawang Spillway has been modelled as a 5.3m wide by 5.6m high concrete lined channel as it passes under the Pacific Highway, then narrowing to 2m wide by 4m high prior to the outlet of the spillway. This is consistent with what was observed during site investigations.

Item 3

Council's Comment

"It has been noticed that channel downstream of access road culvert (downstream of the 3 box culverts) is constricting flows and water is allowed to overflow across the bank and spread into the large area between new spillway, access road and the Pacific Highway. It is not clear, who is going to maintain or manage this land once the channel is handed over to Council. Is this area covered by an easement? Any future works on this area, or restriction on spreading water onto this land would affect the water level and flow rates within the diversion channel. This may impact all upstream water levels (within Kings Hill) and travel lanes within the Highway, etc. This should be documented properly so that no future development changes occur in this area."

Response

Council's comments have been noted.

Item 4

Council's Comment

"LS sections should include water surface profile. This can then be used to compare where the water is overtopping the banks and how much the freeboard is available. Some sections (from 1990 to 3450m) of the LS are missing in the design plan."

Response

Response is to be provided by others.

We trust this is what you require. Should you have any queries, please feel free to contact the undersigned on (02) 4943 1777.

Prepared by:	Reviewed by:
Laurence Gitzel	**Angus Brien**
Civil/Environmental Engineer	Civil Engineer
BEng (Environmental)	*BEng (Civil)*

Flood Study

for

Proposed Stormwater Diversion Channel

Kingshill Urban Release Area

at

North Raymond Terrace, New South Wales

Job No: NL120526
Revision: A
Date: 29/02/2016

	BY	DATE
Prepared	GB	29/02/2016
Checked	BC	29/02/2016
Admin	LD	29/02/2016

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Table of Contents

1 Introduction

Northrop Consulting Engineers have been engaged to undertake a hydrological and hydraulic investigation at the Kingshill Urban Release Area, North Raymond Terrace. The purpose of this correspondence is to summarise the extent of modelling, modelling methodology, results and design implications from a hydraulic perspective.

Kingshill Urban Release Area is located adjacent to Grahamstown Dam which is the Hunter Valley's largest drinking water supply. Hunter Water has previously advised that the eastern catchment that drains from the proposed development into Grahamstown Dam will need to be diverted should development occur. A number of possible routes have been investigated, including running along the eastern side parallel to the Pacific Highway, which has been considered as part of this analysis.

Included herein is;

- a description of the locality and subject catchment,
- a summary of design constraints and previous work with respect to the channel,
- an outline of hydrological modelling undertaken to determine the peak flows reaching the highway,
- the results of hydraulic modelling undertaken to determine the existing and developed flood behaviour, and;
- a discussion around the impact of the proposal as well as design and ongoing maintenance implications.

2 The Subject Site

2.1 Locality Description

The Kingshill Urban Release Area is located approximately ten minutes north of Raymond Terrace. It is bordered on the east by the Pacific Highway, on the north by Six Mile Road, west by Newline Road and south by Irrawang Swamp.

Grahamstown Dam is located to the east, with a portion of the site currently draining to the dam. To the south east of the site, a spillway from the dam releases water to the Irrawang Swamp. A secondary disused spillway is located to the north of the current spillway. Irrawang Swamp drains to the Williams River, just upstream of the confluence point with the Hunter River.

Kings Hill is located within the subject site with a summit elevation of approximately 140m AHD. To the north is Seaham Hill with a summit of approximately 180m AHD.

The major features in the vicinity are shown in Figure A1.

2.2 Subject Catchment

The contributing catchment from Kings Hill Urban Release Area is known as the eastern catchment and is approximately 1.8km^2 in size. It is largely undeveloped with the lower portions currently used for agricultural purposes.

Vegetation is mixed with the upper reaches characterised by densely wooded vegetation and the lower portion covered with pasture grasses. Soil types also vary with highly erosive soils in the upper reaches and dense clay in lower lying areas.

Topography is steep with grades in excess of 25 percent on the western portion of the catchment and levels up to 100m AHD. In the east grades are more accessible and are in the range of one to ten percent. Levels in the lower reaches are in the order of 13m AHD and act as storage volume for the Grahamstown Dam.

The Pacific Highway acts as a major hydraulic control prior to the runoff discharging into the Grahamstown Dam. A number of piped outlets convey water from west to east. On the eastern side of the highway, the land is low lying with an access road running along the length.

The subject catchment, including elevations and piped outlet locations is shown in Figure A2.

2.3 Development Proposal

Several hundred residential lots are proposed within the subject catchment. As mentioned earlier, Hunter Water requires water to be collected and conveyed around the dam. In order to satisfy this design requirement, a channel is proposed along the length of the site on the eastern side of the highway to the existing disused spillway to the south. From here the diverted water will enter the Irrawang Swamp.

Several new basins and swales are proposed for conveyance and water quality treatment within the development footprint. These have not been considered as part of this study due to the fact that they are designed primarily for the more frequent rainfall events, not the extreme cases considered herein.

Modifications have been considered to the outlet pipes, with cut-off swales and detention basins considered to attenuate the runoff sufficiently so as to cause no significant impact to adjacent properties or the highway.

3 Previous Studies

As part of the *Kings Hill Urban Release Area Water Management Strategy Guidelines* produced by BMT WBM, hydrology and hydraulics for the upstream portion of the site were considered along with options for the diversion channel. An XP-RAFTS model was developed for the hydrology and an unsteady TUFLOW analysis was undertaken for the hydraulics.

For the purposes of this study, infrastructure under the Pacific Highway was assumed and the diversion channel was located on the western side of the highway through the middle of the proposed development.

This study has been used for reference and comparison throughout the course of these investigations.

4 Methodology

The study was undertaken through a process of initial negotiation and briefing, data collection, site investigation, client meetings, numerical modelling, validation and review.

An initial brief was undertaken with officers from Port Stephens Council and Hunter Water Corporation. Both these organisations will have ongoing maintenance requirements along the length of the channel and requirements were discussed regarding vegetation control, seepage monitoring and access arrangement. The existing 1% AEP critical event was modelled with tailwater from the Grahamstown Dam and Irrawang Swamp. For the developed case, the 1%AEP was modelled with the tailwater from Irrawang Swamp (the channel makes the Grahamstown Dam hydraulically isolated from the development) in order to assess the no significant impact criteria. The 0.2% AEP (1 in 500yr ARI) critical event was run as the capacity criteria for the channel.

Data collection was undertaken in order to better understand the catchment and issues surrounding the existing flood behaviour of the subject site and its surrounds. A range of data was available including topographic information from LIDAR and detailed survey, aerial photography and previous studies. A number of site investigations were carried out throughout the study area to ground truth the topographic data provided, and review the catchment characteristics.

From all the data sources and site visits described above, numerical modelling of both hydrological and hydraulic processes was undertaken. Firstly, the traditional hydrological modelling was undertaken in order to ascertain the critical duration storm event. XP-RAFTS was used for this purpose. RAFTS was also used to undertake preliminary hydraulic modelling investigating a range of geometric designs. Once design was settled on, this was passed to Hyder (the civil designers) with geometry, water depth and grades. A 12D TIN was created and this was input into XP-STORM to undertake the two-dimensional analysis using rainfall on grid hydrology.

Periodic meetings were held with various stakeholders to present the findings of preliminary modelling, as well as refine and guide the channel design.

5 Hydrological Modelling

5.1 Traditional Hydrology using a RAFTS model

An XP-RAFTS model was prepared to simulate the runoff from the regional catchment and local upstream catchments reaching the subject site. Catchments were discretised and hydrological parameters estimated using the topographic information available. An initial and continuing loss model was adopted. Parameters used in the modelling are outlined below for pervious and impervious subcatchments in Tables 1 and 2.

Table 1 - Pervious catchment parameters

Initial loss	15mm
Continuing loss	2mm/hr
Manning's 'n'	Heavily Treed Areas – n=0.10 Open Areas – n=0.06
Vectored slope	From topography
Impervious percentage	0%

Table 2 - Impervious catchment parameters

Initial loss	1mm
Continuing loss	0mm/hr
Manning's 'n'	0.015
Vectored slope	From topography
Impervious percentage	100%

Design rainfall has been estimated using the IFD parameters for Beresfield and the Australian Rainfall and Runoff temporal patterns. A number of durations ranging from 25 minutes to 72 hours were simulated for the 1% AEP and 0.2% AEP design storms. Catchments are shown attached in Figure B1.

5.2 Direct Rainfall on Grid Hydrology

Using the critcal rainfall pattern adopted for the RAFTS model, runoff was generated directly on the hydraulic grid surface. The benefit of this method is that catchment extents and concentrated flow behaviour do not need to be defined prior to running the model. One of the benefits of this type of modelling was representing the lateral flow along the Pacific Highway and interaction in spill levels both along and over the highway.

The extent of the direct rainfall polygon is shown in Figure B2.

6 Hydraulic Modelling

A hydraulic model was built using the XP-STORM computer software package. This package uses the TUFLOW hydrodynamic modelling engine. A description of some of the modelling parameters is included below.

6.1 Terrain

Terrain data was obtained from a range of data including LIDAR and several difference detailed surveys. These were combined in XP-STORM to form a single existing TIN. In areas not representing the expected ground conditions well, elevation objects were used to alter the surface as required.

6.2 Grid Extents and Cell Size

Due to the selection of direct rainfall on grid, the hydraulic grid extends to the catchment boundary. On the downstream side, the grid extends roughly to the border of the Grahamstown Dam, and Irrawang Swamp.

Cell size is determined as a function of accuracy and model run time. For the upstream reaches of the catchment where the hydraulic representation is not as critical a four metre grid was chosen. Around the highway and for the proposed channel, a finer one metre grid was nested in the larger grid to more accurately represent the hydraulic behaviour.

6.3 Boundary Conditions

Head boundaries and rainfall polygons form the boundary conditions for the model. In the existing scenario these include the Grahamstown Dam, Irrawang Swamp and a catchment ridgeline boundary. In the post developed condition, this includes the Irrawang Swamp and catchment ridgeline only. Table 3 shows these levels below.

Table 3 - Initial water levels

Location	Elevation
Grahamstown Dam 1% AEP	13.60m AHD
Irrawang Swamp 1% AEP	4.59m AHD
Catchment ridgeline	0m AHD (free discharge

As described above, a rainfall polygon extends over the entire catchment to apply the rainfall pattern to the grid. Also, in order to prevent the water from rushing onto the grid and causing instabilities, an initial water level polygon has been applied over areas affected by the nominated tailwater to represent the maximum level, which will likely occur due to the vastly different times of concentration for the separate systems.

A figure showing the location of all these boundary conditions is included in Figure C1.

6.4 Manning's Roughness

Manning's roughness represents the resistance to flow across the surface. Values of Manning's roughness vary over the two dimensional grid depending on surface type and land use. These have been adopted from a literature review and site inspection and are shown below in Table 4.

Table 4- Manning's n roughness parameters

Surface Type	Manning's n
Roads	0.015
High Grass with Scattered Brush	0.060
Water bodies	0.030
Sparse trees	0.080
Dense trees	0.100
Developed	Varies by depth 0.030-0.200
Channel	0.050

The spatial distributions in the pre-developed and post-developed scenario are included in Figures C2 and C3.

6.5 Loss Model

In order to maintain consistency with the traditional hydrological model, an initial and continuing loss model was incorporated in the land use polygons. For impervious areas an initial loss of 1mm was adopted with no continuing loss. For pervious areas, the initial loss was 15mm, with a continuing loss of 2.5mm/hr.

6.6 1D Elements

One dimensional elements have been used to represent the pipes and culverts identified at the outlet to the subject catchment. These include the outlet spillway and associated channel, pipes under the Pacific Highway and Hunter Water Corporation access road.

The size and invert level of these features have been adopted from detailed survey, and their location is shown in the Figure C4.

6.7 Model Run Duration and Time Step

The duration of the model runs were longer than that of the storm event in order to represent the falling limb of the hydrograph. The time step for the model was dependent on the grid size. For the four metre grid a two second time step was adopted, with half a second for the nested one metre grid.

6.8 Blockage

Blockage has been considered on all culverts, with 50 percent applied. Due to the likely impact on the flow reaching the channel, a sensitivity case of no blockage has also been investigated.

6.9 Post Developed Basins and Swales

In order to convey runoff to the outlet points and attenuate runoff sufficiently to utilise the existing infrastructure, swale and basins have been proposed along the highway. These are represented as elevation objects in XP-STORM which modify the existing TIN. The size of these swales and basins do not encroach on the development area and it is anticipated they will be able to be integrated into the landscape and urban design concept.

7 Results

7.1 Critical Storm Durations and Peak Flows

From the RAFTS model, it was determined that the two hour storm was critical for both the 1% AEP and 0.2% AEP events. The peak flows as determined from the various methods are shown below in Table 5.

Table 5 - Peak flows entering the hydraulic model

Outlet	XP-RAFTS	XP-STORM Culverts
	m^3/s	m^3/s
A	0.62	0.55
B	1.44	1.70
C	5.68	3.67
D	6.96	7.64
E	6.48	1.36
F	4.72	8.39

From the above, it is shown that the two methods produce results which are distributed differently. Representing flow behaviour longitudinally along the highway, as well as more accurately representing the existing detention effects and spill levels of the highway embankment is one of the benefits of using the direct rainfall on gird approach. Despite the differences with XP-RAFTS it is noted that the sum of the peaks is within ten percent which is considered a good correlation. Furthermore, the peak obtained from the rainfall on grid method is larger than the XP-RAFTS simulation which reflects a conservative approach.

7.2 Existing Design Flood Behaviour

The existing 1%AEP event was considered as a baseline for comparison with the post developed scenario. Figures showing the existing flood behaviour are included in Figures D1-D4.

7.2.1 1% AEP – Zero Blockage Scenario

In the critical 1%AEP event, flow is concentrated along the watercourses traversing the site prior to intersecting with the highway.

Water is generally contained to the west of the highway with a few notable exceptions. Ponding extends onto the northbound carriageway in the vicinity of Outlet C; whilst at Outlet E, flow completely inundates the northbound travel lanes. Due to the low lying nature of the site around Outlet F, the peak water level from the Grahamstown Dam extends back into the site.

7.2.2 1% AEP – 50 Percent Blocked Scenario

The behaviour for the blocked scenario is similar to that of the unblocked case, apart from the greater ponding extent and depth around the piped outlets. Inundation of the northbound lane extends from Outlet E to Outlet C for this blockage condition.

7.3 Post Development Flood Behaviour

Post developed flood behaviour is significantly different on the eastern side of the highway due to the channel diversion. On the western side, the concentration of flows is faster due to the reduction on catchment roughness. Flow is also diverted to the basins around the outlets via a system of swales. The northbound carriageway is flood affected around outlets C and E in both the 1% and 0.2% AEP events.

Channel water surface elevations are shown in Table 6 below.

Table 6 - Post developed water levels in the channel

Chainage	Outlet	1% AEP 0% Blockage	0.2%AEP 0% Blockage	Channel Invert	Bund Height
24	A	17.61	17.62	17.38	17.78
200		16.96	17.02	16.72	17.80
400	B	16.29	16.38	15.92	17.30
670	C	15.53	15.62	14.87	16.05
885	D	15.30	15.37	14.06	16.45
1200		14.47	14.57	13.33	15.90
1489	E	13.86	14.05	12.66	15.65
1889	F	13.26	13.51	11.71	14.70
2200		12.67	12.92	11.14	14.60
3000		11.47	11.99	9.65	13.50
3107	HWC U/S	11.45	11.97	9.45	13.40
3142	HWC D/S	11.24	11.69	9.38	13.00
3485		11.21	11.69	8.73	13.00

The results are illustrated in Figures E1-E6.

7.4 Comparison of Scenarios

Due to the proposed development, the water elevation in the natural watercourses is elevated. Around the outlet basins, a reduction in water level is calculated. Generally speaking, water elevation is reduced around the highway – in particular, no increases are calculated on the travel lanes. Increases are calculated around the new access track on the eastern side of the highway reflecting the increased surface elevation. Furthermore, an increase is calculated to the south of outlet F of in excess of 200mm. It is noted in this case that the freeboard to the highway is still in excess of one metre.

A comparison at outlet points is shown below in Table 7. The differences are illustrated in Figures F1 and F2 attached.

Table 7 - Comparison 1% AEP water elevations (m AHD)

	1% AEP 50% Blockage			1% AEP 0% Blockage		
Point	**Pre**	**Post**	**Comparison**	**Pre**	**Post**	**Comparison**
Outlet A U/S	21.44	21.29	0.15	21.28	21.17	0.11
Outlet A D/S	18.47	18.47	0.00	18.47	18.02	0.45
Outlet B U/S	20.18	19.90	0.28	18.95	18.87	0.08
Outlet B D/S	17.78	16.69	1.09	17.59	16.70	0.89
Outlet C U/S	19.27	19.13	0.14	19.19	19.13	0.06
Outlet C D/S	16.47	15.91	0.56	16.55	16.06	0.49
Outlet D U/S	18.17	18.02	0.15	17.85	17.75	0.10
Outlet D D/S	16.04	15.81	0.23	16.18	15.37	0.81
Outlet E U/S	16.72	16.20	0.52	16.37	16.06	0.31
Outlet E D/S	15.08	14.42	0.66	15.12	14.01	1.11
Outlet F U/S	14.81	14.56	0.25	14.27	14.02	0.25
Outlet F D/S	13.60	12.98	0.62	13.60	13.28	0.32

8 Discussion

8.1 Significant Impact

The NSW Floodplain Development Manual references “no significant impact” as a means of assessing developments within flood prone land. For the purposes of this study we have assumed that significant impact means increasing the flood level on the highway or decreasing the freeboard in adjacent areas where it is already less than 500mm.

Other potential impacts relate to Grahamstown Dam and existing residential properties along Newline Road. With respect to the dam, a small reduction in storage volume is a consequence of the development proposal. Given the large overall volume, this is expected to have a negligible impact on the flood behaviour and dam operation. In terms of existing residences in Newline Road, we have relied on the information contained in the *Kings Hill Urban Release Area Water Management Strategy Guidelines* prepare by BMT WBM.

8.2 Upstream Development

Upstream development has been taken into account by reducing the catchment roughness to represent the quicker response of impervious areas. A low flow value of n=0.03 was chosen to represent the mixture of pervious and impervious surface coverings. The increased flow is evident from the increased flood level along the natural watercourses throughout the site. Swales and small basins have been included on the western side of the highway in order to convey and attenuate runoff to suit the current capacity of the existing culverts. As discussed earlier, these basins and swales are expected to be incorporated within the urban design and landscape concept in this area. As part of the traditional pit and pipe network of the perimeter road, some of these swales and/or basins may be rendered redundant.

We note that a number of additional water quality devices will be required in order to satisfy the guidelines which may include rainwater tanks, bio-retention basins and raingardens, and constructed ponds and wetlands. These devices will help to attenuate the peak flow and volume leaving the developed area, however have been left out of this modelling. Given the less likely events modelled, this assumption is considered appropriate, albeit slightly conservative.

8.3 Highway Culvert Modification

As part of the hydraulic design process, consideration was given to upgrading the culverts under the Pacific Highway. The purpose of this option was to assess whether the detention basins on the western side of the highway could be removed in order to facilitate more lots. In order to assess the potential of this option, the culverts were doubled at each outlet and an additional outlet was modelled between outlets E and F where a significant amount of runoff is intercepted by the highway.

It was determined that a significant decrease in water levels could be achieved on the western side of the highway from this approach; however increases were still calculated along the site frontage. This option was discounted due to the potential expense and minimal benefit on lot yield.

8.4 Sensitivity Analysis

A sensitivity analysis was undertaken on culvert blockage and channel roughness.

Council originally specified a roughness of n=0.05 which is representative of an excavated channel, not maintained with a “clean bottom, brush on the sides” (Chow, 1959). Consideration was given to an increased roughness of n=0.065 and n=0.08. This maximum value represents “dense weeds, high as flow depth” (Chow, 1959). This situation is considered unlikely due to regular maintenance, however provides confidence that the 0.2%AEP event will be conveyed event if reeds or similar develop within the channel base. The impact of larger roughness on flood level is shown in Figure G1.

A blockage of 50% was considered over the outlet culverts. A sensitivity analysis was also undertaken for no blockage. Both events satisfied the no significant increase in flood impact test for the 1%AEP event, as defined above, and the conveyance was satisfied for the 0.2%AEP event.

8.5 Downstream Outlet and Bund Arrangement

The disused spillway to the south of the site has been used for the outlet of the channel. A bund has been modelled running east west at an elevation of 12m AHD to prevent water interacting with the current spillway. It may be desirable to have a smaller bund in this area with water continuing along parallel to the highway and spilling through the existing spillway. It is not expected to have an impact on the capacity of this infrastructure due to the differing times of concentration of the two catchments; however this scenario has not been considered as part of this modelling.

9 Recommendations

From a hydraulic perspective, the proposed channel has no significant impact on the adjacent highway, Grahamstown Dam, or downstream properties in a 1%AEP event. Furthermore, the capacity of the channel is sufficient to convey a peak 0.2% AEP event. The following recommendations are offered regarding the execution of the development;

- **Staging**; staging of the development may be undertaken as fill becomes available. The channel and bund works should be undertaken at the same time as the first side of the creek is filled.
- **Creek works**; revegetation of the creek should be undertaken as soon as practical to minimise risk to the development. Regular maintenance should be undertaken to ensure efficient hydraulic function of the design.
- **Flood response**; due to the flood prone nature of the future development in the PMF, onsite refuge should be provided above the flood level and a Flood Emergency Response Plan prepared at the appropriate stage.

10 Conclusions

An investigation into the existing flood behaviour and impact of proposed channel at the Kings Hill Urban Release Area has been undertaken. It was concluded from analysis of the modelling that;

- The Pacific Highway is flood affected in the existing 1%AEP and 0.2%AEP scenarios;
- A portion of the site is inundated by the Grahamstown Dam at maximum storage level;
- No significant impact was calculated for the critical 1%AEP event as a result of the proposed development and channel design;
- The channel has sufficient capacity to convey the critical 0.2%AEP event;

We commend our findings for review. Should you have any queries regarding this correspondence, please feel free to contact the undersigned on (02) 4943 1777.

Prepared by:

Angus Brien

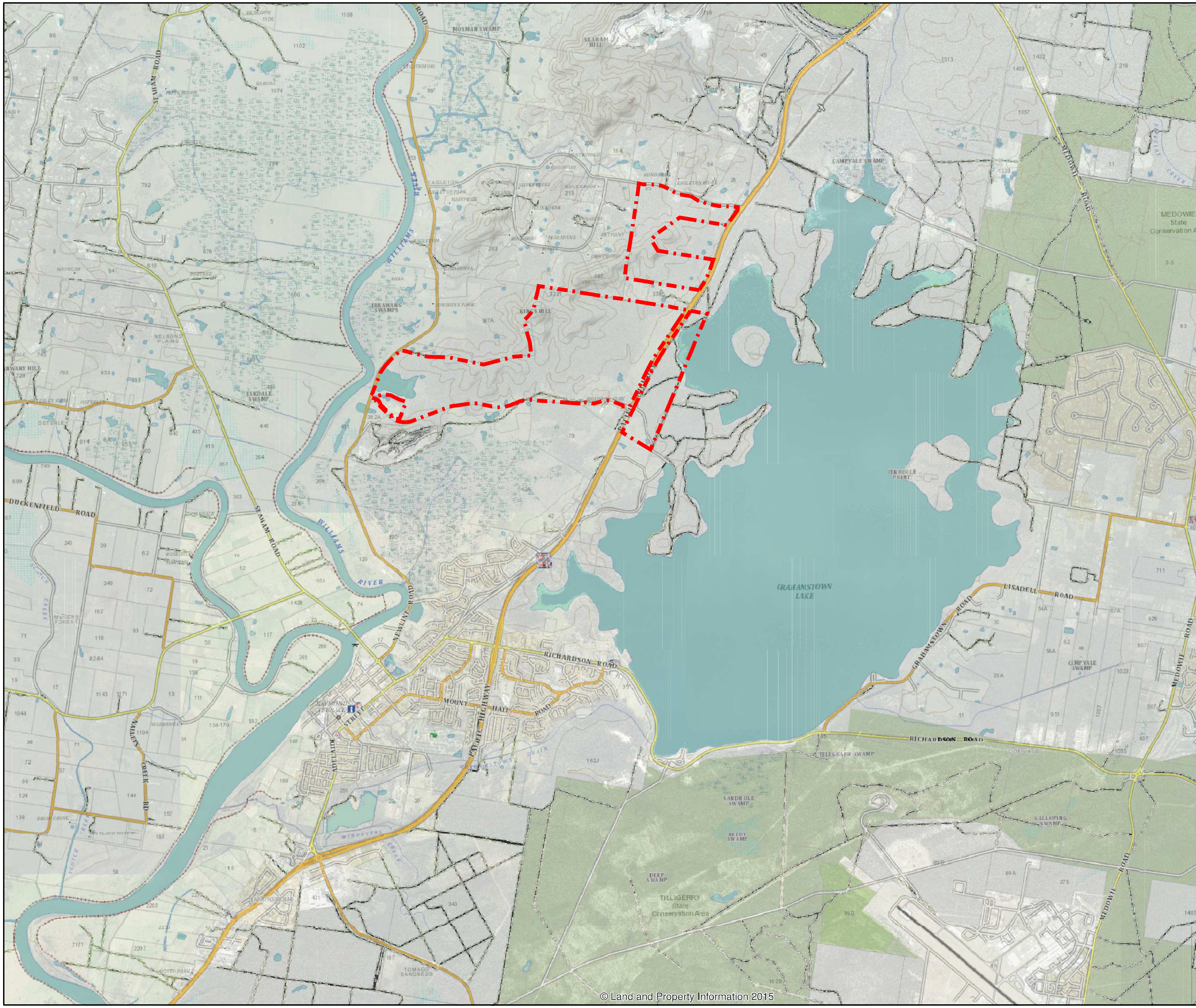
Civil Engineer

Reviewed by:

Ben Clark

Principal

Appendix A – Figures



Legend

Site Boundary

Figure A1

Locality

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 800 1,600 2,400 Meters

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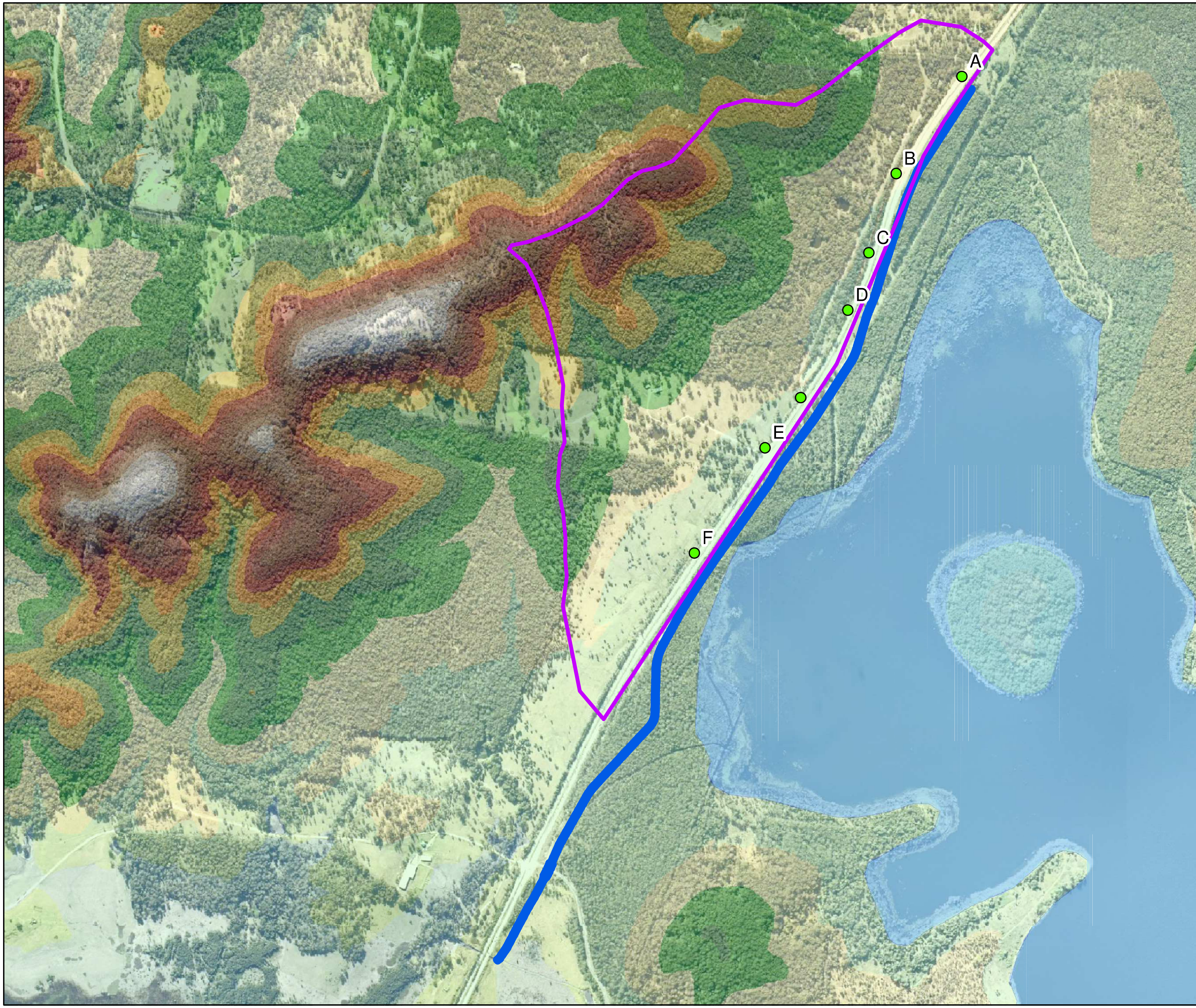

Legend

Pipe Outlets

Eastern Catchment

Proposed Diversion Channel

Elevation (m AHD)

0.0 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
100.1 - 110.0
110.1 - 120.0
120.1 - 130.0
130.1 - 140.0

Figure A2

Catchmemt Features

Date 23 September 2015

Job Name
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Eastern Channel Flood Study

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0 190 380 570 Meters

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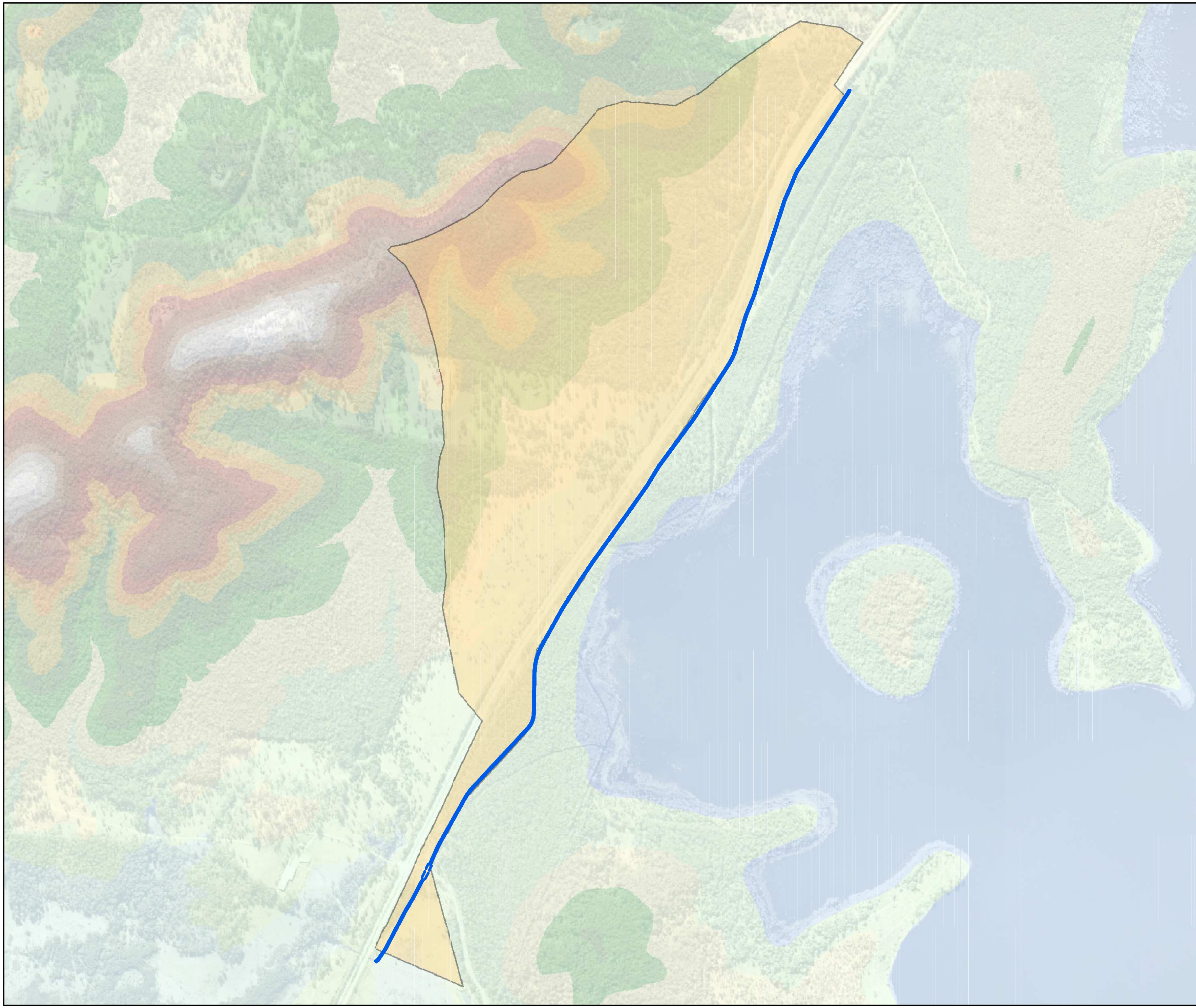

Legend

Channel
Direct Rainfall Extent

Elevation (m AHD)

0.0 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
100.1 - 110.0
110.1 - 120.0
120.1 - 130.0
130.1 - 140.0

Figure B2

Direct Rainfall Hydrology

Date 23 September 2015

Job Name
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Eastern Channel Flood Study

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0 200 400 600 Meters

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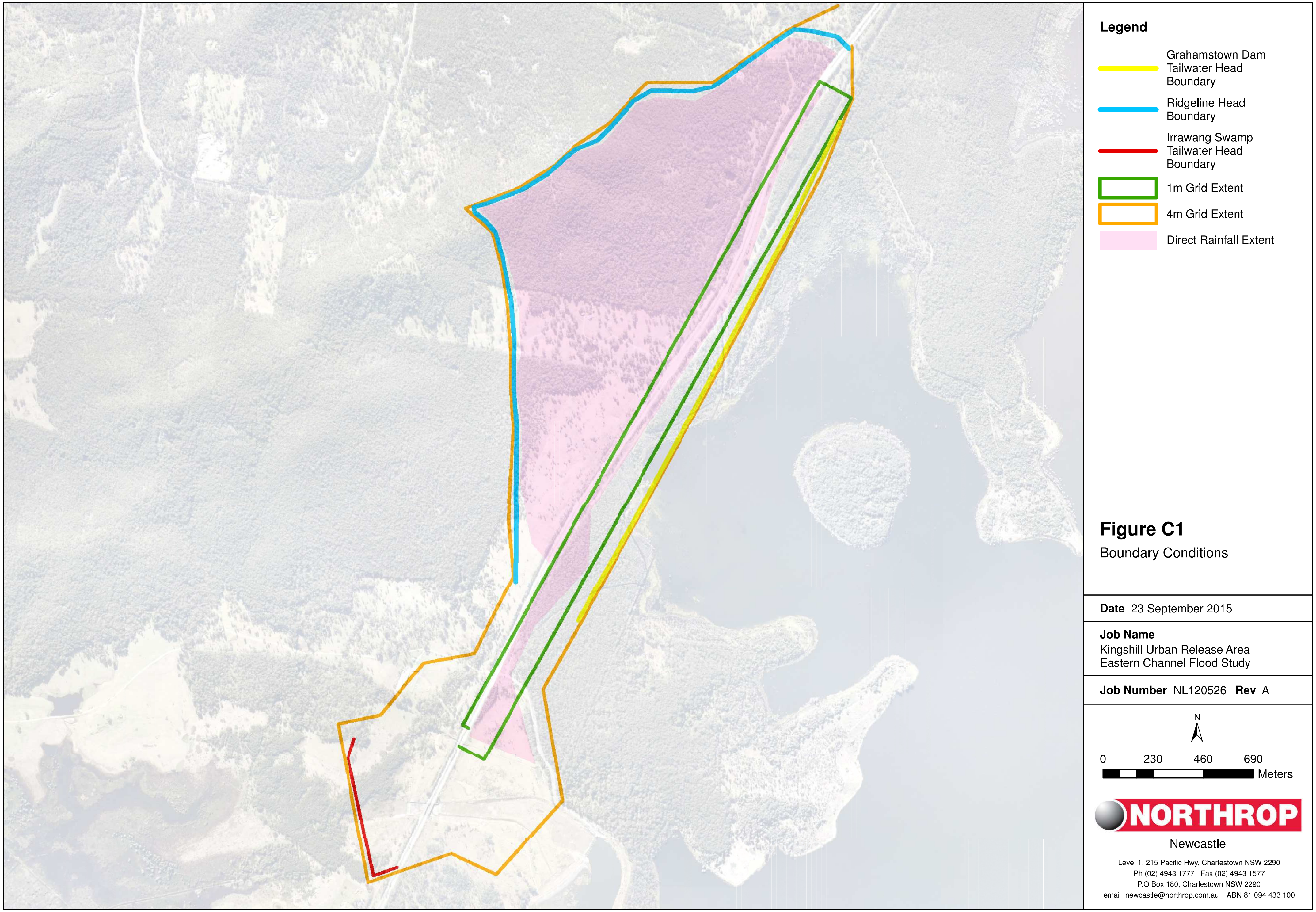

Figure C1

Boundary Conditions

Date 23 September 2015

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Eastern Channel Flood Study

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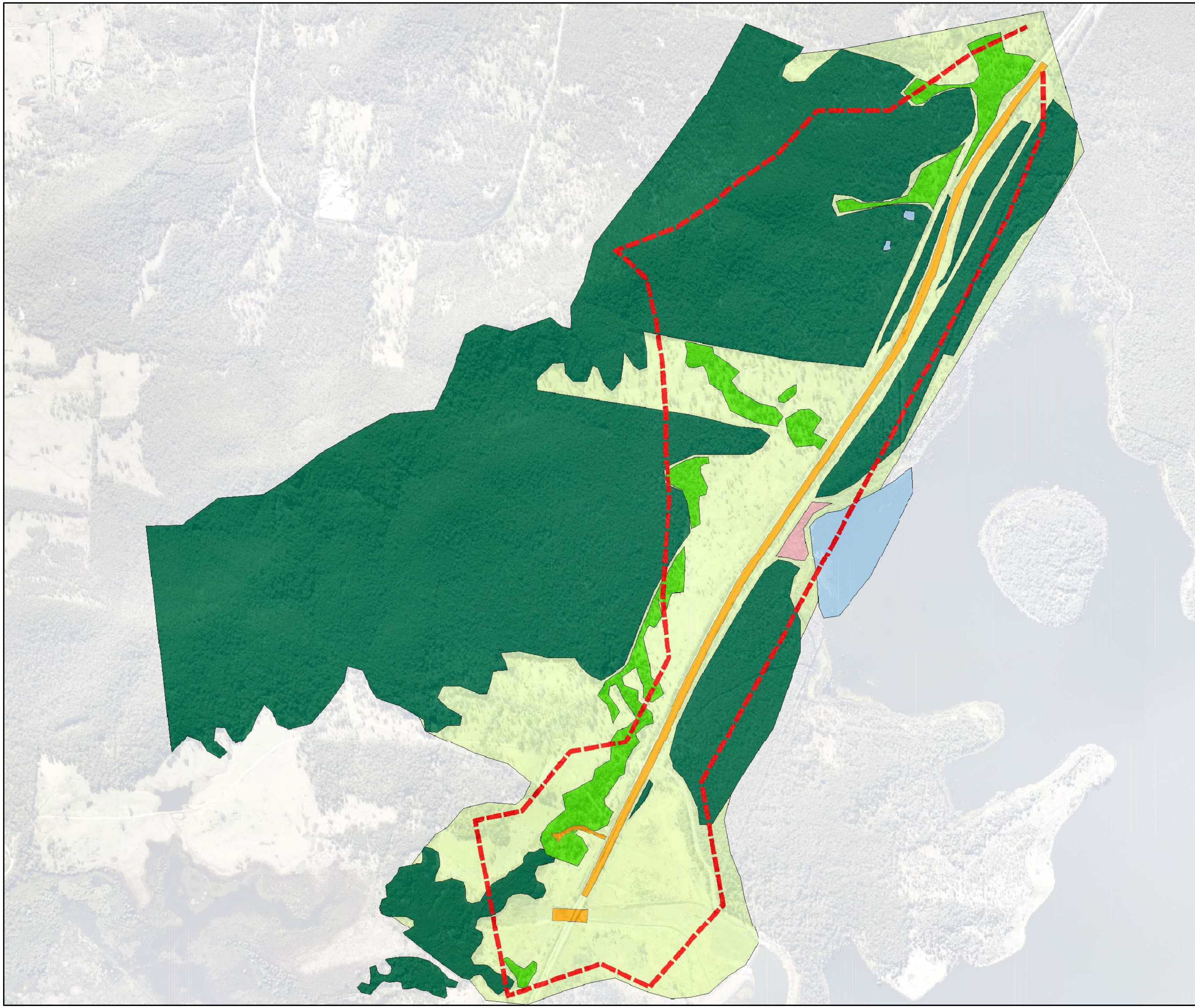

Legend

- Road / Hardstand
- Waterbody
- Sparse Trees
- Dense Trees
- Reeds
- Grass
- 2D Grid Extent

Figure C2

Mannings Roughness Existing

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Eastern Channel Flood Study

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0 240 480 720 Meters

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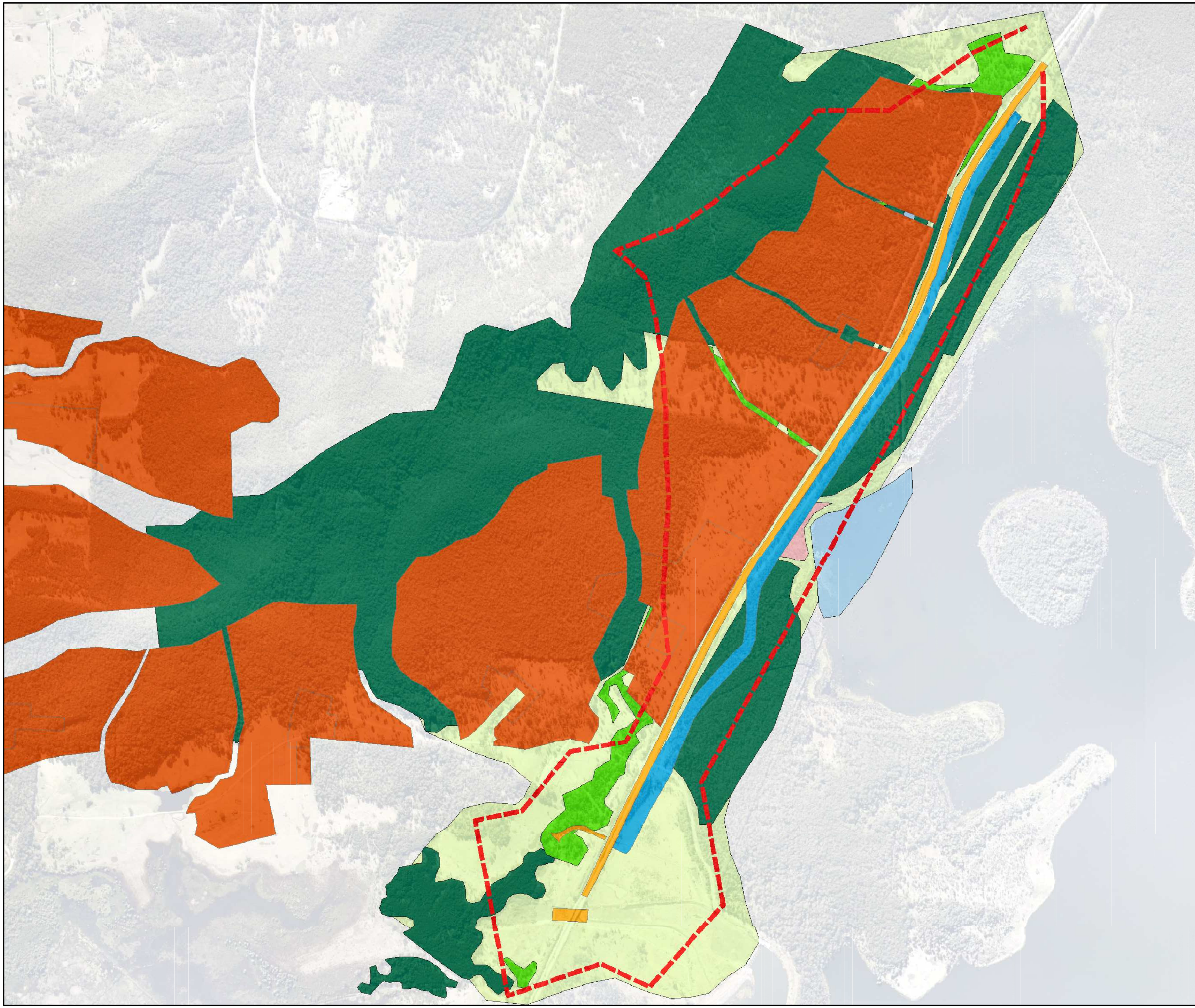

Legend

- Developed
- Channel
- Road / Hardstand
- Waterbody
- Sparse Trees
- Dense Trees
- Reeds
- Grass
- 2D Grid Extent

Figure C3

Mannings Roughness Developed

Date 23 September 2015

Job Name
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Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 240 480 720 Meters

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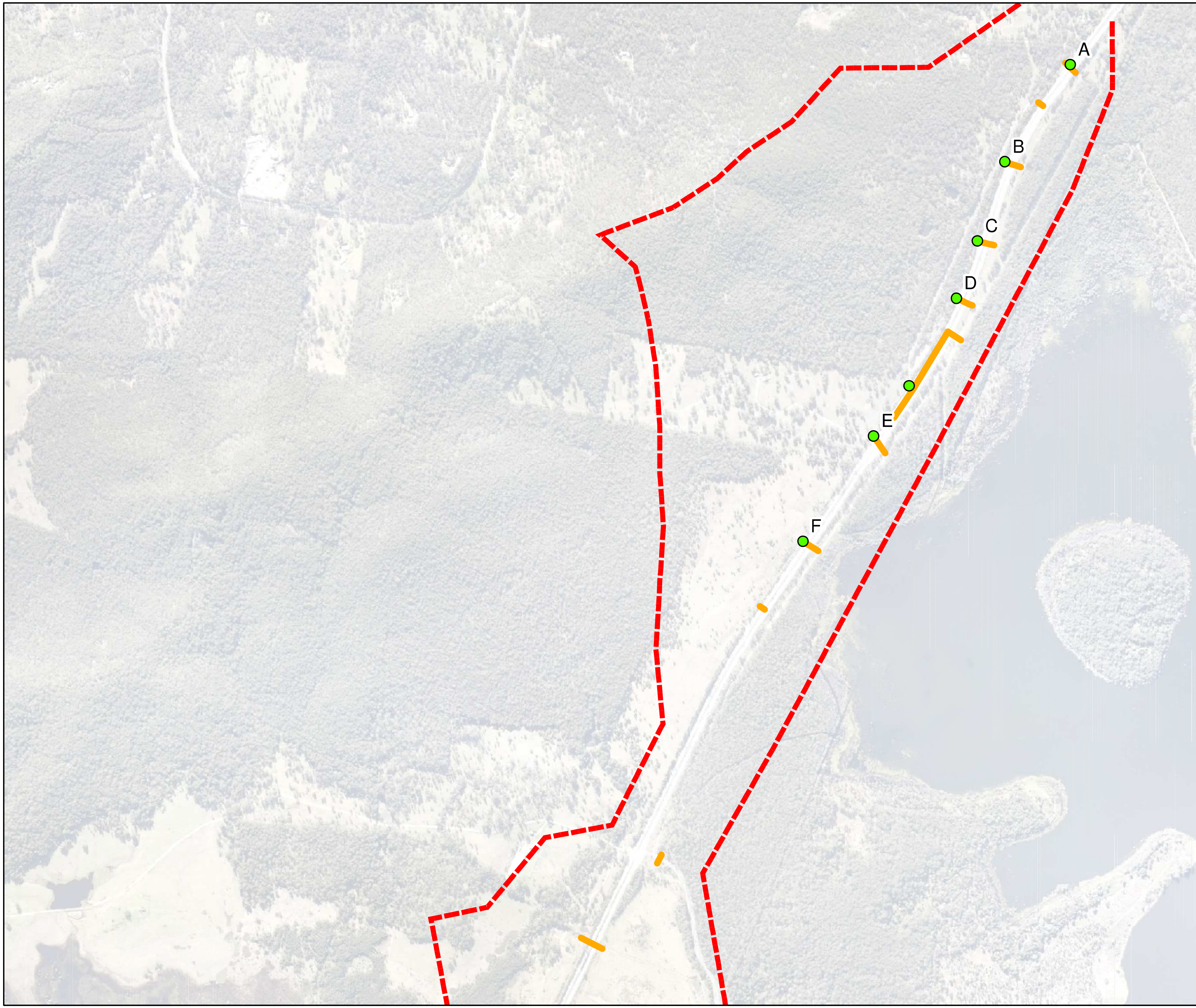

Legend

- 1D Pipes and Culverts
- 2D Grid Extent
- Catchment Outlets

N

0 200 400 600 Meters

Figure C4

1D Elements

Date 23 September 2015

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Eastern Channel Flood Study

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Legend

2D Grid Extent

Depth (m)

0.06 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.25
1.26 - 1.50
1.51 - 1.75
1.76 - 2.00
2.01 - 2.25
2.26 - 2.50
2.51 - 2.75
2.76 - 3.00
3.01 - 3.25
3.26 - 3.50
3.51 - 4.25

Figure D1

1% AEP Existing 50% Blocked Depth

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

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0 230 460 690 Meters

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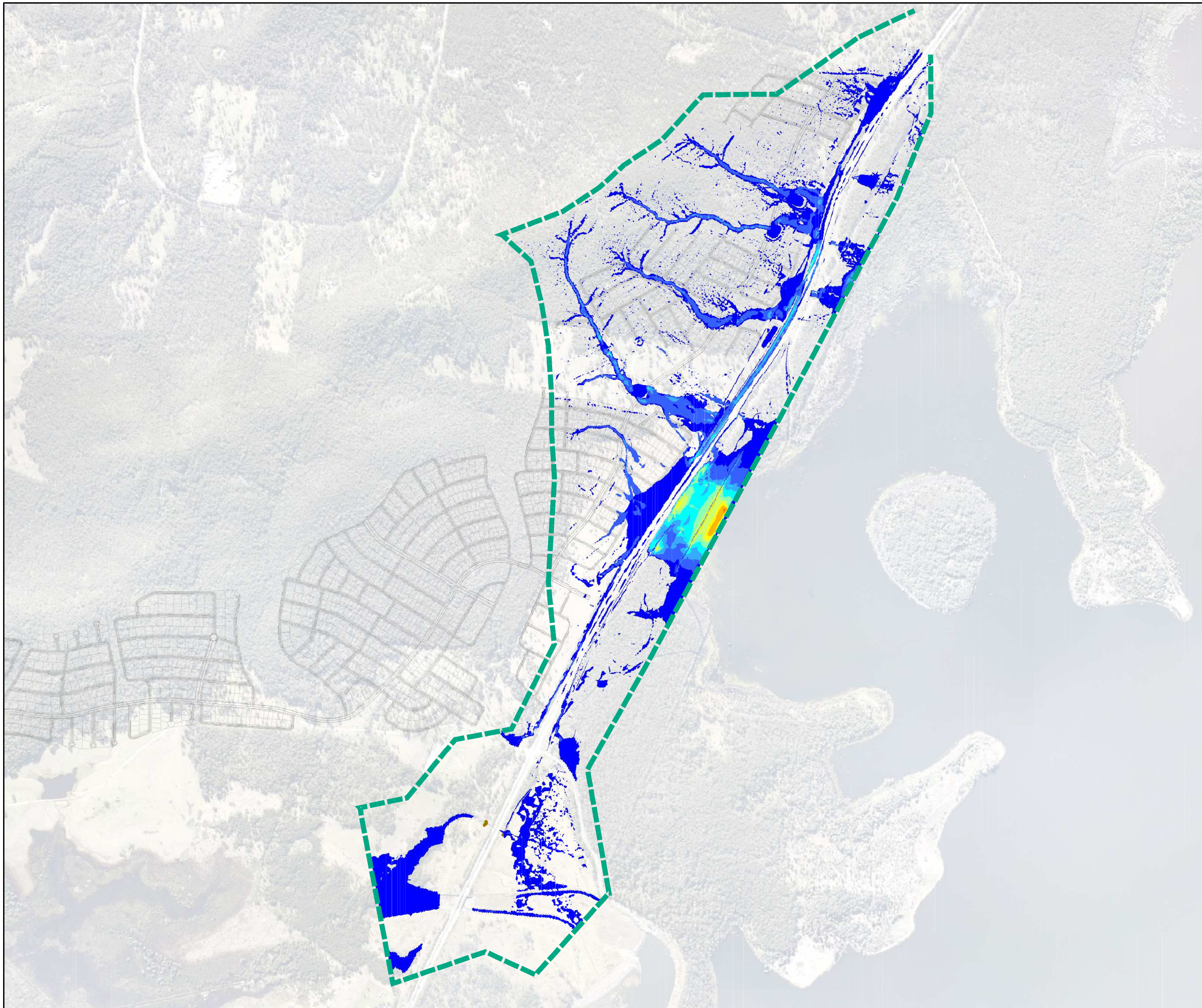

Legend

2D Grid Extent

Velocity (m/s)

- 0.00 - 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- 3.01 - 3.50
- 3.51 - 4.00
- 4.01 - 4.50
- 4.51 - 5.00

Figure D2

1% AEP Existing 50% Blocked Velocity

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690 Meters

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Legend

2D Grid Extent

Depth (m)

0.06 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.25
1.26 - 1.50
1.51 - 1.75
1.76 - 2.00
2.01 - 2.25
2.26 - 2.50
2.51 - 2.75
2.76 - 3.00
3.01 - 3.25
3.26 - 3.50
3.51 - 4.25

Figure D3

1% AEP Existing 0% Blocked Depth

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690 Meters

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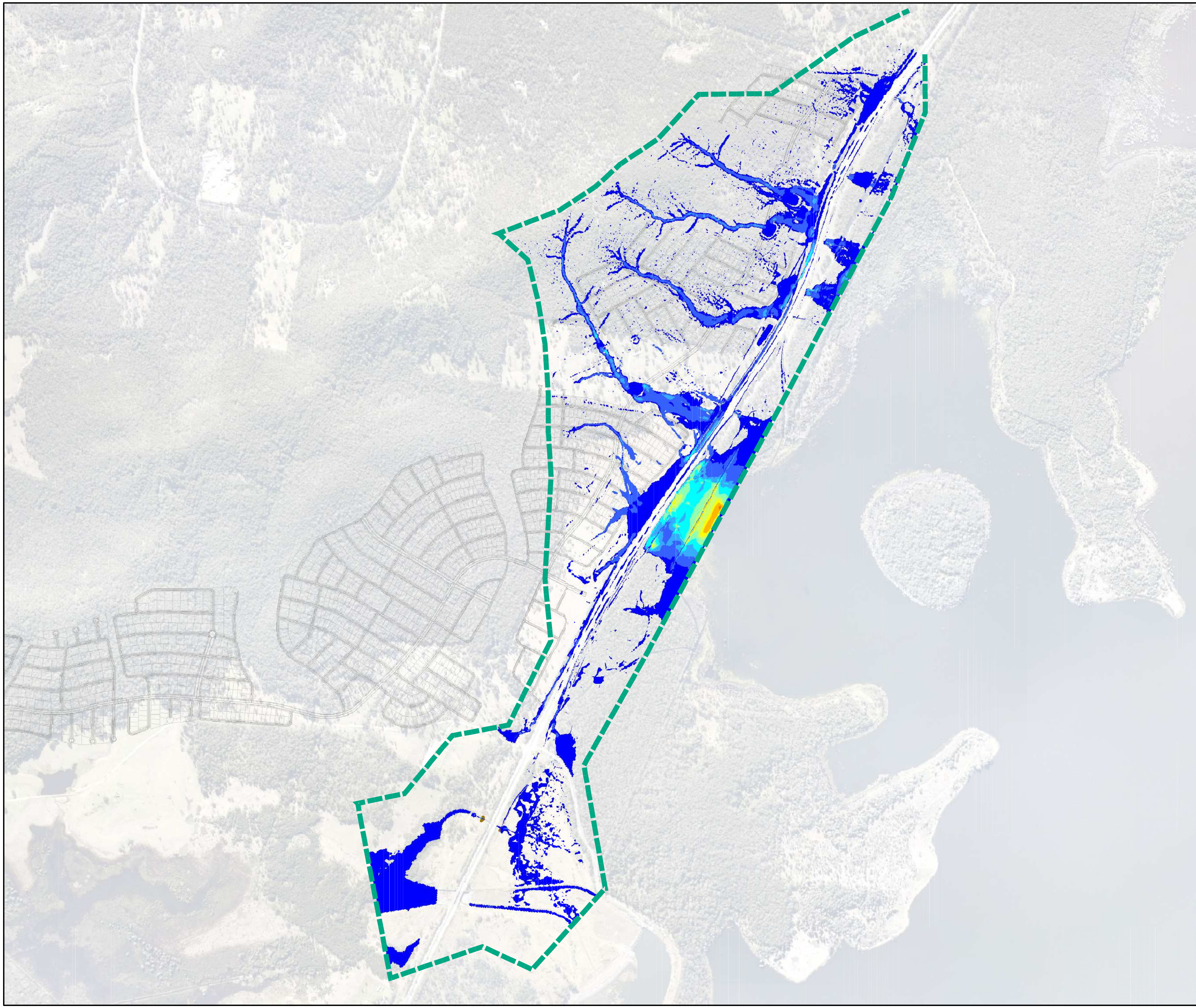

Legend

2D Grid Extent

Velocity (m/s)

	0.00 - 0.50
	0.51 - 1.00
	1.01 - 1.50
	1.51 - 2.00
	2.01 - 2.50
	2.51 - 3.00
	3.01 - 3.50
	3.51 - 4.00
	4.01 - 4.50
	4.51 - 5.00

Figure D4

1% AEP Existing 0% Blocked Velocity

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690 Meters

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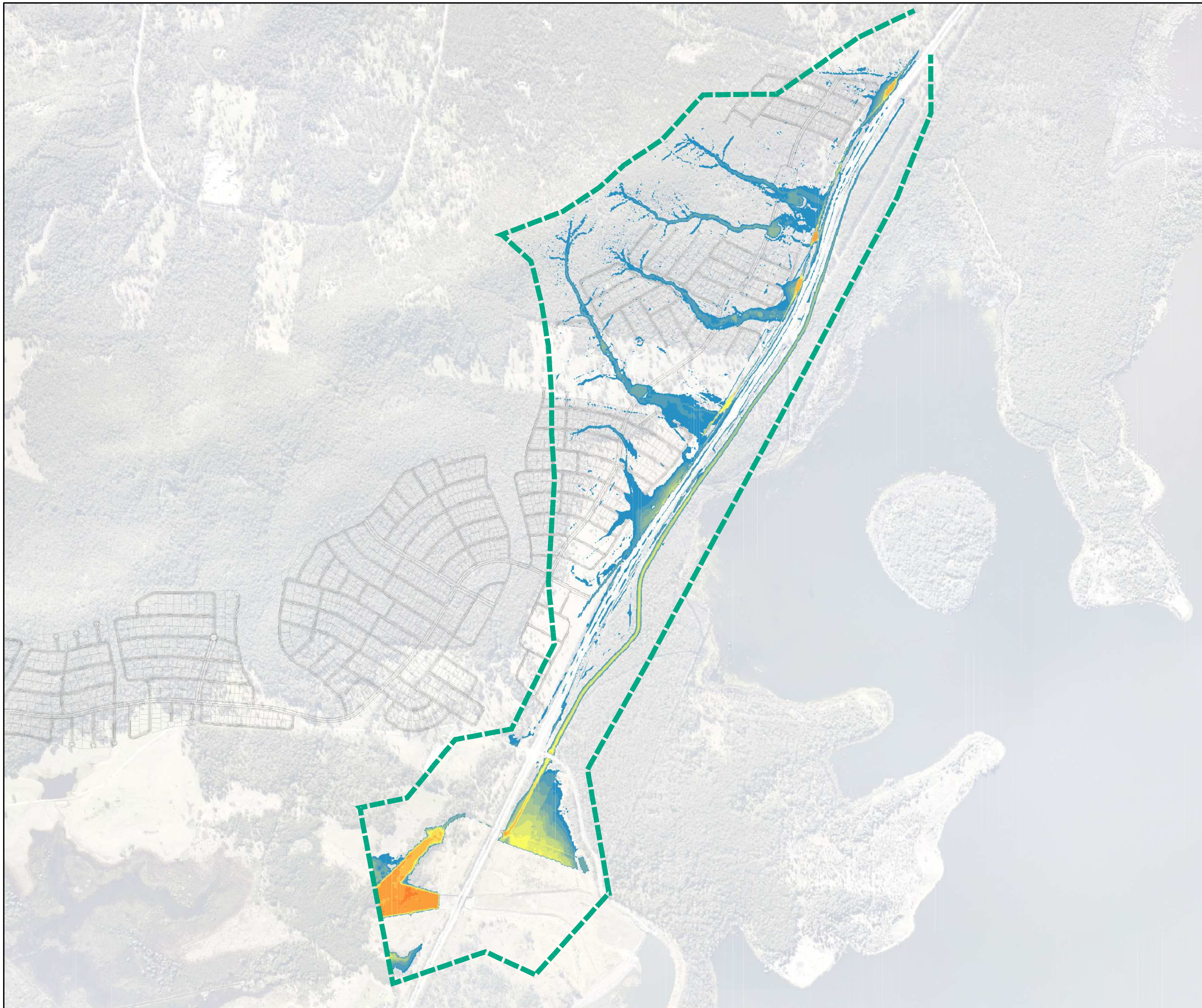

Legend

2D Grid Extent

Depth (m)

- 0.06 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.25
- 1.26 - 1.50
- 1.51 - 1.75
- 1.76 - 2.00
- 2.01 - 2.25
- 2.26 - 2.50
- 2.51 - 2.75
- 2.76 - 3.00
- 3.01 - 3.25
- 3.26 - 3.50
- 3.51 - 4.25

Figure E1

1% AEP Developed 0% Blocked Depth

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690 Meters

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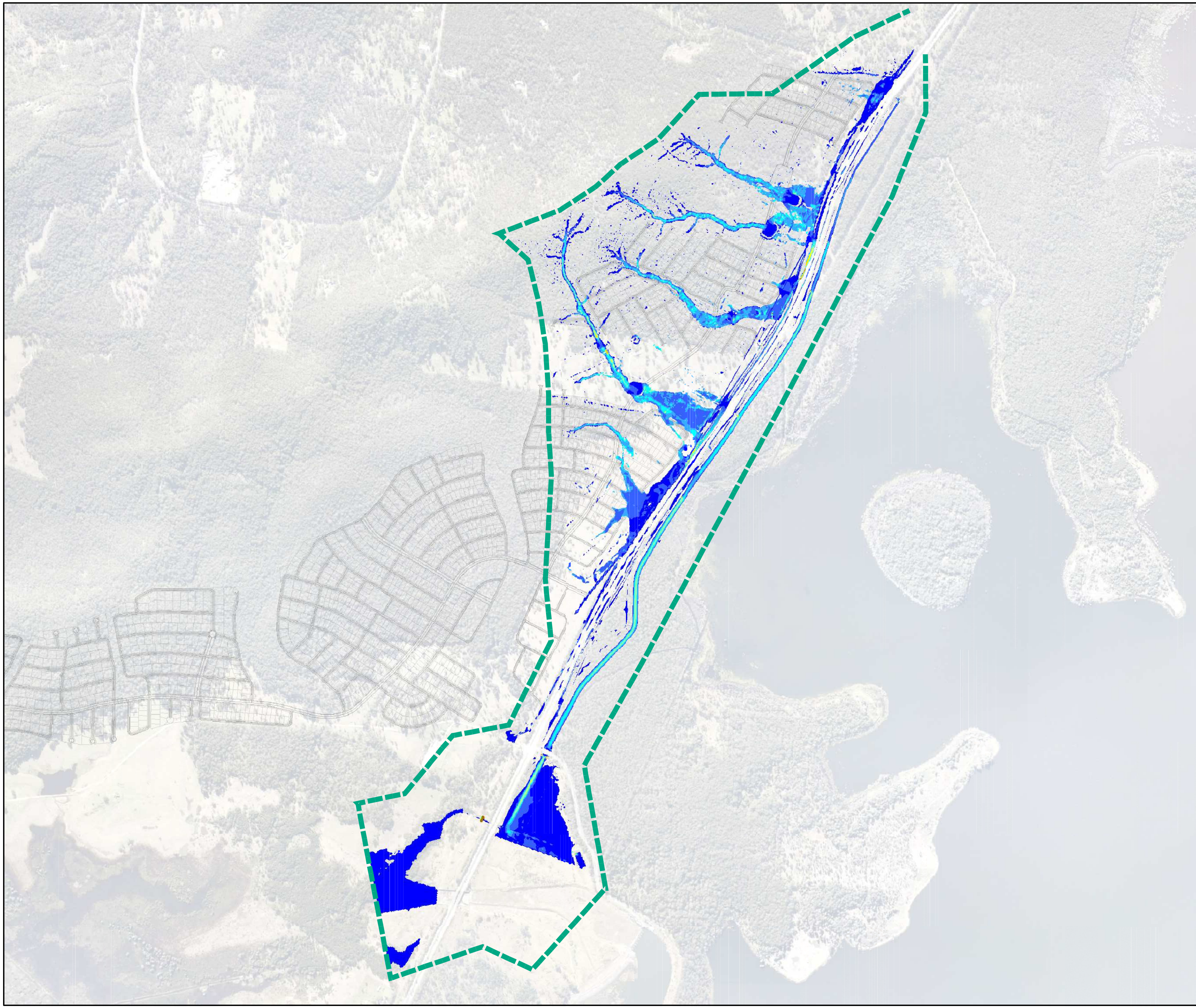

Legend

2D Grid Extent

Velocity (m/s)

	0.00 - 0.25
	0.26 - 0.50
	0.51 - 0.75
	0.76 - 1.00
	1.01 - 1.25
	1.26 - 1.50
	1.51 - 1.75
	1.76 - 2.00
	2.01 - 2.25
	2.26 - 2.50

Figure E2

1% AEP Developed 0% Blocked Velocity

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690 Meters

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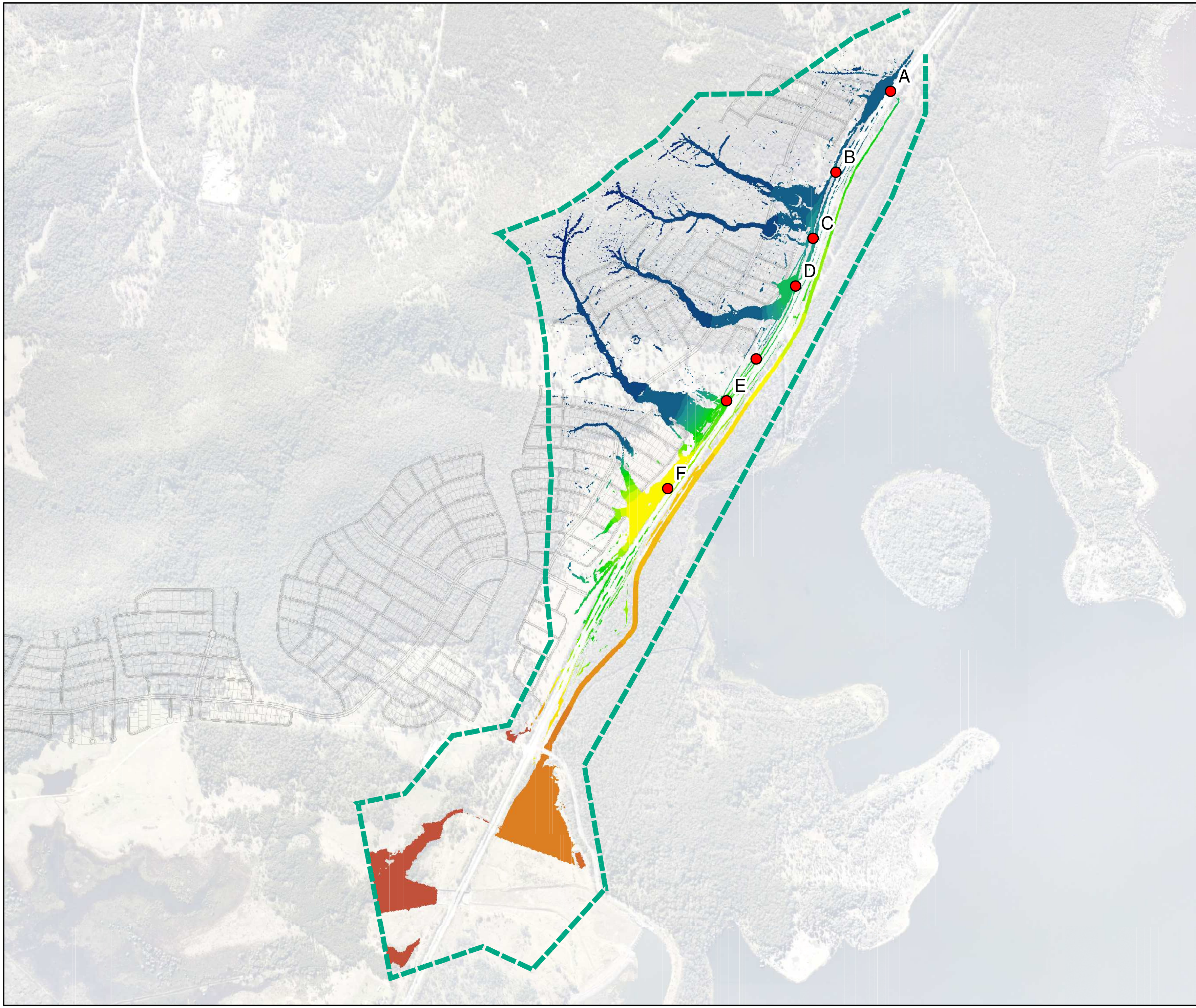

Figure E3

1% AEP Developed 0% Blocked Elevation

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

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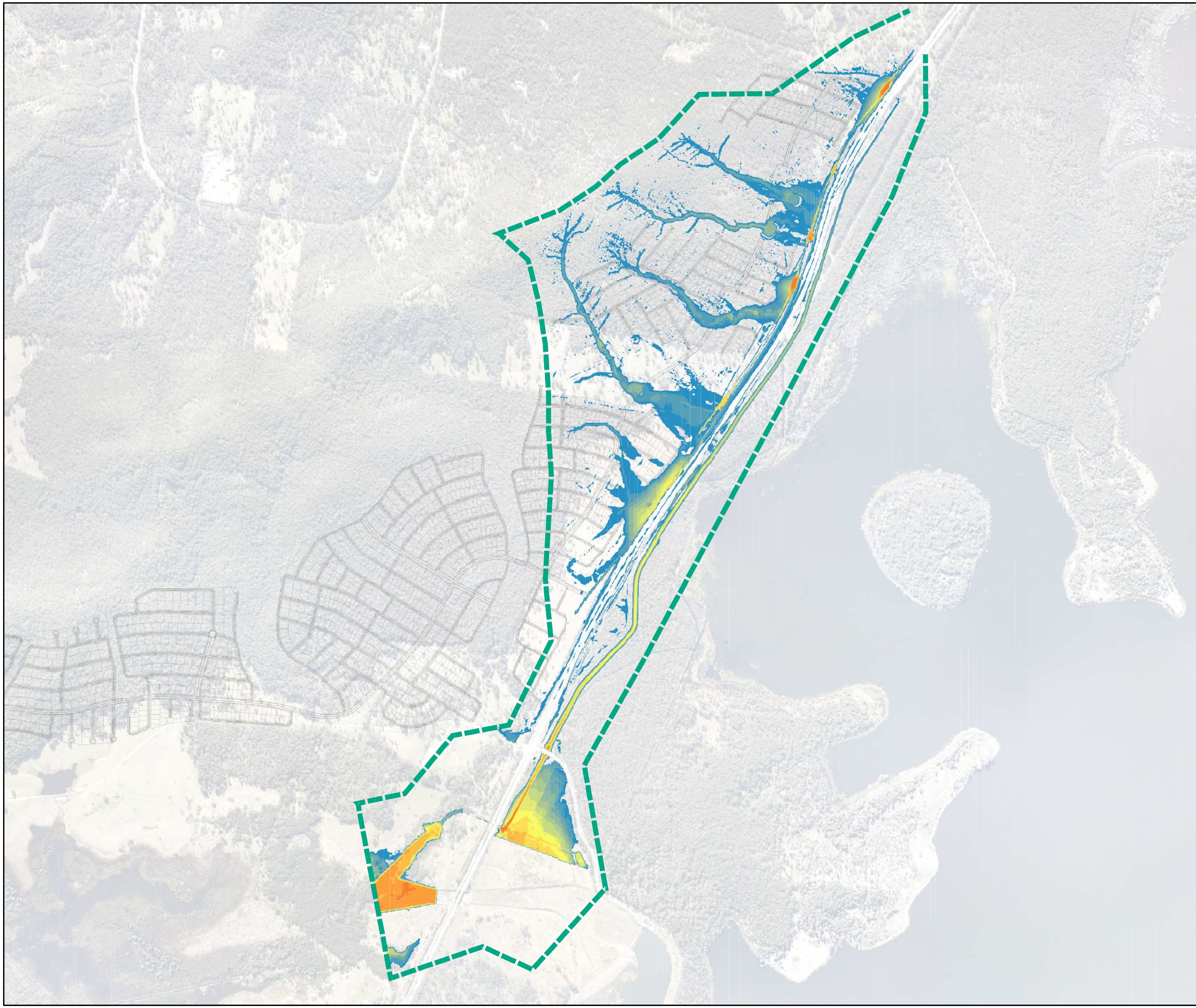

Legend

2D Grid Extent

Depth (m)

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0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.25
1.26 - 1.50
1.51 - 1.75
1.76 - 2.00
2.01 - 2.25
2.26 - 2.50
2.51 - 2.75
2.76 - 3.00
3.01 - 3.25
3.26 - 3.50
3.51 - 4.25

Figure E4

0.2% AEP Developed 0% Blocked Depth

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

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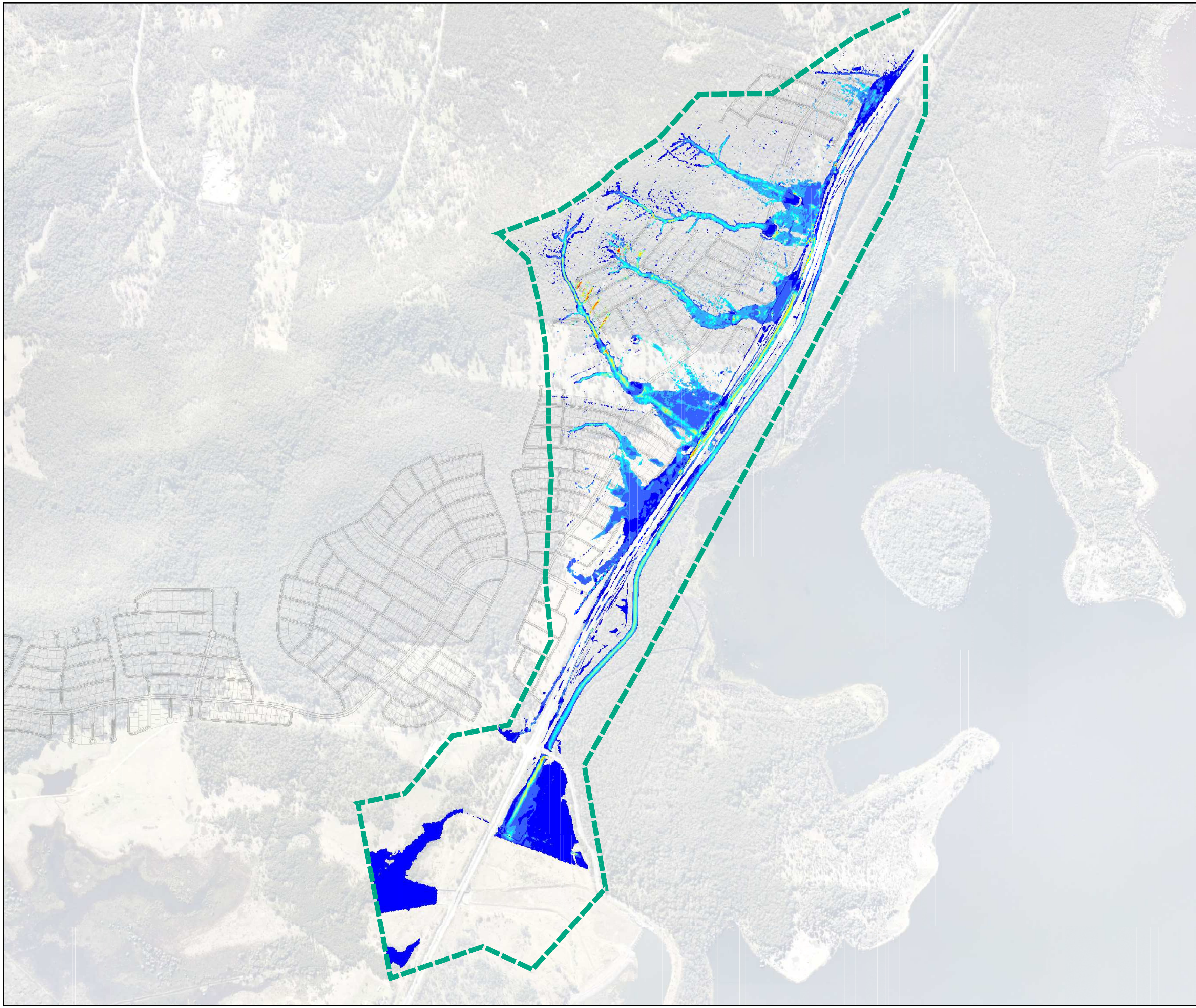

Figure E5

0.2% AEP Developed 0% Blocked Velocity

Date 23 September 2015

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Kingshill Urban Release Area
Eastern Channel Flood Study

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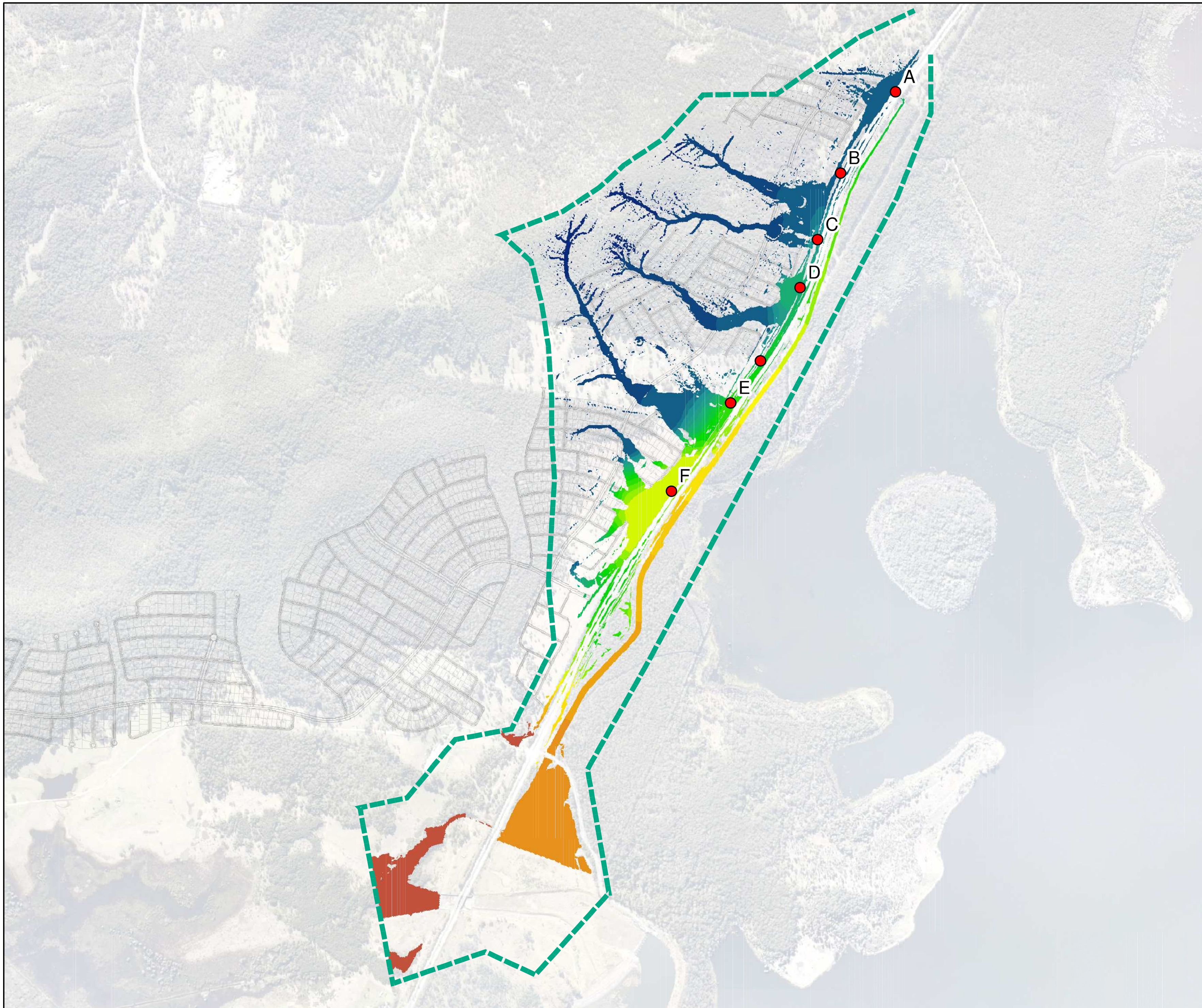

Legend

2D Grid Extent
Outlets

Elevation (m AHD)

4.6 - 10.0	14.6 - 15.0
10.1 - 10.5	15.1 - 15.5
10.6 - 11.0	15.6 - 16.0
11.1 - 11.5	16.1 - 16.5
11.6 - 12.0	16.6 - 17.0
12.1 - 12.5	17.1 - 17.5
12.6 - 13.0	17.6 - 18.0
13.1 - 13.5	18.1 - 18.5
13.6 - 14.0	18.6 - 19.0
14.1 - 14.5	19.1 - 19.5
	19.6 - 20.0
	20.1 - 25.0
	25.1 - 50.0
	50.1 - 125.0

Figure E6

0.2% AEP Developed 0% Blocked
Elevation

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690
Meters

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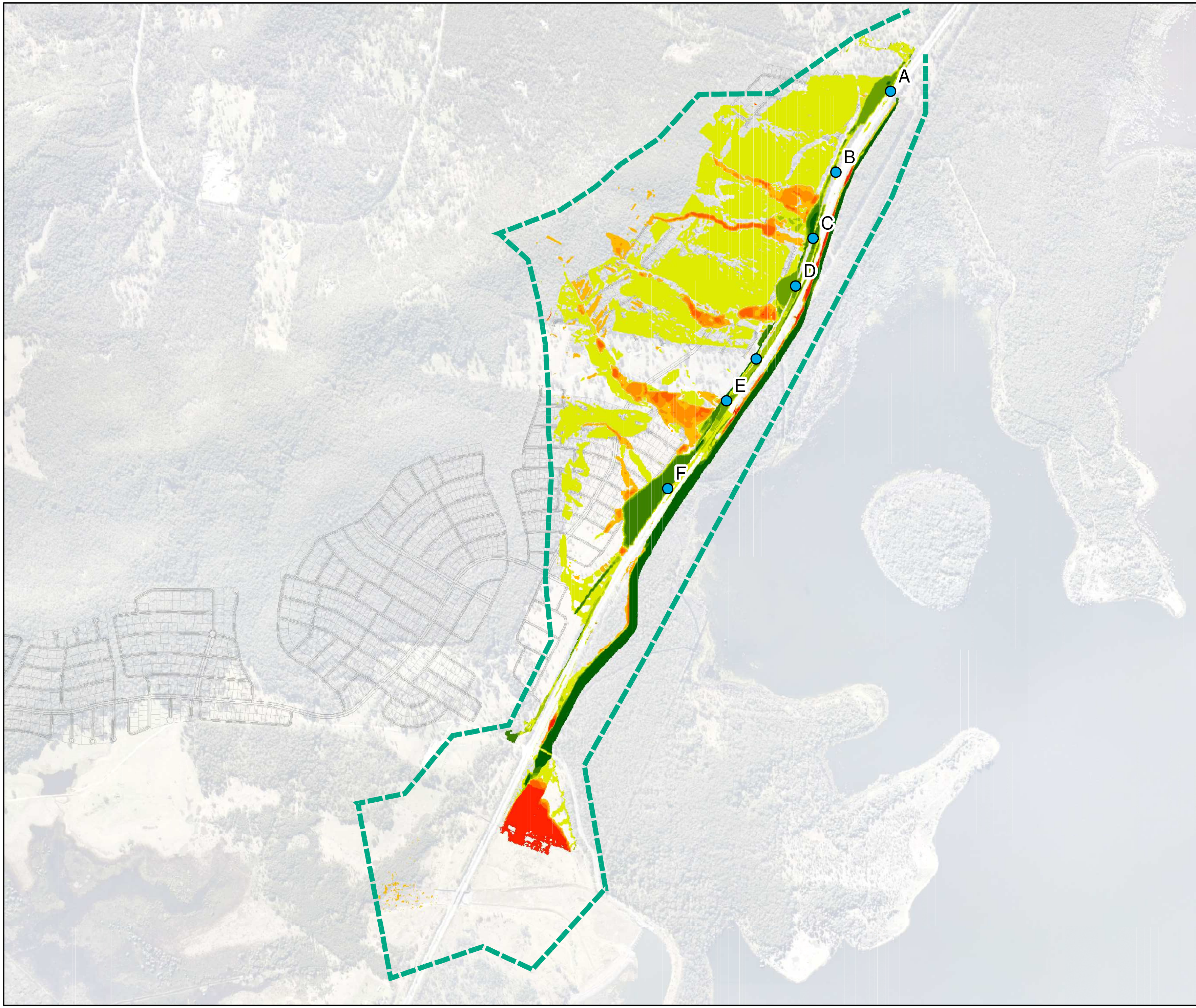

Legend

- 2D Grid Extent
- Outlets

Elevation Comparison (m)

- -4.533 - -0.500
- -0.499 - -0.200
- -0.199 - -0.100
- -0.099 - -0.050
- -0.049 - -0.005
- -0.004 - 0.005
- 0.006 - 0.050
- 0.051 - 0.100
- 0.101 - 0.200
- 0.201 - 0.500

Figure F1

1% AEP 50% Blocked
Elevation Comparison

Date 23 September 2015

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0 230 460 690 Meters

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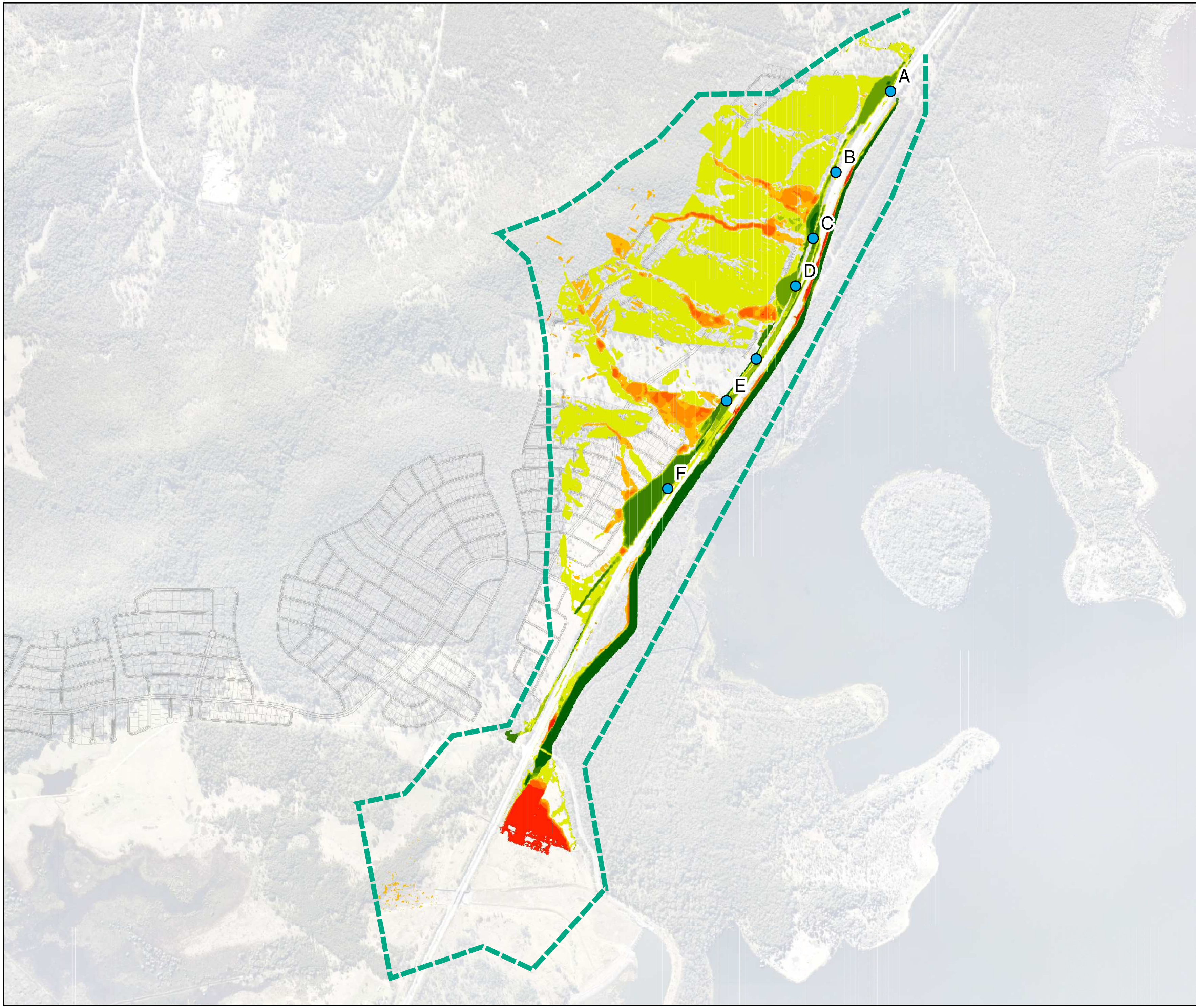

Legend

2D Grid Extent

Outlets

Elevation Comparison (m)

-4.533 - -0.500
-0.499 - -0.200
-0.199 - -0.100
-0.099 - -0.050
-0.049 - -0.005
-0.004 - 0.005
0.006 - 0.050
0.051 - 0.100
0.101 - 0.200
0.201 - 0.500

Figure F2

1% AEP 0% Blocked
Elevation Comparison

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

Job Number NL120526 **Rev** A

N

0 230 460 690 Meters

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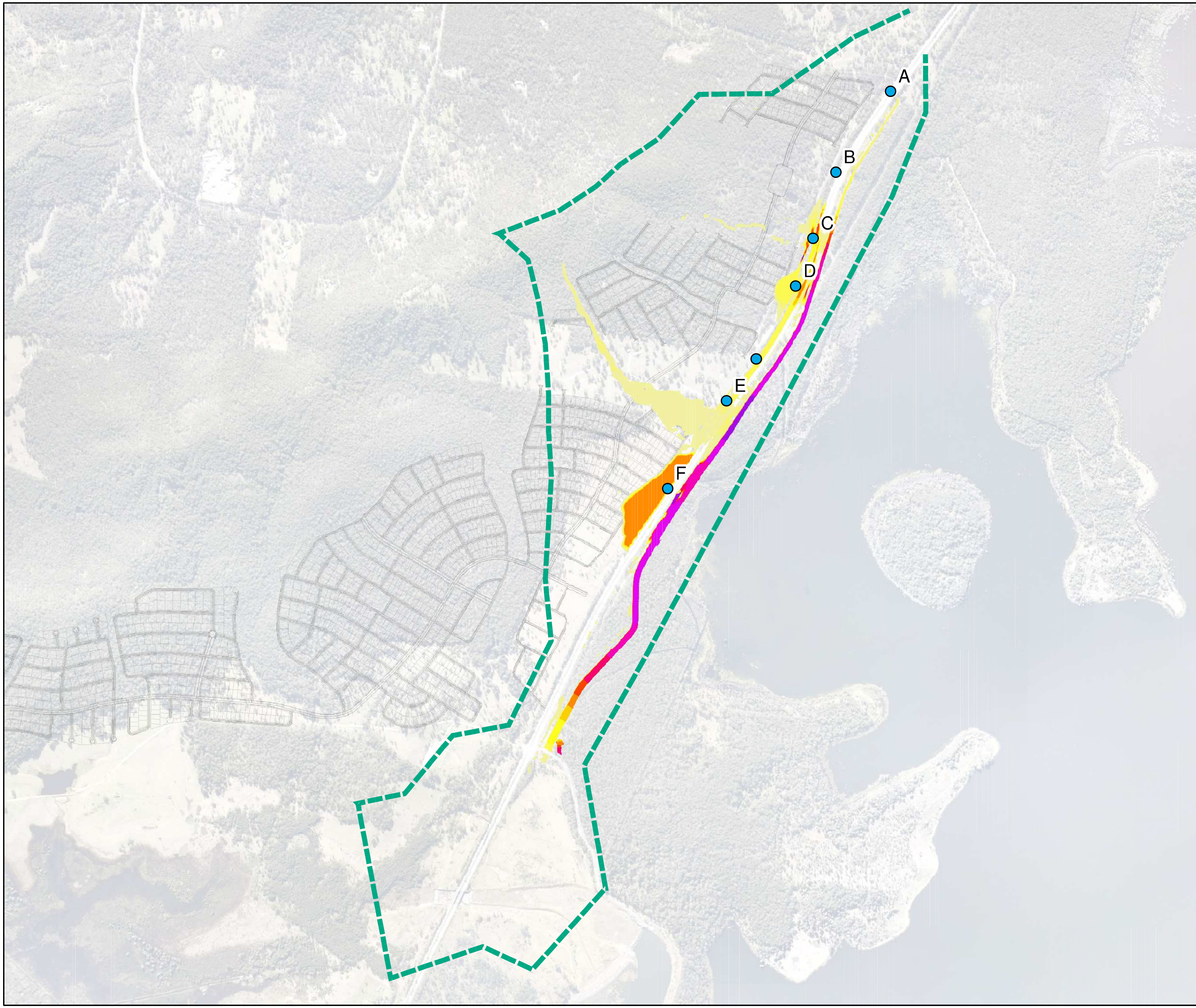

Legend

2D Grid Extent

Outlets

Roughness Elevation Comparison (m)

0.006 - 0.050
0.051 - 0.100
0.101 - 0.150
0.151 - 0.200
0.201 - 0.250
0.251 - 0.300
0.301 - 0.350
0.351 - 0.400
0.401 - 0.450
0.451 - 0.500
0.501 - 0.550
0.551 - 0.600
0.601 - 0.650
0.651 - 0.700

Figure G1

Comparison 0.2%AEP
Roughness n=0.08 to n=0.05

Date 23 September 2015

Job Name
Kingshill Urban Release Area
Eastern Channel Flood Study

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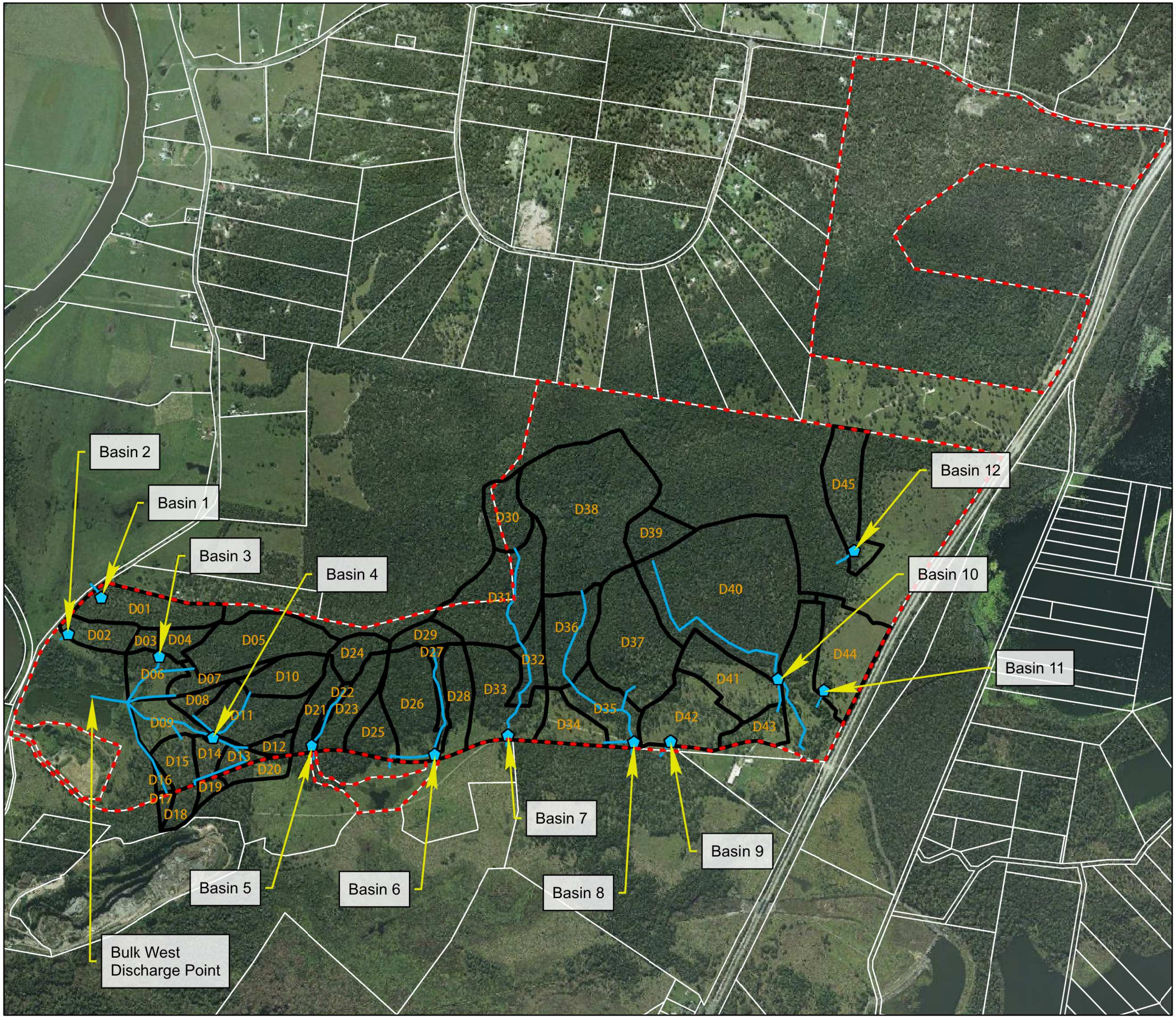
APPENDIX D -
Detention Modelling Figures



24/04/2019

Path Y:\YEAR 2012 Jobs\NL120526\G\STORM\190401 OSD DESIGN\ArcGIS Project\NL120526_ArcGIS_Detention.aprx

Figure A3 [A]
Model Links and Discharge Points

Legend
- Site Boundary
- Developed Catchments
- 1D Links in Model
- Modelled Detention Basin Locations
- Cadastre (Lot)

Kings Hill, North Raymond Terrace

N

0 340 680 1,020
Metres

NORTHROP

APPENDIX E -
Alluvium Irrawang Swamp Assessment

FINAL REPORT

Assessment of the Kings Hill development impacts on the hydrology and vegetation of Irrawang Swamp and Coastal Wetland 803

December 2019

Document history

Revision:

Revision no.	04
Authors	Mark Wainwright, David Carew, Liam Nicholson
Checked	Mark Wainwright, David Carew
Approved	

Distribution:

Revision no.	04
Issue date	4/12/19
Issued to	Chris Piper (Northrop Consulting Engineers)
Description:	This report outlines an assessment of the impacts on the Irrawang Swamp hydrology and vegetation resulting from changes to hydrology associated with the proposed Kings Hill development

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U:\Work\2019\022_Irrawang_Swamp_Assessment\10_Project\1_Deliverables\Final\P619022.02 Irrawang Swamp ecohydrology assessment 191204.docx

Contents

Figures

Tables

1 Executive summary

Kings Hill Developments Pty Ltd (KHD) is proposing to develop residential rezoned land in the Kings Hill Urban Release Area (Kings Hill) located north of Raymond Terrace. The land would be developed over multiple stages across a 10 to 15 year period for residential and other mixed use development. Kings Hill includes three main catchments that each currently drain to separate receiving environments. Kings Hill South drains to Irrawang Swamp (Coastal Wetland 804) which is located between New Line Road and the Pacific Highway. Kings Hill West drains to an unnamed wetland (Coastal Wetland 803) located adjacent to New Line Road to the north of Irrawang Swamp. Kings Hill East currently drains to Grahamstown Dam and runoff from this catchment is proposed to be diverted to Irrawang Swamp to protect water quality in the dam. Irrawang Swamp and Coastal Wetland 803 are both mapped coastal wetlands under SEPP (Coastal Management) 2018 (SEPP 2018).

Each wetland contains a number of species that are susceptible to impacts from altered hydrological regimes. The vegetation communities will be most susceptible to changes in the drying hydrology that typically occurs in the critical warmer September to March period. The dominant risks to the vegetation in the wetlands from hydrological changes include:

- extended periods of increased inundation depth; and
- reductions in seasonal drying patterns

If these are realised, retention of diversity in the Seasonal Swamp Meadow vegetation would be compromised within Irrawang Swamp and the ability for the woody plants to regenerate would be reduced. The hydrological analysis indicates that these risks are unlikely to occur for the reasons that are summarised below.

- Increased runoff from Kings Hill East during low flow periods is expected to flow efficiently and in a relatively linear manner along the proposed diversion drain through the original spillway channel to the Pennington Drain channel and discharge through the existing flood gates to the Williams River. It is expected that these diverted low flows would not impact on the northern Seasonal Swamp Meadow and Melaleuca Woodlands in Irrawang Swamp.
- Increased runoff diverted from Kings Hill East to Irrawang Swamp during high flow periods would typically coincide with periods where inflows to the swamp are already elevated resulting in wide-spread inundation across Irrawang Swamp. The estimated increase in high flows from Kings Hill East represents approximately 10% of the average annual spillway volume from Grahamstown Dam. These high flow events typically dissipate rapidly and would not cause long term ecological damage.
- Increased runoff volumes from King Hill South during low flow periods are estimated to be substantially lower than those from Kings Hill East. Increased runoff from Kings Hill South will disperse more readily through the wetland vegetation and it is estimated that the increase in water depth during the critical drying period will largely be contained within 5 ha area aligned with currently regularly wetted areas in the northern part of the swamp (refer Zone 1 in Figure 1-1). These additional flows will support the existing areas of open water and stands of *Typha orientalis.*
- Increased annual high flow volumes from King Hill South are estimated to be minor and would have an insignificant impact on increasing water levels in Irrawang Swamp during high flow periods.
- There will continue to be seasonal dry periods in the Swamp Oak and Melaleuca Woodlands and Seasonal Swamp Meadow areas and estimated changes in inundation depths are within the ecological tolerance range of the vegetation communities.
- Modelling results for Wetland 803 in Kings Hill West indicate that the WSUD strategy and partial catchment diversion outlined by Northrop Consulting Engineers (NCE, 2019) would result in water levels in the wetland increasing by less than 50mm across the critical drying period. The modelling results also indicate that wetting extents across the wetland would be similar during this period but may increase over existing conditions by up to 15% during short periods (days) during the drying period in response to small rainfall events in the Kings Hill West catchment.

- The Swamp Oak Woodland in Coastal Wetland 803 in Kings Hill West has been impacted due to increased water retention resulting from historical construction of a bund across its outlet and cattle grazing. Nonetheless a Swamp Oak (Casuarina) Woodland persists on the site with a mixture of fresh and saline understorey plants present. Controlling additional runoff to this wetland alone is unlikely to improve conditions for the remnant wetland vegetation. To maintain the condition of this wetland seasonal flow patterns are crucial for providing the conditions for the existing vegetation. This will ensure winter freshes lower the salinity for the less saline seasonal vegetation with lower summer water levels enabling regeneration to occur. The removal of stock may enable regeneration and healthy growth of the *Casuarina glauca* in the wetland and a woodland more representative of natural conditions to develop.

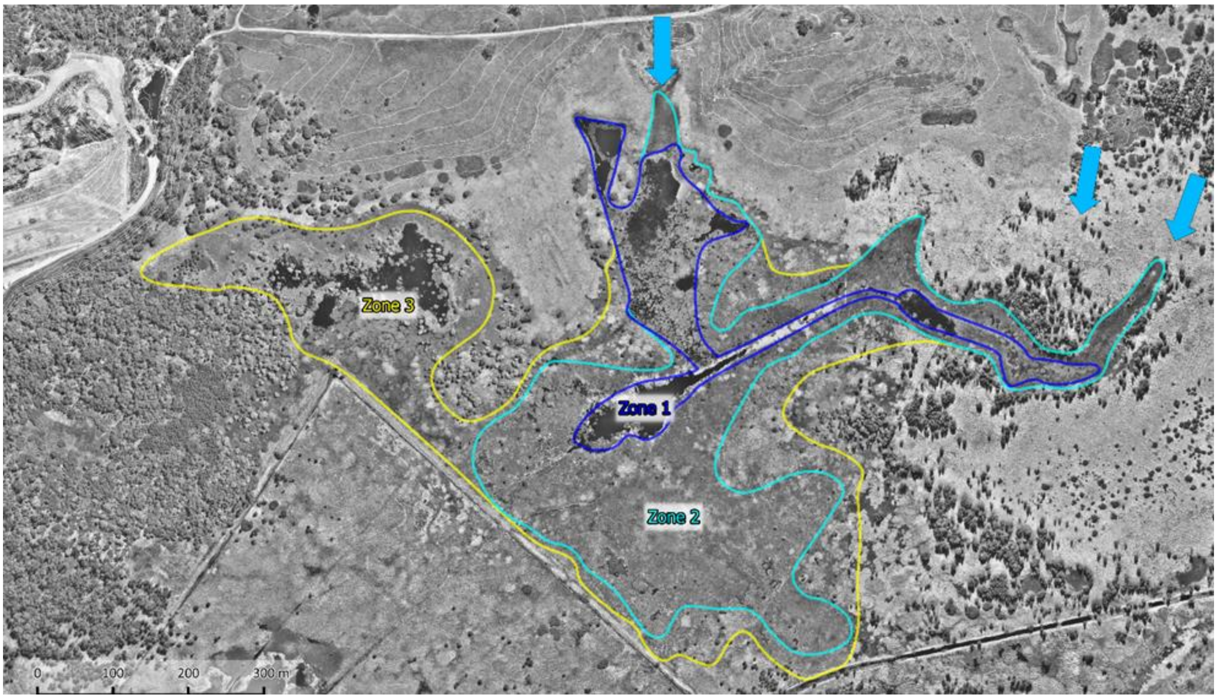

Figure 1-1 *Irrawang Swamp wetting zones showing key inflow locations from Kings Hill South*

2 Introduction

Irrawang Swamp (Coastal Wetland 804) is located just north of Raymond Terrace between New Line Road and the Pacific Highway (refer Figure 2-1), and is a protected Coastal Wetland under SEPP (Coastal Management) 2018 (SEPP 2018). The mapped extents of Irrawang Swamp comprise approximately 450 ha (SEPP 2018).

Kings Hill Developments Pty Ltd (KHD) is proposing to develop rezoned land within the northern catchments draining to the Irrawang Swamp for residential and mixed land uses. This land is referred to as Kings Hill South within this report. Additional land on the eastern side of Kings Hill that currently drains to Grahamstown Dam is also proposed to be developed for residential and mixed land uses. To avoid draining future urban runoff into Grahamstown Dam, a diversion channel is proposed on the eastern side of the Pacific Highway to divert all runoff up to the 0.2% AEP design storm event to the original spillway from Grahamstown Dam. This diverted runoff would be discharged into the eastern side of Irrawang Swamp. The land draining to the proposed diversion channel is referred to as Kings Hill East in this report. Additional development is proposed within the catchment of Coastal Wetland 803 located adjacent to New Line Road to the north of Irrawang Swamp. Development within the catchment of this wetland is referred to as Kings Hill West in this report.

Hunter Water Corporation (HWC) owns all the land within Irrawang Swamp and is currently actively managing the land in accordance with the Irrawang Swamp Plan of Management (Hunter Water, 2012a). Hunter Water previously lodged an application with OEH to register land they own within Irrawang Swamp as a biobanking/biodiversity stewardship site. We understand that HWC has now withdrawn this application and is not actively pursuing this outcome.

HWC's long term objective for Irrawang Swamp is to restore and maintain the environmental quality of the wetland, 'environmental quality' being defined as the range of environmental (predominantly ecological) services or functions provided by the wetland including:

- biodiversity conservation, including supporting habitat for threatened flora and fauna species;
- nursery and breeding grounds for various waterbirds, frogs and aquatic biota such as fish;
- improvement in water quality downstream by removing suspended matter, reducing numbers of faecal microorganisms and using dissolved nitrogen and phosphorus for plant growth;
- biological productivity and nutrient recycling;
- flood mitigation; and
- groundwater recharge.

To support these objectives Hunter Water has progressed a range of measures aimed at restoring the ecological function and integrity of Irrawang Swamp, including:

- Opening of the floodgates on Pennington Drain to reintroduce tidal inundation to the lower areas of the swamp;
- Tree planting;
- Cessation of grazing;
- Allowing drainage channels to naturally infill; and
- Weed control (primarily within the tree planting areas).

It will be important that effective management of stormwater quality and quantity is achieved in the future Kings Hill development areas to support achievement of the ecological protection criteria. HWC has advised that a detailed assessment of the impacts of stormwater discharge from the proposed Kings Hill development on the ecology of the swamp is to be completed before HWC can agree to any discharge into Irrawang Swamp.

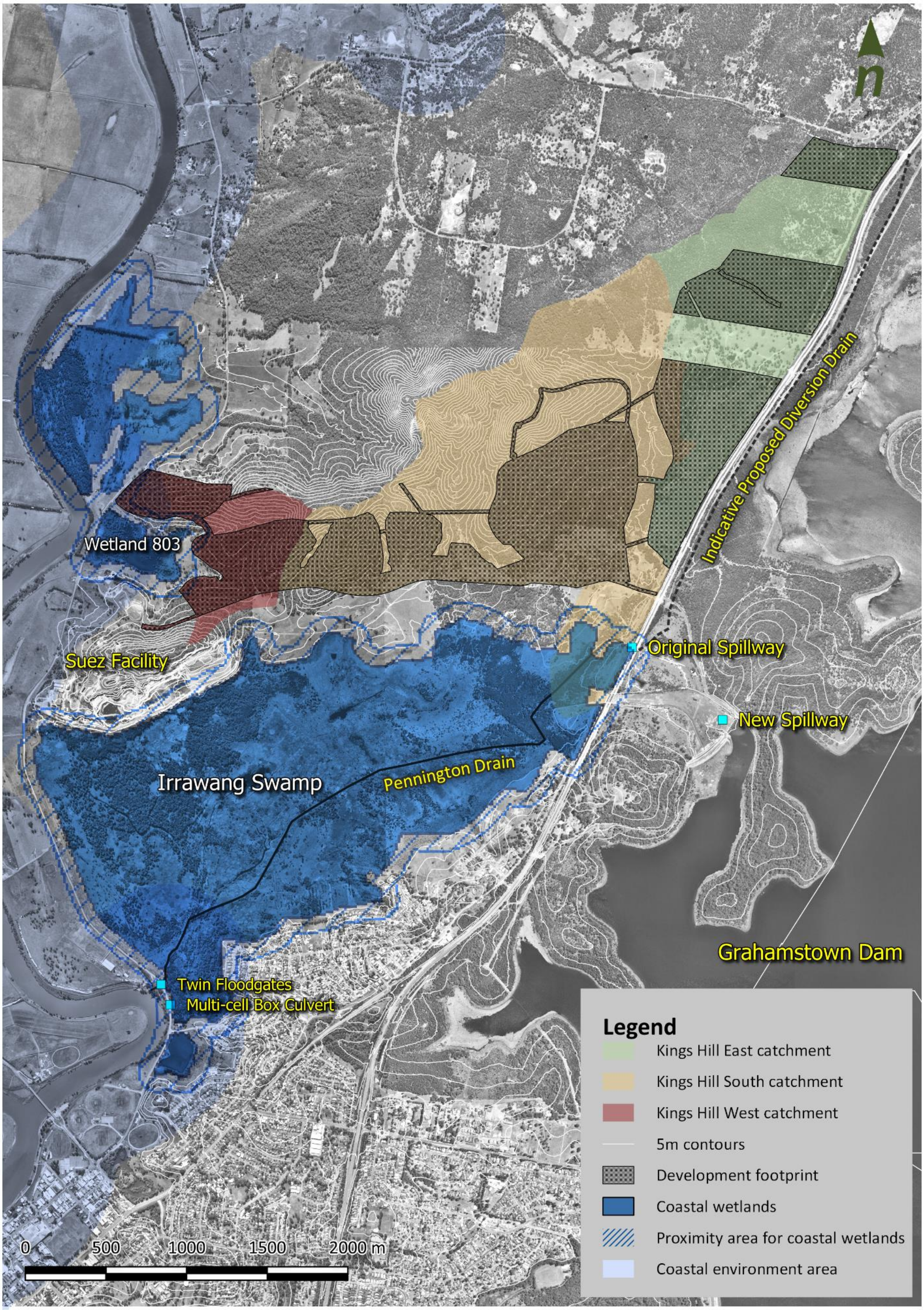

Figure 2-1 *Irrawang Swamp and Coastal Wetland 803 locality*

HWC outlined their concerns regarding the potential impacts of the Kings Hill development on Irrawang Swamp ecology in letter sent to Port Stephens Council dated 9 January 2018 (intended to be dated 9 January 2019) (Hunter Water, 2019). A summary of HWC's key concerns are outlined below:

- HWC has identified that increases in the volume, flow velocity and frequency of stormwater discharges associated with development have the potential to alter wetting/drying regimes in Irrawang Swamp and adversely impact on the composition and distribution of wetland communities.
- HWC has requested that the applicant closely consider the effects of stormwater discharge from the development including both the diverted Kings Hill East catchments and direct discharges from development in Kings Hill South. HWC has requested that consideration of changes to water quality and hydrology be assessed for both the diversion channel and direct discharge catchments.
- HWC has indicated that the applicant would need to demonstrate that the current wetting/drying regime of the receiving environment in Irrawang Swamp would not be adversely impacted by increased stormwater discharges. HWC refers to the "*Water Sensitive Urban Design Solutions for Catchments above Wetlands – Overview Report*" (McManus et al, 2007) prepared for HCCREMS. This guideline indicates that Water Sensitive Urban Design strategies associated with new development in catchments upstream of natural wetlands need to include methods to preserve the pre-development drying and/or flooding hydrology characteristics in order to protect wetland ecology.

This report focuses on potential changes to the Irrawang Swamp and Wetland 803 hydrology associated with the Kings Hill development. The report also includes an assessment of the potential impacts of hydrological changes on the ecology within each wetland. Our assessment is based on stormwater runoff estimates output from MUSIC models prepared by Northrop Consulting Engineers (NCE). We have assumed that the MUSIC modelling completed by NCE appropriately reflects the existing and developed hydrological conditions of the King Hill site and was completed in accordance with the relevant policies and guidelines. The details of NCE's modelling are not duplicated in this report, but are described in NCE, 2019.

The potential impacts on water quality in Irrawang Swamp and Wetland 803 associated with stormwater runoff from the Kings Hill development are also addressed in NCE, 2019.

This report is configured as follows:

- Section 3 summarises our understanding of the existing Irrawang Swamp and Wetland 803 hydrology.
- Section 4 summarises our understanding of the existing vegetation communities in Irrawang Swamp and Wetland 803 and historical changes that have occurred to the vegetation.
- Section 5 summarises the Kings Hill development impacts on catchment hydrology.
- Section 6 outlines the potential impacts of the changed catchment hydrology on the Irrawang Swamp and Wetland 803 hydrology and vegetation.
- Section 7 provides a summary of key points and our conclusions.

3 Existing hydrology

3.1 Irrawang Swamp (Wetland 804)

Overview
The hydrology of Irrawang Swamp has changed significantly from natural conditions due to historical land management practices associated with catchment development, land clearing, pasture irrigation, grazing and drainage channel construction. Under natural conditions, surface runoff from local catchments would have drained to a series of swamps including the Grahamstown Moors, Campvale Swamp and Irrawang Swamp. The hydrology of these swamps would have also been influenced by groundwater from the catchment. Although, clay soils are dominant in the local Irrawang Swamp catchment and it is expected that groundwater inflows to this swamp would be relatively low. The western extents of Irrawang Swamp were regularly inundated by tidal flows and it is envisaged that salt marsh and other salt tolerant species would have previously inhabited these areas.

Construction of the Grahamstown Dam wall across the natural outlet from the Grahamstown Moors resulted in Campvale Swamp and Irrawang Swamp being separated. The natural hydrology of Irrawang Swamp was significantly altered by the dam construction due to catchment flows now being stored in the dam and extracted for water supply. Diversion of river flows from the Williams River to the dam has also modified the Irrawang Swamp hydrology. Surface water flows from the east of the wetland are now limited to infrequent periods when the dam capacity is exceeded initiating spillway discharges to Irrawang Swamp. The dam construction has also modified groundwater flows.

Increasing residential development on the southern side of Irrawang Swamp has altered the hydrology for these catchments with the increased imperviousness in these catchments now contributing more regular pulses of stormwater runoff volume discharges into the southern area of Irrawang Swamp. In addition, the construction of rural dams and water holding dams associated with the waste recycling and recovery site on the northern side of the swamp has altered the hydrology in these areas.

Irrawang Swamp naturally would have received tidal inflows and been inundated during large overbank flooding events from the Williams River. Construction of the New Line Road embankment and flood gates on pipes under Newline Road has resulted in tidal inflows to the swamp and low flows from the swamp now being controlled through these gates. During large spillway events from Grahamstown Dam, water can rapidly fill Irrawang Swamp. To control flooding in these large events, a levee was constructed within the western extents of the swamp parallel to New Line Road to controls overflows from the swamp to the Williams River. A large multi-cell culvert was also constructed under New Line Road just south of the flood gates to convey spillway flows from Grahamstown Dam in a controlled manner to the Williams River.

A large open channel, Pennington Drain, was constructed centrally through Irrawang Swamp in the 1970's as a component of the initial Grahamstown Dam construction to efficiently convey spillway flows through the swamp to the Williams River. Pennington Drain was formed by excavating a trapezoidal-shaped channel from just downstream of the original spillway to the floodgates. A number of other minor interconnected lateral drains were also constructed in the wetland by landowners to enable efficient draining of the land for cattle grazing and to grow pasture grasses. Many of these drainage channels were connected to the Pennington Drain.

Further discussion on the key elements that influence hydrology in the Irrawang Swamp catchment is provided below.

Grahamstown Dam storage
Grahamstown Dam was originally formed by construction of an embankment across the outlet of a natural wetland area known as the Grahamstown Moors. Construction of the dam began in 1955 and was completed in 1965. Prior to completion, water was supplied from the dam in 1960 during a severe drought that extended from 1960 to 1963. Since 1965, the following main modifications to the dam have been completed (https://www.hunterwater.com.au):

- In 1973 a bentonite clay core was installed in the central section of the Grahamstown embankment to provide a watertight seal.
- In 1985 the Full Supply Level (FSL) was reduced from 11.1 metres to 10.6 metres as a temporary measure to reduce the risk of damage to the main embankment from major flooding.
- In 1994 Stage 1 augmentation works were completed to raise the level of the clay core to the road level along the full length of the embankment to enable the flood storage capacity to be increased. Rock armouring of the main embankment was also undertaken.
- In 2005 Stage 2 augmentation works were completed to increase the FSL from 10.6 to 12.8 metres. These works involve construction of a larger spillway and discharge channel under the Pacific Highway.

The Stage 2 augmentation works addressed two key objectives, improving the safety of the dam to bypass major flood events, and increasing the water storage capacity to improve regional drought security (Kinhill, 1993). The works resulted in the dam storage capacity increasing by 50%. Whilst the dam storage capacity increased, there was an associated reduction in temporary flood storage capacity. To reduce risks associated with this reduced temporary storage, the original dam spillway was replaced with a wider spillway.

The dam currently has a total storage volume of over 182 GL and covers an area of 28 km^2. The total catchment area for Grahamstown Dam is 115 km^2 (www.hunterwater.com.au). Additional catchment area is diverted to the dam from the Williams River through the Balickera Canal diversion that forms an off take from the Williams River at Seaham Weir.

Grahamstown Dam spillway

The original Grahamstown Dam spillway was constructed as a component of the Grahamstown Dam construction works between 1955 and 1965. Although the original spillway is no longer in operation, the spillway gates, outlet channel, weir and energy dissipator remain in place.

Figure 3-1 *Original Grahamstown Dam spillway gates*

A larger spillway was constructed as a component of the Stage 2 augmentation works in 2005 approximately 350m south of the original spillway. The current spillway is a labyrinth type spillway that provides more efficient flow discharges at lower depths. The current spillway was designed to have a capacity of 780 m^3/s which is significantly greater than the original spillway capacity of 60 m^3/s (Kinhill, 1993).

Figure 3-2 *New Grahamstown Dam labyrinth spillway (source: Port Stephens Examiner, 2008)*

The Stage 2 augmentation EIS identified that a major impact would be to increase the frequency of spillway discharges with associated increases in inundation frequency within parts of Irrawang Swamp (Kinhill, 1993). Whilst the water supply storage increased with the Stage 2 augmentation, the temporary flood storage reduced. It was identified that the reduction in temporary flood storage would result in the spillway being overtopped more frequently resulting in more frequent discharges to Irrawang Swamp.

It was estimated that Irrawang Swamp would be more frequently inundated for periods up to several days from flood flows from Grahamstown Dam and overbank flows from the Williams River. It was estimated that the new spillway would be overtopped on average once every two years (Kinhill, 1993). Review of spillway flow data provided by HWC indicates that flows have occurred in approximately 40% of the years since the current spillway was completed in 2005 and this aligns well with the EIS predicted spill frequency.

Irrawang Swamp drainage

Surface runoff currently drains into Irrawang Swamp from the surrounding catchment and additional flow is contributed from Grahamstown Dam during periods when the spillway level is exceeded. Surface runoff drains from the forested and pastured upper slopes of Kings Hill in a southerly direction along unnamed ephemeral watercourses into the northern section of Irrawang Swamp. Existing and future residential development in Raymond Terrace drains into the swamp from the south.

Pennington Drain was constructed centrally through Irrawang Swamp as a component of the initial Grahamstown Dam construction works to efficiently drain spillway flows through the swamp to the Williams River. This channel still functions to efficiently convey spillway flows through Irrawang Swamp, although the drain is increasingly becoming infilled and covered by vegetation due to cessation of drain maintenance. This infilling is being encouraged as a restoration action to reduce the drainage efficiency and enable more frequent spills from Pennington Drain into the adjacent wetland areas (Hunter Water, 2012a). This action supports the Irrawang Swamp plan of management objectives and Hunter Water expects this will assist to restore the natural hydrological regime and increase freshwater wetland vegetation (Hunter Water, 2012a).

Excavated soil from the Pennington Drain channel construction was deposited along the sides of the drain to form a levee. This levee functions to preferentially direct overbank flows from the drain into the northern areas of the wetland. In some locations, breaks in the channel banks and levee have been formed to facilitate past agricultural activities and potentially also to drain trapped areas.

A number of other minor interconnected lateral drains were previously constructed in the wetland to enable efficiently draining of the land for cattle grazing and other agricultural activities. Many of these drainage channels were connected to the Pennington Drain. These lateral drains are now not actively maintained and are being allowed to infill.

Newline Road drainage structures
Discharges from Irrawang Swamp to the Williams River can occur through the following mechanisms depending on the water level in Irrawang Swamp:

- Low flows from the swamp and tidal exchange can drain through open flood gates constructed at the end of Pennington Drain immediately downstream of New Line Road.
- High catchment runoff and spillway flows can result in water levels increasing rapidly across the swamp initiating flow through a multi-cell box culvert located just south of the flood gates when a levee in this area is breached.
- Very high flows exceeding the capacity of the multi-cell box culvert and minimum Newline Road crown level would weir flow across the road.

These drainage structures are discussed further below.

Flood gates
Floodgates were installed on the Pennington Drain outlet immediately downstream of Newline Road in the 1970's (Kleinfelder, 2018). We understand that the flood gates are installed on twin 900mm or 1050mm diameter pipe culverts (pers com. Holly Marlin, HWC). The flood gates are owned and operated by the NSW Department of Industry (Water). The gates originally functioned to prevent tidal inundation of the Irrawang Swamp and discharge of stormwater to the Williams River during periods when river water levels were elevated.

The flood gates currently remain open unless a Flood Watch is issued by the Bureau of Meteorology on either the Williams or Hunter Rivers. The flood gates are manually closed during a Flood Watch and re-opened when the flood risk has passed (Hunter Water, 2012b).

Figure 3-3 *Pennington Drain flood gates*

Over the 2010-11 period Hunter Water worked in partnership with the Department of Primary Industries (Fisheries) on the Irrawang SEPP 14 wetland rehabilitation project. The goal of this project was to reintroduce natural tidal flows to Irrawang Swamp through the flood gates. Two trial openings of the flood gates were undertaken and a draft Review of Environmental Factors (REF) prepared for the project (Hunter Water, 2011).

Over the 2011-12 period Hunter Water continued working with DPI (Fisheries) on the wetland rehabilitation project. Flood modelling identified the complexity of determining the impact of simultaneous spills from Grahamstown Dam and flooding from either the Hunter River or Williams River. Although not quantified, the completed modelling indicated that permanent opening of the flood gates could only increase the likelihood of residential impacts in the event of a simultaneous spill from Grahamstown Dam and flooding of either the Hunter River or Williams River. Further modelling was deemed unnecessary and it was decided that the flood gates would not be permanently opened (Hunter Water, 2012b).

New Line Road levee
In 2010, a new levee was constructed on the eastern side of Newline Road within Irrawang Swamp to protect private properties located between Irrawang Swamp and the Williams River during periods of high spillway discharges from Grahamstown Dam. This levee controls overflows from Irrawang Swamp across a section of New Line Road south of the existing flood gates. The construction of this levee was a condition of the Stage 2 augmentation consent (Kleinfelder, 2018).

Multi-cell culvert
HWC provided Alluvium with design details of a multi-cell culvert under Newline Road just north of the Newline Road and Beaton Avenue intersection. The design drawings (Hunter District Water Board, 1975) indicate that a six-cell reinforced concrete box culvert was proposed to be constructed at this location. Each cell was 3.3m (w) x 1.8 m (h). The culvert inverts were designed at 0.97 m AHD and the road crown level was designed at approximately 3.6m AHD.

The multi-cell culvert was constructed as part of the Irrawang Spillway works in 1975 in conjunction with roadworks in Newline Road. The culvert was funded by Hunter Water and constructed by Port Stephens Council, and is owned by Hunter Water (pers. com. Holly Marlin, HWC). The culvert is separated from the swamp by a high levee bank/weir (pers. com. Holly Marlin, HWC). The levee/weir was constructed with a crest at approximately 1.7m AHD (Hunter Water, 2012a). The constructed gabion weir at the entrance to the culvert is shown in Figure 3-4.

Figure 3-4 *Existing gabion supported bund upstream of multi-cell box culvert*

Based on the available data, when water levels in the Irrawang Swamp exceed 1.7m AHD, spills would be initiated over the levee bank/weir into the multi-cell culvert prior to discharge along a short section of channel to the Williams River. The level of the levee bank/weir effectively controls the maximum level for extended duration of water in Irrawang Swamp. Water levels in Irrawang Swamp would only exceed the levee bank/weir level for a relatively short period (days), as water above this level would discharge relatively efficiently through the multi-cell culvert. Water stored at levels below 1.7m AHD drains through the flood gates.

3.2 Wetland 803

The majority of the Kings Hill West development area drains to Wetland 803 located adjacent to New Line Road. The total catchment area draining to Wetland 803 is approximately 97 ha and the wetland covers approximately 14 ha of the catchment. The catchment is primarily forested in the upper reaches with cleared grazing areas observed around the lower reaches and the wetland perimeter. The existing wetland includes a number of distinct shallow cells that receive inflows from separate sub-catchments. The maximum water depth in the wetland prior to overflow through the outlet occurring is estimated to be approximately 0.25m. The shallow cells can be observed partially filled in Figure 3-5.

Figure 3-5 *Wetland 803 partially full*

Water level/electrical conductivity data available for the 210452 Raymond Terrace water level recorder over the 2013 to 2019 period indicates that exchange of saline inflows from the Williams River with the stored water in the wetland will occur (WaterNSW, 2019). Based on a recent survey of the wetland outlet (deWitt Consulting, 2019) it appears that tides can flow into the wetland when water levels in the Williams River exceed approximately 0.65m AHD (the minimum outlet/spill level in the north-western corner of the wetland). This level is estimated to be between the mean high water (MHW) and mean high water springs (MHWS) levels at this location (MHL, 2012).

The hydrology of Wetland 803 is influenced by catchment inflows and tidal inflows from the Williams River. Surface water can drain from the wetland when water levels exceed the outlet level. Surface water drains through a shallow trapezoidal channel located adjacent to the north-western extents of the wetland. The channel connects to a narrow drain located in the Newline Road reserve that conveys surface water through a twin 600mm diameter culvert under New Line Road to the Williams River. In addition to surface flows from the catchment, tidal inflows to the wetland can also occur when the tide level exceeds the outlet level.

During seasonally high rainfall periods, water levels in the wetland will typically be elevated and close to the outlet level for extended periods. During these periods, tidal exchange with the Williams River will occur with saline/brackish water flowing into the wetland when tidal flood flow levels exceed the outlet level. It is expected that tidal flood flows will partially mix with stored water in the wetland close to the outlet location, prior to draining from the wetland during the ebb tide.

During low rainfall and warmer periods, evapotranspiration across the wetland will reduce the water levels below the outlet level. During these periods, catchment inflows will typically be low and water levels primarily influenced by tidal flood flows into the wetland and evapotranspiration. It is envisaged that during these low catchment inflow periods, the water stored in the wetland will become increasingly saline under the dominant influence of tidal flows. During these drier periods, incoming flows during some high tides would be retained in the wetland on the ebb tide, with following high tides also functioning to gradually increase water levels until the outlet level is reached or high tide levels fall below the outlet level.

4 Existing wetland vegetation

4.1 Irrawang Swamp

Historical management practises impacting wetland vegetation
The vegetation in Irrawang Swamp is a mosaic of wetland marsh and woodland communities. These occupy areas of the swamp which experience different hydrological regimes (wetting/drying cycles and depth of inundation). These have developed depending upon the elevation and drainage patterns in the different areas of the Swamp.

The Irrawang Swamp vegetation was significantly modified after the 1950s to enable agricultural uses. This involved the cutting of drains through the central areas of the swamp and the clearing of some of the Swamp Oak (*Casuarina glauca*) woodland areas to enable pasture management. The Irrawang Swamp Plan of Management (Hunter Water, 2012a) outlines the following historical changes:

Irrawang Swamp has been subjected to a range of anthropogenic disturbances, all aimed at improving the area for agricultural activities, particularly grazing. This disturbance history has resulted in a degraded wetland system with a highly altered hydrological regime affecting inundation frequency, duration and extent, as well as salinity.

In addition to the hydrological changes outlined in Section 3, past land management practices that have altered the natural vegetation include:

- Clearing of native vegetation;
- Livestock grazing; and
- Introduction of exotic pasture species.

The 1954 aerial image of the Swamp (Figure 4-1) shows minimal constructed drainage. This contrasts with the 1977 and 2018 images (Figure 4-2 & Figure 4-3 respectively) which show development and constructed drainage through the central areas of the swamp.

The main historical changes in vegetation communities through the swamp were:

- Reduction in Swamp Oak and Paperbark Woodland areas.
- Reduction in Perennial Swamp meadow (Tall marsh) wetland vegetation
- Increase in Seasonal and Transient Swamp Meadow and pasture.

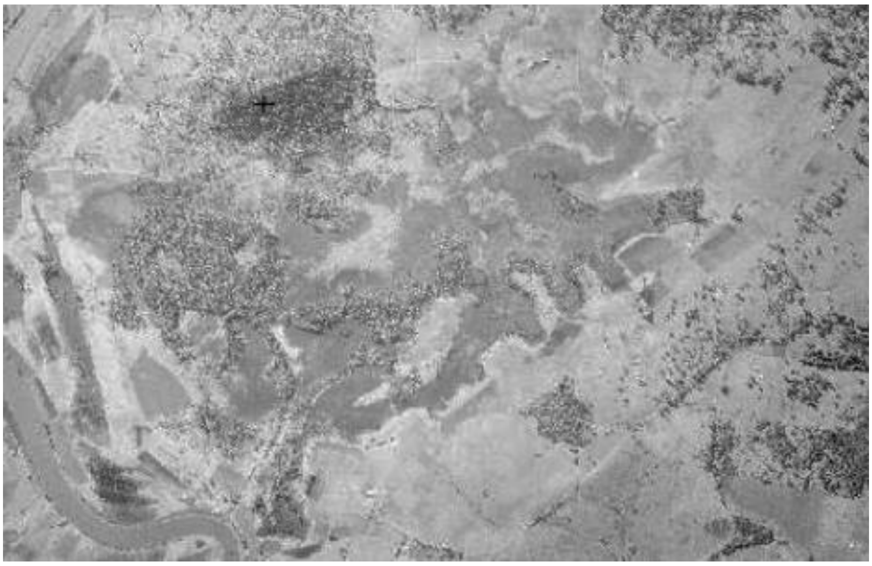

Figure 4-1 *1954 aerial image of Irrawang Swamp*

Figure 4-2 *1977 Aerial image of Irrawang Swamp*

Figure 4-3 *2018 Aerial image of Irrawang Swamp*

The swamp vegetation is adjusting to the current flow regime which includes maintenance practices that are allowing the drainage channels to infill reducing their hydraulic efficiency. This will see water retained in the central areas of the swamp for longer periods and increased inundation for tolerant plant species.

Changes in the flows to Irrawang Swamp will alter the current hydrological regime with different areas more likely to be impacted than others.

Previous studies

The vegetation of Irrawang Swamp has most recently been mapped within the *Grahamstown Dam Stage 2 Augmentation Phase 3 – Flora Monitoring of Irrawang Swamp* monitoring report prepared by Kleinfelder (2018).

Alluvium has not undertaken a detailed flora survey, but has used the Kleinfelder (2018) report as a baseline for viewing the current vegetation community extents. An initial site visit was undertaken by Alluvium on 24 April 2019 to observe the vegetation communities outlined in the Kleinfelder report. A second site visit was undertaken on 16 October 2019 to observe the Melaleuca Swamp Sclerophyll Forest in the north-west area and Seasonal Swamp Meadow in the north-central area of the swamp.

The swamp vegetation mapped by Kleinfelder (2018) has been assigned to different communities (Figure 4-4) depending on the vegetation structure and hydrological regime. For the purposes of this assessment, Table 4-2 shows the alignment with the *Coastal Wetlands Classification* following McManus et al (2007). These communities occupy portions of the study area potentially impacted by changes in catchment runoff. Other more terrestrial areas have not been considered.

No individual flora species listed as threatened or endangered were observed during the site inspections.

Eight flora species listed as vulnerable or endangered species (under NSW and/or federal legislation) are recorded in the NSW BioNet Atlas database for the Irrawang Swamp and surrounding area. Suitable habitat to support four of these species is present within the Irrawang Swamp. One of these (*Maundia triglochinoides*) was recently observed in a dam adjacent to Wetland 803 (Mark Aitkens, pers com), although was not observed during the Alluvium site visits.

Table 4-1 *BioNet records for vulnerable or endangered flora species*

Data from the BioNet BioNet Atlas website.
Report generated on 12/11/2019 3:46 PM

Scientific Name	Common Name	NSW status	Comm. status	Records	Last record	Habitat present within Irrawang Swamp	Habitat likely to exist post development
Maundia triglochinoides	Maundia	V		3	2017	Yes	Yes
Commersonia prostrata	Dwarf Kerrawang	E1	E	1		No	
Eucalyptus camfieldii	Camfield's Stringybark	V	V	79		No	
Eucalyptus parramattensis subsp. decadens	Earp's Gum	V	V	35	2006	No	
Rhodamnia rubescens	Scrub Turpentine	E4A		1	1934	Possible	Possible
^Pterostylis chaetophora	Taree rustyhood	V,P,2		1	2017	No	
Persicaria elatior	Tall Knotweed	V	V	2	2010	Yes	Yes
Asperula asthenes	Trailing Woodruff	V	V	1	2009	Yes	Yes

Twenty-two fauna species (listed as vulnerable or endangered fauna species under NSW and/or federal legislation) which are likely to utilise Irrawang Swamp habitats for foraging or shelter are recorded in the NSW BioNet Atlas database for the Irrawang Swamp and surrounding area. Further consideration of impacts on fauna is provided in RPS (2019).

Table 4-2 *Vegetation community classification*

	Ecological community	Conservation status	Coastal Wetland classification
Woodland	Swamp Oak Woodland (Swamp Oak Floodplain Forest)	EPBC - listed as endangered vegetation community	Forest Swamp Ephemeral
Swamp Meadow Complex	Perennial Swamp-meadow (Freshwater Wetlands on Coastal Floodplains)		Deep Marsh (Tall Marsh)
	Seasonal Swamp-meadow (Freshwater Wetlands on Coastal Floodplains)		Shallow Marsh (wet)
	Transilient Swamp-meadow (Freshwater Wetlands on Coastal Floodplains)		Shallow Marsh (dry)
Woodland	Paperbark Woodland (Swamp Sclerophyll Forest on Coastal Floodplains)	EPBC - listed as endangered vegetation community	Forest Swamp Ephemeral

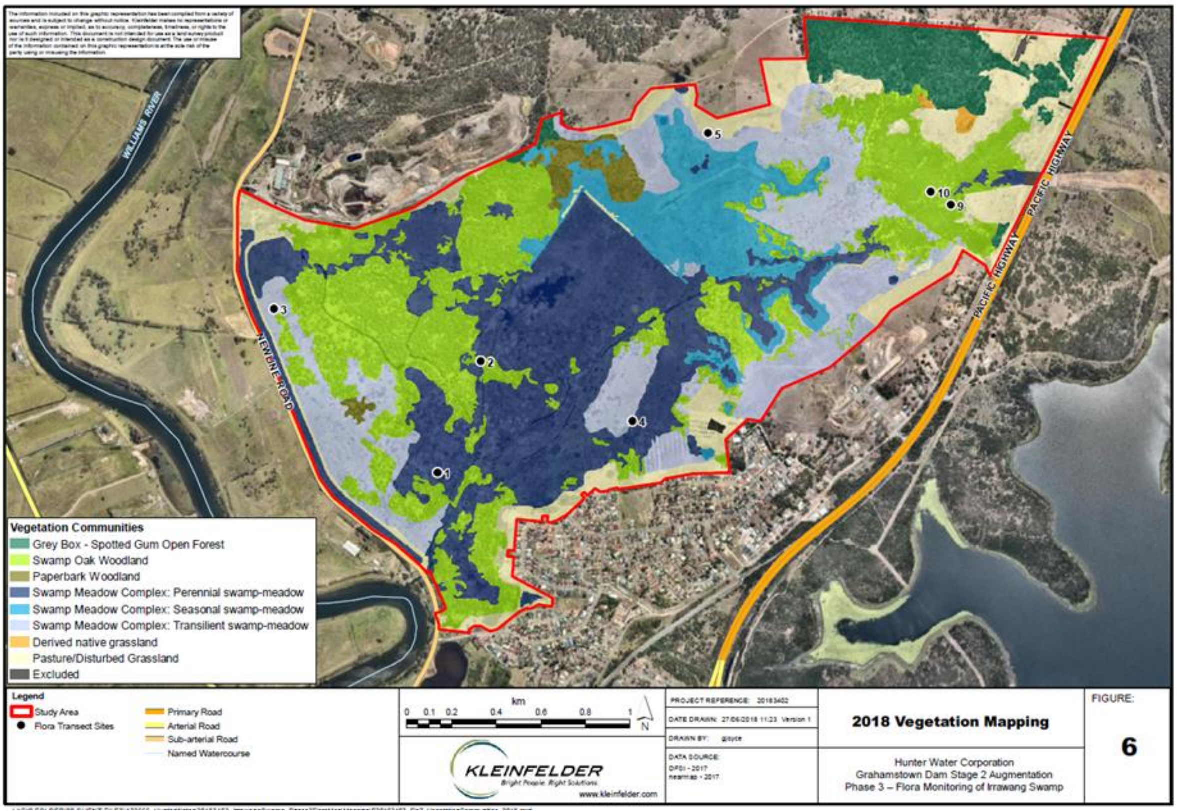

Figure 4-4 *Vegetation mapping by Kleinfelder 2018*

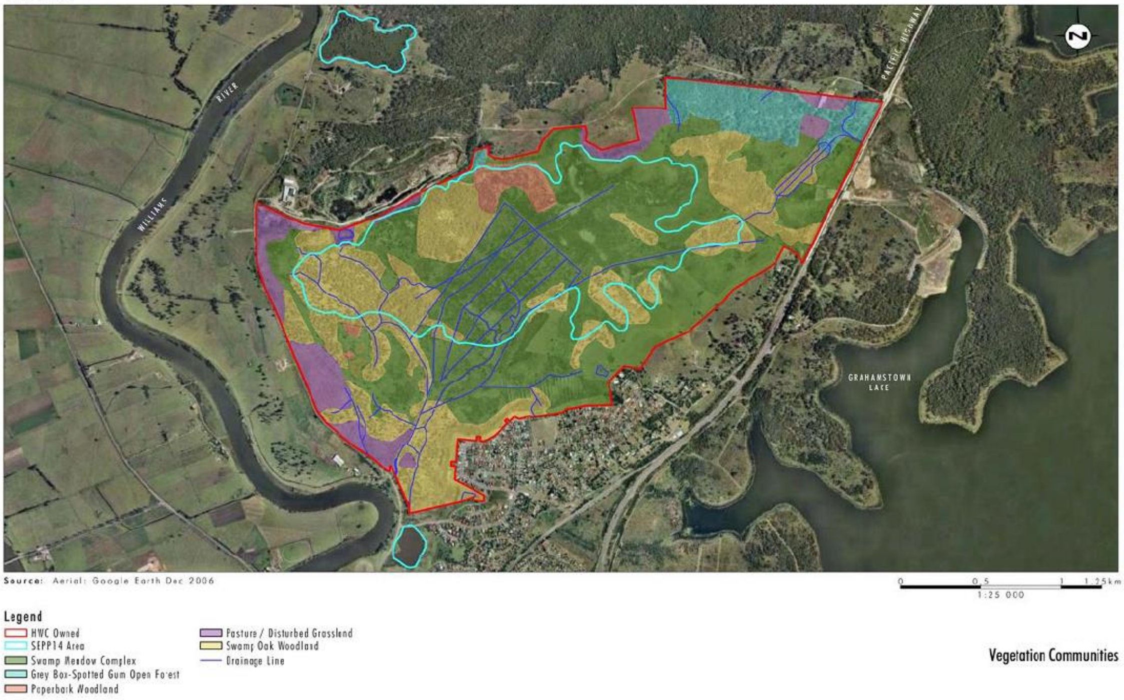

Figure 4-5 *Vegetation mapping by Umwelt 2011*

The Kleinfelder (2018) survey identified the vegetation communities in the wetland to be broadly similar to earlier vegetation assessments undertaken by Umwelt in 2011. Kleinfelder (2018) describes how the extent of the different vegetation communities had changed since the earlier studies in the following way:

> *the key differences are a general increase in the extent of Swamp Oak Woodland vegetation due to significant regeneration of Casuarina glauca (Swamp Oak); and an increase in the extent of swamp-meadow sub-units over the wet meadow sub-unit. In particular, the floristic monitoring shows that increases in the abundances of Bolboschoenus caldwellii, Typha orientalis (Broadleaf Cumbungi) and Casuarina glauca (Swamp Oak), and decreases in the abundance of Cynodon dactylon (Common Couch) over time have made the highest contributions to the overall changes in the vegetation between 2002 and 2018.*

The historic changes in the woodland vegetation can be seen by comparing the estimated Swamp Oak Woodland and Melaleuca Woodland extents from the 1954 image shown in Figure 4-6 with the 2018 extents in Figure 4-4. Due to the clarity of the images, distinctions between the two woodland types cannot be made and therefore they have been combined on the image.

The combined Swamp Woodlands extent in 1954 is estimated to be 174 Ha with the 2018 extent recorded by Kleinfelder (2018) to be 149 Ha. This shows a historic decline in the Swamp Woodlands of approximately 25 Ha (14% of the 1954 extent).

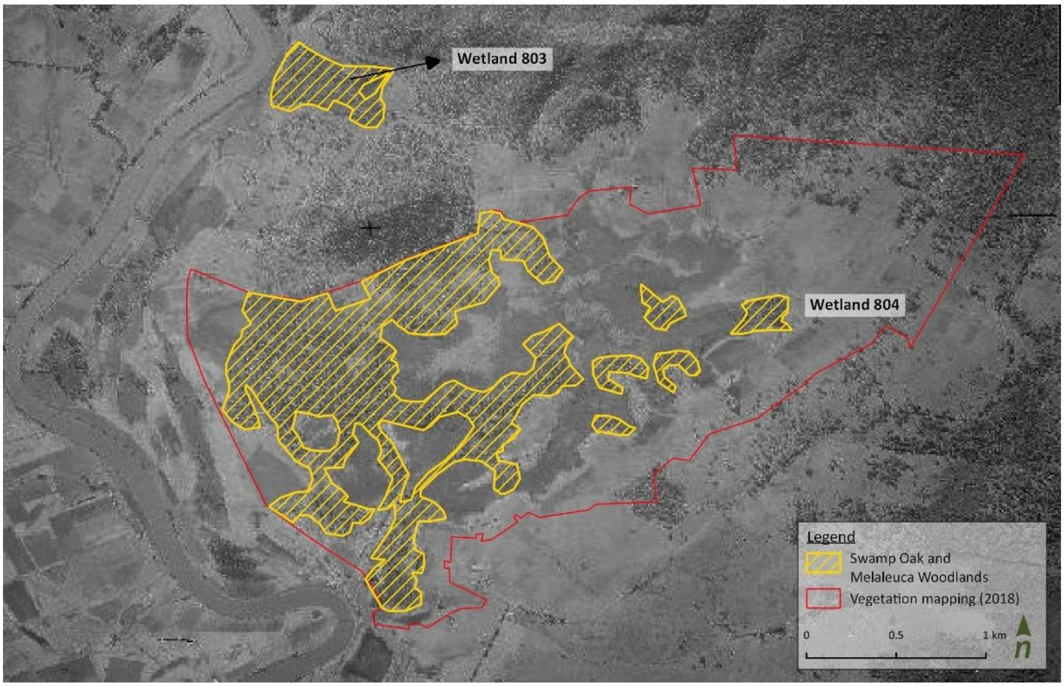

Figure 4-6 *1954 extent of Swamp Oak and Melaleuca Woodlands*

The historic change in Swamp Oak woodland is more pronounced for Wetland 803 which will receive Kings Hill West catchment flows. The Swamp Oak Woodland in this wetland has reduced in extent and density by up to 30%.

Figure 4-7 *1954 and 2019 extents of Swamp Oak Woodland in Wetland 803*

These recent trends of increasing areas of some vegetation communities and species in Irrawang Swamp noted by Kleinfelder (2018) may be a result of a few significant changes that have occurred in the swamp post 2000 including:

- Removal of the cattle and grazing pressure that has:
    - Enabled regeneration of woodland species *Casuarina glauca* and *Melaleuca* sp; and
    - Enabled regeneration of seasonal wetland vegetation such as *Bolboschoenus caldwellii, Carex appressa, Juncus* species.
- Reduction of drainage efficiency to retain water within the swamp that has:
    - Increased perennial marsh *Typha orientalis* and *Phragmites australis*

- Reducing *Cynodon dactylon* (Common Couch) and replacement with more inundation tolerant species such as *Bolboschoenus caldwellii*, *Phragmites australis* and *Typha orientalis*.

4.2 Wetland 803

Wetland 803 is a *Casuarina glauca* Swamp Oak Woodland with areas of submerged vegetation and open water. The wetland is a shallow water body, with a small volume relative to its catchment, which fills readily from the catchment and tidal inflows. Livestock have had historic access to the wetland.

The mature *Casuarina glauca* (Swamp Oak) are growing on pedestals of their own roots (see Figure 4-8) indicating that they have been growing under elevated water levels for a significant period of time. The healthiest *Casuarina glauca* are seen in the north-western corner - which is a shallower area on the wetland and less "pedestaling" is seen in this area. The extent and density of the Casuarina has changed over time with a historic reduction of up to 30% between 1954 and 2019 (see Figure 4-9).

Figure 4-8: *Casuarina glauca growing on a root pedestal within Wetland 803*

Figure 4-9 *1954 and 2019 extents of Swamp Oak Woodland in Wetland 803*

The shallow gradient banks of Wetland 803 have a mixture of herbs, grasses and sedges including: *Paspalum distichum* (Water Couch), *Cotula coronopifolia* (Water Buttons), *Samolus repens* (Creeping Brookweed), *Triglochin* sp (Water Ribbons, Juncus sp, *Bolboschoenus caldwellii* (Marsh Club Rush). In some areas the bank has a sharply stepped bank (at the high water level) reducing the shallow bank vegetation extent.

Extensive emergent macrophytes stands, as seen in Irrawang Swamp, are not present. However, emergent species such as: *Carex appressa* (Tall Sedge), *Eleocharis equisetina* (Spike Sedge), *Bolboschoenus caldwellii* (Sea Club-rush), *Juncus continuus* (Rush), *Ranunculus inundata* (River Buttercup) and Ludwigia peploides (Water Primrose) are present at low cover abundance. This may reflect the hydrology which draws down and then rapidly refills possibly drowning any new emergent macrophyte species. Historic grazing by cattle will have impacted on the emergent vegetation with grazing by water-fowl expected to have some ongoing impact. The lack of *Typha orientalis* indicates that the site periodically dries out.

Areas of submerged vegetation dominated by *Thyridia repens* (Syn *Mimulus repens* - Monkey face) were present during the site visit. This species often occupies areas of sub-saline seasonal mudflats indicating the wetland water level varies through a cycle of complete drying in most years. Other seasonal aquatic species are present including *Callitriche stagnalis* (Common Star-wort), *Potamogeton sulcatus* and *Triglochin* sp. (Water-ribbons).

Wetland 803 has a number of saline tolerant species including *Cotula coronopifolia, Mimulus repens* and *Samolus repens*. Their presence is an indicator of saline influence in the wetland. They are particularly abundant in the areas near the outlet where frequent inflow of saline water occurs. The banks which undergo frequent wetting and drying (which will accumulate salts) are also dominated by these species. However, other non-saline tolerant aquatic plants such as *Callitriche stagnalis* and *Potamogeton sulcatus* were present during the site visit. The presence of these varying tolerance species indicates that inflow from the estuary occurs and that seasonal winter inflow must lower the salinity level significantly. Maintaining these conditions will enable the diversity of flora in the wetland to persist.

4.3 Significant weeds

Two aquatic weeds of national significance (WONS) were identified in vegetation surveys. These are Alligator Weed (*Alternanthera philoxeroides*) and Water Hyacinth (*Eichhornia crassipes*). Both these weeds pose a significant threat to the biodiversity of the wetland and will need to be managed to prevent their spread through the system.

Other WONS recorded or observed on the site are:

- Blackberry (*Rubus fruticosus* species aggregate)
- Lantana (*Lantana camara)*
- *Willows (Salix sp)*

During the April 2019 site visit Alligator Weed was observed adjacent to the north-western boundary of Irrawang Swamp. During the October 2019 site visit a wider area was accessed and Alligator Weed was observed across large areas of Irrawang Swamp. The infestation occupied large areas of the inundated zones and extended into the drier more terrestrial boundary of the swamp. Figure 4-10 shows the spreading infestation smothering over Seasonal Meadow and into the Melaleuca Woodland. A systematic survey of the infestation was not undertaken with Figure 4-11 showing locations where Alligator Weed was observed.

Figure 4-10: *Alligator Weed infestation at North Western corner of Irrawang Swamp*

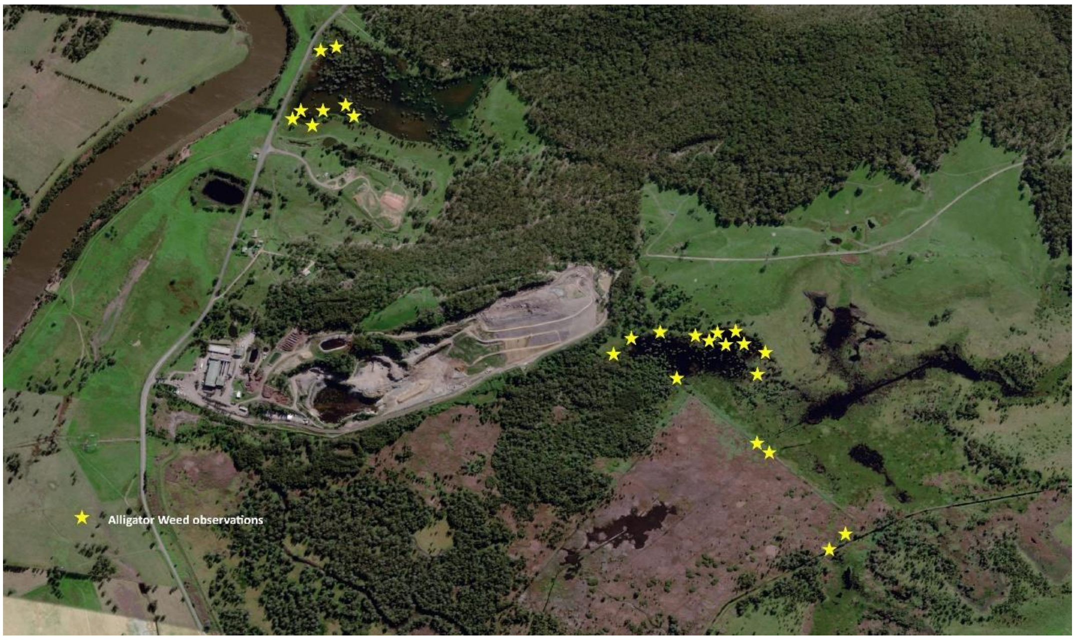

Figure 4-11: *Observed locations of Alligator Weed October 2019*

The infestation in October 2019 is estimated to cover 2 to 5 Ha and is actively expanding. There is an associated infestation of Water Hyacinth which is more restricted to frequently inundated areas and is estimated to cover 1 to 2 Ha within Irrawang Swamp.

Weed control programs need to be implemented and ongoing to ensure these weeds are kept to an acceptable low level throughout the wetland.

4.4 Site visits

A site visit was undertaken on 24 April 2019 to observe the vegetation communities outlined in the Kleinfelder (2018) report. A second site visit was undertaken on 16 October 2019 to review the north-west portion of Irrawang Swamp focussing on the Melaleuca Woodland and Seasonal Meadow north of the central bund/channel. Hydraulic structures were also accessed to further understand their impact on flows through the reserve. The site visits did not include a detailed flora survey, but the Kleinfelder (2018) report was used as a baseline for the current vegetation community extents. Vegetation communities within Wetland 803 were also noted during this site visit.

The site visit was able to confirm the floristic makeup of the different vegetation communities described in Kleinfelder (2018). The relative position of the vegetation communities within the swamp areas and inundation profile was also observed. This has enabled cross checking to historic mapping and LiDAR to determine estimates of the inundation frequency and depths of the vegetation communities.

4.5 Wetland typologies

The vegetation communities in Irrawang Swamp and Wetland 803 occupy different areas depending upon the hydrology of those areas. The hydrological regimes for the different communities described below are shown in Table 4-3. Hydrology risks to these vegetation communities are shown in Table 4-4.

Swamp Meadow Complex

This vegetation community is a mosaic of grasses, sedges and herbs with occasional trees (e.g. Casuarina and Melaleuca) occupying areas of varying inundation. Kleinfelder (2018) mapped this vegetation into three floristic communities shown below. These are stable assemblages of plants but will vary in their composition and extent in response to micro-topography across the site, seasonal water availability and land management practices.

Perennial Swamp Meadow – areas of frequently deep (0.5 to 0.8m deep) and prolonged inundation including during summer. This is found in the lower sections where the Pennington Drain spills frequently and dominates the former agricultural pasture area centrally within the swamp. The vegetation is dominated by monospecific stands of *Typha orientalis* (Broadleaf Cumbungi) and/or *Phragmites australis* (Common Reed). Diversity in these areas is low. Serious weeds such as *Eichhornia crassipes* (Water Hyacinth) and *Alternanthera philoxeroides* (Alligator Weed) have been observed in this zone. Areas of open water occur in within this zone where the water depth prevents tall marsh plants from growing.

This vegetation community is equivalent to the Deep Marsh wetland vegetation in McManus et al (2007). Present in Irrawang Swamp.

Figure 4-12 *Perennial Swamp Meadow on the former agricultural pasture area that is dominated by Typha orientalis.*

Seasonal Swamp Meadow – areas of seasonal inundation (0.2 to 0.5m deep) with an annual drying period of 3 to 6 months. The vegetation of this community can be dominated by *Paspalum distichum* (Water Couch) but shows more diversity in plant species than the Perennial Swamp Meadow areas. Plants observed in this community include *Eleocharis equisetina* (Spike Sedge), *Bolboschoenus caldwellii* (Sea Club-rush), *Juncus continuus* (Rush), *Ranunculus inundata* (River Buttercup), Ludwigia peploides (Water Primrose), *Carex appressa* (Tall Sedge), *Triglochin* sp (Water-ribbons) and *Persicaria decipiens* (Slender Knotweed). Serious weeds such as *Alternanthera philoxeroides* (Alligator Weed) and *Eichhornia crassipes* (Water Hyacinth) have been observed in this zone with *Xanthium occidentale* (Noogoora Burr) also common.

This vegetation community is equivalent to the Shallow Marsh wetland vegetation type in McManus et al (2007). Present in Irrawang Swamp and Wetland 803.

Figure 4-13: *Seasonal Swamp Meadow vegetation with Eleocharis, Triglochin and Paspalum sp.*

Figure 4-14: *Seasonal Swamp Meadow showing variations in vegetation.*

Transient Swamp Meadow – areas that are flooded for short periods after significant rain events. The vegetation is dominated by *Cynodon dactylon* (Common Couch) with *Juncus continuus* and *Carex appressa* commonly seen. Herbaceous weeds such as *Xanthium occidentale* (Noogoora Burr) are also common in this area. Alligator Weed can also invade this zone with this weed invading areas of Transient Swamp Meadow in the NW corner of Irrawang Swamp.

This vegetation community is equivalent to the Shallow Marsh wetland vegetation type in McManus et al (2007). Present in Irrawang Swamp and Wetland 803.

Figure 4-15: *Transient Swamp Meadow dominated by Couch and Tall Sedge (Seasonal Swamp Meadow in lower left corner).*

Swamp Oak Woodland

Swamp Oak Woodland is a floodplain vegetation dominated by *Casuarina glauca* (Swamp Oak) with a variable understorey depending upon the inundation frequency and density of the canopy. Melaleuca species can form part of the canopy structure. This is the most widespread woodland community within Irrawang Swamp. The mapping by Kleinfelder (2018) shows most of the Swamp Oak woodland to be consistent with the community definition under the EPBC Act.

The Swamp Oak Woodlands occupy saturated soils which have a seasonal drying cycle. They periodically flood for short periods (up to 1 month) following large runoff events which recedes rapidly from these areas.

The Swamp Oak Woodland has expanded since the 1970s recolonising areas previously drained and grazed. This is a response to the removal of the cattle and increased soil moisture through the previously drained areas.

This vegetation community is equivalent to the Forest Swamp Ephemeral wetland vegetation type in McManus et al (2007). Present in Irrawang Swamp and Wetland 803.

Figure 4-16 *Swamp Oak Woodland showing recruitment with juvenile plants present.*

Paperbark Woodland

This is an alluvial plain woodland community dominated by Melaleuca species including *Melaleuca linariifoli*a (Snow in Summer), *Melaleuca styphelioide*s (Prickly Paperbark) and *Melaleuca ericifolia* (Swamp Paperbark). This is a seasonally inundated vegetation community with water up to 0.5m deep. It occupies areas at a slightly lower (100-200mm) elevation than the Swamp Oak with longer inundation periods.

Kleinfelder (2018) have mapped it at two main locations. One in the northern boundary of Irrawang Swamp where a drainage line enters and the other near the western boundary.

The northern Paperbark Woodland (Melaleuca Swamp) is susceptible to impacts from increased summer flows as this area is a natural depression and increased summer flows may prevent this area from drying out.

This vegetation community is equivalent to the Forest Swamp Ephemeral wetland vegetation type in McManus et al (2007). Present in Irrawang Swamp.

Figure 4-17 *Melaleuca Woodland with Triglochin dominated understorey***.**

Table 4-3 *Vegetation community hydrological regimes*

	Ecological community	Wetland classification	Dominant species	Hydrological conditions							
				Soil water conditions	Inundation frequency	Inundation depth	Inundation duration	Inundation regularity	Drying period	Drying frequency	Water quality
Woodland	Swamp Oak Woodland (Swamp Oak Floodplain Forest)	Forest Swamp Ephemeral	*Casuarina glauca*	Water logged	Episodic	0 to 0.4m (RL 0.6 to 1)	<3 days	4-6 times per year	4-8 months	Annually	Fresh to brackish
Swamp Meadow Complex	Perennial Swamp-meadow Freshwater Wetlands on Coastal Floodplains	Deep Marsh (Tall Marsh)	*Typha orientlis/Phragmites australis*	Saturated	Seasonal to permanent	0.5 to 0.8m (RL 0.2 to .5)	6 months to perennial	Annual	1 - 4 months	1.5 - 3 years	Fresh to brackish
	Seasonal Swamp-meadow Freshwater Wetlands on Coastal Floodplains	Shallow Marsh (wet)	*Paspalum distichum* (Water Couch), *Bolboschoenus caldwellii, Ludwigia pleboides, Carex appressa. Juncus* sp	Water logged	Seasonal to episodic	0.2 to 0.5m (RL 0.4 to 0.8)	1-2 months	2-3 times per year	3 - 6 months	Annually	Fresh
	Transilient Swamp-meadow Freshwater Wetlands on Coastal Floodplains	Shallow Marsh (dry)	*Cynodon dactylon* (Common Couch), *Juncus sp, Carex appressa*	Water logged	Episodic	0 to 0.4m (RL 0.6 to 1)	1 month	2-3 times per year	8 - 12+ months	Annually	Fresh
Woodland	Paperbark Woodland Swamp Sclerophyll Forest on Coastal Floodplains	Forest Swamp Ephemeral	*Melaleuca styphelioides, Melaleuca linariifolia, Melaleuca ericifolia*	Water logged	Seasonal (Spring)	0 to 0.5m (RL 0.5 to 0.9)	2 to 3 months	Annual	3-6 months	Annually	Fresh to brackish
				Water logged	Episodic	0.2 to 0.4m (RL 0.6 to 0.8)	1 month	2-3 times per year			

Table 4-4 *Vegetation community hydrology risks*

	Ecological community	Wetland classification	Dominant species	Hydrology risk		
				Current trajectory	Increase in depth and duration	Reduced depth and duration
Woodland	Swamp Oak Woodland (Swamp Oak Floodplain Forest)	Forest Swamp Ephemeral	*Casuarina glauca*	Increase in extent. Unclear ff this is due to hydrology or reduced grazing pressure.	>200mm of drawdown depth for more than 1 month duration. Drowning of Swamp Oak, reduced extent.	Increase in Swamp Oak if reduction is low and waterlogged soils are retained.
Swamp Meadow Complex	Perennial Swamp-meadow Freshwater Wetlands on Coastal Floodplains	Deep Marsh (Tall Marsh)	*Typha orientlis/Phragmites australis*	Increase in extent	Further spread especially if summer inundation increses	Reduction in perrennial to Season Swamp-meadow
Swamp Meadow Complex	Seasonal Swamp-meadow Freshwater Wetlands on Coastal Floodplains	Shallow Marsh (wet)	*Paspalum distichum* (Water Couch), *Bolboschoenus caldwellii, Ludwigia pleboides, Carex appressa. Juncus* sp	Reducing	Reduction with increase in Perennial Swamp-meadow	Potential increase
Swamp Meadow Complex	Transilient Swamp-meadow Freshwater Wetlands on Coastal Floodplains	Shallow Marsh (dry)	*Cynodon dactylon* (Common Couch), *Juncus sp, Carex appressa*	Reducing with Swamp Oak Woodland colonising into this area.	Reduction with increase in Perennial Swamp-meadow	Potential increase
Woodland	Paperbark Woodland Swamp Sclerophyll Forest on Coastal Floodplains	Forest Swamp Ephemeral	*Melaleuca styphelioides, Melaleuca linariifolia, Melaleuca ericifolia*	Stable with some increase	>200mm of drawdown depth for more than 1 month duration. Reduction with increase in Perennial Swamp-meadow	Potential increase

5 Development impacts on catchment hydrology

5.1 Hydrological model development

MUSIC models were prepared by Northrop Consulting Engineers (NCE) to evaluate runoff quality from the development site for existing, developed (untreated) and developed (with treatment) scenarios.

The five-year modelling period adopted by NCE for stormwater quality modelling was considered insufficient for the purpose of completing flow regime analysis. Alluvium assisted NCE with extending the modelling period to reflect an appropriately representative period for the hydrology analysis. A representative continuous 20-year rainfall period with good quality and complete 6-minute time step data was selected from the nearby Williamtown RAAF rainfall station. The period from 1989 to 2008 provided good quality data with a mean annual rainfall consistent with the long-term average.

Alluvium sourced appropriate daily potential evapotranspiration data from the SILO database covering the rainfall data period. Daily estimates of Mortons PET (wet) were adopted as being most appropriate for hydrologic modelling.

A MUSIC template was prepared utilising the above data and supplied to NCE. NCE modified their MUSIC models to incorporate the new template and provided updated daily flow estimates for 3 scenarios; existing, developed (untreated) and developed (with treatment).

NCE provided daily flow outputs from their models for Alluvium's hydrological analysis. In completing this analysis, Alluvium has assumed that the models developed by NCE appropriately reflect the site characteristics and conditions for each development scenario. We understand that the process followed to develop the MUSIC models is outlined in a separate report prepared by NCE (NCE, 2019).

Northrop provide flow outputs at three separate locations relevant to the assessment:

- Kings Hill South includes the future development and remaining forest areas that drain into the northern side of Irrawang Swamp through ephemeral gullies.
- Kings Hill East includes areas draining to a location where the original spillway channel joins the eastern side of Irrawang Swamp. For the existing scenario, the sub-catchments only include areas draining to an ephemeral creek located between the Pacific Highway and the Riding for the Disabled site. For the developed (treated) scenario the catchment draining to this location will increase significantly due to construction of a diversion channel required to prevent the discharge of runoff from development in Kings Hill East into Grahamstown Dam.
- Kings Hill West includes areas draining to a small coastal wetland previously listed as Coastal Wetland 803 under repealed SEPP 14 legislation.

5.2 Mean annual runoff volume

Changes in mean annual runoff volume provide a coarse indicator of the catchment hydrology changes associated with the Kings Hill development. Table 5-1 summarises the estimated changes to mean annual runoff volumes draining to Irrawang Swamp and Wetland 803 that are associated with the Kings Hill development.

The Kings Hill East sub-catchment includes all future development areas (and forested areas draining through these areas) that will drain to the original Grahamstown Dam spillway outlet into Irrawang Swamp. The estimated mean annual runoff volumes for the developed and developed (with treatment) scenarios are based on a 0.2% AEP capacity diversion drain being constructed on the eastern side of the Pacific Highway in Hunter Water owned land. This drain would divert runoff that currently drains directly to Grahamstown Dam to the original spillway.

The Kings Hill East sub-catchment also includes an existing ephemeral creek between the existing Riding for the Disabled site and the Pacific Highway. This creek transitions to a section of concrete channel parallel to the original Grahamstown Dam. The creek discharges into Irrawang Swamp at the same location as the original spillway.

The Kings Hill South sub-catchment includes all future development areas (and forested areas draining through these areas) that drain through three existing ephemeral gullies into the northern side of Irrawang Swamp.

The sub-catchment extents for Kings Hill East, Kings Hill South and Kings Hill West are shown on Figure 2-1.

Table 5-1 *Estimated mean annual runoff volumes (1989 to 2008 modelling period)*

Sub-catchment	**Scenario**	**Catchment runoff discharge location**				
		Northern Irrawang Swamp	**Original spillway outlet channel**	**Grahamstown Dam**	**Wetland 803**	**Williams River**
Kings Hill East	Existing	0	625	925	0	0
	Developed	0	2300	0	0	0
	Developed (treated)	0	2120	0	0	0
	Change		+1495 (+240%)	-925 (-100%)		
Kings Hill South	Existing	470	0	0	0	0
	Developed	700	0	0	0	0
	Developed (treated)	575	0	0	0	0
	Change	+105 (+22%)				
King Hill West	Existing	0	0	0	427	0
	Developed	0	0	0	529	0
	Developed (treated)	0	0	0	458	31
	Change				+31 (+7%)	+31

The estimated mean annual runoff volumes summarised in Table 5-1 indicate that:

- The average annual runoff discharged to Grahamstown Dam from the Kings Hill East sub-catchments is estimated to decrease by approximately 925 ML/yr following construction of the diversion drain. Excluding infiltration and evapotranspiration losses along the diversion drain, most of this runoff would discharge to the original spillway channel and then to Pennington Drain.
- The average annual runoff discharged from the local Kings Hill sub-catchments to the original spillway channel is expected to increase by up to approximately 1500 ML/year following development. This increased volume includes the parts of Kings Hill East currently draining to Grahamstown Dam that will be diverted to the original spillway, and the increased runoff from the other parts of Kings Hill East that continue to drain to the original spillway.
- An increase in mean annual runoff of 105 ML is estimated from the Kings Hill South sub-catchments draining into the ephemeral gullies located to the north of Irrawang Swamp.
- The increase in runoff from Kings Hill West to Wetland 803 will be limited 31 ML/yr (7% increase).

As a proportion of the existing runoff, the increase in runoff discharged into the eastern extents of Irrawang Swamp is significantly greater than the increase from the northern catchments. Whilst the total volume of runoff will increase across the full range of small to large storm events, changes in the flow regime during drier low flow periods are expected to be more critical for the vegetation communities within Irrawang Swamp. How runoff characteristics are estimated to change with development for small and large rainfall events is discussed in Section 5.3.

5.3 Cumulative runoff

A plot of daily rainfall totals and associated cumulative runoff volumes for Kings Hill South is provided in Figure 5-1. Figure 5-1 is based on MUSIC model flow outputs from the 20-year models prepared by NCE for the existing and developed scenarios. The trends shown in the hydrologic modelling results presented in Figure 5-1 would also be representative of other areas of the Kings Hill development.

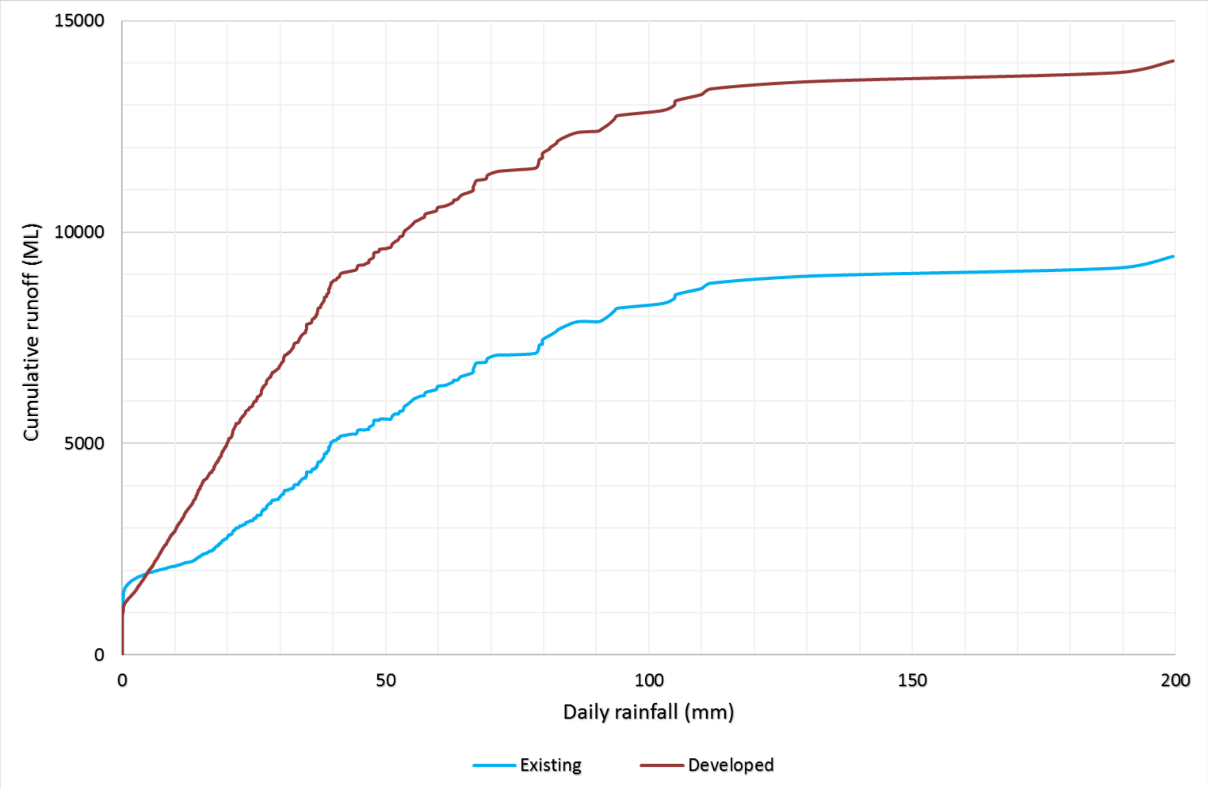

Figure 5-1 *Plot of daily rainfall and estimated cumulative runoff for Kings Hill South catchment (1989 to 2008)*

Figure 5-1 indicates that the most significant differences in runoff volumes between the existing and developed scenarios are likely to occur for days where the daily rainfall is less than 50mm. For daily rainfall totals between 50mm and 100mm there is a small difference, and above daily rainfall totals of 100mm the volume of runoff from the existing and developed site is expected to be similar. The reasons for these differences are discussed below.

For daily rainfall totals less than 50mm, a high proportion of rainfall within the existing forested and pasture areas will be retained in the upper soil layers with some intercepted rainfall draining slowly as either interflow or base flow to creeks in the days immediately following rainfall. Rainfall absorbed by the soil will typically evaporate or be transpired by plants in the days following a storm event. In a developed site, impervious roof and road surfaces only intercept a very small rainfall depth (typically less than 2mm) with any additional rainfall causing stormwater runoff to occur from these surfaces. This results in more frequent runoff from developed catchments during much smaller rainfall events and this cumulatively adds up to a significant volume.

For daily rainfall totals exceeding 50mm, it is likely that soils will become close to saturation in the early stages of a rainfall event, resulting in a high proportion of additional rainfall being converted to runoff. In this manner, pervious surfaces would tend to generate similar runoff volumes as developed impervious surfaces in larger rainfall events and this is why only a marginal increase in estimated runoff volume occurs above a daily rainfall total of 50mm in Figure 5-1.

Figure 5-1 indicates that cumulative changes in hydrology from developing catchments are likely to be more pronounced for days where the daily rainfall is less than 50mm. Mitigation strategies aiming to replicate pre-development hydrology conditions therefore need to focus on reducing changes in runoff volumes for days where the daily rainfall is less than 50mm. This requires a change in approach from conventional drainage and flooding studies where much larger storm events are the focus. It also requires a change from a focus on discrete peak stormwater flow rates to management of stormwater runoff volumes.

5.4 Legislation context

The *NSW Coastal Management Act 2016* replaced the *Coastal Protection Act 1979* and established a new strategic framework and objectives for managing coastal issues in NSW. This act includes *State Environmental Planning Policy (Coastal Management) 2018.* ('the SEPP'). The SEPP identifies areas of interest that are delineated on the *Coastal Wetlands and Littoral Rainforest areas map*. This map highlights the coastal wetlands and a proximity buffer area which the SEPP applies to.

The study area contains two Coastal Wetlands (803 & 804) listed in SEPP 2018 and these are shown on Figure 2-1. Whilst the proposed Kings Hill development extents lie outside the mapped Coastal Wetlands and the Proximity Area for Coastal Wetlands, the development has the potential to impact within the areas of interest to the SEPP.

SEPP Clauses 10 and 11 provide guidance on the threats that need to be considered to determine if an impact will occur (see relevant sections of the SEPP outlined below). The key threatening processes posed by the development are identified in other legislation that is also outlined below.

Clause 10: Development on certain land within coastal wetlands and littoral rainforests area

(1) The following may be carried out on land identified as "coastal wetlands" or "littoral rainforest" on the Coastal Wetlands and Littoral Rainforests Area Map only with development consent:

(a) the clearing of native vegetation within the meaning of Part 5A of the Local Land Services Act 2013,

(b) the harm of marine vegetation within the meaning of Division 4 of Part 7 of the Fisheries Management Act 1994,

(c) the carrying out of any of the following:

(i) earthworks (including the depositing of material on land),

(ii) constructing a levee,

(iii) draining the land,

(iv) environmental protection works,

(d) any other development.

Clause 11: Development on land in proximity to coastal wetlands or littoral rainforest

The Coastal Wetlands and Littoral Rainforests Area Map identifies certain land that is inside the coastal wetlands and littoral rainforests area as "proximity area for coastal wetlands" or "proximity area for littoral rainforest" or both.

(1) Development consent must not be granted to development on land identified as "proximity area for coastal wetlands" or "proximity area for littoral rainforest" on the Coastal Wetlands and Littoral Rainforests Area Map unless the consent authority is satisfied that the proposed development will not significantly impact on:

(a) the biophysical, hydrological or ecological integrity of the adjacent coastal wetland or littoral rainforest, or

(b) the quantity and quality of surface and ground water flows to and from the adjacent coastal wetland or littoral rainforest.

This report documents the potential changes to the surface water flows and the estimated impacts of those changes if the Kings Hill development proceeds. If direct impacts on the values in the wetland are not likely to occur then SEPP 2018 Clause 10 is not active.

***NSW Biodiversity Conservation Act 2016* (BC Act), Threatened Species Conservation Act 1995 and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)**

These Acts provide protection to individual species and vegetation communities throughout NSW. If listed species or vegetation communities are identified in project areas or areas to be impacted as a consequence of development, these Acts must be referred to for assessment and response requirements.

Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is listed as a 'key threatening process' in Schedule 3 of the Threatened Species Conservation Act 1995 [31 May 2002]. Understanding the potential for this threatening process to impact on the values within Irrawang Swamp is a key objective of this assessment. This threatening process aligns to the requirements in SEPP 2018 to protect coastal wetlands.

Eight flora species listed as vulnerable or endangered species (under NSW and/or federal legislation) are recorded in the NSW BioNet Atlas database for the Irrawang Swamp and surrounding area. Conditions suitable to support four of these species occur within the Irrawang Swamp. See Table 4-1 for details on these species. No flora species listed as threatened or endangered were observed during the site visits.

Three vegetation communities listed as vulnerable or endangered in the BC Act or EPBC Act (shown in Table 5-2) have been recorded and observed in the site.

Table 5-2 *Vegetation communities of interest within Irrawang Swamp*

Vegetation community	NSW Biodiversity Conservation Act 2016 (BC Act)	Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)
Swamp Meadow Complex	Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions **Endangered**	
Swamp Oak Woodland	Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions **Endangered**	Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and South East Queensland **Endangered**
Paperbark Woodland (Melaleuca Swamp)	Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions **Endangered**	

The listing of a vegetation community under these Acts requires the protection of the area occupied by them from the key threatening processes listed in the Acts.

Activities which can lead to changes to natural drainage regimes, such as the diversion of water, affecting the ecological community can require a referral under the Acts if they will have an impact on the listed species or communities. With the presence of listed species and vegetation communities in the wetland evidence needs to be provided to ensure that they will not be impacted.

This assessment investigates the potential for the changes in flows from the catchment following development to have an impact on the Irrawang Swamp values.

5.5 Kings Hill East and Kings Hill South flow regimes (Irrawang Swamp)

HWC has requested that an assessment of the effects of changes to stormwater discharges to Irrawang Swamp be completed to address biodiversity values and ecological integrity. HWC has indicated it expects that the Kings Hill development proponent demonstrate that the current wetting / drying regime of the Irrawang Swamp would not be adversely impacted by stormwater discharges from the diversion channel and direct discharges from other catchments areas.

HWC has referred to the approach outlined in the guideline document *Water Sensitive Urban Design Solutions for Catchments above Wetlands – Overview Report* (McManus et al, 2007) which indicates that WSUD strategies associated with new developments in the catchments upstream of natural wetlands need to include measures to preserve the pre-development drying and flooding hydrology characteristics in order to protect the wetland ecology.

McManus et al (2007) outlines drying and flooding hydrology management targets for a range of wetland categories and these are summarised in Table 5-3. Wetland categories identified in Section 4.5 that would be relevant to Irrawang Swamp include Shallow Marsh, Deep Marsh and Forest Swamp - Ephemeral.

Table 5-3 *Hydrologic management targets for natural wetlands (McManus et al, 2007)*

Wetland Category	Flooding Hydrology	Drying Hydrology		Reference Duration
	High Flow Duration Frequency Curve	Low Flow Duration Frequency Curve	Low Flow Spell Frequency	
1. Coastal Flats	✓			7 days
2. Inland Flats	✓	Isolate wetland from upstream catchment		30 to 60 days
3. Bogs	✓	✓	✓	30 to 60 days
4. Deep Marsh		✓	✓	30 to 60 days
5. Fen	✓	✓	✓	30 to 60 days
6. Shallow Marsh		✓	✓	60 days
7. Salt Marsh	✓	✓	✓	7 days
8. Seagrass Beds	✓			7 days
9. Deep Salt Pans	✓	Isolate wetland from upstream catchment		30 to 60 days
10. Deep Open Water	No hydrologic management objectives required			
11. Shallow Open Water		✓	✓	60 days
12. Wet Heath		✓	✓	60 days
13. Mangrove	✓			7 days
14. Scrub Swamp	✓	✓*	✓*	60 days
15. Forest Swamp – Wet		✓	✓	60 days
16. Forest Swamp – Ephemeral		✓	✓	60 days
17. Forest Swamp – Dry	✓	✓*	✓*	60 days

Considering the targets outlined in Table 5-3 for the identified relevant wetland categories within Irrawang Swamp, flow regime analysis was completed focusing on the drying hydrology. Inflows to Irrawang Swamp were analysed to derive dry spells curves (low flow spells) and low flow duration frequency curves for 30 and 60-day reference durations. Additional analysis of 7-day duration high flows was also completed to evaluate the impact of diverting runoff from Kings Hill East to Irrawang Swamp. The completed analysis covers the range of wetland vegetation communities currently observed in the swamp. The approach followed to derive the flow regime curves is described in the following sections.

Critical drying period

The critical drying period for Irrawang Swamp is from September to March when average monthly potential evapotranspiration typically exceeds average monthly rainfall at this location (refer Figure 5-2). It is during this period that rainfall and associated runoff to the wetland would be lower enabling soils to partially dry in areas of a wetland to support new plant growth. Minimising changes to hydrology during this drying period are particularly important for the Shallow Marsh, Deep Marsh and Forest Swamp - Ephemeral communities within Irrawang Swamp.

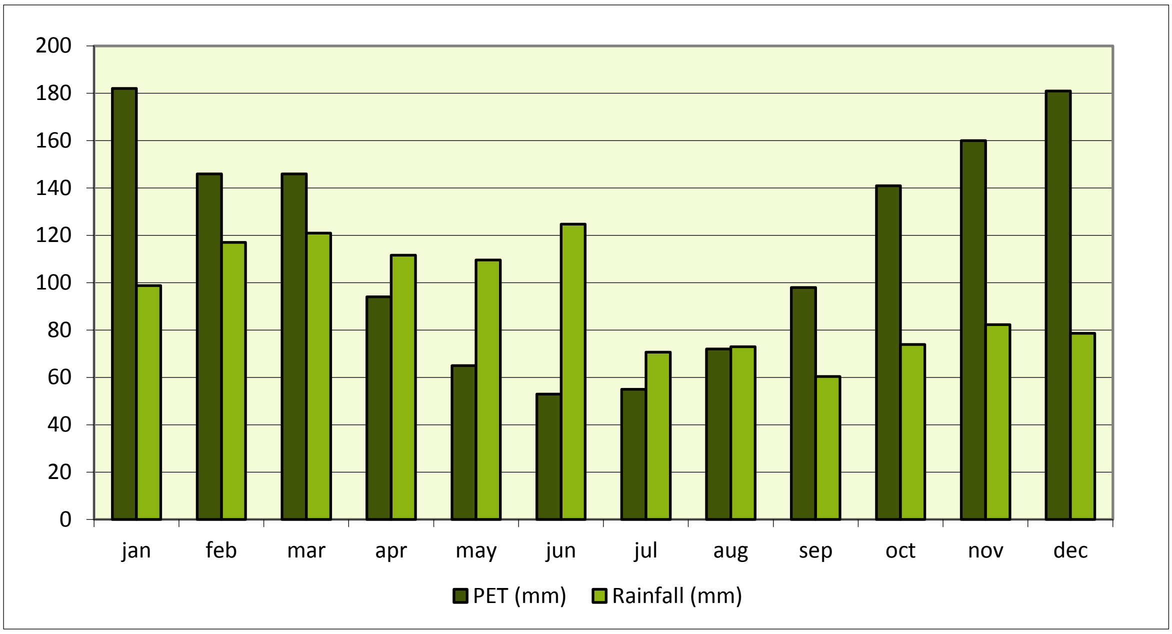

Figure 5-2 *Average monthly potential evapotranspiration and rainfall depths for Irrawang Swamp (BoM Climate Atlas of Australia)*

Dry spells curves

The MUSIC models prepared by NCE to evaluate runoff quality for Kings Hill were adopted for developing the dry spells curves. The approach outlined in McManus et al (2007) was applied to develop the dry spells curves. This approach involves completing annual flow frequency analysis considering the critical drying period for the swamp. As outlined above, for Irrawang Swamp this period was assessed to be from September to March. For each of modelled years, the longest continuous period where estimated daily runoff was lower than the long-term median flow was calculated within the critical drying period. Flow frequency analysis was then completed using the flows estimated by NCE for the existing, developed (untreated) and developed (treated) scenarios and the results plotted. The dry spell curves derived for the Kings Hill South and Kings Hill East sub-catchments are show on Figure 5-3 and Figure 5-4 respectively.

An example of how these curves may be interpreted is indicated by the dashed green line shown on Figure 5-3. This line indicates that there is a 10% chance in any year that the maximum dry spell will exceed 32 days for developed conditions and 190 days for the existing conditions. Typically, a 10% AEP dry spell would be representative of that occurring in a dry year, whilst a 90% AEP dry spell would occur within a wet year. A 50% AEP dry spell is considered to be that occurring in a typical year.

The dry spells curves indicate that the length of the maximum annual dry spell is expected to reduce following development for the full range of dry to wet years. The stormwater management strategy proposed by NCE would partially mitigate reductions in dry spells through the provision of 5 kL rainwater tanks, biofiltration systems and urban lakes throughout the development.

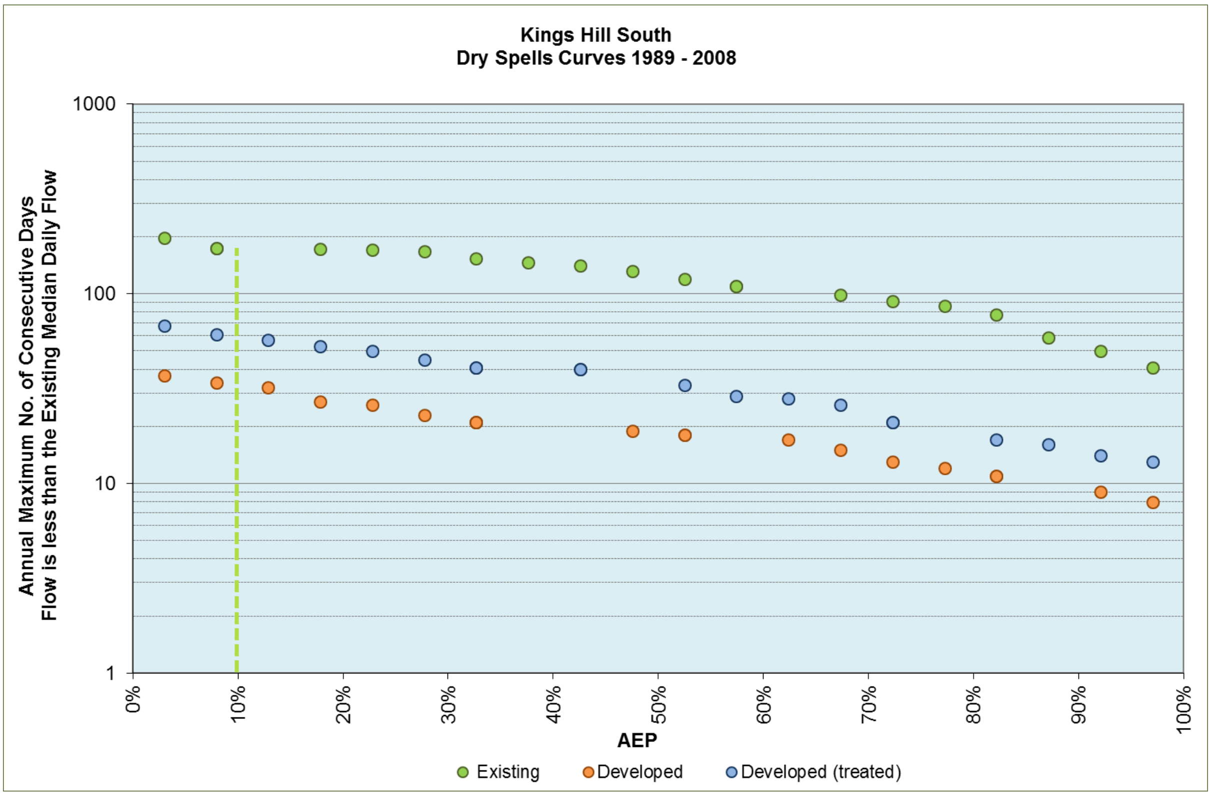

Figure 5-3 *Kings Hill South – Dry Spells Curves*

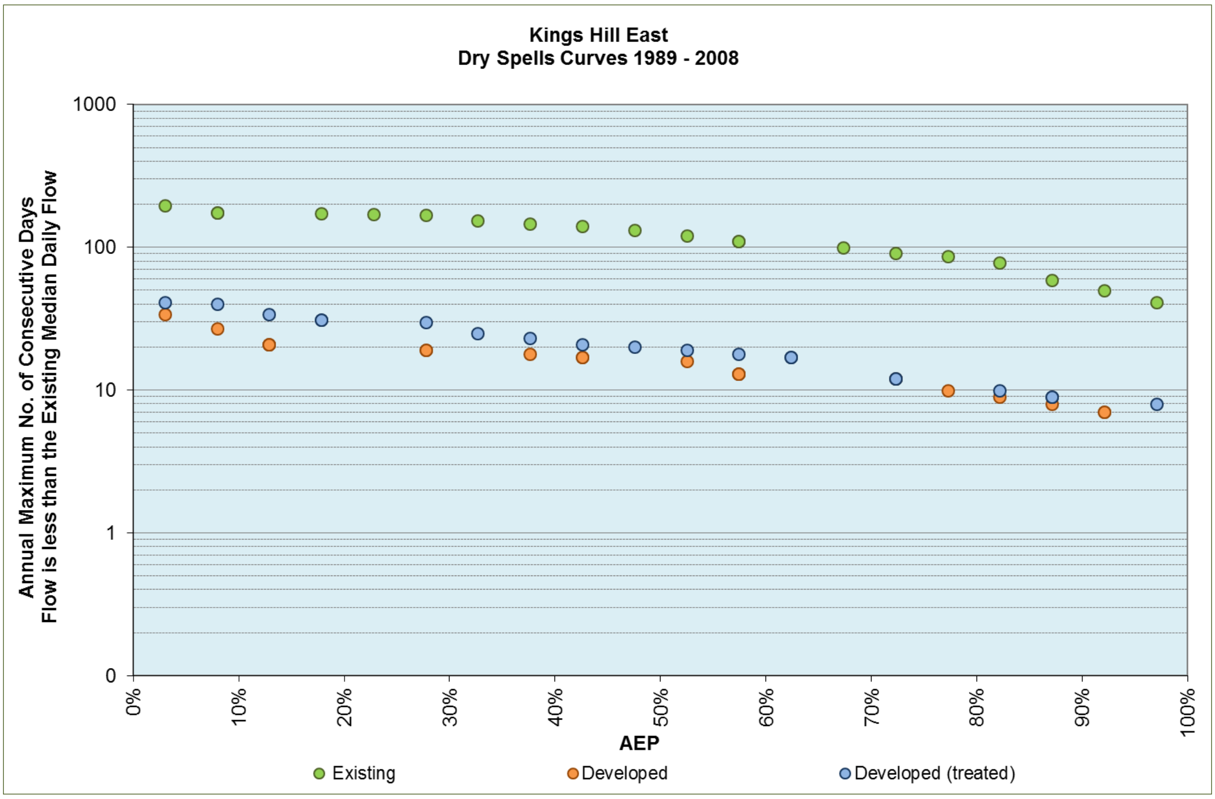

Figure 5-4 *Kings Hill East – Dry Spells Curves*

Low flow duration frequency curves

Similar to the dry spells analysis, the approach outlined in McManus et al (2007) was adopted to develop low flow duration frequency curves. This approach also involves completing annual flow frequency analysis considering the critical drying period for the swamp. A continuous moving average (30 days and 60 days) of the mean daily flow was calculated over the entire modelled period. For each of the modelled years, the maximum average daily 30 and 60-day flows within the critical drying period for each year were calculated. Flow frequency analysis was then completed on the averages for the existing, developed (untreated) and developed (treated) scenarios and the results plotted. The low flow curves derived for the Kings Hill South and Kings Hill East sub-catchments are show on Figure 5-5, Figure 5-6, Figure 5-7 and Figure 5-8.

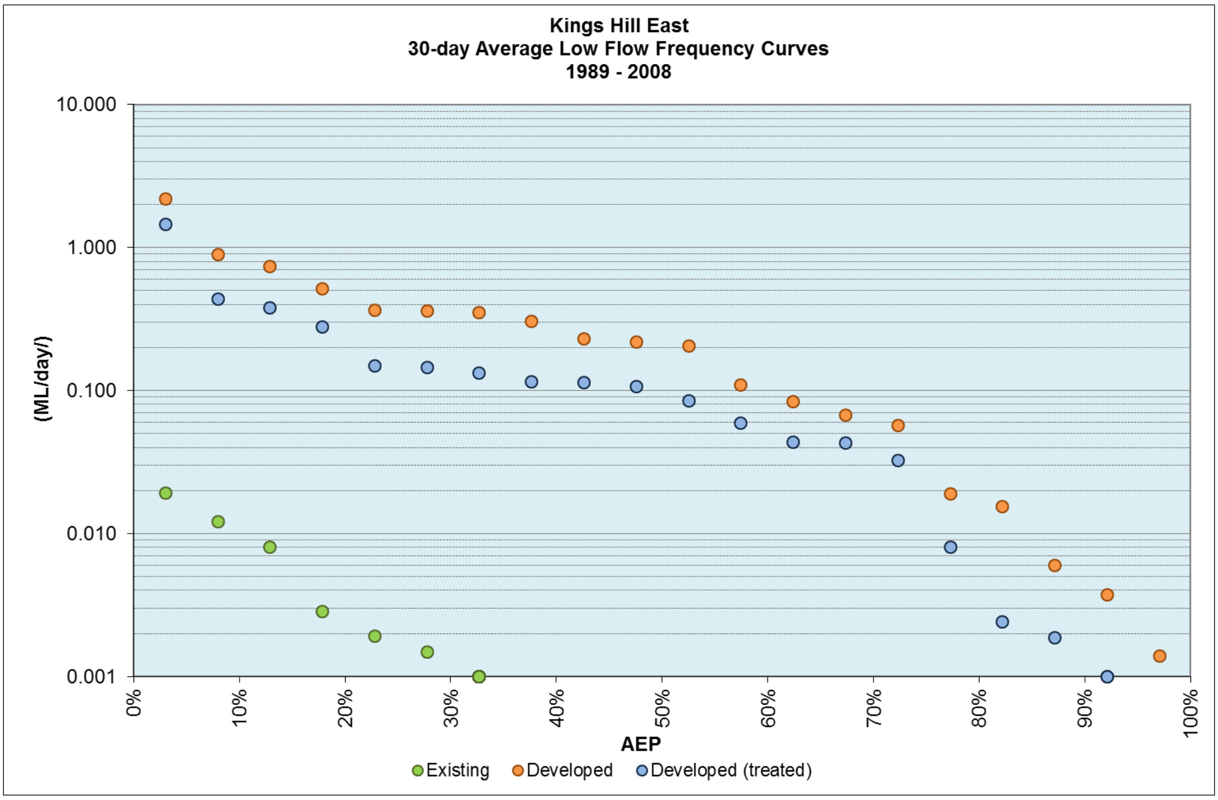

Figure 5-5 *Kings Hill East – 30-day average low flow frequency curves*

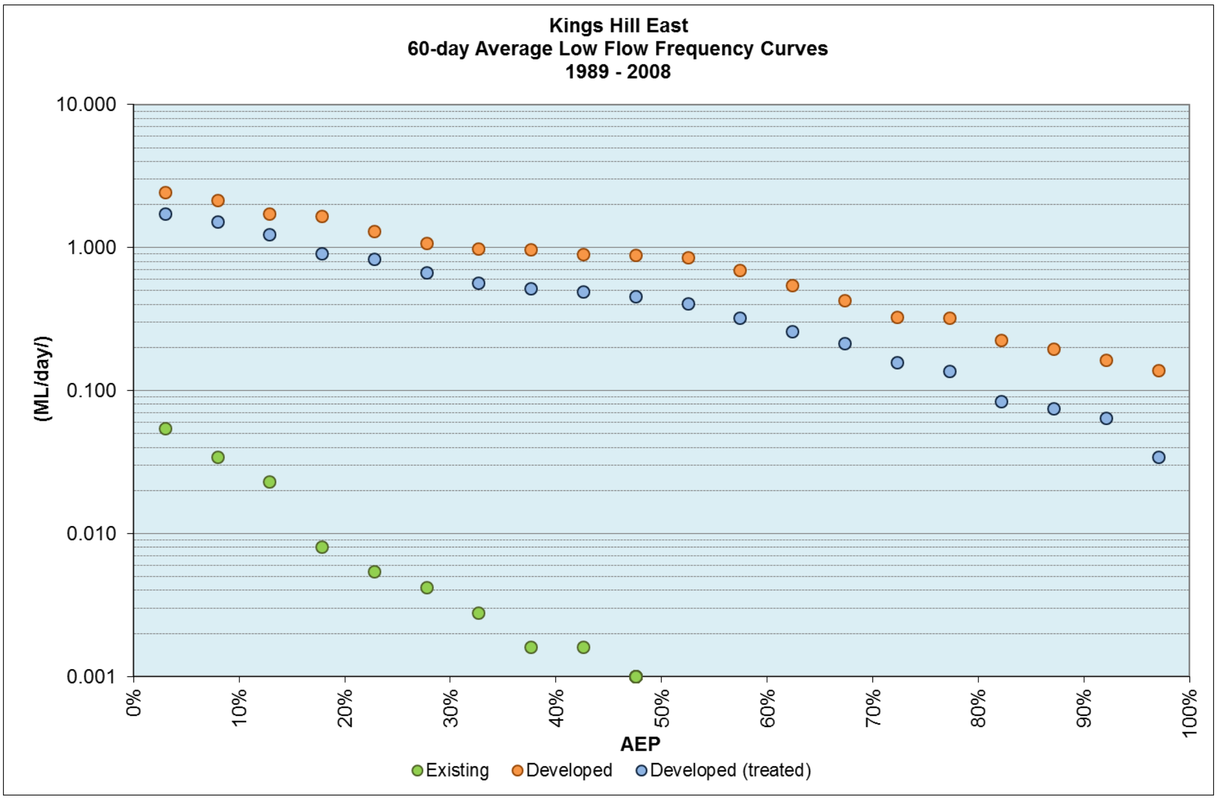

Figure 5-6 *Kings Hill East – 60 day average low flow frequency curves*

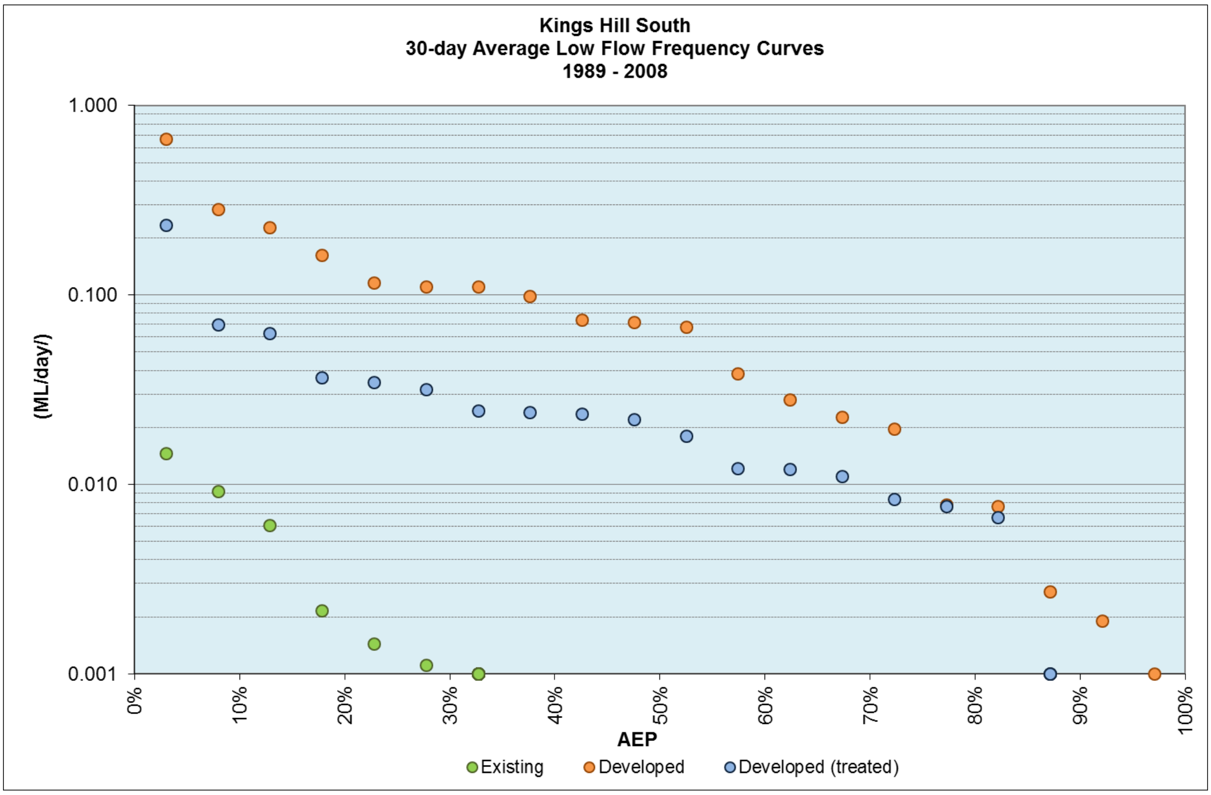

Figure 5-7 *Kings Hill South – 30-day average low flow frequency curves*

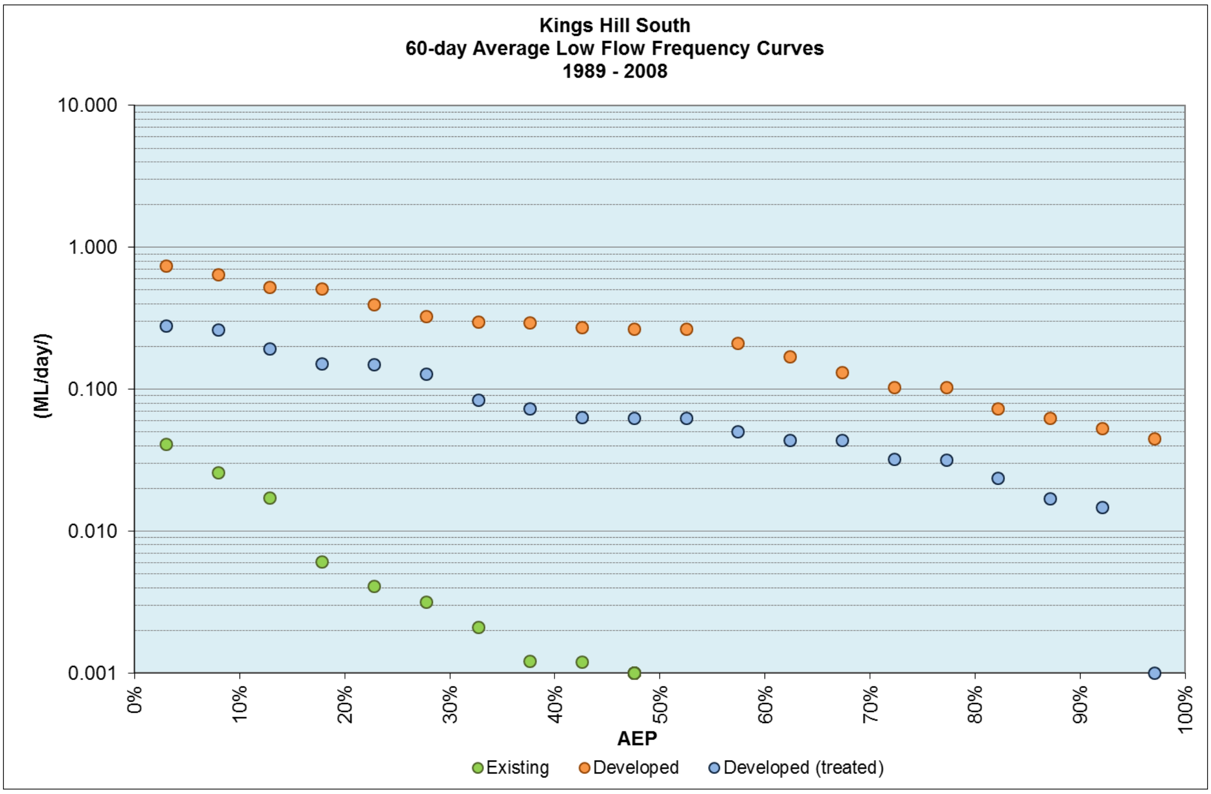

Figure 5-8 *Kings Hill South – 60-day average low flow frequency curves*

The low flow frequency curves indicate that the average daily flow during the 30 and 60-day low flow periods is expected to increase following development for the full range of dry to wet rainfall years. The stormwater management strategy proposed by NCE partially mitigates increased low flows through the provision of 5 kL rainwater tanks, biofiltration systems and urban lakes throughout the development.

The low flow frequency curves indicate that under existing conditions, there is a 50% chance in any year that the average daily flow volume during the critical drying period will be approximately zero. For developed conditions, it is estimated that for all but very dry years, runoff will discharge into Irrawang Swamp from the developed catchments during the critical drying period. Whilst low flow discharges are likely to occur, the magnitude of the increased low flows and associated impacts on wetland vegetation inundation are expected to be low. These impacts are discussed further below.

High flow duration frequency curves

Potential impacts on the wetland vegetation from Kings Hill runoff are expected to be largely related to changes in increased frequency of runoff from impervious surfaces within the development during natural low flow periods. Irrawang Swamp is currently already exposed to high discharges associated with spillway releases from Grahamstown Dam that differ significantly to natural conditions.

It is expected that the runoff volumes from Kings Hill South and Kings Hill West during high flow periods will not change significantly from existing conditions as these would generally align with periods where soils would be saturated or close to saturation for extended periods (refer to Section 5.1 for further discussion on this) and this is demonstrated in Figure 5-9 for Kings Hill South.

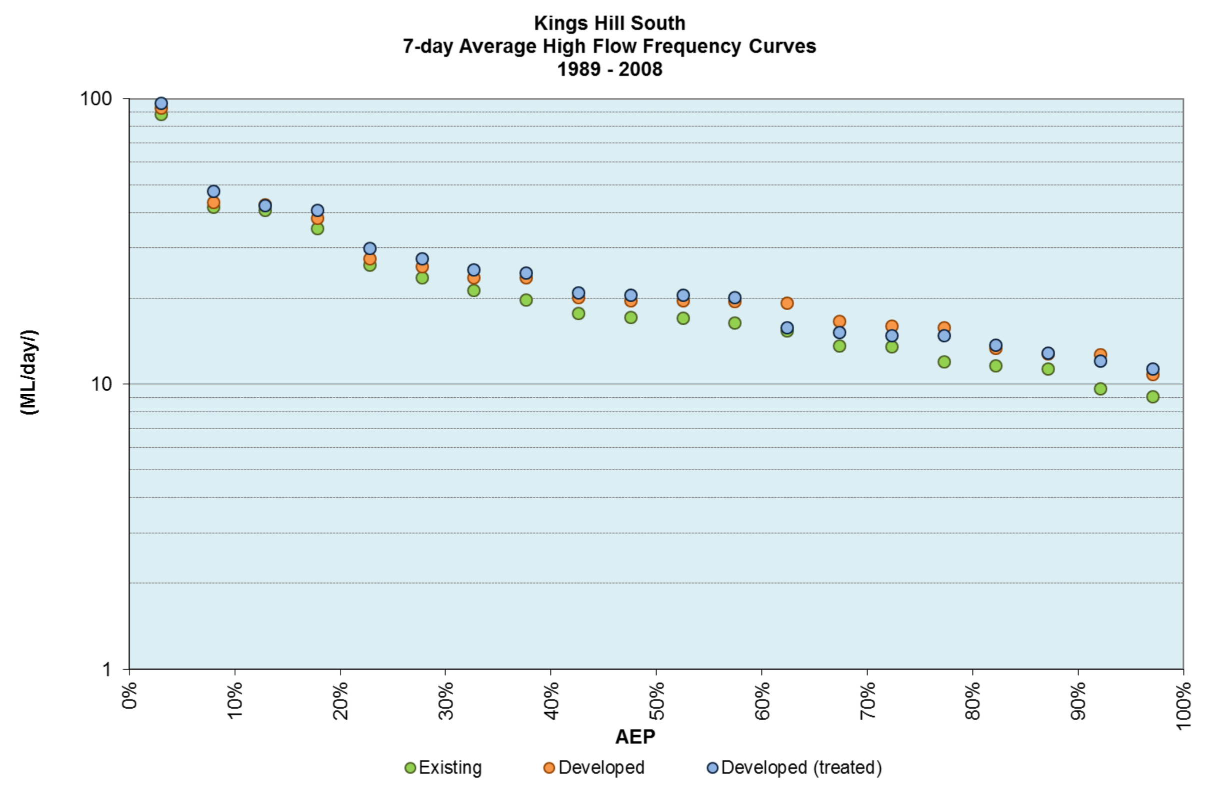

Figure 5-9 *Kings Hill South – 7-day average high flow frequency curves*

The main change from developed conditions would be that increased high flows from Kings Hill East will be directed to Irrawang Swamp along the diversion channel. Under existing conditions, high flows from Kings Hill East discharge directly into Grahamstown Dam. Although, during periods when dam storage levels in Grahamstown Dam are close to the spillway level, existing high flow discharges from Kings Hill East to Grahamstown Dam may indirectly discharge to Irrawang Swamp through the spillway.

Figure 5-10 summarises the estimated high flow discharges from Kings Hill East under existing and developed conditions. The existing high flows are for the portion of the Kings Hill East catchment that drains south of the proposed interchange along an existing ephemeral creek through the Riding for the Disabled site to a concrete channel that joins Irrawang Swamp at the same location as the original Grahamstown Dam spillway. The developed high flows for Kings Hill East include contributions from the catchment described above and the remaining part of the Kings Hill East catchment directed to the proposed diversion channel.

Figure 5-10 indicates that for a high rainfall year (10% AEP), the Kings Hill East development is estimated to increase average 7-day high flows by approximately 85 ML/day (600 ML over the 7 day period). For a typical rainfall year (50% AEP), the model results indicate that the Kings Hill East development and diversion drain would increase average 7-day high flows by approximately 40 ML/day (280 ML over the 7-day period) from Kings Hill East.

Figure 5-10 also indicates that the stormwater management measures proposed by NCE are unlikely to have any significant impact on reducing high flow discharges. This is expected as the magnitude of the high flows would require the provision of an excessively large volume of additional retention storage similar in size to the estimated increase to have any significant influence on reducing the high flow volumes.

The impact of this increase in high flow discharge is discussed and compared with current Grahamstown Dam discharges below.

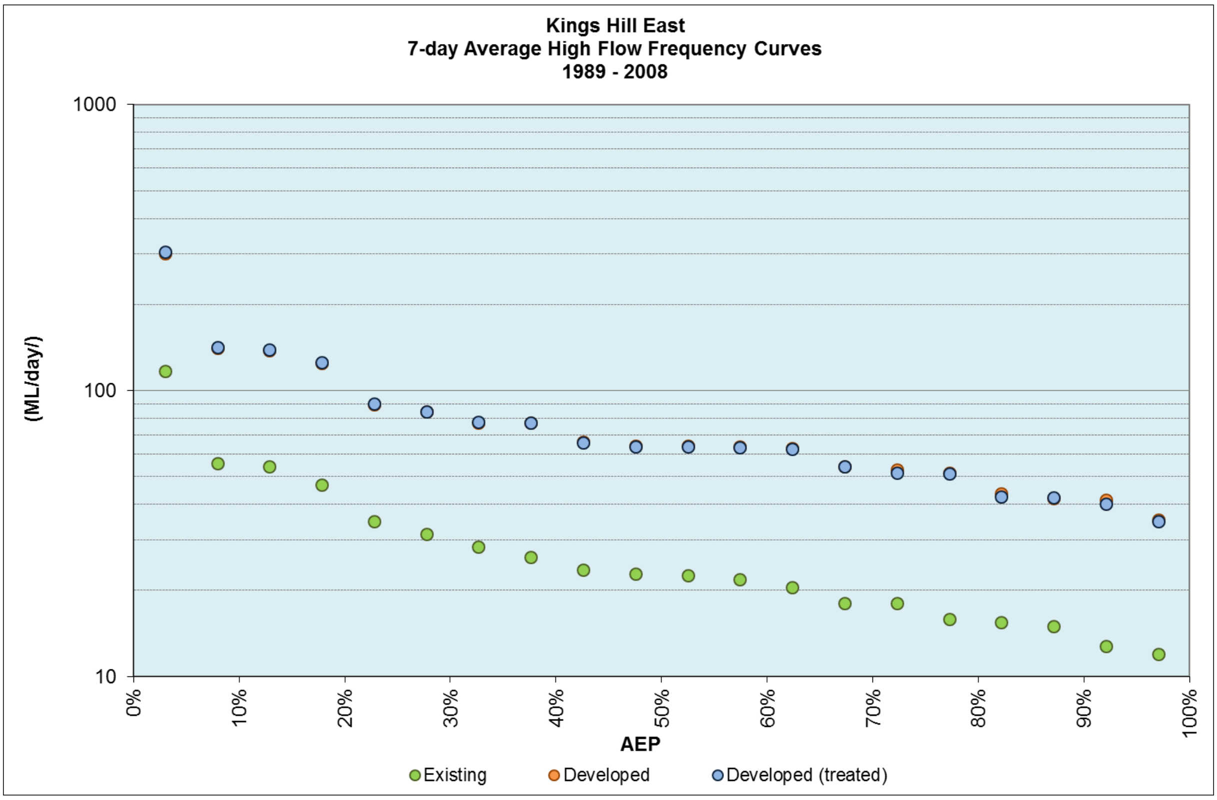

Figure 5-10 *Kings Hill East – 7-day average high flow frequency curves*

Grahamstown Dam spillway discharges

HWC provided Alluvium with estimates of Grahamstown Dam spillway discharges for the period 1974 to 2019. A summary of the recorded spillway discharges is provided in Table 5-4. The data indicates that between 1974 and 1989 no spillway discharges were observed from Grahamstown Dam to Irrawang Swamp. Between 1990 and 2005 (prior to the new spillway being constructed), spillway discharges were recorded in four separate years (1990, 1998, 1999 and 2001). Between 2006 and 2018 (after the new spillway construction), spillway discharges were recorded in five separate years (2008, 2011, 2013, 2015 and 2016).

Table 5-4 *Grahamstown Dam spillway flows (source: Hunter Water Corporation, 2019)*

Years with releases	**Total annual discharge (ML/yr)**	**No. discharge days**	**Discharge months (No. Days)**
1990	18850	13	Aug (13)
1998	9750	15	Aug (7), Nov (8)
1999	24050	37	Apr (6), Jun (12), Jul (17), Aug (2)
2001	10150	7	May (7)
Mean 1990 to 2005	**3925**	**5**	
Mean in overflow years	**15700**	**18**	
2008	9355	25	Apr (8), Jun (12), Sep (5)
2011	4159	8	Jul (6), Oct (2)
2013	484	3	Mar (3)
2015	5539	8	Apr (4), May (4)
2016	15096	17	Jan (17)
Mean 2006 to 2018	**2664**	**5**	
Mean in overflow years	**6927**	**12**	

The average annual spillway flow since the Stage 2 augmentation was completed in 2005 is approximately 2,700 ML/yr, and spills have occurred in 40% of the years and on average for 5 days a year. The increase in average annual 7 day high flow discharge from Kings Hill East to Irrawang Swamp during a typical year (50% AEP) following development is estimated to be 280 ML (refer Figure 5-10).

An increase in flow volume of 280 ML over 7 days represents an average depth of approximately 65mm across the total area of the swamp (estimated to be 450 ha from the SEPP 2018 mapping). This increased flow as a proportion of the average annual spillway flow from Grahamstown Dam to Irrawang Swamp is approximately 10%. This increase in flow is considered a conservative estimate, as it assumes that high flows from Kings Hill East that current drain to Grahamstown Dam do not contribute to existing spillway flows. During high rainfall years (10% AEP), runoff volumes diverted from Kings Hill East would be higher, although it is considered likely that spillway flows during these wetter years would similarly be elevated resulting in the overall proportional increase being similar.

Most spills from Grahamstown Dam to Irrawang Swamp have occurred during the wetter April to August period. Increased high flow discharges from Kings Hill East are likely to coincide with this period when inflows from direct rainfall on the swamp and other local catchment inflows are also elevated resulting in wide-spread inundation across Irrawang Swamp.

The critical drying period for Irrawang Swamp is from September to March (refer to Figure 5-2). Approximately 25% of days where spillway discharges have occurred fall within this critical drying period. The records indicate that spillway discharges to Irrawang Swamp have occurred only once during summer over the entire 1974 to 2019 period. Based on the available data, it appears that spillway discharges are unlikely to have a significant impact on drying hydrology in Irrawang Swamp.

5.6 Kings Hill West flow regimes (Wetland 803)

A different approach to Kings Hill South and Kings Hill East flow regime analysis was adopted for the Kings Hill West development. The entire Kings Hill West catchment drains to Wetland 803 located adjacent to New Line Road. As discussed in Section 3.2, the hydrology of Wetland 803 is currently influenced by catchment inflows from the Kings Hill West catchment and tidal inflows from the Williams River. Whilst catchment inflows are estimated to change following development, there is no proposal to modify the existing outlet/spill level from the wetland to the Williams River that would change the periods where tidal interactions between the river and wetland could occur. The following analysis is based upon changes to catchment inflows only. Discussion is provided in Section 6.4 on how mixing with tidal flows may change with modified catchment inflows.

MUSIC models of the entire Wetland 803 catchment including future developed areas and undeveloped areas were prepared by Northrop Consulting Engineers (NCE) and provided to Alluvium. The MUSIC models included existing, developed and developed (with treatment) scenarios. In addition to including the sub-catchment areas draining to Wetland 803, the models included allowance for direct rainfall within the extents of the wetland. The surface area of this wetland represents approximately 15% of the total catchment area.

NCE also provided estimates of stage / storage within Wetland 803 based on available LiDAR data. The LiDAR data were reviewed closely and assessed to be providing inaccurate wetland bathymetry levels below approximately 0.65m AHD. A level of 0.65m AHD corresponds with the spill level for the wetland adjacent to New Line Road. The LiDAR survey was completed during winter and it is suspected that elevated water levels in the wetland at that stage prevented the gathering of accurate bathymetry levels across inundated areas. Additional survey cross sections were gathered by a surveyor on site to supplement the LiDAR data. The additional survey data were compared with inundation extents shown in historical aerial imagery (refer Figure 5-11) to assist with estimating storage volumes at various stages below the wetland spill level.

Survey detail were also gathered by de Witt Consulting from the wetland overflow location and New Line Road reserve along an existing drainage channel. Culvert dimensions and inverts were confirmed in addition to cross sections of bed and bank levels along the drainage channel leading to the culvert. Surveyed cross sections were also taken of a narrow shallow trapezoidal channel within the wetland leading to the wetland outlet. The above survey data was utilised to develop a one-dimensional hydraulic model of the wetland outlet to assist with developing a stage / discharge relationship for the wetland.

The MUSIC flow estimates and derived stage / storage and stage / discharge relationships were applied to develop a temporal water balance model for Wetland 803. The model outputs were utilised as the basis for the flow regime analysis for this wetland.

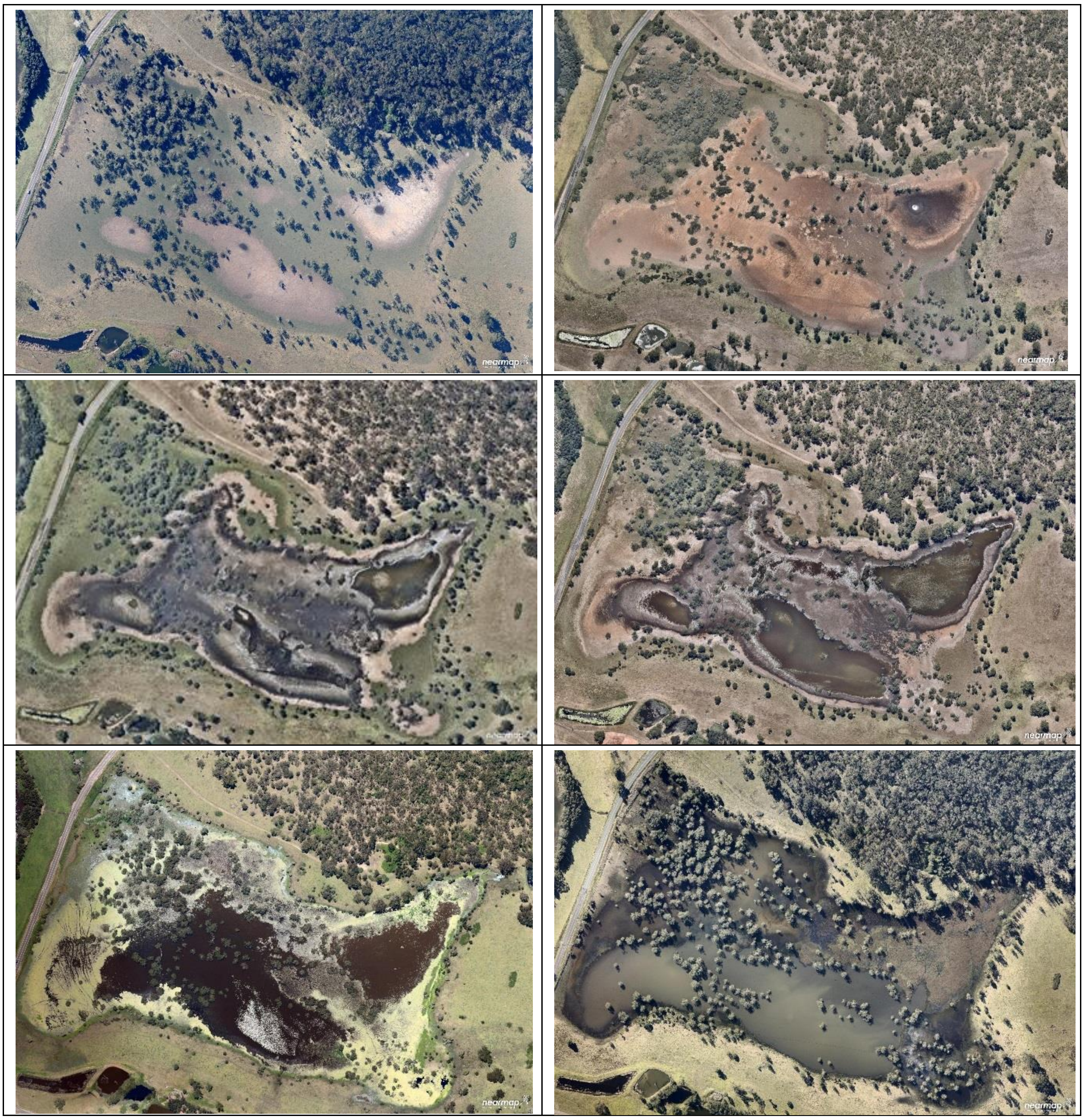

Figure 5-11 *Historical aerial images of Wetland 803 showing varying wetting extents*

The results of the temporal water balance modelling over the 1989 to 2008 modelling period are shown in Figure 5-12 and Figure 5-13. Figure 5-12 provides estimates of the proportion of time in the modelling period (during the September to March drying period) that particular water levels (m AHD) would be exceeded.

The results indicate that for around 50% of the time, water levels in the wetland would be elevated and similar for existing and developed conditions. This period would coincide with the early spring period where initial water levels would be high in the wetland from winter rainfall and evapotranspiration is lower.

In the 50% to 95% range shown in Figure 5-12, there is an apparent divergence in water levels between the modelled existing and developed conditions, with modelled water levels being up to 50mm higher following development. The reason for this divergence is associated with more regular pulses of stormwater during small rainfall events that would flow into the wetland from roof and road surfaces during warmer periods from future development. Under existing conditions during warmer months, a high proportion of the smaller rainfall events would be adsorbed by the soil and evaporate with minimal runoff occurring. The developed condition runoff has the effect of providing regular top ups to the water levels in the wetland.

Above the 95% range shown in Figure 5-12, existing and developed condition water levels would be similar as this range would represent a period closer to the end of summer where runoff from development areas would be low and evapotranspiration rates high.

The developed (with treatment) results shown in Figure 5-12 indicate that the proposed WSUD strategy would reduce impacts on water levels. This reduction is achieved through the application of rainwater tanks that will be effective at harvesting a high proportion of roof runoff during the critical drying period. In addition, the proposed bioretention measures would also absorb a high proportion of additional runoff during the drier periods. The treatment strategy also incorporates a proposal to divert over 5% of the Kings Hill West catchment (modelled developed sub-catchment C02 refer NCE, 2019) around the wetland.

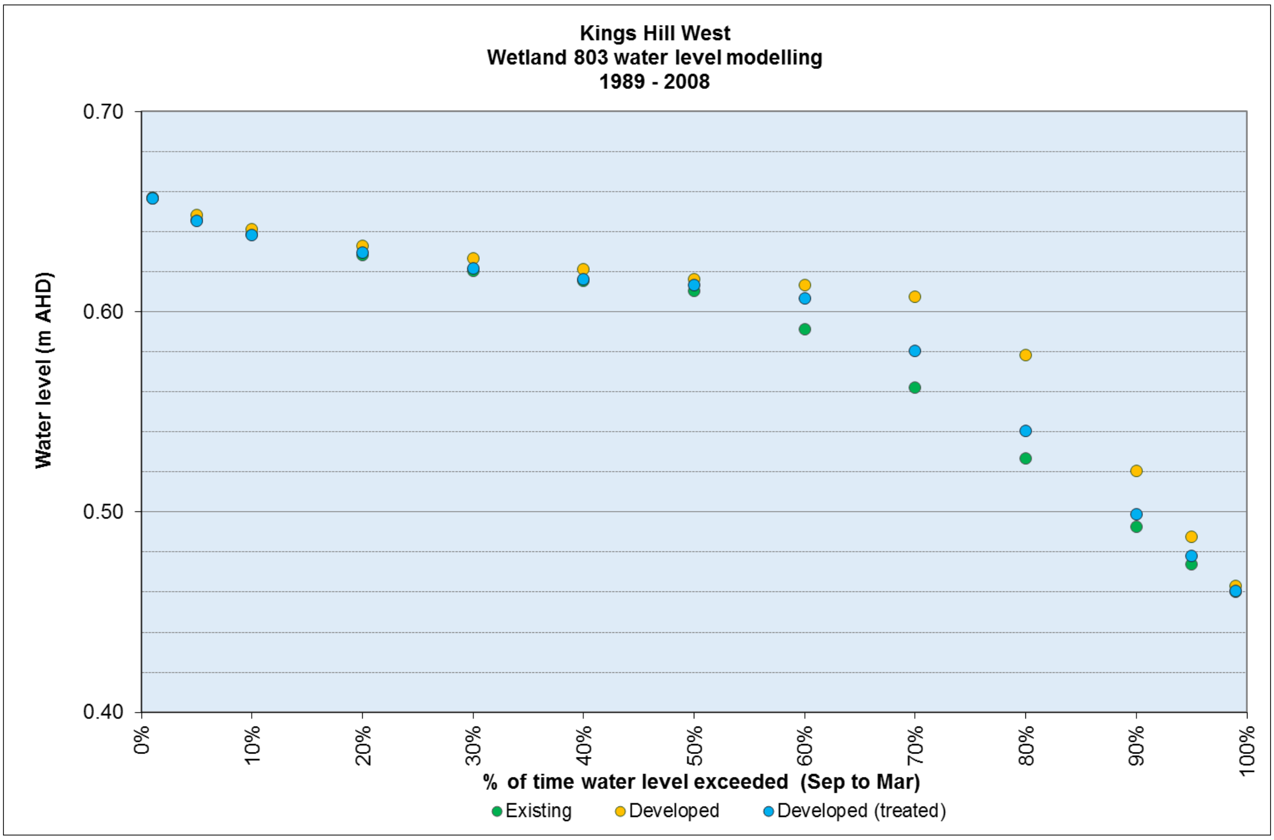

Figure 5-12 *Kings Hill West – Wetland 803 water level modelling results*

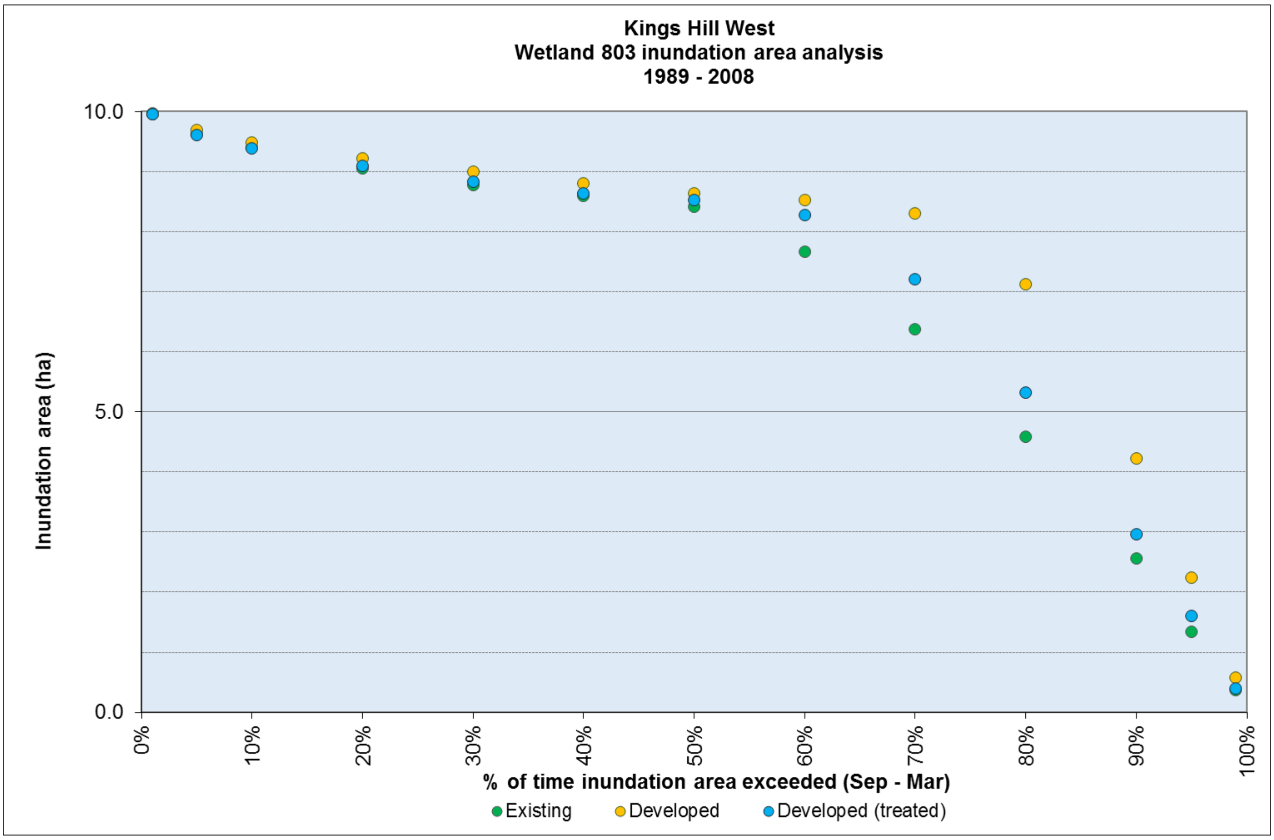

Figure 5-13 *Kings Hill West – Wetland 803 inundation modelling results*

6 Development impacts on wetland hydrology and ecology

6.1 Overview

Section 5 outlines the estimated impacts of future development in Kings Hill on catchment hydrology. This section of the report focuses on the impacts of the development modified catchment hydrology on the wetland hydrology and ecology.

The vegetation communities within Irrawang Swamp and Wetland 803 occupy the sites in a dynamic manner evolving in their extent in response to management practices. The hydrological regimes shown in Table 4-3 detail the inundation depths and drying periods required for the persistence of the different vegetation communities.

The critical hydrological items for the vegetation in the swamp is the presence of waterlogged soils, seasonal inundation and seasonal drying periods for all the communities except for the Perennial Swamp Meadow.

The key concern is the potential change in inundation extents across Irrawang Swamp associated with increased low flows following development.

Wet season flows

It is estimated that the runoff volumes from Kings Hill South and Kings Hill West during high flow periods will not change significantly from existing conditions as these generally occur during periods where soils would be saturated or close to saturation for extended periods. In these conditions pervious areas will generate similar runoff volumes as equivalent impervious areas.

Diversion of the Kings Hill East catchment to Irrawang Swamp is estimated to increase typical high flows (50% AEP) by 280 ML over 7 days. This represents an average water depth of approximately 65mm across the entire area of the swamp (estimated to be 450 ha from the SEPP 2018 mapping). This increased flow as a proportion of the average annual spillway flow from Grahamstown Dam to Irrawang Swamp is approximately 10%.

Increased high flow discharges from Kings Hill East are likely to coincide with periods where direct rainfall on the swamp, other local catchment inflows and dam spillway flows are also elevated resulting in wide-spread inundation across Irrawang Swamp. The increase in high flows will predominately coincide with the wet season flows when the wetland vegetation is seasonally inundated or growing on saturated soils.

The estimated increase in water depth of 65mm over the site for the 7-day high flow duration event is considered insignificant and is only temporary (<5 days). Infrequent wet season inundation events are not a serious concern ecologically as their impact is temporary and doesn't change the long-term seasonal wetting and drying patterns required by the vegetation communities.

Increased high flows are not considered a significant threat to the vegetation within the wetland.

6.2 Kings Hill South

Available LiDAR data and observed inundation extents interpreted from historical aerial imagery were reviewed to predict where additional inflows would drain to and be stored within the wetland during the critical drying period. Considering the available data, three zones were mapped indicating areas of the wetland that would progressively be wetted by inflows from Kings Hill South during dry periods. These three zones are mapped on Figure 6-1 with the three key locations where stormwater runoff from the future development in Kings Hill South would discharge into the wetland along existing gullies**Error! Reference source not found.**. Zone 1 covers a total area of approximately 5 ha, Zone 2 approximately 15 ha and Zone 3 approximately 35 ha.

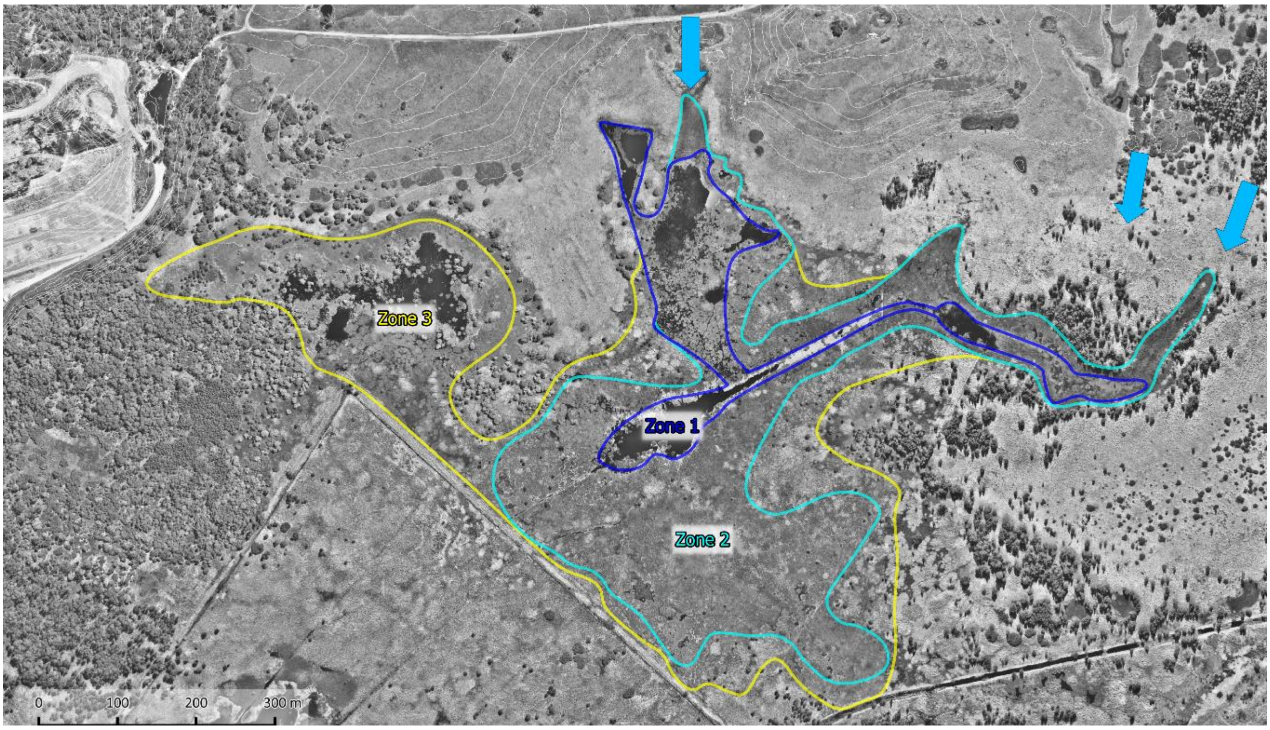

Figure 6-1 *Estimated critical drying period wetting zones in Irrawang Swamp receiving Kings Hill South inflows*

Dry season hydrology impacts

Low flows from Kings Hill South drain along the existing gullies that discharge into the northern extents of Irrawang Swamp. Concentrated flow along these natural gullies naturally spreads out into the wetland where the lower hill slopes meet the wetland floodplain areas. Natural drainage of this area was restricted after 1954 when a channel and elevated bund was constructed in a north-west to south-east alignment across the wetland to enable controlled irrigation of pasture areas south-west of the bund. The channel is connected to Pennington drain enabling irrigation from and drainage to Pennington Drain. It appears that an opening was cut through the bund to enable water to flow from the north-east for distribution along channels for irrigation of the pasture areas. Recent observation of this cut by Alluvium indicates that following cessation of irrigated pasture activities, the cut has partially infilled with sediment and dense growth of *Typha orientalis* (Cumbungi) has established. This has reduced the drainage connectivity between wetland areas on either side of the bund.

Review of historical aerial imagery covering the northern extents of Irrawang Swamp highlighted areas that would be more regularly inundated by stormwater runoff from future development in Kings Hill South. The observed inundation patterns indicate that surface runoff would initially fill areas aligned with the central part of the wetland mapped as Zone 1 on Figure 6-1. It is estimated that the majority of runoff during the critical drying period would be retained within Zone 1.

As inflows from the King Hill South sub-catchments increase, inundation is estimated to increase laterally from Zone 1 into Zone 2 (refer Figure 6-1). Review of historical aerial imagery and LiDAR data indicates that a spur of higher ground extending out into the wetland separates Zone 2 from the Melaleuca Swamp. The Melaleuca Swamp receives direct inflows from a local catchment adjacent to the existing Suez Waste Recycling and Recovery facility. This local catchment does not include any proposed future development in the Kings Hill South.

As inflows from the King Hill South sub-catchments increase further, inundation would increase laterally from Zone 2 into Zone 3 (refer Figure 6-1). At this stage, it is estimated that inflows to the wetland from Kings Hill South would increase water levels in the wetland sufficiently to interact with the Melaleuca Swamp and Pennington Drain.

Table 6-1 *Irrawang Swamp conditions (October 2019)*

 Spur separating the Melaleuca Swamp from other wetland areas	 Seasonal Swamp Meadow infested by Xanthium occidentale (Noogoora Burr).
 Swamp Oak Forest showing minimal inundation.	
 Central channel/bund with Perennial Swamp Meadow on the SW side.	 Central drain from the channel/bund leading to the frequently inundated zone in the northern section of the swamp.
 Perennial Swamp Meadow with Bolboschoenus fluvilatus and Typha orientalis	 Seasonal Swamp Meadow transitioning to Transient Swamp Meadow

Frequently inundated zone (Zone 1) that receives flow from Kings Hill South.

View into Irrawang Swamp from Kings Hill South boundary looking towards Zone 1.

The Kings Hill South 30 and 60 day average low flow frequency curves presented in Figure 5-7 and Figure 5-8 provide estimates of increased flow volumes draining to Irrawang Swamp following development. The estimated increases in flow volumes formed the basis for evaluating changes to inundation extents in areas of the wetland receiving these inflows.

Table 6-2 summarises the estimated increase in average water depths across the potential wetting zones. For example, in a typical 50% AEP year the 60 day inflow volume to Irrawang Swamp from the Kings Hill South development area is estimated to increase by 3.6 ML. If this additional volume is retained within Zone 1, this will result in the average water depth over this area increasing by 1.2 mm/day during the 60 day period.

Table 6-2 *Estimated average increase in wetland water depth during low flow periods from Kings Hill South*

Frequency	**Period (days)**	**Increase in flow volume (ML)**	**Estimated increase in average water depths (mm/day)**		
			Zone 1 (5 ha)	**Zone 2 (20 ha)**	**Zone 3 (35 ha)**
10% AEP	30	1.8	1.2	0.3	0.2
(wet year)	60	12.6	4.2	1.1	0.6
50% AEP	30	0.6	0.4	0.1	0.1
(typical year)	60	3.6	1.2	0.3	0.2
90% AEP	30	0.0	0.0	0.0	0.0
(dry year)	60	1.2	0.4	0.1	0.1

The estimated increases in water depth conservatively assumes that none of the additional flow volume infiltrates, evaporates, transpires or drains from each zone. The results indicate that for the flow frequency and periods evaluated, the average increase in water depth over the zones considered is below the typical average potential evapotranspiration rate of 5mm/day over the critical drying period. In most of the scenarios considered, the estimated increase in average water depth is less than 1mm/day and this water is likely to readily evaporate during these hot and dry periods.

The increase in average water depths outlined in Table 6-2 are approximate only as they are based on a number of simplifying assumptions. The estimated water depths assume that low flows spread out evenly across each of the mapped zones. This is unlikely to occur as subtle variations in terrain across the northern extents of the swamp will result in inundation depths varying. The water depths indicated are based on daily average inflows, and temporally are likely to vary across the relevant period with inflows during some days being higher, and others lower.

It is envisaged that any noticeable change in wetting of wetland areas from development in King Hill South during dry periods will be observed in the areas immediately downslope of the three stormwater outlets into the wetland. It is these locations that will be exposed to more regular stormwater discharges during the critical drying period. It is expected that the increased stormwater volumes during the critical drying period would primarily be intercepted in the existing constructed dams and shallow ponded areas within Zone 1. It is estimated that these dams and shallow ponded areas may experience a localised small increase in water depth, inundation extents and inundation period following development. Whilst additional Zone 2 and Zone 3 areas have been mapped on , it is considered unlikely any significant increased inundation of these zones would occur during the critical drying period following development.

Dry season vegetation impacts
It is expected that low flows from Kings Hill South would interact mostly with the existing swamp meadow vegetation communities located north of the Pennington Drain. It is estimated that increased low flows from Kings Hill South would tend to spread out across northern parts of the swamp and gravitate towards the existing large area of Perennial Swamp Meadow in this area.

A vegetation response to such inflows is already observed with an area of Perennial Swamp Meadow (*Typha* orientalis) below the existing dam on an existing gully from Kings Hill South. The lower areas and depressions in Zone 1 will continue to refill regularly supporting the growth of permanent water tolerant species such as *Typha orientalis in water 300-500mm depth*. Areas of open water in deep holes (>1.5m deep) will continue to be present.

The impact of the flows from Kings Hill South will be to increase the inundation depth in the northern sections of the swamp (Seasonal Swamp Meadow) by less than 10mm during winter and spring. This will not be an equal depth change with the micro-topography of the site that collecting flows into deeper areas resulting in a mosaic of vegetation response.

The increase in inundation depth is within the ecological depth tolerance of the vegetation. Seasonal drying in the Seasonal and Transient Swamp Meadow zones will still occur in most years, although the duration of drying may reduce. The impact of this may be localised changes in extent of the Seasonal Swamp Meadow with potential expansion into the Transient Swamp Meadow. Perennial Swamp Meadow is unlikely to expand into the Seasonal Swamp Meadow as seasonal drying will still occur reducing the spread of *Typha orientalis.*

The area of Paperbark Woodland in the north-west of the swamp may see increased inundation duration compared to the recent hydrology but not a significant increase in depth. If there was a change in permanent inundation of the *Melaleuca* species of >200mm there would be a negative impact. This impact would predominately be on the ability of the *Melaleuca* species to regenerate from seed. Inundation of >200mm over new seedlings for >3months will kill the new germinates reducing the capability of the woodland to regenerate. However, the analysis shows that the inundation depth increase is less than 50mm and drying periods are expected at least 1 in 3 years. This indicates that this vegetation will not be significantly impacted by increased flows from Kings Hill South.

Changes in water retention within Irrawang Swamp are expected to occur with reduced maintenance of the old agricultural drains by Hunter Water to align with actions in the management plan for the swamp. The reduction in the drainage efficiency of the old agricultural drains will see water retained in the areas south of the east-west channel/bund. The vegetation in these areas will adjust over time with consolidation of the perennial marsh in the central agricultural area and potential increase in Swamp Oak in the southern areas. The areas south of the east-west channel/bund are disconnected from the areas impacted by flows from Kings Hill South and the primary driver of their hydrology is the performance of the internal drainage south of the east-west channel/bund.

6.3 Kings Hill East

Dry season hydrology impacts
It is expected that additional low flow discharges would largely be conveyed within the Pennington Drain and if overflows from this drain occur during the critical drying period (September to March) these low flows would

largely be contained in areas on both sides of drain where vegetation currently tolerant of extended inundation during low flow periods is located. As an example, considering the low flow curves in Figure 5-6, for a typical 50% AEP low flow, the increase in average daily low flow discharged to Irrawang Swamp is estimated to be less than 0.5 ML/day (i.e. average flow of 5 litres/s). It is envisaged that this additional flow would readily be conveyed along Pennington Drain without spilling into the adjacent wetland areas prior to discharge through the open flood gates.

Dry season vegetation impacts
The dry season flows from Kings Hill East will mostly be contained in the Pennington drain or spill to the Perennial Swamp Meadow areas. Both outcomes will not result in a negative ecological change to the vegetation.

6.4 Kings Hill West

Dry season hydrology impacts
The water balance modelling results for Wetland 803 outlined in Section 5.6 indicate that the WSUD strategy and partial catchment diversion proposed by NCE would result in water levels in the wetland increasing by less than 50mm across the critical drying period. The modelling results also indicate that wetting extents across the wetland would be similar during this period but may increase over existing conditions by up to 15% during short periods (days) during the drying period in response to small rainfall events in the Kings Hill West catchment.

The results in Figure 5-12 and Figure 5-13 show the estimated relative changes to water levels and inundation in Wetland 803 considering inflows, evapotranspiration and outlet flows associated with catchment runoff. The water levels in the wetland will also be influenced by tidal inflows that (excluding future sea level rise) are expected to be similar in magnitude to existing conditions. The main impact is estimated to be a small reduction in salinity in the wetland during drying periods due to the slight increase in catchment inflows. However, with predicted sea level rise the increased freshwater runoff from the catchment during drying periods may offset the increased saline inflows during the same period.

Dry season vegetation impacts
The vegetation within the wetland is currently adapted to the existing hydrological regime. The treated development flows are quite similar to the existing conditions with a slight (<50mm) increase in depth during the driest times and possible lowering of salinity in high runoff periods. The extent of the wetland surface area inundation will potentially increase for a period over the summer which may support the perimeter vegetation, enabling the more establishment of rushes and sedges.

Submerged plants within the wetland will be able to tolerate an increase in depth through summer and are tolerant of periodic drying if that occurs. Minor changes in the salinity profile can be tolerated due to the presence of species with a range of salinity tolerance.

Maintenance of periodic drawdown will advantage the site as this can stimulate germination of the *Casuarina* and emergent macrophytes in the damp mud. Increased salinity in the deeper sections of the wetland as the water recedes will control the incursion of *Typha* sp into these areas.

Overall the changes indicated for the treated development flows will support the existing vegetation with potential to increase the density and extent of marginal emergent rushes and sedges.

Figure 6-2 *Typical Casuarina glauca 'pedestal' observed in Wetland 803*

7 Summary and conclusions

Irrawang Swamp and Wetland 803 contain a number of vegetation species that are susceptible to impacts from altered hydrological regimes. McManus et al (2007) outlines drying and flooding hydrology management targets for a range of wetland categories represented in Irrawang Swamp include Shallow Marsh, Deep Marsh and Forest Swamp - Ephemeral. These key vegetation communities will be most susceptible to changes in the drying hydrology over the critical September to March period.

Flow regime analysis was completed focusing on drying hydrology in accordance with McManus et al (2007). Inflows to Irrawang Swamp were analysed to derive dry spells curves (low flow spells) and low flow duration frequency curves for 30 and 60-day reference durations. Additional analysis of 7-day duration high flows was also completed to evaluate the impact of diverting runoff from Kings Hill East to Irrawang Swamp. The completed analysis covers the key wetland vegetation communities currently observed in the swamp.

The dominant risks to the vegetation in Irrawang Swamp and Wetland 803 from hydrological changes include:

- increases in periods of increased inundation depth; and
- reductions in seasonal drying patterns

If these are realised, retention of diversity in the Seasonal Swamp Meadow vegetation in Irrawang Swamp would be compromised and the ability for the wood plants to regenerate would be reduced. The hydrological analysis indicates that these risks are unlikely to occur for a range of reasons that are summarised below.

Whilst the total runoff volume from Kings Hill East will increase, a high proportion of the increased runoff volume is expected to flow efficiently in a relatively linear manner along the proposed diversion drain through the original spillway channel to the Pennington Drain channel and discharge through the existing flood gates to the Williams River. During critical drying periods, low flows from Kings Hill East would be significantly lower than the Pennington Drain capacity. It is expected that even with consideration of infilling of the channel over time, increased low flows from Kings Hill East will continue to drain in a relatively linear manner through Irrawang Swamp to the flood gates. It is expected that these diverted low flows would not impact on the northern Seasonal Swamp Meadow and Melaleuca Woodlands.

During typical annual high flow periods, it is estimated that high flows from Kings Hill East would spill outside the Pennington Drain banks into the adjacent vegetated areas. Considering a representative 7-day high flow period, the increased flow from Kings Hill East represents an estimated increase in water depth of 65 mm over Irrawang Swamp. Although high flows would increase, the increase is estimated to be a maximum of 10% of the average annual spillway flow from Grahamstown Dam. It is expected that many of the high flow periods would coincide with periods where inflows from direct rainfall on the swamp, other local catchment inflows and spillway flows would also be elevated resulting in wide-spread inundation across Irrawang Swamp. These high flow events typically dissipate rapidly and would not cause long term ecological damage.

Increased runoff volumes from King Hill South are estimated to be much lower than those from Kings Hill East. Increased runoff from Kings Hill South will disperse more readily through the wetland vegetation. Based on a review of available LiDAR data and historical imagery, it is estimated that the increase in water depth during the critical drying period will largely be contained within a mapped 5 ha area (Zone 1) aligned with currently regularly wetted areas in the northern part of the swamp. These additional flows will support the existing areas of open water and stands of *Typha orientalis.* Localised increases in water depth are likely to occur due to subtle variations in the terrain leading to support of localised pockets of perennial swamp meadow. Some localised impacts on vegetation in Zone 1 are expected along the gullies leading into Irrawang Swamp from Kings Hill South as these areas will be most exposed to more frequent pulses of stormwater.

Increased annual high flow volumes from King Hill South are estimated to be minor and would have an insignificant impact on increasing water levels in Irrawang Swamp during high flow periods.

There will continue to be seasonal dry periods in the Swamp Oak and Melaleuca Woodlands and Seasonal Swamp Meadow areas and estimated changes in inundation depths are within the ecological tolerance range of the vegetation communities.

The Swamp Oak Woodland in Coastal Wetland 803 in Kings Hill West reduced in extent and density by approximately 30% between 1954 and 2019. It is clear that the condition of this wetland has been impacted due to increased water retention resulting from construction of a bund across its outlet and cattle grazing. Controlling additional runoff to this wetland alone is unlikely to improve conditions for the remnant wetland vegetation. To improve conditions for this wetland, ensuring seasonal flow patterns and lowering of the existing outlet weir would be crucial for controlling seasonal water levels to reflect more natural levels. This would enable regeneration and healthy growth of the Casuarina glauca in the wetland that is more representative of natural conditions. Without removal of the cattle and lowering of the current water levels restoring the wetland to a more natural ecological condition is unlikely to be feasible.

It is envisaged that increased runoff volumes could potentially create opportunities that support the management objectives for Irrawang Swamp including:

- Increased flows support the ongoing management actions in Irrawang Swamp which aim to reduce the drainage efficiency of the wetland and increase retention of water in the landscape to assist the wetland to transition back to a more natural state.
- Increased runoff volumes could potentially be diverted from urban lakes and other stormwater storages in the Kings Hill development to irrigate additional habitat and biobanking areas on the fringes of Irrawang Swamp. Harvested stormwater during summer would assist with irrigating young plants and further reduce low flows closer to existing conditions.
- Increase availability of water within the wetland would provide opportunities for increased resilience during extended period of drought and as predicted climate change impacts occur.
- The flows replicate the existing conditions to seasonally saturate the soils in the Swamp Oak and Paperbark Woodland areas of Irrawang Swamp, providing the soil conditions for these vegetation communities ensuring their survival.

Incorporation of effective water sensitive urban design (WSUD) into all stages of the Kings Hill development will be very important for managing water quantity and quality from development areas. Water quantity management strategies should focus on reducing stormwater runoff during frequent smaller rainfall events. Measures including disconnecting impervious areas, oversized BASIX rainwater tanks, infiltrating biofiltration systems, stormwater retention and harvesting systems would all have a role to play at appropriate locations within the development. Ensuring that the majority of future runoff passes through appropriately sized stormwater retention/detention measures will be important for protecting ephemeral watercourses from erosion.

Management of stormwater runoff quality will also be important for preventing coarse sediment, dissolved nutrients, fine sediment and other diffuse source stormwater pollutants from impacting on the wetland ecology. This includes effective measures (including regular inspections) in the subdivision construction, building construction and post development phases.

Proposed monitoring protocols for hydrology and vegetation with Irrawang Swamp and Wetland 803 prior to and following development are outlined in RPS (2019).

8 References

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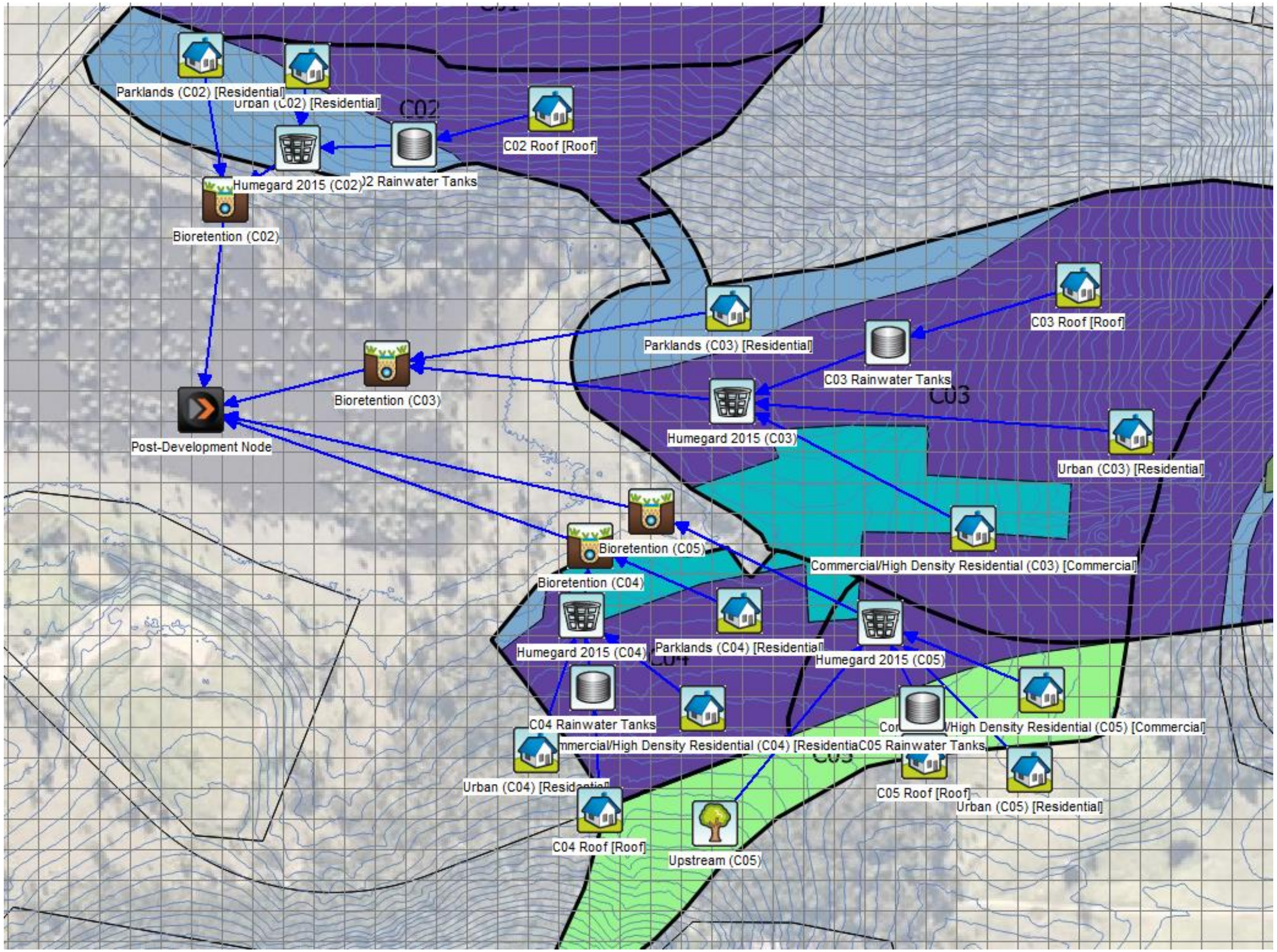
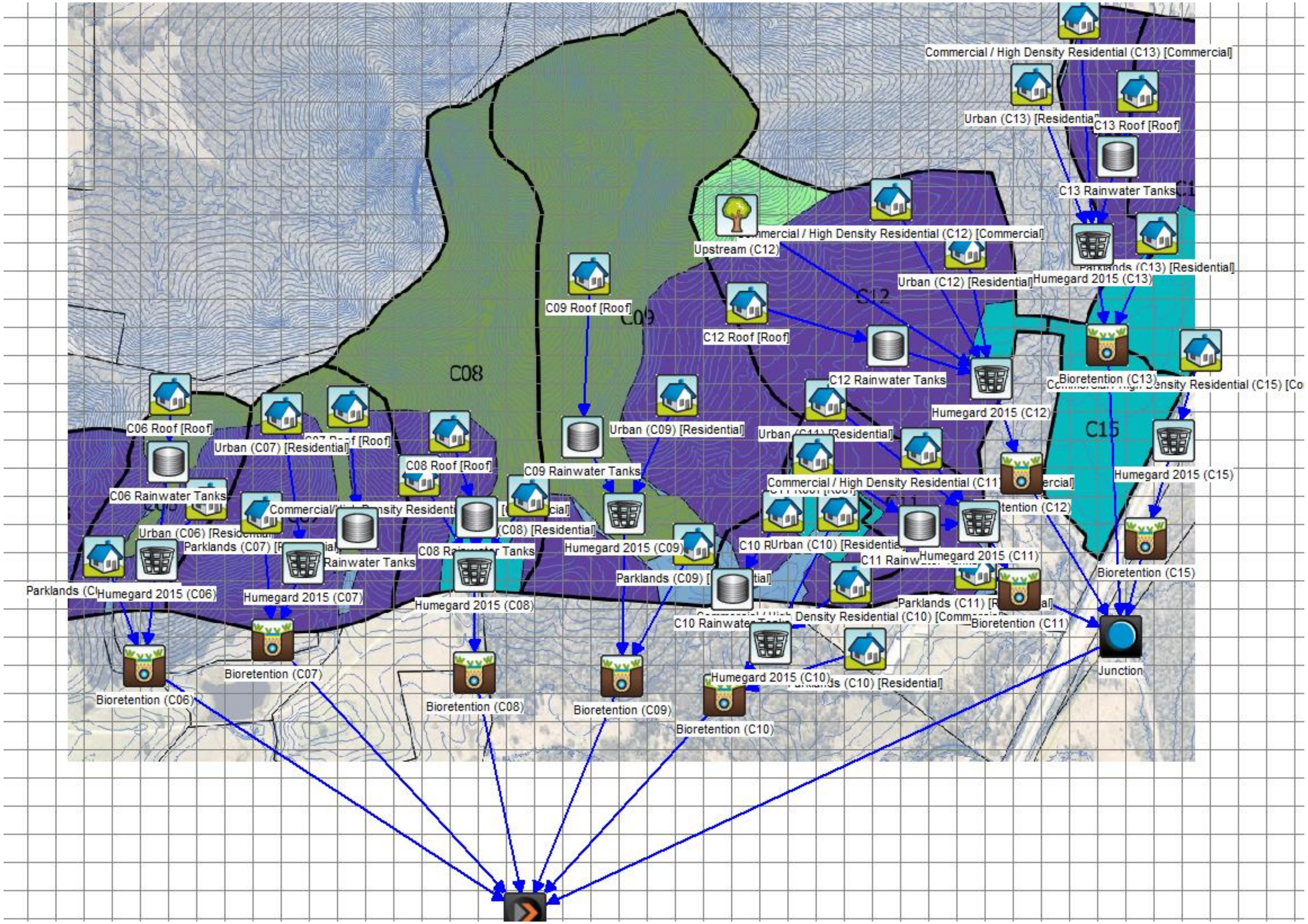
APPENDIX F -
MUSIC Schematic Diagrams

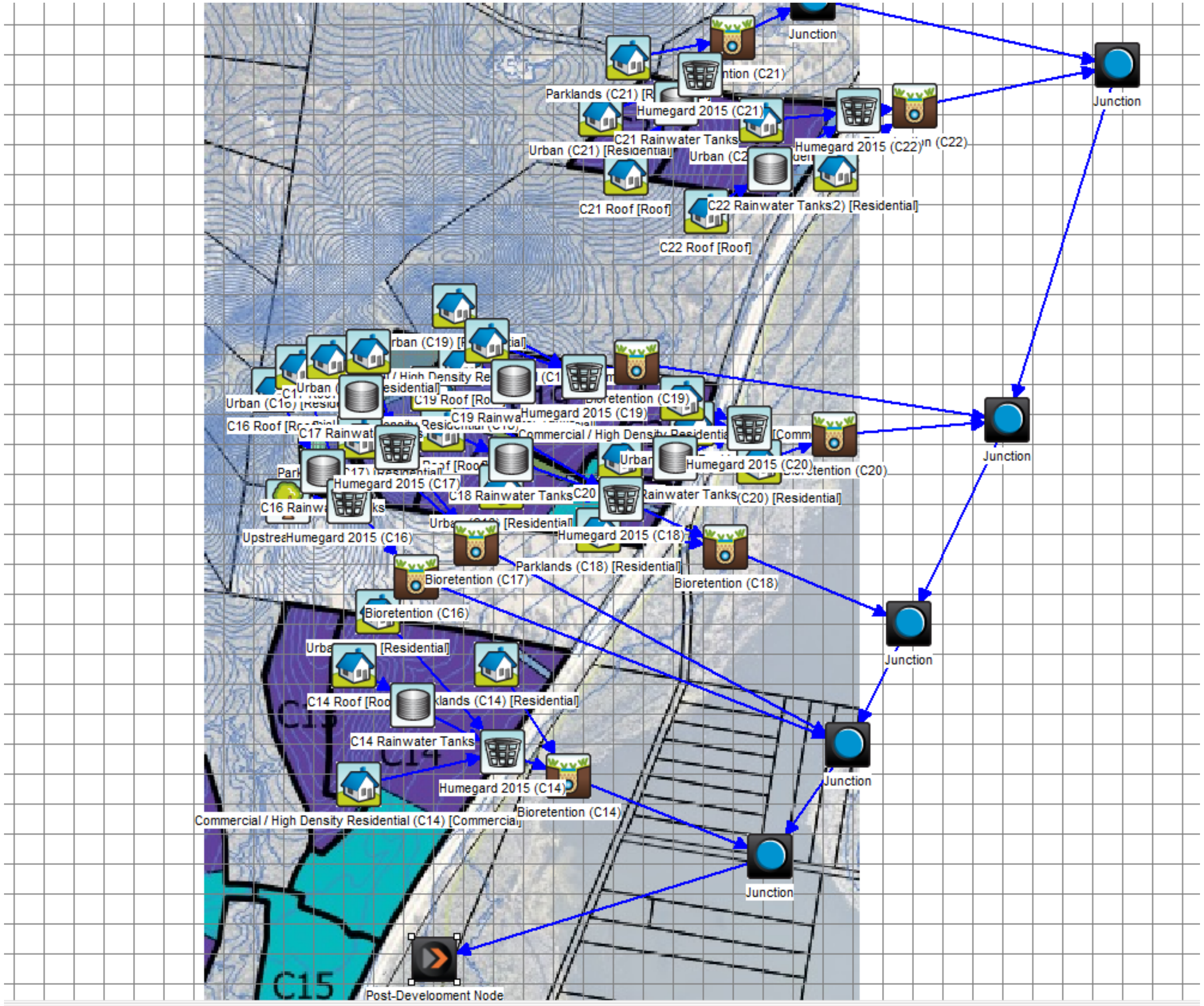
MUSIC Model 1 – Kings Hill West A



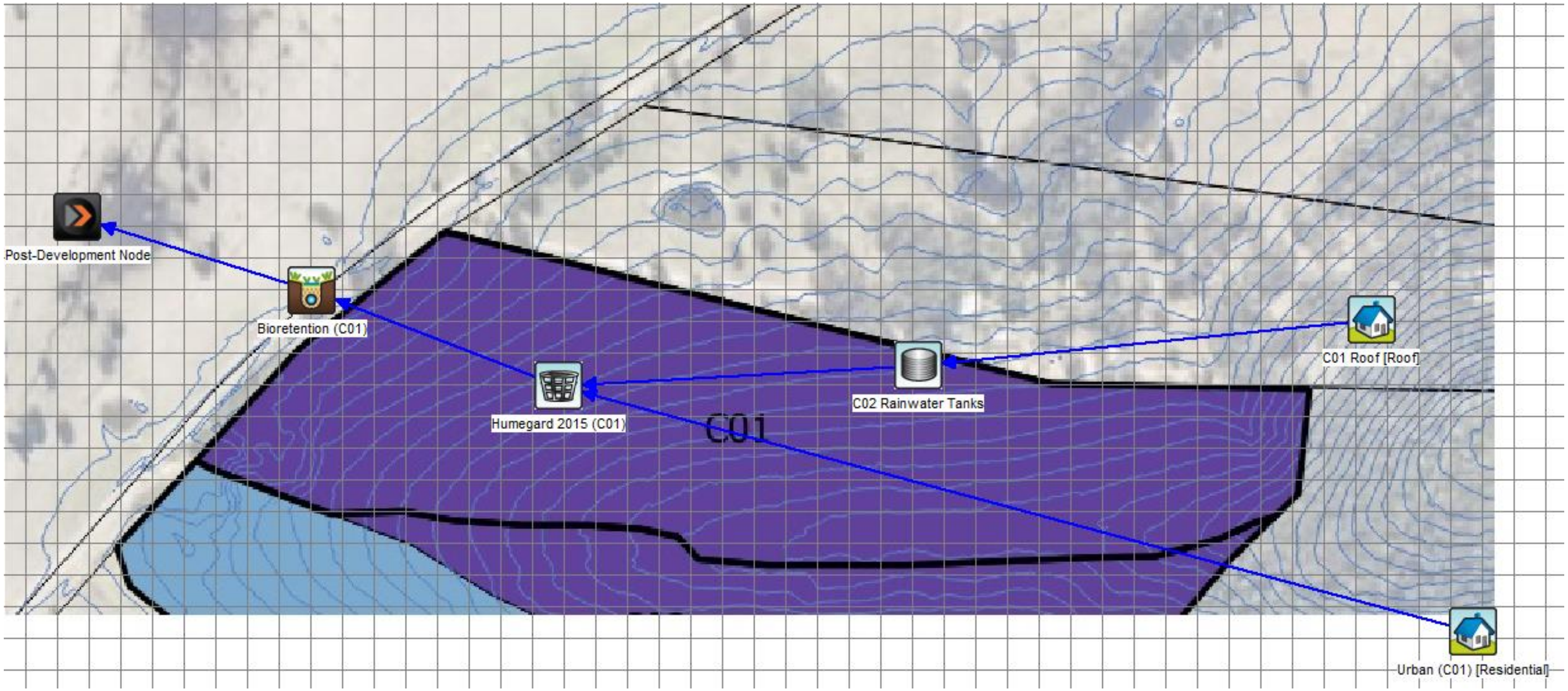
MUSIC Model 2 – Kings Hill South



MUSIC Model 3 – Kings Hill East



MUSIC Model 4 – Kings Hill West B



APPENDIX G -
Hunter Water Corporation Correspondence

Hunter Water Corporation
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19 February 2014

Ref: 2010-678/7

SMEC
PO Box 1346,
NEWCASTLE NSW 2300

Attention: John Kniest

Dear John

APPROVAL OF KINGS HILL WASTEWATER SERVICING STRATEGY – REVISION G, JANUARY 2014

Thank you for your submission of the Kings Hill Waste Water Strategy Revision G – January 2014. Hunter Water is satisfied from your responses that the strategy has been suitably modified to take into account the recommendations made following our most recent review.

Approval of the strategy is therefore given. Three hard copies and one electronic copy of the final strategy (in PDF format) are to be submitted. Please ensure there is a version history in the document and a clear notation on the front cover that the strategy is "final".

The approval of this strategy is valid for a maximum five year period from the date of this letter, however, Hunter Water reserves the right to require a revision to the strategy should any of the following circumstances arise:

- The development does not substantially proceed within this five year timeframe; or
- Significant changes in development profile (ie yield, timing, staging or additional development potential); or
- Significant changes in development yield within the contributing catchment(s); or
- Hunter Water Design Standards or criteria are revised impacting the loading / demand derived from the development; or
- Operation circumstances change; or
- Legislative or regulatory changes are imposed on Hunter Water.

Should any of the above circumstances arise within the five-year approval period, the strategy will require revision by the developer and approval by Hunter Water. Should the maximum 5 year period elapse it is a mandatory requirement that the strategy be reviewed by the developer and approved by Hunter Water prior to proceeding with the works related to water, wastewater or recycled water supply. This process should commence with submission of a new Development Assessment application, Preliminary Servicing application or feasibility analysis to ensure that the most current information, system modelling and performance, and design standards are used in the analysis.

Should the strategy need to be reviewed, the revised servicing strategies shall apply only to those development stages not already completed, or for which detail designs have not yet been approved. The revision of servicing strategies shall be completed by the developer and again be reviewed and approved by Hunter Water. Any costs associated with these reviews shall be borne by the developer.

Please note that approval of a strategy is not a commitment by Hunter Water to fund infrastructure, or an approval to connect the development to Hunter Water's water and sewerage systems. Furthermore, a strategy approval is not a commitment for capacity being allocated to a particular development in existing water and sewerage systems, nor is it an approval to connect to these systems. Connection and/or capacity availability will only be confirmed by submission and determination of a Section 50 application and a valid development consent being issued by the relevant consent authority. Please also note the legal disclaimer attached at Appendix A with respect to the use of Hunter Water's Servicing Strategy Template for the development of this strategy.

Please also note that all intellectual property in a servicing strategy as submitted to Hunter Water vests in Hunter Water on submission and Hunter Water can distribute the strategy, as submitted, and as may be approved by Hunter Water, to third parties (including developer/consultants and members of the public under freedom of information laws). Hunter Water will use reasonable endeavours not to disclose private personal information or information which is commercial in confidence when providing a servicing strategy to third parties.

If you have any questions, please do not hesitate to contact me on 4979 9476.

Yours faithfully

Paul McKoy
Developer Services Engineer

Copy to (by email): Kith Clark, APP
Brad Everett, Hunter Land

Legal Disclaimer

Legal Disclaimer

This disclaimer applies to Hunter Water Corporation ABN 46 228 513 446 ("Hunter Water"), its directors, employees and agents.

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ABN 46 228 513 446

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1300 657 657
(02) 4979 9625 (F)
enquiries@hunterwater.com.au

19 February 2014

Ref: 2010-678/7

SMEC
PO Box 1346,
NEWCASTLE NSW 2300

Attention: John Kniest

Dear John

APPROVAL OF KINGS HILL WASTEWATER SERVICING STRATEGY – REVISION G, JANUARY 2014

Thank you for your submission of the Kings Hill Waste Water Strategy Revision G – January 2014. Hunter Water is satisfied from your responses that the strategy has been suitably modified to take into account the recommendations made following our most recent review.

Approval of the strategy is therefore given. Three hard copies and one electronic copy of the final strategy (in PDF format) are to be submitted. Please ensure there is a version history in the document and a clear notation on the front cover that the strategy is "final".

The approval of this strategy is valid for a maximum five year period from the date of this letter, however, Hunter Water reserves the right to require a revision to the strategy should any of the following circumstances arise:

- The development does not substantially proceed within this five year timeframe; or
- Significant changes in development profile (ie yield, timing, staging or additional development potential); or
- Significant changes in development yield within the contributing catchment(s); or
- Hunter Water Design Standards or criteria are revised impacting the loading / demand derived from the development; or
- Operation circumstances change; or
- Legislative or regulatory changes are imposed on Hunter Water.

Should any of the above circumstances arise within the five-year approval period, the strategy will require revision by the developer and approval by Hunter Water. Should the maximum 5 year period elapse it is a mandatory requirement that the strategy be reviewed by the developer and approved by Hunter Water prior to proceeding with the works related to water, wastewater or recycled water supply. This process should commence with submission of a new Development Assessment application, Preliminary Servicing application or feasibility analysis to ensure that the most current information, system modelling and performance, and design standards are used in the analysis.

Should the strategy need to be reviewed, the revised servicing strategies shall apply only to those development stages not already completed, or for which detail designs have not yet been approved. The revision of servicing strategies shall be completed by the developer and again be reviewed and approved by Hunter Water. Any costs associated with these reviews shall be borne by the developer.

Please note that approval of a strategy is not a commitment by Hunter Water to fund infrastructure, or an approval to connect the development to Hunter Water's water and sewerage systems. Furthermore, a strategy approval is not a commitment for capacity being allocated to a particular development in existing water and sewerage systems, nor is it an approval to connect to these systems. Connection and/or capacity availability will only be confirmed by submission and determination of a Section 50 application and a valid development consent being issued by the relevant consent authority. Please also note the legal disclaimer attached at Appendix A with respect to the use of Hunter Water's Servicing Strategy Template for the development of this strategy.

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If you have any questions, please do not hesitate to contact me on 4979 9476.

Yours faithfully

Paul McKoy
Developer Services Engineer

Copy to (by email): Kith Clark, APP
Brad Everett, Hunter Land

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APPENDIX H -
Ausgrid Correspondence

Address all relevant correspondence to:

Ausgrid Contestability Section
PO Box 487
Newcastle NSW 2300

E: Contestability@ausgrid.com.au

26th August 2019

Northrop Consulting Engineers
Attention: Mr Jack Bevitt
215 Pacific Highway
Charlestown NSW 2290

Email: jbevitt@northrop.com.au

Project Number: 700006174

Dear Jack,

Kings Hill Development – Preliminary Advice – V2.0
Preliminary Investigation of Supply Capacity

Background

Kings Hill development (by Northrop) is located north of Raymond Terrace consisting of approximately 1900 lots with a staged release of approximately 12 years from 2021. The total urban renewal area in Kings Hill is for 3500 lots, with Hunter Land responsible for the development of the other 1600 lots. Ausgrid have been requested to provide details about;

- Current network capacity from connection point with the 2 existing 11kV feeders in the vicinity of the development (ZN00264/81244L & ZN00264/81240L)
- Indications on upgrades in the area to allow for full development
- Any relevant Ausgrid capital works that may occur in the area that will affect the development

Note: The Kings Hill development (in its entirety) was reviewed by Ausgrid in 2011, 2014 and 2017 with a similar Preliminary Enquiry response to this provided.

Load Requirements

The load requirement is estimated on a basis of an ADMD of 3.5kVA. The total load requirement for 1900 lots is 6.7MVA or 350A at 11kV, staged over 12 years. There are also plans for a school in either precinct 4 or 5 with an assumed approximate demand of 1MVA. This gives a total demand for the site at 7.7MVA or 400A at 11kV.
Th entire Kings Hill development (3500 lots) is expected to have a total demand of 13.5MVA or 650A at 11kV.

11kV Supply Capacity

The area is presently supplied by Raymond Terrace 11kV feeders 81240L and 81244L. Brandy Hill 11kV feeder 82578 is to the north of the proposed development. There is currently sufficient capacity on these feeders for the supply of approximately 2 – 3MVA to the general area including surrounding developments. To realise this total available capacity, the new load needs to be divided across feeders with appropriate interconnections through the new development (from the Pacific Highway to Newline Rd). The staging will have an impact on how many lots can be connected without network augmentation. There is presently available capacity for approximately 600 - 800 residential lots in the area including adjacent developments.

Prior to the presence of an interconnection between Newline Rd and the Pacific Highway, there is sufficient spare capacity for approximately 0.5 – 1MVA or 200 lots on both sides of the Kings Hill development area.

Network augmentation will be required to supply the full Kings Hill development area. There are several options for the network augmentation however it is likely that one or more new 11kV feeders will be required from Raymond Terrace Zone Substation. Associated interconnection works between feeders in the area will also be required. The details of the connection requirements will be determined after a formal application is received from the applicant.

There are no significant works planned in the area that effect the proposed development.

Planning Considerations

There are many influencing factors that could affect the available supply capacity including but not limited to other developments, future network augmentation, load growth and policy changes. This preliminary response is based on information available at the time and may change into the future.

It is expected that a connection application will be submitted by the applicant. Upon receipt of the connection application a more detailed planning study will be undertaken to enable a Design Information Package to be produced outlining the connection requirements. The information in this response is for use by Contestability to enable a response to the preliminary enquiry by the applicant.

Yours sincerely,

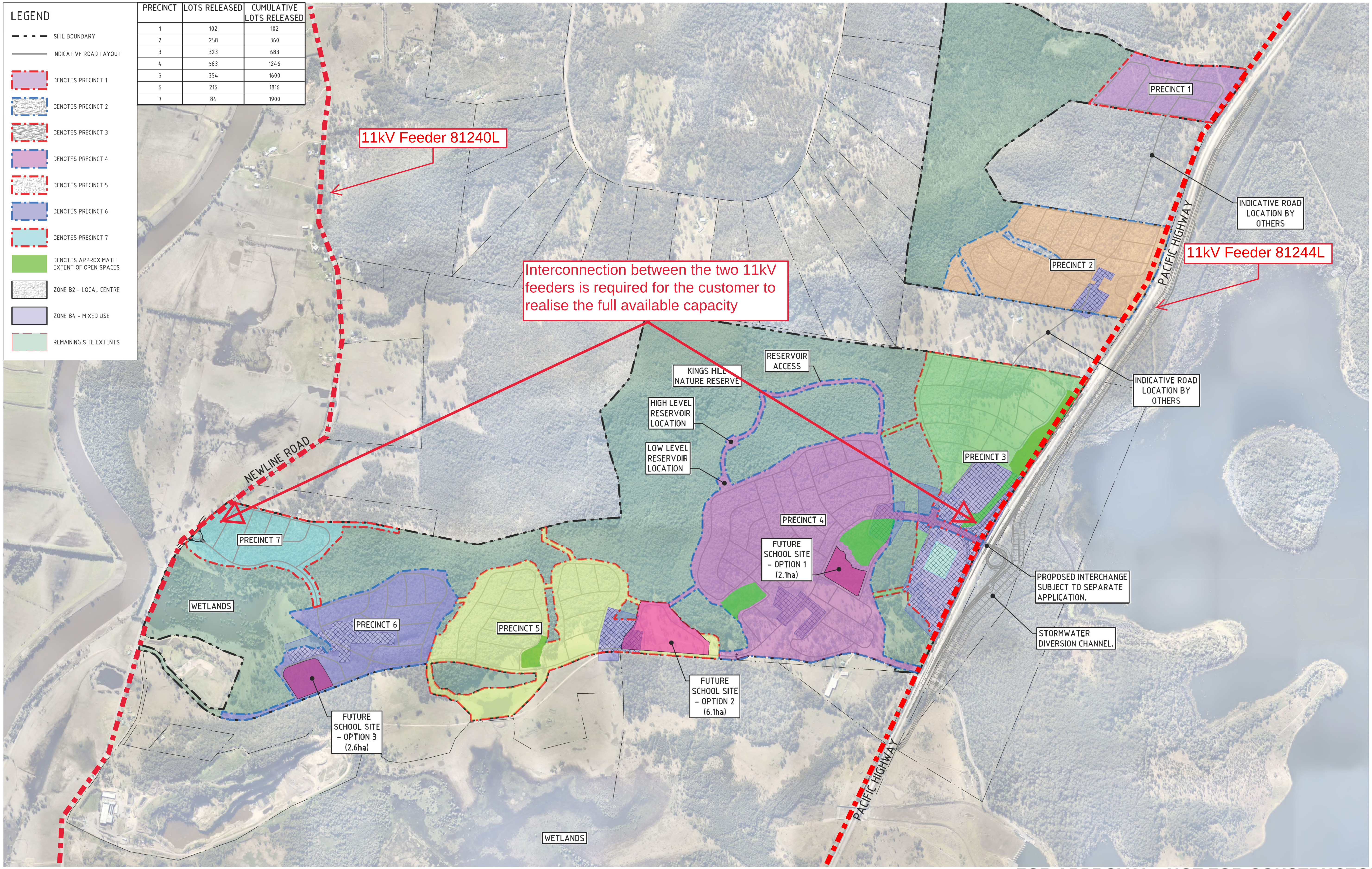
J Evans

Jonathan Evans
Contestability Project Coordinator
Ausgrid

Direct Telephone Number: 43998109
Email: jonevans@ausgrid.com.au

Attachments:

- Masterplan
- Raymond Terrace System Diagram – Sheet 2
- Raymond Terrace System Diagram – Sheet 5



PRECINCT	LOTS RELEASED	CUMULATIVE LOTS RELEASED
1	102	102
2	258	360
3	323	683
4	563	1246
5	354	1600
6	216	1816
7	84	1900

FOR APPROVAL - NOT FOR CONSTRUCTON

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
E	ISSUED FOR APPROVAL	JB	SC	CP	04.12.18
F	ISSUED FOR APPROVAL	WC	SC	CP	06.02.19
G	ISSUED FOR APPROVAL	JB	SC	CP	26.02.19
H	ISSUED FOR APPROVAL	JB	SC	CP	10.05.19
I	ISSUED FOR APPROVAL	JB	SC	CP	20.05.19
J	ISSUED FOR APPROVAL	JB	SC	CP	21.05.19

CLIENT
KINGS HILL DEVELOPMENTS

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PLANNER
JW PLANNING

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SCALE 1:3000@ A1 0 25 50 75 100 125 150m

NORTHROP
Newcastle
Suite 4, 215 Pacific Hwy, Charlestown NSW 2290
P.O. Box 180, Charlestown NSW 2290
Ph (02) 4943 1777 Fax (02) 4943 1577
Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
KINGS HILL DEVELOPMENT APPLICATION MASTERPLAN

DRAWING TITLE
PROPOSED PLAN OF SUBDIVISION

JOB NUMBER **NL120526**

DRAWING NUMBER **DA-08-C2.00**

REVISION **J**

DRAWING SHEET SIZE = A1

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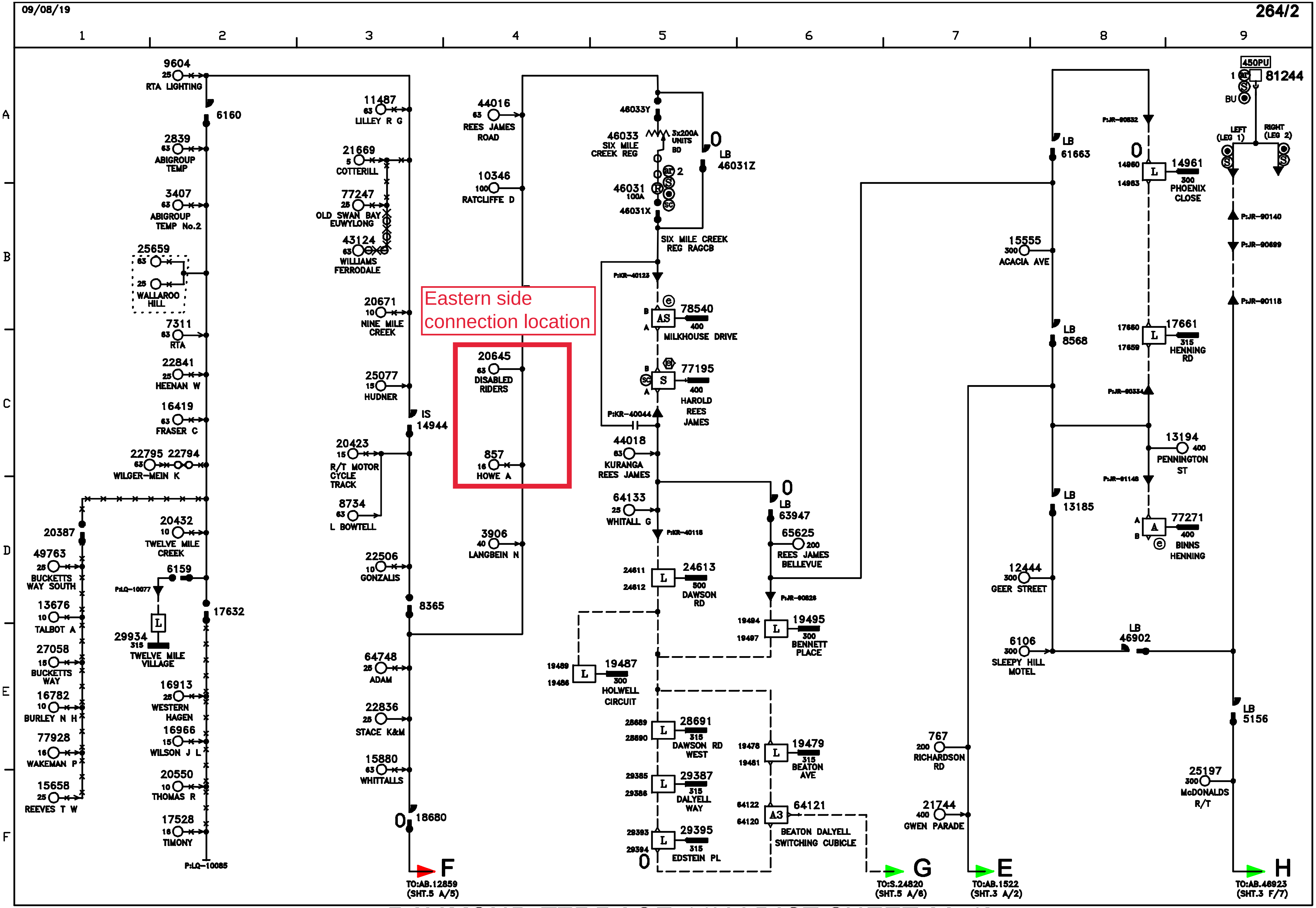
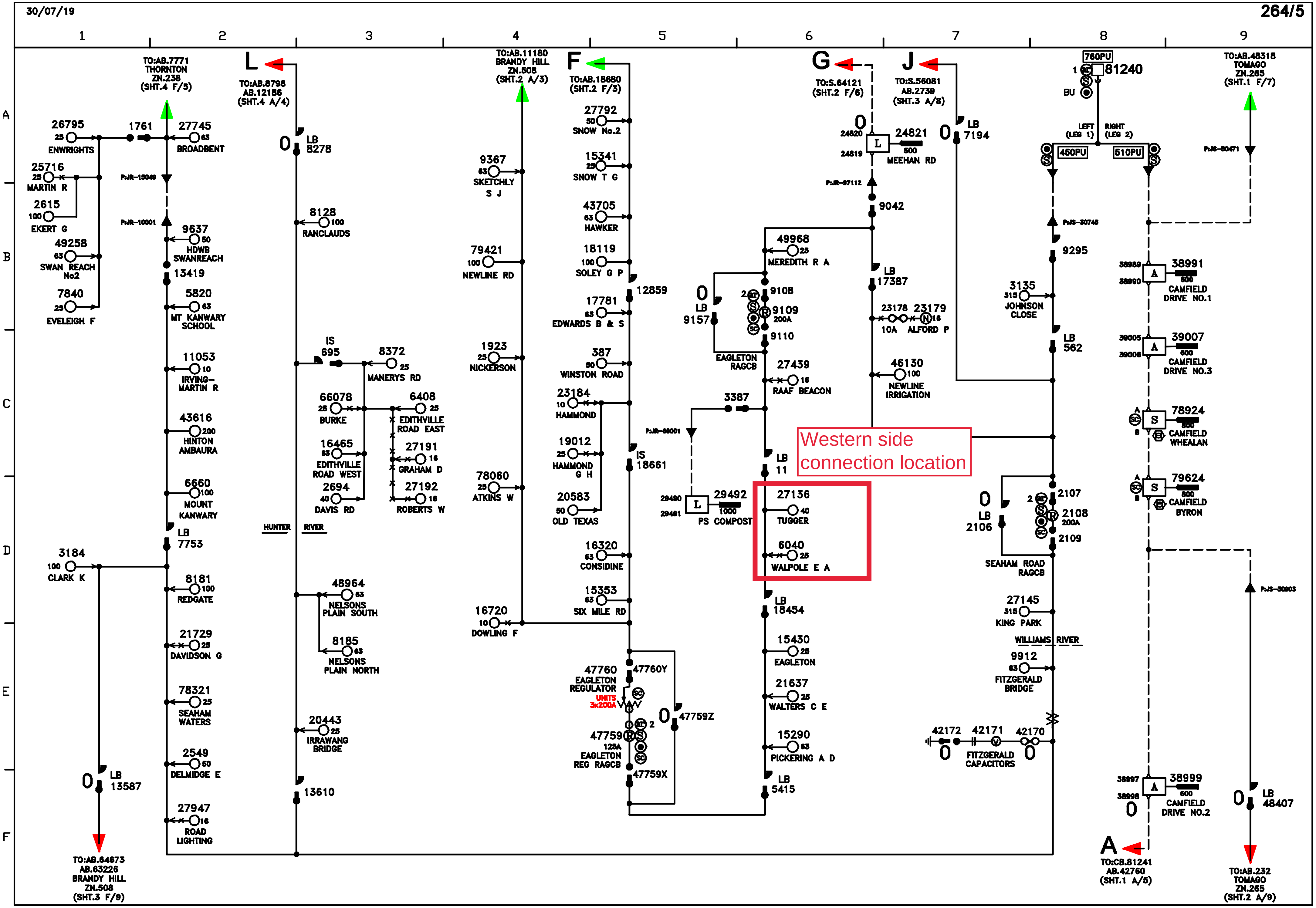


RAYMOND TERRACE 11kV DIST SHEET 264/2



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RAYMOND TERRACE 11kV DIST SHEET 264/5

APPENDIX I -
Preliminary Operational Maintenance Plan for the Eastern Diversion Channel

Item to be Monitored	Monitoring Task	Purpose of Monitoring	Maintenance Action
Eastern Diversion Channel – Preliminary Operational Management Plan			
Overgrowth of vegetation	• Check length of grass and density of trees and shrubs does not exceed design allowances. Inspection to be undertaken on at least a 6 monthly basis.	• If vegetation becomes too dense, the capacity of the channel could become impeded.	• Undertake slashing of vegetation to ensure growth equivalent to a mannings roughness of 0.5 is not exceeded.
Erosion or Scour	• Check for erosion and scour around outlet structures and for the extent of the channel. • If scour is noted check for source of scour.	• Erosion could lead to undermining of the embankment. • If left untreated, small concentrations of erosion can quickly spread over large areas becoming costly to repair.	• Once source of damage is identified and rectified, infill any holes with appropriate material. • Provide energy dissipation if required. • Replace any damaged plants to meet the design plant schedule.
Litter (Organic)	• Check for litter in and around the channel.	• Organic litter can provide an additional source of nutrients which could end up in the Irrawang Swamp. • Accumulated organic matter can also cause offensive odors.	• Address source of organic litter with appropriate action. • Remove litter.
Litter (Anthropogenic)	• Check for litter in and around the channel.	• Litter can potentially block the inlet and outlet structures resulting in flooding, as well as detract from the system's visual amenity. • Litter could end up in the Irrawang Swamp.	• Address source of litter with appropriate action. • Remove litter.

Item to be Monitored	Monitoring Task	Purpose of Monitoring	Maintenance Action

Weeds and Invasive Plants	• Identify the presence of any rapidly spreading weeds or invasive plants.	• The growth of weeds can impair a systems performance by:
		  ◦ Shading and out-competing native plant species.
		  ◦ Weeds can spread to downstream environments, compromising ecosystem health.
		  ◦ Weeds can compromise the visual amenity of the storm water system.
			• Hand remove weed species. The use of herbicide should be avoided.

Plant Condition	Assess plants for; • Disease • Pest infection • Stunted growth • Senescent plants	• During dry periods plants help maintain structure and porosity of the filter media. • During rainfall events above ground vegetation helps to retard and distribute flows and provides scour protection. Below ground the roots provide embankment stability.	• Maintenance action will depend on the cause of die-back or poor plant health. Once the problem is rectified, infill planting may be required. Infill planting must be as per the original planting specification.