# Tumbi Road Upgrade

## Surface Water Assessment Report

Transport for NSW

Document controls

# Approval and authorisation

| | |
|---|---|
| Title | Central Coast Highway and Tumbi Road Intersection Upgrade review of environmental factors – Surface Water Quality Assessment |
| Accepted on behalf of Transport for NSW by: | |
| Signed: | |
| Dated: | |

# Contents

# Tables



# Figures

# Abbreviations

| Abbreviation | Meaning |
|---|---|
| **AECOM** | AECOM Australia Pty Ltd |
| **AEP** | Annual Exceedance Probability |
| **AHD** | Australian Height Datum |
| **ANZECC** | Australia New Zealand Environment and Conservation Council |
| **ARI** | Average Recurrence Interval |
| **BoM** | Bureau of Meteorology |
| **CEMF** | Construction Environmental Management Framework |
| **CEMP** | Construction Environmental Management Plan |
| **DO** | Dissolved Oxygen |
| **DPIE** | Department of Planning, Industry and Environment |
| **GP** | Gross Pollutants |
| **GPT** | Gross Pollutant Trap |
| **LGA** | Local Government Area |
| **MHL** | Manly Hydraulics Laboratory |
| **NSW** | New South Wales |
| **NTU** | Nephelometric Turbidity Unit |
| **OEMP** | Operational Environmental Management Plan |
| **REF** | Review of Environmental Factors |
| **SEARs** | Secretary's environmental assessment requirements |
| **SEED** | The central resource for *Sharing and Enabling Environmental Data* in NSW |
| **SEPP** | State Environmental Planning Policy. A type of planning instrument made under Part 3 of the EP&A Act. |
| **TfNSW** | Transport for NSW |
| **TN** | Total Nitrogen |
| **TP** | Total Phosphorus |
| **TSS** | Total Suspended Solids |
| **WMA** | WMAwater |
| **WQO** | Water Quality Objectives |

# Definitions

| Term | Meaning |
|---|---|
| **Australian Height Datum (AHD)** | The standard reference level used to express the relative height of various features. A height given in metres AHD is the height above mean sea level. |
| **Average Recurrence Interval (ARI)** | The likelihood of occurrence, expressed in terms of the long-term average number of years, between flood events as large as, or larger, than the design flood event.<br><br>For example, floods with a discharge as large as or larger than the 100-year ARI flood would occur on average once every 100 years. |
| **Annual Exceedance Probability (AEP)** | The probability or likelihood of an event occurring or being exceeded within any given year. |
| **Blue Book** | Managing Urban Stormwater: Soils and Construction - Volume 1 (Landcom, 2004) and Volumes 2A, 2B, 2C, 2D and 2E (DECC, 2008). |
| **The Proposal** | The construction and operation of the Tumbi Road Intersection Upgrade |

# Executive Summary

Transport for NSW (TfNSW) propose to upgrade the intersection at Central Coast Highway and Tumbi Road located in Wamberal, NSW (the Proposal). The existing intersection is located adjacent to Wamberal Lagoon Nature Reserve and consists of a two-lane roundabout merging into two lanes travelling northbound and southbound along the Central Coast Highway, and a single lane into Tumbi Road. The Proposal includes the conversion of this intersection into one controlled by traffic lights, as well as localised road widening to the north and along Tumbi Road. The Proposal is part of a broader commitment to improve travel on the Central Coast Highway between Tumbi Road, Wamberal and Bateau Bay Road, Bateau Bay which will see the highway widened to two lanes in both directions for 3.8 kilometres.

The purpose of this report is to describe the surface water quality and flooding environments relative to the study area and to assess the potential impact of the Proposal during both the construction phase and operational phase. The study area includes the proposed site of the road upgrade and three sites for ancillary construction facilities.

## Surface Water

### Methodology

Relevant legislation, water quality policy and guidelines were identified and reviewed to determine the obligations of the construction of the Proposal with respect to the water quality objectives for the downstream Wamberal Lagoon catchment. Available water quality, flooding data and existing conditions were reviewed.

### Existing Environment

The key aquatic environmental feature for water quality was Wamberal Lagoon, which is a Nature Reserve protected under the *National Parks and Wildlife Act 1974*. It discharges to the Pacific Ocean.

Runoff generated by the catchment generally moves in an easterly direction, from the ridgeline running along the western boundary, through the steep slopes across residential development zones, through natural bush land leading into the Wamberal Lagoon, and then finally discharging to the coast. The Central Coast Highway has significant portions that experience overtopping, even in frequent flood events as inundation occurs in events as small as the 50% AEP event.

### Potential Impacts

During construction the Proposal has the potential to cause the impacts on local water quality within local receiving waters, including Wamberal Lagoon. During runoff events or flood conditions, sediment laden waters, chemicals stored on site, and construction waste have the potential to mobilise and enter waterways.

The construction phase has potential risks to flooding due to their potential impact to existing flood behaviour across the intersection. The Proposal is located along a roadside channel that runs along the northern side of Tumbi Road, so there is potential for construction works to impede flows and worsen flooding impacts.

Mitigation measures including controlled management of stormwater and drainage patterns (such as diversions or designed flow paths), stockpiles located outside the floodplain and drainage lines, flooding management and evacuation procedures and plans to ensure that maintenance of access for all workers, residents is not affected by proposed flow paths (see Section 4.1.4 and 5) to mitigate the potential impact of construction on flooding and stormwater.

Operational phase water quality impacts could result from increases in the impervious surface area within the Proposal Area, which could result in increased surface runoff and increased runoff of contaminants from the roadway into the nearest catchment and into the downstream environments, which includes Wamberal Lagoon. Opportunities for stormwater treatment were considered during the design process (see Section 4.2 and Table 4-2). The project corridor is highly constrained, and based on site design constraints, none of the opportunities considered were able to be incorporated into the design. The project would result in an increase in imperviousness of about 1 ha, an increase of 0.2 % in imperviousness over the total catchment area. This small change is unlikely to result in any measurable changes in the hydrology or water quality of the receiving environment.

The Proposal includes upgrades to the existing cross drainage structures across the intersection, which allows flow to move at a faster rate through the intersection. This helps to reduce peak flood levels on the upstream sides of the intersection and improves flooding across adjacent private properties. This does slightly increase peak flows and flood levels within the channel downstream of the intersection located within the nature reserve; however, the increase in flood levels is localised to the channel and adjacent bushland and does not have an impact on flooding across private properties further downstream.

By allowing flows to move at a faster rate through the intersection, peak velocities within the existing open channels are slightly increased, increasing their erosive potential. To mitigate this, scour protection measures are proposed where peak velocities exceed the maximum allowable velocity for grassed channels. Most notably, scour protection is proposed immediately upstream and downstream of the cross-drainage structure passing under the Central Coast Highway.

**Environmental Management**

A number of mitigation and management measures are proposed in Section 4 and 5 of this report to minimise potential surface water impacts during both the construction and operational phases. This includes the preparation of a Soil and Water Management Plan and Erosion and Sediment Control Plan.

**Cumulative Impacts**

Cumulative impacts were considered (see Section 4.5), and no developments or events within the Wamberal Lagoon catchment were identified that would lead to cumulative impacts for surface waters.

**Conclusion**

This construction and operation of the Proposal is unlikely to result in serious adverse impacts on local surface water quality and quantity, including receiving environments such as Wamberal Lagoon Nature Reserve and Wamberal Lagoon itself.

# 1. Introduction

## 1.1 Proposal identification

Transport for NSW (TfNSW) propose to upgrade the intersection of the Central Coast Highway and Tumbi Road, Wamberal NSW. This would involve the replacement of the existing roundabout with a new Traffic Control System (TCS) along with localised road widening throughout the intersection (the Proposal). A Review of Environmental Factors (REF) has been prepared to assess the potential impacts of the Proposal on the environment. This report has been prepared as a technical report to the REF for the purpose of assessing the impact of the Proposal on the local surface water hydrology, quality, and flooding.

The Proposal's total construction extent along the Central Coast Highway would be about 650 metres, from Old Tumbi Road at the south of the proposed intersection extending north to the driveway entrance to the Forresters Beach Garden Centre. The total construction extent also extends about 150 m along Tumbi Road, from the intersection with Central Coast highway to just north of the intersection with Dalpura Road.

The surface water impacts and constraints for the following proposed ancillary site options for the construction phase have also been assessed:

- Ancillary facility 1 – existing commercial plant nursery north of the construction boundary at Part Lot 4 in DP603395 – 893 The Entrance Road, Wamberal
- Ancillary facility 2 –property proposed for subdivision opposite Forresters Beach Road at Part Lot 522 in DP1077907 – 987-991 The Entrance Road, Foresters Beach
- Ancillary facility 3 – property at 35 Bellevue Road at Part Lot 197 in DP755234.

The upgrade of the Tumbi Road intersection would include:

- Site preparation works, including establishment of ancillary facilities, vegetation clearing, site fencing, temporary drainage measures, and implementation of environmental management measures
- Relocation of the following bus stops to a common location on the western side of the Central Coast Highway, just the north of the intersection:
    - Bus stop 2260187 - Tumbi Road at Central Coast Highway
    - Bus stop 2260174 - Central Coast Highway opposite Ulamba Avenue.
- Minor relocation of bus stop 2260137 (Central Coast Highway at Ulamba Avenue) approximately 30 metres north
- All existing bus services would remain in operation during construction of the Proposal
- Localised demolition of existing footpaths to accommodate works. Alternative access would be provided for pedestrians throughout construction
- Temporary relocation of active traffic lanes, including the placement of temporary pavement, to maintain traffic flow during construction and local access
- Demolition of the existing roundabout and sections of pavement over each arm of the intersection
- Widening of the Central Coast Highway to the north of the intersection to dual lanes in both directions, with a transition back to single lanes prior to the northern limit of works
- Widening of Tumbi Road as it approaches the intersection. This would include dual left turn lanes and a single right turn lane for traffic approaching the intersection. Tumbi Road would remain single lane for traffic leaving the intersection (heading north)
- Installation of new traffic lights at the intersection of the Central Coast Highway and Tumbi Road, including the following road changes:
    - Construction of a slip lane for left turn onto Tumbi Road from the northbound lanes of the Central Coast Highway

    - Construction of a dedicated right turn lane onto Tumbi Road from the southbound lanes of the Central Coast Highway
    - Construction of a slip lane for left turn onto the northbound lanes of the Central Coast Highway from Tumbi Road
    - Construction of dedicated dual right turn lanes onto the southbound lanes of the Central Coast highway from Tumbi Road.
- Construction of concrete and vegetated medians on Tumbi Road and the Central Coast Highway to separate opposing lanes of traffic
- Earthworks, including excavation and the construction of retaining walls and batters to accommodate the widened road
- Construction of retaining walls and batters on both sides of the Central Coast Highway
- Changes to the existing culvert under the Central Coast Highway immediately north of the Tumbi Road intersection. This would include:
    - Extension of eastern side the culvert to accommodate the widened road
    - Addition of a new pipe under the road to increase capacity of the culvert
    - Construction of new inlet and outlet structures at both ends of the culvert
    - Construction of an energy dissipation device at the eastern end of the culvert to reduce the velocity of water entering the Wamberal Lagoon Nature Reserve.
- Provision of a new pedestrian footpath adjacent to the northbound lanes of the Central Coast Highway between Old Tumbi Road and Tumbi Road, including a pedestrian connection to the Old Tumbi Road cul-de-sac
- Provision of a new pedestrian footpath along the northern side of Tumbi Road from a point 20 metres north of the intersection with Dalpura Road towards the intersection with the Central Coast Highway intersection, and continuing north adjacent to the northbound lanes of Central Coast Highway to the Pacific Garden Hotel
- Provision of suitable temporary and permanent entry arrangements for private properties fronting the Central Coast Highway and Tumbi Road within the limit of works
- Provision of a U-turn facility adjacent to the Pacific Garden Hotel for southbound traffic to turn back northbound, including a new kerbside lane on the northbound side of the road to facilitate entry to the hotel
- Permanent and temporary acquisition of private property, both full and partial, to accommodate the widened road and associated construction activities
- Subject to landowner agreement, property adjustments to the Wamberal Grocer and Fruit Market, including removal of the existing parking area provision of a new replacement parking and loading facility immediately south of the existing shop
- Drainage upgrade works within the road corridor and adjacent private property
- Provision of formalised drainage along the Central Coast Highway at the north eastern limit of works, discharging into an existing waterway
- Provision of a new permanent maintenance vehicle access ramp on the eastern side of the Central Coast Highway, north of the intersection.
- Street lighting upgrades within and approaching the upgraded intersection
- Provision of new pavements and upgrade of existing pavements throughout the Proposal Area
- New and adjusted signage and line marking
- Construction of new and upgraded active transport connections, including the re-establishment of any footpaths or shared paths removed to facilitate construction
- Construction of a new permanent bus stop adjacent to the northbound lanes of the Central Coast Highway, just north of the intersection. This new bus stop would consolidate bus stops 2260187 and 2260174 with all services being transferred to the new permanent bus stop
- Landscaping, including the planting of trees, shrubs and grass within the Proposal Area and the regeneration of bushland adjacent to the Wamberal Lagoon Nature Reserve boundary. Drainage channels would be planted with suitable mix of species aimed at improving water quality

- Relocation and adjustment of existing utilities including water, sewerage, electricity, gas, and telecommunications as required to accommodate the Proposal. This includes adjustments to existing utility connections into private property where these are affected by the Proposal, and may include short adjustments outside the limit of works to allow for connection back to existing utility alignments
- Demobilisation of construction activities, including removal of ancillary facilities, remaining construction materials and stockpiles and temporary environmental management measures. All temporary sites occupied during construction would be rehabilitated upon completion to at least their condition prior to the start of works.

## 1.2 Purpose of this report

The purpose of this report is to describe the surface water quality and flooding environments relative to the study area and to assess the potential impact of the Proposal during both the construction phase and operational phase.

# 2. Assessment methodology

## 2.1 Legislation and policy

### 2.1.1 Relevant legislation

The following NSW legislation and statutory requirements apply to the surface water assessment:

- *Protection of the Environment Operations Act 1997* (POEO Act)
- *Protection of the Environment Administration Act 1991*
- *Local Government Act 1993*
- *Fisheries Management Act 1994*
- *Water Management Act 2000* and the *Water Management (General) Regulation 2011*
- *State Environmental Planning Policy (Coastal Management) 2018*
- *State Environmental Planning Policy (Infrastructure) 2007*

In addition to this the following Commonwealth policy has been considered:

- National Environment Protection (Assessment of Site Contamination) Measure 2013.

#### *State Environmental Planning Policy (Infrastructure) 2007*

The Proposal is not located on land reserved under the *National Parks and Wildlife Act 1974* and does not require development consent or approval under *State Environmental Planning Policy (Coastal Management) 2018*, *State Environmental Planning Policy (State and Regional Development) 2011* or *State Environmental Planning Policy (State Significant Precincts) 2005*. The Proposal is located nearby to Wamberal Lagoon Nature Reserve, which is protected under the *National Parks and Wildlife Act 1974*. No work would take place on this land, and mitigation measures in Section 5 would minimise any potential indirect impacts on this land.

#### *State Environmental Planning Policy (Coastal Management) 2018*

The *State Environmental Planning Policy (Coastal Management) 2018* (Coastal Management SEPP) provides a strategic framework and objectives for managing coastal issues in NSW, with an aim to protect and enhance coastal environments, habitats, and natural processes.

The Proposal is located in a 'Proximity Area' to mapped 'Coastal Wetlands' under the Coastal Management SEPP. The Proximity Area extends from opposite the Wamberal Grocer and Fruit Market to just south of the intersection of the Central Coast Highway with Crystal Street. Works proposed within the Proximity Area would include retaining walls, road and pavement construction, drainage, lighting, and other ancillary works. The Proposal would not directly impact on or occupy any land designated as 'Coastal Wetlands' under this policy.

As the Proposal is located in a 'Proximity Area' but is not located within the 'Coastal Wetlands' footprint, and the work is being carried by or on behalf of a public authority, the provisions of the Coastal Management SEPP do not apply to this Proposal. Despite this, mitigation measures provided in this section would manage associated with construction such that impacts upon the adjacent coastal wetlands area are acceptable. For operation, flooding impacts associated with the Proposal are considered acceptable, and any impacts to drainage would be mitigated with the design. Operational water quality would include a small incremental increase in pollutant loads.

### 2.1.2 Specific construction phase guidelines

The following design guidelines and management procedures are relevant in identifying the appropriate water quality management and mitigation measures to be implemented during the construction phase of the Proposal:

- *NSW DECC 2008 'Managing Urban Stormwater-Volume 2D Main Road Construction', NSW Department of Environment, Climate Change and Water (known as the Blue Book Volume 2)*
- *Landcom, 2004 'Managing Urban Stormwater- Soils and Construction, Volume 1', 4th Edition (known as the Blue Book Volume 1)*
- *Roads and Traffic Authority 2009, 'Erosion and Sediment Management Procedure'*
- *Roads and Traffic Authority 2012, 'Environmental Direction: Management of Tannins from Vegetation Mulch'*
- *Roads and Maritime 2011 'Technical Guideline: Temporary Stormwater Drainage for Road Construction'*
- *Roads and Maritime 2011 'Technical Guideline – Environmental Management of Construction Site Dewatering'.*
- *Roads and Maritime 2015 'Guideline for Batter Surface Stabilisation using vegetation'.*

### 2.1.3 Specific operational phase guidelines

The following design guidelines and management procedures are relevant in identifying the appropriate water quality management and mitigation measures to be implemented during the operational phase of the Proposal:

- *Roads and Traffic Authority 2003 Procedure for selecting treatment strategies to control road runoff*
- *Austroads, 2001 Road Runoff and Drainage: Environmental Impact and Management Options, Austroads AP-R180*
- *Austroads, 2003 Guidelines for Treatment of Stormwater Runoff from the Road Infrastructure, Austroads AP-R232*
- *Austroads, 2013 Guide to Road Design, Part 5: Drainage – General and Hydrology Considerations*
- *Austroads, 2013 Guide to Road Design, Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface*
- *Austroads, 2013 Guide to Road Design, Part 5B: Drainage – Open Channels, Culverts and Floodways.*

### 2.1.4 Water quality policy and guidelines

The following water quality guidelines were identified as relevant and reviewed to determine obligations for the construction of the Proposal with respect to the water quality objectives for the Wamberal Lagoon catchment.

#### *Managing Urban Stormwater: Soils and Construction - Volume 1 and Volume 2A (the Blue Book)*

The principles for the management of stormwater during the construction phase are documented in this publication, also known as 'the Blue Book'. The management principles within this document have been accounted for in the mitigation and management measures developed for the construction phase of the Proposal.

### *ANZECC (2000) and ANZG (2018) Water Quality Guidelines*

The ANZECC Water Quality Guidelines provide a nationally consistent approach to water quality management based on the principle of the ecologically sustainable development of water resources. The ANZECC (2000) guidelines have been recently revised and are now known as ANZG 2018.

The guidelines contain a set of tools for the assessment and management of water quality across a range of water resource types based on designated environmental values. These include ambient water quality guidelines which are appropriate for the assessment of the existing water quality of watercourses downstream of the Proposal, such as Wamberal Lagoon.

### *Australian Rainfall and Runoff*

Australian Rainfall and Runoff (Geoscience Australia, 2019) is the primary technical publication for hydrological estimates and design considerations. The latest issue was finalised in 2019 and was the result of several years of updates to the previous version of Australian Rainfall and Runoff (Engineers Australia, 1987).

### *Other guidance*

The following standards were also used to establish the flooding design criteria for the Proposal:

- Austroads Guide to Road Design Part 5,6 and 8 (Austroads, 2021)
- Australian Rainfall and Runoff (AR&R) 2019 (Geoscience Australia, 2019)
- Australian Rainfall and Runoff Project 11 Blockage of Hydraulic Structures – Stage 2 Report (Engineers Australia, 2013)
- Transport for New South Wales guidelines and standards including the following project specific standards:
    - QA Specification PS271 – Hydrology and Drainage Design
    - QA Specification PS371 – Hydrology and Drainage Design
    - QA Specification PS261 – Bridge and Structure Concept Design
- RMS Technical Guide, Climate Change Adaptation for the Road Network
- Flood plain Development Manual (DIPNR, 2005).

## 2.1.5 NSW Water Quality and River Flow Objectives

To safeguard the long-term health of waterways, NSW Government has developed the Gosford and Northern Beaches Lagoons Water Quality Objectives (WQO) and River Flow Objectives (RFO) (DECCW, 2006). The objectives outline the physical and chemical conditions of waterways and their physical flow characteristics for the Gosford Lagoons (Wamberal, Terrigal, Avoca and Cockrone) and their catchments. The objectives were developed to represent the community's environmental values and long-term goals for waterways. The objectives guide plans and actions to achieve healthy waters and ensure the maintenance or improvement of water quality. The receiving waterway of Wamberal Lagoon is classified as a ‘waterway affected by urban development’ in accordance with above document (DECCW 2006). The WQO and RFO for Gosford Lagoons and Catchments are outlined in Figure 2-1 and discussed further below.

## Catchment at a glance

# Gosford and Northern Beaches Lagoons Catchments

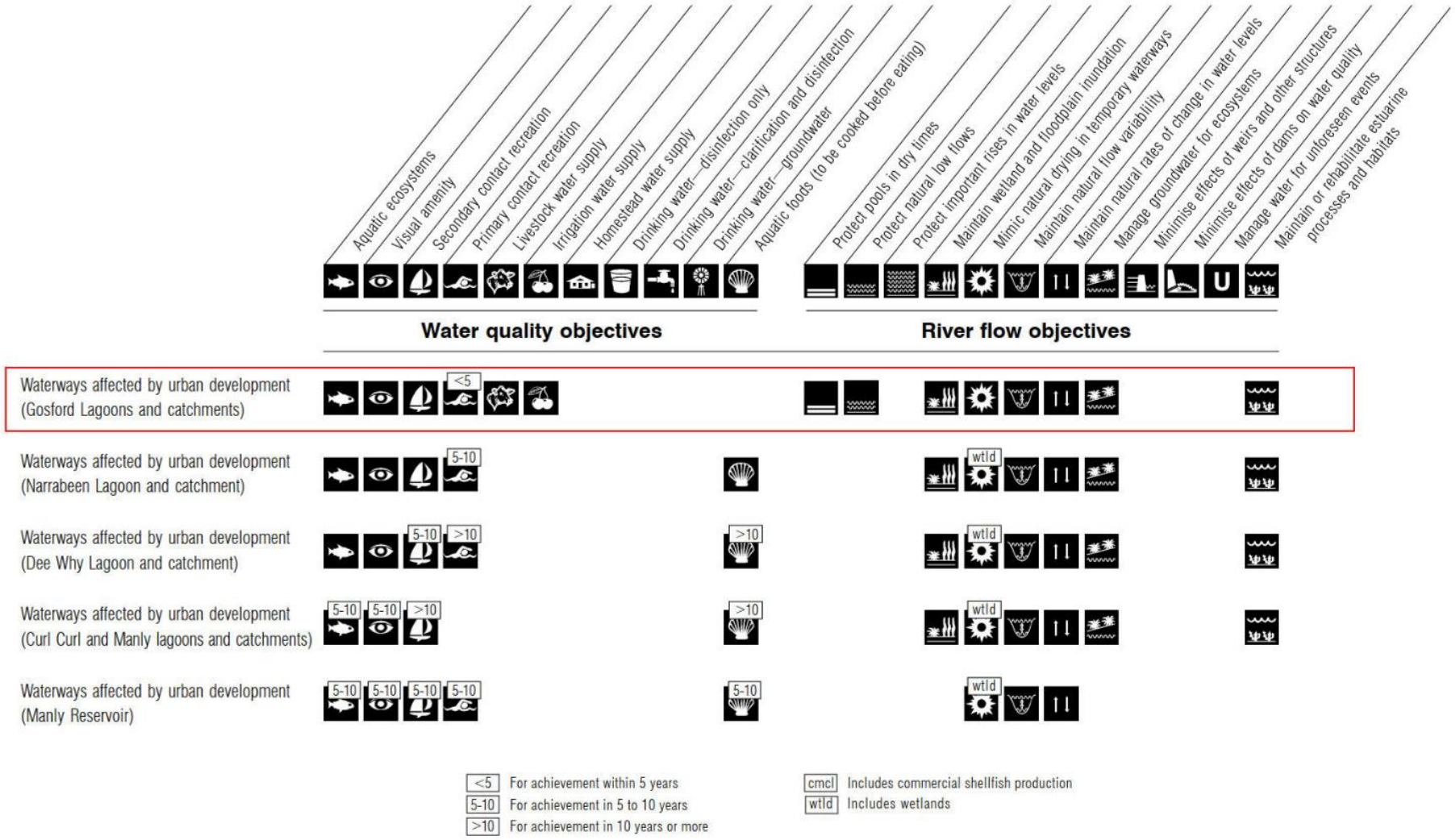



Figure 2-1 Gosford and Northern Beaches Lagoons Catchments at a glance (NSW WQOs and RFOs (DECCW, 2006))

### *Water Quality Objectives*

- **Aquatic Ecosystems -** maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term
- **Visual Amenity -** aesthetic qualities of waters
- **Secondary contact recreation -** maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed
- **Primary contact recreation -** maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed
- **Livestock water supply -** protecting water quality to maximise the production of healthy livestock **Irrigation water supply -** protecting the quality of waters applied to crops and pasture (DECCW, 2006).

### *River Flow Objectives*

- **Protect pools in dry times -** protect natural water levels in pools of creeks and rivers and wetlands during periods of no flows
- **Protect natural low flows**
- **Maintain wetland and floodplain inundation -** maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems
- **Mimic natural drying in temporary waterways -** mimic the natural frequency, duration, and seasonal nature of drying periods in naturally temporary waterways
- **Maintain natural flow variability -** maintain or mimic natural flow variability in all streams
- **Maintain natural rates of change in water levels -** maintain rates of rise and fall of river heights within natural bounds
- **Manage groundwater for ecosystems -** maintain groundwater within natural levels and variability, critical to surface flows and ecosystems
- **Maintain or rehabilitate estuarine processes and habitats.**
(DECCW, 2006)

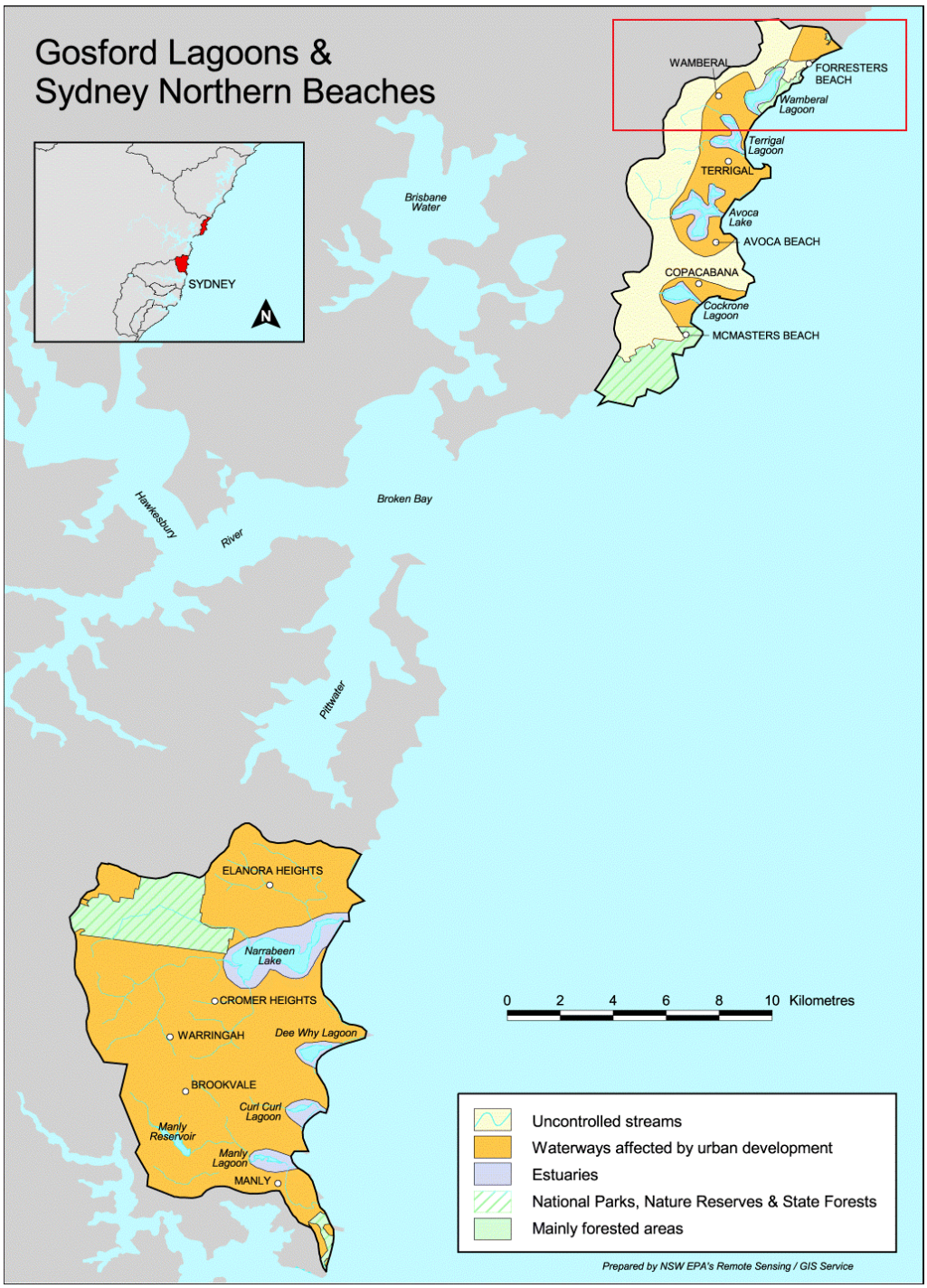



Figure 2-2 Gosford Lagoons and Sydney Northern Beaches Catchment Map (DECCW, 2006)

### 2.1.6 Project scope/design water quality requirements

To determine the water quality requirements for the design of this Proposal, several of TfNSW's project specific scope and specification documents were considered:

- QA Specification PS271: Hydrology and Drainage Design (Concept Design), Roads and Maritime Services
- QA Specification PS371: Hydrology and Drainage Design (Detailed Design), Roads and Maritime Services
- QU Specification PS311: Environmental Design and Compliance (REF and EIS), Roads and Maritime Services.

These documents make the following references to requirements to address water quality during the construction phase and the operation phase:

- Construction phase measures to manage water quality include erosion and sediment control measures, and these would be applied to the project as part of the Construction Environmental Management Plan (CEMP).
- For the operation phase, the most stringent requirement for water quality is:

  *PS311 2.4.2 Operational Water Quality - Operational water quality control measures are to be designed to provide the following:*
  *(i) Average annual pollutant load reductions of Total Suspended Soils (TSS) of 80%...*

## 2.2 Methodology

A qualitative and quantitative assessment has been undertaken to address the potential impacts to surface water quality and flooding as a result of the Proposal.

This assessment has applied the following methodology:

- Review available water quality, flooding data and existing conditions to obtain background information on catchment history and land use, define the existing environment and to describe the catchment. The downstream receiving environment has been the subject of several studies; therefore, it was assumed that adequate data are available to characterise the environment. As such, no onsite monitoring was required
- Define the area that influences the surface water environments
- Review existing flood conditions and the design flood simulations
- Identify potential impact of construction and operational activities and potential cumulative impact on surface water quality with reference to the ANZG (2018) water quality guidelines for protection of the relevant environmental values. This includes a review of surface water impacts and constraints for the following proposed ancillary site options:
  - Ancillary facility 1 – existing commercial plant nursery north of the construction boundary at Part Lot 4 in DP603395 – 893 The Entrance Road, Wamberal
  - Ancillary facility 2 –property proposed for subdivision opposite Forresters Beach Road at Part Lot 522 in DP1077907 – 987-991 The Entrance Road, Foresters Beach
  - Ancillary facility 3 – property at 35 Bellevue Road at Part Lot 197 in DP755234.
- Develop water quality treatment measures to mitigate the impact of construction on surface water quality, following the principles of the Managing Urban Stormwater: Soils and Construction, Volume 1 (Landcom, 2004) and Volume 2D (DECC, 2008)
- If surface water quality treatment measures are required by the project to reduce the operational impact of the Proposal on water quality, a description of the proposed treatment designs and outcomes would be provided
- Provide a consolidated list of measures to be applied during construction and operational phase to mitigate potential impact to surface water.

# 3. Existing environment

## 3.1 Data

To understand the existing conditions at the site, several recently published studies were reviewed for the Wamberal Lagoon Catchment, including:

- *Wamberal Flood Assessment* report and TUFLOW model prepared by WMA Water in 2020
- *Coastal Lagoons Catchments Overland Flood Study* report prepared by the Manly Hydraulics Laboratory in 2020
- *Central Coast Highway and Tumbi Road intersection upgrade, Wamberal – Biodiversity Assessment Report* prepared by Transport for NSW in May 2020
- *Central Coast Waterways Report Card 2017-18* prepared by Central Coast Council in 2018
- *Gosford City Waterways: The Health of Gosford City Waterways Report 2015* prepared by Central Coast Council in 2016.

## 3.2 Climate

The Proposal is located in a region with a temperate, coastal climate. Three nearby Bureau of Meteorology weather stations were reviewed for annual rainfall statistics. These indicated an average rainfall of between 1,244.0 mm and 1,328.7 mm for the region (Table 3-1).

Wamberal has a mean maximum temp in summer of 27.8°C, with January as the warmest month and a cool mean minimum temperature of 7.7°C in winter, with June being the coolest month (data recorded at Gosford AWS, site number 61425, data series between 2013 and January 2021).

Table 3-1 Mean monthly rainfall based on records, measured at three BoM stations near the Proposal (current as at 22 Feb 2021)

| | | Mean monthly rainfall (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location (Site Number)** | **Distance from Proposal** | **January** | **February** | **March** | **April** | **May** | **June** | **July** | **August** | **September** | **October** | **November** | **December** | **Annual** |
| **Wamberal (61369)** | 2km South West | 99.4 | 156.4 | 121.9 | 141.9 | 152.3 | 129.5 | 105.9 | 79.8 | 73.5 | 82.1 | 97.4 | 102.0 | 1224 |
| **Gosford (061087)** | 12km East | 134.7 | 154.7 | 149.9 | 139.4 | 118.3 | 130.5 | 80.2 | 72.4 | 68.5 | 84.5 | 91.7 | 104.2 | 1329 |
| **Gosford AWS (61425)** | 9km South West | 117.5 | 119.6 | 185.4 | 132.3 | 47.9 | 159.5 | 49.9 | 87.8 | 60.2 | 106.2 | 82.1 | 78.7 | 1284 |

*All data was taken from the BoM website on 22 February 2021*

## 3.3 Geology and soil landscapes

The presence of Acid Sulfate Soils (ASS) in the Proposal Area was reviewed in Section 6.5 of the REF. This review indicated that the majority of the Proposal Area and its surrounds are mapped as Class 5 (extremely low probability of ASS occurrence (1-5%)). Acid sulfate soils are not typically found in Class 5 mapped areas.

According to DPIE's soil mapping, areas classified as Class 5 are likely to be located within 500 metres of adjacent Class 1, 2, 3 or 4 land. Class 3 ASS has been previously mapped on the eastern boundary of the Proposal Area, just north of the Tumbi Road intersection. Class 3 areas indicate a high probability of ASS occurrence (>70%). In these areas, ASS are likely to be found deeper than one metre below the natural ground surface. Should construction require excavation deeper than this, suitable management measures should be put in place to manage ASS.

The soils in the Proposal Area are part of the Gosford-Lake Macquarie Landscape and are generally low-moderately fertile, mainly compromising of yellow podzolic soils. Various Soil Essentials reports from the surrounding area record a mixture of different sand and clay type soils (eSPADE V2.1, 2020). For a detailed review of the geology and soil landscapes in the area please refer to Section 6.5 of the Review of Environmental Factors.

## 3.4 Catchment features

The Central Coast of NSW features four coastal lagoon systems (Wamberal, Terrigal, Avoca and Cockrone). The catchments of these four lagoons are shown in Figure 3-1 and cover a total area of 39.1 km$^2$. The Proposal sits within the Wamberal Lagoon catchment, which is the northernmost catchment in the region.

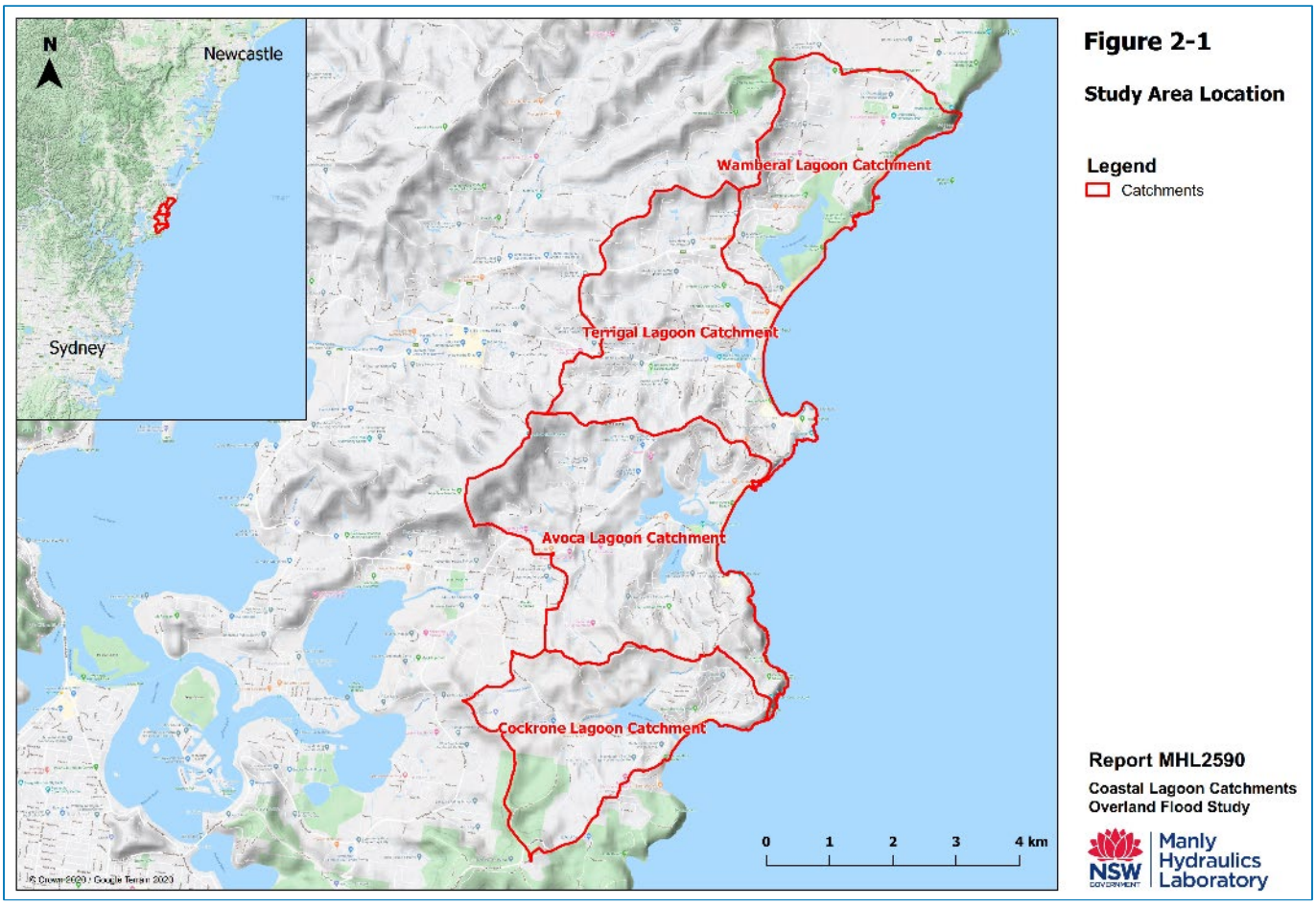



Figure 3-1 Coastal Lagoon Catchments - Overland Flood Study (MHL, 2020)

The catchment of Wamberal Lagoon is about 580 ha (McCormack 2010) and comprises urban, rural residential and natural land uses (Figure 3-2). The impervious surfaces within the catchment are estimated to be 116 ha (Table 3-2). This impervious area was derived by multiplying the total area with the percent impervious.

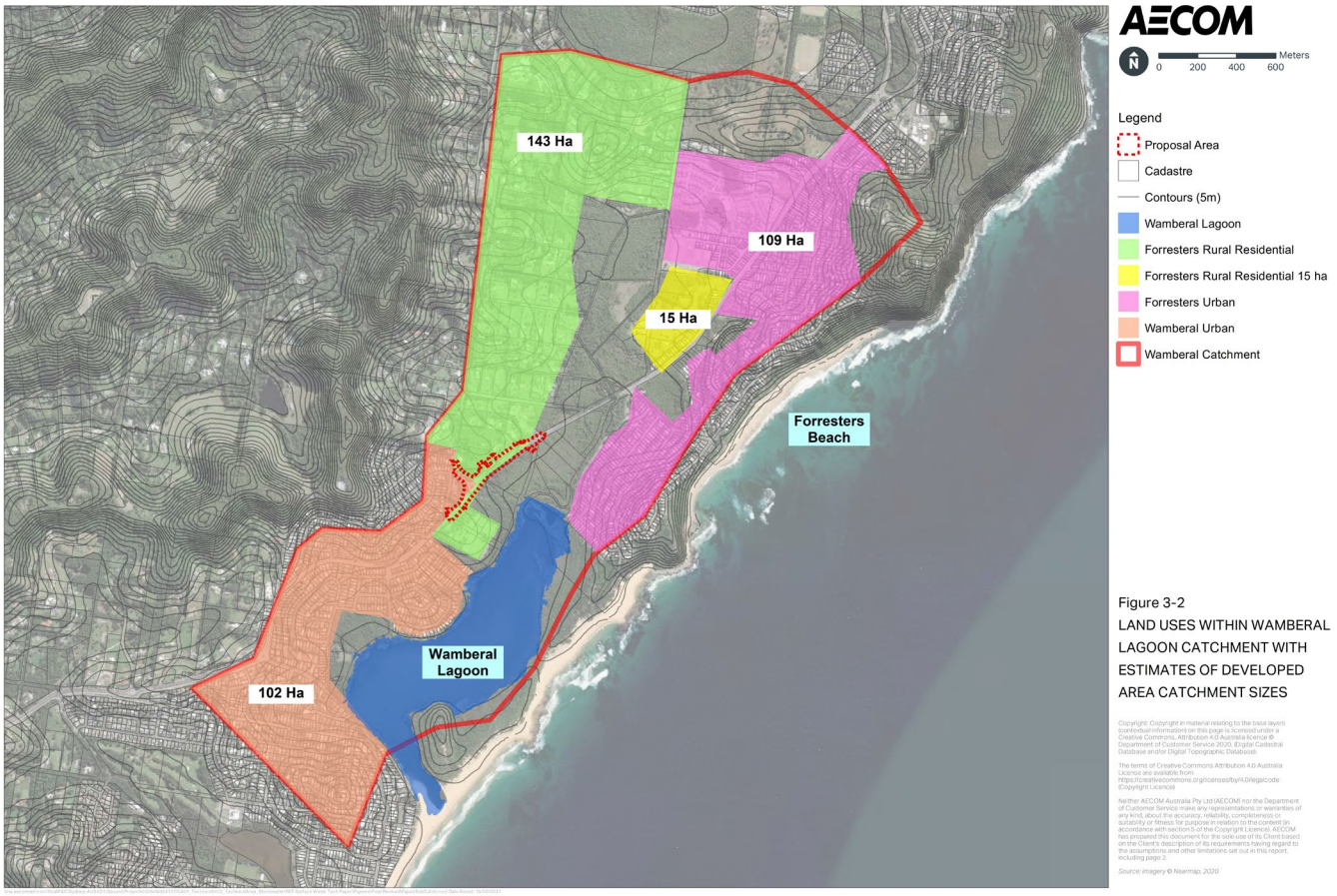



Figure 3-2
LAND USES WITHIN WAMBERAL LAGOON CATCHMENT WITH ESTIMATES OF DEVELOPED AREA CATCHMENT SIZES

Figure 3-2 Land uses within Wamberal Lagoon Catchment with estimates of developed area catchment sizes.

Table 3-2 Land uses of the Wamberal Lagoon Catchment (correlates to Figure 3-4).

| Catchment | Total Area (ha) | Percent Impervious (%) | Impervious area (ha) |
|---|---|---|---|
| **Wamberal Urban** | 102 | 40% | 40.8 |
| **Forresters Urban** | 109 | 40% | 43.6 |
| **Forresters Rural Residential** | 143 | 20% | 28.6 |
| **Rural Residential** | 15 | 20% | 3.0 |
| **Subtotal Developed Areas** | 369 | | 116.0 |
| **Natural Catchment** | 211 | | |
| **Total Catchment** | 580 | | |

Some residential areas around the Wamberal Lagoon foreshores are low-lying and subject to flooding. The upper reaches of the Wamberal Lagoon catchment rise to approximately 120 m AHD along the western

boundary with the lower reaches at sea level. The main tributary (Forresters Creek) flows south through the middle of the catchment and discharges to the lagoon. The banks of the tributary generally consist of low-lying bushland (MHL, 2020).

The average depth of the lagoon is 1.7 metres (DPIE, 2018) with the bed level typically varying between +0.0 m AHD (approximately mean sea level) to +1.0 m AHD. The outlet to the Pacific Ocean is generally blocked by a sand bar or beach berm, thus the water level in the lagoon is generally not influenced by the tides (MHL, 2020).

The Biodiversity Assessment Report for the Central Coast Highway and Tumbi Road Intersection Upgrade (WSP, 2020) found that the aquatic habitat in the Proposal study area is limited to one unnamed stream (Strahler 1st order stream). This stream supports intermittent flow following rain events. The stream has been channelled through existing concrete pipes under the Central Coast Highway, and discharges via a concrete apron on the eastern side of the road before flowing into Wamberal Lagoon Nature Reserve (WSP, 2020).

The Biodiversity Assessment indicates that no Key Fish Habitat has been mapped within the Proposal Area. The closest area of mapped Key Fish Habitat occurs within Wamberal Lagoon Nature Reserve to the east of the Proposal, indicated on Figure 3-3 (WSP, 2020).

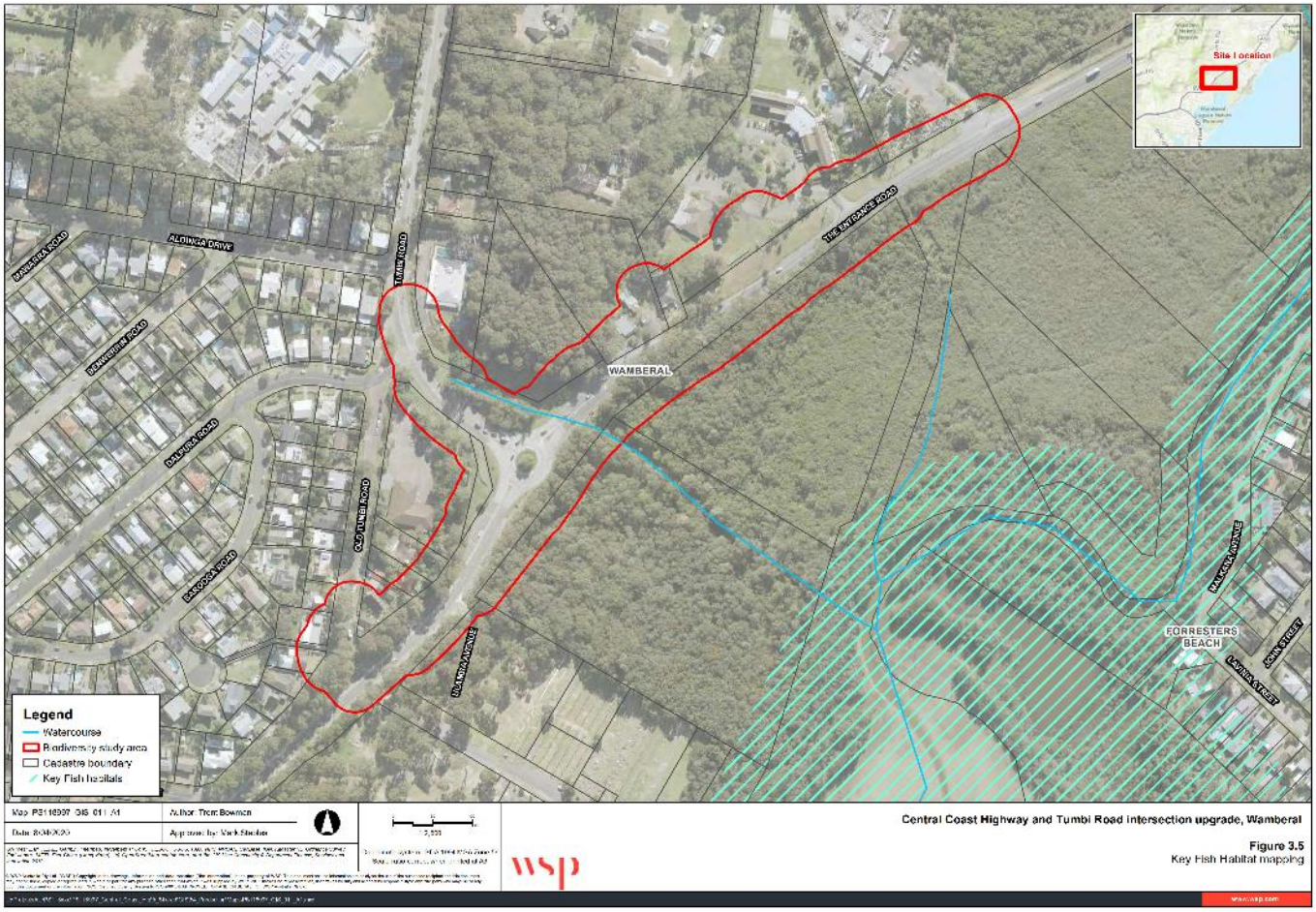



Figure 3-3 Proposal Study Area with Key Fish Habitat Mapping (WSP, 2020)

## 3.5 Drainage

The main drainage line running through the intersection consists of:

- a large underground drainage network that collects runoff from an upstream catchment in the order of 22 ha and discharges to an open channel on the northern side of Tumbi Road
- a 60 m long open channel along the northern side of Tumbi Road that conveys flow from the upstream drainage network and directs it into an existing culvert crossing under the Central Coast Highway
- a crossing under the Central Coast Highway, which consists of three 1050 mm diameter pipes
- a 300 m long open channel that conveys flow from the Central Coast Highway culvert crossing towards the Wamberal Lagoon, which eventually discharges directly to the coast.

Runoff from both Tumbi Road and the Central Coast Highway (i.e. across the Proposal Area) generally drains towards either side of the road which then drains directly to cross drainage structures or to open channels leading towards the Wamberal Lagoon. Both roads have little in the way of existing drainage infrastructure.

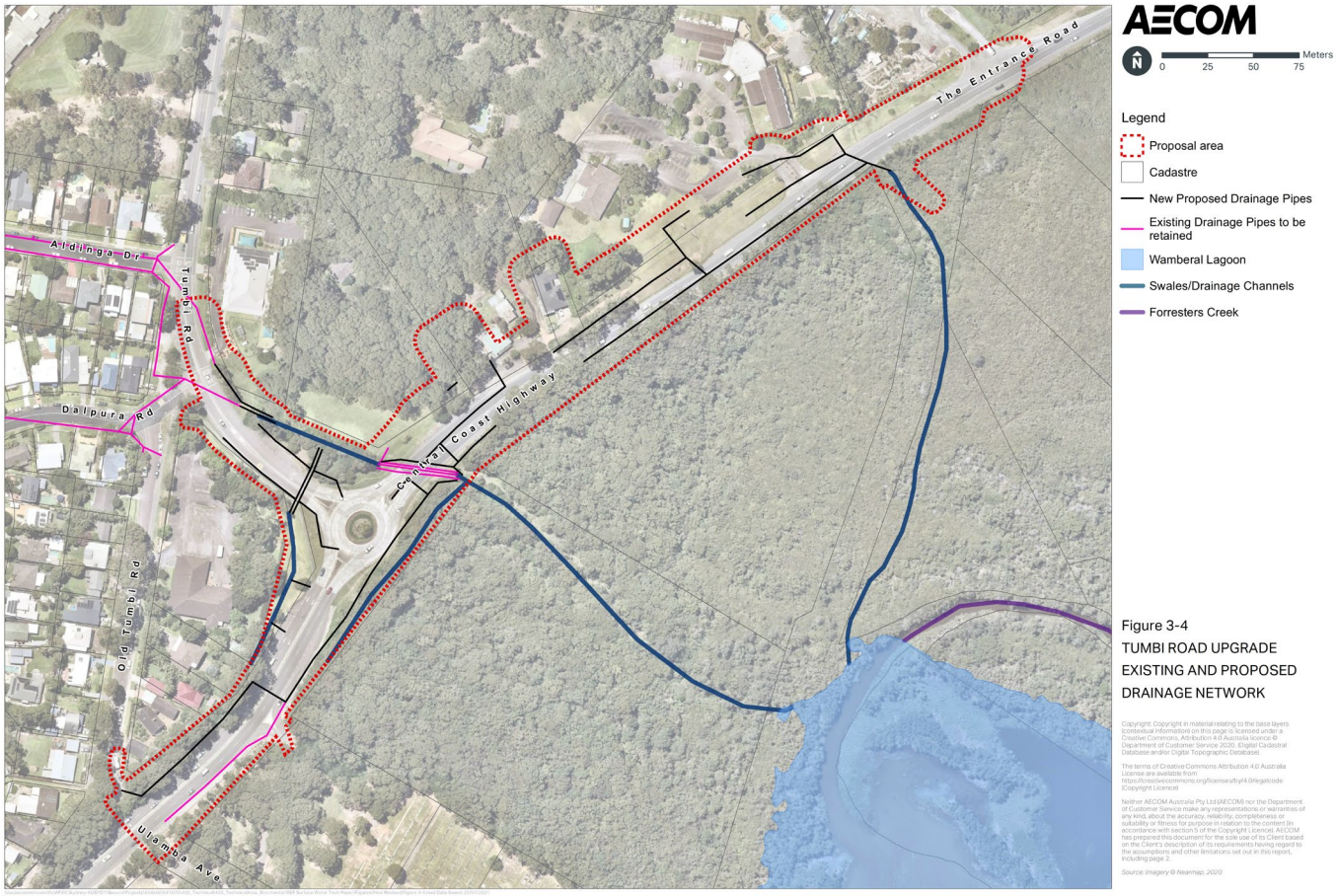



Figure 3-4
TUMBI ROAD UPGRADE
EXISTING AND PROPOSED
DRAINAGE NETWORK

Figure 3-4 Tumbi Road Upgrade – Existing and Proposed Drainage Network

## 3.6 Surface water quality

One of the key influences on surface water quality in the Proposal Area is stormwater. Stormwater entrains material (soluble or insoluble) mobilised in its path of flow and these materials may pollute the quality of runoff. Stormwater runoff quality in the Proposal Area is likely to be influenced by surface pollutants typical of urban catchments, including:

- oils and hydrocarbons

- heavy metals
- chemicals from spills, localised pesticide application or inappropriate waste disposal
- sediments
- gross pollutants including litter and debris.

One existing water quality treatment device has been identified within the Proposal Area. This device is a trash rack located in the vegetated channel north of Tumbi Road, directly north-west of the intersection between Tumbi Road and the Central Coast Highway. A trash rack will remove litter and debris but does not contribute to the removal of suspended solids or dissolved pollutants.

Wamberal Lagoon is part of Central Coast Council's Water Quality Monitoring Program and Beachwatch Program, which monitors the water quality of ten waterways throughout the Central Coast LGA. At each site, physical and chemical water quality parameters including temperature, salinity, total dissolved solids, conductivity, dissolved oxygen, oxidation reduction potential, pH and turbidity are measured. General observations of the appearance of the water and any surface scums, algae, oily films, odours, weather, wind, rain, and tide/flows are also recorded. Water samples are analysed by a laboratory for enterococci, chlorophyll-a, ammonia, soluble reactive phosphorus, total nitrogen, total phosphorus, and oxidised nitrogen (Central Coast Council, 2016).

Additionally, individual parameter trigger values have been set based on ANZECC 2000 and historical water quality data for each monitoring site. Table 3-3 provides a summary of this. Water quality results that exceed these limits are expected to negatively impact on the scorecard and meeting the target score.

Table 3-3 Default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems and Central Coast Council set trigger values based on historic water quality data sets

| Water Quality Parameter (units) | ANZECC 2000 Marine and Estuarine Waters | Central Coast Council Estuarine Trigger Values |
|---|---|---|
| **Chlorophyll a (µg/L)** | < 4 | < 2 |
| **Total Phosphorus (mg/L)** | < 0.03 | < 0.05 |
| **Filterable Reactive Phosphate (mg/L)** | < 0.005 | < 0.01 |
| **Total Nitrogen (mg/L)** | < 0.3 | < 1.0 |
| **Oxides of nitrogen (mg/L)** | < 0.015 | < 0.02 |
| **Ammonia (mg/L)** | < 0.91 | < 0.01 |
| **Dissolved oxygen (% saturation)** | 80% - 110% | > 75% |
| **pH** | 7.0 – 8.5 | 7.0 – 8.5 |
| **Turbidity** | < 10 | < 5 |

According to the Central Coast Waterways Report Card 2018, water quality within Wamberal Lagoon was considered good (a Report Value of 'B') for the 2017-18 sampling period. Turbidity within the lagoon frequently exceeded the trigger value. Higher turbidity values were often recorded from Zone 1 (furthest upstream). Chlorophyll-a was excellent within the lagoon for much of the sampling period. (Central Coast Council, 2018).

These outcomes were also compared to the findings of 'The Health of Gosford Waterways Report 2015' (Central Coast Council, 2016) which gave Wamberal Lagoon a Water Quality Rating of 'B+' and a descriptor of 'Good', reporting that the target score (scorecard value of 8 and above) had been met and the results had been maintained compared to the previous six years (Figure 3-5).

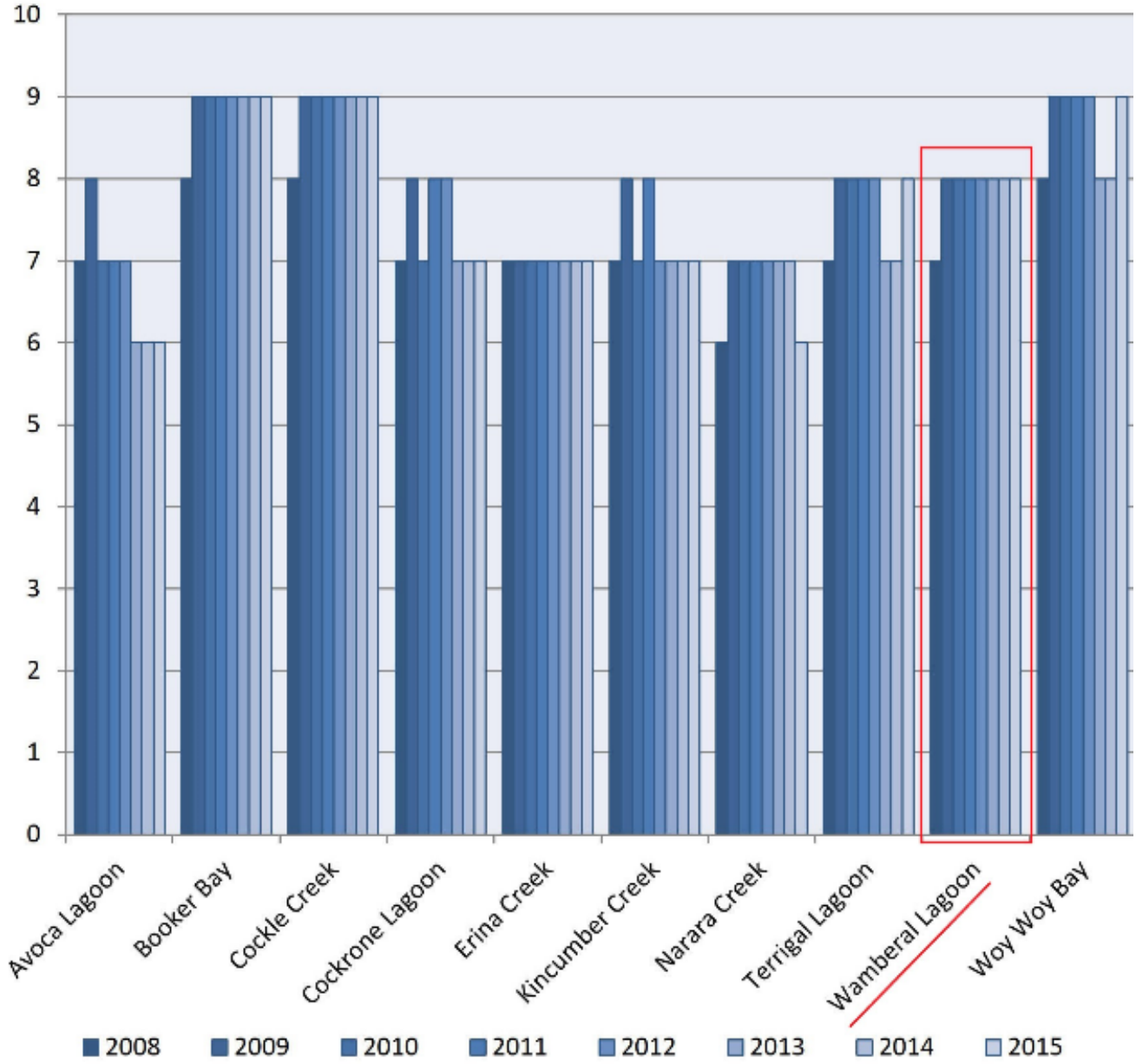



Figure 3-5 Annual water quality scorecard results from 2008 until 2015 for the 10 water quality monitoring sites (Central Coast Council, 2016)

## 3.7 Flooding

Existing flood behaviour across the Proposal Area was captured by flood modelling that covers the entire Wamberal Lagoon catchment area. The modelling was undertaken using the Wamberal Lagoon TUFLOW model that was developed as part of previous flood studies; the most notable being:

- The *Coastal Lagoons Catchment Overland Flood Study* prepared by the Manly Hydraulics Laboratory (MHL), in 2020, to assist with the floodplain management process across a number of the coastal lagoon catchments (MHL, 2020).
- The flood assessment for the *Central Coast Highway Upgrade at Forresters* which was prepared by WMAwater, in 2020, to assess the impacts of the proposed duplication of the Central Coast Highway from Tumbi Road through to Bateau Bay Road (WMAwater, 2020). This model built upon the model that was originally developed by MHL (2020) and was updated to incorporate more

accurate data that was collected during site visits (e.g. measured culvert dimensions, invert levels and bridge parameters).

The extent of the Wamberal Lagoon TUFLOW model, relevant to the Proposal Area, is shown in Figure 3-6.

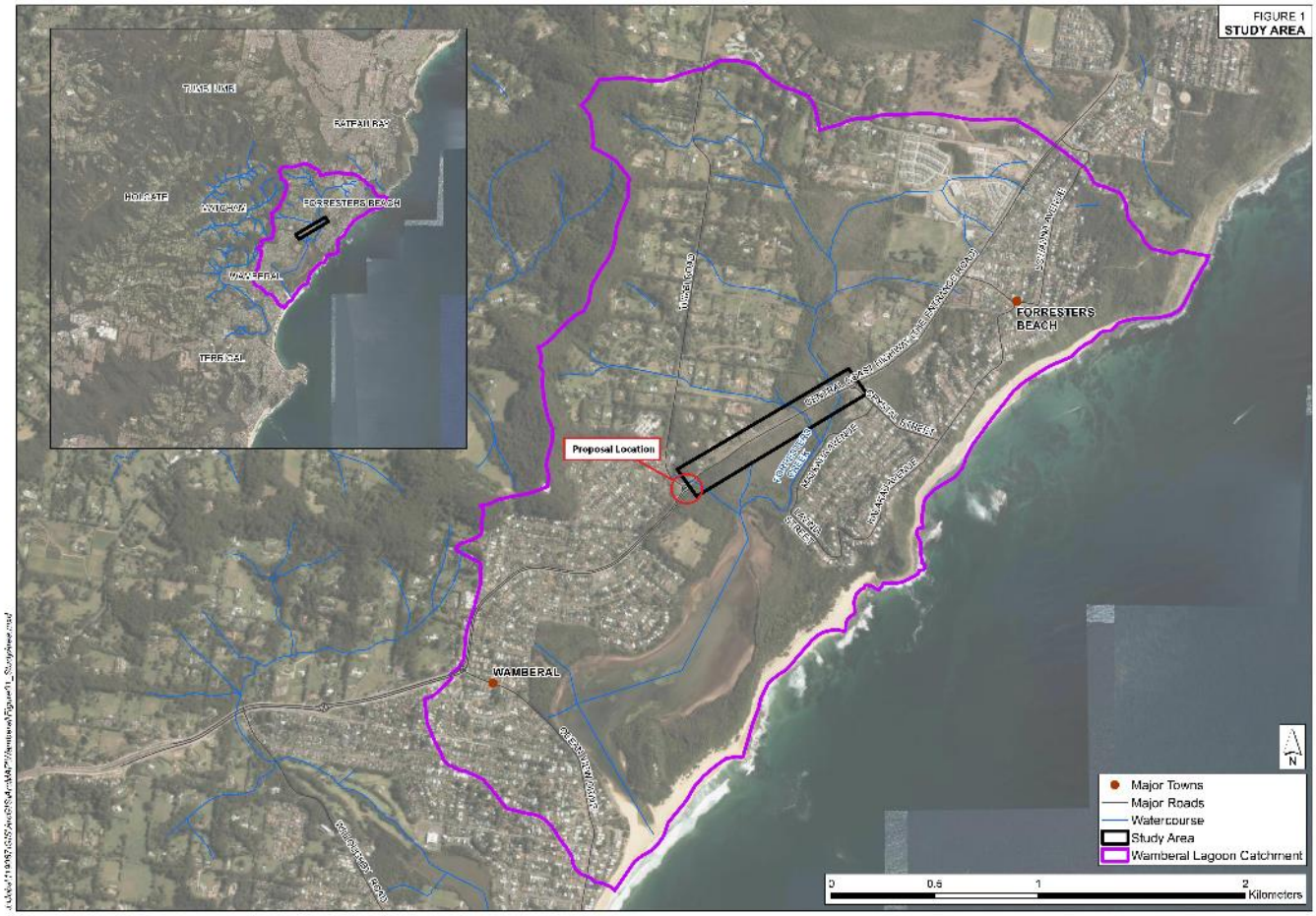



Figure 3-6 Wamberal Lagoon TUFLOW model boundary (WMAwater, 2020)

To understand the existing flood behaviour across the Proposal Area, the Wamberal Lagoon TUFLOW model developed by WMAwater (2020) was obtained and updated to include the latest topographical survey across the project area. This version of the model was adopted as it captures the latest updates and provides the most accurate representation of existing drainage structures across the project area and broader catchment area. All other aspects of the model remained consistent with previous modelling undertaken by WMAwater, including the adopted hydrological approach, rainfall hyetographs, loss parameters, critical storm durations, grid cell size and downstream conditions.

More details on the model development can be found in the technical flooding assessment report that was undertaken as part of the *Central Coast Highway, Tumbi Road Intersection Upgrade* (AECOM, 2021).

Flooding across the catchment has previously been described as *"dominated by slow moving water across relatively flat terrain"* (WMAwater, 2020). The difference in flood levels across the range of flood events that were modelled is quite small and there are significant portions of the Central Coast Highway that experience overtopping, even in frequent flood events (as small as a 50% AEP event).

The existing or 'base case' scenario that was modelled to represent the existing flood behaviour across the project area, prior to the completion of the project, showed that floodwaters began to overtop both Tumbi Road and the Central Coast Highway in a 5% AEP event. Flows on the southern side of Tumbi Road would

overtop the Tumbi Road embankment and spill towards the northern side of Tumbi Road, and floodwaters on the northern side of Tumbi Road would then overtop the Central Coast Highway and spill to the existing open channel leading to the Wamberal Lagoon. Floodwaters moving within this channel could be contained entirely within the banks of the channel in all events up to and including the 1% AEP event.

The *Coastal Lagoon Catchments Flood Study* stated that the Wamberal Lagoon catchment can be susceptible to multiple modes of flooding, including that caused by overland flows generated by local catchments, mainstream flows, and/or tidal sea levels (MHL, 2020). The latest flood modelling, conducted by AECOM (2021), assessed any sensitivities to increased tide levels which indicated that a rise in sea levels would have minimal impact on flooding across the Tumbi Road/Central Coast Highway intersection. Flooding across the intersection is therefore mainly influenced by a combination of overland flows generated by local catchments (including the road), and mainstream flooding from flows heading along the existing channel that runs along the northern side of Tumbi Road.

# 4. Potential impacts – the Proposal Area

## 4.1 Construction impacts

This section discusses the potential impact of the construction phase activities on surface water quality, hydrology, and flooding. This assessment is based upon construction activities for the Proposal outlined in Section 3.3 of the Central Coast Highway and Tumbi Road Intersection Upgrade Review of Environmental Factors.

A detailed list of works to be undertaken in the road area of this Proposal have been identified in Section 1.1 of this report. Relevant construction activities include:

- Demolition and construction work
- Civil earthworks i.e. excavation and trenching
- Concreting, asphalt, and surfacing (including chemicals and spill hazards).
- Temporary works i.e. construction of access roads, hardstand, access roads, compounds, laydown areas and pads
- Temporary diversion of drainage infrastructure
- Clearing and scrubbing
- Stockpiling of materials

### 4.1.1 Surface water quality

During construction the Proposal has the potential to affect local water quality within local waterways, including Wamberal Lagoon. During runoff events or flood conditions, sediment laden waters, chemicals stored on site, and construction waste have the potential to mobilise and enter waterways.

Water quality impacts to the main Proposal Area include (but are not limited to) increased turbidity, increased pH and elevated concentrations of nutrients and other pollutants, such as heavy metals and organic chemicals. Other potential sources that may impact surface water quality during construction include:

- Accidental spills of fuels, oils or other chemicals from construction vehicles or equipment. Contaminants could enter the local stormwater system and be transported to nearby waterways (Wamberal Lagoon).
- Waste and litter from building activities and personnel
- Release of nutrients from fertilisers, herbicides, and pesticides (e.g. used in site landscaping)
- Paint and paint wastes
- Acids from acid-based washes
- Concrete spills and new concrete
- Disturbance of soils, erosion and mobilisation of sediment or other pollutants pose a potential risk to downstream surface water quality.
- Disturbance of contaminated soils and/or ASS, which may adversely affect water chemistry including pH and dissolved solids.
- Transport of chemicals used in treatment and curing of concrete and mobilisation of concrete dust to waterways through wind and runoff
- If flood waters were to affect any areas where chemicals and fuels have been stored, this could lead to chemical pollution of the local stormwater network and downstream receiving environment.
- Introduction of new drainage network elements into the water ways in addition to the risk of working on an ‘online’ drainage network has the potential to impact water quality, by disrupting existing flow paths and runoff velocities, which can cause an additional disturbance to soils.

Erosion and disturbance of soils can create an increased sediment load in the runoff. This increased sedimentation can:

- Mobilise nutrients and contaminants which might be present in soils and materials
- Smother downstream aquatic habitats and lagoon/streambank vegetation
- Cause turbidity which prevents light from penetrating the water column which leads to aquatic plants being impacted
- Have an oxygen demand which can impact aquatic organisms

Spills or ineffective chemical containment has the potential to have severe impacts on water quality which could affect the environment of Wamberal Lagoon, surrounding habitats and the activity of local residents who utilise the amenity of the lagoon.

Whilst these risks are noted, it is not expected that the Proposal would result in a change in hydrology for the downstream environment as the degree of impact is limited to an area of works that is small in relation to the size of the Wamberal Lagoon Catchment. The volume of runoff from the total Wamberal Lagoon Catchment is much larger than compared to the proportion of that volume which would be generated by the Proposal is minimal.

The biodiversity assessment determined that the unnamed stream and existing drainage which conveys runoff flows over 250 metres through the nature reserve to Wamberal Lagoon from the Proposal Area is highly disturbed and thus not likely to be sensitive to changes at the Proposal site, on the basis that it is heavily exposed to existing urban runoff. This stream is also densely vegetated with weeds for the first 40 linear metres beyond the existing road culvert. Despite its composition, this vegetation along the channel would assist in removing some degree of pollutants present within stormwater runoff. Flow velocities along this channel will slightly increase as a result of widening the road and increasing the impervious area, as well as upgrading the cross-drainage structure under the Central Coast Highway and allowing more flow to pass under the road. The existing vegetative growth along this channel will be capable of providing sufficient scour protection against these slightly increased flow velocities. Heavy duty scour protection and energy dissipation measures (i.e. rock rip rap) will be provided at localised areas of higher velocities (e.g. immediately upstream and downstream of the upgraded cross drainage structure under the Central Coast Highway) to mitigate the potential for scour in these locations.

### 4.1.2 Aquatic habitats

Based on the limited physical extent of the Proposal and the implementation of the recommended management measures, the overall impacts of the Proposal upon threatened and non-threatened biodiversity is be considered to be low.

The biodiversity assessment report stated that the construction of the Proposal has the potential to affect the first order drainage line which runs from the northern side of Tumbi Road, traversing the Central Coast Highway via culverts and continues into Wamberal Lagoon Nature Reserve to the east (WSP, 2020). This unnamed stream is in poor condition, highly disturbed and highly modified and unlikely to be utilised by any threatened species listed under the FM Act.

Additionally, the unnamed stream within the Proposal study area is not a Type 1, Type 2, or Type 3 sensitive key fish habitat. There are no Class 1 (major key fish habitat), Class 2 (moderate key fish habitat) or Class 3 (minimal key fish habitat) waterways in the study area. The potential impacts to the unnamed stream include very small changes to flows and water quality (discussed in Section 4.2.1). Further, any changes would be buffered by the interaction of water with vegetation, organic matter, and soils in the stream such that changes to the biophysical environment would be negligible.

As such, there would be no direct impacts to sensitive or key fish habitats (TfNSW, 2020).

Potential changes to runoff quality including increases in sediments or pH would be likely buffered by the vegetation, soils, and organic matter at the point of discharge from the Central Coast Highway to the stream. Energy dissipation structures are proposed that would allow sediments to settle amongst the vegetation. pH would be buffered by the interaction with soils and organic matter.

Potential low magnitude impacts to aquatic habitats downstream of the Proposal, including Wamberal Lagoon would be limited and managed by the implementation of the proposed mitigation measures. These include soil and water management measures (to be included in the project CEMP and implemented during construction) aimed at reducing construction and operational off-site water quality impacts.

### 4.1.3 Flooding and drainage

The assessment of potential risks and impacts of flooding during the construction phase of the project has been based on a review of the likely construction works and their potential impact to the existing flood behaviour across the intersection.

Construction flooding and drainage impacts could potentially arise as a result of:

- Work sites may increase runoff volumes and peak flows (e.g. maximum flow rates) following rainfall events due to an increase in impermeable surfaces.
- Drainage infrastructure may become blocked (e.g. by soil, vegetation, waste) or temporarily diverted due to construction activities.
- Earthworks during construction could alter overland flow paths, which could direct more flow to some areas. This would risk overloading existing drainage systems.

Conveyance of flood waters is not likely to change due to construction phase activities if existing drainage paths are not impacted or blocked. Construction activities will be managed to minimise the potential that drainage infrastructure becomes blocked (e.g. by soil, vegetation, waste) or obstructed.

The main drainage line on the northern side of Tumbi Road carries the majority of flow moving towards and through the intersection. Therefore, it is important to maintain this drainage path in order to prevent flooding issues upstream and to prevent water from entering the construction site. As it is likely that construction works would partially or completely obstruct this drainage line, a temporary diversion path with equal hydraulic capacity would need to be established prior to commencing construction works. Similarly, for flow moving towards the existing cross drainage structures under Tumbi Road, it will be important to maintain in construction work methods, diverted or alternative drainage paths if construction works are likely to impede these flows.

If existing cross drainage structures or existing flood storage were to become partially or fully blocked as part of construction works, then floodwaters could potentially overtop the road during frequent rainfall events. This would present a safety risk to traffic moving along both Tumbi Road and the Central Coast Highway. This could also result in more surcharging at inlet pits within the upstream drainage network, causing more water to travel as overland flow.

### 4.1.4 Mitigation measures

The primary measure proposed to mitigate potential flooding, drainage and water quality impacts during construction is the development and implementation of a construction work methodology. This would manage all drainage construction activity and would include measures to protect existing water quality and outline the staging of works to maintain existing flows. The construction work methodology will inform a CEMP with a Soil and Water Management plan that describes progressive sediment and erosion control plans, to be implemented at each stage of construction. A specific section of the Soil and Water Management Plan will be prepared to account for significant weather events and flooding.

This methodology may include the following:

- Specifying that existing drainage should remain operational until the new drainage for the Proposal has been constructed. In the event that construction activities require that existing drainage is removed prior to the provision of new drainage infrastructure, alternative temporary drainage arrangements would need to be provided (prior to removal of existing drainage) or works would need to be timed to avoid any periods of wet weather
- If existing drainage lines are to be cut off during construction, then an alternate (diversion) path (with equal capacity) would need to be established prior to commencing construction works or the timing of construction works should be aligned with a period of no wet weather
- Areas with a high risk of flooding would be considered when planning for work areas, identifying areas of onsite storage and access roads, staging plans, and other management plans, which would also influence the placement of barriers and equipment. This would be documented in the CEMP
- A site-specific severe or significant weather event and Flood Management and Evacuation Procedure would be prepared prior to construction as part of the CEMP and implemented during construction
- A site plan for the proposal and ancillary sites will be developed in the CEMP to control construction activities and work locations. For this site, important receptors to consider include the impacts to local residents and the surrounding road network.

## 4.2 Operational impacts

### 4.2.1 Surface water quality

The Proposal would increase the amount of impervious surface area within the Wamberal Lagoon catchment by 0.2% (see Table 4-1). During operation, this would slightly increase the overall volume of surface water runoff by a small amount. Pollutants built up on impervious surfaces over time and may be discharged to the receiving environment during rainfall events. As such, the increases in impervious surfaces within the catchment have the potential to add to an increase in pollutant loads discharged to the broader environment, including Wamberal Lagoon.

Contaminants that have the potential to be present within stormwater include litter, sediment and suspended solids, nutrients, heavy metals, toxic organics compounds, oils, and surfactants. Potential sources of these contaminants include:

- Exhaust particles from vehicle engines
- Wear products from brakes, tyres, and other mechanical parts
- Minor discharges from vehicle engines, including fluids, lubricants, and other similar materials
- Minor discharges from leaking or damaged loads
- Litter or other waste
- Loss of goods and other materials due to vehicle incidents.

The potential impact of the Proposal on the hydrology or water quality of runoff from the Wamberal Lagoon catchment was estimated by assessing the increase in impervious areas that would result from the additional pavement areas associated with the Proposal. The existing land uses and imperviousness of the catchment of Wamberal Lagoon has been described in Section 3.4, where the total existing impervious surfaces resulting from urbanisation within the catchment are estimated to be 116 ha. The existing impervious area within the Proposal Area is about 1.1 ha. The Proposal would result in an increase in impervious areas of about 1 ha, making the total Proposal impervious area about 2.1 ha.

Table 4-1 Proposal footprint and imperviousness

| Catchment | Existing Area (ha) | Post development Area (ha) |
|---|---|---|
| **Proposal Area impervious surface** | 1.1 | 2.1 |
| **Total impervious surfaces in Wamberal Lagoon catchment** | 116 | 117 |
| **Increase in impervious surfaces** | - | 1 |
| **Total Impervious area of Wamberal Lagoon catchment** | 20.0 % | 20.2 % |

Opportunities for stormwater treatment were considered during the design process. The project corridor is highly constrained, and based on site design constraints, few of the opportunities considered were able to be incorporated into the design. Stormwater treatment opportunities considered are described in Table 4-2.

Table 4-2 Treatment opportunities considered for stormwater runoff

| Treatment Options | Description | Constraints | Outcome |
|---|---|---|---|
| **Trash Rack** | Trash racks are screens designed to capture litter and debris. They are typically built on-line, and once full flows bypass over the top of the screen.<br>Trash racks are not effective for the removal of pollutants such as suspended solids, total phosphorus, and total nitrogen, because velocities through the rack are too high to encourage settlement. | Not considered further as trash racks do not treat contaminants of concern in stormwater runoff.<br>A trash rack exists where several flow paths come together immediately north-west of the roundabout at Tumbi Rd/Central Coast Highway. This has not been cleaned out for a long time, perhaps due to access difficulties, and is overloaded and in permanent bypass as a result. | Not suitable for water quality mitigation |
| **Buffer Strips** | Vegetated road verges can filter runoff as it flows down the batter.<br>Effective for the removal of predominantly particulate pollutants such as suspended solids and total phosphorus where sheet flow can be directed to the road verge along its full length. | Buffer strips to treat road runoff were precluded due to the requirement for kerbs and gutters. Buffer strips would treat runoff from footpaths where turf is adjacent to the paths. | Not feasible for road runoff |
| **Grass Swales** | Vegetated table drains can provide water conveyance and filtration functions.<br>Effective for the removal of predominantly particulate pollutants such as suspended solids and total phosphorus if used extensively for drainage. | Existing swales were not considered as a treatment measure for the project because these areas already provide treatment for existing road runoff i.e. these would not provide any additional water quality benefit. Existing areas are not extensive and would be replaced like-for-like after construction.<br>Some treatment is provided for runoff from the northern catchment of the Proposal. This area discharges to a flat meadow via a vegetated table drain. The table drain would provide swale-like treatment for runoff. Swales are known to be effective at removing total suspended solids and the particulate portion of total phosphorus. This table drain discharges to a flat meadow where runoff is expected to mostly infiltrate into the local soils. The infiltration would provide a high degree of buffering for any pollutants in stormwater runoff, and very little untreated surface runoff from this catchment would be expected to reach Wamberal Lagoon.<br>The use of swales was precluded in other areas due to the requirement for stormwater drainage to be within a pipe network and be fully contained within the project corridor boundaries. | Not feasible |

| Treatment Options | Description | Constraints | Outcome |
|---|---|---|---|
| **Bioretention Systems** | Bioretention systems temporarily detain runoff and allow it to filter vertically through a vegetated filter media. Treated water is collected by subsoil drains and discharged to the downstream drainage network or streams.<br><br>Effective for the removal of predominantly particulate pollutants such as suspended solids and total phosphorus, and for the removal of dissolved pollutants such as total nitrogen.<br><br>A footprint of ~4% of the contributing catchment is typically required to meet treatment targets for stormwater runoff. | Due to existing space constraints along the road corridor. additional land would need to be acquired to use bioretention for stormwater treatment. Bioretention not feasible due to:<br>• Buried power lines (132kV) prevent excavation works in some areas<br>• Flat terrain to neighbouring property. Any temporary flow attenuation would be likely to flood neighbouring property in some areas<br>• Flat terrain downstream where it would not be possible to 'daylight' subsoil drainage<br>• Existing native vegetation on the eastern/downstream side of the project would need to be cleared. | Not feasible |
| **Constructed Wetlands** | Constructed wetlands detain runoff and allow it to filter through densely vegetated ponds.<br><br>Effective for the removal of predominantly particulate pollutants such as suspended solids and total phosphorus, and for the removal of dissolved pollutants such as total nitrogen.<br><br>A footprint of ~7% of the contributing catchment is typically required to meet treatment targets for stormwater runoff. | Due to existing space constraints along the road corridor. additional land would need to be acquired to use constructed wetlands for stormwater treatment. This was not considered feasible as this would necessitate the occupation of land currently reserved under the *National Parks and Wildlife Act 1974*, which is not permissible for development under Part 5 of the *Environmental Planning and Assessment Act 1979*. | Not feasible |
| **French Drain/ Infiltration** | Similar filtration to bioretention systems, but infiltration is drained to surrounding soils instead of subsoil drains. | French Drain/infiltration was considered along the eastern boundary of the project. It was considered not feasible due to:<br>• Space and requirement for access track on the eastern side of the road precluded a French drain<br>• Would have required clearing of existing native vegetation<br>• Infiltration at the foot of the batter could impact geotechnical stability. | Not feasible |
| **Sedimentation Basin/Trap** | Sedimentation basins detain water and allow particulate matter to settle from the water. To allow for settlement of suspended solids, these devices rely on a creating a body of slowly moving water below a critical velocity. | A sediment trap was considered where several flow paths come together immediately north-west of the roundabout at Tumbi Road/Central Coast Highway. Due to the small available space and high velocities of water flowing through this area, it would not be possible to provide enough volume to provide the settling conditions necessary for sediment removal. | Not feasible |

| Treatment Options | Description | Constraints | Outcome |
|---|---|---|---|
| **Creek Filtration System / Flow Spreader** | A “Creek Filtration System” (flow spreader that encourages shallow sheet flow and filtration into the soil) can provide similar treatment to a bioretention system. | A flow spreader was considered at the northern extent of the project. At this location the proposed new discharge pipe will daylight deeper than 1 m below the surrounding soil surface. This will require a channel to be excavated to drain the pipe. The channel will need to be kept narrow to minimise the requirement for tree clearing.<br>A flow spreader was not considered feasible as this would require extensive clearing of native vegetation to facilitate earthworks at this location. The spreader would also require at least annual maintenance and clearing, which would further necessitate maintenance access being kept clear, with ongoing consequences for native vegetation in this sensitive environment. | Not feasible |
| **Gross Pollutant Traps (GPT)** | Gross pollutant traps such as the CDS / Holcim Humeceptor / Ocean Protect Cascade are proprietary products designed to screen and settle particulates in stormwater runoff. These can typically be accommodated in the stormwater pipe network.<br>Clean-outs would require a vacuum truck to remove the accumulated pollutants, and clean-out frequency would be about once per year. Clean outs are expected to take several hours. | Potential locations throughout the Proposal area for gross pollutant traps were considered during concept design development. This included areas within the road pavement area as well as other parts of the road corridor. Despite detailed analysis of the area new gross pollutant traps were not feasible for one or more of the following reasons:<br>• The physical space available in and around the Proposal area is extremely limited and does not allow for a suitably sized device without encroaching into the Wamberal Lagoon Nature Reserve or private properties<br>• The positioning of any devices within or very near active traffic would require traffic control for future maintenance activities. In the event that these maintenance activities exceed 30 minutes, lane closures and traffic management is required to ensure the safety of workers and road users. For all such devices considered the benefit provided was marginal as the overall reduction of pollutant loads was low and would be outweighed by the adverse impacts on road safety and the traffic and transport and network arising from maintenance activities. | Not feasible |

Mitigation of surface water quality impacts is typically modelled using MUSIC software to quantify the extent of treatment provided for comparison against pollutant reduction targets. MUSIC is the industry standard software used to estimate pollutant loads generated by development, and to assess the effectiveness of the proposed mitigation measures. Since it was not possible to incorporate any stormwater treatment devices into the design, no MUSIC modelling results are reported here. An assessment of the potential impact of the project on the quality of the stormwater runoff can be made by assessing the extent of new impervious areas introduced by the project.

The Wamberal Lagoon catchment has an existing total imperviousness of about 20% (116 ha/580 ha). The Wamberal suburb is highly urbanised and contributes substantially to the total imperviousness of the Wamberal Lagoon catchment, and hence also contributes to the water quality of the runoff that drains principally through the culverts in the Proposal Area. The Proposal is expected to increase of the imperviousness over the total catchment area by 0.2%, bringing the total to 20.2% (117 ha/480 ha). This small change in total impervious area of the Wamberal Lagoon catchment is unlikely to result in any measurable changes in the hydrology or pollutant loads discharged to the receiving environment.

### 4.2.2 Flooding

Flooding impacts resulting from the Proposal were assessed using the Wamberal Lagoon TUFLOW model, discussed in Section 3.7. A design scenario was modelled using the proposed road and drainage design. This included the proposed widening and raising of the road to accommodate for a signalised intersection and two through-lanes, as well as upgrades to both the road drainage network and cross drainage structures.

Proposed upgrades to the two main cross drainage structures involve:

- Introducing a new 1050 mm diameter pipe in parallel to the three existing 1050 mm diameter pipes passing under the Central Coast Highway
- Replacing the existing 600 mm diameter pipe crossing under Tumbi Road with twin 900 mm diameter pipes to service the new road drainage network in addition to conveying more of the upstream flows under the road.

While these two new culverts are being constructed, the existing culverts in parallel can be maintained to continue servicing flows moving through the Proposal Area.

**Flood immunity**

Raising road levels in combination with upgrading the existing cross drainage structures helps to improve flood immunity across the intersection. Where the Central Coast Highway and Tumbi Road were previously (under existing conditions) overtopped in a 5% AEP event, both roads are now (with the proposed design upgrades) capable of achieving flood immunity in a 1% AEP event. It should be noted that these results do not include any allowance for pit or pipe blockage.

The events that cause overtopping of both Tumbi Road and the Central Coast Highway, under both existing and design conditions are shown in Table 4-3. The depth of overtopping during these events are also provided.

Table 4-3 Flood depths overtopping the roads (zero blockage allowance)

| Location | Scenario | Peak flood depths (mm) over roads | | | | | |
|---|---|---|---|---|---|---|---|
| | | **50% AEP** | **20% AEP** | **10% AEP** | **5% AEP** | **2% AEP** | **1% AEP** |
| **Tumbi Road** | Existing | Not flooded[1] | | | 125 | 200 | 220 |
| | Design | Not flooded[1] | | | | | |
| **Central Coast Highway** | Existing | Not flooded[1] | | | 40 | 245 | 280 |
| | Design | Not flooded[1] | | | | | |

[1] No flooding with depths greater than 0.05 m

### Flood levels

To assess changes in peak flood levels across the intersection, flood levels under both existing and design conditions were compared at a number of key locations shown in Figure 4-1.

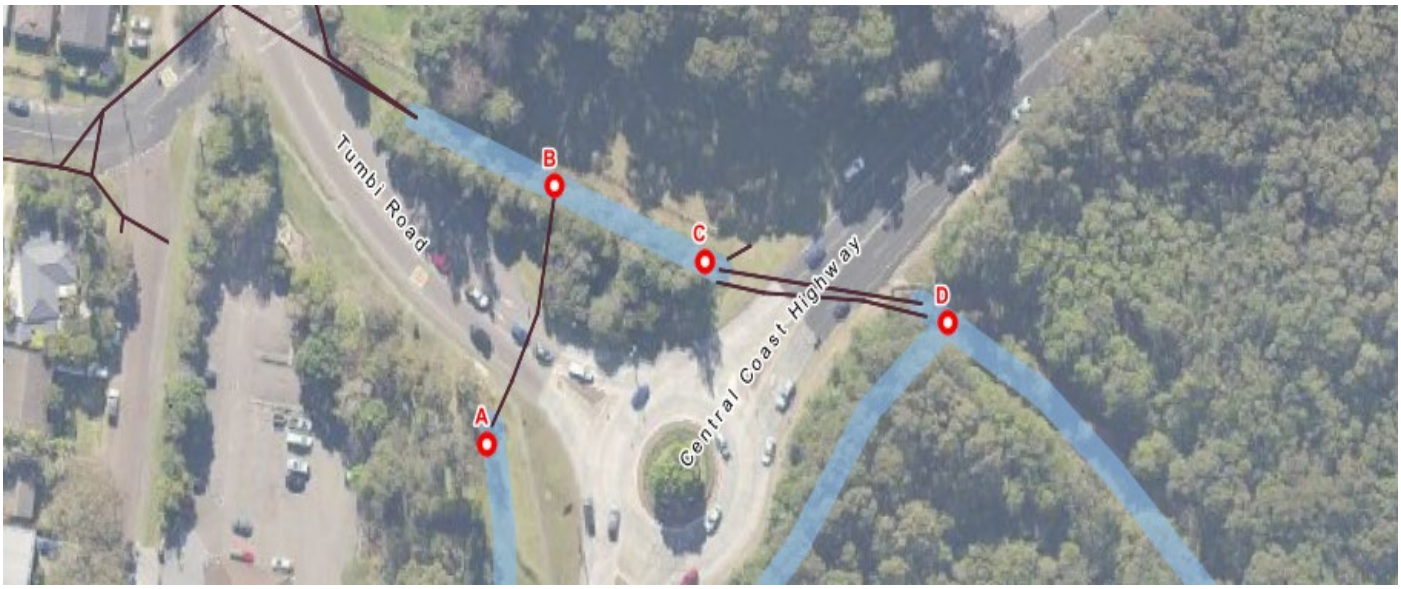



Figure 4-1 Key flood locations across the intersection

The peak flood levels at these locations are summarised in Table 4-4. Levels in green text represent a reduction in flood levels, while red text represents an increase in flood levels.

Table 4-4 Flood levels at key locations across the intersection

| AEP | Scenario | Flood Levels at Key locations (mAHD) | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| **50%** | Existing | 9.41 | 9.28 | 9.22 | 7.62 |
| | Design | 9.36 | 9.03 | 8.89 | 7.63 |
| **20%** | Existing | 9.85 | 9.44 | 9.41 | 7.73 |
| | Design | 9.38 | 9.21 | 9.13 | 7.75 |
| **10%** | Existing | 10.00 | 9.49 | 9.44 | 7.74 |
| | Design | 9.44 | 9.25 | 9.18 | 7.76 |
| **5%** | Existing | 10.26 | 9.55 | 9.47 | 7.75 |
| | Design | 9.49 | 9.27 | 9.20 | 7.77 |
| **2%** | Existing | 10.34 | 9.72 | 9.69 | 7.87 |
| | Design | 9.91 | 9.48 | 9.43 | 7.89 |
| **1%** | Existing | 10.36 | 9.77 | 9.73 | 7.90 |
| | Design | 10.23 | 9.57 | 9.52 | 7.92 |

As can be seen from the above results, flood levels are generally reduced by 200-300 mm at all locations on the upstream side of the intersection (Locations A, B and C). This is due to the proposed upgrades at the two main cross drainage structures. Increasing the size of these cross-drainage structures allows flow

to move faster through the intersection, which helps to delay the rate at which water levels rise within land immediately upstream of these cross-drainage structures.

By reducing peak flood levels at all locations on the upstream side of the intersection, the Proposal has a positive impact on flooding (*i.e.* reduction in water levels during inundation) across the adjacent private properties.

As the proposed upgraded pipes allow floodwaters to move faster through the intersection, the peak flows discharging to the downstream channel (Location D) increase and so do the peak flood levels in the downstream channel. These peak flood levels are only estimated to increase by up to 20 mm across all the modelled events, which is less than the maximum allowable increase across bushland (100 mm). Peak flows along this channel can still be contained within the banks of the channel in all events up to and including a 1% AEP event, and increased flood levels along this channel do not have an impact on flood levels across private properties further downstream (south-east).

**Flood velocities**

The proposed upgrades to cross drainage structures will improve the hydraulic efficiency across the intersection, which will also increase peak velocities within culverts and open channels as flow moves faster through the intersection. Velocities will be fastest along the section of open channel that runs along the northern side of Tumbi Road (between B and C on Figure 4-1), through the culverts passing under the Central Coast Highway, and along the open channel downstream of these culverts (location D on Figure 4-1).

The existing open channels along this path are lined with well-established vegetation, and as per Austroads Part 5B (Austroads, 2021) these channels should be capable of withstanding velocities of up to 2.4 to 2.8 m/s before scouring of the channel begins to occur. Peak velocities along this path generally do not exceed 2.0 m/s across all of the modelled events and therefore the channels should be adequately protected from the scouring effects of fast-moving floodwaters.

There is however some localised areas, immediately upstream and downstream of the cross drainage structure under the Central Coast Highway, where velocities exceed this allowable 2.4 to 2.8 m/s. Peak velocities are capable of reaching up to 3.5 m/s as flows jet out of the culverts. These high velocities have the potential to erode or scour out the channels, which could result in increased sediment transportation, blockage of culverts, stability issues at the toe of batters, etc.

As a result of the proposed works, peak velocities at the upstream end of the culverts passing under the Central Coast Highway increase by up to 0.5 to 1.0 m/s. Peak velocities at the downstream end of the culverts only increase by up to 0.2 m/s.

To protect against these high-velocity flows entering and exiting the cross-drainage structure scour protection has been included as per section 3.13 in Austroads Part 5B (Austroads, 2021). Minimum rock size and length of apron at the outlet has been checked and will be based upon the pipe diameter at the outlet and the outlet flow velocity as per the hydraulic model. Design of the size of the scour protection required for each outlet will be undertaken in the detailed design stage within the Proposal boundary.

There is also a new discharge location proposed approximately 340 m north of the intersection, to drain the northern catchments of the proposal. Scour protection would also be provided at the outlet to ensure that discharges would not scour or erode the earth downstream of this discharge point.

## 4.3 Potential impacts – ancillary site options

This section includes a review of the surface water impacts and constraints for the three potential ancillary site options.

The impacts of three possible ancillary sites have been considered for the construction phase of the Proposal. After the construction phase, it can be assumed that the ancillary sites could be returned to pre-construction condition or the landowners may wish as part of later leases to leave pads, access roads and sealed areas. If the landowners do not want the sites returned to their pre-construction condition and would like to retain some of the features of the ancillary sites then further assessment of the impacts to surface water and flooding will be necessary before leases are agreed and signed.

Table 4-5 provides a summary of the quantitative details of each option regarding the estimated change in impervious area which is important in assessing the potential impact to surface water quality and peak flows from the sites. Figure 4-2 provides detail on the location of these sites in relation to the Proposal Area. The results of the assessment in Table 4-5 revealed that the use of the ancillary sites would result in very small changes in imperviousness, maximum increases of 0.1 %. Therefore, due to the small expected changes in imperviousness, it is not expected that the change in land use of these sites would result in a measurable increase in pollutants or peak flows.

Figure 4-3 and Figure 4-4 show the peak flood depths in the across the area for the 1% AEP and 5% AEP storm events in relation to the proposed facility locations.

It should be noted that the worst case scenario is being evaluated for these sites for the construction phase as a detailed plan for these ancillary compounds has not been finalised and site-specific flood modelling for the construction phase has not been conducted to assess the impacts of the activities and buildings that will be temporarily constructed at these sites. Figure 4-5, Figure 4-6 and Figure 4-7 provide a detailed overview of the flood behaviour and topography at each proposed ancillary site and identify locations which are not impacted by the 1% AEP and 5% AEP events. Table 4-6 contains a detailed impact assessment for each site. The potential impacts to the existing flood behaviour would be managed as part of the construction methodology, site plan and the CEMP.

Table 4-5 Ancillary Site Options Quantitative Details

| | Estimated Area of Site | Estimated Existing % Impervious (based on publicly available Aerial Imagery) | Estimated Proposed % Impervious due to Construction Facility | Overall increase in impervious area in relation to Wamberal Lagoon Catchment |
|---|---|---|---|---|
| **Ancillary Facility 1** | Up to 13,500 $m^2$ = 1.35 ha | 80% impervious  | Total required impervious area for activities within facility = 0.5 ha<br>Construction compound is not expected to increase the % impermeable area of the site as the existing site is already 80% impermeable. | No change in total impervious area |
| **Ancillary Facility 2** | 8,000 $m^2$ = 8 ha | 5% impervious  | Total required impervious area for activities within facility = 0.5 ha<br>It is estimated that the construction compound will increase the impervious portion of the site to 9%. | Existing total impervious area of Wamberal Lagoon Catchment expected to increase from 116 ha to 116.5 ha during construction<br>Total Wamberal Lagoon Catchment Area = 580 ha<br>Existing % impervious area = 20%<br>Proposed % impervious area during construction = 20.1% |
| **Ancillary Facility 3** | Up to 50,000$m^2$ = 50 ha | 5% impervious  | Total required impervious area for activities within facility = 0.5 ha<br>It is estimated that the construction compound will increase the impervious portion of the site to 6%. | Existing total impervious area of Wamberal Lagoon Catchment expected to increase from 116 ha to 116.5 ha during construction<br>Total Wamberal Lagoon catchment area = 580 ha<br>Existing % impervious area = 20%<br>Proposed % impervious Area = 20.1% |


AECOM

N

0 100 200 300 Meters

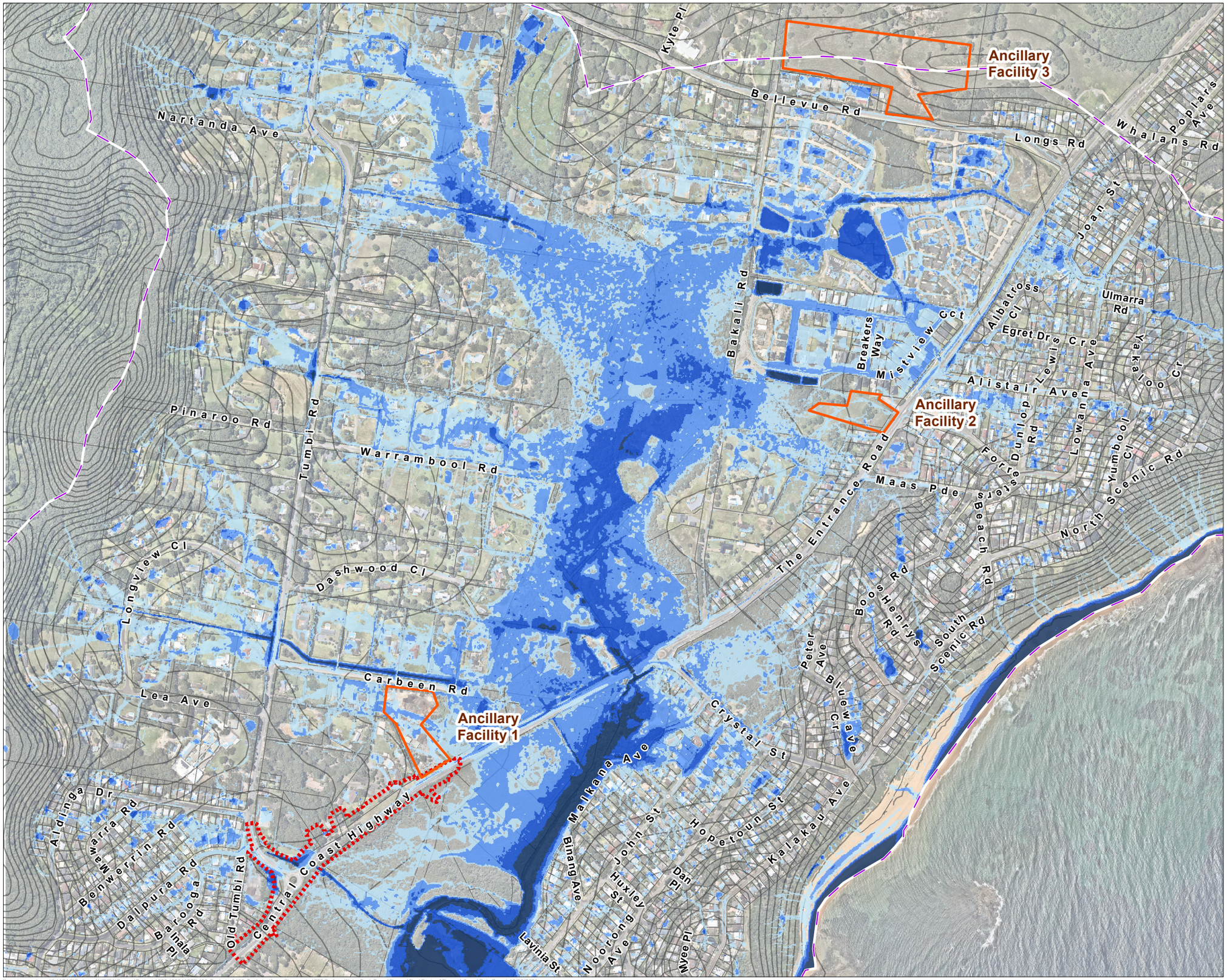
Legend

- Proposal area
- Cadastre
- Contours (5m)
- Ancillary Site Options
- Wamberal Lagoon

Figure 4-2
TUMBI ROAD UPGRADE
ANCILLARY SITE OPTIONS



*Source: Imagery © Nearmap, 2020*




AECOM

N

0 100 200 300 Meters

Legend

- Proposal Area
- Cadastre
- Contours (5m)
- Ancillary Site Options
- Flood Model Extent

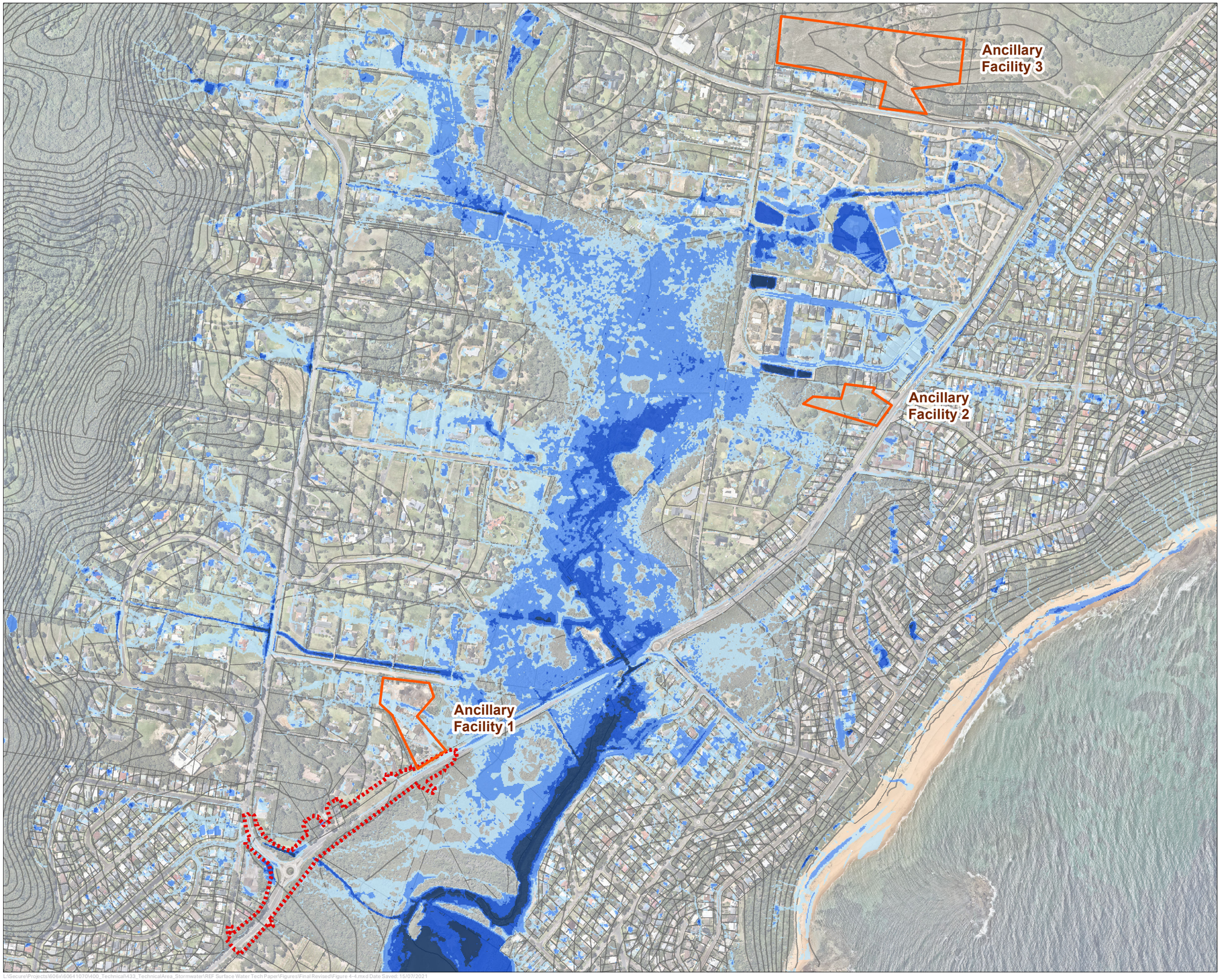
**1% AEP Peak Flood Depths (m)**

- 0.05 - 0.20
- 0.20 - 0.50
- 0.50 - 1.0
- > 1.0

Figure 4-3
TUMBI ROAD UPGRADE
ANCILLARY SITE OPTIONS
(1% AEP EXISTING RESULTS)



*Source: Imagery © Nearmap, 2020*




AECOM

N

0 100 200 300 Meters

Legend

- Proposal Area
- Cadastre
- Contours (5m)
- Ancillary Site Options

**5% AEP Peak Flood Depths (m)**

- 0.05 - 0.20
- 0.20 - 0.50
- 0.50 - 1.0
- > 1.0

Figure 4-4
TUMBI ROAD UPGRADE
ANCILLARY SITE OPTIONS
(5% AEP EXISTING RESULTS)



*Source: Imagery © Nearmap, 2020*

AECOM

N

Meters
0 25 50

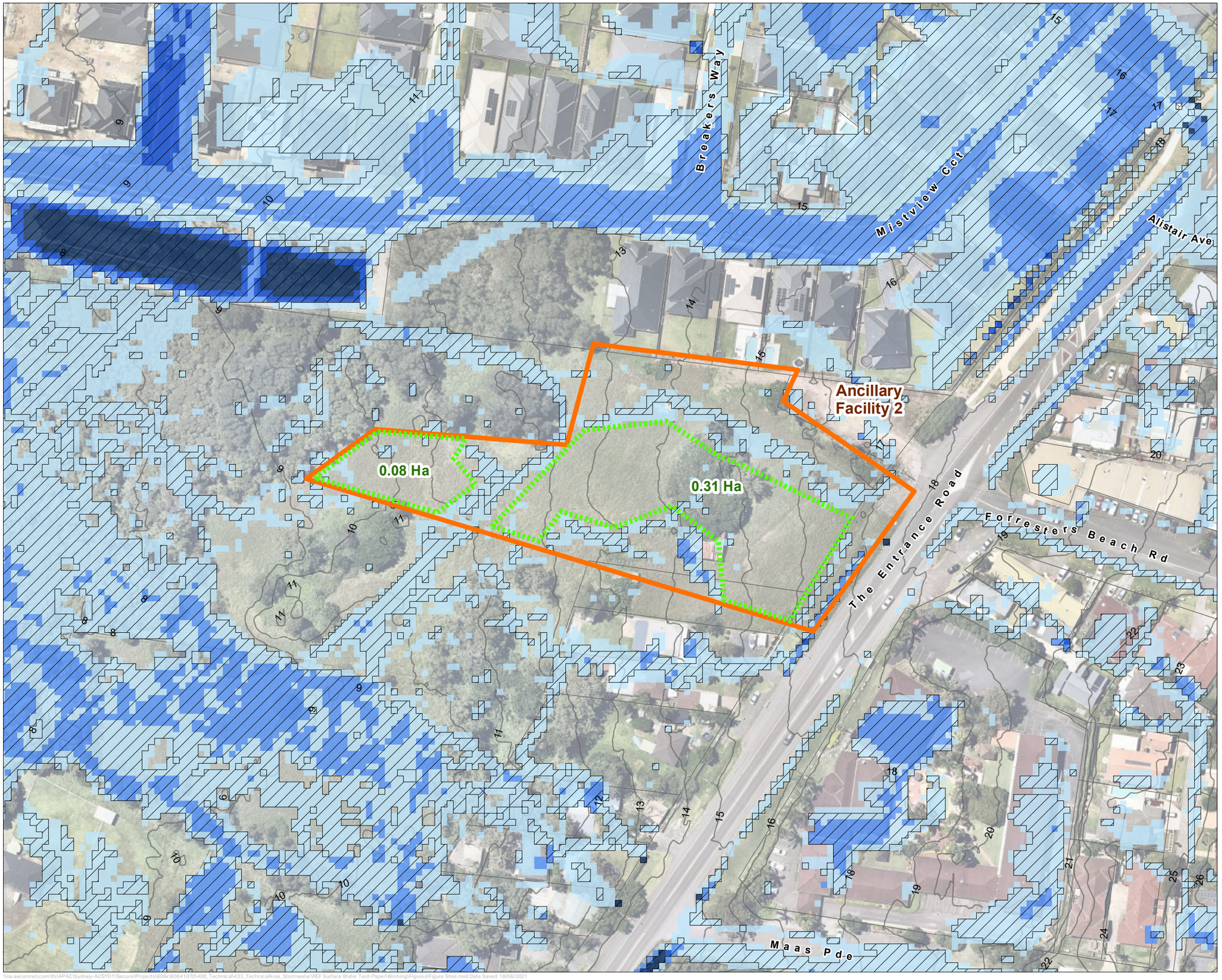
Legend

- Proposal area
- Cadastre
- Contours (1m)
- Ancillary Site Options
- Possible Areas for New Site Operations
- Flood Model Extent
- 5% AEP Existing Flood Depth Extent

**1% AEP Peak Existing Flood Depths (m)**

- 0.05 - 0.20
- 0.20 - 0.50
- 0.50 - 1.0
- > 1.0

Figure 4-5
TUMBI ROAD UPGRADE
ANCILLARY SITE 1




AECOM

N

0 25 50 Meters

Legend

- Proposal area
- Cadastre
- Contours (1m)
- Ancillary Site Options
- Possible Areas for New Site Operations
- Flood Model Extent
- 5% AEP Existing Flood Depth Extent

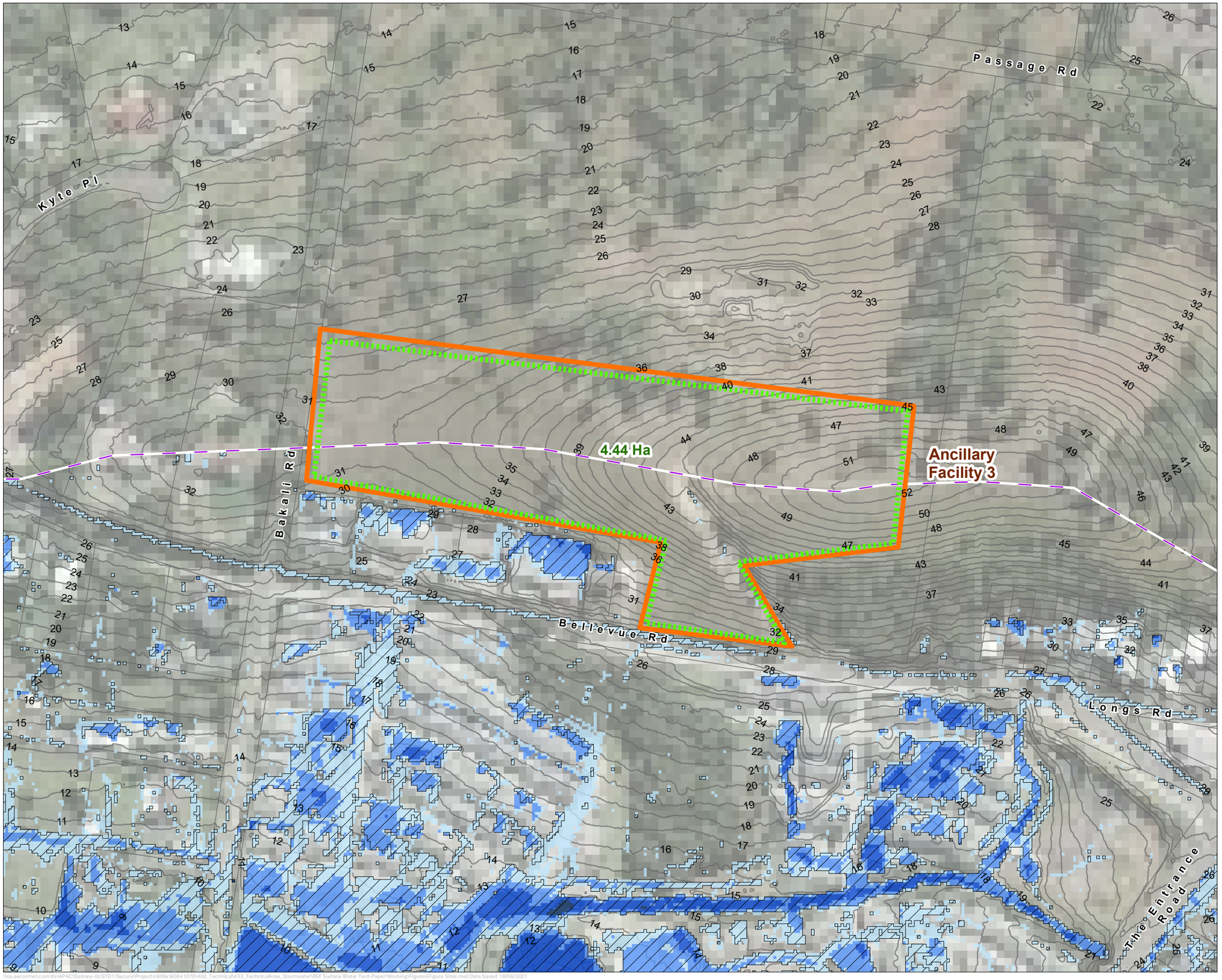
**1% AEP Peak Existing Flood Depths (m)**

- 0.05 - 0.20
- 0.20 - 0.50
- 0.50 - 1.0
- > 1.0

Figure 4-6
TUMBI ROAD UPGRADE
ANCILLARY SITE 2



*Source: Imagery © Nearmap, 2020*




AECOM

N

0 25 50 Meters

Legend

- Proposal area
- Cadastre
- Contours (1m)
- Ancillary Site Options
- Possible Areas for New Site Operations
- Flood Model Extent
- 5% AEP Existing Flood Depth Extent

**1% AEP Peak Existing Flood Depths (m)**

- 0.05 - 0.20
- 0.20 - 0.50
- 0.50 - 1.0
- > 1.0

Figure 4-7
TUMBI ROAD UPGRADE
ANCILLARY SITE 3



*Source: Imagery © Nearmap, 2020*

Table 4-6 Detailed potential construction impacts and proposed mitigation measures for construction ancillary facility options.

| Area | Associated Construction Activities | Potential impacts of construction activities on water quality | Specific water quality impacts (including impacts including to Wamberal Lagoon) | Potential for flooding | Potential for construction works to disrupt drainage flow paths? | Severity of potential impacts (Including impacts to Wamberal Lagoon) | Mitigation Measures (Site specific requirements for mitigation) |
|---|---|---|---|---|---|---|---|
| **Ancillary Facility 1** | [This site is currently a nursery and is used for stockpiles and storage in its existing condition].<br><br>Temporary construction compounds would be subjected to the following activities for the following facilities and uses:<br><br>• Disturbance of soil<br>• Temporary diversion of drainage infrastructure<br>• Construction of Site Office and worker amenities<br>• Equipment and materials storage<br>• Temporary stockpiling of excavated or imported material<br>• Holding facilities for water from dewatering activities<br>• Temporary storage of waste awaiting classification<br>• Chemical and fuel storage<br>• Storage of construction plant and parking for light and heavy materials. | Disturbance of soils, erosion and mobilisation of sediment or other pollutants pose a potential risk to downstream surface water quality.<br><br>Accidental spills of fuels, oils or other chemicals from construction vehicles or equipment, could lead to contaminants entering the local stormwater system and being transported to nearby waterways (Wamberal Lagoon).<br><br>If flood waters were to impact any areas where chemicals and fuels have been stored, this could lead to chemical pollution of the local stormwater network and downstream receiving environment. | Erosion and disturbance of soils can create an increased sediment load in the runoff. This increased sedimentation can:<br><br>• smother downstream aquatic habitats<br>• cause turbidity which prevents light from penetrating the water column which leads to aquatic plants being impacted<br>• have an oxygen demand which can impact aquatic organisms.<br><br>Spills and uncontrolled use of chemicals on site can impact water quality due to the toxicity of the compounds spilled, which can kill aquatic organisms. | Figure 4-5 shows that there is a concentrated flow path through the centre of the property which has localised flood depths of up to 0.4m in depth for the 1% AEP event.<br><br>Figure 4-4 and Figure 4-5 show that this concentrated flow path also exists in the 5% AEP event, reaching a slightly smaller extent that the 1% AEP. | If surface levels are raised in areas with existing flow paths, then the compound could cause a change in the flood behaviour and disrupt the existing path of flow. Figure 4-5 provides approximate areas which are outside of flow paths for the 1% AEP and 5% AEP results, where construction activities could potentially occur.<br><br>Any construction works should still aim to avoid disturbance of these existing flow paths and if disturbance does occur, then mitigation measures, such as alternate flow paths or on-site storage, should be put in place. | Severity of impacts is dependent on the activities undertaken on the site. This will be assessed as part of the construction contractor's development of a site plan for the ancillary facility.<br><br>For this site, important receptors to consider include; impacts to the local residents and the road network, if the existing flow path was to be blocked due to storage and materials encroaching on its extent, it is possible that neighbouring properties would experience increased flooding impacts.<br><br>Spills or ineffective chemical containment have the potential to severely impact water quality, which could impact the receiving environment of Wamberal Lagoon, surrounding habitats and local residents who utilise the amenity of the lagoon. | Stockpiles and construction facilities should be established clear of the 1% and 5% AEP flood path in the centre of the property and with controls to contain or prevent mobilisation of pollutants and sediment in overland flows outside the flood path (Figure 4-5), if this is not possible, bunding and other protective measures will be required to redirect flows.<br><br>Erosion and disturbance of soils is guided by Landcom's Managing Urban Stormwater-Soils and Construction (the Blue Book).<br><br>Storage and handling of chemicals is included in the CEMP and appropriate standards should be followed. Storage must not occur in areas affected by the 1% and 5%AEP flood extents, these areas are shown in Figure 4-5. |
| **Ancillary Facility 2** | Construction activities as listed above | Potential impacts of construction activities as described above | Potential water quality impacts as described above | Figure 4-6 shows that there are some areas of localised flooding up to 0.45m in depth for the 1% AEP. There are also a few defined flow paths moving through the site.<br><br>Figure 4-4 and Figure 4-6 show that these shallow flow paths also exist in the 5% AEP event, reaching a slightly smaller extent that the 1% AEP | If construction works were to obstruct the flow paths through the sites, then there could potentially be some adverse impacts on flooding at nearby properties. These impacts are however not likely to be significant as flow depths along these paths are generally shallow (typically less than 200 mm) in all events up to and including the 1% AEP.<br><br>Figure 4-6 provides approximate areas which are outside of flow paths for the 1% AEP and 5% AEP results, where construction activities could potentially occur. | Severity of impacts is dependent on the activities undertaken on the site. This will be assessed as part of the construction contractor's development of a site plan for the ancillary facility.<br><br>Spills or ineffective chemical containment has the potential to have severe impacts on water quality which could impact the receiving environment of Wamberal Lagoon, surrounding habitats and local residents who utilise the amenity of the lagoon. | Stockpiles and construction facilities should be established so that the so that the existing localised flow paths for the 1% AEP and 5% AEP are not compromised. This is shown in Figure 4-6.<br><br>Additionally, controls to contain or prevent mobilisation of pollutants and sediment in overland flows outside the flood path should also be in place.<br><br>Erosion and disturbance of soils is guided by Landcom's Managing Urban Stormwater-Soils and Construction (the Blue Book). |

| Area | Associated Construction Activities | Potential impacts of construction activities on water quality | Specific water quality impacts (including impacts including to Wamberal Lagoon) | Potential for flooding | Potential for construction works to disrupt drainage flow paths? | Severity of potential impacts (Including impacts to Wamberal Lagoon) | Mitigation Measures (Site specific requirements for mitigation) |
|---|---|---|---|---|---|---|---|
| | | | | | Any construction works should still aim to avoid disturbance of these existing flow paths and if disturbance does occur, then mitigation measures, such as alternate flow paths or on-site storage, should be put in place. | | Storage and handling of chemicals is included in the CEMP and appropriate standards should be followed. Storage must not occur in areas affected by the 1% and 5% AEP flood extents, these areas are shown in Figure 4-6. |
| **Ancillary Facility 3** | Construction activities as listed above | Potential impacts of construction activities as described above | Potential water quality impacts as described above | Majority of property is outside the flood model extents. Contours on Figure 4-7 indicate that the site is located on a ridge line. It could be subject to concentrated flows generated by the site itself, which might increase the risk of mobilising sediment or directing flows into neighbouring properties if not managed with a site plan and drainage controls.<br><br>Figure 4-7 shows that the site is steeper towards the east, but relatively flat towards the west. The western side also has a primary road access so would be the most likely place for a compound, | This site is outside the flood modelling extent. There are no identified water courses within this property area, and contours indicate that there are no external catchments (see Figure 4-7). Therefore, it is unlikely that any external flows would enter this site and the compound would not impede flow paths from any upstream catchments. | Severity of impacts is dependent on the activities undertaken on the site. This will be assessed as part of the construction contractor's development of a site plan for the ancillary facility.<br><br>Spills or ineffective chemical containment has the potential to have severe impacts on water quality which could impact the receiving environment of Wamberal Lagoon, surrounding habitats and local residents who utilise the amenity of the lagoon. | Because it is unlikely that any external flows would enter this site as it is located along a ridge line, surface water management on site would only need to consider the management of local runoff generated by the site itself.<br><br>Stockpiles and construction facilities should be established on the western side of the side which is relatively flat, if this is not possible, bunding and other protective measures will be required to redirect flows from the slopes above.<br><br>Erosion and disturbance of soils is guided by Landcom's Managing Urban Stormwater-Soils and Construction (the Blue Book).<br><br>Storage and handling of chemicals is included in the CEMP and appropriate standards should be followed. |

## 4.4 Risk assessment for spill containment

The Proposal is designed to accommodate larger vehicles at a signalised intersection and is expected to improve safety and reduce the potential for accidents that could result in spills, in comparison to the existing condition. Aspects of the project design that relate to safety are described in the Section 2.6 of the REF.

It is noted in the REF, that the replacement of an existing roundabout with a signalised intersection can increase minor additional risks with vehicles approaching the intersection at a higher speed not requiring to slow down to navigate the roundabout. However, the overall project will incorporate numerous upgrades which will provide an overall safer section of road. These being:

- Road geometry
- Street lighting
- Signage and line marking
- Separated lanes (duplication)
- Barrier kerb and guttering
- Drainage

Given the overall improvements in safety, the provision of spill containment facilities was not considered necessary

## 4.5 Cumulative impacts

The potential impacts of the Proposal were considered as a consequence of the construction and operation of the Proposal within the surrounding existing environment. The Proposal would not act alone in causing impacts to surface water. The incremental effects of multiple sources of impact (past, present and future) are referred to as cumulative impacts and provide an opportunity to consider the Proposal within a strategic context.

There are no substantial developments or projects within the Wamberal Lagoon Catchment listed on the NSW Government Major Projects website (DPIE, 2021) that would have any substantial impacts on surface water. Several other isolated property development applications other proposed developments in the surrounding areas of Wamberal and Forresters Beach exist which may have limited impacts on surface water in the future, there developments include:

- DA 60476/2020 at 801 The Entrance Road, Wamberal: STAGED Development - Stage 1: Alterations & Additions, Stage 2: Swimming Pool.
- Central Coast Highway upgrade - Wamberal to Bateau Bay (the broader Central Coast Highway Upgrade Proposal), including dual lanes in each traffic direction, as well as installation of traffic lights, pedestrian, and cyclist facilities.

Section 6.15 of the REF provides additional detail of these developments and their impacts, including a detailed figure indicating the broader program of works for the Central Coast Highway Upgrade – Wamberal to Bateau Bay. The DA for 801 The Entrance Road is a minor residential redevelopment and very small in scale, and it is expected that any cumulative surface water impacts would be negligible. The broader upgrade of the Central Coast Highway –between Wamberal and Bateau Bay will be subject to its own Review of Environmental Factors. This project will need to consider its cumulative impacts for elements within the Wamberal Lagoon Catchment in combination with the impacts identified in this assessment. This would be undertaken as part of a separate environmental assessment that would need to demonstrate that any downstream impacts are acceptable.

Incremental increases in imperviousness would contribute to incremental increases in pollutant loads discharged to the receiving environment. The Proposal does not significantly add to the urban development

impacts on the surface water environments since the extent of increased imperviousness of the Proposal is only about 0.2%.

Flood modelling undertaken for the Proposal includes all the development within the catchment to date. Future proposals will be assessed with the Tumbi Rd upgrade as a baseline, so cumulative impacts in the future will be captured in those assessments.

For flooding, the increase in afflux associated with flooding is predicted to remain within the stream banks and is not likely to influence the stream ecosystems due to the short period of inundation. Environments further downstream are strongly tidally influenced, and not expected to be influenced by small changes in hydrology that may result from the Proposal (small increases in flow). The potential scour from runoff and associated erosion in the unnamed creek is prevented because high runoff velocities would be mitigated in the proposal design by energy dissipation structures (i.e. scour protection). Flooding impacts in the urban areas would be mitigated by the measures outlined in Table 5-1.Therefore, no cumulative impacts are expected for flooding.

Impacts to surface water are related to the small increase in urban imperviousness (0.2 % for the Wamberal Lagoon catchment) arising from the Proposal, and the commensurate increase in pollutants washed off impervious surfaces. Those pollutants are likely to comprise a small increase (i.e. 0.2 % or less) in total suspended solids, nutrients such as nitrogen and phosphorus, pH and potentially other toxicants associated with urban runoff. The magnitude of change in water chemistry is likely to be similar in magnitude to the increase in imperviousness (i.e. 0.2 %).

# 5. Environmental management

This chapter describes how the Proposal would be managed to reduce potential environmental impacts throughout detailed design, construction, and operation. A framework for managing the potential impacts is provided. A summary of site-specific environmental safeguards is provided and the licence and/or approval requirements required prior to construction are also listed.

## 5.1 Summary Safeguards and management measures

The safeguards and management measures for the management of potential surface water and flooding impacts are summarised in Table 5-1.

Table 5-1 Summary of safeguards and management measures

| Impact | Environmental safeguards | Responsibility | Timing |
|---|---|---|---|
| General | A Soil and Water Management Plan will be prepared in accordance with TfNSW QA Specification G38 and implemented as part of the CEMP. The Plan will at a minimum;<br>• Develop detailed designs for the major erosion and sedimentation control measures.<br>• Assess erosion and sedimentation risks and impacts.<br>• Develop erosion and sedimentation avoidance, mitigation, and management measures for the project.<br>• Procedures for managing pollution risks associated with spillage or contamination on the site and adjoining areas, and<br>• Inspection, monitoring and review of the effectiveness of all controls during construction and following significant wet weather events or onsite incidents. | Construction Contractor | Pre-construction/ Construction |
| **Erosion and sediment control mitigation** | | | |
| Erosion and sediment control mitigation | A site-specific Erosion and Sediment Control Plan(s) will be prepared and implemented and included in the Soil and Water Management Plan. This plan should be progressive and revised and re-submitted with each stage of construction. The Plan(s) will identify detailed measures and controls to be applied to minimise erosion and sediment control risks.<br>In particular the Plan will provide detailed and specific management controls for the large drainage channel flowing beside Tumbi Road to the Wamberal Nature Reserve and for the edge of the works along the Wamberal Nature Reserve boundary. Constraints on access for regular maintenance and final removal after stabilisation of the works must also be considered in the selection of controls for these locations.<br>The Plan will also include arrangements for managing wet weather events, including monitoring of potential high-risk events (such as storms, severe weather warnings) and specific controls and follow-up measures to be applied in the event of wet weather. | Construction Contractor | Construction |
| Erosion and sediment control mitigation | Any areas established within the Proposal boundary for stockpiling will be planned, operated, and decommissioned in accordance with the RTA Stockpile Site Management Guideline 2011. | Construction Contractor | Construction |
| Erosion and sediment control mitigation | Any areas used for stockpiling within the ancillary sites (outside the main Proposal Area) will be included in the development of an Ancillary Site Management Plan. Stockpiles and storage areas will be planned, operated, and decommissioned in accordance with the RTA | Construction Contractor | Construction |

| Impact | Environmental safeguards | Responsibility | Timing |
|---|---|---|---|
| | Stockpile Site Management Guideline 2011. These stockpiles and storage areas will also need specific Erosion and Sediment Control Plans. | | |
| Erosion and sediment control mitigation | The rehabilitation of disturbed areas will be undertaken progressively as construction stages are completed, and in accordance with:<br>• Landcom's Managing Urban Stormwater: Soils and Construction series<br>• RTA Landscape Guideline<br>• RMS Guideline for Batter Stabilisation using Vegetation (2015) | Construction Contractor | Construction |
| Erosion and sediment control mitigation | Consistent with any specific requirements of the approved Soil and Water Management, control measures will be implemented to minimise risks associated with erosion and sedimentation and entry of materials to drainage lines and waterways. Controls that may be considered, include:<br>• Identification of upslope run-on waters from undisturbed areas of catchment and diversion of these around un-stabilised areas of the Proposal.<br>• Sediment management devices, such as fencing, hay bales or sandbags, coir logs and graded or lined earth or sandbag diversion bunds and banks.<br>• Measures to divert or capture and filter water prior to discharge, such as drainage diversion channels to flush and sediment sumps or traps<br>• Scour protection and energy dissipaters at locations of high erosion risk<br>• Installation of measures at key work entry and exit points to minimise movement of material onto adjoining roads, such as Rumble grids or wheel wash bays, or regular sweeping<br>• Location and storage of construction materials, fuels, and chemicals, including controls where possible will be managed in accordance with *Managing urban stormwater: soils and construction* (the Blue Book). Controls may include:<br>  ○ cover before significant weather events<br>  ○ bunds<br>  ○ diversion of offsite flows away from storage<br>  ○ stabilised laydowns<br>  ○ storage clear of frequently flooded low-lying areas and from residential areas.<br>• Stabilisation of the surface of batters and drains, including temporary works and diversions. | Construction Contractor | Construction |

| Impact | Environmental safeguards | Responsibility | Timing |
|---|---|---|---|
| Erosion and sediment control mitigation | Batters will be designed and constructed to minimise risk of exposure, instability, and erosion, and to support long-term, on-going best practice management, in accordance with Roads and Maritime 'Guideline for Batter Surface Stabilisation using vegetation' (2015).<br><br>Temporary surface stabilisation and batter drainage controls will be considered in the Soil and water management Plan and ESCP for the construction of permanent or temporary batters/banks near the boundary of the Wamberal Nature Reserve or the large drainage line beside Tumbi Road, before permanent stabilisation. | Roads and Maritime project manager / Construction Contractor | Detailed design /construction |
| **Water Quality** | | | |
| Water Quality and Surface water mitigation | A background water quality assessment should be conducted for the drainage lines into the nature reserve and Wamberal Lagoon. This assessment will inform the water quality objectives for the construction water quality program. The parameters measured, and the timing and frequency of water quality monitoring to be agreed between TfNSW and the Contractor prior to construction commencing. | Construction Contractor | Pre-construction/ |
| Water Quality and Surface water mitigation | A water quality monitoring program for construction would be developed and implemented as part of the Soil and Water Management Plan in accordance with Roads and Maritime Guideline for Construction Water Quality Monitoring (Roads and Maritime, 2003).<br><br>The monitoring program is to include:<br>• Visual monitoring of the quality of site runoff, and of downstream water quality (particularly at Wamberal Lagoon) should be conducted daily, including a simple site record<br>• Downstream water quality monitoring of Wamberal Lagoon prior to the start of construction<br>• Weekly downstream water quality monitoring for the duration of work within the Wamberal Lagoon. At a minimum, monitoring within or immediately downstream of the large drainage line adjacent to Tumbi Road (the 3 x 1050mm Stormwater Channel, location C to D on Figure 4-1), and at an upstream location that is beyond the influence of the works. | Construction Contractor | Construction |
| Surface water quality mitigation | A Spill Management Procedure will be prepared and implemented as part of the CEMP to minimise the risk of pollution arising from spillage or contamination on the site and adjoining areas. The Spill Management Plan will address, but not necessarily be limited to: | Construction Contractor | Pre-construction / Construction |

| Impact | Environmental safeguards | Responsibility | Timing |
|---|---|---|---|
| | • Management of chemicals and potentially polluting materials<br>• Any specialised containment, security and bunding requirements<br>• Maintenance of plant and equipment<br>• Emergency management, including notification, response, and clean-up procedures | | |
| Surface water contamination | There is to be no release of dirty water into drainage lines and/or waterways.<br><br>Surface water will be managed in accordance with *Managing urban stormwater: soils and construction* (the Blue Book) | Construction contractor | Construction |
| Surface water contamination | Water quality control measures are to be used to prevent any contamination of surface waters from construction materials (e.g. Litter or waste, concrete, grout, etc) entering drain inlets or waterways. This is to be addressed in the CEMP. | Construction contractor | Construction |
| **Flooding and Drainage** | | | |
| Water – Flood Management and Evacuation Procedure | A Flood Management and Evacuation Procedure would be prepared as part of the CEMP to manage a potential flood event during construction and will outline evacuation procedures and measures to reduce risk, including removal of all plant/equipment, stabilising exposed areas and removing or securing any potential storage area to prevent pollution from chemicals and waste materials. The plan will include:<br><br>• Processes for monitoring and mitigation of flood risk for the Proposal site and any ancillary facilities<br>• Evaluation of what rainfall and storm events will trigger the plan, based on the local rainfall patterns and flood modelling.<br>• Evacuation procedures along with a map indicating the potential locations where to evacuate.<br>• Process to evaluate conditions post-event for re-opening of the site and ancillary facilities including but not limited to plant access, clean up and de-watering.<br>• Immediate post-event inspection and review of plans and processes for future events<br>• Links to incident reporting processes for managing any breaches or failures or site controls | Contractor | Pre-construction |

| Impact | Environmental safeguards | Responsibility | Timing |
|---|---|---|---|
| Flood Mitigation | Weather and rainfall conditions will be regularly monitored in advance to identify potential flood conditions and manage potential flooding impacts in accordance with the CEMP, including stop work periods. | Construction Contractor | Construction |
| Flood Mitigation | If existing drainage lines are to be impacted during construction, then an alternate (diversion) path, of equal capacity, would need to be established prior to commencing construction works. This should be included in the construction methodology to be developed in advance of drainage works commencing. The construction methodology must aim to maintain existing flows and consider the provision of alternate flow paths or diversions, and temporary stabilisation of disturbed outlets and banks of drainage lines. | Construction Contractor | Pre-construction and Construction |

# 6. Conclusion

This report involved a review of available drainage, flooding and water quality information related to the Proposal, and has assessed and identified surface water and flooding impacts that may occur as a result of the construction and operation of the Tumbi Road Intersection Upgrade. The assessment indicates that the construction and operation of the Proposal is unlikely to result in serious adverse impacts to local surface water quality and quantity, including receiving environments such as Wamberal Lagoon Nature Reserve and Wamberal Lagoon itself. This Proposal is unlikely to have any serious adverse impacts on surface water for the following reasons:

- Construction impacts would be managed through the implementation of measures in accordance with the Blue Book, including a site-specific soil and water management plan, site Erosion and Sediment Control Plan prepared as part of the CEMP and the development of construction methodologies to manage flows during works.
- Detailed planning and management of construction ancillary sites through an ancillary site management plan is recommended to avoid impacting existing overland flow paths and water quality of the surrounding environments without appropriate mitigation measures and contingency plans in place.
- Ancillary facilities will also be included in the development of the Proposal soil and water management plan and ESCPs and the implementation of soil and water controls to manage offsite flows, site run-off, pollution, and dust.
- Operational impacts are predicted to reduce flooding due to drainage provisions and upgrades to increase the capacity of pipes under the Central Coast Highway and increase the height of the road. The modelled flooding results, in all of the modelled events, from the 20% AEP to 1% AEP, indicate that these improvements provide a greater level of flood immunity to the road, as well as reduced flooding to adjacent private properties on the upstream side of the intersection.
- Operational impacts on water quality are not expected. The Proposal will result in a small increase in impervious areas of about 1 ha. This small change in the imperviousness over the total catchment area (an increase of 0.2 %) is unlikely to result in any measurable changes in the hydrology or water quality of the downstream receiving environment of the nature reserve and Wamberal Lagoon.

Cumulative impacts were considered, though no developments or events within the catchment were identified that would lead to cumulative impacts for surface waters.

# 7. References


AECOM (2021). *Central Coast Highway, Tumbi Road Intersection Upgrade – Flooding Assessment.* Prepared for Transport for New South Wales. Document Number: 60614070-P.0044037-RP-SW-0002. Revision: 1.

ANZG (2018). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments,* Canberra ACT, Australia. Available at: *www.waterquality.gov.au/anz-guidelines*

Austroads (2021). *Guide to Road Design Part 5: Drainage-General and Hydrology Considerations. Austroads.com.au. Available at: <https://austroads.com.au/publications/road-design/agrd05>*

Central Coast Council (2018). *Central Coast Waterways Report Card 2017-18*, NSW. Available At: *https://cdn.centralcoast.nsw.gov.au/sites/default/files/Environment/Central_Coast_Waterways_Report_Card_2018.pdf*

Central Coast Council (2016). *Gosford City Waterways: The Health of Gosford City Waterways Report 2015*, NSW. Available At: *https://cdn.centralcoast.nsw.gov.au/sites/default/files/final-gosford-waters-2015-annual-water-quality-report.pdf*

DECCW (2006). *NSW Water Quality and River Flow Objectives*, Department of Environment, Climate Change and Water, NSW Government. Available At: *https://www.environment.nsw.gov.au/ieo/Gosford/index.htm*

DIPNR (2005). *Floodplain Development Manual – the management of flood liable land,* NSW Government Department of Infrastructure, Planning and Natural Resources. Available at: *https://www.environment.nsw.gov.au/research-and-publications/publications-search/floodplain-development-manual*

DPIE (2018). *Wamberal Lagoon. [online] NSW Environment, Energy and Science,* Department of Planning, Industry and Environment. Available at: *https://www.environment.nsw.gov.au/topics/water/estuaries/estuaries-of-nsw/wamberal-lagoon*

DPIE (2021). *Major Projects, NSW Planning Portal,* Department of Planning, Industry and Environment. Available at: *https://www.planningportal.nsw.gov.au/major-projects/projects/search-location?name=&searchvalue=Wamberal%2C+Central+Coast%2C+New+South+Wales&minx=&maxx=&miny=&maxy=&project-search-type=location*

eSPADE (2020). *eSPADE NSW Soil and Land Information*, Department of Planning, Industry and Environment. Available at: *https://www.environment.nsw.gov.au/eSpade2Webapp#*

Engineers Australia (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Vol. 1, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted edition 1998), Barton, ACT

Engineers Australia (2013). *Australian Rainfall & Runoff – Revision Projects – Project 11: Blockage of Hydraulic Structures, Stage 2 Report,* Engineers Australia. Available at: *http://arr.ga.gov.au/__data/assets/pdf_file/0008/40499/ARR_Project_11_Stage2_report_Final.pdf*

Geoscience Australia (2019). *Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia*. Available At: *http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/*

Landcom (2004*). Managing Urban Stormwater- Soils and Construction, Volume 1, 4th Edition (known as the Blue Book Volume 1).* Available at: *https://www.environment.nsw.gov.au/research-and-publications/publications-search/managing-urban-stormwater-soils-and-construction-volume-1-4th-editon*

McCormack, R.B. (2010). *Wamberal Lagoon Freshwater Aquatic Biological Survey 2010*. Prepared for Gosford City Council. Australian Aquatic Biological Pty. Ltd. 36pp. *http://www.gosford.nsw.gov.au/environment/education/documents/surveys/wamberal-lagoon.pdf*

MHL (2020). *Coastal Lagoon Catchments: Overland Flood Study*, Manly Hydraulics Laboratory, Department of Planning, Industry and Environment, November 2020.

NSW DECC (2008). *Managing Urban Stormwater-Volume 2D Main Road Construction*, NSW Department of Environment, Climate Change and Water (known as the Blue Book Volume 2). Available at: *https://www.environment.nsw.gov.au/research-and-publications/publications-search/managing-urban-stormwater-soils-and-construction-volume-2d-main-road-construction*

RTA (2009). *Erosion and Sediment Management Procedure*, Roads and Traffic Authority. Available at: *https://www.rms.nsw.gov.au/documents/about/environment/erosion-sedimentation-management-pn143p.pdf*

RTA (2011*). Technical Guideline – Environmental Management of Construction Site Dewatering*, Roads and Maritime Services, Technical guideline EMS-TG-011 published by Roads and Traffic Authority dated April 2011. Available at: *https://www.rms.nsw.gov.au/business-industry/partners-suppliers/documents/guides-manuals/techguide-environmental-mg-construction-site-dewatering.pdf*

Roads and Maritime (2011). *Technical Guideline: Temporary Stormwater Drainage for Road Construction*. Available at: *https://www.rms.nsw.gov.au/business-industry/partners-suppliers/documents/guides-manuals/tech-guide-11-068-temp-stormwater-drainage-road-const.pdf*

SEED (2020). *Soil Landscapes of the Gosford-Lake Macquarie 1:100,000 Sheets,* Department of Planning, Industry and Environment. Available At: *https://datasets.seed.nsw.gov.au/dataset/soil-landscapes-of-the-gosford-lake-macquarie-1-100000-sheets9ac92*

TfNSW (2020). *Central Coast Highway and Tumbi Road intersection upgrade, Wamberal – Biodiversity Assessment Report*, Transport for NSW, May 2020, Sydney

WMAwater (2020). *Central Coast Highway Upgrade at Forresters Beach – Flood Assessment*, Transport for NSW, WMAwater, May 2020, Sydney