Central Coast Council

ENVIRONMENT AND PLANNING COMMITTEE

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Tuesday 5 August 2025

Central Coast Council

ATTACHMENTS PROVIDED UNDER SEPARATE COVER to the

Environment and Planning Committee

To be held ,
2 Hely Street, Wyong
on Tuesday 5 August 2025
Commencing at 7:00 PM

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Tuggerah Lakes Flood Study Review

Draft Report

Report MHL2929
20 May 2025

Prepared for: Central Coast Council

Department of Climate Change, Energy, the Environment and Water

Cover Photograph: Looking across Geoffrey Road, Chittaway Point over Tuggerah Lake towards The Entrance, 3 March 2022, courtesy of Central Coast Council.

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Matthieu Glatz

Team Leader, Investigations

110B King Street

Manly Vale NSW 2093

T: 02 9949 0200

E: Matthieu.Glatz@mhl.nsw.gov.au

W: www.mhl.nsw.gov.au

Document Control

Issue/ Revision	Author	Reviewer	Approved for Issue	
			Name	Date
Draft Report	K. Hasler, A. Severi, A. Islam, M. Phillips	M. Glatz	B. McPherson	20/05/2025

Central Coast Council
PO Box 20 Wyong, NSW 2259
ask@centralcoast.nsw.gov.au
1300 463 954

Report Classification

☒	Public	Report existence and contents publicly available.

Report No. MHL2929

First published as draft in February 2023

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110B King Street
Manly Vale NSW 2093
T 02 9949 0200 **TTY** 1300 301 181
ABN 20 770 707 468 www.mhl.nsw.gov.au

Foreword

The NSW Government's professional specialist advisor, Manly Hydraulics Laboratory (MHL), were commissioned by Central Coast Council to undertake a review of the Tuggerah Lakes Flood Study, improve understanding of flood behaviour and impacts, and better inform management of flood risk in the study area in consideration of the available information and relevant standards and guidelines.

The report was prepared by Kyle Hasler, Armaghan Severi, Matthew Phillips, Atikul Islam and Matthieu Glatz.

Executive summary

The original Tuggerah Lakes Flood Study was completed in 1994 by Lawson and Treloar. The study was undertaken to determine the flood behaviour events with Annual Exceedance Probabilities (AEP) of 50%, 20%, 5% and 1% as well as the Probable Maximum Flood (PMF). The model results from this study form the basis of Council's currently adopted flood planning levels for Tuggerah Lakes.

This study was followed by the Tuggerah Lakes Floodplain Risk Management Study and Plan (FRMSP) published in 2014 (WMA Water, 2014). The Tuggerah Lakes FRMSP provided management recommendations to reduce risk to life, public and private infrastructure associated with flooding.

A review and update of the original flood study investigations is now warranted for a number of reasons including recent advances in rainfall and runoff modelling techniques, significant changes in key guidelines (Australian Rainfall and Runoff, ARR 2019), an additional 30 years of monitoring data available throughout the catchment, several historical floods including a number of recent events, new interim entrance management procedures (MHL, 2022), increased development of the foreshores of Tuggerah Lakes and the benefits associated with making more informed land use planning decisions. As such, this flood study provides an updated assessment of flooding in the Tuggerah Lakes region, with a specific focus on inundation originating from the Tuggerah Lakes themselves.

The scope of this study does not encompass catchment flooding from the Tuggerah Lakes tributaries, such as the Wyong River, Ourimbah Creek, and Wallarah Creek, or overland flooding, as these matters have been extensively addressed in the respective catchment and overland flood studies in the area. The key components of the flooding assessment included:

- Review of existing studies and data;
- Community consultation;
- Extreme value analysis;
- Hydrological and hydraulic analysis and modelling;
- Sensitivity analysis;
- Flood mapping;
- Evaluation of climate change impacts;
- Assessment of flooding consequences on the community; and
- Development of this draft flood study report.

The flood modelling included a comprehensive range of events, from the 20% to the 1 in 500 Annual Exceedance Probability (AEP) events and the Probable Maximum Flood (PMF) scenarios, representing the critical durations and patterns for the Tuggerah Lakes.

To supplement this modelling, an extreme value analysis was performed on the long-term partial peak water level series and more recent continuous water level data using the annual maximum and peak-over-threshold approaches, respectively, to estimate the flood levels for the abovementioned AEP events.

As part of the hydrologic and hydraulic modelling process, this report identified that the lack of well-rated water level stations upstream of the study area limited flow data quality for calibration, potentially introducing uncertainties regarding inflows. Furthermore, significant uncertainty was found to exist regarding the behaviour of the entrance channel, particularly in the largest flooding events, for which no detailed data for entrance behaviour are available. To enhance the reliability of the findings of a similar study, future research should consider establishing enhanced gauging stations and ensuring detailed data capture for any large events which may occur in the meantime.

A comprehensive sensitivity analysis was undertaken to evaluate the influence of key hydrologic and hydraulic parameters on flood behaviour within the Tuggerah Lakes system under the 1% AEP flood event scenario. This analysis aimed to assess the relative sensitivity of peak lake water levels and hydrograph characteristics to variations in rainfall losses, catchment response, entrance dynamics, and boundary conditions.

- Rainfall Losses: Varying rainfall loss parameters demonstrated the most significant impact on flood peak levels. The removal of losses led to an increase of 0.14 m in peak water level compared to baseline conditions, while doubling the losses reduced the peak by 0.13 m. These results highlight the critical influence of rainfall-runoff processes on flood magnitude.
- Catchment Lag: Adjustments to catchment lag (±10%) had a minimal impact on peak water levels (±0.01 m), with effects primarily confined to the rising limb of the hydrograph. This indicates the timing of inflows is less critical than total runoff volume for this system.
- Hydraulic Roughness: Increasing or decreasing channel roughness by 20% resulted in changes of ±0.04 m in peak lake levels. Reduced roughness facilitated quicker recession, whereas increased roughness caused higher and more prolonged flood peaks due to lower conveyance efficiency.
- Initial lake level: Shifting the initial lake water level to 0.2 mAHD and 0.5 mAHD resulted in variations of -0.05 m and +0.04 m respectively in peak water level. Differences were most pronounced early in the event, with convergence towards baseline levels over time.
- Tailwater Conditions: Tailwater level had a moderate to significant impact, depending on scenario. A high (Type C) ocean water level (2.35 mAHD) increased the lake peak by +0.12 m, reflecting tidal backflow potential. Changes in timing of peak tailwater level (±6 hours) resulted in only minor variations (±0.01–0.03 m), indicating limited sensitivity within a 12-hour alignment window.
- Entrance Configuration: Scenarios modifying entrance geometry and scour dynamics yielded varied results:
  - A higher initial berm increased peak levels by +0.06 m.
  - A narrower or shallower channel configuration increased peak levels by up to +0.04 m.
  - Delayed scour or slower scour duration raised peaks by up to +0.15 m.
  - A deeper final channel or faster scour duration led to reductions of up to -0.07 m.

- Pre-dredged shoals: A dredged entrance scenario (based on 2019 post-dredging survey) resulted in a negligible change (-0.01 m) to peak levels but showed slightly improved recession characteristics during the falling limb of the hydrograph.

The sensitivity analysis confirmed that rainfall losses, scour duration, and tailwater level are the most influential parameters affecting flood peak levels and hydrograph shape. While other factors such as roughness, initial conditions, and entrance configuration also play a role, their relative influence is more modest.

Analysis of the results of the hydrologic and hydraulic modelling found that flooding within the Tuggerah Lakes catchment is relatively slow onset in nature, driven by prolonged rainfall events of moderate intensity, with critical durations ranging between 72 and 144 hours. While short-duration, high-intensity events may cause overland runoff in adjoining areas, the flood mechanism of interest to this study is lake-driven. Floodwaters typically recede within hours to days following peak levels. Key flood-prone districts were identified as:

- Chittaway Point;
- Tacoma and Tacoma South;
- Tuggerawong; and
- The Entrance North behind the Wilfred Barrett Drive levee, but only in events equal to or greater than the 1% AEP, among other areas.

Flood mapping was prepared for each of the abovementioned scenarios, consisting of peak water level, depth and velocity mapping. Various oceanic inundation scenarios under present-day and future climate change scenarios were also modelled. Post-processing of these results was performed to confine the mapped results only to those areas arising directly because of lake flooding and excluding areas that may be inundated by catchment tributaries and/or overland flow. Furthermore, from these post-processed results, flood hazard, flood function, and preliminary flood emergency response classifications communities were defined as per the Floodplain Guidelines and mapped.

A preliminary impact assessment of flood consequences on the community was undertaken by identifying the number of lots, key infrastructure, and roads affected by inundation by the lakes in the various scenarios modelled. This also involved the definition of a preliminary flood planning area, where a freeboard of 0.8 m was determined to be appropriate to account for the moderate levels of modelling uncertainties and potential effects of future climate change.

Moreover, climate change scenarios projected for 2040, 2090, and 2120 indicate increases in rainfall intensity and ocean tailwater, which could exacerbate flood conditions. However, it is noted that these effects may be partially counteracted by higher hydrological losses in these future scenarios. Specifically, for the representative 1% AEP event:

- 2040 tailwater and hydrological conditions may lead to a 0.28 m rise in lake levels.
- 2070 tailwater and hydrological conditions may lead to a 0.50 m rise in lake levels.
- 2120 tailwater and hydrological conditions may lead to a 0.83 m rise in lake levels.

This study lays a robust technical foundation for ongoing flood risk management and further investigations into the Tuggerah Lakes, contributing to enhanced resilience against future flooding events.

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1 Introduction

1.1 Background

Under the NSW Flood Prone Land Policy and Flood Risk Management Manual (2023; superseding the 2005 Floodplain Development Manual), the management of flood liable land remains the responsibility of local government.

The original Tuggerah Lakes Flood Study was completed in 1994 by Lawson and Treloar. The study was undertaken to determine the flood behaviour events with Annual Exceedance Probabilities (AEP) of 50%, 20%, 5% and 1% as well as the Probable Maximum Flood (PMF). The model results from this study form the basis of Council's currently adopted flood planning levels for Tuggerah Lakes.

This study was followed by the Tuggerah Lakes Floodplain Risk Management Study and Plan (FRMSP) published in 2014 (WMA Water, 2014). The Tuggerah Lakes FRMSP provided management recommendations to reduce risk to life, public and private infrastructure associated with flooding. A number of recommendations were made to reduce flood risk including adaptation planning for foreshore suburbs, flood emergency management planning, development of public education and awareness, adoption of development controls and formalising an entrance management strategy. The FRMSP was based on modelled flood behaviour from the Tuggerah Lakes Flood Study (Lawson and Treloar, 1994).

A review and update of the original flood study investigations is now warranted for a number of reasons including recent advances in rainfall and runoff modelling techniques, significant changes in key guidelines (Australian Rainfall and Runoff, ARR 2019), additional 29 years of monitoring data available throughout the catchment, several historical floods including a number of recent events, new interim entrance management procedures (MHL, 2022), increased development of the foreshores of Tuggerah Lakes and the benefits associated with making more informed land use planning decisions.

1.2 Study objectives

The objective of this study is to improve understanding of flood behaviour and impacts, and better inform management of flood risk in the Tuggerah Lakes study area in consideration of the available information, and relevant standards and guidelines. The aim of this study is to inform:

- Relevant government information systems;
- Government and strategic decision makers on flood risk;
- The community;
- Flood risk management planning for existing and future development;
- Emergency management planning for existing and future development, and strategic and development scale land-use planning to manage growth in flood risk; and
- Other key stakeholders (including utility providers and the insurance industry) on flood risk.

The outputs of the study may be able to assist this by facilitating information sharing on flood risk across government and with the community, and providing a better understanding of:

- The variation in flood behaviour, flood function, flood hazard and flood risk in the study area;
- Impacts and costs for a range of flood events or risks on the existing and future community;
- Impacts of changes in development and climate on flood risk;
- Emergency response situation and limitations; and
- Effectiveness of current management measures.

1.3 Study area

The Tuggerah Lakes system is located within the traditional boundaries of Darkinjung (Darkinyung) land on the Central Coast of NSW, approximately 80 km north of Sydney. The study area comprises three main interconnected lakes including Tuggerah Lake, Budgewoi Lake and Lake Munmorah. Tuggerah Lake is the largest of the three lakes and is connected to Budgewoi Lake and Lake Munmorah by narrow channels at Gorokan and Budgewoi. The lakes system is connected to the ocean via a tidal channel through the barrier dune at The Entrance. The condition of the entrance of Tuggerah Lakes, where flows exchange to/from the ocean, is dynamic and subject to entrance sediment infilling and scour, such that the estuary is classified as an Intermittently Closed and Open Lakes and Lagoon (ICOLL).

The Tuggerah Lakes system covers a total catchment area of approximately 790 km^2 of which approximately 10% is covered by lakes. Wyong River, Ourimbah Creek, Tumbi Umbi Creek and Wallarah Creek are the major catchments contributing to the lakes system. Wyong River, Ourimbah Creek and Tumbi Umbi Creek drain catchment areas of approximately 447 km^2, 160 km^2 and 14 km^2 respectively to the southern end of Tuggerah Lake, and Wallarah Creek drains a catchment area of around 32 km^2 into Budgewoi Lake.

Prior to European settlement in 1825, Aboriginal peoples occupied the Tuggerah Lakes catchment area (Darkinjung land) with minimal environmental impact, utilising the lakes and adjacent beaches for the collection of a variety of seafood (CSIRO, 1999). After European settlement in the 19th and 20th centuries, properties were acquired (originally for farming purposes) around the low-lying foreshore of the lakes. Nowadays, around 80% of the shorelines of the Tuggerah Lakes are urbanised, primarily in the form of residential land use, and is susceptible to flood damages. In 2014, it was estimated that approximately 1,300 buildings would be impacted by the 1% AEP lake flood event and with a long-term annual average damage for the foreshore properties surrounding Tuggerah Lakes of $2.2 million (WMA Water, 2014).

Ocean tides in the region are microtidal with mean spring and neap ranges of 1.3 m and 0.8 m, respectively. The regional wave climate is of moderate to high energy. The tidal range within the lakes is relatively small in the order of centimetres and average lake levels vary between 0.2 to 0.3 m AHD due to the dynamic constriction of the entrance channel and shoals. Over the past 29 years, recorded lake levels at Long Jetty (211418) typically vary between 0.09 and 0.50 m AHD (90% of the time) and have been measured to reach in excess of 1.75 m AHD during flood events.

The study area is presented in **Figure 1.1**. Hydrologic modelling for the present study covered the full catchment area presented, while hydraulic modelling and analysis of flood impacts and behaviour in the present study was focussed on flooding of the Tuggerah Lakes system in lower reaches of the catchment, with elevations less than approximately 3 mAHD.

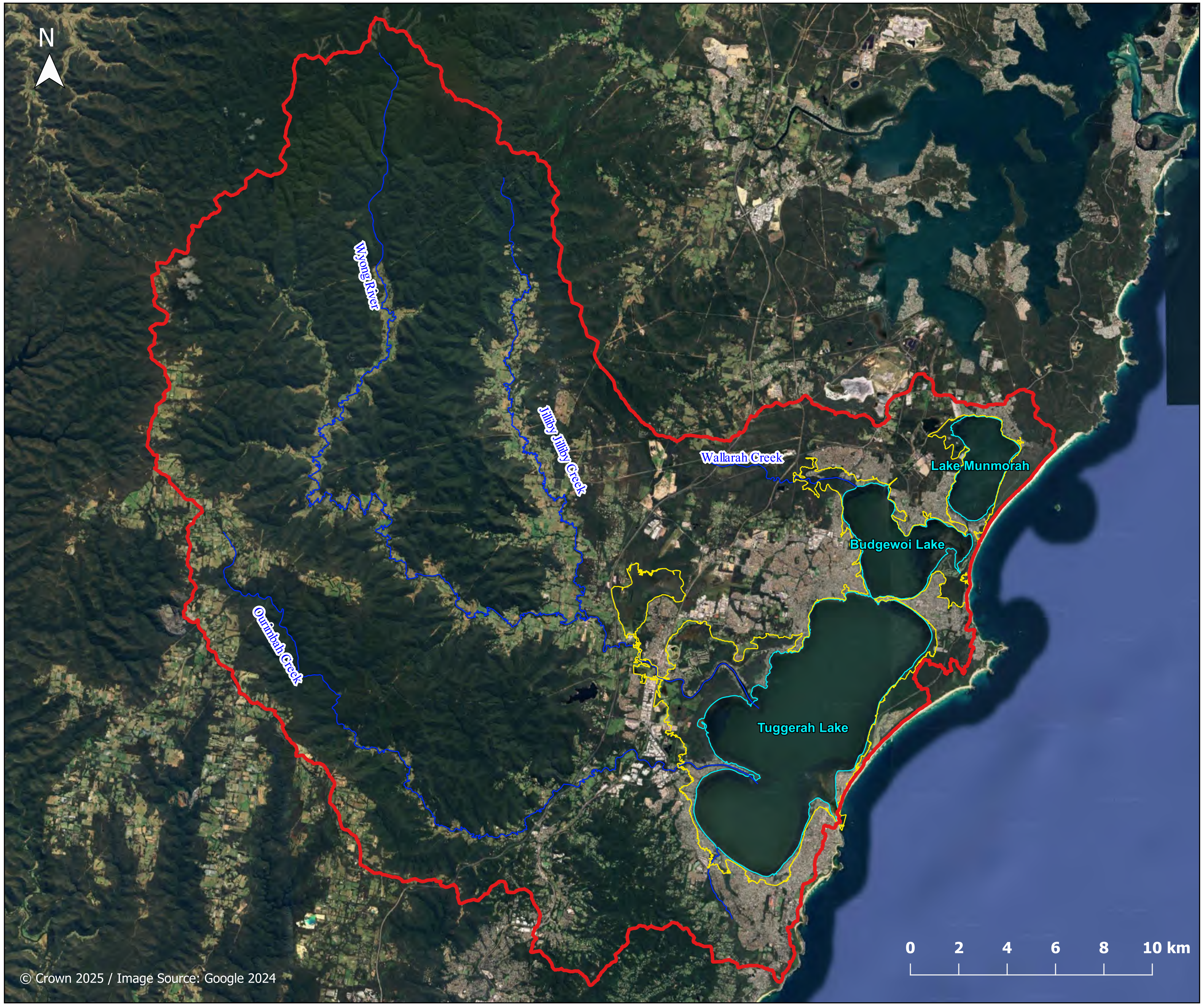

Figure 1.1

Tuggerah Lakes catchment and study area

Legend

- Catchment boundary
- 3 mAHD Contour
- Primary tributaries

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1.4 History of flooding and rainfall

Historical records and observations provide valuable evidence of historic flood behaviour in the Tuggerah Lakes catchment in response to heavy rainfall. Flood events have had a history of resulting in inundation of land and, in some instances, built assets. A summary of historical peak lake water levels for Tuggerah Lakes is shown in **Table 1.1**. It is noted that accurate gauged water levels measurement commenced in Tuggerah Lakes in 1985 after installation of the Toukley and Killarney Vale gauges. Prior lake water levels are based on historical observations.

The largest known flood occurred on the 18 June 1949, reaching a lake level of approximately 2.1 m AHD. Lake flood levels are estimated to have equalled or exceeded 1.5 m AHD at least 14 times over the last 100 years and five times since gauged water level records began in 1985 (February 1990, June 2007, February 2020, March 2021 and July 2022). Recent flooding in July 2022 resulted in lake levels reaching 1.76 m AHD at Toukley and Wallarah Creek Bridge gauges, the highest on record since gauging began in 1985.

Table 1.1 Summary of historical peak lake water levels (adapted from WMA Water, 2014)

Event	Historical recorded peak lake level (m AHD)	Measured gauge peak lake level (m AHD)		
		Toukley	Wallarah Creek Bridge	Long Jetty
18 June 1949	2.10	-	-	-
April 1946	1.88	-	-	-
2 May 1964	1.87	-	-	-
April 1927	1.81	-	-	-
1931	1.81	-	-	-
6 July 2022	-	1.76	1.76	1.72
11 Feb 2020	-	1.66	1.66	1.67
10 June 2007	-	1.68	1.65	1.64
4 February 1990	-	1.61	-	-
4 March 1977	1.59	-	-	-
22 March 2021	-	1.50	1.49	1.52
1963	1.53	-	-	-
1953	1.49	-	-	-
1941	1.48	-	-	-

Notes: Historical records obtained from WMA Water (2014) and Lawson and Treloar (1994). It is likely that several floods prior to 1970 may not have been recorded. Gauged lake levels can be subject to wind and wave setup effects.

Photographs of recent and historical flood events have been provided by community members as part of the community consultation process and from Central Coast Council's Library Service. Selected photos and historical accounts of past flood events (chronologically listed) are shown below (**Figure 1.2** to **Figure 1.18**).

A detailed summary of historical flood information and accounts spanning 1867 to 1992 is provided in *Tuggerah Lakes Flood Study Compendium of Data. New South Wales. Coast and Rivers Branch. October 1992*.

Also associated with past flood events is historical information describing changing entrance conditions and past interventions at the dynamic entrance channel opening to the ocean. This information is summarised in the *Tuggerah Lakes Entrance Management Study, MHL, 2022.*

Additional flood history in various upstream catchments and tributaries feeding into Tuggerah Lakes is documented in previous flood studies (see **Section 2**).

Figure 1.2 Flooding c. 1909 looking south from Wyong through to Tuggerah over the road and train lines. Courtesy of Central Coast Council

Figure 1.3 Damages to the original Long Jetty (built 1914 by William Henry Price) following flooding in Easter 1927. Courtesy of Central Coast Council

Figure 1.4 Northern railway line just north of Tuggerah Station covered by flood waters, Wyong 1927. Courtesy of Central Coast Council

FEARS OF FLOOD

There is considerable apprehension among residents of Tuggerah, Wyong, Gosford and Woy Woy as a result of the flood waters again rising. Early yesterday afternoon the floods showed signs of receding, but towards evening commenced to rise again. Three feet of water washed through some homes at Woy Woy, and although the position was slightly easier this morning grave fears are entertained unless the rain ceases. The Wyong River burst its banks at Wyong this morning, marooning many homes. Road traffic between Peats Ferry and Gosford is suspended owing to washaways.

The rainfall in Sydney for the 24 hours ended 9 a.m. to-day was 780 points, which is the highest since 1883.

Figure 1.5 The Northern Star Newspaper, Page 7, July 8 1931
https://trove.nla.gov.au/newspaper/article/94187368

WYONG

Families sat on the rooftops at Wyong and watched the floodwaters swirl past the houses. Hundreds were rescued by police boats. Several houses outside the town are completely submerged.

The main railway line between Sydney and Newcastle was under water for more than half a mile south of Wyong.

When the Wyong river burst its banks the floodwaters spread over hundreds of acres of low lying country.

The Pacific Highway at places was feet deep in water and traffic ceased.

Sergeant M. D. McAuliffe and Constable R. Wilson, of Wyong, rescued more than 50 people from their marooned houses in two motor launches.

The main road between Wyong and Tuggerah Lakes was flooded to a depth of five feet.

Citrus fruit growers in the Gosford district suffered heavily. More than 2,000 orange trees at one farm were under water, and the owner estimated he would lose £5,000.

Figure 1.6 The Canberra Times, Page 1. 20 June 1949
https://trove.nla.gov.au/newspaper/article/2809821

Figure 1.7 Parry's Jetty under flood c. 1960s. Bailey, Harold. Courtesy of Central Coast Council

Figure 1.8 Payne's boat shed on Tuggerah Lake at Long Jetty during flood 1960s. Bailey, Harold. Courtesy of Central Coast Council

Figure 1.9 Approximately 250 m north along South Tacoma Rd from Kingsland Cl, facing northwest, 5th February 1990. Courtesy of a local resident

Figure 1.10 Marine Rescue Tuggerah Lakes Unit, Peet St, Toukley, 10th February 2020. Courtesy of a local resident

Figure 1.11 Leonard St, The Entrance North, Facing southwest, 11th February 2020. Courtesy of a local resident

Figure 1.12 Lakedge Ave, Berkeley Vale, immediately south of Kingsford Smith Dr, facing east, 4th March 2022. Courtesy of a local resident

Figure 1.13 Lakedge Ave, Berkeley Vale, 100 m south of Kingsford Smith Dr intersection, Facing south, July 2022. Courtesy of a local resident

Figure 1.14 Lakedge Ave, Berkeley Vale, Facing south along Albatross Road at the intersection of Lakedge Avenue and Albatross Road, 8th July 2022. Courtesy of a local resident

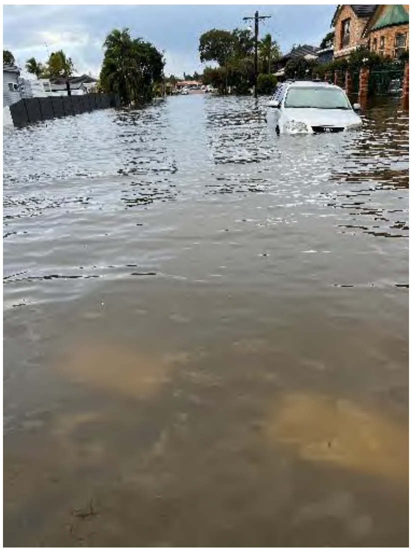

Figure 1.15 Tuggerah Pde, Long Jetty, Facing east along Venice Street at the intersection of Tuggerah Pde and Venice Street, July 2022. Courtesy of a local resident

Figure 1.16 Moui Ave, Chittaway Bay, July 2022. Courtesy of a local resident

Figure 1.17 230 Geoffrey Road facing southwest, Chittaway Point. July 2022. Courtesy of a local resident

Figure 1.18 Facing north along Crosby Crescent, Killarney Vale, July 2022. Courtesy of a local resident

1.5 Land use and zoning

Land zoning GIS spatial data was provided by the Council, shown in **Figure 1.19**. The land zoning within the floodplain surrounding the lakes is classified under a range of zonings. Land use within the catchment primarily consists of Forestry (RU3), National parks and natural reserves (E1), Environmental management (E3), Primary production (RU1), Recreational waterways (W2), Environmental conservation (E2), Low density residential (R2).