74 O'BRIENS ROAD, CATTAI (RIVERSIDE OAKS RESIDENTIAL DEVELOPMENT)

STORMWATER MANAGEMENT REPORT AND FLOOD STUDY

Calibre Consulting (NSW) Pty Ltd

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Stormwater Management Report and Flood Study

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1 EXECUTIVE SUMMARY

This Stormwater Management Report and Flood Study for 74 O'Briens Road, Cattai (also known as Riverside Oaks Golf Resort) has been prepared in response to conditions within Gateway Determination PP_2013_THILL_013_00 issued by the NSW Department of Planning and Infrastructure on 27 August 2013. The conditions within the Gateway Determination have been determined under Section 56(2) of the EP&A Act to inform "*an amendment to the Hills Local Environmental Plan (LEP 2012) to permit up to 300 dwelling houses on lots with a minimum lot size of 450sqm."* This Study and Report have been prepared to conform with the specific flooding and stormwater management conditions within the Gateway Determination and industry best practice for stormwater management, flooding and flood evacuation egress.

In addition to the requirements of the Department of Planning and Infrastructure, The Hills Shire Council also require the following to be addressed:

- Identify the extent of the 1 in 100 year flood event and the Flood Planning Level.
- Consider the proximity of future development lots and internal road network with respect to the 1 in 100 year flood event and Flood Planning Level.
- Identification of what improvements such as earthworks and bridges will be required to manage the potential impact of flooding and stormwater within the site.
- Information is to be provided on the location of evacuation egress from the site.

The Riverside Oaks Golf Resort is located within The Hills Shire Council Local Government Area. The Resort is approximately 570 Ha in area and consists of two (2) 18-hole championship golf courses with accommodation and function facilities as well as a 3.5 km long 4WD track. The site is bordered by O'Briens Road to the north, Wisemans Ferry Road to the east, Little Cattai River to the south and the Hawkesbury River to the west. There are two (2) distinct internal catchments within the site. The largest drains the northern, eastern and southern portions of the site towards Little Cattai Creek, while the smaller of the two drains the western portion of the site directly to the Hawkesbury River.

The proposed development plan for the Riverside Oaks site is based on providing 300 residential lots, approximately 450 m^2 in area, located in four (4) separate precincts located within the elevated areas of the site.

This investigation has identified the possible stormwater controls and flooding and evacuation issues associated with the future development of the Riverside Oaks Golf Resort and has identified an appropriate evacuation strategy for residents during extreme flood events. The proposed stormwater and flood management strategies, required to address these issues, including preliminary sizes and locations for the stormwater management measures, have been determined and shown indicatively on the figures that form part of this report.

The Stormwater Management Strategy proposed for the Riverside Oaks development consists of a series of individual structural stormwater treatment measures, or a "treatment train" approach to Water Sensitive Urban Design (WSUD), and includes on lot treatment, street level treatment and subdivision / development treatment measures. The structural elements proposed for the development consist of:

- Gross pollutant traps at each stormwater discharge point.
- Ten (10) bio-retention raingardens of total area 1,790m^2.

- Three (3) proposed detention basins of approximate total volume 2,790 m^3.

Provision of the proposed stormwater treatment measures within the development will ensure that the post development stormwater discharges will meet The Hills Shire Council's and the Department of Environment and Heritage's water quality objectives.

The provision of WSUD based stormwater treatment measures within the development will also assist in minimising the impact of changes to catchment hydrology that may impact on Little Cattai Creek and the Hawkesbury River as a result of the development.

This investigation included the development of a new hydrologic model to determine peak flow hydrographs for input to the flood model. A new two-dimensional flood model was also developed to estimate both peak local and regional flood levels adjacent to the proposed development for the 1%, 0.2% AEP and PMF events. The flood model was also used to assist in preparation of the flood evacuation strategy.

Stormwater detention basins are proposed for the catchments that drain toward Wisemans Ferry Road to ensure that peak post development flows do not exceed existing levels at the road. For the remaining catchments that discharge directly to Little Cattai Creek and the Hawkesbury River, no detention basins are proposed. It is considered beneficial to not attenuate flows from these catchments to avoid peak discharges from the Riverside Oaks coinciding with the larger peak flows from upstream catchments that are likely to result in increased flood impacts.

The flatter floodplain areas adjacent to the Hawkesbury River and Little Cattai Creek are affected by regional 1% AEP and PMF flooding. The proposed development is generally located at least 0.5 metres above the 1% AEP level of RL 16.7 in the northern arm of Little Cattai Creek and RL 16.8 in the southern arm of Little Cattai Creek, with the majority of development significantly higher. Part of the development is below the regional PMF level of RL 25.6. The main existing access road to three (3) of the proposed Precincts is also below the 1% AEP and PMF flood levels. It is proposed to raise the access road above the 1% AEP flood level. A Flood Evacuation Assessment has been prepared to consider this issue for the development. The assessment has highlighted some issues that will be required to be addressed, which are summarised as:

- Field survey has confirmed that the lowest point of the existing main access road to the southern portion of the proposed development is RL 14.26. This equates to a current level of serviceability of approximately a 1 in 40 year ARI or 2.5% AEP storm event. The access road will be raised above the regional 1% AEP flood level of RL 16.7.

- The residents of the proposed development are able to be evacuated within the available time for Hawkesbury River flooding.

- Even if local creek flooding coincides with the Hawkesbury River flooding, the evacuation time surplus of 3.6 hours (minimum) suggests that a 1.5 hour interruption from local flooding could be accommodated within the evacuation process.

- Local flooding only events in very rare events (> 0.2% AEP) isolate the population, but the short duration suggests that the period of isolation would be tolerable.

- The key evacuation routes are to be raised to provide flood immunity in the 1% AEP event.

- Installation of gates to obstruct drivers from entering flooded roads.

- Development of a flood warning/evacuation system including a local water level recorder that issues SMS when pre-determined levels are reached and automatic dialling technology to rapidly issue residents with evacuation warnings or orders.
- Development of a flood education program.
- Preparation of a detailed flood emergency plan.

A water quality model was also developed for the proposed Riverside Oaks development to establish the size of devices required to reduce the pollutant runoff loads to the targets established by the Office of Environment and Heritage.

The Stormwater and Flood Management Strategy proposed for the Riverside Oaks Golf Resort is practicable, minimises the impact of runoff from the site on the receiving waters and provides a 'soft' sustainable solution for stormwater management within the site.

The proposed Stormwater and Flood Management Strategy provides a basis for the detailed design and development of the site to ensure that the environmental amenity and flood risks for future residents are managed sustainably.

2 INTRODUCTION

The Riverside Oaks Golf Resort at 74 O'Briens Road, Cattai is located within The Hills Shire Local Government area, adjacent to the confluence of Little Cattai Creek and the Hawkesbury River.

The Resort consists of approximately 570 Ha of land and is bordered by O'Briens Road to the north, Wisemans Ferry Road to the east, Little Cattai River to the south and the Hawkesbury River to the west. Two (2) distinct internal catchments drain the Resort in a southerly direction to Little Cattai Creek and in a westerly direction to the Hawkesbury River.

This report details the procedures used and presents the results of investigations undertaken by J. Wyndham Prince together with Molino Stewart in developing a Stormwater and Flood Management Strategy, as well as a Flood Evacuation Assessment for the development to integrate with and inform the planning process (Hills LEP 2012) to permit up to 300 dwellings to be built within the Riverside Oaks site.

The objectives of this investigation are to identify the stormwater and flooding issues associated with the future development of the Riverside Oaks Golf Resort and to identify an appropriate evacuation strategy for residents during extreme flood events. The stormwater and flood management strategies, required to overcome these issues, are to include preliminary sizes and locations for any proposed infrastructure and incorporated into a preliminary layout plan for the Resort.

The investigation addresses engineering considerations, whilst placing a strong focus on conserving and enhancing the bio-diversity, ecological health and positive water quality benefits in the existing riparian corridors adjacent to the site to provide an integrated natural resource for the incoming residents.

The investigation involved the following specific tasks:

- Investigation of a range of stormwater management and water sensitive urban design measures to achieve the pollutant reduction and discharge targets established by The Hills Shire Council including liaise with the Council and the Resort's Master Planner to identify the most appropriate strategies for the Resort.
- Undertaking a hydrologic analysis to determine the peak flows for the 1% and 0.2% AEP together with the Probable Maximum Flood under pre-development conditions.
- Development of a two dimensional hydraulic flood model for the site and assessment of the above mentioned storm events under existing conditions.
- Determination of the minimum detention storage requirements to restrict post-development flows to pre-development levels for catchments that drain to Wisemans Ferry Road.
- Identification of an appropriate flood evacuation strategy for the development.
- Assessment of the impacts of the proposed construction of 300 additional dwellings on runoff water quality discharging from the development into Little Cattai Creek and the Hawkesbury River. Determine the minimum treatment device areas required to achieve The Hills Shire Council's and the Office of Environment and Heritage (OEH) water quality targets.
- Preparation of plans showing indicative sizes and locations of the stormwater management devices proposed as part of the development to achieve the water quality and quantity objectives.

- Preparation of a Stormwater Management Report and Flood Study as required to inform an amendment to the Hills Local Environmental Plan 2012 to permit the 300 additional dwellings to be built within the Riverside Oaks site, including details of the investigations, findings, calculations and preliminary sizes and locations of the proposed stormwater treatment measures.

3 PREVIOUS STUDIES

No studies specifically relating to Stormwater and Flood Management within the Riverside Oaks Golf Resort have been undertaken previously. There have been flood studies and impact investigations undertaken at a regional level that have been used to inform these investigations.

4 THE EXISTING ENVIRONMENT

4.1 The Site

Riverside Oaks Golf Resort is located in Cattai, a suburb within The Hills Shire Council's Local Government Area. The Resort consists of approximately 570 Ha of land fronting Wisemans Ferry and O'Brien's Roads, as well as water frontages along Little Cattai Creek and the Hawkesbury River. The Resort currently consists of two (2) 18-hole championship golf courses with accommodation and function facilities as well as a 3.5 km long 4WD track. The existing site is shown on Figure 4.1.

The Riverside Oaks landform consists of undulating land with slopes, on either side of the ridges in excess of 10%, and along the river flat areas less than 2%. Much of the flatter portions of the site, adjacent to Little Cattai Creek and the Hawkesbury River, have been cleared as part of the development of the two 18 hole golf courses, the 3.5 km 4WD track and the construction of ancillary buildings, resort accommodation and associated servicing facilities. A small amount of remnant vegetation exists along the ridgelines that separate the two (2) existing 18 hole golf courses from one another and provides the watershed for the Little Cattai Creek and Hawkesbury River catchments.

There are two main ridgelines within the site that determine whether stormwater runoff discharges to Little Cattai Creek or directly to the Hawkesbury River. The general direction of stormwater runoff from the Riverside Oaks site is shown below on Plate 4.1. In extreme storm events, such as the PMF, stormwater flows against the normal direction of flow through the northern golf course, across the low lying portion of the ridge and to the Hawkesbury River.

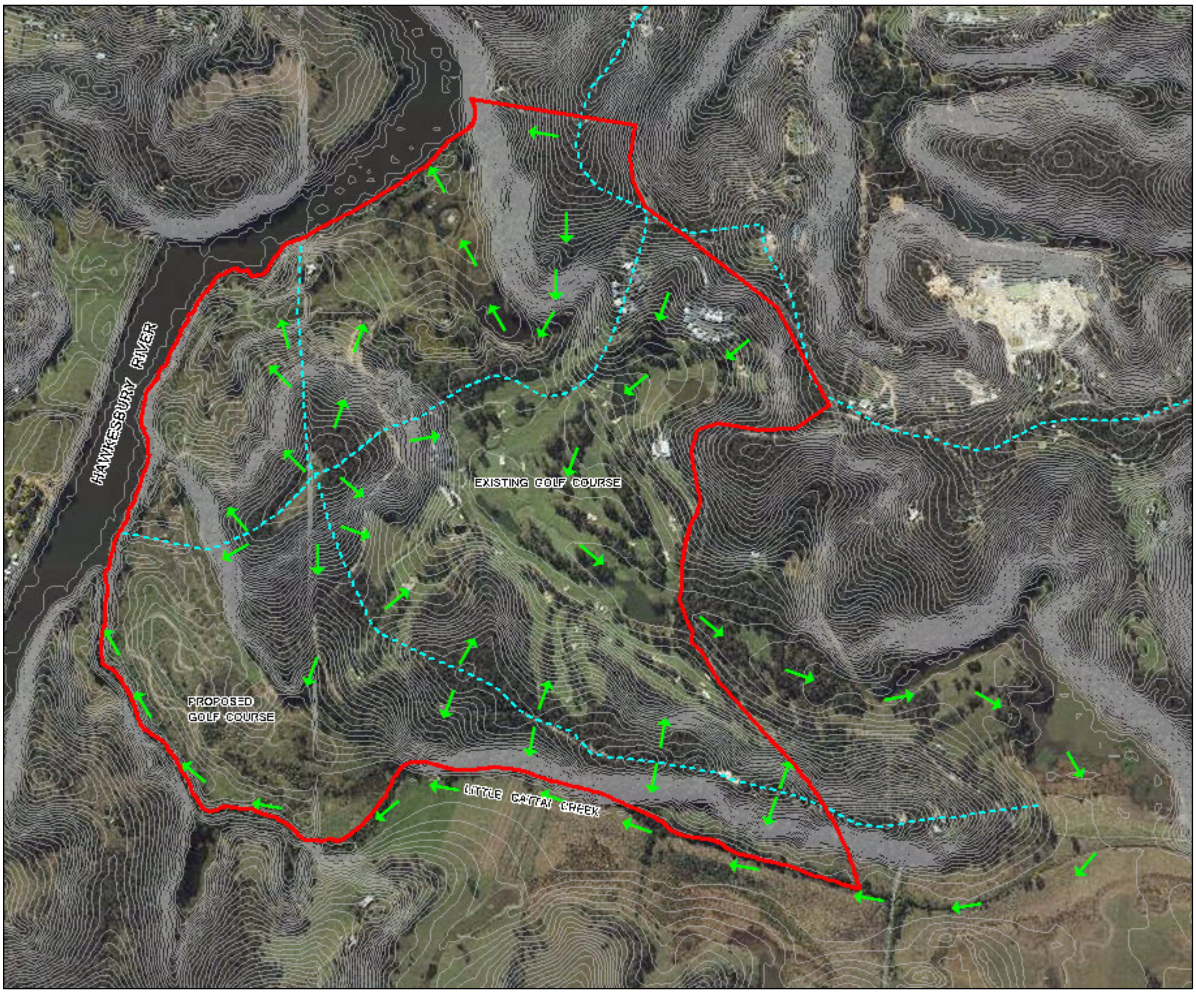


PLATE 4.1 – EXISTING DRAINAGE CONDITIONS FOR THE RIVERSIDE OAKS SITE

5 THE PROPOSED DEVELOPMENT

A Planning Proposal has been submitted to The Hills Shire Council for the site seeking approval for up to 300 dwellings on lots with a minimum area of 450 m^2. Consequently, an amendment to the Hills Local Environment Plan 2012 is required and the NSW Department of Planning and Infrastructure has required that as part of the Gateway Determination additional information on the local and regional flood impacts be provided as well as details of the location of evacuation egress from the site.

The indicative layout for the proposed development (refer to Plate 5.1) identifies four (4) separate Precincts (Precinct A to Precinct D) along the main ridgeline and internal spine road that will accommodate the 300 new lots.

Stormwater detention basins will be provided within the catchments that drain toward Wisemans Ferry Road to mitigate peak flows resulting from the increase in impervious area. It is not proposed to provide detention basins for the catchments that drain directly to the Hawkesbury River or Little Cattai Creek, as it is considered beneficial to allow these flows to go early rather than have them coincide with larger peaks on these watercourses. Water quality devices are also proposed throughout the development at each discharge point to minimise the impact of stormwater discharges on the environment.

The proposed development is shown below on Plate 5.1 and on Figure 5.1.

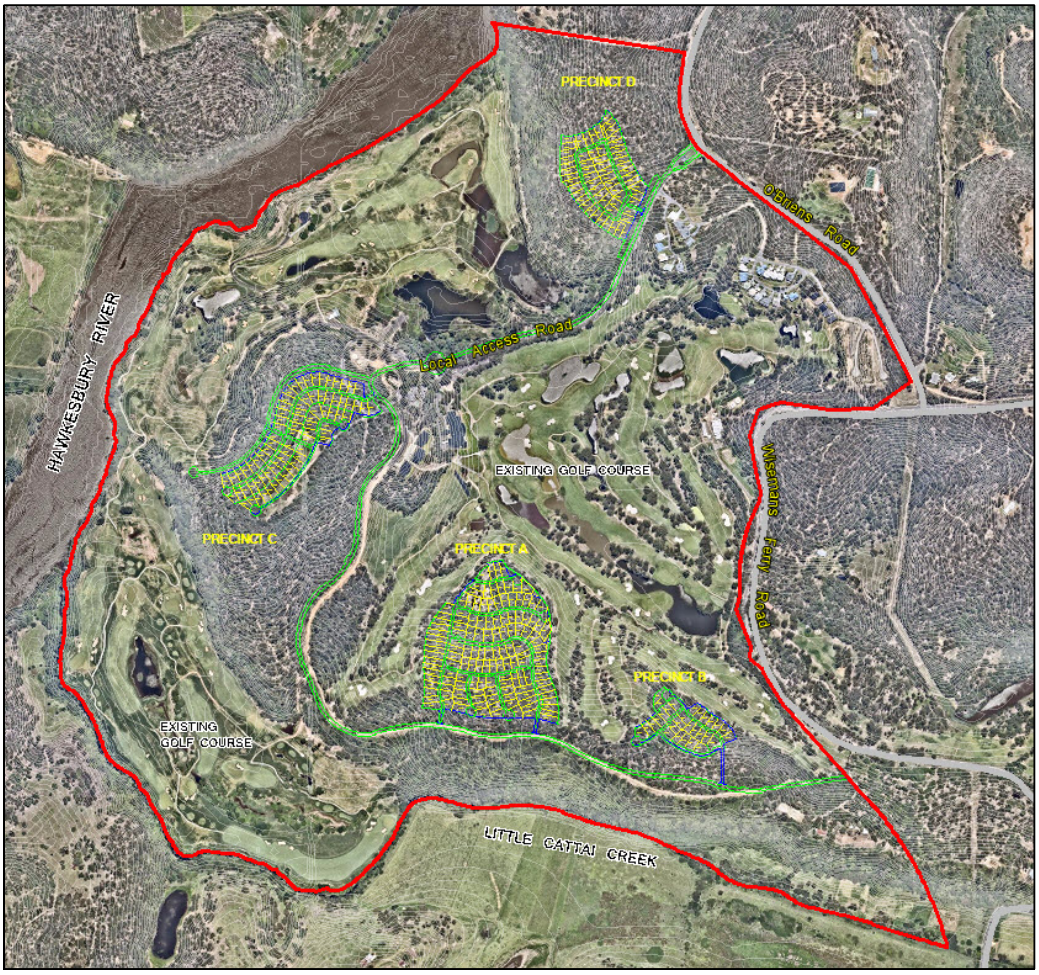


PLATE 5.1 – DRAFT INDICATIVE LAYOUT PLAN FOR THE RIVERSIDE OAKS GOLF RESORT DEVELOPMENT

6 DEVELOPMENT GUIDELINES, OPPORTUNITIES & CONSTRAINTS

The following guidelines were considered in developing the Stormwater Management and Flood Management Strategies for the Riverside Oaks development.

6.1 The Hills Shire Council Development Control Plan (2012)

The Hills Shire Council Development Control Plan (including Appendix B – Water Sensitive Urban Design) (THSC, 2012) identifies the following objectives for consideration with regard to stormwater management:

- To provide for the disposal of stormwater from the site in efficient and environmentally sensible ways in accordance with Council's ESD objectives.
- Control stormwater and to ensure that developments do not increase downstream drainage flows or adversely impact adjoining or downstream properties.
- To ensure the integrity of watercourses is protected and enhanced in accordance with Council's ESD objectives.
- To provide for on-site detention of stormwater.
- To encourage the reuse of stormwater.

6.2 New South Wales Office of Environment and Heritage

The NSW Office of Environment and Heritage, formerly the Department of Environment, Climate Change and Water and Environment Protection Authority (EPA), has set guidelines for stormwater quality from urban developments in their Interim Recommended Parameters for Stormwater Modelling – North-West and South-West Growth Centres (DECCW). In the absence of specific pollution retention criteria in Council's DCP, this guideline has been adopted for Riverside Oaks Golf Resort.

This document nominates quantitative post construction phase stormwater management objectives for the reduction of various pollutants for a range of new developments. The retention criteria for the site are nominated as follows:

Total Phosphorous	65% retention of average annual load
Total Nitrogen	45% retention of average annual load
Suspended Solids	85% of average annual load for particles 0.5 mm or less
Gross Pollutants	90% retention of material greater than 5mm

6.3 Salinity and Groundwater

Salinity is the accumulation of mineral salts in the soil, groundwater and surface waters. Dry land salinity results when soluble salts are transported to the surface by a rising water table. The groundwater itself can also cause soluble salts to migrate under the ground surface and emerge as saline seepage in low lying areas. Salinity can lead to vegetation loss, weed invasion, soil structure decline and in some cases structural damage to buildings.

It is anticipated that a detailed Land Capability and Salinity Assessment would be undertaken in the future to provide guidance and recommendations on salinity and groundwater management for the Riverside Oaks development.

6.4 Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design aims to minimise the hydrological impacts of urban development and maximise the multiple use benefits of a stormwater system.

Australian Runoff Quality (ARQ, 2006) identifies the objectives of WSUD to include:

- Reducing potable water demand through water efficient appliances, rainwater and grey water reuse.
- Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse opportunities and/or release to receiving waters.
- Treating urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters.
- Preserving the natural hydrological regime of catchments.

Australian Runoff Quality also identifies WSUD as the adoption of the following planning and design approaches that integrate the following opportunities into the built form of cities and towns:

- Detention, rather than rapid conveyance of stormwater.
- Capture and use of stormwater as an alternative source of water to conserve potable water.
- Use of vegetation for filtering purposes.
- Protection of water-related environmental, recreational and cultural values.
- Localised water harvesting for various uses.

6.5 Stormwater Management Objectives

6.5.1 Overall Objectives

The overall site stormwater management objectives have been identified as follows:

Environmental

- Promote an environment where the community can increase their knowledge and understanding of water, which will help modify their behaviour accordingly to more water smart actions.
- Provision of appropriately designed and functional water quality facilities.
- Limitation of downstream discharge peaks and velocities.
- Maintenance of existing downstream water quality.
- Maintenance of stormwater flows to ecosystems downstream of the site.

Urban Amenity

- Provision of a stormwater management strategy that identifies and controls limits of flood affectation and provision of aesthetic design forms that enhance amenity.

Engineering Considerations

- Effective management and control of peak discharges, discharge velocities, site detention, and water quality.
- Industry best practice technical analysis of catchment hydrology and system hydraulic performance.

Economics

- Provision of a cost effective, functional site drainage system that optimises performance, provides maximum value for expenditure and keeps on-going maintenance requirements to a minimum.

6.5.2 Specific Development Objectives

In accordance with the principles of Ecologically Sustainable Development (ESD), the area needs to be designed, developed and maintained in accordance with the following stormwater management objectives:

- Preserve the ecological integrity of the identified riparian zones.
- Restrict development to above the 1% AEP flood level.
- Incorporate water sensitive urban design principles within the development.
- Ensure post-development water quality complies with Council's and the OEH's requirements.
- Provision of a sustainable aquatic environment that preserves the potential for creating habitat for local indigenous flora and fauna.
- Minimise Council's or the Community's maintenance requirements for open space, litter control structures and nutrient and sediment removal devices.
- Enhance the biodiversity, ecological health and positive water quality benefits within the adjacent riparian corridors to provide an integrated natural resource for the incoming residents.
- Provision of a flood evacuation strategy.

6.6 Opportunities

In the design of any urban drainage scheme it is desirable to build on the naturally occurring physical and environmental assets of the site to maximise the quality of the ultimate living environment. In particular water should be recognised as an important resource that can enhance and bring a focus to areas accessible to the whole community.

For the Riverside Oaks Development site there are major opportunities to:

- Maintain the quality of riparian corridors adjacent to the Precinct.
- Maximise habitat retention along the riparian corridor to provide sustainable aquatic and terrestrial ecosystems.
- Incorporate storm water reuse schemes to irrigate the golf courses and any proposed public reserves wherever possible.

6.7 Constraints

The constraints to be considered in the preparation of a Stormwater and Flood Management Strategy for the development include:

- Steep slopes within the development areas.
- Regional flooding from the Hawkesbury River and required flood evacuation.
- Areas of land that have been identified within the site where development is restricted (e.g. possible Cumberland Plain Woodland).
- Water quality and quantity objectives that will require allocation of land for stormwater control structures.
- Potential existing site soil salinity and groundwater salinity constraints.
- The need to ensure that flood storage within the floodplain is maintained and the hydraulic conveyance needs of the floodplain are catered for.

6.8 Statutory Requirements

The recommendations contained in the following guidelines have also been considered in the master planning process.

- The Hills Shire Council Design Guidelines Subdivision/Developments 2012.

7 WATER CYCLE MANAGEMENT OPTIONS

The Stormwater and Flood Management Strategy proposed for the Riverside Oaks development has been prepared with consideration of the statutory requirements and guidelines listed in Section 6 of this report. The strategy focuses on mitigating the impacts of the development on the total water cycle and maximising the environmental, social and economic benefits achievable by utilising responsible and sustainable stormwater management practices.

A range of stormwater management techniques and options considered for the management of nutrients and suspended solids discharging from the site are summarised below.

Each of these management techniques were evaluated and compared with consideration of a range of environmental, social/amenity, economic, maintenance and engineering criteria.

7.1 Vegetated Swales and Buffers

Swales are formed, vegetated depressions that are used for the conveyance of stormwater runoff from impervious areas. They provide a number of functions including:

- Removing sediments by filtration through the vegetated surface.
- Reducing runoff volumes (by promoting some infiltration to the sub-soils).
- Delaying runoff peaks by reducing flow velocities.

Swales are typically linear, shallow, wide, vegetation lined channels. They are often used as an alternative to kerb and gutter along roadways but can also be used to convey stormwater flows in recreation areas and car parks.

Comment: The grade of the land within the majority of the Riverside Oaks development site is unsuitable for swales and buffers (i.e. > 3%). The areas within the golf courses and on the fringes of the riparian corridors are generally more suitable. Swales and buffers within urban residential streets are not recommended due to the large number of culvert crossings required for driveways, safety concerns, increased number of GPT's required and significant maintenance requirements. Swales within central road medians, if provided within the development, or within the flatter, lower lying areas may be appropriate. Swales along the access road between the Precincts are also recommended where the grade is not excessive.

7.2 Sand Filters

Sand filters typically include a bed of filter media through which stormwater is passed to treat it prior to discharging to the downstream stormwater system. The filter media is usually sand, but can also contain sand/gravel and peat/organic mixtures. Sand filters provide a number of functions including:

- Removing fine to coarse sediments and attached pollutants by infiltration through a sand media layer.
- Delaying runoff peaks by providing retention capacity and reducing flow velocities.

Sand filters can be constructed as either small or large scale devices. Small scale units are usually located in below ground concrete pits (at residential/lot level) comprising of a preliminary sediment trap chamber with a secondary filtration chamber. Larger scale units may comprise of a preliminary sedimentation basin with a downstream sand filter basin-type arrangement.

Comment: Sand filters are generally suited to smaller catchments. They are less efficient when compared to bio-retention systems and require frequent maintenance to remove solids from the surface of the sand.

7.3 Permeable Pavement

Permeable pavements, which are an alternative to typical impermeable pavements, allow runoff to percolate through hard surfaces to an underlying granular sub-base reservoir for temporary storage until the water either infiltrates into the ground or discharges to a stormwater outlet. They provide a number of functions including:

- Removing some sediments and attached pollutants by infiltration through an underlying sand/gravel media layer.
- Reducing runoff volumes (by infiltration to the sub-soils).
- Delaying runoff peaks by providing retention/detention storage capacity and reducing flow velocities.

Commercially available permeable pavements include pervious/open-graded asphalt, no fines concrete, modular concrete blocks and modular flexible block pavements.

There are two (2) main functional types of permeable pavements:

- Infiltration (or retention) systems – temporarily holding surface water for a sufficient period to allow percolation into the underlying soils.
- Detention systems – temporarily holding surface water for short periods to reduce peak flows and later releasing into the stormwater system.

Comment: Permeable pavements are generally a more 'at source' solution and best suited as an 'on lot' approach or for small roadway catchments. Permeable pavers may possibly be considered at the development application stage for on lot treatment or for areas draining small catchment areas with low sediment loads and low vehicle weights. These systems are also prone to clogging and are not suitable in saline soils that may be encountered at the Riverside Oaks site and are therefore unlikely to be recommended for the site.

7.4 Infiltration Trenches and Basins

Infiltration trenches temporarily hold stormwater runoff in a sub-surface trench prior to infiltrating into the surrounding soils. Infiltration trenches provide the following main functions:

- Removing sediments and attached pollutants by infiltration through the sub-soils.
- Reducing runoff volumes (by infiltration to the sub-soils).
- Delaying runoff peaks by providing detention storage capacity and reducing flow velocities.

Infiltration trenches typically comprise of a shallow, excavated trench filled with reservoir storage aggregate. The aggregate is typically gravel or cobbles but can also comprise modular plastic cells (similar to a milk crate). Runoff entering the system is stored in the void space of the aggregate material or modular cells prior to percolating into the surrounding soils. Overflow from the trench is usually to downstream drainage system. Infiltration trenches are similar in concept to infiltration basins, however trenches store runoff water below ground in a pit and tank system, whereas basins utilise above ground storage.

Comment: Infiltration trenches and basins are not appropriate for clay soils or where there is potential for salinity issues. Infiltration trenches and basins are therefore unlikely to be suitable for the Riverside Oaks site.

7.5 Constructed Wetlands and Ponds

Constructed wetlands can take the form of either a surface or sub surface system.

- **Surface –** Conventional wetlands
- **Sub Surface –** Gravel filled shallow wetland.

Wetlands are shallow water body systems, densely vegetated with emergent aquatic macrophytes. Wetlands are effective in trapping suspended solids, as well as chemical and biological uptake of pollutants. Ponds are similar devices to constructed wetlands, but without the vegetation.

Comment: Wetlands and ponds are effective in removing sediment and nutrient loads typically generated from urban development. They do however require a large footprint area in relation to the catchment size. Wetlands and ponds generally also require a significant amount of maintenance. They are susceptible to algal blooms and require recirculation systems. Consideration of public safety measures are also required due to permanent deep water areas. Wetlands (as treatment devices) would be suitable within the flatter areas of the Riverside Oaks development, provided the development areas can drain to them.

7.6 Base Flow Management Basins

Base Flow Management Basins are a similar device to constructed wetlands, however they do not include a permanent water body or macrophytes. Base Flow Management Basins are effective in trapping suspended solids and attached nutrients and delay runoff peaks by providing detention storage capacity and reducing flow velocities. These devices also provide an aesthetic value within the Precinct.

Comment: Base Flow Management Basins are effective in removing sediments and nutrient loads typically generated from urban development. These devices are effective at ensuring that increase stream forming flows from urban development are reduced. Base Flow Management Basins could potentially be provided within the flatter areas of the Riverside Oaks development.

7.7 Bio-retention Systems

Bio-retention systems consist of a filtration bed with either gravel or sandy loam media and an extended detention zone typically from 100-300 mm deep designed to detain and treat first flush flows from the upstream catchment. They typically take the form of an irregular bed or a linear swale and are located within the verge area of a road reserve or extend within the bushland corridors or other open space areas. The surface of the bio-retention system can be grassed or mass planted with water tolerant species. Filtration beds of bio-retention systems are typically 0.5 - 0.6 metres deep.

Comment: Bio-retention systems are an effective and efficient means of treating pollutants from urban development when part of an overall treatment train. Bio-retention systems require a reasonable amount of maintenance during the vegetation establishment phase. Bio-retention systems are recommended for the Riverside Oaks development. Careful consideration of their location and design will be required due to the steep grades. Alternatively, the systems could be located within the flatter areas of the site provided the development can be drained to them.

7.8 Cartridge Filtration Systems

Cartridge filtration systems are underground pollution control devices that treat first flush flows. The unit consists of a vault containing a number of cartridges each loaded with media that targets specific pollutants. Each cartridge has a maximum treatable flowrate of approximately 1-1.5 litres per second, and the unit can accommodate up to 24 cartridges providing a maximum treatable flowrate of 24-36 litres per second.

Comment: Cartridge filtration systems are an efficient means of treating pollutants from urban development as they are typically located underground and therefore do not require additional landtake. As cartridge systems have a low treatable flow rate, additional 'buffer' storage is usually provided to keep the capital costs down. Cartridge filtration systems also need to be supplemented with additional treatment devices to achieve pollutant reduction targets. This requires significant height differences between the inlet to the filtration system and the discharge point from the supplementary system. It also generally results in expensive capital and ongoing maintenance costs.

7.9 Rainwater Tanks

Rainwater tanks are sealed tanks designed to contain rainwater collected from roofs.

Rainwater tanks provide the following main functions:

- Allow the reuse of collected rainwater as a substitute for mains water supply, for use for toilet flushing, laundry, or garden watering.
- When designed with additional storage capacity above the overflow, provide some on-site detention, thus reducing peak flows and reducing downstream velocities.

The water collected can be reused as a substitute for mains water supply either indoors (toilet flushing) or outdoors (garden watering). Rainwater tanks can be either above ground or underground. Above ground tanks can be placed on stands to prevent the need of installing a pump to distribute the water. Such systems are referred to as gravity systems. Pressure systems require a pump and can be either above or below ground tanks.

Tanks can be constructed of various materials such as ColorbondTM, galvanised iron, polymer or concrete.

Comment: Rainwater tanks are effective in removing suspended solids and a small amount of nutrient pollutants. They are also effective in reducing overall runoff volumes. The effectiveness of rainwater tanks is also increased when plumbed in for internal use. Rainwater tanks are recommended for the development.

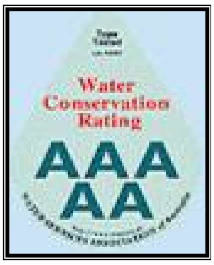
8 PROPOSED STORMWATER MANAGEMENT STRATEGY

A critical consideration for the Stormwater and Flood Management strategy for the development is the ecological sustainability of the riparian corridors. To maintain stormwater quality at the required levels, a 'treatment train' approach is proposed where various types of pollutants are removed and flow volumes and discharge rates are managed by a number of devices acting in series. The stormwater management treatment train will consist of the following elements.

8.1 Water Efficiency

8.1.1 On Lot Treatment

- Implementation of water efficient fittings and appliances in all dwellings (dual flush toilet, AAA shower heads, water efficient taps and plumbing).
- Minimisation of impervious areas through acceptable development controls.
- The provision of rainwater tanks on each allotment, along with implementation of the above water efficient devices, will satisfy the requirements of BASIX. The connection of water tank to service internal uses will ensure any requirements are met and additional benefits are realised.



8.2 Water Quality Measures

8.2.1 Street Level Treatments

Inlet Pit Filter Inserts and Gross Pollutant Traps (GPTs)

GPT devices are typically provided at the outlet to stormwater pipes. These systems operate as a primary treatment to remove litter, vegetative matter, free oils and grease and coarse sediments prior to discharge to downstream (Secondary and Tertiary) treatment devices. They can take the form of trash screens or litter control pits, pit filter inserts and wet sump gross pollutant traps.

In theory, inlet pit filter inserts have several advantages over end of pipe GPT's, such as providing a dry, at source collection of litter, vegetative matter and sediment as well as allowing for staged construction works without having to provide additional / temporary GPT units. Pit filter inserts will provide an at source mechanism for treatment of gross pollutants as development proceeds throughout the site.

In practice, feedback from various Council's have found that inlet pit filter inserts result in an unreasonable maintenance burden, particularly through access for cleaning and damage / vandalism. Pit inserts may be appropriate in low density residential areas where on street parking is unlikely or not permitted and where additional primary / secondary treatment measures are provided downstream in case of pit insert failure.

The form and configuration of GPT's can be further considered at development application and detailed design stages in conjunction with the streetscape design.

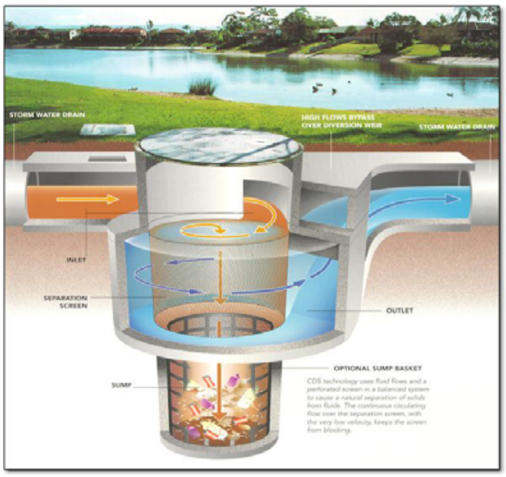


PLATE 8.1 – VORTEX STYLE GPT

8.2.2 Subdivision / Development Treatment

i. Swales

Swales are proposed along the edges of the access roads that link the Precincts where grades permit. The swales will collect and convey base flows from the roads for treatment. The inclusion of additional swales should be considered at the development application and detailed design stages to maximise their use where practical.

PLATE 8.2 – TYPICAL SWALE

ii. Bio-retention Raingardens

Approximately ten (10) bio-retention 'raingardens' are proposed within the development. Raingardens are large scale, non-linear bioretention systems. The systems will be appropriately sized to achieve the nutrient reduction targets outlined in the Office of Environment and Heritage draft guidelines (2006). The raingardens will also attenuate first flush flows to reduce the risk of stream erosion within the water courses. The location of the nine (9) bio-retention systems and raingardens are shown indicatively on Figure 8.1. Refer to Section 11 for further discussion.

PLATE 8.3 – TYPICAL RAINGARDEN AFTER PLANT ESTABLISHMENT

The proposed strategy for the Riverside Oaks development does not preclude the use of additional or alternate WSUD elements within the streetscape or landscape. These elements, such as swales or bioretention systems in the medians of dual carriageways (or elsewhere) and ponds and wetlands within the golf course, can be considered at the development application and detailed design stages. The use of such elements would require consideration of issues such as practicality in the urban environment, safety, maintenance and performance.

8.3 Water Quantity (Flood Control) Measures

8.3.1 Subdivision / Development Treatment

Detention Basins

Peak storm flow attenuation up to the 1% AEP event is addressed through the provision of three (3) detention storages located adjacent to the Riverside Oaks Development Precincts. Basins are proposed only for the catchments that discharge toward Wisemans Ferry Road to ensure that the proposed development does not increase peak flows at this location. It is not proposed to provide detention basins for the catchments that drain directly to Little Cattai Creek or the Hawkesbury River, as it is considered beneficial to let these flows escape in the minimum time to avoid local peak flows coinciding with larger peak flows from these watercourses. The detention basins have been sized at 350m^3/ha, which is generally conservative for detention basins attenuating flows from urban residential development. Refer to Section 9 for further discussion.

A General Arrangement Plan indicating proposed locations for the water quantity and water quality treatments for the Riverside Oaks is included in Figure 8.1.

8.4 Construction Stage

Erosion and sediment control measures are to be implemented during the construction phase in accordance with the requirements of The Hills Shire Council and the guidelines set out by Landcom (the "Blue Book" 2004).

As the operation of "bio-retention" (raingarden) type water quality treatment systems are sensitive to the impact of sedimentation, construction phase controls should generally be maintained until the majority of site building works (approximately 80%) are complete. Alternatively, a very high level of at source control on individual allotments during the building and site landscaping works, which is regularly inspected by Council officers, would be required.

8.5 Interim Treatment Measures

The raingarden media bed should be protected throughout the civil and housing construction phases of the development. The floor of the raingarden should be lined with either a layer of turf or a sacrificial upper media bed layer and planting that would need to be replaced upon 80% completion of housing construction.

Upon 80% completion of housing construction within the catchment, the turf or sacrificial layer can be removed, replaced and the final media planting completed.

8.6 Long Term Management

Regular maintenance of the stormwater quality treatment devices is required to control weeds, remove rubbish, and monitor plant establishment and health. Some sediment build-up may occur on the surface of the raingardens and within the swales and may require removal to maintain the high standard of stormwater treatment.

Proper management and maintenance of the water quality control systems will ensure long-term, functional stormwater treatment. It is strongly recommended that a site-specific Operation and Maintenance (O & M) Manual is prepared for the system. The O & M Manual will provide information on the Best Management Practices (BMP's) for the long-term operation of the treatment devices. The manual will provide site-specific management procedures for:

- Maintenance of the GPT structures including rubbish and sediment removal.
- Management of the swales, raingardens (and other treatment devices that may be incorporated within the development) including plant monitoring, replanting guidelines, monitoring and replacement of the filtration media and general maintenance (i.e. weed control, sediment removal).

9 HYDROLOGIC ANALYSIS

The hydrologic analyses for this study were undertaken using the rainfall - runoff flood routing model XP-RAFTS (Runoff and Flow Training Simulation with XP Graphical Interface) (Willing, 1996 & 1994). The hydrologic analysis for the Riverside Oaks development was undertaken primarily to develop peak flow hydrographs for input to the flood model.

Detention basin sizing is based on 350m^3 of storage per hectare of development, which is generally a conservative estimate of the volume required to attenuate peak post development flows to existing levels for urban residential development. More detailed hydrologic modelling would be undertaken at the development application and detailed design stages to refine the size of detention basins required.

9.1 Sub-Catchments (Existing)

Sub-catchment areas contributing to the drainage system were determined from one (1) metre contour data over the site (derived from data obtained from the Land and Property Management Authority). Catchment boundaries for the local water courses are shown on Figure 9.1.

It is beyond the scope of this current assessment to determine a detailed breakdown of the Little Cattai Creek sub-catchment boundaries. The majority of the Little Cattai Creek catchment is included as a single node in the hydrology model. No hydrologic assessment of the Hawkesbury River has been undertaken.

The general layout of the existing case XP-RAFTS model is shown in Appendix A.

9.2 Sub-Catchments (Post Development)

The developed case sub-catchment areas contributing to the drainage system were determined for each of the Precinct areas for the purpose of estimating basin volumes only. Developed catchment boundaries within the Precincts have been determined on the best information available with regard to the Indicative Layout Plan and likely site grading and levels.

Final catchment boundaries and areas contributing to each detention basin and water quality device should be confirmed as part of the Development Approval process for each stage of the development. The developed case catchment boundaries for each Precinct within the Riverside Oaks development are shown on Figure 9.2.

9.3 Rainfall Data & XP-Rafts Parameters

9.3.1 Intensity-Frequency-Duration (I.F.D.)

Design rainfall intensity-frequency-duration (I.F.D.) data for the site were obtained using methods set out in Australian Rainfall and Runoff (A.R.R.) (1987). A summary of the rainfall intensities adopted in this study is provided in Table 9.1. The critical storm durations were determined using these values for each sub-catchment.

TABLE 9.1 – RIVERSIDE OAKS RAINFALL INTENSITIES

Storm Duration (min)	Rainfall Intensities (mm/hr) Average Recurrence Interval (ARI)	
	100	**PMF**
25	109	-
30	98.8	460
45	79	387
60	66.9	330
90	53.2	273
120	45	235
150	-	208
240	-	158
270	27.8	-
300	-	138
360	23.6	122
540	18.5	-
720	15.7	-
1440	10.6	-
2880	8.29	-

9.3.2 *XP-RAFTS Parameters*

The PERN (n) values and losses adopted for the catchments in the XP-RAFTS modelling are listed in Table 9.2.

TABLE 9.2 – ADOPTED XP-RAFTS PARAMETERS

Parameter	Catchment Condition	Adopted Value
Pern	Existing Pervious	0.05
	Existing Impervious	0.015
Losses		
Initial Loss	Pervious Catchment	15.0
Continuing Loss	Impervious Catchment	2.5
Initial Loss	Pervious Catchment	1.5
Continuing Loss	Impervious Catchment	0.0

Link lagging between sub-catchments was adopted throughout the hydrological model. The lag times adopted are generally based on a flow velocity of 2m/s.

9.4 Calibration

It is normal practice for flood routing models such as XP-RAFTS to be calibrated with historical rainfall and stream flow data for the catchment being investigated in order to produce the most reliable results. The model parameter values (in particular Bx) are adjusted so that the model adequately reproduces observed hydrographs. However, no stream flow records were available for the site and the default Bx value of 1.0 was adopted for the modelling.

9.5 Proposed Basin Volumes

A summary of the proposed detention basin volumes for the Riverside Oaks development are shown in Table 9.3.

TABLE 9.3 – SUMMARY OF DETENTION BASIN VOLUMES

Basin	Total Storage, m^3
BAS-A1	1400
BAS-A2	760
BAS-B1	630

The detention basin volumes are based on the provision of $350m^3$ of storage per hectare of development area. The basin volumes will be refined with more detailed modelling at the development application and detailed design stages in the future. The location of the detention basins are shown on Figure 8.1.

9.6 Peak Flow Hydrographs

Peak flow hydrographs were derived for the existing catchments for the 1% AEP event as well as the Probable Maximum Flood. A range of storm durations from 25 minutes to 72 hours were analysed to determine the critical storm duration for each sub-catchment. The peak flow hydrographs have been used in the flood model (refer to Section 10) to determine the peak flood levels adjacent to the development and to inform the Flood Evacuation Assessment.

9.7 Volume Management

Urban development results in an increase in impervious area, which in turn also results in an additional volume of stormwater runoff due to the inability for water to infiltrate as would have occurred under natural conditions. Detention basins are usually incorporated within urban development to attenuate peak post development flow rates so they do not exceed existing levels, however they will not reduce the additional volume of stormwater runoff generated by urban development.

A significant stormwater harvesting scheme or a facility that is able to reuse harvested stormwater, such as a golf course, are necessary to reduce urban development runoff volumes to natural condition levels.

For the Riverside Oaks development, there are opportunities to capture stormwater runoff and reuse it within the golf courses. A detailed water balance assessment is beyond the scope of this current assessment, however could be considered at the development application and detailed design stages.

In addition to possible stormwater reuse on the golf courses, a number of additional or alternate measures are possible that will assist in reducing the volume of urban runoff. At the residential lot level, rainwater tanks are expected to be provided with every dwelling. Captured stormwater can be reused both internally (toilet flushing, laundry) and externally (irrigation). The volume of the rainwater tank should be maximised to capture as much roof water runoff as possible. The area of roof draining to the rainwater tanks should also be maximised.

At the subdivision level a number of Water Sensitive Urban Design measures are proposed to assist in reducing the volume of stormwater runoff. Swales and raingardens will provide a small amount of volume reduction through evapotranspiration. Additional losses through infiltration in the base of these devices is potentially possible, however likely to be restricted due to the risk of salinity issues (to be determined in future geotechnical studies). Additional sources for reuse can also be explored at the future development application and detailed design stages.

10 FLOOD MODELLING

The 2D flood modelling of the water courses that run through and adjacent to the Riverside Oaks development was undertaken using TUFLOW (Two-Dimensional Unsteady Flow). TUFLOW is a computational engine that provides two-dimensional (2D) and one-dimensional (1D) solutions of the free-surface flow equations to simulate flood and tidal wave propagation (TUFLOW 2010). TUFLOW is specifically beneficial where the hydrodynamic behaviour in coastal waters, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be difficult to represent using traditional 1D network models.

All flows within the creeks and over the floodplains were modelled as 2D flows. A 2D model provides a better estimation of the effects of momentum transfer between in-bank and overbank flows and the energy losses due to meanders or bends in creeks. MapInfo, a GIS based software tool, was used for interrogating and plotting the results as well as creating the flood extents maps and the flood level difference maps.

Flood modelling for the existing and developed scenarios was undertaken to determine the flood affectation within the Riverside Oaks development, to establish flood planning levels and to assist in preparation of a flood evacuation strategy.

10.1 TUFLOW Model Set-Up and Modelling Assumptions

As with any flood modelling a number of assumptions are necessary to allow for the modelling process to proceed. The assumptions made within the TUFLOW model for the Riverside Oaks site are summarised below and are provided in more detail in Appendix B. The modelling has been completed using the TUFLOW release 2013-12-AD, which is the current version at the time of modelling.

10.2 Source and Accuracy of Survey Base

Survey information was sourced from the Land and Property Management Authority for use in the investigation. The data is considered reasonable for broad scale flood modelling, such as for the Hawkesbury River and Little Cattai Creek flood plains. Additional detailed survey should be undertaken at the development application stage and the flood model refined to confirm flood levels and depths of inundation at key locations within the development, such as the access roads.

Additional detail survey information was taken on the main access road following the exhibition period to confirm the level of serviceability and the extent of works required to raise it above the 1% AEP flood level. The existing case modelling was updated to include the detail survey information for the access road.

10.3 Regional Tailwater Conditions

The floodplain adjacent to the Riverside Oaks development is impacted by regional flooding from the Hawkesbury River in both the 1% AEP and PMF events. Details of the peak regional flood levels applicable to the Hawkesbury/Nepean Basin at the location of the Riverside Oaks site were provided by The Hills Shire Council are provided in Table 10.1 below. The variable 1% AEP stage hydrograph for the Hawkesbury River was also provided by The Hills Shire Council and incorporated into the flood model.

TABLE 10.1 – HAWKESBURY RIVER REGIONAL FLOOD LEVEL IMPACT AT CATTAI

Event	Flood Level (m AHD)
PMF	25.6
1% AEP	16.7 - 16.8

The proposed development Precincts are generally located above the 1% AEP flood level of RL 16.7 (for the northern arm of Little Cattai Creek and RL 16.8 for the southern arm, as shown on Plate 10.1. It is also proposed to raise the main access road to the southern Precincts above the 1% AEP flood level as part of the development. Seven (7) lots within Precinct B are shown to be slightly impacted by the regional 1% AEP event. Pad levels for the future dwellings can be located to provide the necessary 0.5 metre freeboard requirement for these lots.

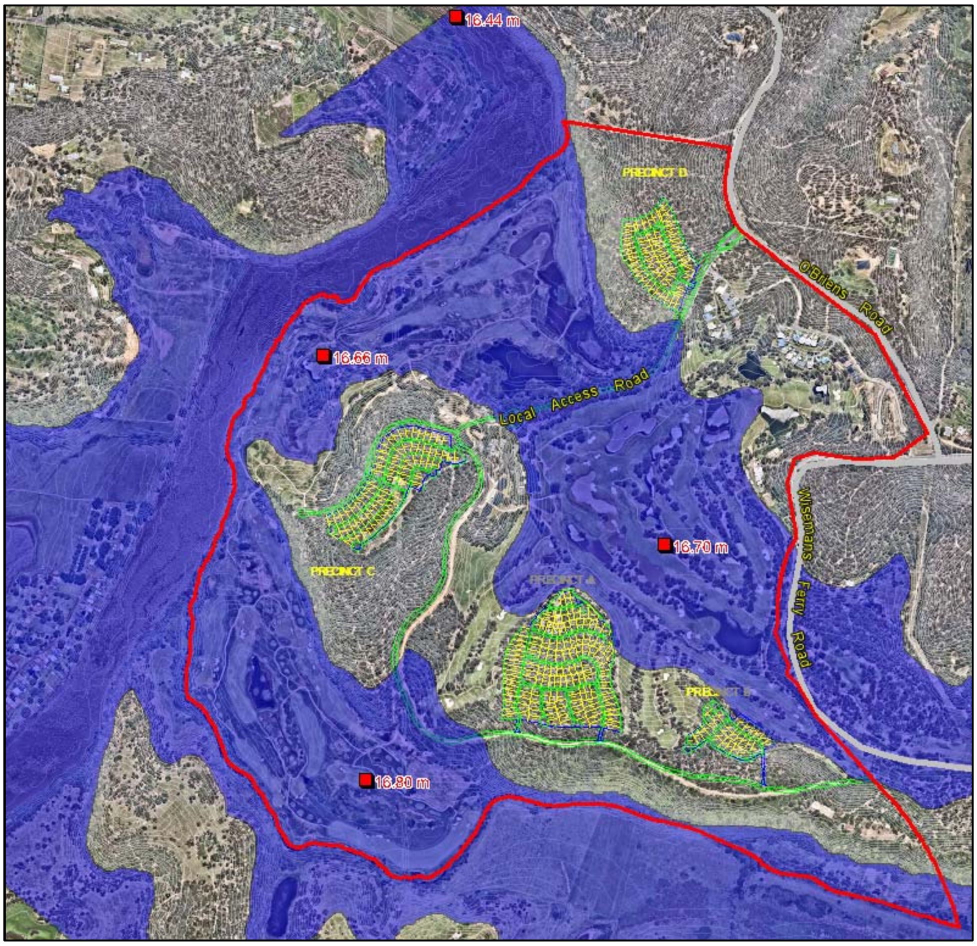


PLATE 10.1 – REGIONAL 1% AEP FLOOD LEVELS

The extents of the existing and developed case 1% AEP regional flood events are illustrated on Figures 10.2 and 10.9, respectively. The regional PMF flood event for the developed case is shown on Figure 10.11.

10.4 Hydraulic Structures

There are two (2) existing road crossings below the regional 1% AEP flood levels within or adjacent to the site. The first crossing is the existing access road to the club house off O'Briens Road. This crosses the floodplain at a minimum level of approximately RL 14.26. This road is to be raised above the 1% AEP flood level as part of the proposed development. New culverts will be provided to allow conveyance of floodwater to either side when the road is raised and have been included in the flood modelling. The second crossing is at Wisemans Ferry Road, just to the east of the Riverside Oaks site. The level at Wisemans Ferry Road is approximately RL 7.0. Given that the Wisemans Ferry Road crossing is low in relation to the flood level of major flows and the existing culvert is expected to have limited capacity, it has been conservatively excluded from the modelling.

The level of the access road has been determined from field survey, while the level at Wisemans Ferry Road is derived from elevation data obtained from the Land and Property Management Authority.

10.5 Overland Flow Paths

The Hills Shire Council have previously undertaken a broad scale creek and overland flow path assessment. The creeks and overland flow paths identified by Council within the Riverside Oaks development are shown below on Plate 10.2.

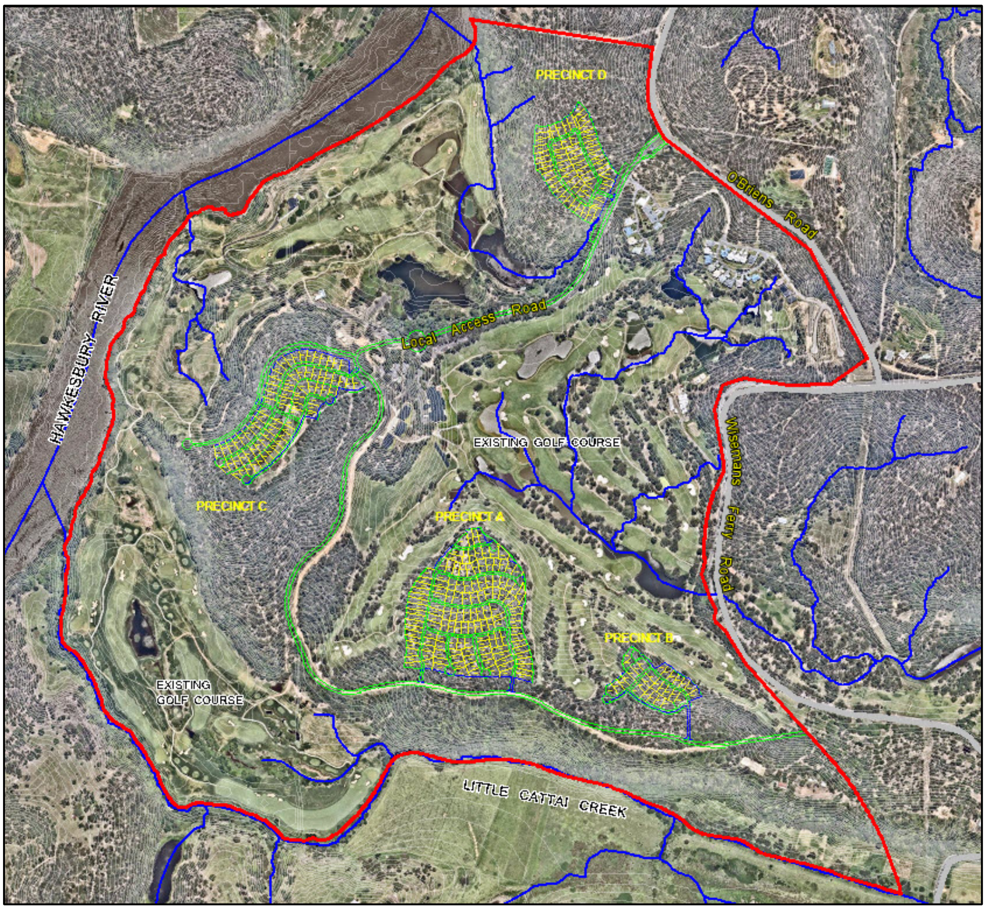


PLATE 10.2 – THE HILLS SHIRE COUNCIL CREEK AND OVERLAND FLOW MAPPING

The mapping confirms that the proposed Riverside Oaks development is not affected by overland flow paths.

10.6 Flood Extent Mapping

Flood extent, depth and level mapping has been completed for the 1% AEP and PMF events under existing and developed conditions with and without the impact of regional 1% AEP tailwater. Separate hazard classification mapping was also completed for the 1% AEP and PMF events.

The flood depth, extent and level mapping for the existing case is shown in Figures 10.3 – 10.8.

The flood mapping indicates that the access road between the existing club house and O'Briens Road is located above the 1% AEP local flood level. Additional detailed survey should be undertaken at the development application stage to confirm the levels in this area (and the site generally) and update the flood modelling accordingly.

Flood extent, depth and level mapping has also been completed for the 1% AEP event under developed conditions with the regional 1% AEP tailwater to confirm the impact of raising the main access road and determine the preliminary size of culverts required to allow regional floodwater to pass to either side of the road.

The flood depth, extent and level mapping for the developed case is shown in Figures 10.9 – 10.13.

10.6.1 Hazard Categories

Hazard can be considered to be a measure of the impact that floodwater may have on both people and/or property. Hazard mapping was undertaken for the 1% AEP and PMF events from the TUFLOW runs completed as part of this study.

Hazard grids are developed directly out of the TUFLOW model and have been used to produce the Hazard plans presented in this report. The floodplain has been divided into three Hazard categories (consistent with the NSW Floodplain Development Manual (FDM, 2005) as follows.

- Low Hazard
- Transitional Hazard
- High Hazard

Hazards maps are useful to obtain an appreciation of the relative depth and velocity of floodwater within a locality and are a critical element in determining:

- The locations of critical public infrastructure such as hospitals and aged care facilities.
- The areas in the floodplain for which public safety is "at risk".
- Assist in the Flood Emergency response and Evacuation Management process.

The existing case flood hazard mapping for the 1% AEP event is shown on Figure 10.5 for the scenario with no regional tailwater impacts and Figure 10.6 with a 1% AEP regional tailwater. The flood hazard mapping for the existing PMF event is shown on Figure 10.7 for the scenario with no regional tailwater impacts and Figure 10.8 for the regional event.

The developed case flood hazard mapping for the 1% AEP event is shown on Figure 10.12 with a 1% AEP regional tailwater. The flood hazard mapping for the existing PMF event is shown on Figure 10.13 for the regional event.

10.7 Flood Planning Levels

The flood planning level is defined as the flood level for a specific AEP plus an allowance for freeboard. For the Riverside Oaks development, the flood planning level is the 1% AEP event with 0.5 metre freeboard. The peak flood levels for the Riverside Oaks site are dictated by regional flooding in the Hawkesbury River. That is, the regional flood level in the Hawkesbury River is higher than local flooding on Little Cattai Creek.

The regional flood level applicable to the Cattai locality varies from RL 16.7 to RL 16.8 for the 1% AEP event. As the proposed development Precincts are contained close to the top of the subcatchment boundaries, there are no other local water courses that may impact on the development. Therefore, the recommended Flood Planning Level for the development varies from RL 17.2 to RL 17.3, depending on whether it fronts the north or south arm of Little Cattai Creek.

10.8 Flood Evacuation Assessment

Part of the Riverside Oaks development Precincts are impacted by the regional PMF event. The main access road to the development Precincts within the southern portion of the site is also impacted by regional 1% AEP flooding as well as the regional PMF. A Flood Evacuation Assessment has been undertaken by Molino Stewart, which is included as Appendix C of this report. The findings of the assessment are summarised as follows:

- The residents of the proposed development are able to be evacuated within the available time for Hawkesbury River flooding.
- Even if local creek flooding coincides with the Hawkesbury River flooding, the evacuation time surplus of 2.3 hours (minimum) suggests that a 1.5 hour interruption from local flooding could be accommodated within the evacuation process.
- Local flooding only events in very rare events (> 0.2% AEP) isolate the population, but the short duration suggests that the period of isolation would be tolerable.
- The main access road to the three (3) southern Precincts, as well as the access road between Precincts A and C are at risk, based on the available elevation data. It is proposed that the main access road between Precincts C and D be raised above the 1% AEP regional flood level. It is also proposed that an alternate access track be provided between Precincts A and C, located above the 1% AEP regional flood level, to allow flood free access/egress. The indicative location of the access track is shown on Figure 10.9.
- Gates are to be installed to obstruct drivers from entering flooded roads.
- A flood warning/evacuation system is to be developed including a local water level recorder that issues SMS when pre-determined levels are reached and automatic dialling technology to rapidly issue residents with evacuation warnings or orders.
- A flood education program is to be developed.
- A detailed flood emergency plan is to be prepared.

An Emergency Management Considerations letter was prepared by Molino Stewart following the exhibition phase, which is included in Appendix C.

11 WATER QUALITY ANALYSIS

The stormwater quality analysis for this study was undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). This water quality modelling software was developed by the Cooperative Research Centre (CRC) for Catchment Hydrology, which is based at Monash University and was first released in July 2002. Version 6 was adopted for this study.

The model provides a number of features relevant for the development:

- It is able to model the potential nutrient reduction benefits of gross pollutant traps, constructed wetlands, grass swales, bio-retention systems, sedimentation basins, infiltration systems, ponds and it incorporates mechanisms to model stormwater re-use as a treatment technique;
- It provides mechanisms to evaluate the attainment of water quality objectives;

The MUSIC modelling was undertaken to demonstrate that the water cycle management system proposed for the Precinct will result in reductions in overall post-development pollutant loads and that concentrations being discharged from the Precinct comply with the designated target objectives.

The Office of Environment and Heritage have established default parameters for use in MUSIC models to represent the generation of various pollutants by different land uses. A MUSIC model representing the proposed Riverside Oaks development was prepared to demonstrate compliance with the recommended post development annual load reductions (DECCW, 2006).

11.1 Catchments

A simplistic MUSIC model was established for the proposed stormwater management system for the Riverside Oaks development. The extent of catchment to each proposed water quality element is shown on Figure 9.2. The extent of the model is shown in Plate 11.1 with the general arrangements of the MUSIC model included in Appendix D.

In accordance with The Hills Shire Council Design Guidelines (THSC, 2011) an overall fraction impervious of 0.80 was adopted (new residential lot including half road) for the proposed development areas.

A simplistic model was prepared for the proposed development, combining all land use areas (roofs, roads, other impervious and pervious area) into a single urban node. This is a conservative approach as it does not account for the benefit of rainwater tanks and varying pollutant load concentrations within the different land use areas. This modelling approach is considered appropriate at the planning stage of development for sizing water quality devices. More detailed modelling can be undertaken at the development application and detailed design stages to further refine the device sizes.

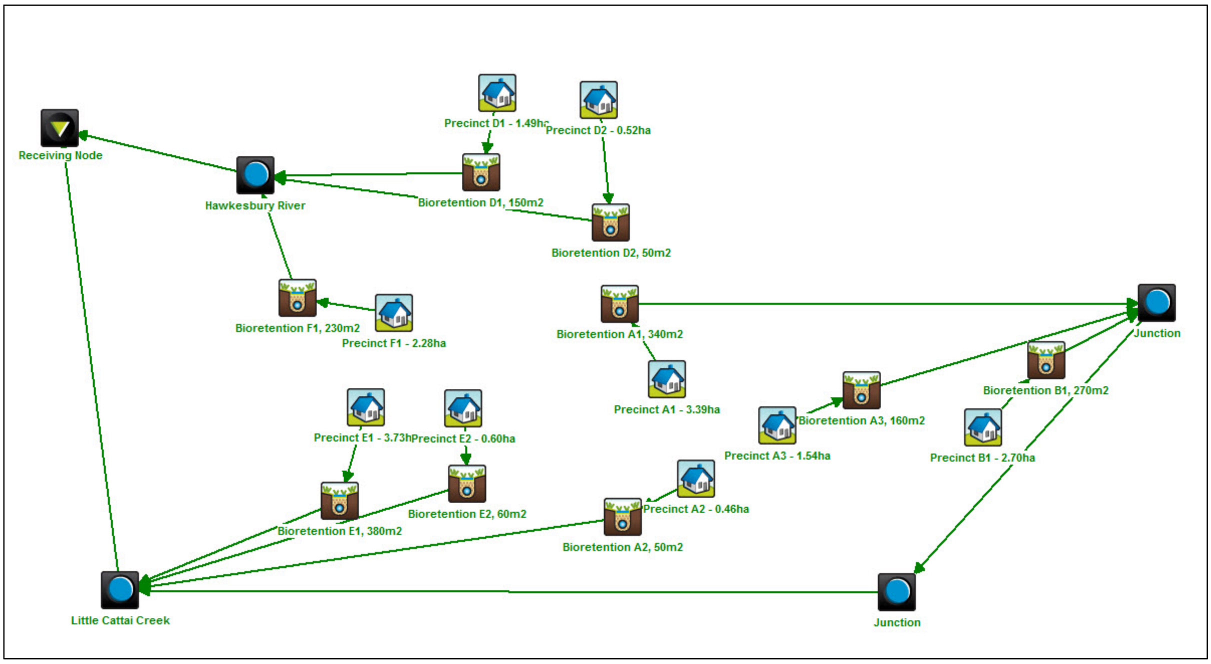


PLATE 11.1 – RIVERSIDE OAKS MUSIC MODEL LAYOUT (9856MU1.SQZ)

11.1.1 Swales

It is expected that the access road linking the Riverside Oaks Precincts would be rural in nature with stormwater runoff from the pavement discharging to road side swales, where grades permit. Given the rural nature of the area and expected low volume of traffic (local residents only), the pollutant runoff from the access road is expected to be minor and treated by the swales.

The general location of the proposed swales is shown on Figure 8.1. Consideration of additional swales within the development is encouraged wherever possible and practical at subsequent development application and detailed design stages.

11.1.2 Bio-Retention Raingardens

Approximately ten (10) co-located and independent raingardens are proposed throughout the Riverside Oaks development. The proposed preliminary development layout facilitates the provision of co-located raingardens within the detention basins as well as independent devices where no detention basins are proposed. Wherever possible the co-located raingardens are located off-line from the major inflows into the detention basins to limit scouring of the filter media; preserve the vegetation; and minimise the re-mobilisation of pollutants.

The media beds of the raingardens are typically 500 - 600mm deep with an average particle size of 0.5 mm, a minimum hydraulic conductivity of 100 mm/hr and minimum depth of storage above the media of 300 mm. A discharge control structure can be configured (during the Development Application process) to promote extended detention times if required.

It is assumed that flows in excess of the 3 month ARI storm event will bypass the raingardens. It is also assumed that trash and gross sediments will be effectively removed prior to entering the raingardens by the proposed GPT units. In order to reduce the ongoing maintenance requirements for the raingardens, the GPTs should be selected on the basis that they intercept, as a minimum, 90% of the sediment loads greater than 0.15 mm diameter.

Treatment is attained by detaining flows to promote sedimentation, direct filtration of particulate matter and nutrient stripping by bio-films which establish on the surface of the media bed and within the gravel layer. The organic sandy loam bed and plant system minimises evaporation losses and the raingarden will be constructed with an impermeable barrier to prevent seepage losses and to avoid groundwater salinity impacts.

The location and size of the proposed raingardens are shown on Figure 8.1. The general features and configuration of the raingardens for the Riverside Oaks development, as modelled in MUSIC, are detailed in Table 11.1.

TABLE 11.1 – RAINGARDEN GENERAL FEATURES AND CONFIGURATIONS

Raingarden Name	Total Receiving Catchment Area (ha)	Bioretention Area (m^2)
RG-A1	4.00	400
RG-A2	2.16	220
RG-A3	0.59	60
RG-A4	0.94	95
RG-B1	1.80	180
RG-C1	1.73	170
RG-C2	1.93	190
RG-C3	1.48	150
RG-D1	0.65	65
RG-D2	2.58	260

The raingarden treatment areas are approximately 1.0% of the catchment that drains to them. Details of the expected removal performance together with the general modelling parameters and rainfall data used in the MUSIC modelling are provided in Appendix D.

11.2 Pollutant Load Estimates

Total annual pollutant load estimates were derived from the results of a MUSIC model based on a stochastic assessment of the developed site incorporating the proposed water quality treatment system. The estimated annual pollutant loads and reductions for TSS, TP and TN for the proposed Riverside Oaks development are presented in Tables 11.2 – 11.4.

TABLE 11.2 – SUMMARY OF ESTIMATED MEAN ANNUAL POLLUTANT LOADS & REDUCTIONS - TSS

Location	Total Catchment Source Loads (kg/yr)	Minimum Reduction Required (kg/yr)	Total Residual Load from Catchment (kg/yr)	Total Reduction Achieved (kg/yr)	Total Reduction Achieved (%)
Little Cattai Creek	10,600	9,010	1,510	9,090	85.8%
Hawkesbury River	9,360	7,956	1,360	8,000	85.5%
Total Development	19,900	16,915	2,870	17,030	85.6%

TABLE 11.3 – SUMMARY OF ESTIMATED MEAN ANNUAL POLLUTANT LOADS & REDUCTIONS - TP

Location	Total Catchment Source Loads (kg/yr)	Minimum Reduction Required (kg/yr)	Total Residual Load from Catchment (kg/yr)	Total Reduction Achieved (kg/yr)	Total Reduction Achieved (%)
Little Cattai Creek	17.4	11.3	5.75	11.7	67.0%
Hawkesbury River	15.1	9.82	5.02	10.1	66.8%
Total Development	32.4	21.1	10.8	21.6	66.7%

TABLE 11.4 – SUMMARY OF ESTIMATED MEAN ANNUAL POLLUTANT LOADS & REDUCTIONS - TN

Location	Total Catchment Source Loads (kg/yr)	Minimum Reduction Required (kg/yr)	Total Residual Load from Catchment (kg/yr)	Total Reduction Achieved (kg/yr)	Total Reduction Achieved (%)
Little Cattai Creek	128	57.6	61.0	67.0	52.3%
Hawkesbury River	114	51.3	53.9	60.1	52.7%
Total Development	243	109	115	128	52.7%

11.3 Discussion of Modelling Results

Tables 11.2 – 11.4 provide a summary of the total load of pollutants anticipated to discharge from the site after the proposed development. The performance of the proposed water quality management strategy for the Riverside Oaks development, as determined through a stochastic MUSIC assessment, is summarised in Tables 11.3 – 11.5. The results demonstrate that the proposed strategy achieves the reduction targets specified by the Office of Environment and Heritage.

12 SUMMARY & CONCLUSION

The Stormwater and Flood Management Strategy for the Riverside Oaks development has been prepared to inform the Precinct Planning process and support the rezoning process for the site. The strategy has been prepared to conform with the statutory requirements and industry best practice for stormwater management in this catchment.

The Water Cycle and Flood Management Strategy consists of a treatment train consisting of on lot treatment, street level treatment and subdivision / development treatment measures. The structural elements proposed for the development consist of:

- Gross Pollutant Traps at each stormwater discharge point.
- Roadside swales along the access road to the development Precincts.
- Ten (10) proposed bio-retention raingardens of total area 1,790m^2.
- Three (3) proposed detention basins of approximate total volume 2,790 m^3.

Provision of the proposed water quality treatment devices within the development will ensure that the post development stormwater discharges will meet the Office of Environment and Heritage's water quality objectives for the Riverside Oaks development.

The provision of WSUD elements within the Riverside Oaks development will assist in minimising the impact of urbanisation on the waterway stability of Little Cattai Creek and the Hawkesbury River.

Preliminary detention basin sizing has been undertaken for the catchments that drain toward Wisemans Ferry Road to ensure that peak post development flows at the road do not exceed existing levels. Detention basins have not been provided for the developed catchments that drain directly to Little Cattai Creek or the Hawkesbury River. It is considered beneficial to not attenuate flows from these catchments to avoid peak discharges from the Riverside Oaks coinciding with the larger peak flows from upstream catchments.

An existing case hydrology model has been prepared for the local catchments within the Riverside Oaks and the Little Cattai Creek catchment for the purpose of extracting peak flow hydrographs for use in the flood model.

The detailed flood assessment completed for the strategy has demonstrated that flood levels adjacent to the proposed Riverside Oaks development are dictated by regional flooding. The Hills Shire Council confirmed that the 1% AEP regional flood level adjacent to the site is RL 16.7 on the north arm of Little Cattai Creek and RL 16.8 on the southern arm of Little Cattai Creek. The flood planning level for the development is therefore varies from RL 17.2 to RL 17.3, which is the regional 1% AEP flood level plus 0.5 metres freeboard.

The flood evacuation assessment has highlighted a some issues that will need to be addressed, which are summarised as:

- The residents of the proposed development are able to be evacuated within the available time for Hawkesbury River flooding.
- Even if local creek flooding coincides with the Hawkesbury River flooding, the evacuation time surplus of 2.3 hours (minimum) suggests that a 1.5 hour interruption from local flooding could be accommodated within the evacuation process.

- Local flooding only events in very rare events (> 0.2% AEP) isolate the population, but the short duration suggests that the period of isolation would be tolerable.
- The main access road to the three (3) southern Precincts, as well as the access road between Precincts A and C are at risk, based on the available elevation data. It is proposed that the main access road between Precincts C and D be raised above the 1% AEP regional flood level of RL 16.7. It is also proposed that an alternate access track be provided between Precincts A and C, located above the 1% AEP regional flood level, to allow flood free access/egress. The indicative location of the access track is shown on Figure 10.9.
- Gates are to be installed to obstruct drivers from entering flooded roads.
- A flood warning/evacuation system is to be developed including a local water level recorder that issues SMS when pre-determined levels are reached and automatic dialling technology to rapidly issue residents with evacuation warnings or orders.
- A flood education program is to be developed.
- A detailed flood emergency plan is to be prepared.

The proposed Stormwater and Flood Management Strategy for the developed site provides a basis for the detailed design and development of the site to ensure that the environmental, urban amenity, engineering and economic objectives for stormwater management and site discharge are achieved.

The Stormwater and Flood Management Strategy proposed for the Riverside Oaks development site is functional; delivers the required technical performance; lessens environmental degradation and pressure on downstream ecosystems and infrastructure; and provides for a 'soft' sustainable solution for stormwater management within the release area.

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14 GLOSSARY OF TERMS

12D Model is a powerful terrain modelling, surveying and civil engineering software package used to develop the underlying surface for the 2D modelling.

Airborne Laser Survey (ALS) is a technique for obtaining a definition of the surface elevation (ground, buildings, power lines, trees, etc.) by pulsing a laser beam at the ground from an airborne vehicle (generally a plane) and measuring the time taken for the laser beam to return to a scanning device fixed to the plane. The time taken is a measure of the distance which, when ground truthed, is generally accurate to + 150mm.

Average Recurrence Interval (ARI) means the average statistical interval (in years) between occurrences of floods, storms and flows of a particular magnitude.

Australian Rainfall and Runoff (AR&R) refers to the current edition of Australian Rainfall and Runoff published by the Institution of Engineers, Australia.

CatchmentSIM is a 3D-GIS application specifically tailored to hydrology based applications. CatchmentSIM is used to delineate a catchment, break it up into sub catchments, determine their areas and spatial topographic attributes and analyse each sub catchment's hydrologic characteristics to provide insight into the rainfall response of various catchments and the resultant assignment of hydrologic modelling parameters.

Council refers to The Hills Shire Council

Digital Terrain Model (DTM) is a spatially referenced three-dimensional (3D) representation of the ground surface represented as discrete point elevations where each cell in the grid represents an elevation above an established datum.

Floodplain Development Manual (FDM) and Guidelines (April 2005), the FDM is a document issued by DECCW that provides a strategic approach to floodplain management. The guidelines have been issued by the NSW DoP to clarify issues regarding the setting of FPL's.

Hydrograph is a graph that shows how the stormwater discharge changes with time at any particular location.

Hydrology The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

J. Wyndham Prince Pty Ltd (JWP) Consultant Civil Infrastructure Engineers and Project Managers undertaking these investigations

MUSIC is a modelling package designed to help urban stormwater professionals visualise possible strategies to tackle urban stormwater hydrology and pollution impacts. MUSIC stands for Model for Urban Stormwater Improvement Conceptualisation and has been developed by Cooperative Research Centre (CRC),

Peak Discharge is the maximum stormwater runoff that occurs during a flood event3

Probable Maximum Flood (PMF) is the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends." largest flood that could be

Triangular Irregular Network (TIN) is a technique used in the created DTM by developing a mass of interconnected triangles. For each triangle, the ground level is defined at each of the three vertices, thereby defining a plane surface over the area of the triangle

TUFLOW is a computer program that provides two-dimensional (2D) and one dimensional (1D) solutions of the free surface flow equations to simulate flood and tidal wave propagation. It is specifically beneficial where the hydrodynamic behaviour, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be awkward to represent using traditional 1D network models.

XP-RAFTS runoff routing model that uses the Laurenson non-linear runoff routing procedure to develop a subcatchment stormwater runoff hydrograph from either an actual event (recorded rainfall time series) or a design storm utilising Intensity-Frequency-Duration data together with dimensionless storm temporal patterns as well as standard AR&R 1987 data.

APPENDIX A – Hydrologic Modelling Information

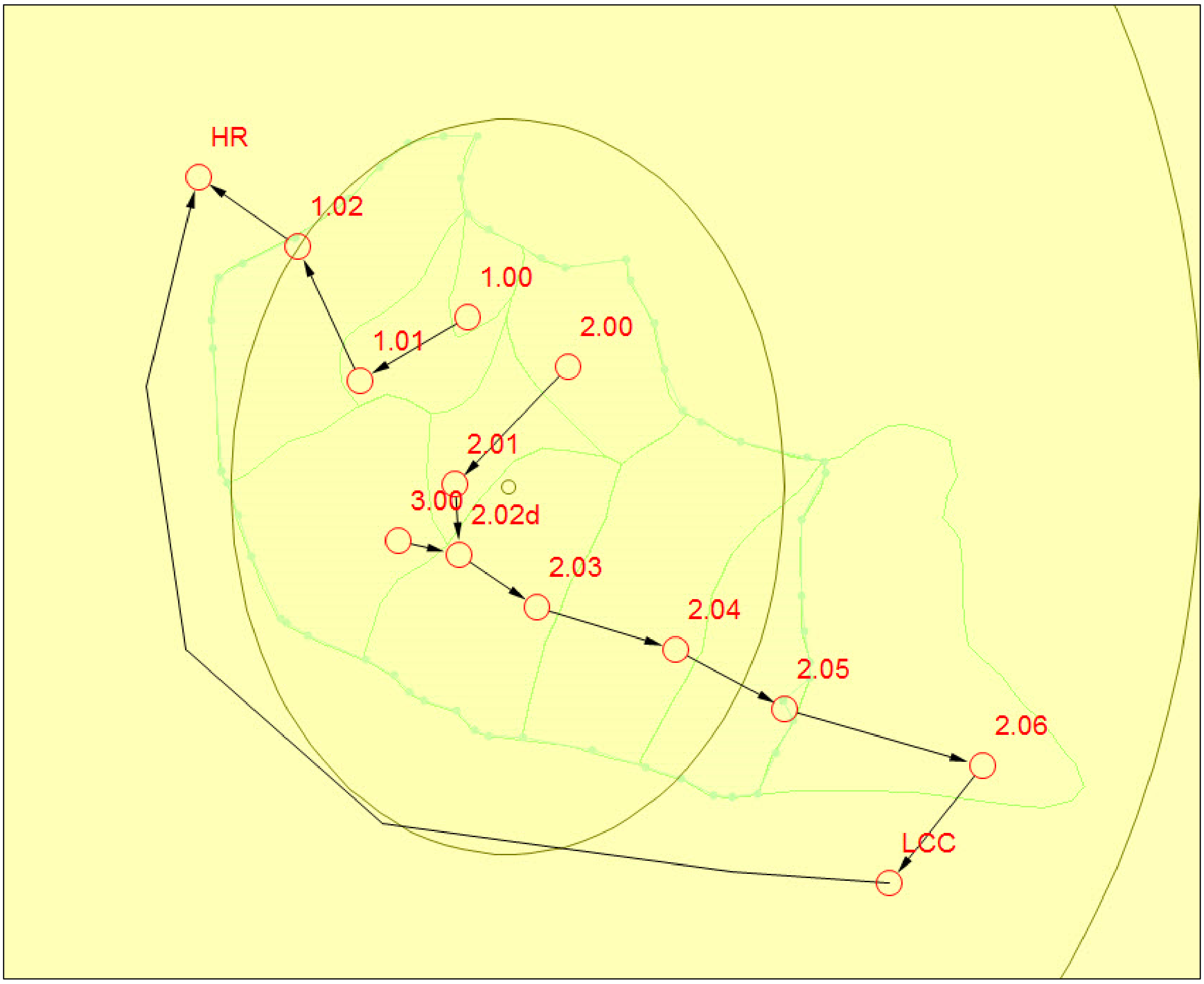

Plate A.1 – Local Catchment XP-RAFTS Layout

APPENDIX B – TUFLOW Modelling Assumptions

DIGITAL TERRAIN MODEL (DTM)

The terrain for the Riverside Oaks TUFLOW model consists of the survey data obtained from the Land and Property Management Authority.

A grid size of 4 m was adopted in the TUFLOW model. This grid size was found to be a reasonable balance between computing time and flooding definition.

Catchment Roughness

One of the advantages of using TUFLOW for the hydraulic assessment is that different landuse can be assigned different roughness factors. For the Riverside Oaks model the following roughness assumptions are summarised in the below table.

TABLE B.1 – TUFLOW MATERIAL ROUGHNESS

Material ID	Mannings 'n'	Description
1	0.035	Floodplain high grass
2	0.05	Light vegetation
3	0.08	Medium Vegetation
4	0.10	Dense Vegetation
5	0.03	Dams with vegetation or short grass
7	0.03	River

.

BOUNDARY CONDITIONS

The boundary conditions adopted in the TUFLOW model are as follows:

- LOCAL INFLOWS – Local inflow hydrographs were included in the model (as SA layers) at locations representing various subcatchments within the Riverside Oaks site.
- DOWNSTREAM – The Riverside Oaks site is affected by the regional flood events below the 1% AEP event. Two scenarios have therefore been considered, being no tailwater and a 1% AEP variable regional tailwater (as provided by The Hills Shire Council).

APPENDIX C – Flood Evacuation Assessment & Emergency Management Considerations

MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

17 February 2015

Mr Daniel Gardiner
Senior Water Resources Engineer
J Wyndham Prince
PO Box 4366
PENRITH WESTFIELD NSW 2750

Dear Daniel

Re: Riverside Oaks Resort Residential Development Flood Evacuation Issues

1. Introduction

Gateway planning approval has been obtained for the rezoning of part of the land associated with Riverside Oaks Resort, Cattai, to permit up to 300 dwelling houses. This approval has been granted conditional on several issues being satisfactorily addressed, including flood management and evacuation egress.

This report evaluates the evacuation capacity of the site and recommends several flood safety provisions to satisfactorily manage the flood risk.

2. Proposed Development

Figure 1 shows the distribution of the 300 dwelling houses. Four distinct residential precincts are proposed, numbered ‘A’ to ‘D’. The breakdown of the 300 residential lots across these four areas is summarised in Table 1. The existing internal road will form the primary route for access to and egress from each of the four precincts.

Table 1 – Proposed new residential areas at Riverside Oaks Resort

Residential precinct	No. of lots	Flood Emergency Response Classification (PMF) (based on Hawkesbury River flooding)
A	135	High Flood Island (part subject to inundation)
B	29	High Flood Island (part subject to inundation)
C	77	High Flood Island
D	59	Indirectly Affected Area
Total	300	

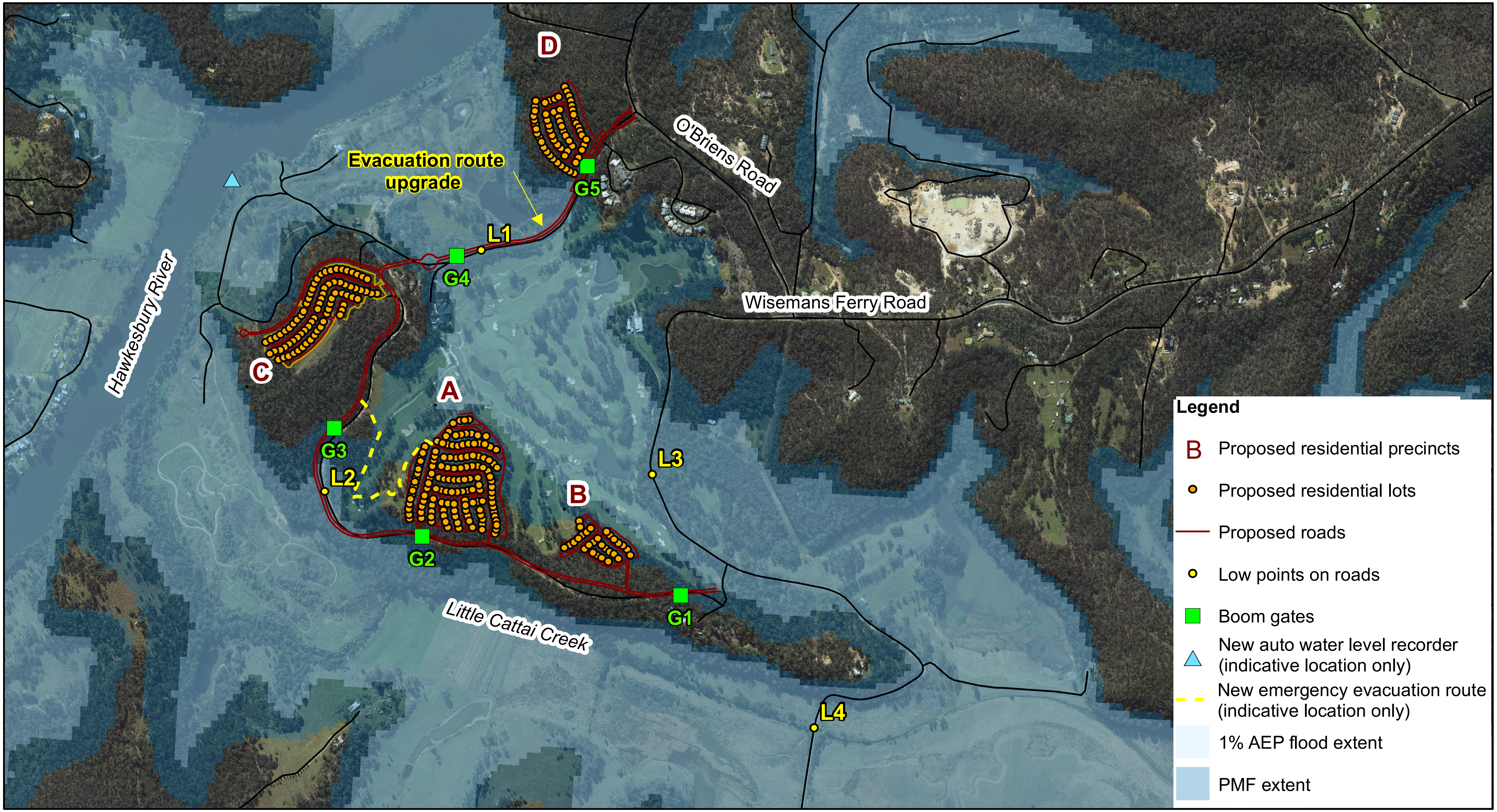

Figure 1 - Flood risk considerations and proposed safety provisions, RIverside Oaks Resort

MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

Date: 13/02/2015	Checked By: S.Y	Job No: 589

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3. Flood Risk Overview

Riverside Oaks Resort and potential flood evacuation routes from the Resort are subject to flooding from local creeks (including unnamed minor watercourses incorporated into the existing golf course and Little Cattai Creek) and from the Hawkesbury River, either independently or in combination.

3.1 Local Creek Flooding

J. Wyndham Prince has conducted flood modelling of local creeks for the current project. The internal road near low-point '1' on Figure 1 is close to a watershed between two minor watercourses, one of which flows in a southeast direction to join Little Cattai Creek, while the other flows in a northwest direction to the Hawkesbury River. Given its location near a small watershed, modelling suggests that local flooding in a 500 year ARI event is not expected to cut this evacuation route.

Little Cattai Creek is located on the southern side of Riverside Oaks Resort. This creek produces a peak flow of about 900 m^3/s for the 100 year ARI event (based on a critical storm duration of 2 days) and about 6,400 m^3/s for the PMF (based on a critical storm duration of 2 hours) at its junction with the Hawkesbury River.

In the PMF, a significant diversion of flow from Little Cattai Creek occurs which is not observed in the 500 year ARI event. The PMF scenario sees flow extending in a northwest direction *up* the minor tributary (that typically carries flow *towards* Little Cattai Creek), through the existing golf course, to the Hawkesbury River. A local event PMF hydrograph at the internal road crossing near low-point '1' shows the flood peaking 2 hours after the onset of rain. The flood would recede within about 2 hours.

The extent of inundation in the local creek PMF event completely surrounds the proposed residential areas 'A' to 'C', which would therefore be considered 'High Flood Islands' according to the Flood Emergency Response Classifications described in the relevant *Floodplain Risk Management Guideline* (NSW Department of Environment and Climate Change [DECC], 2007). The short duration of flooding in such a rare event suggests that a brief and very infrequent period of isolation due to *local* flooding would be tolerable.

3.2 Hawkesbury River Flooding

Information about the threat of Hawkesbury River flooding to Riverside Oaks Resort is derived from regional investigations.

Hawkesbury River design flood levels adjacent to Riverside Oaks Resort are listed in Table 2, together with the equivalent levels for the Windsor gauge upstream.

Inundation extents for the 100 year Average Recurrence Interval (ARI) and Probable Maximum Flood (PMF) Hawkesbury River events are plotted on Figure 1.

Based on the PMF extent, Flood Emergency Response Classifications for each of the four proposed residential precincts are stated in Table 1 (after DECC, 2007).

Table 2 – Design Hawkesbury River flood levels, Windsor and Riverside Oaks Resort, Cattai

Average Recurrence Interval (ARI)	**Windsor gauge** (m AHD) [a]	(m) [b]	**Riverside Oaks Resort, Cattai** (m AHD) [a]
5 year	10.4	10.25	8.7
10 year	12.2	12.05	10.9
20 year	13.7	13.55	12.6
50 year	15.8	15.65	14.7
100 year	17.3	17.15	16.2 (16.6-16.8)[c]
200 year	18.3	18.15	17.2
500 year	19.6	19.45	18.6
1000 year	20.4	20.25	19.5
2000 year	22.1	21.95	21.2
5000 year	23.8	23.65	23.0
PMF	26.2	26.05	25.5

Notes:

[a] These flood levels are extracted from recent, regional flood modelling prepared by WMAwater. The Hills Shire prefers information sourced from the *Flood Hazard Definition Tool* (FHDT), which is based on earlier modelling. The FHDT provides levels only for the 100 year, 200 year, 500 year and 1000 year ARI and PMF events.

[b] Windsor Bridge gauge zero is 0.15m AHD (source: *Hawkesbury/Nepean Flood Emergency Sub Plan*, SEMC, 2005, p.56).

[c] The FHDT puts the 100 year ARI flood level at Riverside Oaks at about 16.6-16.8m AHD.

Precincts ‘A’ and ‘B’ are partially inundated in the PMF, and the evacuation route would be cut at two locations, resulting in isolation. Evacuation prior to isolation is recommended given the flood duration in such an event could exceed three days.

Precinct ‘C’ is not inundated in the PMF, but its evacuation route would be lost, resulting in isolation. Evacuation prior to isolation is recommended given the flood duration in such an event could exceed three days.

Apart from two lots, precinct ‘D’ is not inundated in the PMF, and evacuation routes are not known to be flood-affected. Since this is only an indirectly affected area (through possible disruption to utilities), the 59 dwellings in this precinct are discounted from the local evacuation capacity assessment.

Flood evacuation for Hawkesbury River flooding is facilitated to some degree by the catchment response times. It takes 16 hours for water to travel from Warragamba Dam to Windsor. The Bureau of Meteorology is committed to providing 9 hours’ warning time of a reasonably accurate prediction for Windsor. Since Cattai is located downstream of Windsor, it is expected that there would be a similar or slightly longer catchment response time for the Hawkesbury River at Riverside Oaks Resort.

4. Flood Evacuation Routes

Evacuation traffic from the proposed residential areas at Riverside Oaks Resort could follow one of three routes:

(1) North along the internal road through the Resort to the main entrance, southeast along O'Briens Road, and generally northeast along Wisemans Ferry Road to Old Northern Road;

(2) East along the internal road through the Resort to the southern (Wisemans Ferry Road) entrance, and generally northeast along Wisemans Ferry Road to Old Northern Road;

(3) Generally southeast along Wisemans Ferry Road to Halcrows Road, Cattai Ridge Road and Old Northern Road.

The flood immunity of each route is considered in Table 3, with the low-point locations depicted in Figure 1.

Table 3 – Assessment of low-points along potential evacuation routes

Evacuation route	**Riverside Oaks Resort Evacuation Routes Low-points**			**Windsor Gauge**	
	Location (see Figure 1)	**Level** (m AHD)	**Approx. ARI at which flooded** [a]	**Level** (m AHD)	**Level** (m) [b]
1) North along internal road and northeast along Wisemans Ferry Road	(L1): Internal road between precinct 'C' and O'Briens Rd entrance	14.2	40 yr	15.32	15.17
	(L2): Internal road between precincts 'A' and 'C'	9.3	6 yr	10.86	10.71
2) East along internal road and northeast along Wisemans Ferry Road	(L3): Wisemans Ferry Rd between southern entrance and O'Briens Rd	7.9	4 yr	9.70	9.55
3) Southeast along Wisemans Ferry Road	(L4): Wisemans Ferry Rd near Little Cattai Creek	4.6	1-2 yr	7.00	6.85

Notes:

[a] Based on regional flood modelling for the Hawkesbury River undertaken by WMAwater.

[b] Windsor Bridge gauge zero is 0.15m AHD (source: *Hawkesbury/Nepean Flood Emergency Sub Plan*, SEMC, 2005, p.56).

A critical low-point is located on the evacuation route along the internal road north of precinct 'C', surveyed to a level of 14.26m AHD (low-point 'L1').

J. Wyndham Prince's local creek modelling suggests that low-point 'L1' could be subject to very shallow inundation (<100mm) in the 100 year and 500 year ARI events, but is still expected to be trafficable. The PMF scenario indicates that floodwater from Little Cattai Creek would flow through the golf course and probably cut this road.

Recent, regional flood modelling indicates that low-point ‘L1’ would be free of Hawkesbury River flooding up to about a 40 year ARI event. Since this potential evacuation route offers most immunity, evacuation from the high flood islands to the south of this point (i.e. precincts ‘A’ to ‘C’) would need to be completed prior to loss of this route.

Another important low-point is located on the evacuation route along the internal road between precincts ‘A’ and ‘C’, at about 9.3m AHD (low-point ‘L2’).

J. Wyndham Prince’s local creek modelling suggests that low-point ‘L2’ is not inundated in the 100 year and 500 year ARI events, but would be flooded in the PMF.

Regional flood modelling indicates that low-point ‘L2’ offers immunity only up to about the 6 year ARI Hawkesbury River flood event. Unless this road is upgraded or a special vehicular evacuation route is constructed, residential areas ‘A’ and ‘B’ could be relatively frequently isolated.

Evacuation through the southern entrance to Riverside Oaks Resort, then north along Wisemans Ferry Road, is compromised by low-point ‘L3’, which is expected to be inundated by Hawkesbury River flooding more frequently than once in 5 years on average. Since this evacuation route is inferior to the internal road northbound, it is not considered further in this assessment.

Evacuation along Wisemans Ferry Road to the south is cut very frequently by Hawkesbury River floodwater (and probably by local flooding) at the Little Cattai Creek floodplain (low-point ‘L4’), and is therefore not a suitable designated flood evacuation route.

Most flood immunity is afforded by the route north along the internal road, through the main site entrance, southeast along O’Briens Road, generally northeast along Wisemans Ferry Road, and south along Old Northern Road. The *Hawkesbury-Nepean Flood Emergency Sub Plan* (SEMC, 2005) reports that in a major flood evacuation operation, evacuation centres would be opened at Homebush or Rosehill. Evacuees from Cattai might also be housed at Castle Hill RSL or Dural Country Club.

5. Flood Evacuation Capacity Assessment

Evacuation capacity is assessed following the procedure set out in the *Flood Evacuation Capacity Assessment Guideline* prepared by Molino Stewart for the NSW State Emergency Service. This essentially compares the time available for evacuation to the time required for evacuation to ascertain whether there is a time surplus or deficit. If at first the analysis yields a time deficit, there may be opportunities to enhance the evacuation process by increasing the time available and/or decreasing the time required.

Because the preferred evacuation route from the proposed residential precincts to the O’Briens Road entrance crosses two different low-points, because these low-points constrain evacuation from different residential areas, and because two modes of flooding with different warning times need to be considered, several assessments follow.

5.1 Local Flooding Only

As presented in Section 5, the preferred evacuation route is not expected to be cut for local floods up to and including the 500 year ARI event but would be lost in the PMF. Local floods could occur when a storm produces very intense local rainfall. It is possible that a little warning time might be provided by observation of local watercourses. This, however, is unlikely to provide the required 5.6 hours for complete evacuation an ‘ultimate’ developed site (as calculated in Section 5.2), and so there would be an evacuation time **deficit**.

Nevertheless, inundation from the local creek catchment is of short duration – probably no more than 90 minutes over the road – so the short isolation period is considered tolerable.

5.2 Hawkesbury River Flooding: Low-Point ‘L1’

Time Available for Evacuation

The time available for evacuation is comprised of the warning time plus the flood travel time from the upstream flood warning gauge.

The equivalent gauge height at Windsor corresponding to the evacuation route low-point ‘L1’ is about 15.2m (gauge datum) (Table 3).

The *NSW State Flood Sub Plan* (SEMC, 2008) sets out the following flood classification levels for the Windsor gauge:

- Minor 5.8m
- Moderate 7.0m
- Major 12.2m

It also stipulates that the Bureau of Meteorology is required to provide the following warnings for the Windsor gauge:

- 6 hours’ notice required of 9.6 metres if peak height expected to be greater than 16.0 metres;
- 15 hours’ notice required of 13.7 metres if peak height expected to be greater than 16.0 metres.

Whilst a critical gauge height of 15.2m may not necessarily trigger the requirements for a minimum 6 or 15 hours’ notice (being below the 16.0m trigger), it is noted that the Bureau’s current practice is to issue flood warnings even for ‘minor’ flooding at Windsor. A flood exceeding 15.2m would be a major flood, exceeding the highest 20th century flood (November 1961). Such an event is anticipated to have many hours’ warning. Levels at the Windsor gauge could be pre-selected as triggers for various evacuation responses at Riverside Oaks Resort (such as ‘Ready’, ‘Set’, ‘Go’). This would require a local manager to remotely monitor the Windsor gauge (via the Bureau’s or Manly Hydraulics Laboratory’s websites) once a Flood Watch or any Flood Warnings were issued. For the purposes of this evacuation capacity assessment, a warning time of 9 hours is assumed for this road low-point.

Information available to us suggests negligible flood travel time from Windsor gauge to Riverside Oaks.

Thus the time available for evacuation (based on road low-point ‘L1’) is equal to the warning time which is estimated as 9 hours.

Time Required for Evacuation

The time required for evacuation of vehicles from residential areas ‘A’, ‘B’ and ‘C’ is a function of several variables as outlined in Table 4.

Table 4 – Time required for evacuation from residential precincts ‘A’, ‘B’ and ‘C’

Variable	Value	Source
No. of dwellings	241	Concept plan for 300 dwellings minus the 59 in precinct ‘D’ which are only indirectly affected
Vehicles per dwelling	2.4	2011 Census data for the suburb of Cattai (conservative if a proportion of the proposed residential lots at Riverside Oaks Resort are going to be occupied by retirees and overseas visitors)
Residential vehicles (RV)	578	Calculation
Evacuation route capacity (RC)	600 veh/hr	SES recommended value
Warning acceptance factor (WAF)	1 hour	SES recommended value
Warning lag factor (WLF)	1 hour	SES recommended value
Travel time (RV/RC)	1.0 hour	Calculation
Traffic safety factor (TSF)	1 hour	SES recommended value
Total time required to evacuate	4 hours	Calculation

Thus the time required for evacuation of precincts ‘A’, ‘B’ and ‘C’, including allowances to accept an evacuation order and prepare for evacuation, is 4 hours.

But it is also necessary to factor in existing traffic from the Resort as well as traffic in an **‘ultimate developed’** scenario. This includes the following facilities:

- Clubhouse event facility (300 person);
- Proposed hotel (150 rooms);
- 5 existing corporate lodges (60 rooms);
- 5 proposed corporate lodges (60 rooms);
- 42 existing or under construction holiday cabins/villas (42 rooms);
- Restaurant (capacity for 100 persons);
- Spa and treatment facility.

Like the proposed residential precinct ‘D’, the holiday cabins/villas are located close to O’Briens Road so access is not compromised by flooding of road low-point ‘L1’. The evacuation traffic generated by the 42 holiday cabins/villas is therefore discounted from the evacuation assessment.

Based on the above data, we calculate the *additional* number of vehicles from Riverside Oaks that could require evacuation. We adopt the following conservative assumptions:

- One vehicle per person from the Clubhouse (= 300 vehicles);
- One vehicle per hotel room (= 150 vehicles);
- One vehicle per corporate lodge room (= 120 vehicles);
- One vehicle per person at the restaurant (= 100 vehicles);

- A nominal 100 vehicles for any day-trippers using the spa and treatment facility;
- A nominal 100 vehicles for any day-trippers playing the golf course (considered conservative given the likely adverse weather, which would be expected to deter many day-trippers from journeying to Riverside Oaks);
- A nominal 100 vehicles for staff;
- Full capacity;
- No double-counting.

In an ultimate development scenario, this equates to 970 vehicles in addition to the 578 counted for residential precincts ‘A’, ‘B’ and ‘C’, which totals 1,548 vehicles potentially needing to evacuate in advance of a flood. Using the SES recommended value for evacuation route capacity of 600 veh/hr, the time required for evacuation would be 5.6 hours (Table 5).

Table 5 – Time required for evacuation from Riverside Oaks in ultimate development scenario

Variable	Value	Source
Total vehicles (TV)	1548	Calculation
Evacuation route capacity (RC)	600 veh/hr	SES recommended value
Warning acceptance factor (WAF)	1 hour	SES recommended value
Warning lag factor (WLF)	1 hour	SES recommended value
Travel time (TV/RC)	2.6 hours	Calculation
Traffic safety factor (TSF)	1 hour	SES recommended value
Total time required to evacuate	5.6 hours	Calculation

Evacuation Time Budget

Since the time available for evacuation across road low-point ‘L1’ is estimated as 9 hours, and the time required for evacuation in an ultimate development (and fully utilised) scenario is 5.6 hours, there is an evacuation time **surplus** of 3.4 hours. This surplus is likely sufficient to accommodate any interruption to evacuation from local flooding.

5.3 Hawkesbury River Flooding: Low-Point ‘L2’

Time Available for Evacuation

The equivalent gauge height at Windsor corresponding to the evacuation route low-point ‘L2’ is about 10.7m (gauge datum) (Table 3).

Following the earlier discussion, for the purposes of this evacuation capacity assessment, a warning time of 6 hours is assumed for Windsor, related to this road low-point.

With negligible flood travel time from Windsor, the time available for evacuation (based on road low-point ‘L2’) is equal to the warning time (estimated 6 hours).

Time Required for Evacuation

The time required for evacuation of vehicles from residential precincts ‘A’ and ‘B’ is a function of several variables as outlined in Table 6.

Table 6 – Time required for evacuation from residential precincts 'A' and 'B' to Clubhouse/Hotel

Variable	Value	Source
No. of dwellings	164	Concept plan showing number of affected dwellings in precincts 'A' and 'B'
Vehicles per dwelling	2.4	2011 Census data for the suburb of Cattai (conservative if a proportion of the proposed residential lots at Riverside Oaks Resort are going to be occupied by retirees and overseas visitors)
Residential vehicles (RV)	394	Calculation
Evacuation route capacity (RC)	600 veh/hr	SES recommended value
Warning acceptance factor (WAF)	1 hour	SES recommended value
Warning lag factor (WLF)	1 hour	SES recommended value
Travel time (RV/RC)	0.7 hour	Calculation
Traffic safety factor (TSF)	1 hour	SES recommended value
Total time required to evacuate	3.7 hours	Calculation

Thus the time required for evacuation of these areas, including allowances to accept an evacuation warning and prepare for evacuation, is 3.7 hours.

Evacuation Time Budget

Since the time available for evacuation across road low-point 'L2' is estimated as 6 hours, and the time required for evacuation is 3.7 hours, there is an evacuation time **surplus** of 2.3 hours. This is more marginal than for road low-point 'L1', and relies more heavily on an effective flood warning and flood evacuation system. Also, the average frequency with which this low-point is estimated to be inundated – once in 6 years (Table 3) – suggests that the frequency of isolation for precincts 'A' and 'B' may be intolerable. For these reasons it is proposed that a special flood evacuation route be developed to link these precincts to the main part of the resort including the Clubhouse and proposed Hotel (see Section 6.1).

5.4 Combined Local and Hawkesbury River Flooding

Another scenario is for local flooding to coincide with Hawkesbury River flooding and compromise a flood evacuation. However, local flooding is not expected to cut the preferred evacuation route for much more than about 90 minutes. A local flood could occur early or late in a flood evacuation, and the selected evacuation triggers based on the Windsor gauge need to allow sufficient 'slack' – i.e. at least 90 minutes – for such an interruption. However, the surplus times of 3.4 hours and 2.3 hours calculated for evacuations across the preferred route's two low-points in response to Hawkesbury River flooding, indicate that such 'slack' is available.

5.5 Regional Evacuation Traffic

Another consideration is the potential effect of evacuation traffic from Riverside Oaks on the capacity of regional flood evacuation routes. Traffic from the Resort would join other local traffic from flood-affected areas of Cattai (north of Little Cattai Creek), South Maroota, Sackville North, Lower Portland (east of the Hawkesbury River), Leets Vale and Wisemans Ferry (south of the Hawkesbury River) on the Old Northern Road Evacuation Route.

A coarse estimate of evacuation traffic from these suburbs is made using 2011 Census data on the number of occupied private dwellings and the average number of vehicles per dwelling (Table 7).

Table 7 –Potential local evacuation traffic for Old Northern Road Evacuation Route

Suburb	Number of Occupied Private Dwellings Source: ABS	Average Number of Vehicles per Dwellings Source: ABS	Number of Vehicles
Cattai	110*	2.4	264
South Maroota	88*	2.4	210
Sackville North	89	2.4	214
Lower Portland	87*	2.3	200
Leets Vale	107	2.2	235
Wisemans Ferry	37*	1.6	59
Total		–	1,182

* The number of Occupied Private Dwellings for these suburbs has been halved to provide a more realistic estimate, since evacuation traffic for that part of Cattai south of Little Cattai Creek, that part of Lower Portland west of the Hawkesbury River, and that part of Wisemans Ferry north of the Hawkesbury River is unlikely to use the Old Northern Road Evacuation Route.

Based on this data, there could be up to about 1,200 residents' vehicles evacuating potentially flood-affected areas between Riverside Oaks and Wisemans Ferry. There might be some additional tourist evacuation traffic from caravan parks, water ski parks and lodges – say 200 vehicles. A total of 1,400 vehicles is therefore added to the evacuation traffic from Riverside Oaks. This is considered highly conservative, because it is improbable that residents would evacuate all their vehicles, and the likely adverse weather would constrain tourist traffic. Using the SES recommended value for evacuation route capacity of 600 vehicles/hour, the time required for evacuation of the (fully developed and utilised) Riverside Oaks traffic plus this local traffic – including a Traffic Safety Factor now increased to 1.5 hours – is 8.4 hours (Table 8), which yields a small evacuation time **surplus**. But this is very conservative because it is unlikely that this traffic would all be seeking to use the Old Northern Road Evacuation Route at the same time. Some low-lying and quickly isolated areas along River Road would probably need to evacuate earlier than Riverside Oaks (e.g. in 5-10 year ARI events) and other areas at higher levels could delay evacuation until well after access to Riverside Oaks is cut. In the unlikely event that there were delays due to convergence, these would probably be confined to the intersection of Wisemans Ferry Road and Old Northern Road at Maroota, which is located on high ground, with ample 'leeway' to the floodplain.

Table 8 – Time required for evacuation in ultimate development scenario plus other local evacuation traffic using the Old Northern Road Evacuation Route simultaneously

Variable	Value	Source
Total vehicles (TV)	2948	Calculation
Evacuation route capacity (RC)	600 veh/hr	SES recommended value
Warning acceptance factor (WAF)	1 hour	SES recommended value
Warning lag factor (WLF)	1 hour	SES recommended value
Travel time (TV/RC)	4.9 hours	Calculation
Traffic safety factor (TSF)	1.5 hours	SES recommended value
Total time required to evacuate	8.4 hours	Calculation

6. Flood Safety Provisions of the Development

Section 5 demonstrates that it is expected that *all* the population from the proposed residential precincts that become isolated in a significant flood have sufficient time to evacuate prior to inundation of the access road. This is so even accounting for 'ultimate' development and full utilisation of the Resort.

Nonetheless, several flood safety provisions are proposed to reduce the frequency of isolation, to increase the effective warning time (prior to inundation of evacuation routes), to streamline evacuation operations, and to promote safe behaviours. Three factors particularly commend these efforts:

(1) Demographics

- A proportion of the population may be retirees who should not be cut off from access to medical facilities;
- A proportion of the population may be overseas investors who stay at Riverside Oaks for a few months a year and may not speak English as their first language;

(2) Flood duration

- Although each residential precinct has a sizeable 'High Flood Island' area in a PMF, which minimises the direct risk to life from inundation, the area south of road low-point 'L1' could be isolated for up to about 3 days in a large flood. Services such as electricity and water could be compromised.

(3) Human behaviours

- Experience from other floods indicates that people sometimes delay evacuation from areas potentially isolated by rising floodwater until it is too late to safely evacuate;
- Another all-too-common risky behaviour is attempting to drive through floodwater, noting that most flood-related deaths result from crossing floodwater.

6.1 Evacuation Route Upgrades

One means of reducing the frequency and duration of isolation is to **raise the evacuation routes** to provide greater immunity against flooding.

It is proposed to bypass road low-point 'L2' by constructing a higher level emergency flood evacuation track, with an indicative route shown on Figure 1. This route would be above the

100 year ARI flood level and, based on the PMF hydrograph, would enable residents to delay evacuation from precincts ‘A’ and ‘B’ by about 13 hours. The indicative route takes advantage of an existing concrete-paved golf cart track, which is about 2.5m wide and might require widening by only about 0.5m for a single lane emergency evacuation route. This would minimise the costs and impact on the golf course. During a flood evacuation, staff would need to ‘man’ the route to direct vehicles. Some lighting and signage could also be required.

It is also proposed to raise the main access road near low-point ‘L1’ to be at the 100 year ARI level. This would enable residents to delay evacuation from the evacuation-constrained part of the Resort located south of the low-point by about four hours. Given the current low-point has been surveyed to a level of 14.26m AHD, raising this road to Council’s adopted 100 year ARI flood level of about 16.7m AHD at this site represents a significant undertaking. Nevertheless, in reducing the average frequency of inundation from about 1 in 40 to 1 in 100, the likelihood of isolation and driving over flooded roads will be significantly reduced.

6.2 Installation of Boom or Lockable Gates

Despite best efforts at education (see Section 6.4), it is likely that some people may delay their evacuation and be tempted to cross flooded roads. Experience indicates that simple ‘road closed’ signage is often ignored by motorists. For that reason, the installation of **boom gates** or lockable gates is recommended at five locations as detailed in Table 9 and also marked on Figure 1. The gates could be manually operated (and potentially locked) by staff of Riverside Oaks based on pre-selected triggers reflecting the respective road low-points (Table 9).

Table 9 – Recommended installation of gates to control motorist behaviour during floods

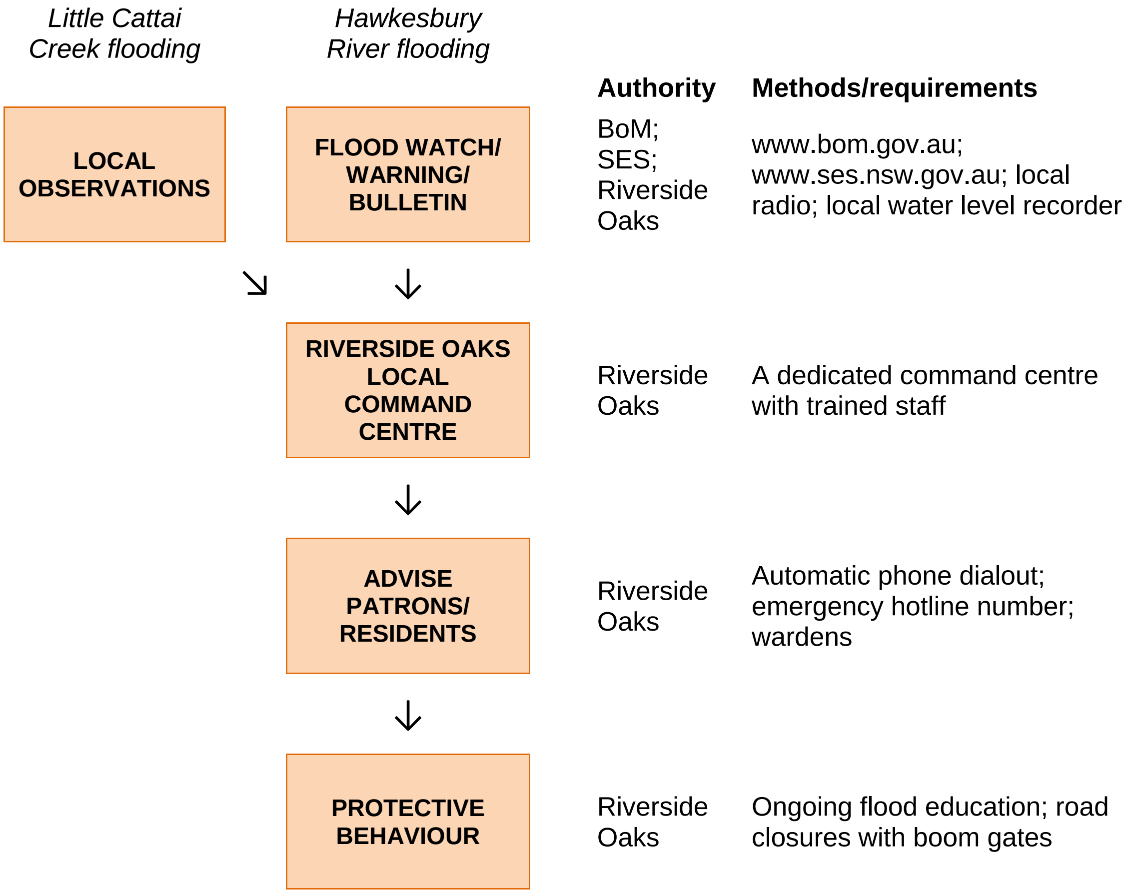
Gate #	**Gate location** (see Figure 1)	**Trigger for gate closure**
G1	Just east of the entrance to residential precinct ‘B’, so as to indicate that access to Wisemans Ferry Road via the southern (secondary) entrance to Riverside Oaks is closed	no later than 9.5m on the Windsor gauge (at which point inundation of Wisemans Ferry Road both south and north of the access road is expected)
G2	On the precinct ‘A’ side of road low-point ‘L2’, west of the entrance to ‘A’ (‘detour’ signage to the proposed high level emergency evacuation route would be required in this vicinity too)	no later than 10.7m on the Windsor gauge
G3	On the precinct ‘C’ side of road low-point ‘L2’, south of the entrance to ‘C’ (‘detour’ signage to the proposed high level emergency evacuation route would be required in this vicinity too)	no later than 10.7m on the Windsor gauge
G4	On the Clubhouse side of road low-point ‘L1’, just east of the roundabout	no later than 17.1m on the Windsor gauge*
G5	On the O’Briens Road side of road low-point ‘L1’, just beyond the PMF extent	no later than 17.1m on the Windsor gauge*

* Allows for raising of this access road to the 100 year ARI flood level.

6.3 *Develop Flood Warning/Evacuation System including Infrastructure*

Critical to ensuring the timely evacuation of residents, patrons and staff from the Riverside Oaks Resort is an effective flood warning and evacuation system. Figure 2 presents a schematic of the components required to achieve the required appropriate behaviour of timely evacuation.

Figure 2 – Concept for effective flood warning/evacuation system at Riverside Oaks



<u>Detecting a Rising Flood</u>

A starting point for responding to a flood is *knowing* that a flood is threatening. The Bureau of Meteorology (BoM) issues Flood Watches and Flood Warnings for the Hawkesbury River at Windsor, and the State Emergency Service (SES) issues Flood Bulletins that add value to the Bureau's warning products. A Flood Watch would likely be issued prior to significant flooding of the Hawkesbury River, and broadcast via local radio. The Bureau is continuing to develop its communication pathways including a mobile 'app', and social media including 'Twitter' would also likely be a means for receiving advice of flood threats. Management at Riverside Oaks will need to routinely check weather forecasts and warnings and monitor water levels (remotely via the BoM website) at the Windsor gauge.

In the case of flooding generated from Little Cattai Creek, whilst there might still be a Flood Watch or a Severe Weather Warning, directly observing the local weather and creek heights will be required.

Council has also indicated the desirability of installing a **local water level recorder** for the Hawkesbury River at Riverside Oaks. While this may not be required to initiate evacuations – since these will most likely be required based on the Bureau's *predicted* flood heights at the Windsor gauge – a local gauge would help Riverside Oaks' management to understand how much time is available before the key access road is inundated in a rising flood. A water level recorder could be configured such that it issues SMS messages to selected phone numbers – including the duty manager at Riverside Oaks and at the SES Unit and Region – when pre-determined levels are reached.

Local Command Centre

As soon as a Flood Watch (or Flood Warning) for the Hawkesbury River is received, a local emergency operations centre (EOC) should be set up at Riverside Oaks. Ideally this would be located in a building on the O'Briens Road side of the development, which is expected to have uninterrupted access throughout a flood, though until the access road is cut, an office at the Clubhouse or Hotel could suffice. As a decision-making hub, the EOC will need to have good communications infrastructure both externally and internal to Riverside Oaks. The main function of the EOC will be to monitor and interpret flood levels, and to inform the residents and patrons of Riverside Oaks what they need to do.

Ongoing training of personnel at Riverside Oaks would be required to ensure those who staff an EOC are capable of fulfilling the key functions in a flood emergency.

Advising Patrons and Residents

Door-knocking is regarded as an effective strategy for communicating evacuation instructions to affected populations, since it enables the resident to interact directly with the emergency official. However, given the number of dwellings and facilities that would need to be advised in the event of a flood emergency at Riverside Oaks, door-knocking could consume too much time (> 20 hours, allowing for one door-knocking team at 5 minutes per dwelling and 241 dwellings, recalling that as little as 9 hours warning time may be available).

In order to quickly reach a large number of people, **automatic dialling technology** is recommended. Several messages should be pre-prepared and possibly pre-recorded, appropriate to each phase of the emergency, as outlined below. (Consideration should also be given to providing these in non-English languages).

1) A message issued when a Flood Watch is issued, reminding people that early evacuation may be required and to be prepared.
2) A message issued when management considers that evacuation is likely to be required, persuading people to be ready to evacuate shortly.
3) A message issued when management considers that evacuation is required (since the evacuation routes are expected to be cut), urging immediate evacuation.
4) A message issued when the evacuation routes have been cut, urging people not to attempt to drive through floodwater but to call for assistance if required.

Appropriate triggers would need to be set for the issuance of each warning message to each precinct, including consideration of the varying road low-points.

It is likely that any residents receiving an automated phone call or SMS may seek confirmation of the threat before acting. This natural tendency could be somewhat addressed in advance by flood education that sets out the particular flood risk situation of Riverside Oaks, which demands early evacuation to avoid people becoming trapped on an island (see

Section 6.4). But people may still seek confirmation, and guidance on where to go. Riverside Oaks should advertise a local emergency **hotline** and provide trained staff to operate a local call centre for such scenarios. A system of **wardens** (and deputy wardens) for each residential precinct could also be established and renewed annually (with some incentive offered for the volunteer wardens). Residents within each area could be advised of the warden's address and contact details. Training of wardens would be required.

Figure 3 depicts a PMF hydrograph showing approximately when warning messages would need to be issued to residents. Warning of 'major' flooding at Windsor might be an appropriate trigger for issuance of an Evacuation Warning, while warning of a flood height that would close the now raised access road would be an appropriate trigger for issuance of an Evacuation Order. It is expected that the Bureau would provide at least 9 hours' advance notice of the latter, as depicted in Figure 3.

It is stressed that even a flood which does not reach the peak of a PMF could rise as fast as the depicted PMF hydrograph during the critical period between warnings being given and the evacuation routes being cut. The hydrograph focusses on the rising limb, so it was not possible to include a full hydrograph and indicate the timing of an 'All Clear', which could be several days after the site gets isolated by floodwaters.

Overcoming Barriers to Evacuation

Consideration should also be given to the barriers to timely evacuation and to measures aimed at overcoming these barriers. Some residents may lack private transport, so the management of Riverside Oaks will need to maintain a register of any such residents and **provide transport** for their evacuation. Some residents may be concerned about the **security** of their evacuated homes, so assurances will need to be provided that NSW Police or the resort's own security can fulfil this function.

Ensuring Safe Isolation

Every effort must be put into evacuating people before the access road is cut. Nevertheless, it is possible that some people may fail to evacuate in a timely fashion. Much of the proposed development is on land above the PMF extent, so these areas effectively become 'high flood islands'. Whilst there may not be a direct threat to life, the ambulance or fire services would find difficulty accessing the site if the need arose. Access to normal utilities services like electricity and water could also be disrupted for any isolated residents.

In order to not draw upon limited SES resources, Riverside Oaks could purchase some small powered **boats** for the purpose of any flood rescues that may be required. It could also consider equipping one of the corporate lodges located above PMF level with an **emergency generator and water supply**, which could act as a place of refuge for any stranded residents.

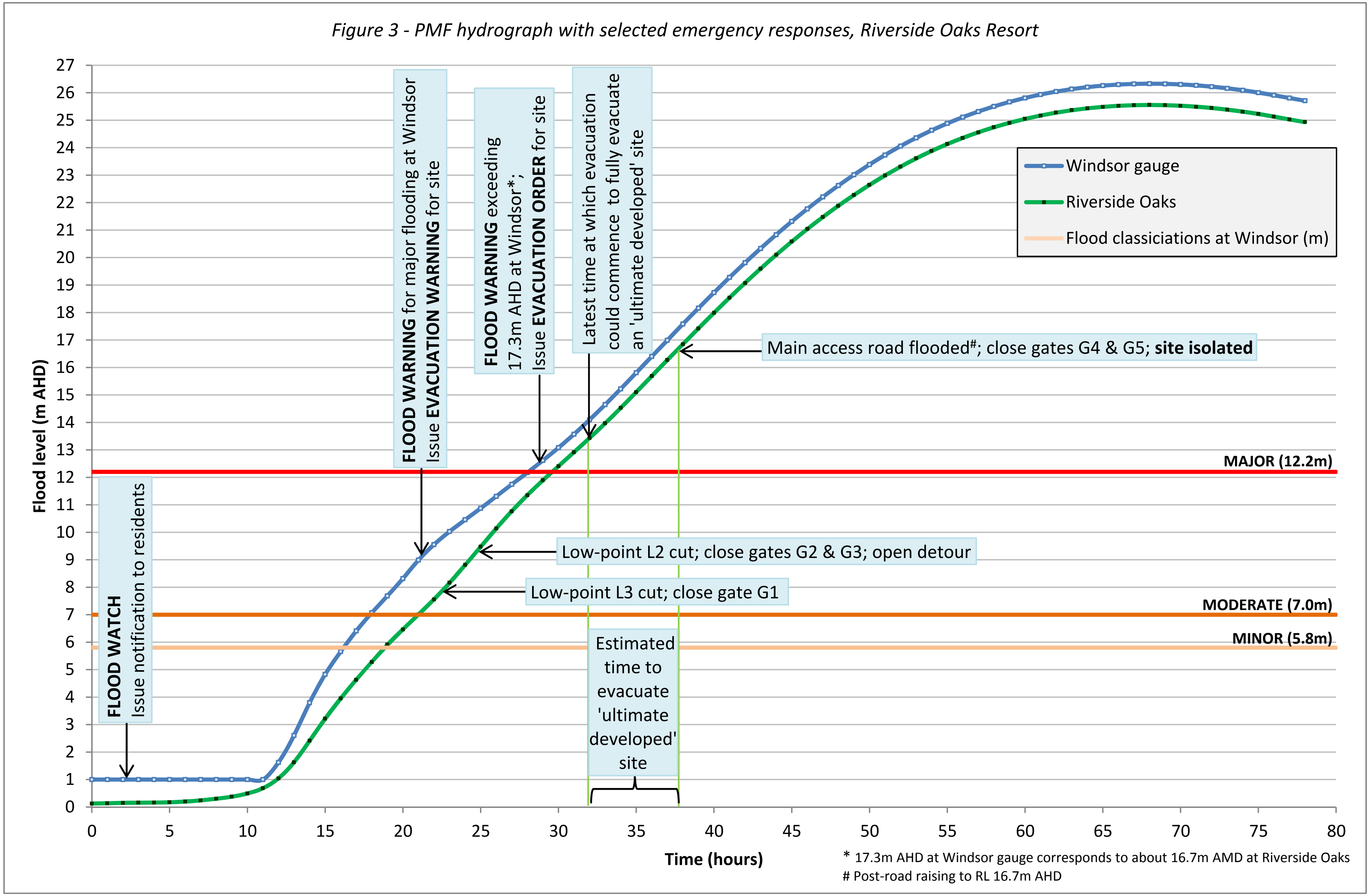


Figure 3 Windsor_RiversideOaks_pmf_hydrograph revised

6.4 Flood Education Program

Flood education is a key to promoting safe behaviours during a flood. There would be benefit in preparing a **FloodSafe** (or similar) **guide** specific to the circumstances of Riverside Oaks, making clear that people will need to evacuate even though their houses may not be directly threatened, in order not to be isolated for periods of several days. Every resident should be provided with such information annually, and every hotel unit and corporate lodge should contain the evacuation information also. Given the likelihood that some residents may be overseas investors, there may also be a need to provide this material in non-English languages.

In our view, the best mechanism for bringing home the reality of the flood risk situation would be to hold **regular drills** (say, once every 2 years), simulating what is likely to happen in the event of a flood evacuation. One approach would be to simulate flood behaviour in an 1867-like flood, which rose to 19.7m AHD at Windsor.

6.5 Flood Emergency Plan

All these considerations need to be brought together in a detailed Flood Emergency Plan for Riverside Oaks, which would set out what needs to be done:

- before a flood in the **Preparation** phase, including ongoing education of residents and training of staff during the sometimes long intervals between floods;
- during a flood in the **Response** phase, linking Flood Watch/Warning and Windsor gauge height and local gauge height triggers to various actions; and
- after a flood in the **Recovery** phase.

Responsibilities of staff and residents would need to be clearly demarcated.

A review of the flood warning/evacuation system should be undertaken after every flood and flood response drill. This would also highlight any weaknesses in the flood warning/evacuation system that needs to be addressed.

7. Conclusion

Riverside Oaks Resort in Cattai is subject to flooding from local creeks or from the Hawkesbury River, with the greater risk presented by the latter. The current configuration of roads sees the site isolated in about a 40 year ARI Hawkesbury River flood, though much of the site would be a High Flood Island in the PMF event. An assessment of evacuation capability suggests that even applying conservative assumptions about the number of vehicles needing to evacuate a fully utilised and ultimate developed site, there is an evacuation time surplus. Nevertheless, a number of flood safety provisions are proposed to reduce the frequency of isolation, to streamline evacuation operations and to promote safe behaviours. These include measures to:

- Raise the key evacuation routes to provide immunity in the 100 year ARI event;
- Install gates to obstruct drivers from entering flooded roads;
- Develop a flood warning/evacuation system including a local water level recorder that issues SMS when pre-determined levels are reached and automatic dialling technology to rapidly issue residents with evacuation warnings or orders;
- Develop a flood education program;
- Prepare a detailed flood emergency plan.

In our opinion, these provisions, properly maintained, would satisfactorily manage the risk to life from flooding for the proposed residential development at Riverside Oaks Resort.

Yours faithfully

For Molino Stewart Pty Ltd

Stephen Yeo and Steven Molino

APPENDIX D – MUSIC Modelling Parameters

BIORETENTION RAINGARDEN SYSTEM

TABLE D.1 – RAINGARDEN – GENERAL FEATURES & CONFIGURATION

Storage Properties	
Extended Detention Depth (m)	0.3
Surface Area (m^2)	Varies
Filter and Media Properties	
Filter Area (m^2)	Varies
Saturated Hydraulic Conductivity (mm/hr)	100
Filter Depth (m)	0.5

The expected sediment and nutrient removal performance of the raingarden systems was determined using the default equations and parameters provided in the MUSIC model. The water quality reduction mechanisms in MUSIC are based on an exponential decay equation referred to as the k – C* curve

The viability of the raingardens and the longevity of their pollutant removal efficiency is dependent on the capacity of the pre-treatment GPTs to intercept and remove light litter, detritus and coarse sediment.

A summary of the estimated performance of the raingarden systems is detailed in Section 11.2 of this report.

Once the catchments upstream of the raingardens are stabilised, maintenance would generally involve plant replacement, weed control, repair of localised erosion and minor structural damage and the removal of localised sediment build-up. This would be undertaken on a quarterly basis on average with vegetation replacement budgeted for on a decadal cycle.

TABLE D.2 – MUSIC – PERFORMANCE PARAMETERS

	Bio-Retention	
Pollutant	**k (m/yr)**	**C* (mg/L)**
TSS	8000	20.000
TP	6000	0.130
TN	500	1.400

Rainfall Data

The MUSIC model is able to utilise rainfall data based on 6 minute, hourly, 6 hourly and daily time steps. A 6 minute time step was used in the analysis which was chosen in accordance with the recommendations for selecting a time step within the MUSIC User's Manual.

Rainfall records for the area were obtained from the Bureau of Meteorology. The nearest rainfall station to the site with a reasonable period of 6 minute rainfall data for a suitably representative period of rainfall for the site was Richmond:

Station No	**Location**	**Years of Record**	**Type of Data**
67033	Richmond	1980 - 1990	6 minute

The mean annual rainfall in the data set used in the modelling is 831mm, while the mean annual rainfall for Richmond is 802mm. The rainfall and potential evapo-transpiration data for the period analysed is shown on the graph which is provided in Plate D.1.

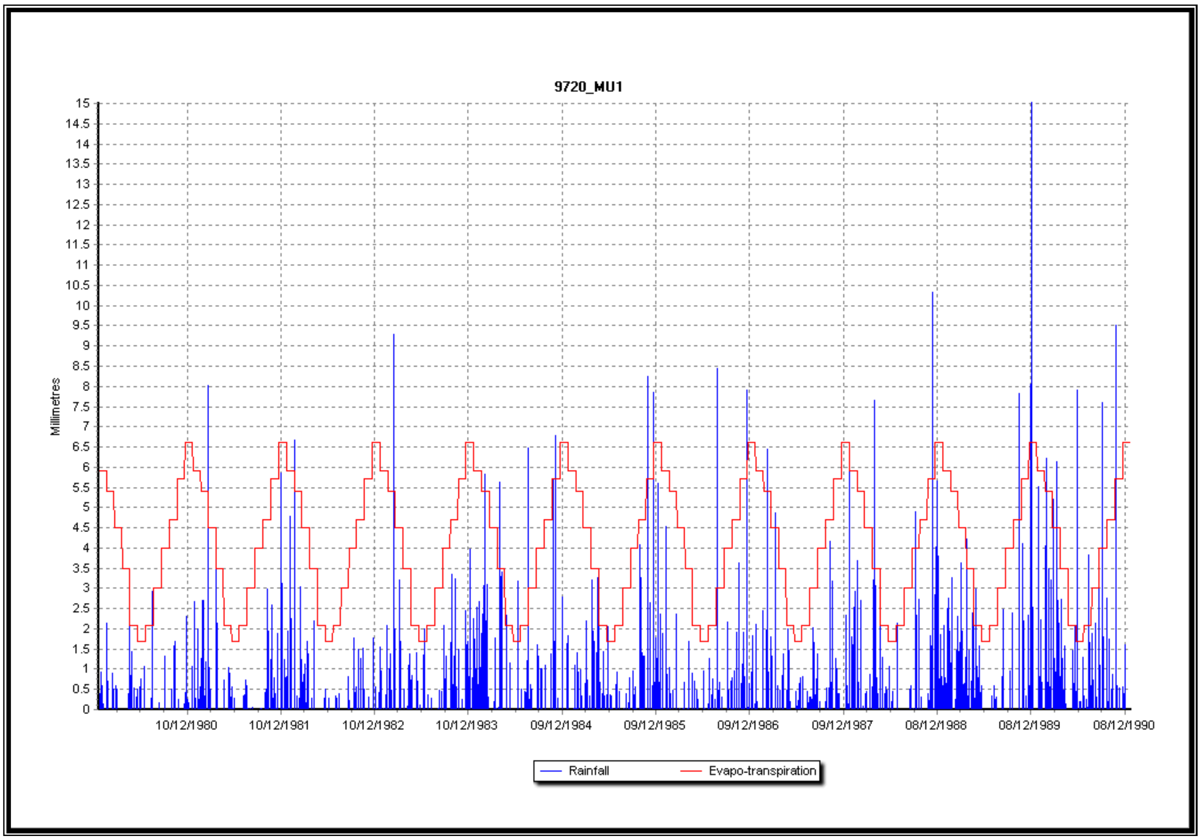


PLATE D.1 – RAINFALL & EVAPO-TRANSPIRATION DATA ADOPTED FOR THE RIVERSIDE OAKS SITE

A summary of the rainfall data set (Richmond 1980 – 1990) used in the MUSIC model for the Riverside Oaks and comparable rainfall data sets provided by the Bureau of Meteorology rainfall station gauge in Richmond is shown below in Table D.3.

TABLE D.3 – SUMMARY OF RAINFALL DATA FOR THE SITE

Property	MUSIC Model Data Set - Richmond (1980 - 1990)	Bureau of Meteorology Data (Richmond)
Mean Yearly Rainfall (mm)	831	802
Decile 1 Rainfall (mm)	474	529
Decile 5 Rainfall (mm)	843	792
Decile 9 Rainfall (mm)	1086	1066
Mean No. Rain Days	126	117
Mean No. Rain Days > 1mm	76	77
Mean No. Rain Days > 10mm	25	22
Mean No. Rain Days > 25mm	9.0	7.3

Soil / Groundwater Parameters and Pollutant Loading Rates

In the absence of site specific data, the soil / groundwater parameters and pollutant loading rates adopted for the natural and urban catchments of the Riverside Oaks site, were based on the recommended parameters provided by the Department of Environment and Climate Change for areas within Western Sydney and the Cooperative Research Centre for Catchment Hydrology The adopted parameters are presented in Tables D.4 and D.5.

TABLE D.4 – ADOPTED SOIL / GROUNDWATER PARAMETERS FORTHE SITE
(Source : DECC Technical Note)

	Units	Urban	Non-Urban
Impervious Area Parameters			
Rainfall threshold (Roof 0.5, Road 1)	mm/day	1.4	1.4
Pervious Area Parameters			
Soil storage capacity	mm	170	210
Initial storage	% of capacity	30	30
Field capacity	mm	70	80
Infiltration capacity coefficient - a		210	175
Infiltration capacity coefficient - b		4.7	3.1
Groundwater Properties			
Initial depth	mm	10	10
Daily recharge rate	%	50	35
Daily baseflow rate	%	4	20
Daily deep seepage rate	%	0	0

TABLE D.5 – ADOPTED EVENT MEAN CONCENTRATIONS (SOURCE: CRCCH)

Pollutant	Urban	
	Base Flow (mg/L)	Storm Flow (mg/L)
TSS	15.8	141
TP	0.141	0.251
TN	1.29	2.00

Treatment Device Performance

Each element of the series of treatment practice (commonly referred to as a treatment train), as represented in the MUSIC model for the Riverside Oaks development, is described below.

Rainwater Tanks

The impacts of the use of rainwater tanks have been conservatively excluded from the modelling.

Litter and Sediment Control Structures

Drainage systems collecting runoff from local roads and hardstand areas throughout the Riverside Oaks development are expected to be provided with Gross Pollutant Traps (GPTs) to remove litter and coarse sediment prior to discharge into the downstream drainage systems, bio-retention raingardens and riparian corridors. GPTs are available as inlet pit filter inserts, purpose built cast in situ systems or precast proprietary traps using either dry or wet sump storage chambers. As the type of GPT to be used within the development is unknown, they have been conservatively excluded from the modelling.

It is expected that the site drainage strategy would require approximately nine (9) GPTs (at least one per bio-retention and detention basin system). Wherever possible, dewatering systems should be provided to facilitate de-watering of wet sumps (if wet sump GPTs are provided). These dewatering lines must be discharged to the raingardens or some other appropriate filtration system to allow nutrients and fine particulates to be stripped out of the supernatant water.

APPENDIX E – Figures

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LEGEND

- RIVERSIDE OAKS SITE BOUNDARY
- EXISTING ROAD / TRACK
- EXISTING RIDGE LINE

N W E S

Scale 1: 10,000@ A3

200 0 200 m

Figure 4.1

Proposed Riverside Oaks Development

Existing Site Plan

File Name: 9856Fig4.1_SitePlan
Date : 22/11/13 Issue : A

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LEGEND

RIVERSIDE OAKS SITE BOUNDARY

N W E S

Scale 1: 10,000@ A3

200 0 200 m

Figure 5.1

Proposed Riverside Oaks Development

Proposed Development Layout Plan

File Name: 9856Fig5_1-DevPlan
Date : 23/02/15 Issue :B

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LEGEND

- RIVERSIDE OAKS SITE BOUNDARY
- PROPOSED DETENTION BASIN
- PROPOSED BIORETENTION RAINGARDEN
- PROPOSED SWALE (INDICATIVE LOCATION ONLY)

N
W E
S

Scale 1: 10,000@ A3

200 0 200 m

Figure 8.1

Proposed Riverside Oaks Development

Stormwater Management Strategy Plan

File Name: 9856Fig8_1-SWMS
Date : 23/02/15 Issue : C

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LEGEND

RIVERSIDE OAKS SITE BOUNDARY

LOCAL WATERCOURSE CATCHMENT BOUNDARY

N W E S

Scale 1: 10,000@ A3

200 0 200 m

Figure 9.1

Proposed Riverside Oaks Development

Local Watercourse Catchment Plan

File Name: 9856Fig9_1-LocCatchPlan

Date : 22/11/13 Issue : A

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LEGEND

RIVERSIDE OAKS SITE BOUNDARY

LOCAL WATERCOURSE CATCHMENT BOUNDARY

N W E S

Scale 1: 10,000@ A3

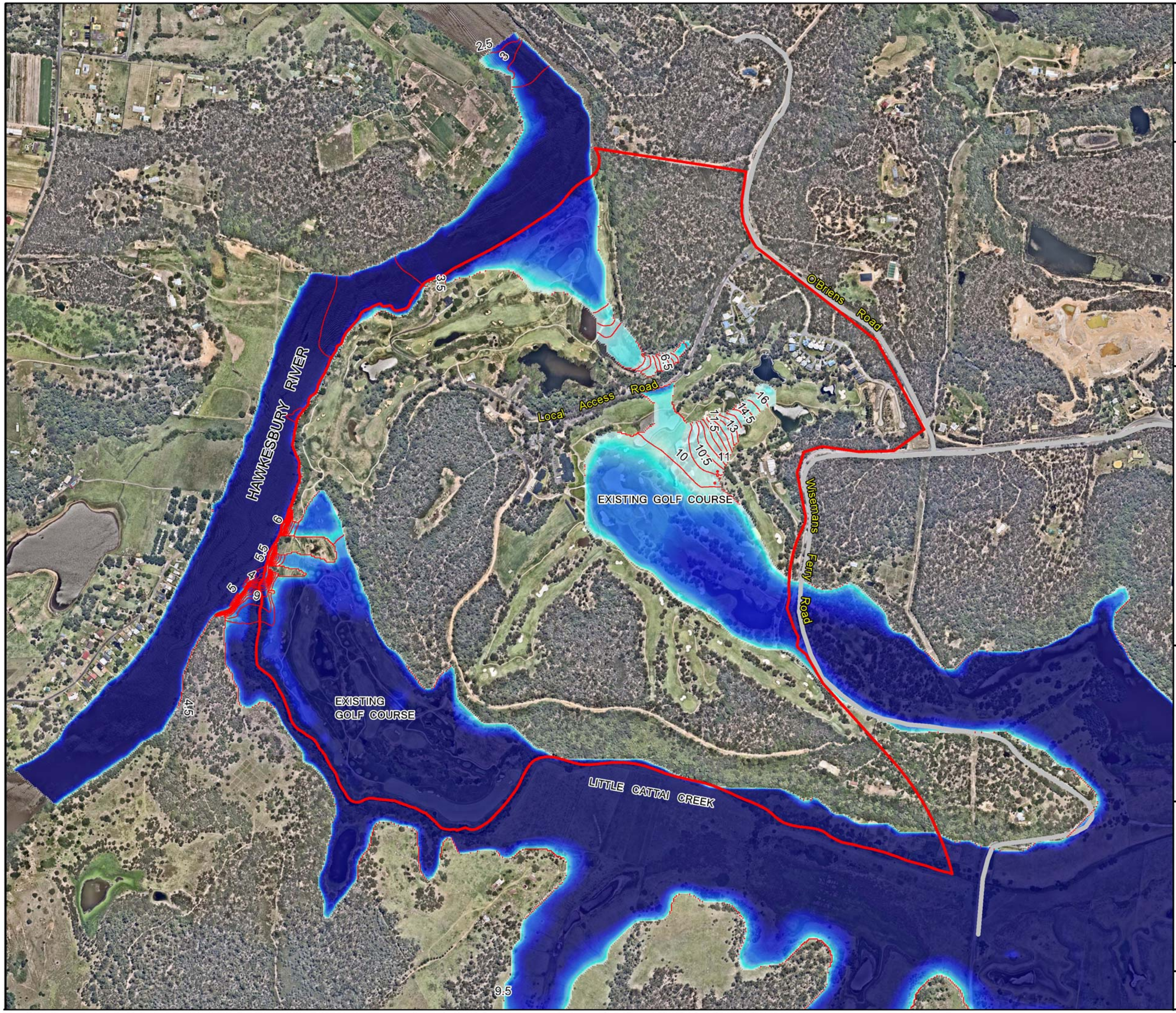
200 0 200 m

Figure 9.2

Proposed Riverside Oaks Development

Precinct Developed Catchment Plan

File Name: 9856Fig9_2-DevCatchPlan
Date : 23/02/15 Issue : B



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LEGEND

DEPTH (m)

	0.0 to 0.1
	0.1 to 0.2
	0.2 to 0.3
	0.3 to 0.5
	0.5 to 1.0
	1.0 to 2.0
	2.0 +

N
W E
S

Scale 1: 10,000@ A3

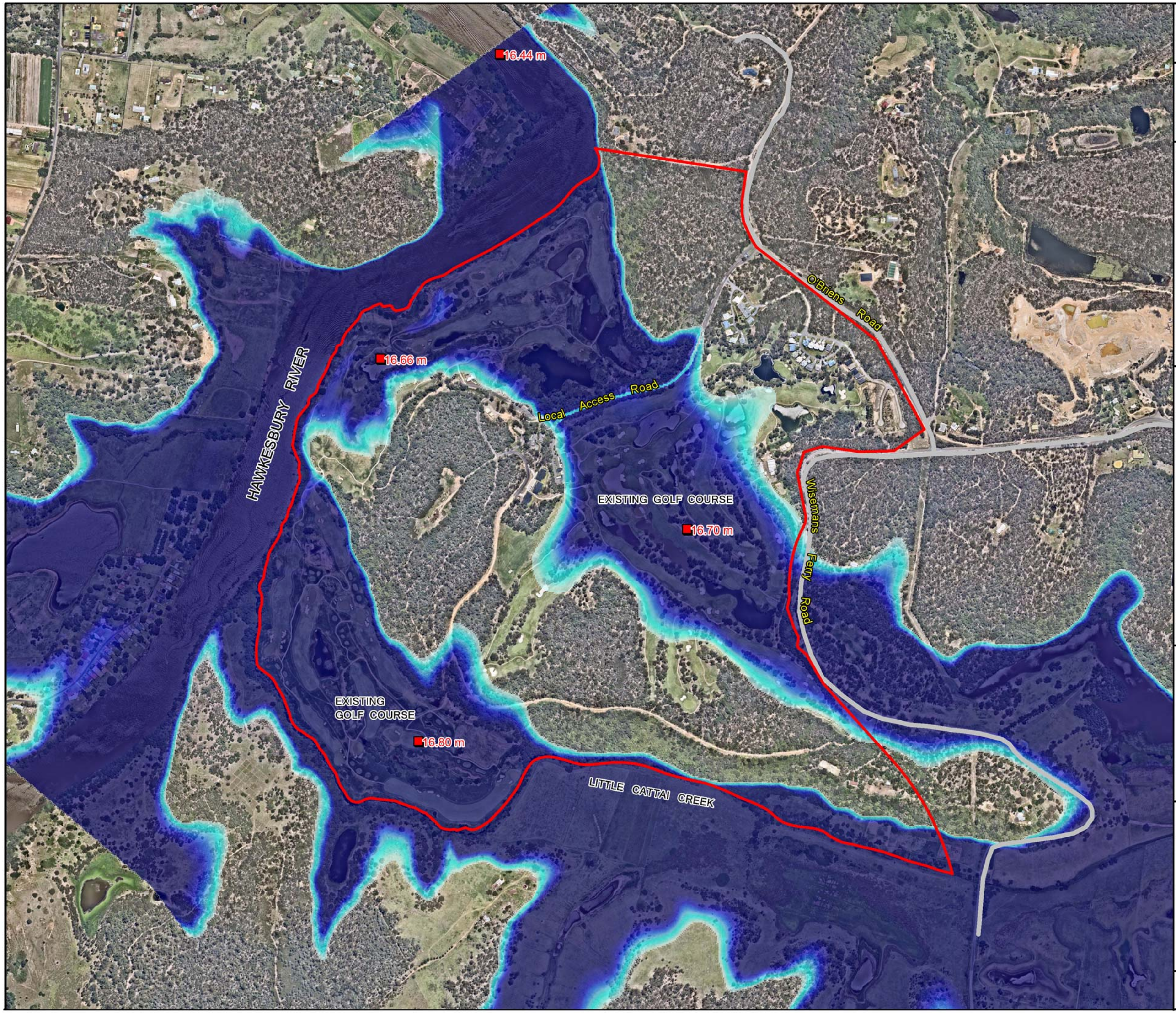
200 0 200 m

Figure 10.1

Proposed Riverside Oaks Development

1% AEP Local Flood Extents, Levels and Depths No Tailwater

File Name: 9856Fig10_1-1%AEPLocNoTW
Date : 23/02/15 Issue : B



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LEGEND

DEPTH (m)

- 0.0 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- 5.0 to 7.0
- 7.0 +
- 16.70 m — 1% AEP REGIONAL FLOOD LEVEL

N
W E
S

Scale 1: 10,000@ A3

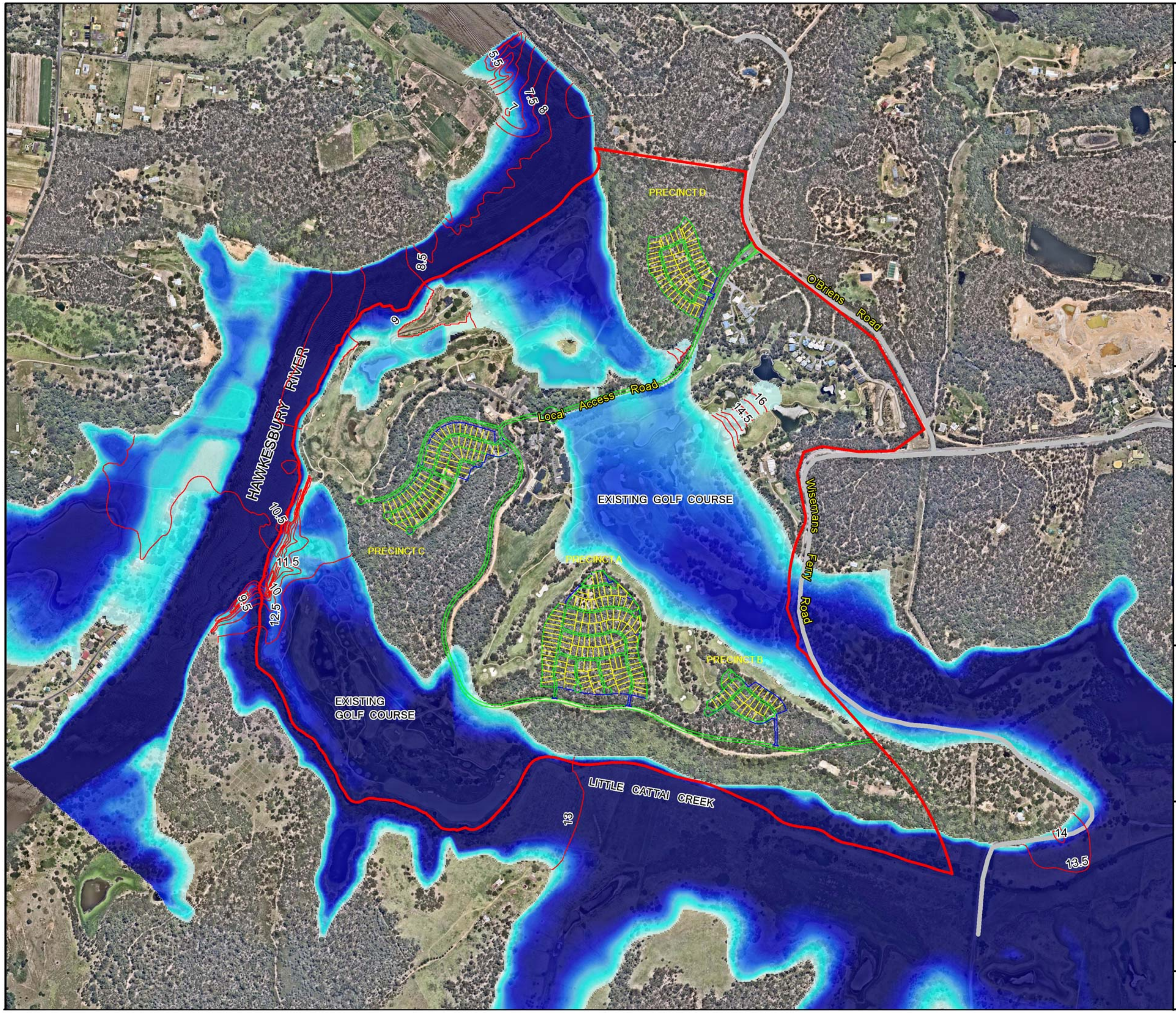
200 0 200 m

Figure 10.2

Proposed Riverside Oaks Development

Existing 1% AEP Local Flood Extents and Depths 1% AEP Regional Tailwater

File Name: 9856Fig10_2-1%AEPReg
Date : 23/2/15
Issue : C



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LEGEND

DEPTH (m)

- 0.0 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- 5.0 to 7.0
- 7.0 +

N W E S

Scale 1: 10,000@ A3

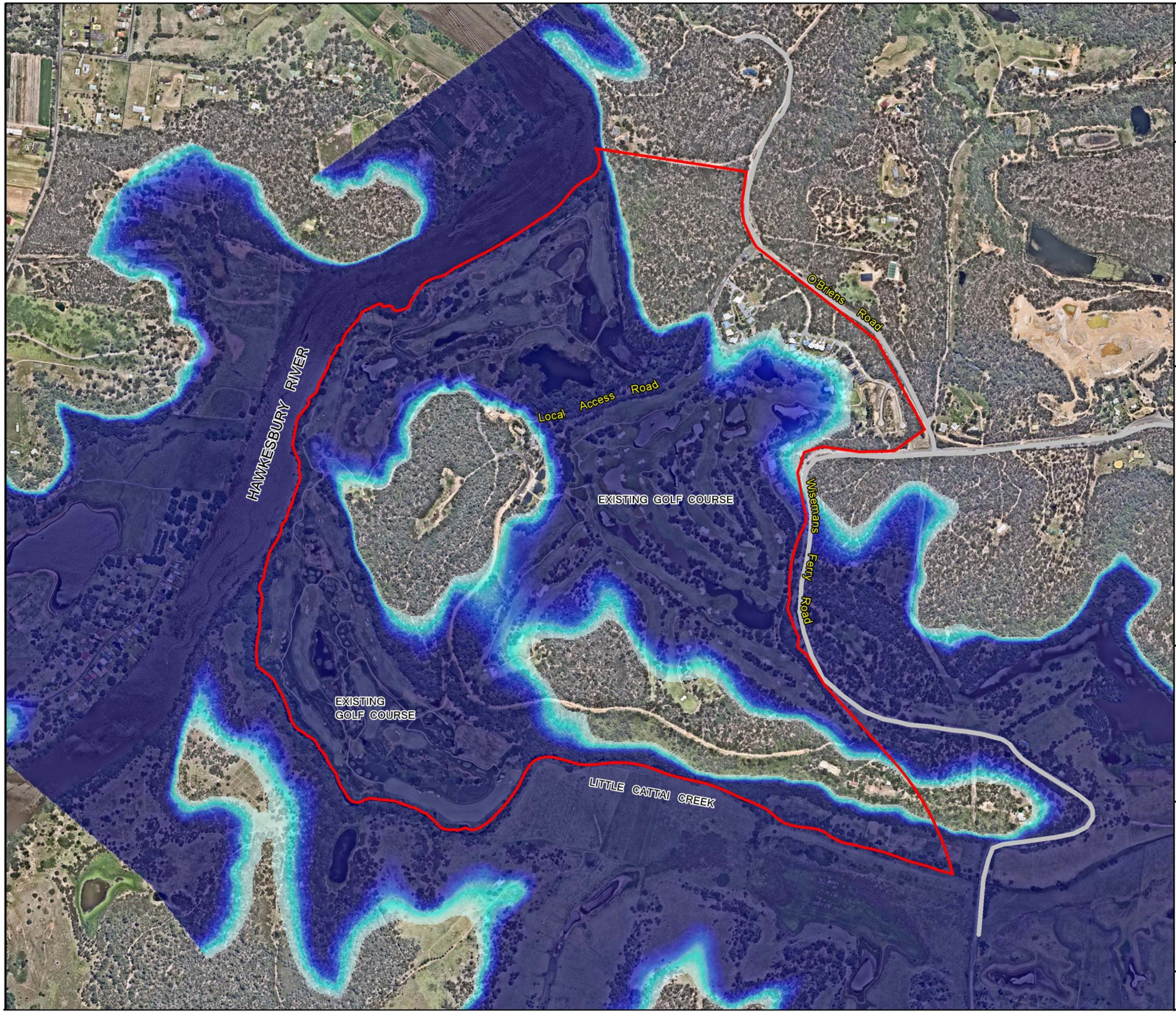
200 0 200 m

Figure 10.3

Proposed Riverside Oaks Development

Existing PMF Local Flood Extents, Levels and Depths No Tailwater

File Name: 9856Fig10_3-PMFLocNoTW
Date : 23/02/15 Issue : B



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LEGEND

DEPTH (m)

- 0.0 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- 5.0 to 7.0
- 7.0 +

N S W E

Scale 1: 10,000@ A3

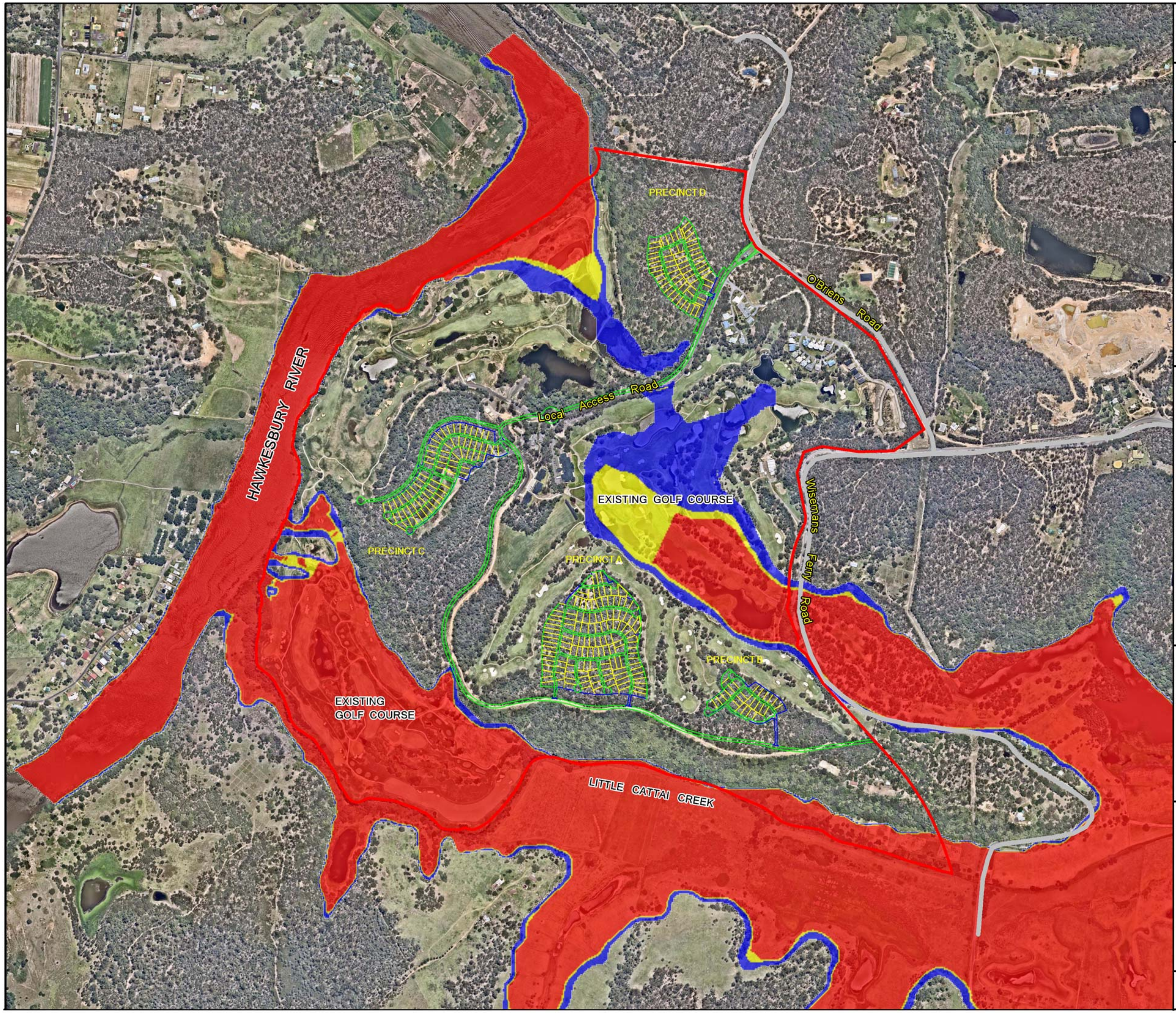
200 0 200 m

Figure 10.4

Proposed Riverside Oaks Development

Existing PMF Regional Flood Extents and Depths (RL 25.6)

File Name: 9856Fig10_4-PMFReg
Date : 23/02/15 Issue : A



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LEGEND

RIVERSIDE OAKS SITE

HAZARD CATEGORISATION

- LOW HAZARD
- TRANSITION HAZARD
- HIGH HAZARD

N W E S

Scale 1: 10,000@ A3

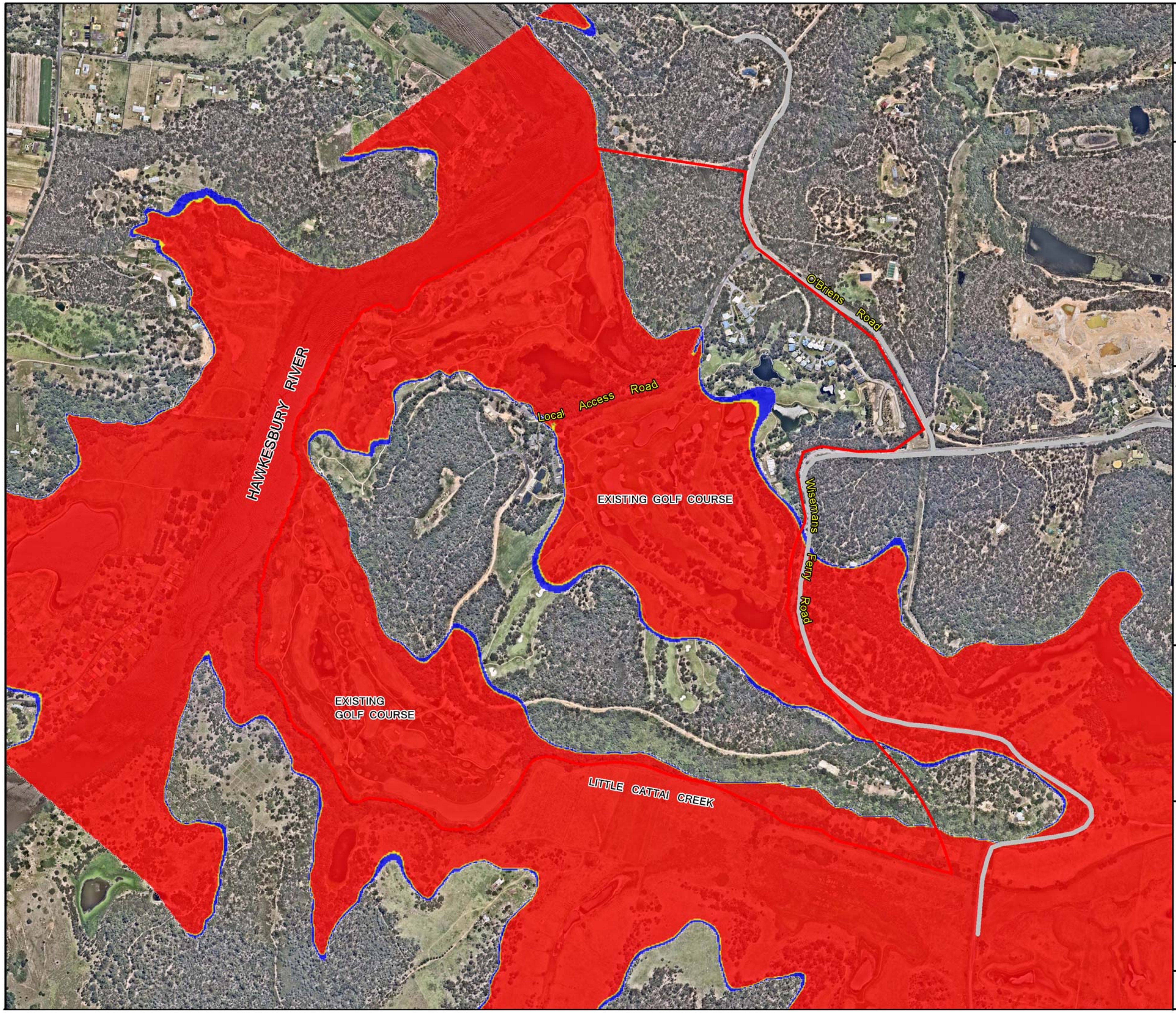
200 0 200 m

Figure 10.5

Proposed Riverside Oaks Development

Existing 1% AEP Flood Hazard No Tailwater

File Name: 9856Fig10_5-1%HazLocNoTW
Date : 23/02/15 Issue : B



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LEGEND

- RIVERSIDE OAKS SITE

HAZARD CATEGORISATION

- LOW HAZARD
- TRANSITION HAZARD
- HIGH HAZARD

N W E S

Scale 1: 10,000@ A3

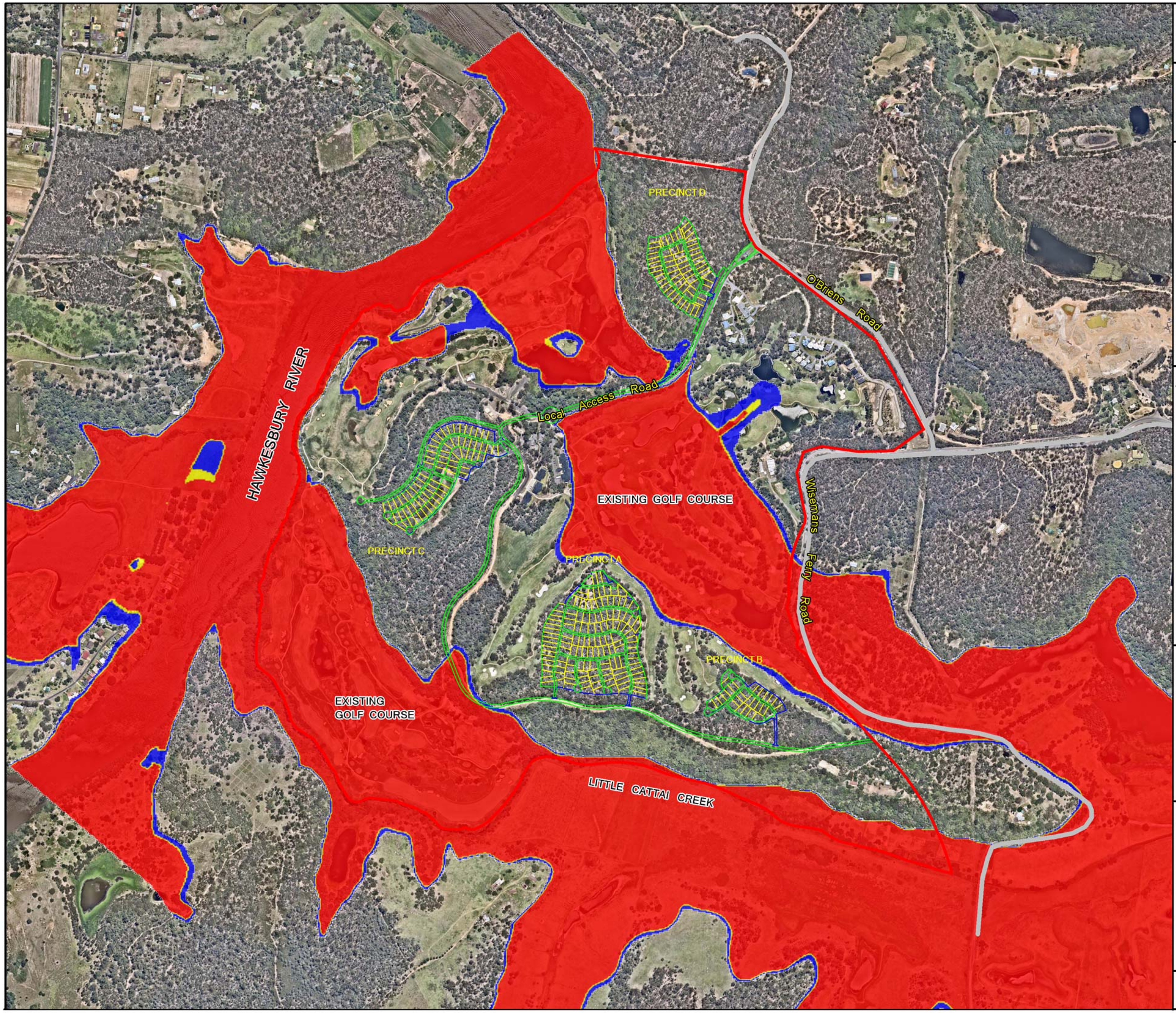
200 0 200 m

Figure 10.6

Proposed Riverside Oaks Development

Existing 1% AEP Flood Hazard 1% AEP Tailwater

File Name: 9856Fig10_6-1%Haz1%TW
Date : 25/02/15 Issue : B



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LEGEND

RIVERSIDE OAKS SITE

HAZARD CATEGORISATION
- LOW HAZARD
- TRANSITION HAZARD
- HIGH HAZARD

N W E S

Scale 1: 10,000@ A3

200 0 200 m

Figure 10.7

Proposed Riverside Oaks Development

Existing PMF Flood Hazard No Tailwater

File Name: 9856Fig10_7-ExPMFHazNoTW
Date : 25/02/15 Issue :B

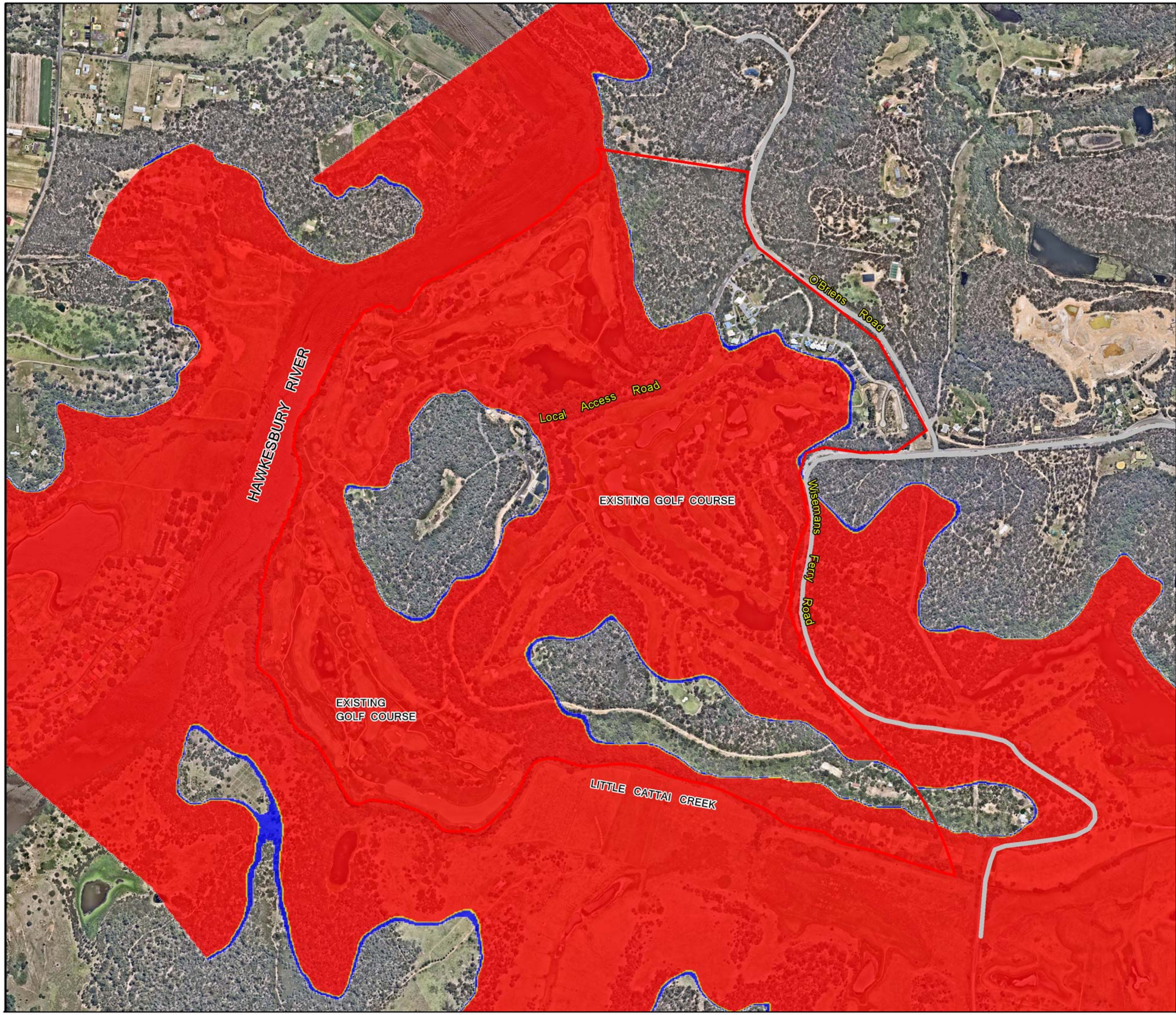

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Figure 10.8

Proposed Riverside Oaks Development

Existing Regional PMF Flood Hazard

File Name: 9856Fig10_8-ExRegPMFHaz
Date : 25/02/15
Issue : B

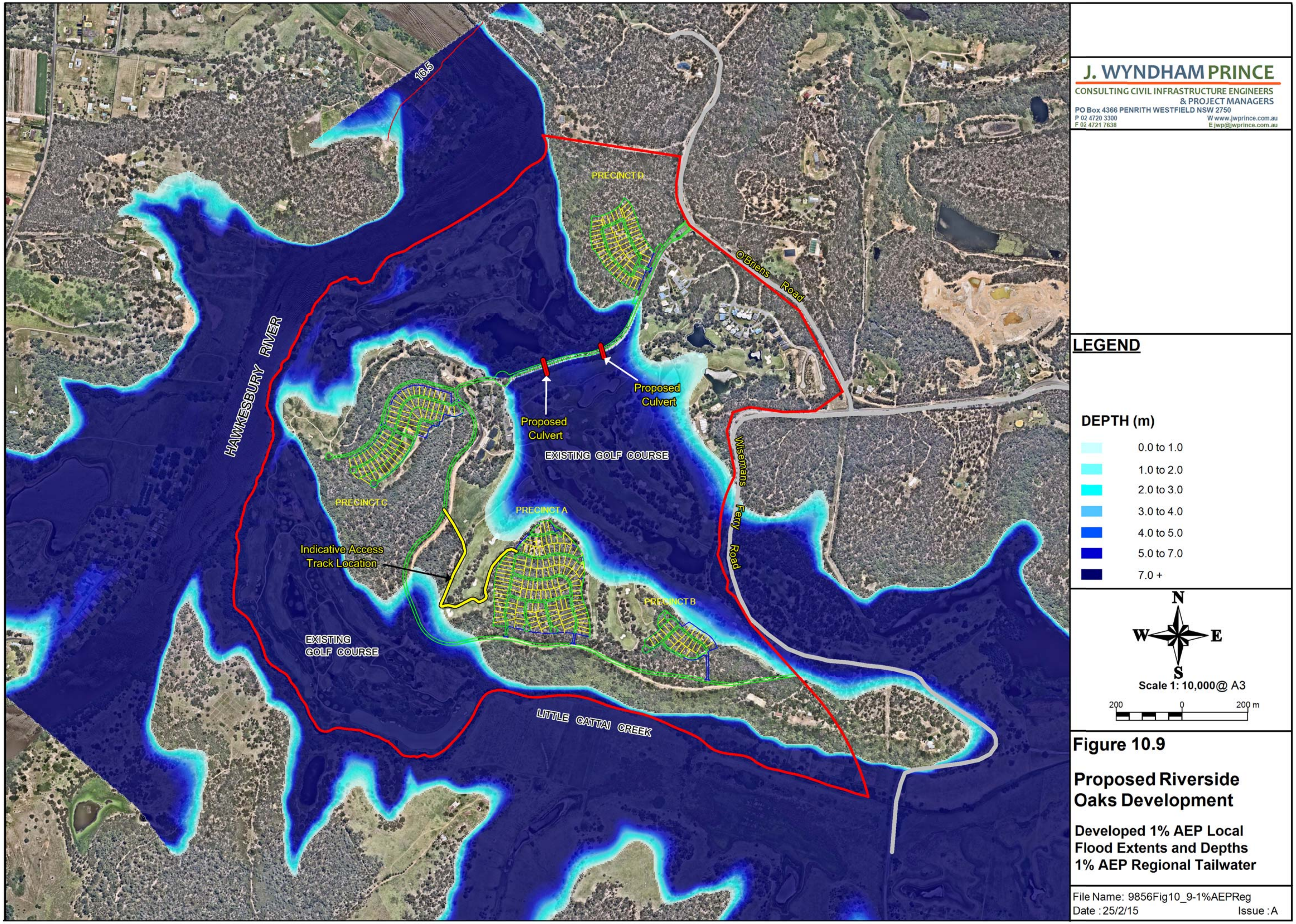

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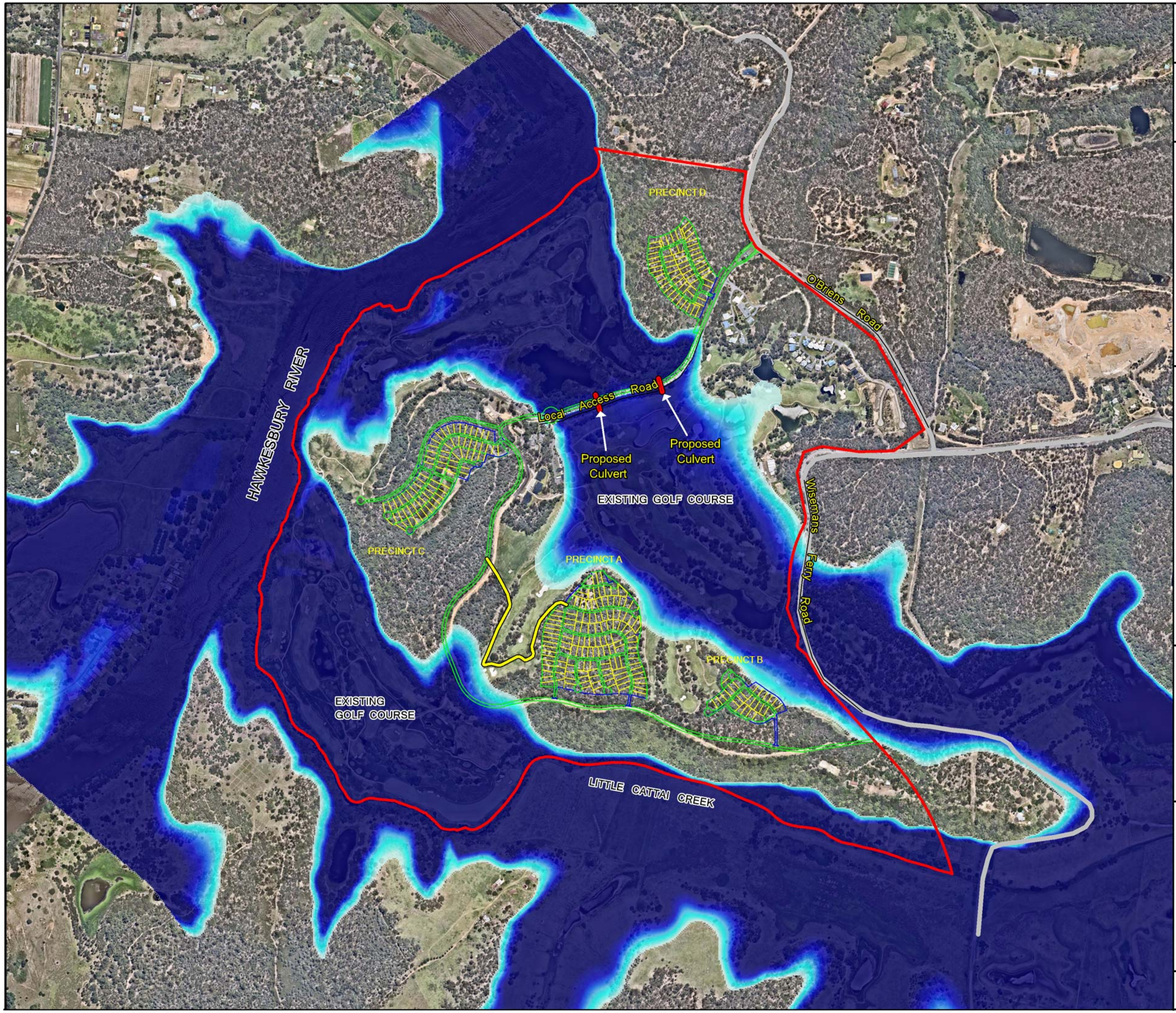
Figure 10.9

Proposed Riverside Oaks Development

Developed 1% AEP Local Flood Extents and Depths 1% AEP Regional Tailwater

File Name: 9856Fig10_9-1%AEPReg
Date : 25/2/15 Issue : A



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LEGEND

DEPTH (m)

- 0.0 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- 5.0 to 7.0
- 7.0 +

N W E S

Scale 1: 10,000@ A3

200 0 200 m

Figure 10.10

Proposed Riverside Oaks Development

Developed PMF With 1% AEP Regional Tailwater Extents and Depths

File Name: 9856Fig10_10-DevPMF1%TW
Date : 23/02/15 Issue : A

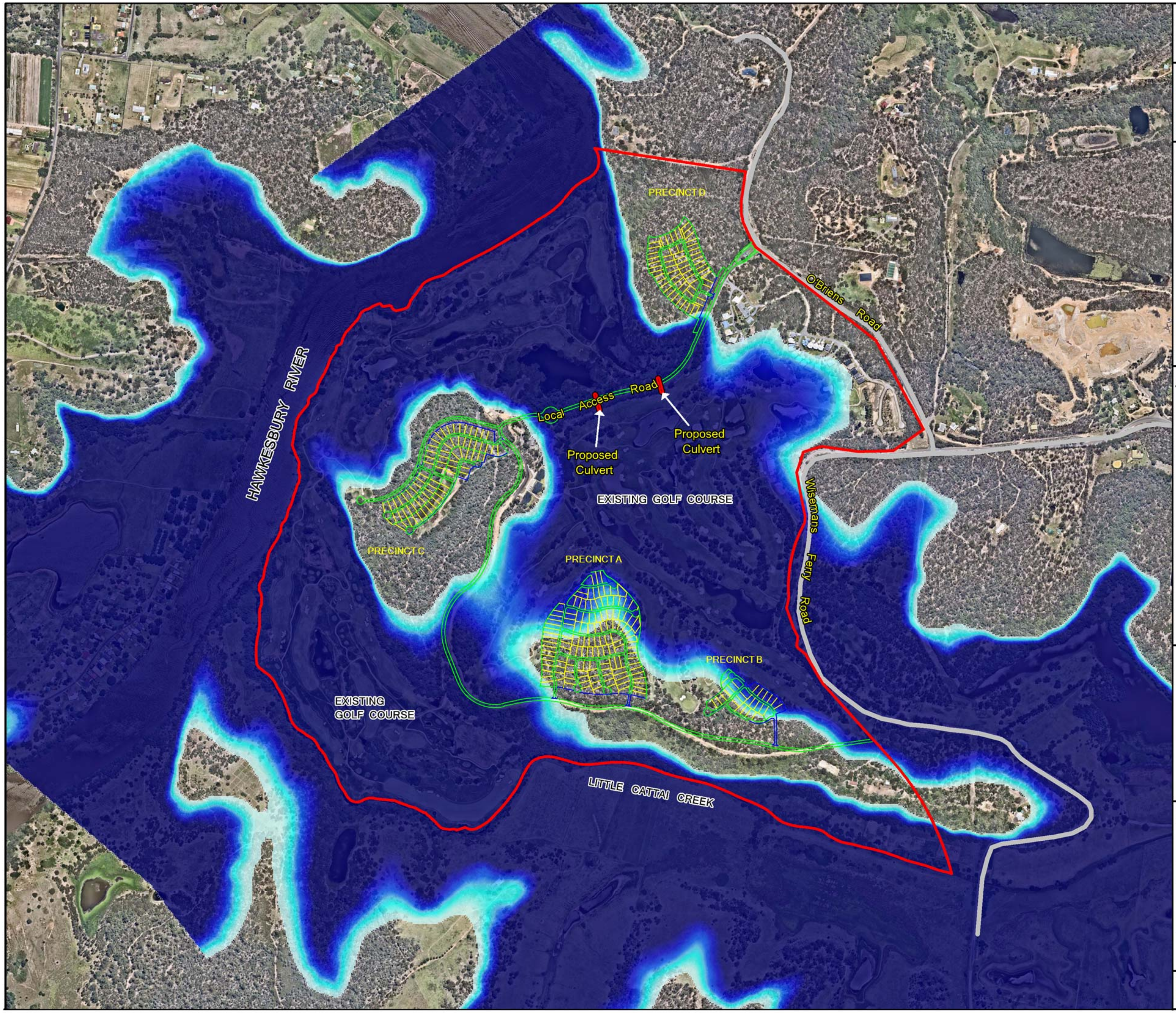

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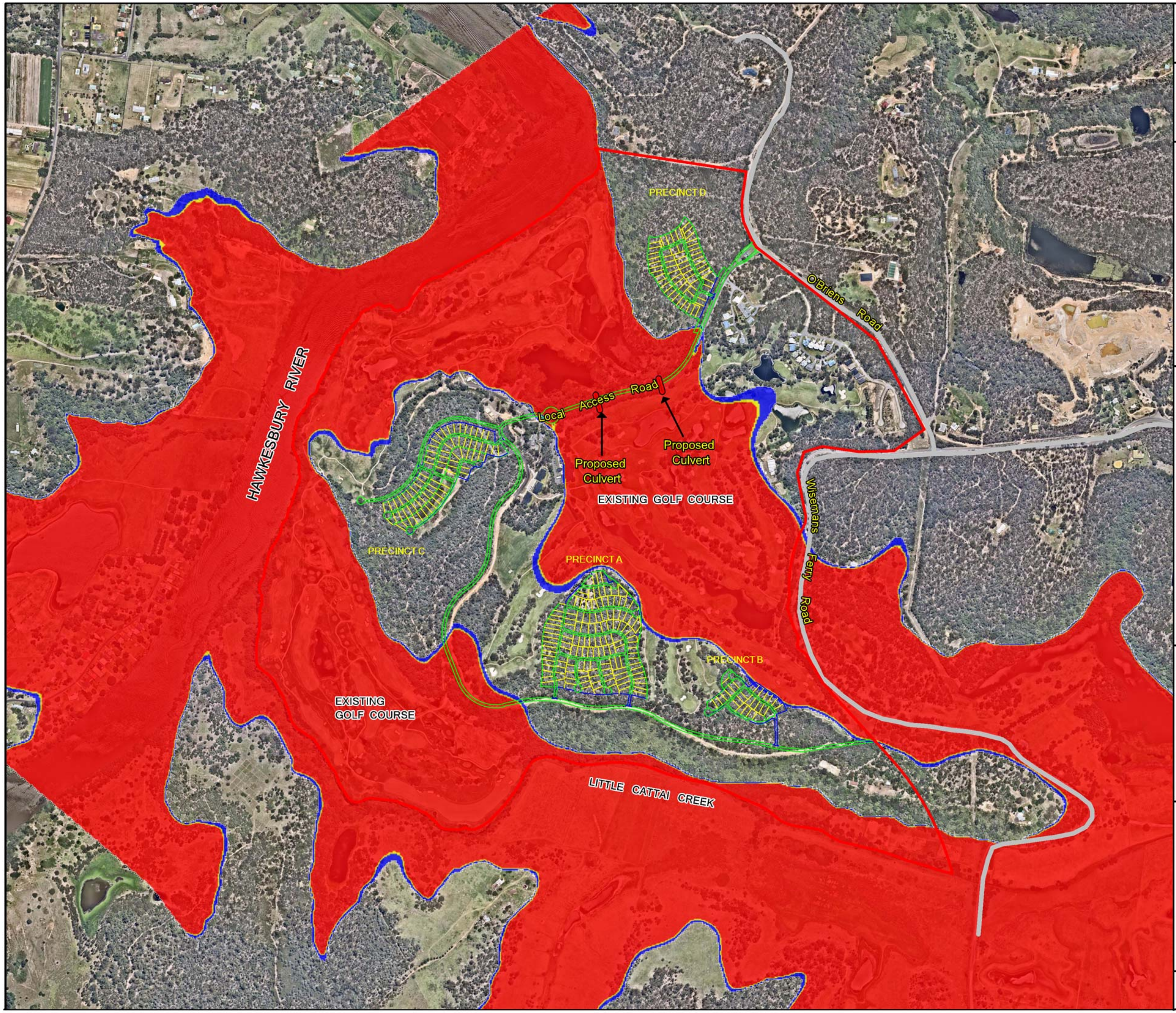
Figure 10.11

Proposed Riverside Oaks Development

Developed Regional PMF Extents and Depths

File Name: 9856Fig10_11-DevRegPMF
Date : 23/02/15 Issue : A



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LEGEND

RIVERSIDE OAKS SITE

HAZARD CATEGORISATION
- LOW HAZARD
- TRANSITION HAZARD
- HIGH HAZARD

N
W E
S

Scale 1: 10,000@ A3

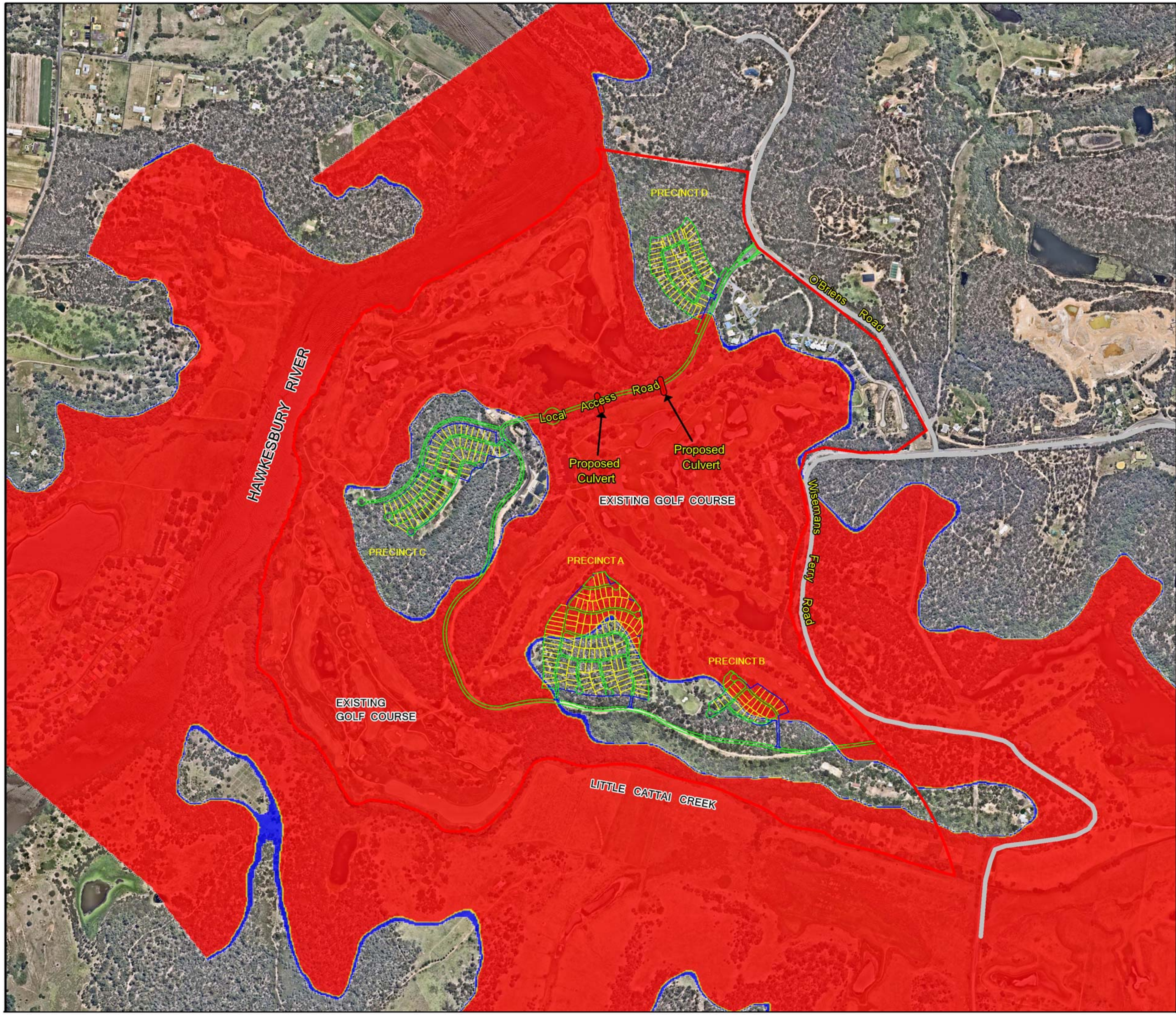
200 0 200 m

Figure 10.12

Proposed Riverside Oaks Development

Developed 1% AEP Flood Hazard 1% AEP Tailwater

File Name: 9856Fig10_12-1%DevHaz1%TW
Date : 25/02/15 Issue : B



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LEGEND

RIVERSIDE OAKS SITE

HAZARD CATEGORISATION
LOW HAZARD
TRANSITION HAZARD
HIGH HAZARD

N W E S

Scale 1: 10,000@ A3

200 0 200 m

Figure 10.13

Proposed Riverside Oaks Development

Developed Regional PMF Flood Hazard

File Name: 9856Fig10_13-DevRegPMFHaz
Date : 25/02/15 Issue : B