bluecoast
CONSULTING ENGINEERS

Central Coast Council

Rhelm
engineering | environmental | economics | engagement

Central Coast Council

Coastal Processes and Socio-Economic Assessment

Tuggerah Lakes estuary

24 February 2026

Report No: P22224_CoastalSocio-Economic_TechReport_R6.00

Document Summary

Document Title	Coastal Processes and Socio-Economic Assessment
Project Name	Tuggerah Lakes estuary
Client	Central Coast Council
Report No.	P22224_CoastalSocio-Economic_TechReport_R6.00
Central Coast Council Project No.	CPA/4085

Central Coast Council has prepared this document with financial assistance from the NSW Government through its Coastal and Estuary Grants Program. This document does not necessarily represent the opinions of the NSW Government or the NSW Department of Climate Change, Energy, the Environment and Water.

Document History

Version	Date	Author(s)	Reviewer(s)	Status	Signature
1.0	18.08.2022	R. Dermek	E. Watterson	Table of contents	
2.0	31.10.2022	R. Dermek	E. Watterson	Working draft (*coastal processes only*)	
3.0	15.03.2023	L. Drynan	L. Drynan	Working draft (*socio-economic assessment*)	
4.0	21.07.2023	S. Perrin, H. Loehr	H. Loehr	Final draft	
5.0	28.03.2025	L. De Lucia	H. Loehr	Revised final draft	
6.0	24.02.2026	H. Loehr	H. Loehr	Final	

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 About this report

This report supports Central Coast Council's (Council's) Tuggerah Lakes Estuary Coastal Management Program (CMP). The purpose of this report is to gather and simplify information relating to the coastal processes shaping the entrance to Tuggerah Lakes and the impacts of past, current and proposed management interventions have on entrance state/condition, tidal exchange, estuary flushing, water quality and other important variables, and align these with socio-economic values. This report forms part of Stage 2 of the Tuggerah Lakes Estuary CMP. Entrance coastal processes and socio-economic appraisal were identified in the CMP Stage 1 Scoping Study (CCC, 2021) as requiring further investigation to support later stages of the CMP process. The outcomes of this report will provide input to an Entrance Management Strategy that forms part of Stage 3 of the CMP.

A separate entrance management 'Options Paper' that documents the key findings and recommendation for broader community engagement and to inform Council's Entrance Management Strategy will be developed as part of the Tuggerah Lakes CMP.

1.2 Study area

The study is located at the Tuggerah Lakes estuary on the Central Coast of NSW (Figure 1 and Figure 2). While the study considers the whole estuary, a particular focus is given to the lower estuary east of The Entrance Bridge (shown in Figure 2).

The Tuggerah Lakes catchment is approximately 790 km^2 (MHL, 2022). The upper catchment flows through main tributaries of Wyong River, Ourimbah Creek and Wallarah Creek which feed into three connected lakes – Tuggerah Lake, Budgewoi Lake and Lake Munmorah, collectively referred to as Tuggerah Lakes estuary in this reporting. Tuggerah Lakes estuary has a total surface area of approximately 81km^2 (OEH, 2013a) and is connected to the ocean through a small channel at The Entrance. The Tuggerah Lakes estuary is defined as a wave dominated estuary of the type intermittently closed or open lakes or lagoons (ICOLL) (as per classification in Dalrymple et al., 1992 and Boyd et al., 1992).

The Tuggerah Lakes estuary and catchment has a rich and long-lasting Aboriginal history and forms part of the traditional Country of the First Nations People. Darkinjung Local Aboriginal Land Council has remit over the traditional boundaries of land extending from the Hawkesbury River in the south, Lake Macquarie in the north, the McDonald River and Wollombi up to Mt Yengo in the west and the Pacific Ocean in the East (CCC, pers. comm.).

The Tuggerah Lakes estuary is located within the Central Coast Council Local Government Area, the State Electorates of The Entrance, Wyong and Swansea and the Federal Electorates of Dobell and Shortland.

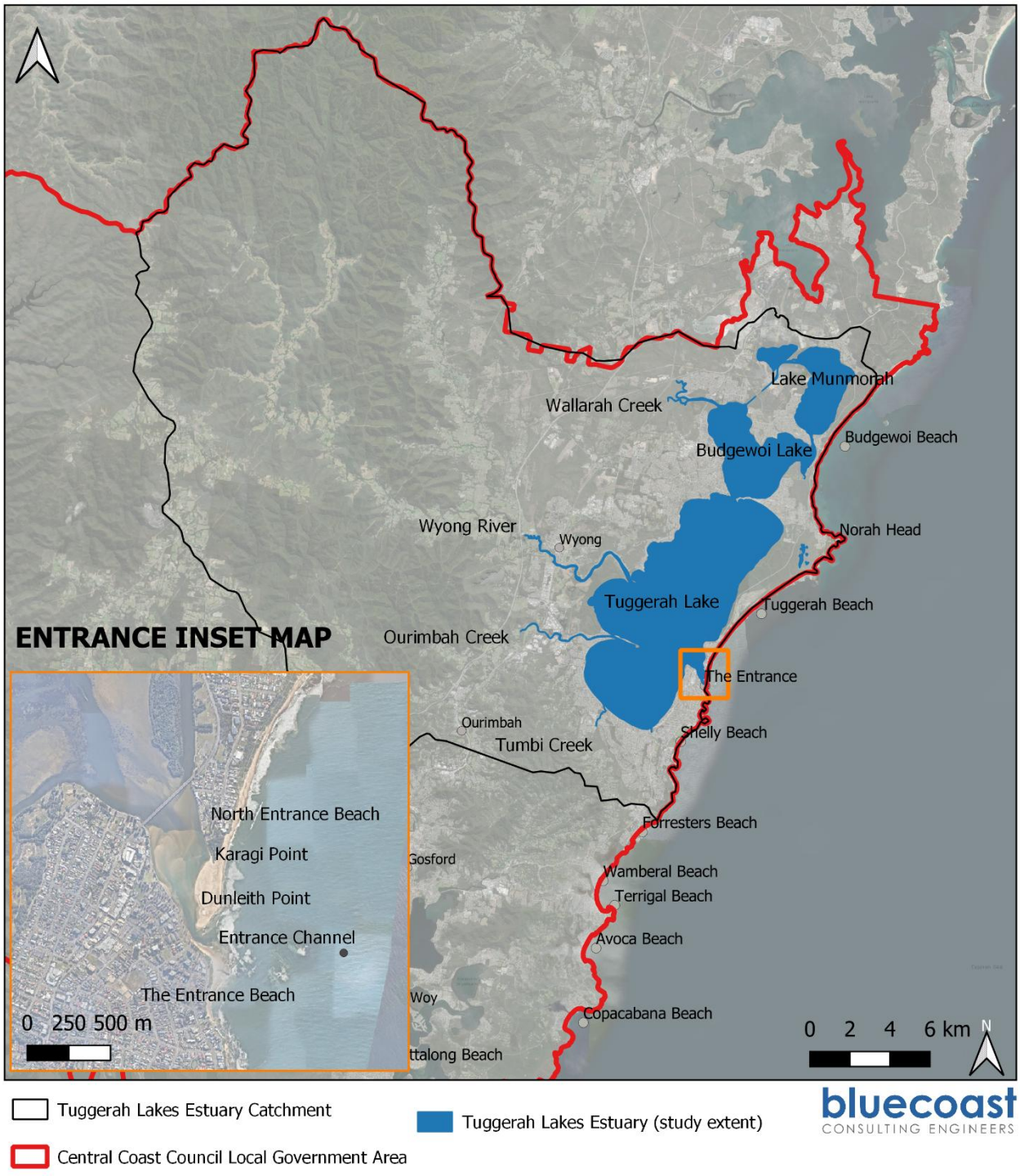


Figure 1: Map of the project area.

Figure 2: Tuggerah Lakes entrance location map.

1.3 Project objectives

The aim of this study is to better inform the community and stakeholders on entrance management at Tuggerah Lakes and provide the scientific and social basis for future decision-making around the entrance management strategy by Council. This study informs the next stages of the CMP, leading to the development and implementation of an entrance management strategy and wider Tuggerah Lakes Estuary CMP adopted by Council.

Through the information gathered during consultation and via the numerous previous studies and available data, the objectives of the present study are to provide:

- A clear understanding of the entrance coastal processes that shape the entrance to Tuggerah Lakes and how past dredging practises and already proposed management options influence the environment of the six functional zones (functional zones introduced further in Section 2.5.4).
- An understanding of the socio-economic aspects of the Tuggerah Lakes estuary, as well as a high-level valuation of the estuary and the potential dependency of this value upon entrance conditions, including the value of “a clear and flowing entrance”.
- Identify feasible entrance management options, their associated benefits and impacts and relationship to the community values identified.

1.4 Context of this report

Central Coast Council have commenced preparation of CMPs for the entire LGA coastline, including the various estuaries and open coast. The NSW Coastal Management Framework specifies five stages of preparing a CMP (see Figure 3). The purpose of a CMP is to set the long-term strategy for the coordinated management of the coastal zone with a focus on achieving the objects of the CM Act.

The CM manual specifies five stages of preparing a CMP (see Figure 3). Council completed a scoping study for the Tuggerah Lakes Estuary CMP, Stage 1 of the CMP process, in July 2021 (CCC, 2021). Stage 2 of CMP preparation involves undertaking detailed studies that help Council to identify, analyse and evaluate risks, vulnerabilities and opportunities. The studies conducted during Stage 2 are to provide information to support decision-making in the subsequent stages of the CMP planning process. Further detail around studies completed as part of Stage 2 of the Tuggerah Lakes Estuary CMP is provided below.

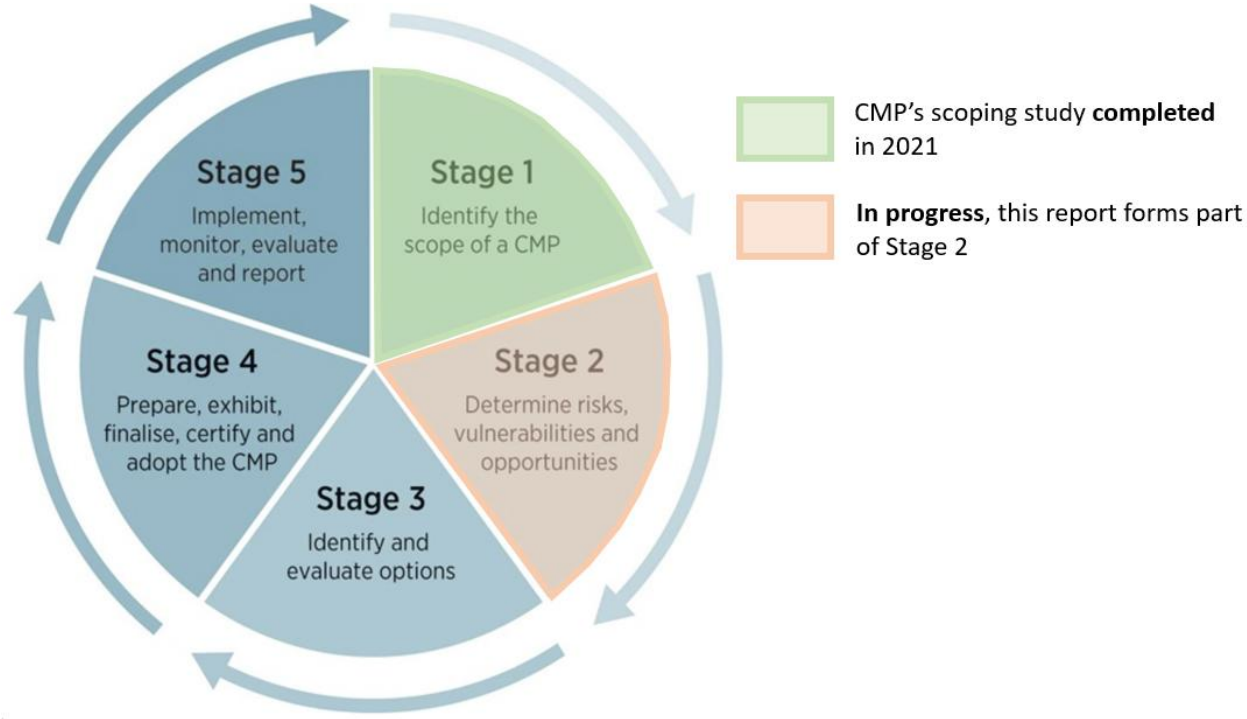


Figure 3: Stages in preparing and implementing a CMP (modified after the NSW Government).

The Tuggerah Lakes estuary is a complex system, with interdependencies between the greater catchment inflows, the lakes themselves, the entrance channel condition, and the open coast. Consequently, addressing the needs of the community and environment of the Tuggerah Lakes estuary has been the subject of multiple studies and reports. The last 50 years of these studies are summarised

in Section 2.3 of this reporting. Numerous entrance management options have been proposed and explored based on varying hypotheses as to the dominant drivers and available technologies.

Robust scientific knowledge is essential for effective assessment of strategic solutions. Figure 4 provides an overview of the Tuggerah Lakes Estuary CMP, with the present study highlighted in red. This report (the 'Tuggerah Lakes estuary coastal processes and socio-economic assessment') provides a comprehensive review of physical and socio-economic processes likely to influence the development of a formalised entrance management strategy and wider Tuggerah Lakes Estuary CMP.

Of the project objectives noted in Section 1.3 above, the first two relate to Stage 2 of the CMP process, that is to provide information to support decision-making in later stages of the CMP process. The third objective contributes to starting to identify and evaluate options, which is typically Stage 3 of the CMP process.

Concurrent to this study, Central Coast Council are undertaking Stage 2 studies for the Open Coast and Coastal Lagoon's CMP (or open coast CMP). The open coast CMP is a separate CMP to the Tuggerah Lakes Estuary CMP. Importantly, the Stage 2 studies for the open coast CMP consider coastal processes, including the regional coastal sand budget and local sand budget in the beach compartment of The Entrance, North Entrance Beach and Tuggerah Beach (Bluecoast, 2023).

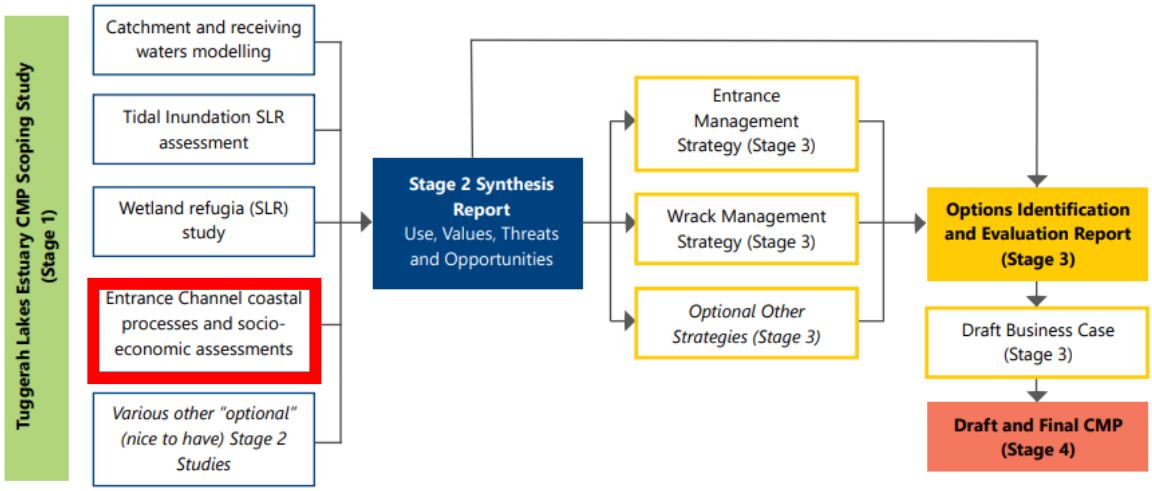


Figure 4: Tuggerah Lakes Estuary CMP workflow (from CMP Stage 1. CCC, 2021).

1.5 Scope and structure of this report

The report covers a dynamic and active estuary and entrance channel. It is a study area that is impacted by river flows, wind, tides, waves, human modification and bio-geochemical processes, all of which's influence vary within the length of the estuary and in the entrance compartment itself.

The study adopts a data-driven approach. It also draws on the wealth of previous literature covering estuarine processes in the project area. The report is set out as follows:

- Section 2 provides background information including a timeline of key anthropogenic changes, summary of previous literature and existing data and understanding of the coastal environment.
- Section 3 provides a description of the previous community and stakeholder engagement undertaken.
- Section 4 provides a description of the coastal processes assessment undertaken.
- Section 5 provides the socio-economic context and appraisal.

- Section 6 provides an evaluation of potential options and identifies a shortlist of options available to take forward into the later stages of the CMP.
- Section 7 provides recommendations and next steps.

1.6 Statement of assumptions and uncertainties

The approach adopted herein is reasonable and valid for improving the understanding of coastal and estuarine processes that are expected to affect the entrance management strategy and wider CMP process. However, it is important to recognise the assumptions underlining the estimates as well as the inherent uncertainties. It is recommended that these are considered throughout the CMP and are communicated to the community and stakeholders. It is further recommended to undertake on-going monitoring of key coastal and estuarine processes to reduce the degree of uncertainty in later stages of the program (see Section 7). The key assumptions and uncertainties include the following:

- Analysed meteorological, estuarine and coastal data and hydrographic surveys are representative of prevailing conditions at the time and some are influenced by the dynamic behaviour of the entrance and adjacent sand spit.
- Historic records of anthropogenic interventions within the project area are limited and available records are incomplete.
- Water quality data is not continuous and is instead provided at monthly sampling intervals. This non-continuous sampling interval can increase the uncertainty when linking water quality to processes occurring in the estuary.
- Comparative volumetric analysis of available survey data has been used to estimate the sediment budget and the rates of sand movement. These estimates are therefore subject to the accuracy of these surveys as well as spatial and temporal gaps in the survey coverage. Only limited or no survey data is available for sections of the sediment compartment and survey analysis was therefore undertaken over shorter time periods which may result in higher uncertainties in estimated long-term averages. Where no data was available, literature values were adopted and/or justified assumptions were made.
- Uncertainty remains around projections for climate change impacts, specifically on a local scale.

2. Study context

2.1 Regulatory and policy context

In addition to the NSW Coastal Management Framework described in Section 1.4, there are numerous legislative instruments which, to greater or lesser extent, regulate the activities in the Central Coast coastal area and which establish a strategic direction for the Tuggerah Lakes estuary. Management of Tuggerah Lakes is guided by frameworks, policies and plans on local, regional and state level (see detailed list in CCC, 2021). While Council is responsible for entrance management under their duty of care to the community their strategic direction is required to consider several statewide policies and plans, including:

- Marine Estate Management Strategy
- State Environmental Planning Policy (Resilience and Hazards) 2021
- Crown Land 2031 State Strategic Plan for Crown
- NSW DPI Policy and guidelines for fish habitat conservation and management.

The NSW Government generally only supports minimal interference with ICOLL entrance barriers and encourages natural processes being allowed to operate to the greatest extent possible. Any proposals for entrance management, including artificial opening, of ICOLLs must seek the approval or concurrence under the *Fisheries Management Act 1994*. The artificial opening of an ICOLL is typically not supported unless Council can demonstrate that the social, environmental and economic benefits greatly outweigh any potential adverse impacts.

2.2 Timeline of human intervention

Human modifications and interventions have had a material effect, whether intended or unintended, on the Tuggerah Lakes entrance channel and wider estuary. These are broadly classified into direct management of the entrance channels and surrounds, and indirect and direct management of the wider estuary which are outlined and explained under the following sub-headings.

2.2.1 Interim entrance management procedure

In August 2022, Council completed the Tuggerah Lakes Entrance Management Study (MHL, 2022) which included the development of the Interim Entrance Management Procedure, to assist in reducing flood risk and impacts to the community. The interim procedure is intended to guide Council's channel management until the Entrance Management Strategy is completed, as part of the Tuggerah Lakes CMP. This procedure is supported by flood intelligence tools that provide real-time predictive estuary levels (from predicted rainfall) and in combination with monitoring data to allow a proactive response from Council when flood events are predicted. The Interim Entrance Management Procedure has been implemented during recent flooding events.

Depending on the prevailing entrance condition at the time of a predicted flood (classified into five entrance states), the procedure prescribes different predefined responses as outlined in MHL (2022). Works may include berm scraping (reducing the height of the sand berm), pilot channels (creating a narrow channel with heavy machinery to create a second opening that will naturally widen) and reactive openings (in the rare situation of a completely closed channel).

The procedure includes real-time monitoring of the M2 tidal constituent as a measurable indication of tidal influence on the estuary used as a proxy for the level of constriction of the entrance channel in addition to camera-based monitoring of the entrance throat width. MHL's Flood Intelligence Tool (MHLFIT) is used with Bureau of Meteorology predicted rainfall data to forecast potential estuary levels up to four days before they occur.

MHL (2022) states the flood level reduction associated with the procedure are relatively small (typically less than 0.2m), however, are considered beneficial in assisting to reduce flood damages. It is important to note that flooding in Tuggerah Lakes cannot be eliminated. The impacts of flooding will continue to be experienced even under the implementation of the procedure and will likely worsen with sea level rise.

2.2.2 Historical entrance management

Numerous investigations have been undertaken into a permanent entrance channel at a fixed location. However, Tuggerah Lakes estuary entrance remains in an untrained state with no structures directly fixing the channel or current continuous operations to maintain an open entrance channel. The entrance channel and its adjacent shorelines have a long history of management actions. An overview of these interventions is provided in Figure 5 and described below.

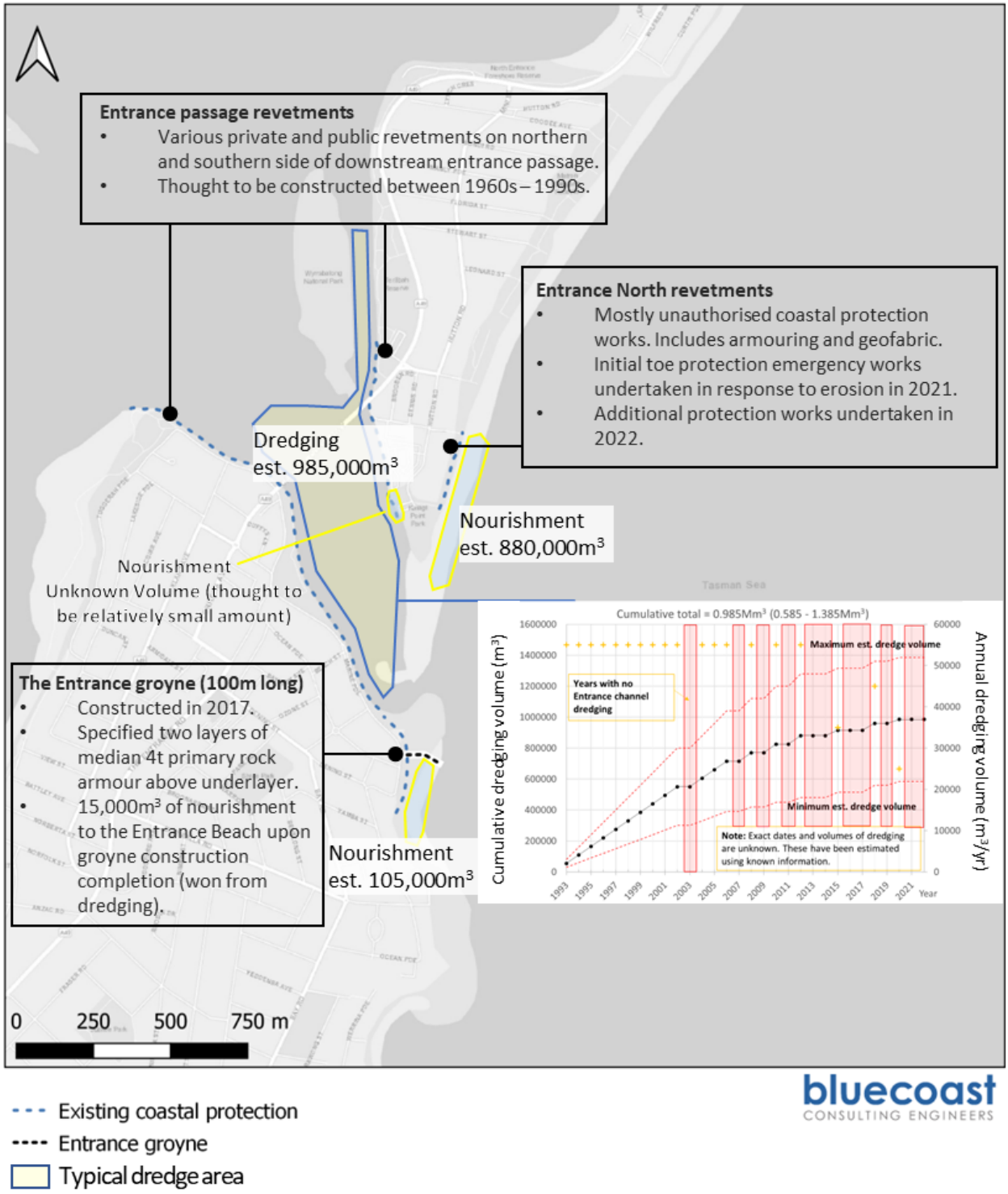


Figure 5: Summary of key entrance interventions.

In terms of structures, most of the southern and northern shorelines of the Lower Tuggerah Lakes estuary upstream and downstream of The Entrance bridge are fixed with revetments, generally thought to be constructed between the 1960s through to 1990s. Whilst these revetments constrain the flood tide delta from major shifts to the north or south, they are generally thought to have minimal impact on the location of the entrance berm at Dunleith Point, and the general management of the estuary.

A significant local structural intervention came in 2017, when a 100m long rock groyne was constructed by the NSW Government at The Entrance Beach, approximately 150m south of the typical entrance channel. It is intended to retain sand on The Entrance Beach for amenity purposes. The effects of this groyne in the context of the Tuggerah Lakes estuary are further evaluated in Section 4.4.

The entrance channels have a history of dredging and entrance management activities. Records of these early activities are minimal but are evident in historical aerial imagery (see Figure 6). There are several newspaper articles of entrance management and dredging prior to 1993 (See CSIRO 1998a and 1998b), including by Erina Shire Council (Council area of Tuggerah Lakes estuary 1906 – 1947) excavating the entrance channel in 1939, and Wyong Shire Council (i.e., Council area of Tuggerah Lakes estuary 1947 – 2017) carrying out a dredging program including the entrance channels in Tuggerah Lakes between 1957 – 1968, and also excavating (deepening) the channel(s) to alleviate flooding in 1986 (CSIRO, 1998a). The works resulted in reclamation of tidal flats along the south-western foreshore (including around Memorial Park), channel straightening, building of islands, removal of some channels and reclamation along the northern foreshore (Umwelt, 2011) as visible in Figure 6.

Attempts of manual intervention by fisherman and residents have also been noted to open the entrance channel. Despite this intermittent dredging and opening by various methods, Umwelt (2011) found the entrance channel to have been closed at least 13 times in the 20th century.

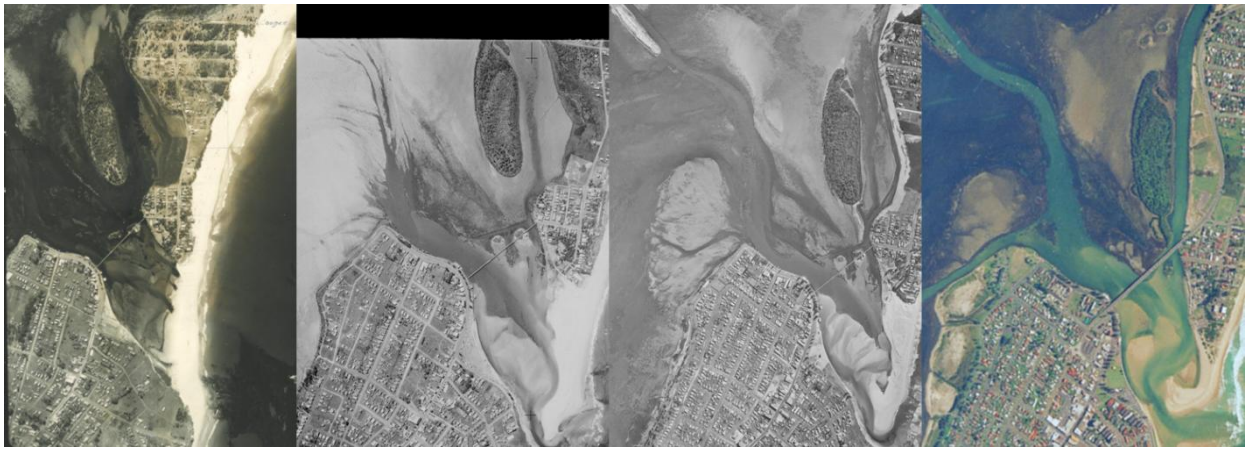


Figure 6: Historic aerial imagery of Lower Tuggerah Lakes estuary (left to right: 1941, 1953, 1964, 1995).

A significant and consistent dredging intervention of the entrance channels was undertaken between 1993 and 2018 during a time that Wyong Shire Council (now Central Coast Council) owned and operated a small Cutter Suction Dredge (CSD). An overview of known historical dredging volumes is provided in Table 1. Council's small dredger was used on an as needed basis, with an estimated annual average of 30,000 to 80,000m^3/yr extracted from the entrance area (GHD, 2019), within the typical extents shown in Figure 7. While no formal entrance management strategy existed during this period of dredging, dredge programs were triggered based on the following guidelines (WorleyParsons, 2009):

- *The throat[1] of the channel at The Entrance reduces to an estimated width of less than 15m measured at mid-tide level;*

[1]*The throat is that section of the channel near the southern tip of the sand spit having minimum cross section dimensions.*

- *the flood tide sand shoals threaten to block[2] the ebb tide dominant channel along the northern/eastern side of The Entrance Area; and/or*
- *the flood tide sand shoals threaten to block the main channel east of the bridge.*

Dredged sand is typically reused as nourishment on North Entrance Beach. Typically, placement was south of Hargraves St, thought to be a longshore sediment transport null point, allowing most of the sand to be worked back towards the entrance channel and not lost from the system. Sand was pumped through a temporary pipeline from the dredge vessel, connected to a permanent pipeline through North Entrance Beach dune directly onto North Entrance beach. For a variety of reasons including the age, condition, dimensions and regulatory constraints the pipeline is no longer used.

Sand was typically placed in accordance with the requirements in the Review of Environmental Factors (REF) (WorleyParsons, 2009) for the dredging and sand placement works, with sand placed to:

- Match the crest level of the emplaced material with the existing dune crest level,
- Achieve a stable seaward gradient of the foredune of not more than 1 in 5 (1 vertical : 5 horizontal), and
- Achieve a beach berm gradient of 1 in 20 to 1 in 30.

Other than North Entrance Beach, The Entrance Beach was also regularly nourished at frequency of approximately every 5 years including 1994, 1999 and 2004 (reported as 30,000m^3 of material) and 2018. The estuary eastern bank downstream of The Entrance bridge was regularly nourished by dredged sand at an unknown frequency, thought to be negligible in the context of this study (WorleyParsons, 2009).

Table 1: Overview of known significant dredging activities at The Entrance.

Year	Dredged volume (m^3)	Extraction location	Placement location
Pre-1993	Unknown	Various	Unknown
1993 - 2012	480,000 – 1,280,000	See Figure 7 for footprint	North Entrance Beach and The Entrance Beach
2015	35,000	The entrance channels	North Entrance Beach and The Entrance Beach
2018	45,000	The entrance channels	North Entrance Beach and The Entrance Beach
2020	25,000	Downstream and upstream of highway bridge	North Entrance Beach
Total	**585,000 – 1,385,000**		

Note: Actual dredged volumes were not available and estimated volumes are reported in WorleyParsons, 2009 and GHD, 2019. Pre- and post-dredging surveys were not available for this study, except for the 2020 campaign.

[2] *Some judgment would be required to assess when actual blockage could occur so as to allow adequate time to initiate dredging and avoid constraints such as peak recreational use of the waterway and ecological impacts, e.g. Little Tern breeding and nesting.*

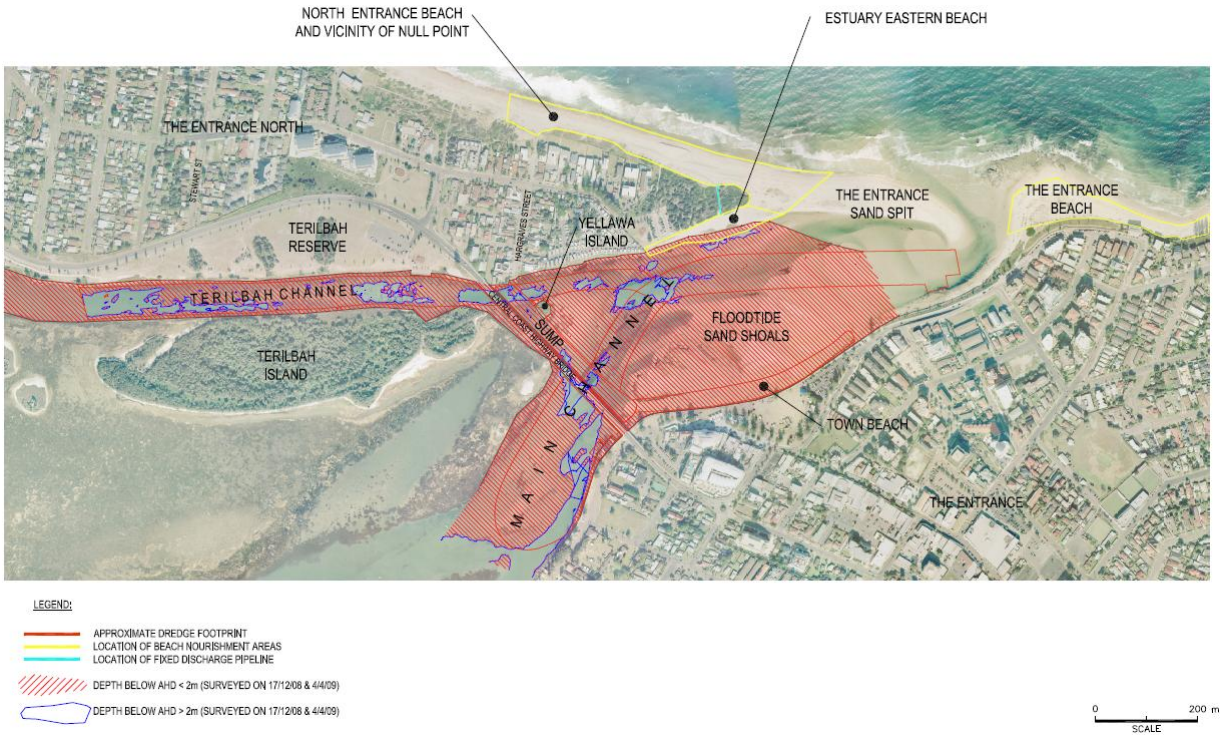


Figure 7: Dredge footprint 1993 – 2018 (WorleyParsons, 2009).

In 2018 Council was issued a stop work order by EPA due to allegations of dredge spoil causing pollution on North Entrance Beach. In this same year Council's dredge vessel reached the end of its functional life and was decommissioned. Council has on occasion dredged using external contractors, with the first campaign in 2020 (see Figure 8). This dredge campaign removed approximately 25,000m^3 of sand from the entrance channels. In 2020, sand was pumped to the foreshore at Karagi Park for dewatering and stockpiling, and then trucked to North Entrance Beach The recent dredging activity was undertaken in accordance with Royal HaskoningDHV's (2020) REF which allows for dredging upstream and downstream of the highway bridge, pumping and dewatering at a compound adjacent to Karagi carpark and then re-handling the sand for placement on North Entrance Beach. This is the current approved dredging workflow and any dredge campaigns in the near future are expected to be similar in scale and methodology.

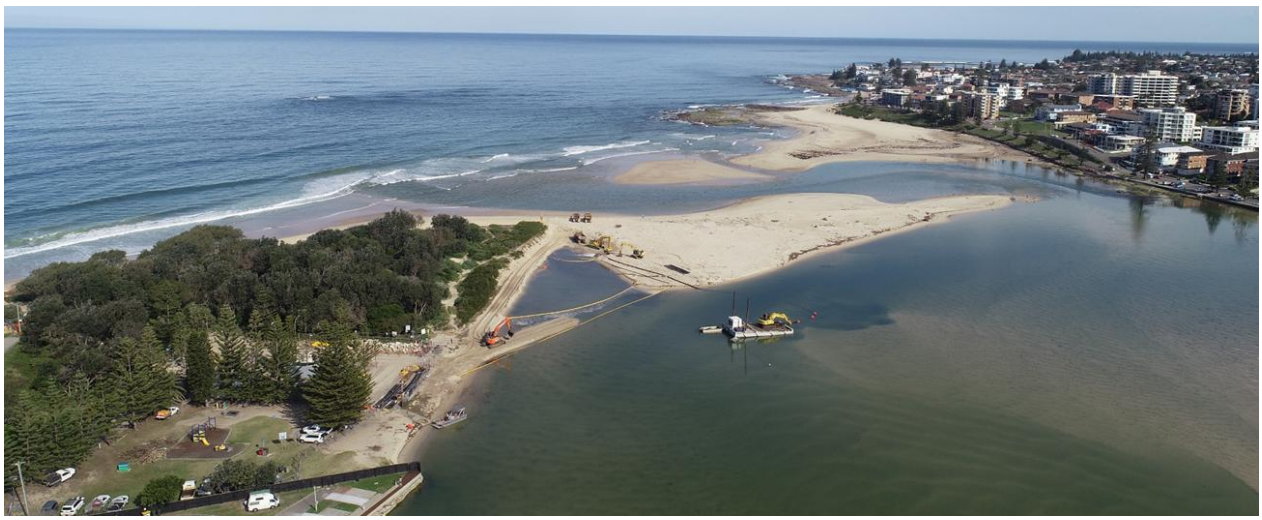


Figure 8: Photograph showing entrance dredging works in September 2020 (source: CCC).

2.2.3 Estuary management

Outside of the works and structure installed at the entrance channel, the wider Tuggerah Lakes estuary has also been subject to management. Typically, these management actions have been aimed at specific issues in the estuary (wrack, macroalgae and ooze as discussed further below), or, in more recent times, the overall water quality and ecological health of the estuary.

Modern management actions have been dominated by two works programs, the *Tuggerah Lakes Restoration Project* (1990) and works flowing from the Tuggerah Lakes Estuary Management Plan (2006). Prior to these projects, management actions were more ad-hoc in nature.

CSIRO (1998a and 1998b) documents some of the earlier management of the estuary, including removal of 'weed' (in this context seagrass or wrack are incorrectly referred to as 'weeds' which include eel weed *[Zostera Capricorni],* and stackweed *[Ruppia megacarpa]*) initially to improve fishing as the wrack impeded use of nets, but extensive wrack coverage in the estuary was also thought to affect recreational beach and waterway use of the estuary and, in turn, reduce tourism. Wrack was attempted to be managed using numerous methods from the 1940s onward, including through smothering with sand and working bees by residents. In the 1960s a draught horse with rake was hired and eventually in the late 1980s Wyong Shire Council designed and constructed tractor and rake/beach cleaning implements, as well as a dedicated Wrack and Algae Collector to skim dead wrack from the surface.

The *Tuggerah Lakes Restoration Project (1990)* expanded on these earlier reactive management measures in the estuary by undertaking a major works program. This involved the removal of wrack and 'ooze' (a black sludge formed likely due to high nutrient levels after macroalgal blooms) from key areas around the estuary (primarily the entrance, Long Jetty and Berkeley Vale) using large-scale dredging. The dredge spoil was then used to reclaim large segments of the estuary's shoreline up to 50m wide with clean sand also placed on the reclaimed foreshores to create sandy beaches (pers. comm. CCC). OEH's (2013a) review of this project found it had severe negative consequences for lake ecology and the marine environment. Short-term impacts included fish kills and the destruction of habitat. The practice also likely exacerbates macroalgal blooms by exposing dredge spoil in foreshore areas and allowing a regular leach of nutrients into the estuary. The project had minimal long-term benefits on 'restored' areas, with wrack and ooze returning to most areas within 18 months. Reclamation activities resulted in changes to the foreshore conditions including loss of salt marshes and creation of artificial slopes.

The Tuggerah Lakes Estuary Management Plan (2006) is the current certified Coastal Zone Management Plan for the estuary. The Estuary Management Plan is a holistic management plan that provided the framework to sustainably manage the estuary from a water quality, ecology and socio-economic perspective through integrated catchment management. It was developed in consultation with the local community and relevant stakeholders and was comprehensively implemented primarily with the support of Australian Government funding. Actions included to address the wrack and ooze issues at their source (rather than reactively), including streambank rehabilitation and erosion control, stormwater quality improvements, recreational upgrades, saltmarsh rehabilitation and wrack assimilation. A recent review (CCC, 2020) has found that 86% of the recommended actions from the plan have been completed or are ongoing, including, among many other actions:

- Saltmarsh restoration and rehabilitation - Passive rehabilitation of 29ha of saltmarsh has been undertaken while 2.5ha of saltmarsh has been actively reconstructed.
- Seagrass wrack collection - Wrack collection and management in areas where wrack accumulates is done to improve public amenity and improve estuarine health. Typically, over 8,000m^3 of wrack is removed per year.
- Over 277 gross pollutant traps (GPTs) and 37 constructed wetlands installed to improve stormwater quality. An average of 10 upgrades per year in recent years.

- 13km of urban and 40km rural stream rehabilitation, including bank erosion protection and urban creek naturalisation.
- 374ha of wetland conservation and rehabilitation.

Glamore et al. (2020) notes that the above measures are expected to have increased the resilience of the catchment and estuary to water quality impacts. This is evidenced by the water quality monitoring that has been undertaken which suggests a stable water quality condition of most of the estuary. The monitoring shows a measurable improvement in water quality at 69% of sites over a ten year period, 19% of sites are stable and 12% are declining (pers. comms. CCC).

Apart from the GPTs, the performance of individual measures was not able to be quantified as the water quality report card results provide a general report on how the estuary and catchment are responding (Glamore et al., 2020). In addition, variations in water quality are also affected by preceding rainfall, development growth and quality of catchment runoff (Swanson, 2018).

2.3 Summary of previous literature

2.3.1 Coastal, estuarine and flood studies

There have been many historical studies undertaken in relation to Tuggerah Lakes and its entrance over the last 50 years. This section presents a list of the key technical studies, design reports and management records, together with a summary of the key anthropogenic influences and major storms at Tuggerah Lakes estuary that this reporting will use as background and reference.

A non-exhaustive list of the key contemporary studies and events used to inform this study is presented in Table 2. In addition, the literature is referred to throughout our technical reports wherever relevant to do so.

Table 2: Summary of previous studies and plans for Tuggerah Lakes entrance.

Natural hazard event	Studies and plans	On-ground works
• 1974: A major ocean storm in May 1974, with major damage recorded along NSW coast. Tuggerah Lake records moderate flood level below 1.3m AHD. • 1990: Major flooding recorded in February 1990 of up to 1.6m AHD in Tuggerah Lakes.	• 1978: Public Works Department (PWD) publishes Tuggerah Lakes – The Future of the Waterway, reporting on a development plan for Tuggerah Lakes, looking towards long term maintenance and ecology improvement. The study notes the pressures development and increased recreational use is likely to put on the lakes, and the need for a long-term plan. • 1987: PWD undertakes study into use of jet pumps at Tuggerah Lakes Entrance to retain a permanently open entrance. The outcome was that jet pumps did not appear to be feasible at the site as a standalone option. • 1988: PWD (with Patterson Britton & Partners) undertakes study and concept design into entrance 'restraining' wall to train the channel by constructing a geotextile tube wall. This structure was not implemented. • 1992: Webb, McKeown & Associates undertakes modelling of sensitivity of flooding to the entrance's channel width. The results suggest the entrance width does affect lake levels during storm tides and catchment flooding. • 1994: Lawson & Treloar undertakes flood study for Wyong Council, which includes entrance breach modelling. Study produces design flood levels, with a 1% AEP flood level of 2.23m AHD in Tuggerah Lakes. Study notes the entrance condition is an important aspect controlling lake levels. • 1994: Patterson Britton & Partners undertakes Tuggerah Lakes Entrance Training Walls: Technical Discussion recommended to maintain an open entrance to avoid flooding, among other issues. Training walls were considered impractical due to the impacts on lake levels and possible increases to storm tide inundation. Intermittent large-scale dredging was recommended as the preferred option. • 1998: CSIRO produced two reports related to Tuggerah Lakes history, one of them related to 'what the newspapers said' and one of them a 'history of fishing in the Tuggerah Lakes and Surrounding Areas'. These reports detail history of Tuggerah Lakes through the 20th century, particularly in relation to fishing and seaweed growth. • 1999: Lawson & Treloar updated their 1994 flood modelling to evaluate entrance dredging impacts on the tidal conditions, in the case that a much wider and deeper channel was dredged. As expected, the tidal range was increased, and typical lake levels lowered in this process. Impact on flooding was not evaluated.	• 1990: Tuggerah Lakes Restoration Project starts. Significant estuary dredging and use of dredge spoil for land reclamation, particularly around The Entrance, Long Jetty and Berkley Vale. • 1993: Maintenance dredging begins as part of Tuggerah Lakes Restoration Project by Council.

Natural hazard event	Studies and plans	On-ground works
• 2007: Tuggerah Lakes experiencing significant flood event, with lake levels up to 1.65m AHD.	• 2005 & 2006: A Coastal Zone Management Plan was developed for Tuggerah Lakes and its catchment. The Tuggerah Lakes Estuary Management Study and Plan were undertaken by Bio-Analysis for Wyong Shire Council. The study evaluated Tuggerah Lakes from a holistic management perspective, taking into account water quality, vegetation and riparian zones, land use, biodiversity, socio-economics and general estuary health. The plan included a recommendation to maintain an exchange with the ocean (i.e., an open entrance) through continuation of the existing dredging program. • 2009: WorleyParsons undertakes a review of environmental factors (REF) related to maintenance dredging at Tuggerah Lakes Entrance. It found that there are minor and temporary impacts of the dredging and sand placement and suggested changes to mitigate these impacts. • 2011: SMEC undertakes the Longshore Sand Transport and Tidal Inlet Stability Study for The Entrance and The Entrance North for Wyong Shire Council. This study found the entrance to be unstable, requiring dredging to stay open. The study also devised a schematic of coastal processes north of the entrance to help inform sand placement activities. • 2011: A Coastal Zone Management Plan (CZMP) for the Wyong open coast was developed for Wyong Shire Council by Umwelt. This includes a recommendation to continue maintenance dredging at the entrance as an interim measure, with a condition that monitoring should occur to clarify response to storm events and dredging activity. The study also recommended not to construct training walls or permanently open the entrance due to enhanced wave penetration and increased lake water levels. • 2010 - 2013: Morphodynamic modelling of the entrance was undertaken by Cardno for NSW Office of Environment and Heritage (OEH) – [now DPE]. Several options were modelled in relation to managing the Entrance Beach and the entrance, including groynes for Entrance Beach and fully training the entrance. The study also found that training the entrance would not have a significant impact on flood levels, and would not self-scour, therefore would require continued maintenance dredging similar to that currently undertaken. This study also found a training wall less than 150m wide would also actually worsen flooding due to the constriction imposed. • 2010 – 2013: Several water quality related studies undertaken by OEH for Council, including ooze management, water quality monitoring and a wrack harvesting strategy. • 2014: A Floodplain Risk Management Plan was developed by WMA Water for Wyong Shire Council. This included updating the 1994 Lawson & Treloar modelling and evaluating a range of management options. A previously modelled option to dredge a 250m wide entrance channel was considered,	

Natural hazard event	Studies and plans	On-ground works
• 2020: Water levels in Tuggerah Lakes peaked at 1.67m AHD during flooding from an east coast low in February 2020. • 2021: Water levels peaked at 1.52m AHD in Tuggerah Lakes during a flooding event on 22 March 2021.	which was estimated to reduce the 1% AEP flood event by up to 0.31m when fully dredged. The present dredging regime (during the study period) was estimated to have a benefit in the order of 0.03m (i.e.,30mm) reduction in flood levels. And whilst these reductions in flood level are welcome, they were not recommended as preferred flood mitigation measures due to the economic constraints, environmental impacts and potential impact of ocean storm events. The study suggests there is very limited justification for the adopted dredging regime, and other measures are likely to provide a much better cost benefit ratio in reducing flood damages. The study recommended to formalise an entrance management strategy, with the prime objective to include consideration of emergency entrance opening for the management of flooding. • 2015: Cardno undertakes additional morphologic modelling for OEH. This additional modelling included removal of the rock shelf from the model, allowing for consideration of deeper dredging. Dredging below -2.5m AHD results in only minor effects in the lake system in terms of conveyance, salinity and flushing, as the shoals upstream of the dredging area still constricting tidal fluctuations. Deep dredging may also cause impacts with scour around the bridge foundations and shoreline change along Terilbah Reserve. The study also noted a reduction in mean lake level may have recreational and ecological impacts. • 2016: Wyong Shire Council and Gosford City Council amalgamate to form Central Coast Council. • 2018: Review of the Wyong Coastal Hazard Study undertaken by BMT for Central Coast Council (CCC), to re-assess coastal hazards. Minimal comment is made on The Entrance, apart to note that the Wyong coastline is relatively stable. • 2018: Impact assessment of Berkeley Vale Subcatchment Pollutant Loads by OEH. This report focuses on Berkeley Vale because of issues identified that include eutrophication and resulting macroalgal blooms, wrack accumulation and ooze build up in the nearshore zone. Factors contributing to eutrophication are identified and management recommendations provided based on assessed pollutant inputs and surveys of drains, nearshore water quality and groundwater influence. • 2019: The Entrance Channel Dredging Operations Feasibility Review was undertaken by Cardno for CCC. This study suggested that the benefits of the dredging program do not appear to be well-founded. The study recommends an interim entrance opening procedure should be developed for actioning during flood events. • 2020: NSW Minister for the Environment commissioned an independent expert panel to undertake a review of Tuggerah Lakes Water Quality. This study concludes that a permanent ocean entrance is not recommended for water quality purposes. Other catchment pressures, such as development, are	• 2017: NSW Department of Primary Industries constructs rock groyne south of The Entrance. It is approximately 100m long and intended to retain sand on Entrance Beach for amenity purposes. • 2018: Council is issued stop work order by EPA due to allegations of dredge spoil causing pollution on North Entrance Beach. • 2018: Council's dredge vessel reaches the end of its functional life and is decommissioned. Council continues to dredge using external contractors.

Natural hazard event	Studies and plans	On-ground works
	determined to be the drivers behind water quality issues in the lakes and notes the improvement in water quality over the years. • 2021: CCC commissioned Coastal Zone Management and Planning to undertake a Review of Central Coast Council's Lagoon and Entrance Management, Policies and Practices. This review recommended an Entrance Management Policy be developed and placed on public exhibition for community input before being finalised. • 2021: CCC completes Stage 1 of its Tuggerah Lakes Estuary CMP. This recommends investigation into coastal and socio-economic processes in the lake and engaging with the community throughout the development of the CMP to facilitate a shared vision of the lakes to be established and ensure community buy-in and ownership of both the CMP process and final certified CMP. The later stages of the CMP and associated reporting are ongoing, including the subject of this study. • 2021: Transport for NSW commissions Salients to undertake The Entrance Rock Groyne Impact Assessment Study. The study found limited spatial impacts of the groyne and that the groyne was performing as intended, to retain sand on The Entrance Beach. Further updates to this assessment and report have been undertaken as report addenda in 2022 and 2024 which highlight impacts to downdrift areas due to the groyne (refer Section 4.4)	• 2020: Council undertakes first dredging program since decommissioning its dredge vessel, using external contractor. Approximately 25,000m^3 of sand is removed.
Further events have occurred since the time of writing (2022) which are not listed herein.	• 2020 – 2022: CCC engaged Manly Hydraulics Laboratory to complete the Tuggerah Lakes Entrance Management Study. This involved a review of previous literature, modelling and analysis to develop an evidence based Interim Management Procedure to reduce the risk to life, public and private infrastructure and public health from flooding which is currently in use by Council.	

2.3.2 Previous socio-economic studies

Two key socio-economic studies previously undertaken for Tuggerah Lakes have been reviewed as part of this study, these include:

- **2021:** Community and stakeholder engagement to inform the CMP Scoping Study (Stage 1) was undertaken by Central Coast Council (see the summary included in Section 2.3.3 below).
- **2021:** The Entrance Place Plan is a guiding document that helps Council and the Community work together to re-imagine and kick start The Entrance for the better. This information is used to create a series of projects that can be delivered by Council and the Community - independently and in collaboration (see the summary included in Section 2.3.3 below).

2.3.3 Summary of previous community and stakeholder engagement

Extensive engagement with the local community and stakeholders has been previously undertaken to inform the entrance management practices at Tuggerah Lakes. A summary of the key engagement reports and a short overview of the engagement methods is below.

2006: Tuggerah Lakes Estuary Management Plan

Wyong Shire Council (now Central Coast Council), in partnership with the Department of Natural Resources (now DCCEEW), developed an Estuary Management Plan for the Tuggerah Lakes (including the Estuary Processes Study).

Consultation methods utilised during the preparation of the Estuary Management Plan included:

- Open days at Lakehaven, Westfield Tuggerah and Bay Village shopping centres.
- Poster displays at Council chambers and local libraries.
- Advertorials on key lakes issues in local newspapers.
- Community input called for in newspapers, on display posters and through media interviews on local radio.
- Guiding local media on a tour of the estuary to discuss issues.
- Workshops with technical, community and business focus groups.
- Ongoing liaison with the Tuggerah Lakes estuary, Coastline and Floodplain Management Committee
- Engaging local school children to assist with developing a logo for the lakes.
- Public Exhibition of the draft Estuary Management Plan.
- Field Day Sessions held at three locations around the estuary.
- Town hall style public information sessions.

2021: Tuggerah Lakes Estuary Coastal Management Program Scoping Study (Stage 1)

An engagement strategy was prepared by Twyfords (2021) to support the Tuggerah Lakes Estuary Coastal Management Program. The strategy includes suggested key messages, stakeholder mapping analysis and proposed engagement methods to use throughout the development of the CMP.

The first phase of community consultation and engagement outcomes included:

- Key interest focus groups – three focus groups hosted with over 20 participants.
- A dedicated project webpage – 3,198 visits to the Your Voice Our Coast project page.

- An online waterways survey – 1,168 survey responses received.
- Community pop-up information stalls – over 400 community members reached.

The online survey delivered the following results:

- 94.5% of participants agree that waterways are a significant reason they live on the Central Coast
- 98% of participants agree that waterways contribute to their personal health and wellbeing (e.g. fitness, relaxation, happiness, lifestyle, sense of place, cultural heritage)
- 88.7% of respondents agree that if waterway access, safety or condition declined significantly they would reduce the frequency they visit and use waterways.
- 65.6% of respondents agree that if waterway access, safety or condition declined significantly they would consider moving away from the Central Coast to another location
- 96.5% of respondents agree that more should be done to protect and enhance the natural aspects of waterways such as the cleanliness of water, health of coastal vegetation, and the protection of wildlife
- 69.2% of respondents would support more resources being used for the management of our waterways and coast, even if it meant a very small increase in their property rates or rent a further 13.6% neither agreed or disagreed.

When asked what participants value about our waterways, the top three topics covered in these comments were:

- Recreational opportunities and access to waterways 28.1%
- Beauty and aesthetic 15.8%
- Environment and natural amenity 11.2%

When asked what the top three focus areas for Coastal Management Programs should be, respondents advised:

- Reducing pollutant loads (sediment, nutrients and microbes) entering waterways 16.6%
- Improving and maintain water quality 15%
- Restoring and maintaining key habitats 12.5%

2021: The Entrance Place Plan

Engagement for the Place Plan was undertake using three (3) methods:

Method 1: Historical Engagement drawing together the studies, reports, data, plans produced for the Central Coast and The Entrance for the past ten years.

Method 2: One on one meetings and workshops- Individual or small group meetings were held during the engagement process.

Method 3: Online Engagement - This included an Ideas Wall which encouraged the community to put forward their ideas and start discussions about other people's ideas. The project was further promoted on social media and in window displays.

Key messages were called out during the engagement process. These ideas, concerns and opportunities were integrated into the Place Plan. The key messages from the community are summarised in **Figure 7**.

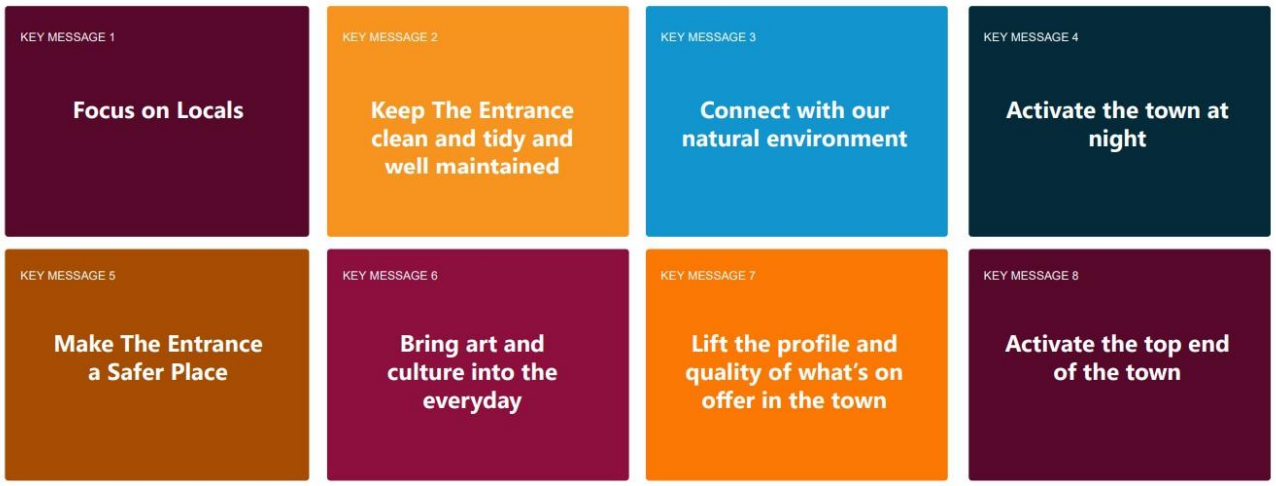


Figure 7: Key Messages identified during the Place Plan (2021) engagement process.

2.4 Data used in this study

This study follows a data-driven or evidence-based approach using data kindly made available for use. A summary of these extensive datasets is presented in Figure 9, with associated monitoring sites (where applicable) displayed in Table 3.

Table 3: Overview of existing observational data used in this study.

ID	Description	Source	Dates
Estuary survey	Digitised historical chart	PWD	1975
Coastal and entrance surveys	Beach profile data (Photogrammetry)	DPIE	1941 - 2020
	Historical charts	PWD	1989
	Depth contours	PWD	1970
	Multibeam bathymetry survey	OEH	2008
	Drone survey (The Entrance)	WRL	2015, 2016
	The Entrance channel survey	CCC	2015, 2018, 2019, 2020, 2021, 2022, 2023, 2024
	Central Coast coastline LIDAR survey	WRL	2018, 2019, 2020
	Coastal lidar data at 5-meter resolution	OEH	2018

ID	Description	Source	Dates
Aerial imagery	High resolution, rectified aerial imagery	Nearmap	2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2021
	Historical aerial imagery	NSW Government	From 1941
Waves	Measured wave heights, directions and periods at Sydney WRB at a 1-hour sampling period	MHL	• Mar 1992 – May 2022
Water Levels	Water levels from: • Long Jetty • Toukley • Tumbi Umbi • Wallarah Creek Bridge	MHL	• Sep 1991 – Oct 2024 • Feb 1985 – May 2022 • Apr 1994 – May 2022 • May 1994 – May 2022
	Streamflow volumes from: • Wyong River at Wyong Fishway • Wyong River at Yarramalong	BoM	• Sep 2011 – Dec 2024 • Nov 1976 – Dec 2024
	Tide data at: • Patonga	MHL	• Jun 1992 – May 2022
	Rainfall data at: • Ourimbah (Dog Trap Rd)	BoM	• Aug 1953 – Dec 2024
Winds	Wind data at: • Norah Head AWS	BOM	• Jun 2013 – Apr 2022
Water Quality	Monthly water quality sampling at: • Tuggerah Lake (north, south and central) • Budgewoi Lake • Lake Munmorah	Central Coast Council	• Dec 2011 – Jun 2020

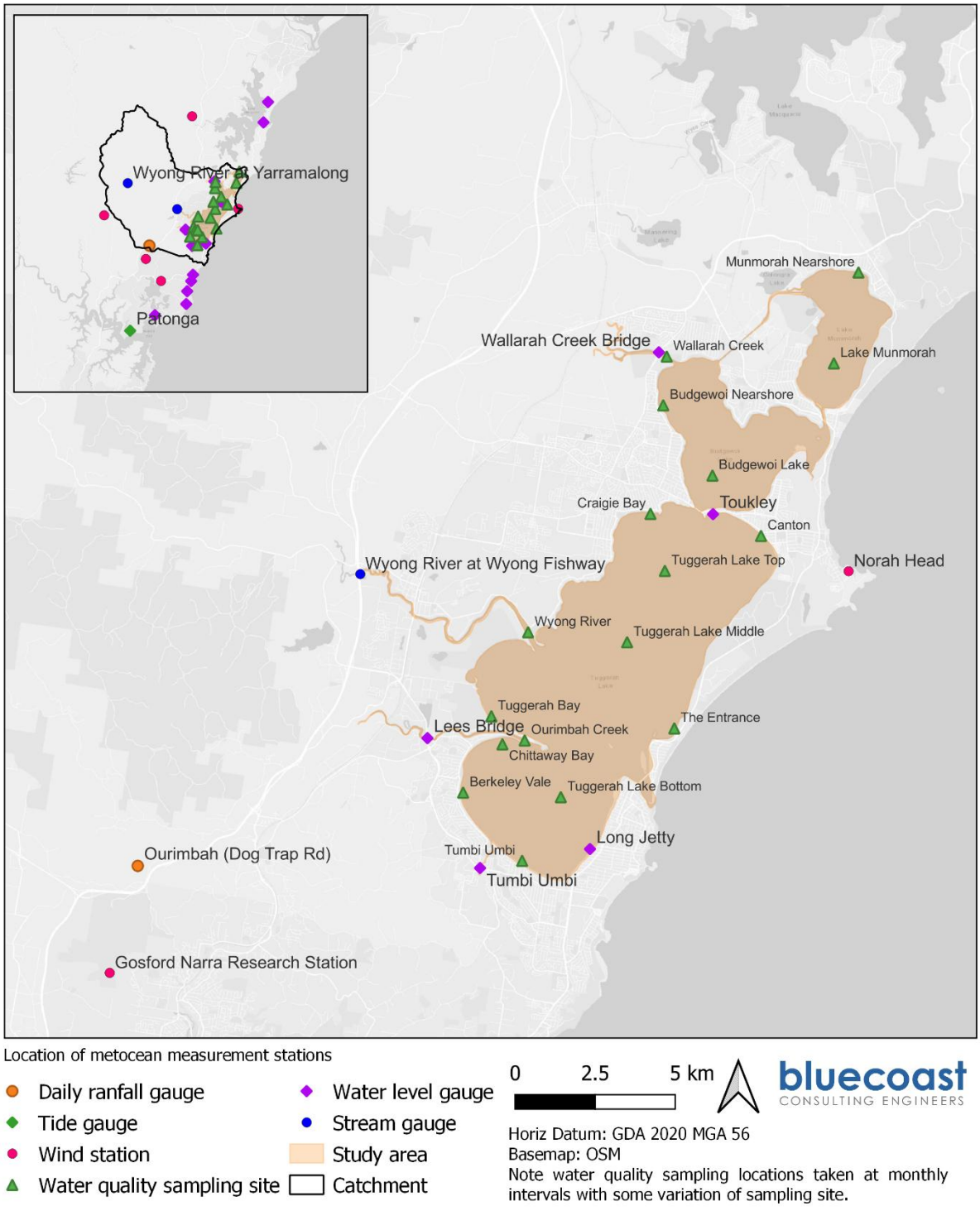


Figure 9: Location of metocean measurement stations available for this study.

2.5 Existing environment

2.5.1 Tuggerah Lakes physical characteristics

Tuggerah Lakes estuary has a total surface area of approximately 81km^2 (OEH, 2013a) and average depth of approximately 2.4m (Roper et al., 2011). Lake Munmorah is the deepest of the lakes, up to 3.5m depth, whilst Tuggerah Lake is typically up to 3m depth and Lake Budgewoi reaches 2.5m depth (Erskine, 2013). The lakes are shallower at the main creek deltas, at the entrance channel and at the north-western end of Lake Budgewoi, known as the Budgewoi Sand Mass. Bathymetric maps have been produced by the Public Works Department as part of the 1978 *Tuggerah Lakes Study Report* and by Erskine (2013). The two maps show minimal differences in bed levels. The 1975 survey data was available for this study and is shown in Figure 10.

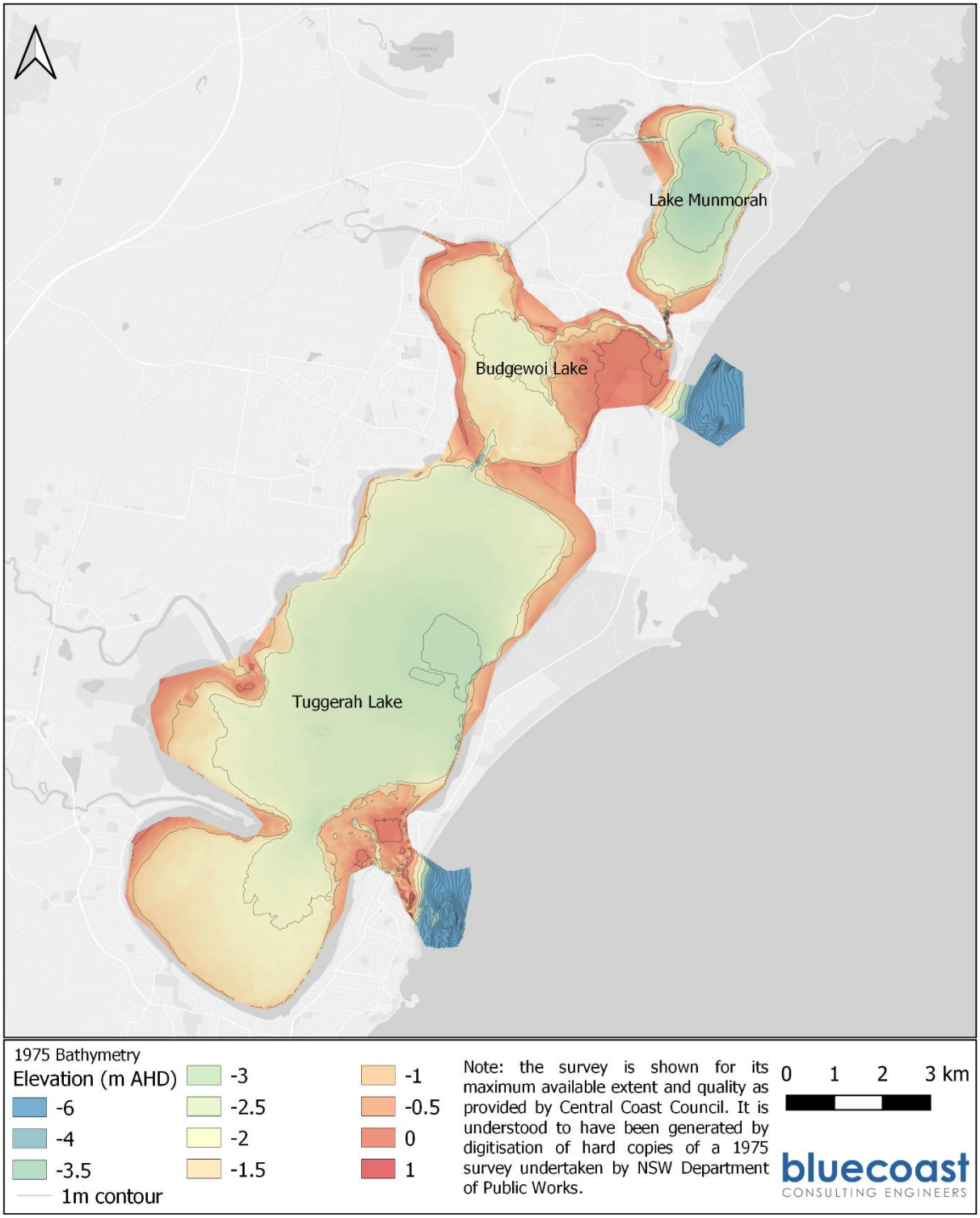


Figure 10: 1975 bathymetry of Tuggerah Lakes estuary.

2.5.2 Geology and geomorphology

The general geomorphology of the formation of Tuggerah Lakes is typical of wave dominated barrier estuaries observed along the NSW coast. These types of estuaries are formed in response to changes in sea level, particularly over the last 20,000 years. During periods of low sea levels the estuary discharge point was many kilometres offshore of its current location. Periods of high sea levels then reworked marine sediment up to form the coastal barrier system present in the modern day estuary. At Tuggerah Lakes, this barrier is controlled by headlands at Norah Head and the rocky outcrop immediately south of the entrance as far south as Shelly Beach. After this period of high sea levels and formation of the barriers, water levels then receded and allowed for realisation of the barrier estuary in its current general form. Tuggerah Lakes estuary is considered a young barrier estuary as it has not had time to stabilise with infilling sediment, and is slowly filling from incoming sediment from upstream, however at current rates it will take over 1,000 years before the lakes are infilled. Such barrier estuaries that are prone to closing have been defined as intermittently closed or open lakes or lagoons (ICOLL) (as per classification in Dalrymple et al., 1992 and Boyd et al., 1992). The water level variations and other processes within these systems are dependent on whether the barrier is open to the ocean.

The study area is defined by an embayed bedrock coast, controlled by prominent headlands at Norah Head in the north and a rock outcrop immediately south of the Entrance. Between the headlands, a sandy embayment infilled with barrier (dune and beach), estuarine and fluvial deposits comprise The Entrance Beach, North Entrance Beach and Tuggerah Beach.

Most of the study area is underlain by sub-horizontal to westward dipping sedimentary rocks of the Triassic (252 to 201 million years old) Narrabeen Group. The other key bedrock groups in the study area are listed below:

- Triassic Tuggerah Formation Sandstone: Grey to green-grey laminite, to red-brown claystone and siltstone, (in turn interbedded with) fine- to medium-grained green-grey sandstone (Narrabeen Group). This layer is exposed at Norah Head and the rock platforms at The Entrance that control the embayment. Karagi Point rock outcrop is of this formation.
- Triassic Patonga Claystone; red-brown and grey-green claystone and siltstone, grey siltstone and laminate and fine lithic sandstone (Narrabeen Group). This layer typically underlies the Tuggerah Formation Sandstone.
- Triassic Munmorah conglomerate. Comprises pebbly sandstones, fine to medium grained sandstones and some siltstones. The Munmorah Conglomerate is a largely lithic to quartz-lithic, medium to very coarse-grained sandstone and granule to pebble conglomerate. The conglomerate is usually consistently fresh and medium strong, to strong (Shirley Consulting Engineers, 2010).
- The Karagi Point Sandstone shelf is an important feature in the context of the entrance channel, and has previously been surveyed to ascertain its approximate depth. Surveys were undertaken by Council in 2020, surveying the exposed rock shelf at approximately 0.3 – 1.0m AHD in the typical entrance channel location. This is in agreeance with information presented in PWD (1988, data from Council/PWD investigation), which also shows the exposed rock shelf near the entrance channel above 0m AHD. This report also shows a relatively steeply graded underlying rock shelf to the north, with the rock shelf mapped as low as -7m AHD below some parts of Karagi Point.

Figure 11: Rock shelf survey undertaken by CCC in 2020 (Glamore et al., 2021).

2.5.3 Sediments

Sediments of the Tuggerah Lakes estuary basins are dominated by deposits of sandy silts, muds and clays. However, functional zones show a variety of sediments. The tidal delta entrance channel is dominated by marine sands. This is also true of the Budgewoi Sand Mass which is likely a historic flood tide delta which has been inactive for over 1,000 years (Bio-analysis, 2006). Other areas within the lakes, especially the river deltas and nearshore zones, exhibit a wide variety of sediment classifications, as shown below in Figure 12.

Erskine (2013) undertook sampling and mapping of the sediment of Tuggerah Lakes estuary, as shown in Figure 13. This sediment maps suggests impacts of human intervention, with mapped areas of dredge spoil in Chittaway Bay. Glamore et al. (2020) suggests that the spatial variation of sediment along the shoreline is largely driven by wind wave energy, with resuspension of fine particles in the more exposed nearshore areas such as Gorokan and Canton Beach meaning these areas are dominated by coarser

sediments. Whereas the more protected areas are dominated by finer muds and silts, which settle in these low energy environments.

Related to the protected shorelines and deposition of fine muds and silts, is the notable occurrence of formation of black 'ooze' in Tuggerah Lakes. OEH (2013b) discusses the conditions surrounding the ooze formation. The ooze forms when fine sediments also have high concentrations of nutrients and organic matter, especially macroalgae detritus. This was the case in the 1980s when ooze formation had reached a critical point in the estuary, and the estuary was thought to be in a eutrophic state. Ooze formation remains an issue throughout parts of the estuary. However, catchment and sewerage improvements works undertaken to reduce nutrient levels in the estuary is allowing for a general reduction of nutrients to a medium nutrient status (Bio-analysis, 2006) and thus also reduced the rate of ooze formation.

At the entrance compartment including Dunleith Spit, sediments are incoming from the adjacent beaches. These are generally thought to be unconsolidated sediments of the quaternary period (within the last 2.6 million years). The sands were typically deposited by beach ridge progradation during the last inter-glacial period (Shirley Consulting Engineers, 2010).

Of note is the flood tide delta (labelled in Figure 12 as 'Holocene Tidal Delta'), of which sediments extend upstream of The Entrance bridge to the south and north. Glamore et al. (2020) suggests this sediment was carried by tidal action, however, also notes the sediment appears to be currently inactive upstream of The Entrance bridge under typical conditions, with seagrasses able to grow. Umwelt (2011) notes that aerial imagery shows a more active delta prior to the late 1970s, including active sand shoals to the north and south upstream of the bridge. It is suggested this may be due to deeper dredged channels from this time period inhibiting sand movement in the outer flood tide delta.

Sediment sampling in the flood tide delta was undertaken by WorleyParsons (2009) and Royal Haskoning (2020) and the distribution of the identified sediment types and qualitative characterisation is provided in Table and sampling location shown Figure 15. Analysis of the sediment data undertaken in WorleyParsons (2009), suggests dominance by fine to coarse sand (typically >90% sand), with some muds (typically <10%) and minimal gravel. Royal HaskoningDHV (2020) produced similar results for the samples, with very low fines contents and defined the sediment as 'fine to medium grained sands', with sediment distribution plots shown from this sampling in Figure 14.

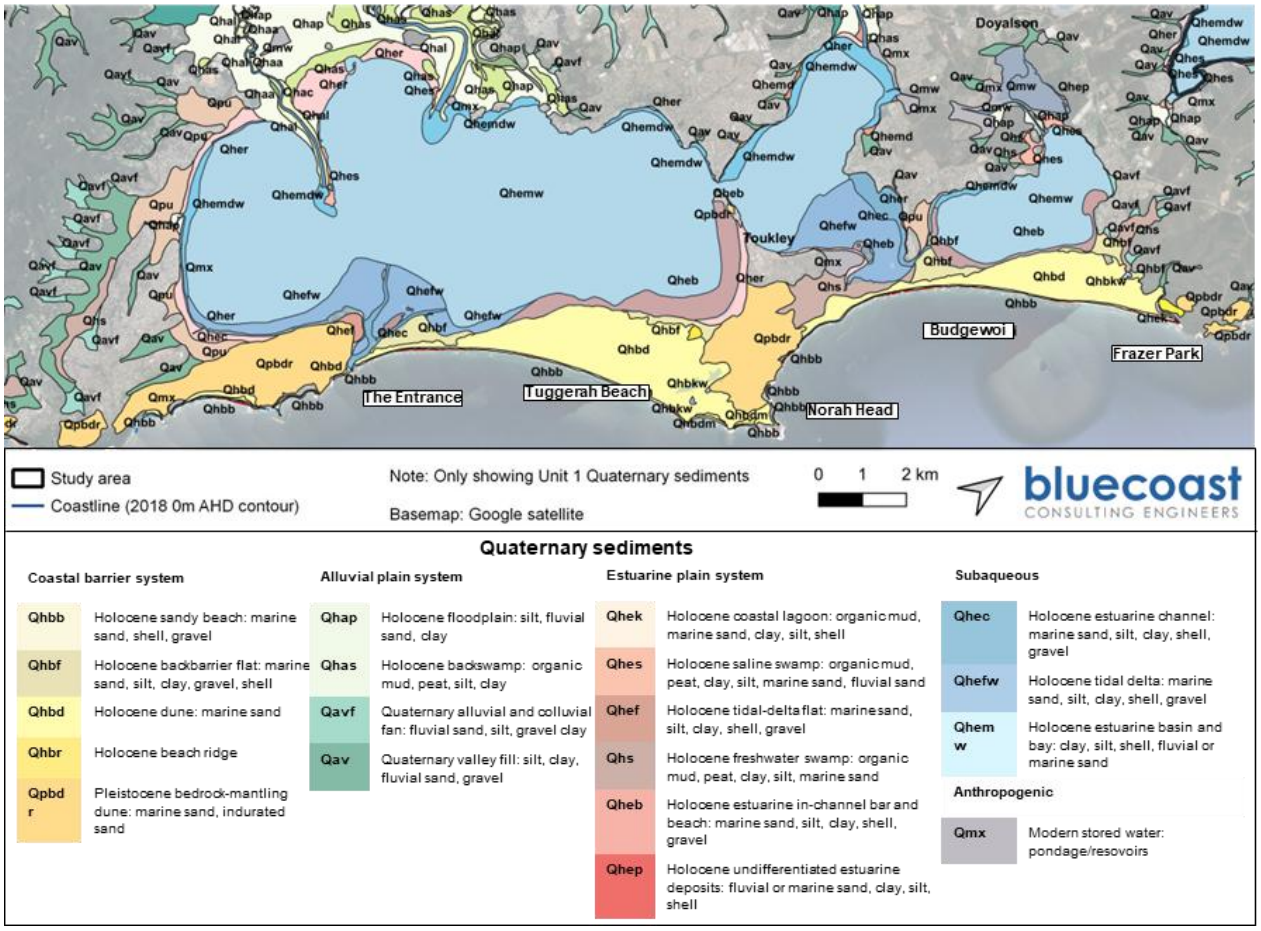


Figure 12: Quaternary sediments map for study area.

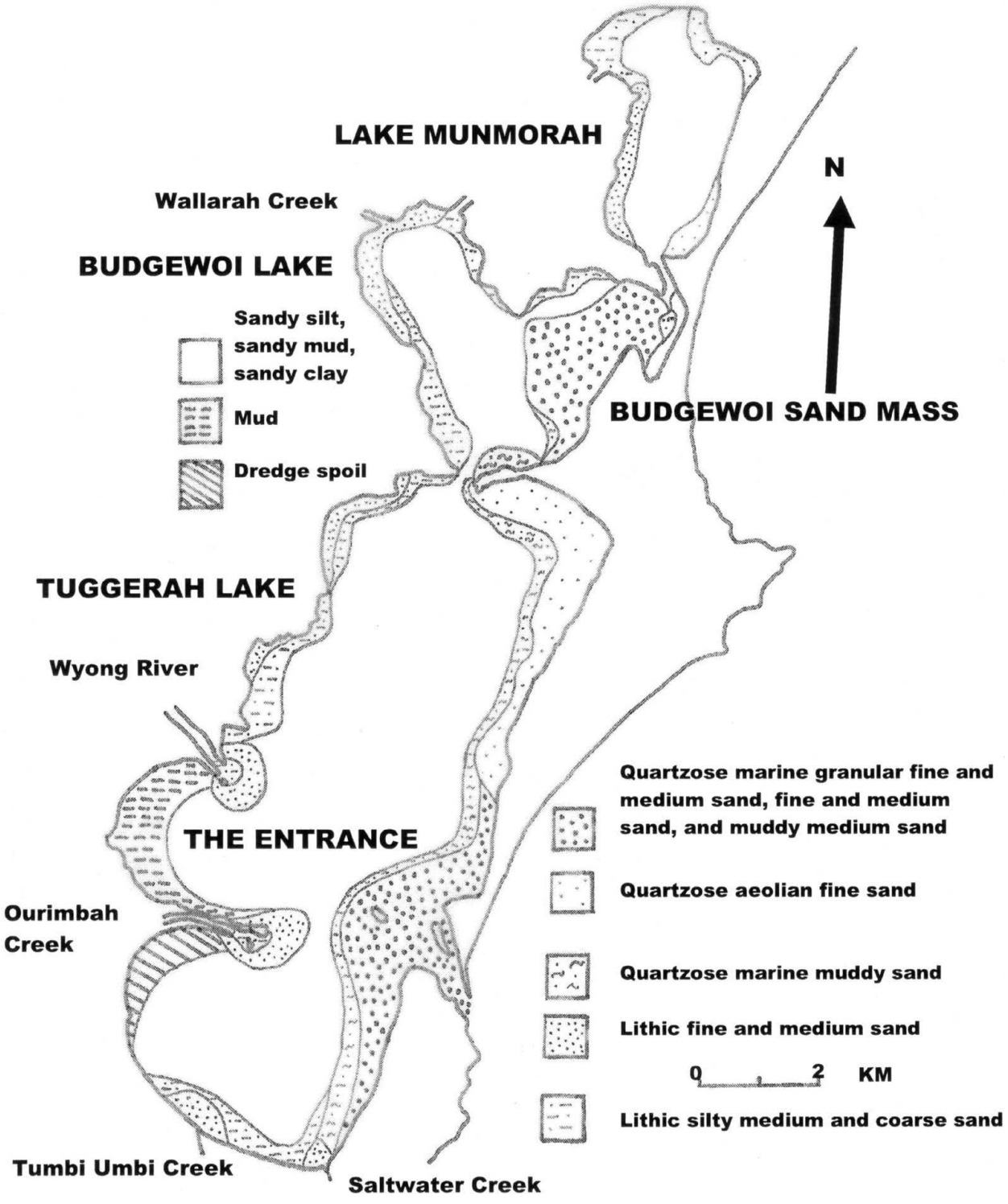


Figure 13: Tuggerah Lakes estuary sediment (source: Erskine, 2013).

Table 4: Sediment sampling summary (from WorleyParsons, 2009) [see site locations in Figure 15].

Sampling site (depth of sample)	Sediment distribution (%)			Description (from sediment distribution)
	Mud (<63µm)	Sand (>63µm and <2mm)	Gravel (>2mm)	
S1 (0.5-1.0m)	5	95	<1	Med to coarse sand
S2 (0-0.7m)	9	90	1	Fine to med sand
S3 (0-0.4m)	18	80	2	Fine to coarse sand and silt
S4 (0.4-0.9m)	5	95	<1	Med to coarse sand
S5 (0.4-0.9m)	2	97	1	Predominantly coarse sand
S5 (1.0-1.3m)	4	95	1	Med to coarse sand
S6 (0.1-0.6m)	4	94	2	Med to coarse sand
S7 (0.1-0.6m)	3	96	1	Med to coarse sand
S8 (0.8-1.3m)	10	89	1	Fine to med sand
S9 (0.1-0.6m)	8	91	1	Fine to med sand
S10 (0.8-1.3m)	6	87	7	Med to coarse sand

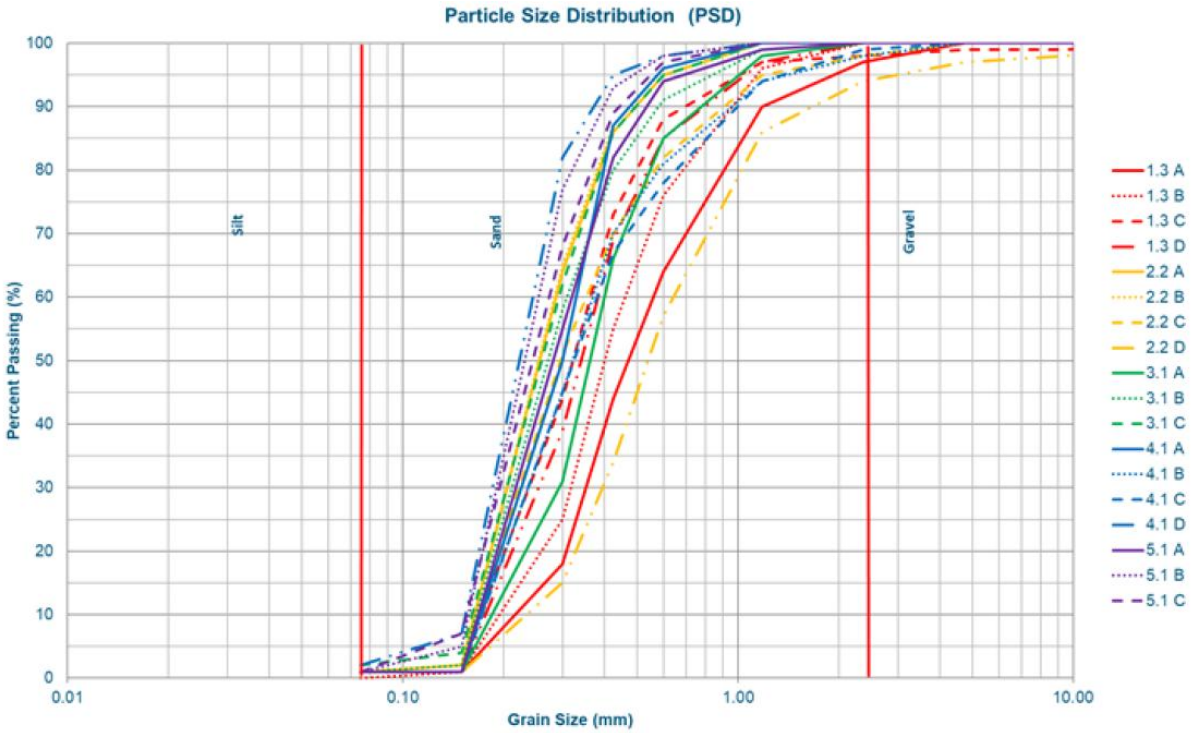


Figure 14: Sediment sample particle size distribution curves (from Royal HaskoningDHV, 2020).

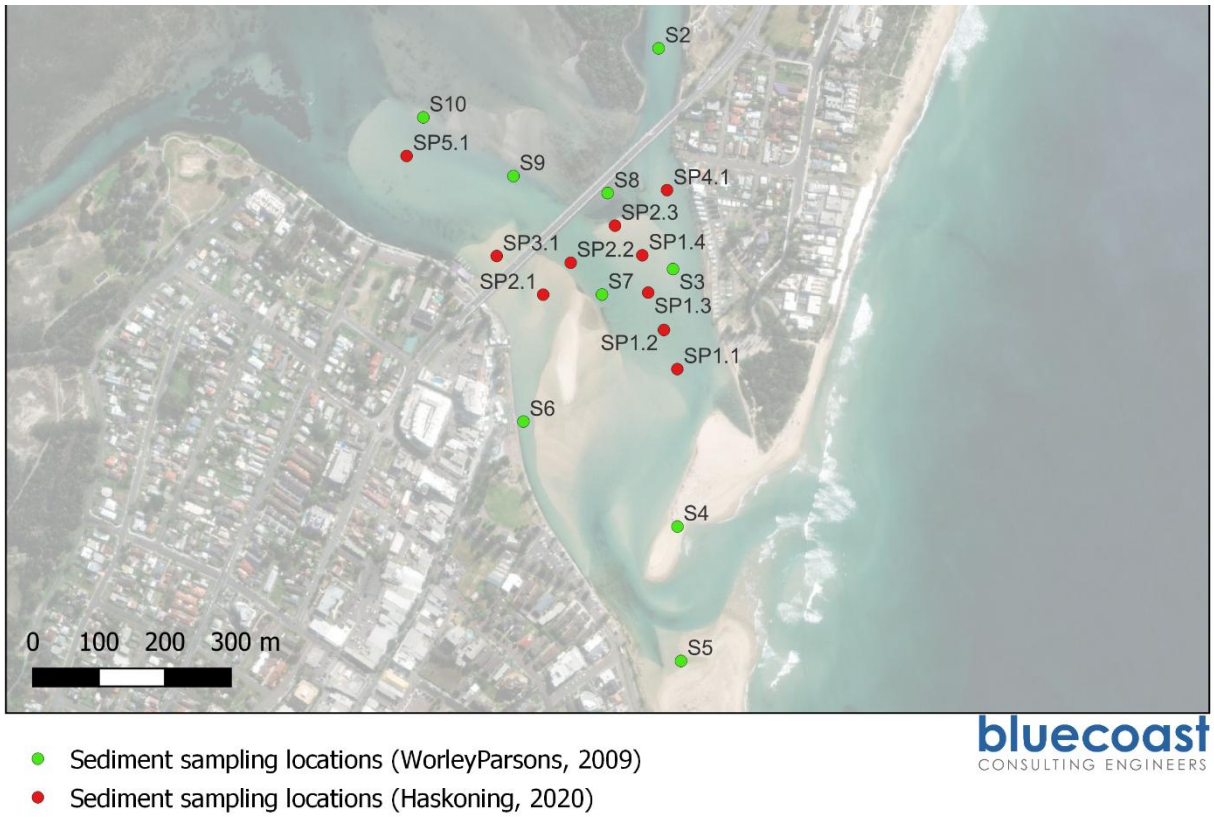


Figure 15: Sediment sampling locations.

2.5.4 Functional zones

To assist defining estuary characteristics and interrelationships, Glamore et al. (2020) identified six main physical zones in the Tuggerah Lakes estuary, as defined below:

1. **Open lake basins** - As noted above, the open lake basins are relatively shallow (up to 3.5m deep). These basins generally have fine-grained organic-rich sediments due to infilling sediment from creeks. The basins are slowly filling due to incoming catchment sediment.
2. **Soft-sediment nearshore zones** - The predominate lake nearshore zone (defined as from the shoreline to approximately 100 - 250m offshore) consists of shallow (<1.5m deep) sandy and silty sediments, subject to sorting and transport due to wind waves. This zone has also been subject to the formation of 'ooze' on the surface layer, due to excessive growth and subsequent decomposition of macroalgae.
3. **Rocky nearshore zones** - The lake nearshore zone also has some areas of foreshore with rocky shores and sub-tidal reefs. This zone is similar to the soft-sediment nearshore zone, however the hard shoreline impacts physical and ecological processes differently.
4. **Entrance compartment** - This marine delta zone is consists of Dunleith Point (entrance berm) and the entrance channel and shoals to west of The Entrance bridge. The eastern portion of this compartment is highly dynamic in terms of depth and channel location (if any) with marine sands susceptible to prevailing ocean and fluvial conditions, and mechanical intervention.
5. **Estuarine river channels** – This zone includes Wyong River, Ourimbah Creek, Tumbi Creek and Wallarah Creek. These waterways are consistently deep (>3m), with steep banks.

6. **Fringing wetlands** – These wetlands sit around the typical lake and creek extents and are irregularly inundated during high water levels so subject to wetting and drying phases. This zone has an important ecological function.

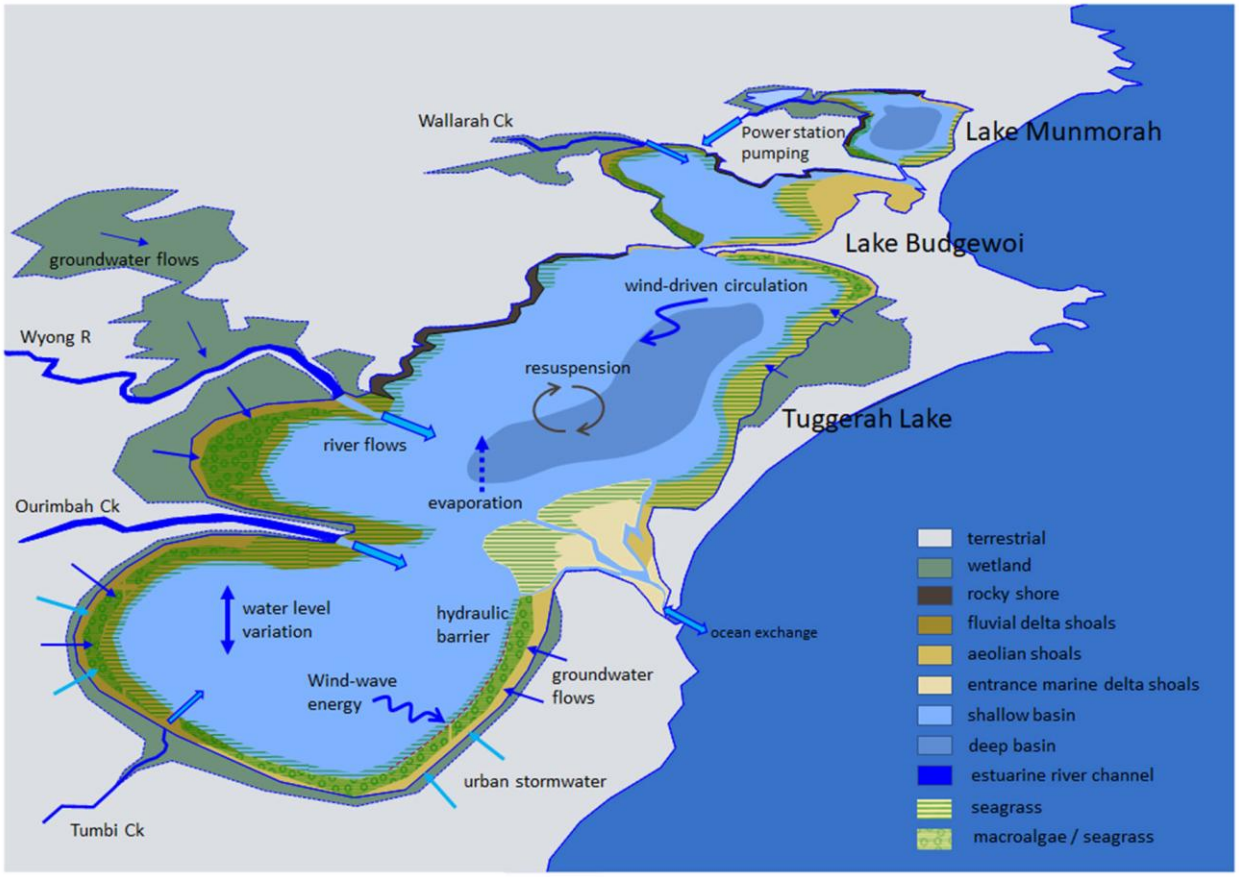


Figure 16: Lake functional zones (source: Glamore et al., 2020).

2.5.5 Tides and other oceanic water level variations

Due to the constricted entrance opening, water levels within the estuary are dominated by seasonal changes in flow from upstream creeks and rivers (rather than oceanic water level variations) as evidenced by the minimal tidal range within the estuary.

Most of the time estuary water levels sit higher than ocean water levels, at a long-term average of 0.26m AHD, due to the incoming stream inflows and streamflow friction effects within the entrance. This elevated water level and lack of tidal signal is shown below in Figure 17 and Figure 18, by comparing water level gauges on the ocean side of the entrance channel (at Patonga, MHL Station 212440) and the estuary side of the entrance channel (at Long Jetty, MHL Station 211418). Figure 17 compares the stations water level exceedance curves, while Figure 18 shows example datasets from each gauge from April 2020. The comparison also shows that for a significant portion of time ocean water levels exceed the typical estuary water levels (i.e., around 30% of time). This shows the effect of the constricted entrance conditions in maintaining a relatively ‘stable’ estuary water level during non-flood periods.

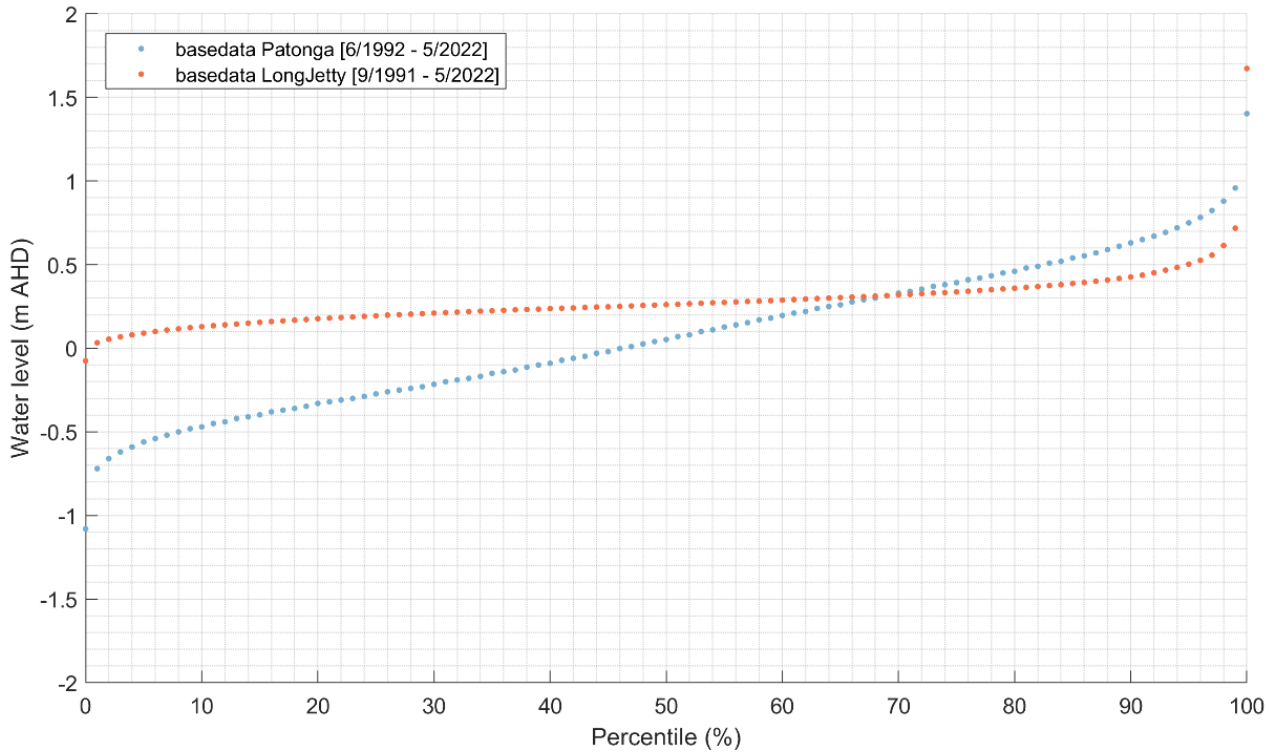


Figure 17: Water Level exceedance for ocean (Patonga) and estuary (Long Jetty) water level gauges.

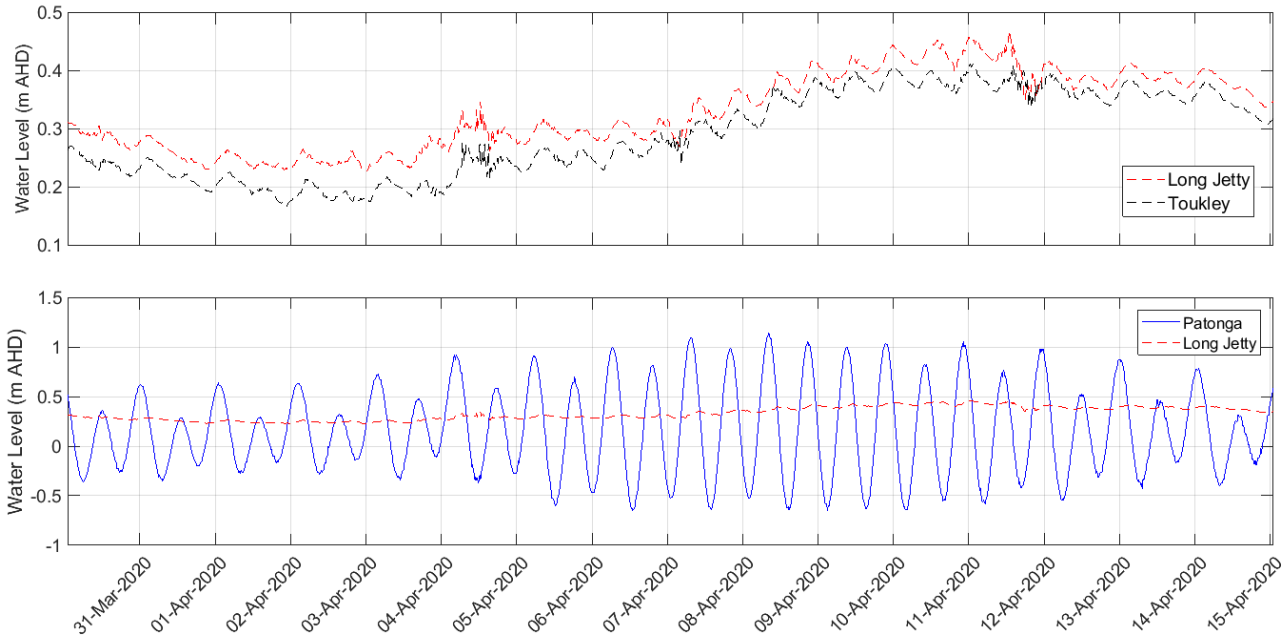


Figure 18: Top: Example water levels from April 2020 at Long Jetty. Bottom: Comparison of typical water levels at Long Jetty (estuary) and Patonga (ocean) from April 2020.

The spring tidal range at the ocean-side gauge at Patonga is 1.27m, typical of the micro-tidal environment along the NSW coast. This semi-diurnal tidal range experienced on the open coast is much attenuated within the Tuggerah Lakes estuary by the heavily shoaled entrance channel. The result is a maximum tidal range of 0.15m (MHL, 2022) and a very small typical spring tidal range of 0.005 - 0.025m recorded at Long Jetty. Figure 18 shows observed water levels during early April 2020, i.e., following the February

2020 flood event, at either end of Tuggerah Lake. It shows the observed tidal range at Toukley, at the northern-eastern side of Tuggerah Lake, is very similar to that observed at Long Jetty (i.e., closer to the entrance). Tidal range in Tuggerah Lake is at its maximum after flood events when the entrance channel is least shoaled, however the magnitude of tidal fluctuation within the estuary remains very small. This is also evident in Figure 19 which presents a yearly output of spring tidal ranges observed at Long Jetty from 1991 – 2022.

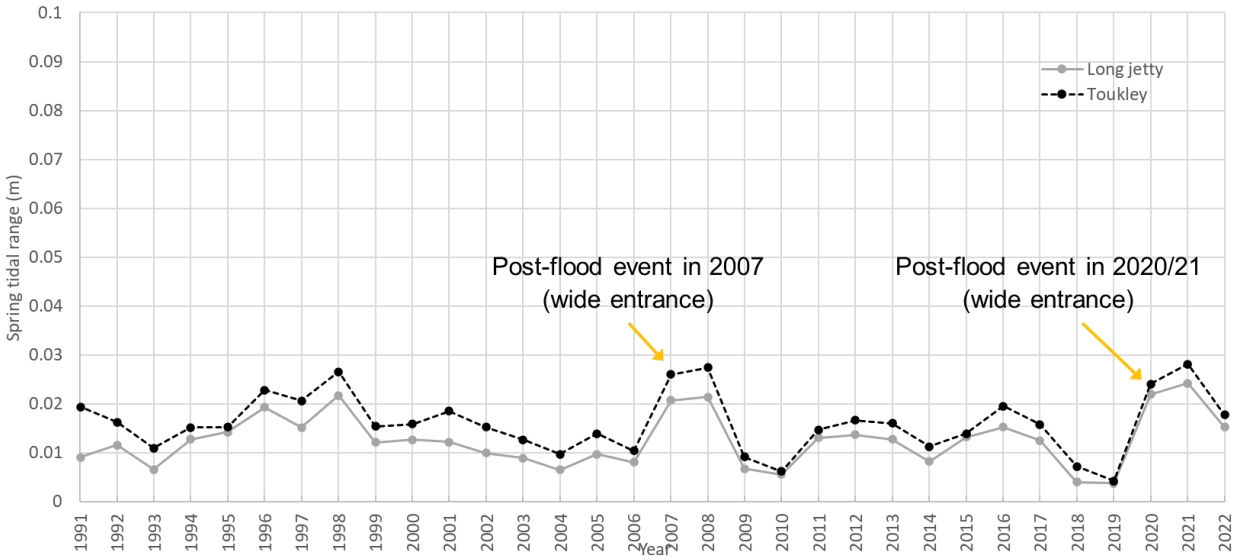


Figure 19: Yearly average spring tidal range at Long Jetty.

Along the NSW coast, ocean water levels[3] can also be influenced by other non-tidal variations such as:

- Storm surge - elevation water levels during storms typically including barometric effect and wind-driven surge.
- Coastal trapped waves - long period waves with periods of days to weeks, generated by strong wind events on the southern Australian coastline and Bass Strait.
- Tsunamis - shallow water progressive wave, potentially catastrophic, caused by underwater seismic activity.
- Ocean circulation - ocean currents can raise the water level for extended periods by transporting large quantities of water onshore (e.g., migration of eddy currents along a coastline).

As per tidal fluctuations, the constricted entrance attenuates the effects of these other ocean influences on water level. As such, extreme water levels within the estuary are dominated by catchment flooding, with those levels discussed further in Section 2.5.12 below.

2.5.6 Tidal flows

As noted above, the tidal range in the estuary is much attenuated by the entrance channel. This in turn minimises the influence of tidal currents within the estuary with high flows only occurring directly adjacent to the entrance channels Glamore et al. (2020). The ebb and flood tidal currents within the entrance

[3] The term 'ocean water levels' is used to refer to water levels offshore of wave breaking. Inshore of wave breaking additional non-astronomical processes can also influence water levels including wave setup and wave runup

continuously rework sand in this area. This tidal reworking has historically occurred from the entrance to approximate 500m upstream of The Entrance Bridge.

MHL (1993) undertook a gauging exercise of flood and ebb tides immediately upstream of The Entrance Bridge, using an Acoustic Doppler Current Profiler (ADCP), see Figure 20. The results of this study (shown in Figure 21) indicate that, on a typical tidal regime, a flood tide flow of up to 96m^3/s (split 75% Main Channel, 25% Terilbah Channel), and a peak ebb tide flow of 39m^3/s. This flood tide dominance suggests a much higher capacity for the entrance channel to naturally import sand rather than export sand. This ADCP measurement was undertaken prior to dredging of the channel. A second gauging was taken post Wyong Shire Council's first major dredging campaign in 1993, and in this case a flood tide peak flow of 166m^3/s was recorded, an increase of approximately 70%. The peak ebb tide flow also increased to 75m^3/s, a 90% increase. The total tidal prism for a similar tidal cycle also approximately doubled after dredging from 1.29x10^6 m^3 to 2.59x10^6 m^3. With the increased tidal flows following dredging, higher rates of channel infilling were observed upstream of the bridge (Channel 1 in Figure 20).

Multiple studies have shown that due to the size and shape of Tuggerah Lakes, oceanic flushing is limited to around 1% percent of the volume of the estuary during each tidal cycle during open entrance conditions (Sanderson, 2009; Glamore et al., 2020). Glamore et al. (2020) notes that oceanic water is only apparent in the entrance compartment flood tides, as wind-driven processes rapidly mix and disperse tidal flows entering the lake basin.

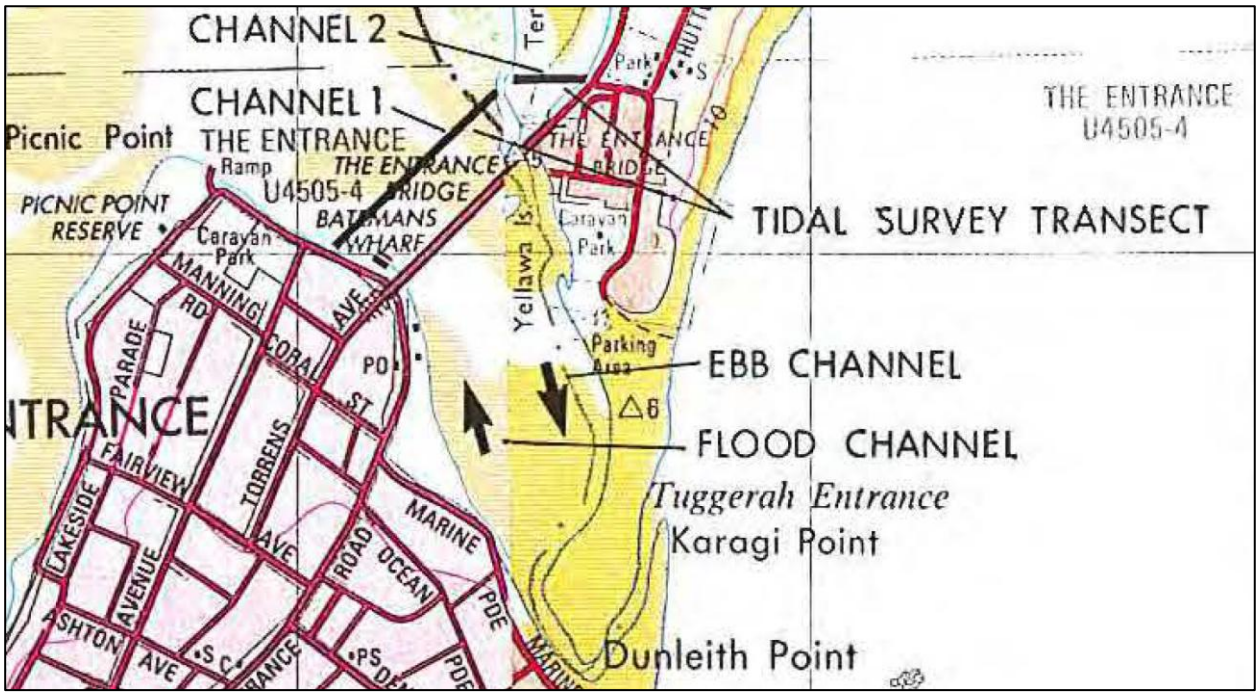


Figure 20: MHL, 2013 ADCP gauging transect. Channel 1 is the main channel and channel 2 is Terilbah channel.

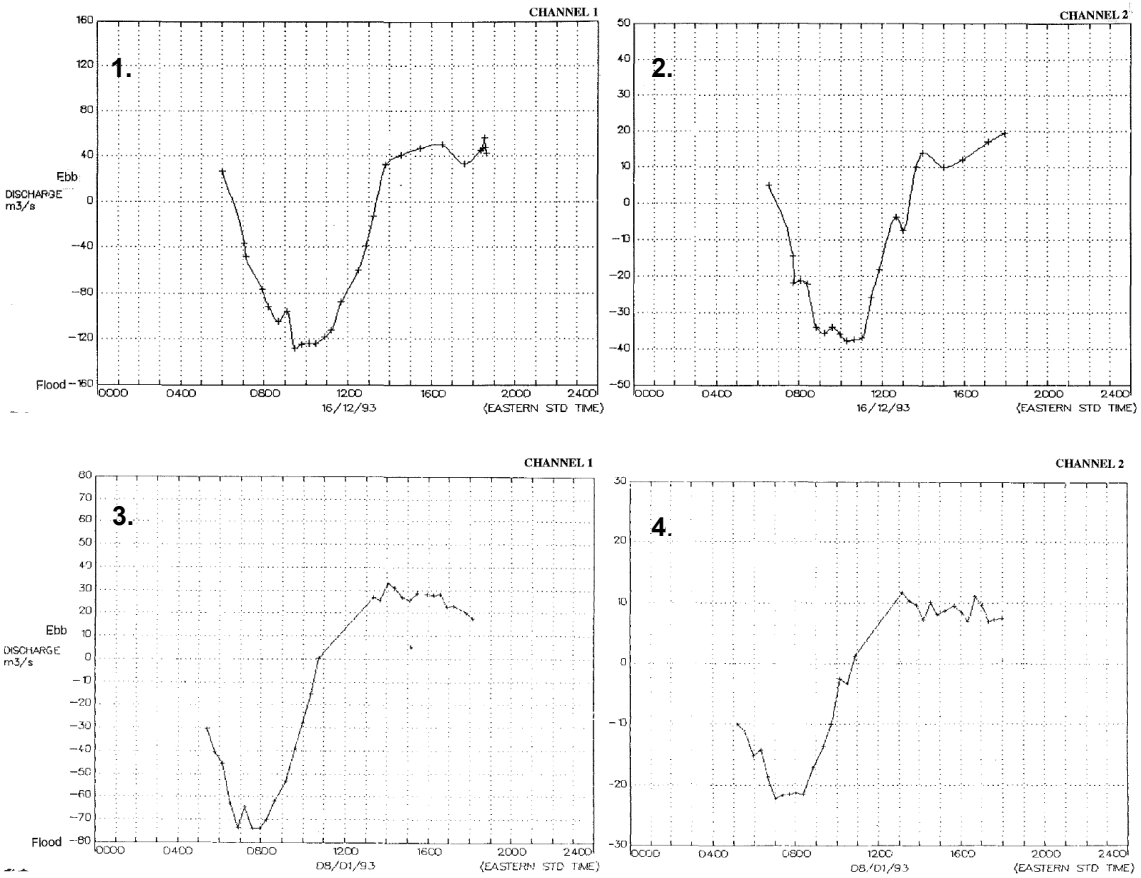


Figure 21: Tidal discharge plot from MHL, 1995 - 1) Main channel post-dredge discharge 2) Terilbah channel post-dredge discharge, 3) Main channel pre-dredge discharge, 4) Terilbah channel pre-dredge discharge.

2.5.7 Wind climate

An analysis of wind records from 1989 until 2022 at Norah Head weather station was carried out. Seasonal wind roses are provided in Figure 22. Wind statistics are presented in Table .

There is a predominance of winds from the northeast and south during summer and a prevalence of westerly winds during winter. Winds from the south typically continue through autumn. Spring shows more variation in directions with winds tending to be from the northeast, south and west sectors. Light winds are observed from the west, whereas stronger winds from the southerly and north-east sectors tend to exceed 6m/s.

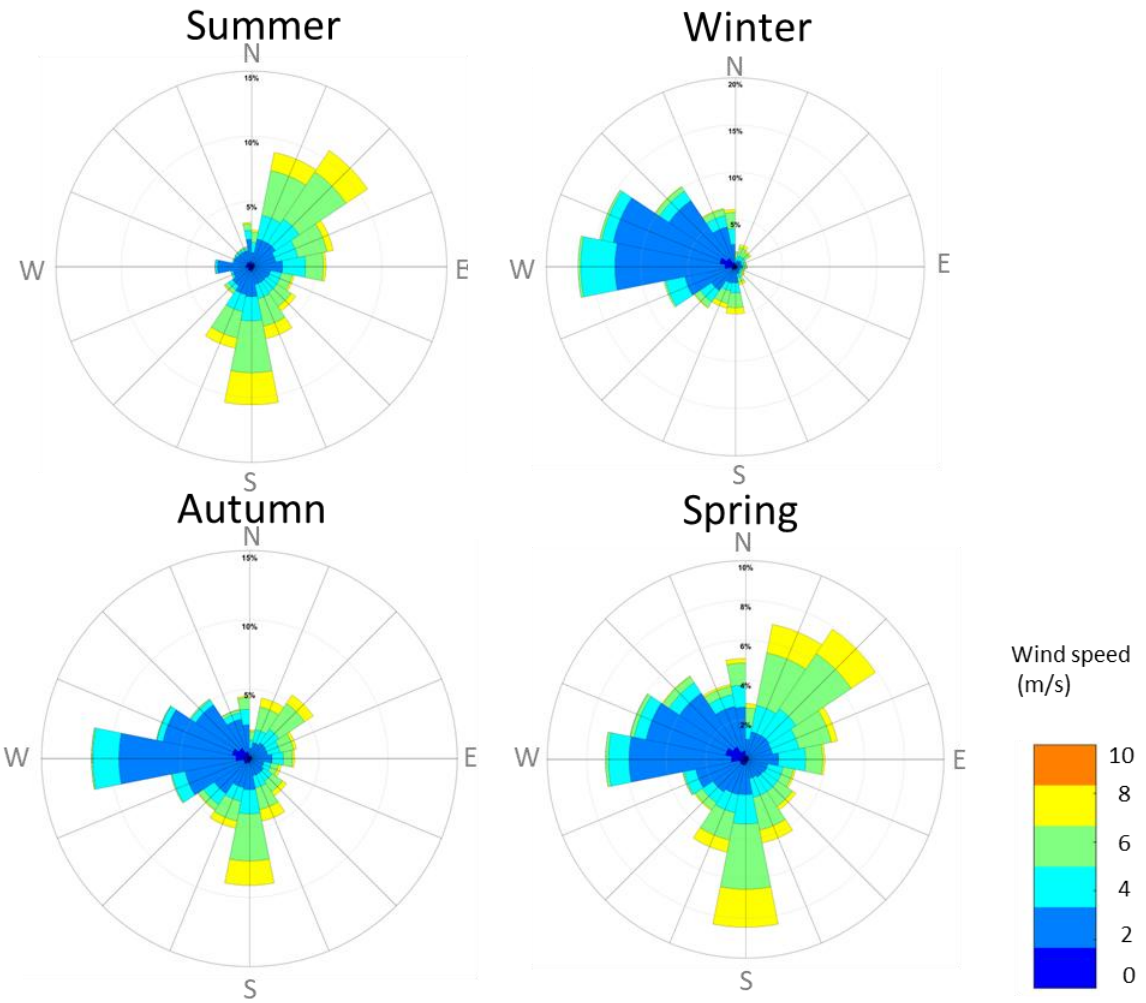


Figure 22: Wind roses from Norah Head station from 1989 to 2022.

Table 5: Wind measurement statistics for Norah Head station from 1989 to 2022.

Parameter	Statistic	Annual long-term average (33 -years)	Summer	Autumn	Winter	Spring
Wind speed [m/s]	Mean	5.2	6.0	5.1	4.3	5.6
	20%ile	2.6	3.1	2.6	2.6	2.6
	90%ile	9.8	10.3	9.8	7.7	10.3
	Max	27.8	22.1	27.8	24.2	24.2
Wind Direction [˚TN]	Mean	144	136	193	242	173

Wind and wind-wave mixing on the wide, shallow estuary plays a critical role in water quality, due to the mixing and re-suspension of fine sediment by the action of wind. Wind driven lake circulation also affects wrack generation and accumulation. Wind driven circulation patterns occur within the estuary, with the surface currents tending to flow in the direction of the wind. Wind also can affect water levels within the lakes, with setup and re-circulation patterns after a setup event enhancing mixing processes (Glamore et al, 2020). The wind-driven currents result in 'seiching', i.e., the setting up of a standing wave across the lake basin (see Figure 23) which causes a return current at depth in the opposite direction to the wind. The net effect of these processes is to mix the water column both vertically and laterally on considerably shorter timescales (hours to days) than the timescales of ocean water intrusion due to tides (weeks).

Such wind driven currents can be observed in aerial imagery as shown in an example photograph captured on 9 November 2011 in Figure 24.

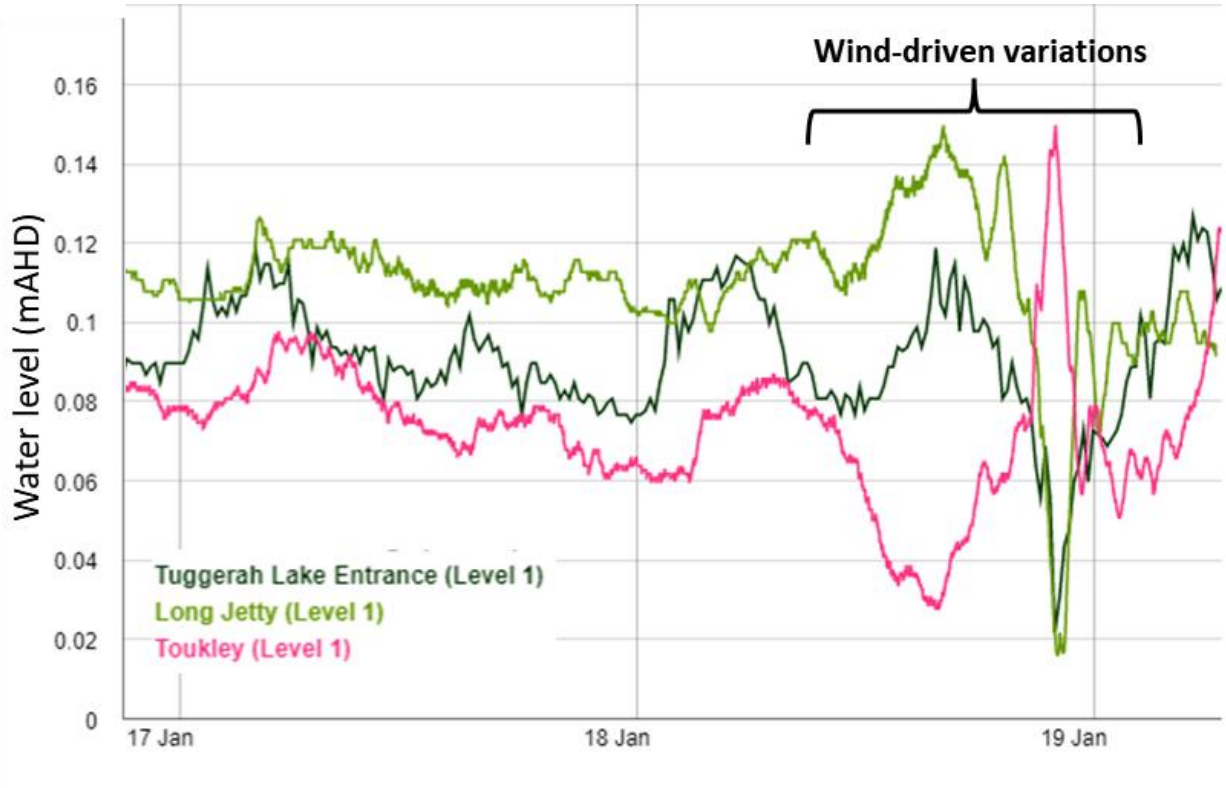


Figure 23: Seiching observed in water level gauges at opposite ends of Tuggerah Lake during strong wind event in January 2023.

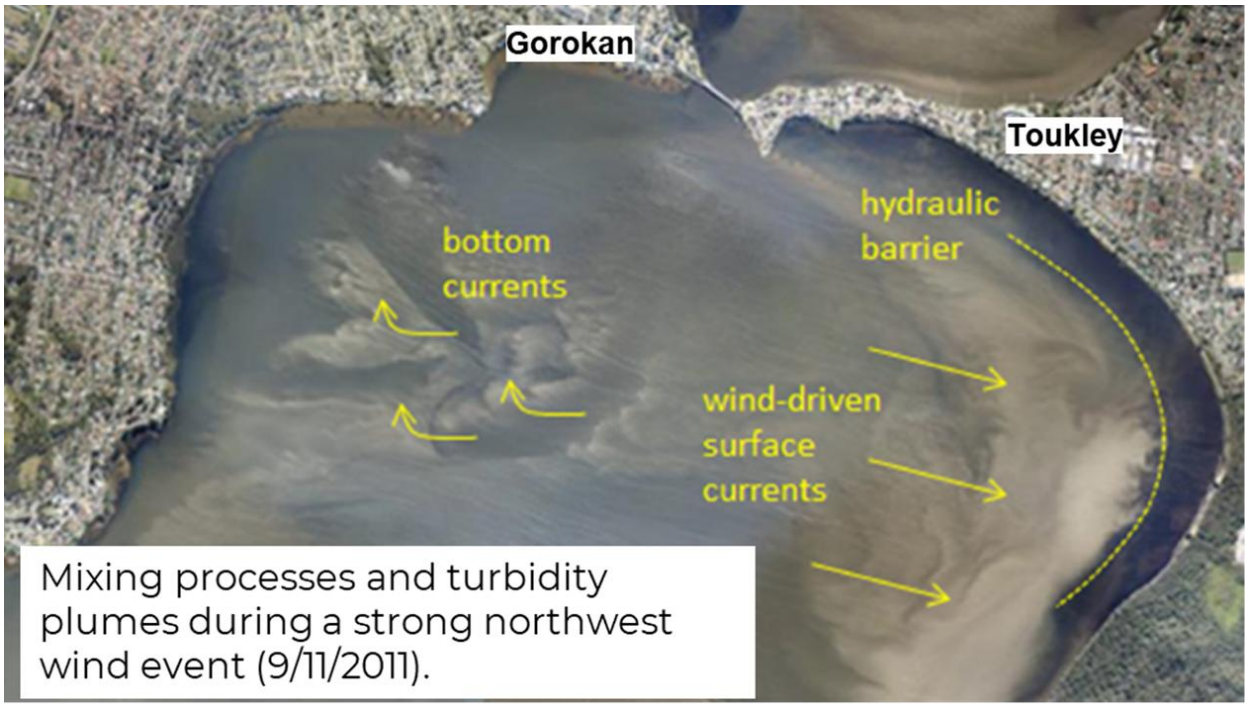


Figure 24: Example of observed mixing currents in Tuggerah Lake during strong northwest wind events on 9 November 2011 (source: Glamore et al., 2020).

Note: refer to Section 2.5.13 for discussion on the organic hydraulic barrier in the nearshore zone.

2.5.8 Wave climate

Nearshore wave data was provided by Manly Hydraulics Laboratory. The Sydney waverider buoy (WRB) offshore wave data was transformed to nearshore, at the -10m depth contour, using the NSW Nearshore Wave Tool over from 3 March 1993 to 10 June 2022.

The directional wave climate in the nearshore of the Tuggerah Lakes estuary and wider northern Central Coast region is provided in Figure 25. The average wave climate statistics for the entrance and wider coastline are also provided in Table 6.

Nearshore wave direction is typically southeast, with The Entrance Beach showing more of an east-southeast wave direction than other adjacent locations. This is of importance considering the location of the entrance channel, with the general dominant direction of wave action at the site suggesting a typical net northerly transport of sand. However, the nearshore wave climate is reported at a location just offshore of the protection by the Karagi Point rock shelf, particularly for south-easterly waves. At the typical entrance channel location, the southeast waves will be much attenuated by the rock shelf, protecting shoreward sites. It is typical of ICOLLs such as Tuggerah Lakes estuary for their entrances to migrate to locations where they are protected from wave action (Glamore et al., 2020). It should also be noted there is a fraction of north-easterly waves, which are not attenuated by Karagi Point rock shelf, and likely contribute to sand moving in a southerly direction, and growth of Dunleith sand spit at times.

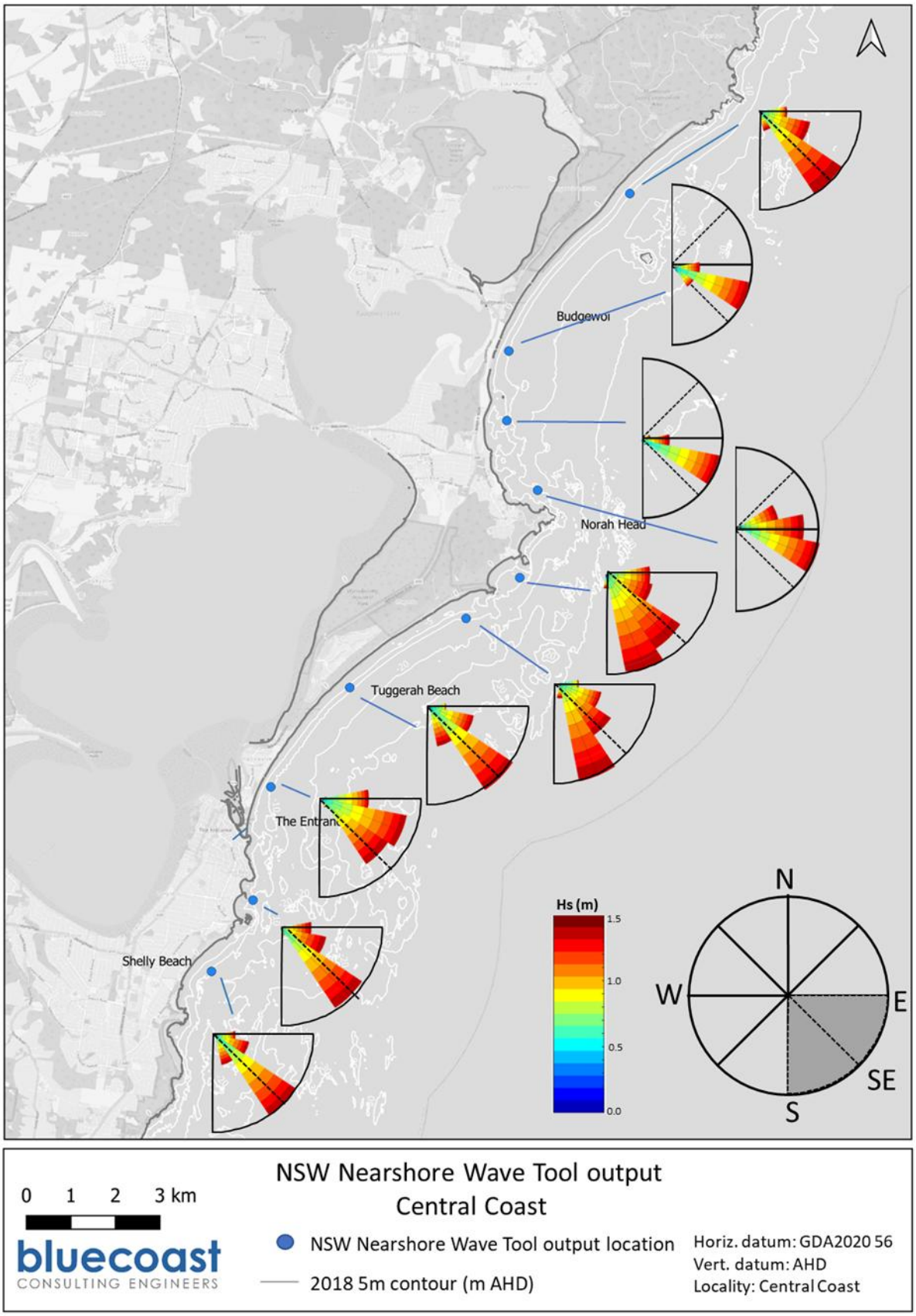


Figure 25: Nearshore wave roses from Forresters to Budgewoi Beach.

Table 6: Nearshore wave statistics.

Beach	Significant wave height (Hs) [m]		Peak wave period [Tp] (s)	Weighted average wave direction [Dp] (°deg)
	Mean	Max	Mean	
Forresters Beach	1.39	8.04	9.7	135
Shelly Beach	1.22	7.19	9.7	132
Toowoon Bay	1.57	10.77	9.8	125
The Entrance	1.31	8.78	9.7	114
The Entrance North	1.23	6.72	9.7	130
Tuggerah Beach	1.38	9.39	9.8	144
Soldiers Beach	1.39	8.63	9.7	135
Hargraves Beach	1.17	7.22	9.8	98
Lakes Beach	1.19	7.61	9.8	109
Budgewoi Beach	1.45	9.55	9.7	133

2.5.9 Sea level rise

The latest advice from IPCC (AR6) on sea level rise (SLR) assesses the climate response to five illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate. The report concludes that in the longer term, sea level is committed to rise for centuries to millennia due to continuing deep ocean warming and ice sheet melt and will remain elevated for thousands of years.

In the shorter term, it is certain that global mean sea level will continue to rise over the 21st century. The latest SLR (above 1995 - 2014 baseline) projections for Newcastle[4] for the 'likely' mean SLR ranges (17th to 83rd percentiles) by 2100 are given below (refer to Figure 26):

- 0.38m (0.25-0.57m) under the very low greenhouse gas (GHG) emissions scenario (SSP1-1.95)
- 0.43m (0.30-0.62m) under the low GHG emissions scenario (SSP1-2.6)
- 0.57m (0.43-0.79m) under the intermediate GHG emissions scenario (SSP2-4.5)

[4] Regional SLR projections are available for Sydney and Newcastle. Conservatively, Newcastle was adopted in this study due slightly higher values compared to Sydney.
[5] Shared Socioeconomic Pathways (SSPs) are scenarios of projected socioeconomic global changes up to 2100. They are used to derive greenhouse gas emissions scenarios with different climate policies.

- 0.72m (0.55-0.96m) under the high GHG emissions scenario (SSP3-7.0)
- 0.82m (0.63-1.11m) under the very high GHG emissions scenario (SSP5-8.5).
- The full range of sea level rise values is presented in Table 6 (extracted from IPCC AR6 Sea Level Projection Tool).

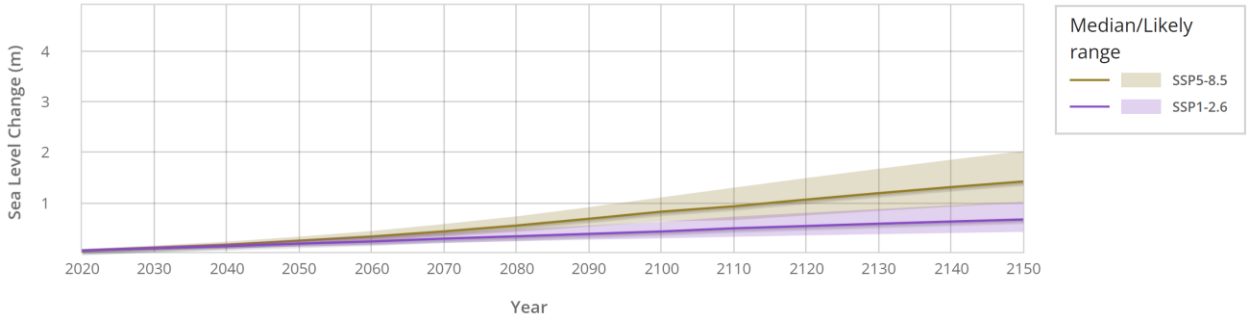


Figure 26: IPCC AR6 sea level rise projections for Newcastle, NSW relative to 1995 - 2014 baseline for the low and very high future greenhouse gas emission scenarios (Garner et al., 2021).

Table 7: Sea level rise projections for Newcastle in metres relative to 1995 - 2014 baseline.

Quantile	2050	2100	2120	Comment
5th percentile	0.10	0.22	0.27	SSP2.6
17th percentile	0.14	0.30	0.36	SSP2.6
50th percentile	0.23	0.71	0.93	Mid-value between above (17th %ile) and below (83rd %ile) values
83rd percentile	0.33	1.11	1.49	SSP8.5
95th percentile	0.40	1.35	1.82	SSP8.5

In terms of the Tuggerah Lakes estuary, it is not immediately clear what the impact of this sea level rise (and wider climate change) will be. With sea level rise, the entrance berm, separating the lake from the ocean, and sand spit would typically be expected to roll back in landward direction, i.e., the barrier would recede in its current alignment, rebuilding further landward. However, the position of the entrance and much of the lower estuary is largely fixed due to development, including the various seawalls, roads and bridge. If maintained into the future, this development is expected to restrict the ability for the lower estuary to naturally adjust its morphology to sea level rise. As argued in Eysink (1990) and Kinsela et al. (2017), it is likely that the active flood delta and entrance berm will act as a sink for sand from the littoral zone as these features adjust (vertical growth) to higher sea levels. This potential sequestration of sand into the estuary would be a slow process and may contribute to future recession of the adjacent beaches.

Higher entrance berm and ocean water levels will also encourage higher water levels within the lake, with flow on effects to flooding and lake ecosystems. The Karagi rock shelf will also offer slightly less protection to the entrance channel, potentially making the entrance more inclined to closure and more variable in location.

2.5.10 Catchment influences

The Tuggerah Lakes estuary is a series of three interconnected lakes. The estuary upper catchment flows through main tributaries of Wyong River, Ourimbah Creek and Wallarah Creek, typically flowing in a south-west orientation from headwaters at the base of the Watagan Mountains (up to 300m AHD) to the Tuggerah Lakes estuary, and eventually to its ocean discharge point at the entrance channel. It drains a catchment of some 790km^2 (MHL, 2022). An overview of the catchment, including the topography, is shown in Figure 27.

The upper catchment contains significant densely vegetated forestry and national parks, with the Wyong River and Ourimbah Creek floodplain principally occupied by agricultural lands. A significant amount of rural residential properties and small towns are present in the upper catchment. Further downstream, in the vicinity of the estuary, urban development is much more prominent with a mix of residential, industrial and commercial land uses.

Pressures on the catchment are thought to be a major contributing factor to water quality, and some of the historic issues identified in the estuary (Glamore et al., 2020), include:

- Increased development in catchment, resulting in increased volume of stormwater discharge.
- Development and land use changes causing additional pollutants in stormwater and resulting poor water quality outcomes.
- Concentration of stormwater discharge through outfalls at specific nearshore locations, locally affecting water quality. This issue can also be enhanced by fringing marine plants reducing circulation and mixing in the nearshore areas.
- Land clearing and stock access to waterways for agricultural practices altering stormwater flows, increasing bank erosion and sediment delivery to the estuary.
- As noted in Section 2.2.3 above, recent practices from Central Coast Council have aimed to address some of these catchment pressures in the rural and urban environment. However, new developments and growth in the Central Coast region will continue to add catchment pressures to the estuary.

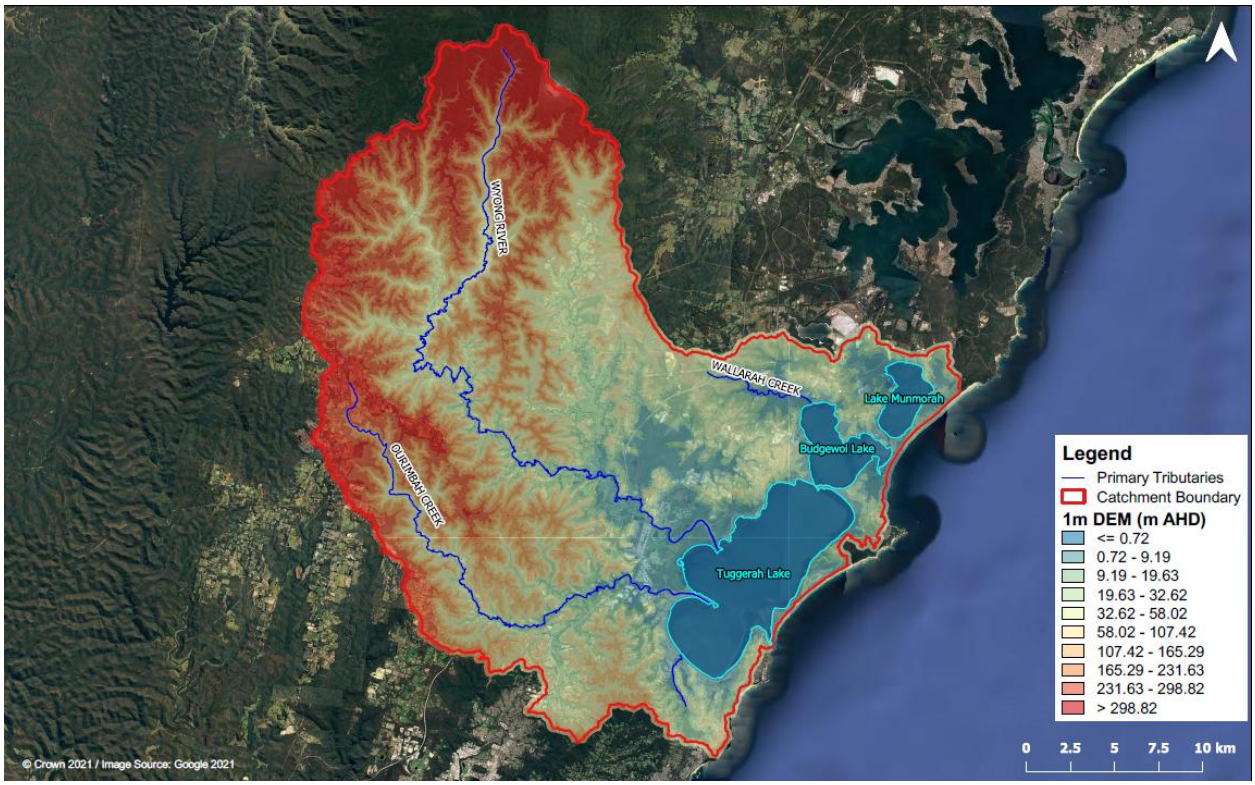


Figure 27: Tuggerah Lakes estuary catchment (source: MHL, 2022).

2.5.11 Rainfall and freshwater inflows

Freshwater input into Tuggerah Lakes estuary primarily originates from the runoff from rainfall in the catchment. The mean annual rainfall observed at Ourimbah (Dog Trap Road) between 1953 and 2021 was 1,408mm. Figure 28 illustrates the mean monthly precipitation observed at Ourimbah. Rainfall is unevenly distributed throughout the year with a high variability between seasons. The region gets most of its rainfall in summer and autumn, but experiences relatively dry winters. Average monthly rainfall records between the years 1953 and 2021 ranged from a minimum of 65mm in September to a maximum of 192mm in February.

Rainfall in the Tuggerah Lakes catchment varies significantly from one year to another. For example, over the 68-year record period, a low of 838mm was recorded in 1957 and a high of 2,163mm was measured in 1990. Much of the variability in precipitation is due to large-scale climate variations, with El Niño – Southern Oscillation being the most important.

BMT WBM (2010) estimated catchment inflows into the estuary come from three main sources of Wyong River (55%), Ourimbah Creek (24%) and Wallarah Creek (5%). The rest of the inflows are thought to be from local drainage adjacent to the estuary and groundwater inputs, which are more significant during times of drought and lowered water levels in the estuary. Figure 30 shows a breakdown of the catchments discharging into the estuary.

During extended periods of low rainfall the estuary water levels can reduce significantly as the estuary continues to drain though the entrance (during open entrance condition) in combination with evaporation and other processes. An example of such lowering of the estuary water levels is shown in Figure 29.

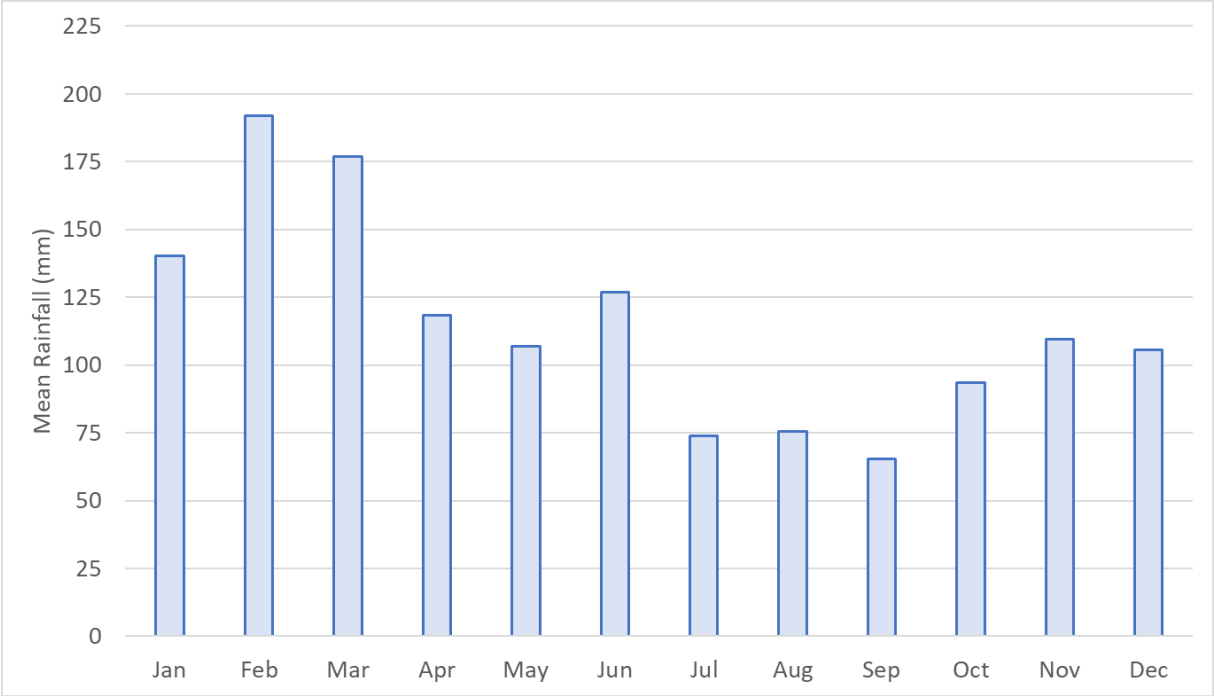


Figure 28: Mean monthly rainfall observed at Ourimbah (Dog Trap Rd) 1953 – 2021.

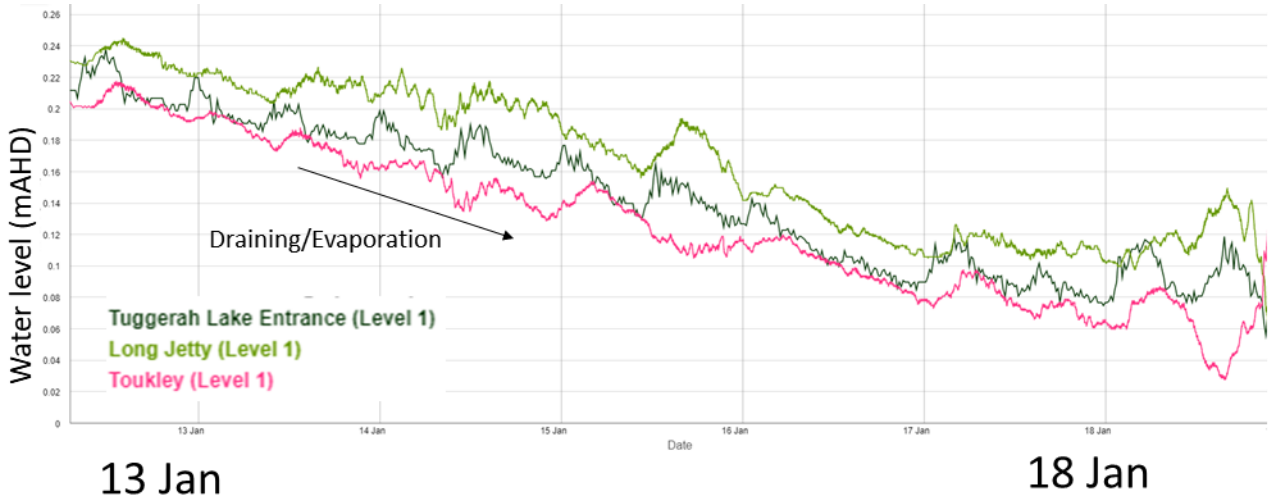


Figure 29: Observed estuary water levels in January 2023.

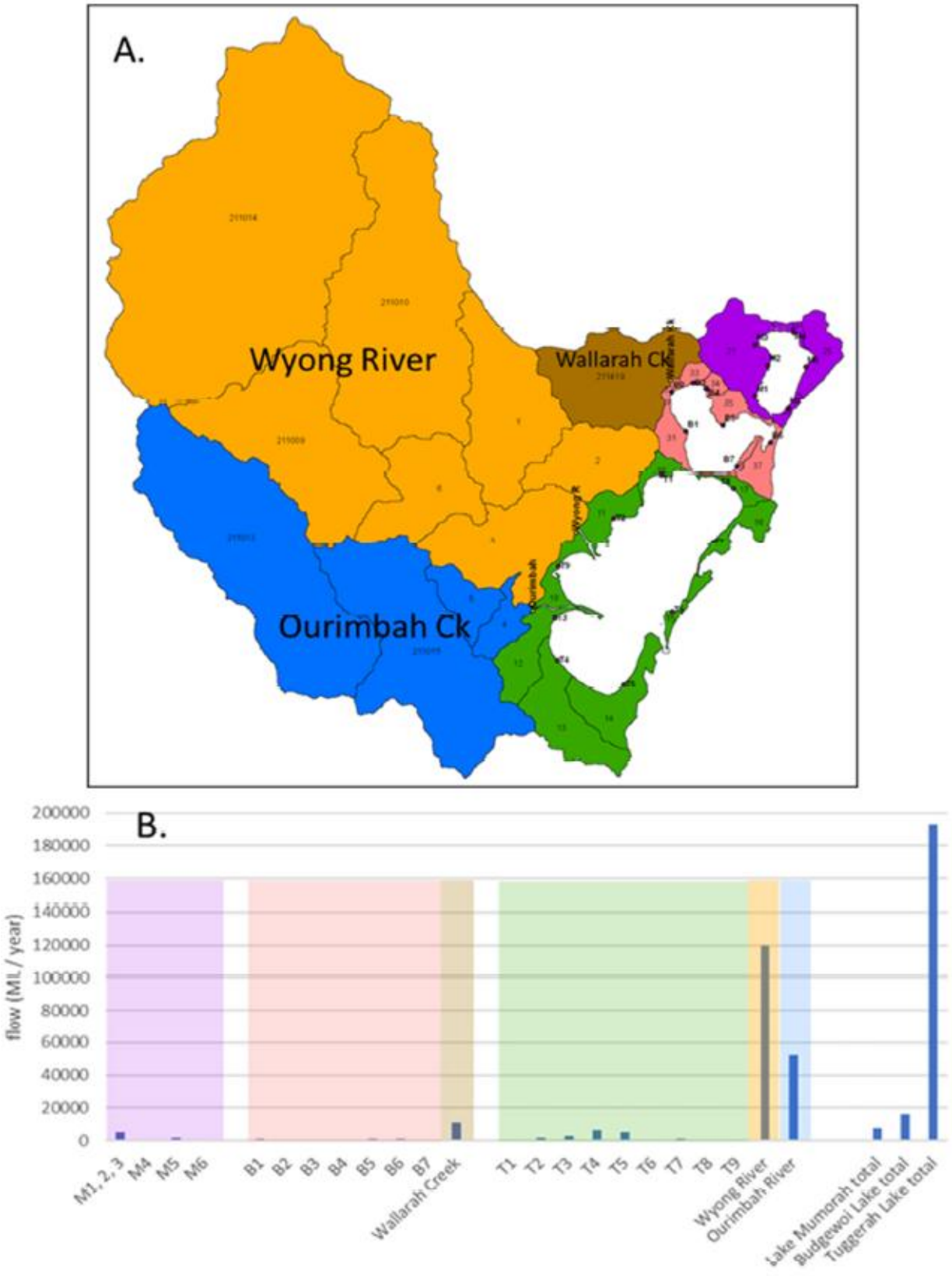


Figure 30: A) Catchment of Tuggerah Lakes estuary B) Estimated discharge from catchments (source: Glamore et al., 2020, based on reporting in Brennan et al., 2010).

2.5.12 Tuggerah Lakes flooding

The Tuggerah Lakes estuary is wide and shallow. Whilst having considerable volume capacity throughout the 81km^2 estuary footprint, the estuary has minimal outflow capacity due to its restricted hydraulic grade and hydraulic capacity at its single ocean outlet. Flooding is typically caused due to inflows from rivers and creeks exceeding outflow capacity, where the estuary rises and exceeds its typical footprint and affects low-lying adjacent areas. The rate of rise of floodwaters is generally considered slow in comparison to river systems and is also of low velocity due to the nature of the estuary rising compared to a flowing river system (WMAwater, 2014). However, due to the low-lying foreshore surrounding Tuggerah Lakes relatively small increases in water level compared to other NSW estuaries can initiate widespread flooding. Flooding at Tuggerah Lakes may also be increased due to other factors including elevated ocean water levels, wind and waves causing setup and runup within the estuary and local drainage issues.

WMAwater (2014) reported extreme flood conditions within the Tuggerah Lakes estuary catchment based on hydrologic and hydraulic model simulations. Figure 31 presents the flood extents for the Probable Maximum Flood (PMF) event while peak water level values are given in Table 8. Due to the considerable storage area offered by the floodplain, the depth of flood water is low and slow moving. Properties fringing the estuary are affected during all events from the 20% AEP event and larger. The minor flood level for Tuggerah Lakes is just 0.9m AHD, which is the level at which some roads start to be flooded.

Table 8: 1% AEP and PMF modelled peak flood levels (m AHD). Source: WMAwater (2014).

Event	Peak flood level (m AHD)
50% AEP	0.91
20% AEP	1.36
5% AEP	1.80
1% AEP	2.23
PMF	2.70

Figure 31: Flood extents at Tuggerah Lakes estuary for a 2.7m AHD Probable Maximum Flood event (source: CCC online maps portal accessed April 2023).

Whilst the 2014 Floodplain Risk Management Study (WMAwater, 2014) generally assumed a constricted entrance, it noted that flooding is somewhat affected by the condition of the entrance channel. A wide and open entrance before the flood likely allows draining flood waters more efficiently at the start of the flood event. MHL (2022) undertook flood modelling with varying entrance conditions for a series of flood events. The model was provided with a pre-flood entrance condition ranging from fully closed to wide

open and allowed for scour of the entrance as flood waters pass through. For events greater than the 20% AEP, peak levels were found to reduce by typically 0.1 - 0.35m for wider entrance conditions prior to flooding. Smaller reductions in peak water levels of around 0.05 - 0.15m were modelled for more frequent flood events. MHL (2022) suggest that this is likely due to the greater tailwater influence of ocean water levels for such events. Overall, the modelling results suggest that peak estuary water levels are reduced by 5 – 15% for a wide-open entrance compared to a heavily constricted entrance (pre-flood). This reduction of peak flood levels is relatively minor (yet may be significant in terms of flood impacts) and may reduce the duration of the peak flood levels. However, it is noted that like other NSW ICOLL entrances, the entrance to Tuggerah Lakes naturally scours as flood water pass through the entrance which quickly results in a wider and more efficient entrance. This is further discussed in Section 4.3.

The relationship of observed peak flood water levels in the estuary and post-flood entrance condition has been further assessed in MHL (2022). The amplitude of the M2 tidal constituent observed at the Entrance Bridge (previously Long Jetty) tide gauge was used as a proxy for entrance efficiency (or level of constriction) as this relates to tidal propagation through the entrance (see Figure 32). Of interest are the similar observed peak water levels during the June 2007 and February 2020 flood events. Catchment inflows were around 45% higher during the peak of the June 2007 flood event compared the February 2020 and the entrance was heavily constricted leading up to both flood events (see Table 9). This further suggests peak flood levels in the estuary are somewhat limited by the ability of natural scouring of the entrance during such events. Further assessment of the 2020 flood event, including rainfall intensity, is presented in MHL (2020).

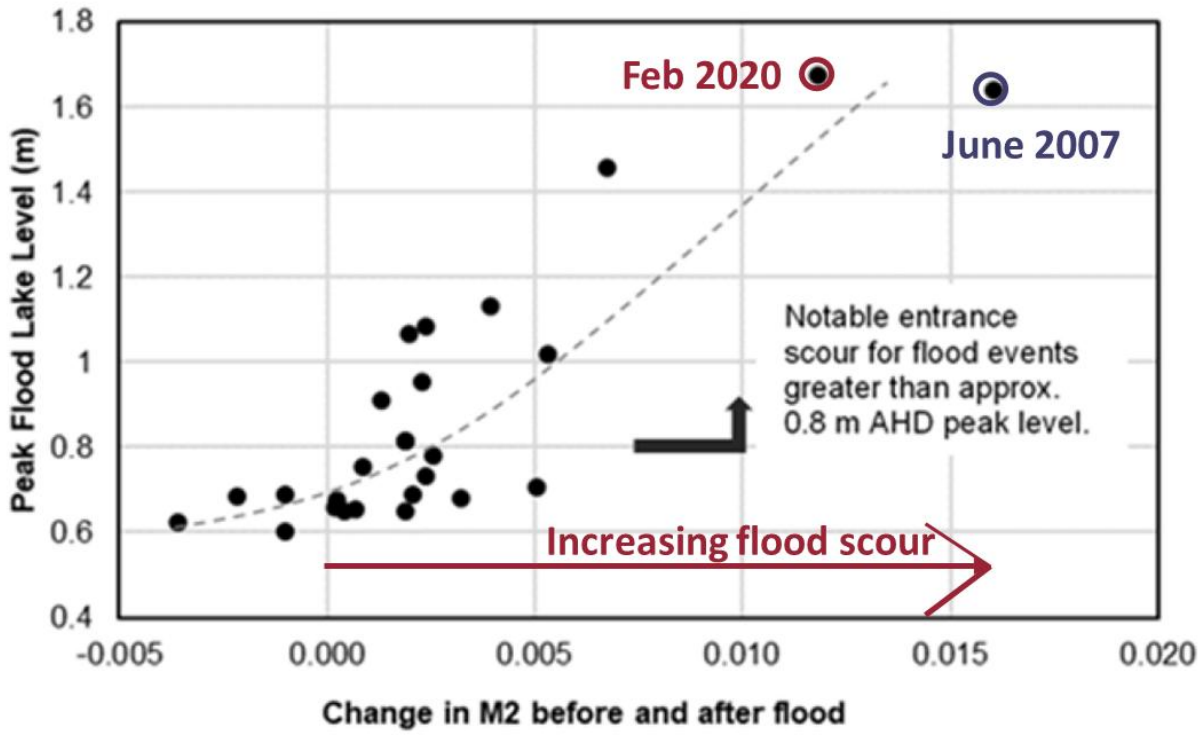


Figure 32: Relationship of M2 tidal amplitude (as a proxy of entrance constriction) and peak flood estuary water levels (adapted from MHL, 2022).

Table 9: Comparison of 2007 and 2020 flood events.

Flood event	Peak stream flow at Wyong River gauge (ML/day)	Cumulative stream flow at Wyong River gauge over event duration (ML)	Pre-flood entrance condition	Aerial photograph of pre-flood entrance condition
Feb 2020	12,600	21,955 (6-days)	Heavily constricted but dredged ebb channel and berm management	 18 December 2019
Jun 2007	18,400	27,323 (4-days)	Heavily constricted	 6 March 2007

2.5.13 Water quality

The water quality system in the estuary is a complex product of incoming waters, physical and biological processes and how these processes interact spatially within the nominated functional zones. A detailed assessment of water quality at Tuggerah Lakes has been completed in Glamore et al. (2020).

Historically, it is thought that the estuary has been through three key phases (Bio-analysis, 2006):

- Pre-1950s: historically the estuary is thought to have been oligotrophic (nutrient-poor).
- 1950s – 1990s: a period of rapid urbanisation and resulting increase in nutrient delivery, leading to a eutrophication of the estuary. This is a period where accumulating seaweed, algal blooms and resultant 'ooze' were symptoms of a eutrophic system.
- 2000s – recent: ongoing period of improved catchment management processes (and improved sewerage management) leading to a mesotrophic (medium-nutrient status) estuary. Given recent major inflows into the estuary and continuing urban development, the estuary remains at risk. This is especially true in the nearshore zone, where thick seagrass decouples the deeper lake basins from interacting with the nearshore zones, and stormwater discharges, greatly increasing the probability of eutrophic conditions. The developmental pressures in the catchment are likely to be

an increasing concern in the near future with an additional 41,500 houses proposed for the region by 2036 (Glamore et al., 2020).

Central Coast Council undertakes periodic water quality monitoring at several sites within the Tuggerah Lakes estuary since at least 2012 (and earlier as discussed in the Tuggerah Lakes Estuary Process Study 2001 – however no earlier data was available for this study), allowing Council to report on the health of the estuary (see Figure 33). The water quality monitoring is aligned with the NSW statewide Estuarine Monitoring, Evaluation and Reporting Program. Council typically use the key indicators of Chlorophyll-a, turbidity and seagrass depth range to grade their waterway health in a report card that is publicly released. The most recent (2021/22) report card suggests Tuggerah Lake and Budgewoi Lake to be in good condition, with Chittaway Bay in excellent condition. Lake Munmorah and the main inflowing waterways of Wallarah Creek, Ourimbah Creek and Wyong River were deemed to be in poorer condition, primarily due to Chlorophyll-a grading exceeding trigger levels in these waterways.

In terms of variability Glamore et al. (2020) reviewed Chlorophyll-a (among other parameters) in more detail than the report card format (see Figure 34). Brennan et al. (2010) describe Chlorophyll-a concentrations as an important parameter in the Tuggerah Lakes estuary, as it measures abundance of phytoplankton in the waterway. This has a direct correlation with high nutrient levels, and the key water quality concerns in the estuary are typically related to sites with high nutrient levels. The data generally suggests some correlation between wetter seasonal and inter-annual conditions and higher chlorophyll-a levels.

No correlation between the level of constriction of the entrance and water quality in the wider estuary was found (Glamore et al., 2020). Improved water quality due to tidal flushing is typically limited to the entrance compartment. The effect of tidal flushing on water clarity following high catchment runoff is evident in aerial imagery with an example shown in Figure 35 (dated 25 April 1990).

In the main estuary (away from the entrance), organic barriers that resist flows comprising seagrass, wrack and macroalgae are often found in the nearshore zone (see example in Figure 36). This can protect the water surface from wind stress, impeding water flow and trapping stormwater discharges from urban catchments fringing the estuary. This can result in stagnant and shallow nearshore zones. This creates a potential for poor water quality conditions to arise which is often raised as a key concern for the community. The stagnant nearshore zones can result in anaerobic decomposition of algae and other organic matter which is often accompanied by ‘rotten egg’ smell associated with release of Hydrogen Sulphide gas.

It is also noted that flooding is thought to be a driver in water quality in the estuary. Large floods have the capacity to abruptly change water quality conditions in the estuary (Glamore et al., 2020). Floods can dislodge vegetative matter and transport it to higher levels where it can dry out, enable recoupling of lake basins and the nearshore zone, allowing mixing of suspended material and flushing through a scoured entrance channel.

Figure 33: 2021 Water quality report card for Tuggerah Lakes (source: CCC, 2021b).

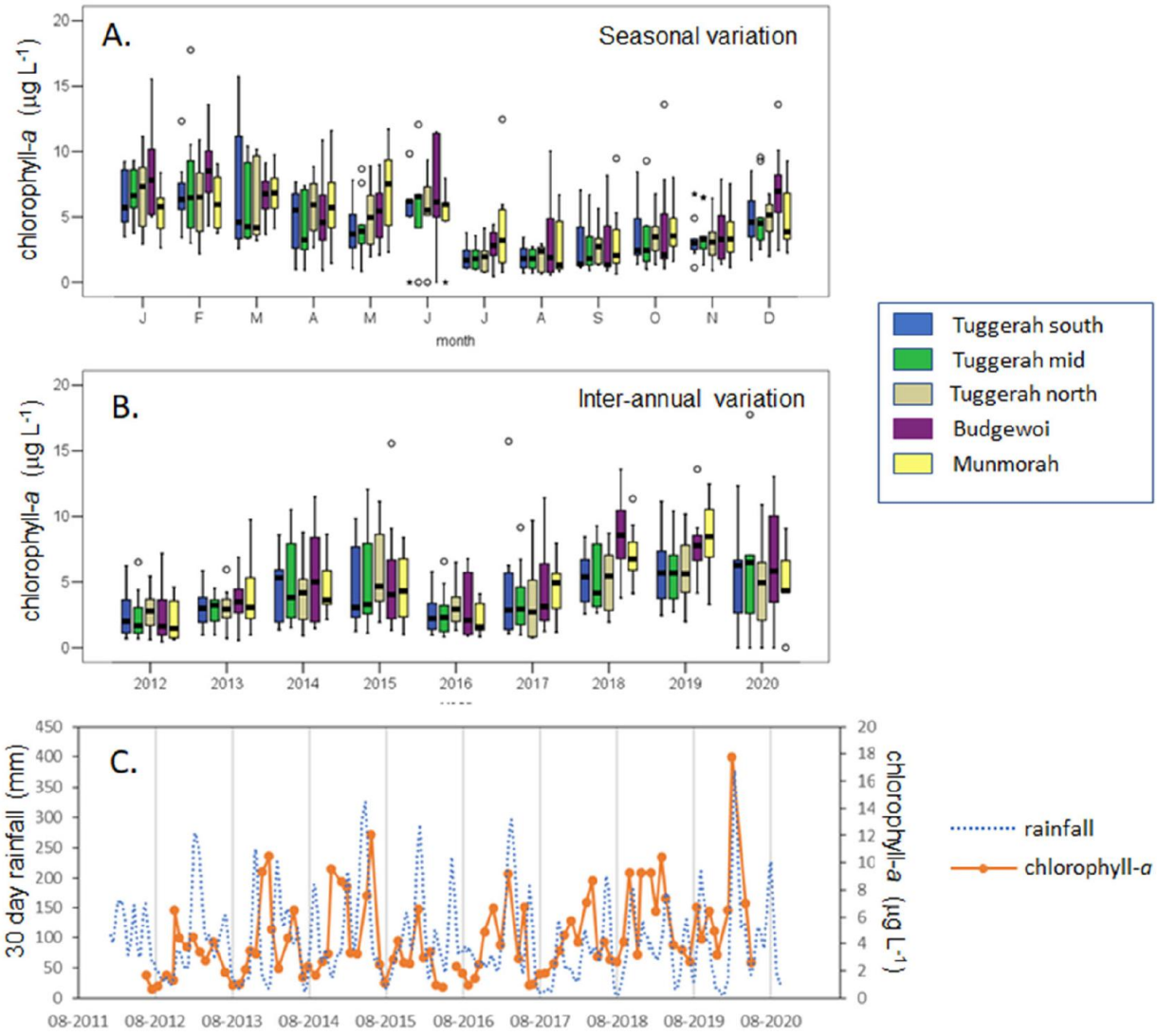


Figure 34: Chlorophyll-a Variation within the estuary. Top (A.) shows seasonal variations within the estuary at the different sites. Middle (B.) shows inter-annual variation at the sites. And bottom (C.) shows a comparison of Chlorophyll-a levels with rainfall at Gorokan. Source Glamore et al. (2020), based on reporting in Brennan et al. (2010).

Figure 35: Example aerial photograph captured 25 April 1990 showing spatial extent of tidal flushing (clear water) at Tuggerah Lakes entrance following high catchment runoff (source: NSW Government). At the time of this photo reclamation activties are underway and Terilbah Channel is blocked.

Figure 36: Photograph of organic hydraulic barrier in nearshore zone at Toukley (photo source: CCC).

Note: 'Dead waters' refers to stagnant and anerobic nearshore zone.

3. Community and stakeholder engagement

Effective community engagement and communication with the Central Coast community is an important aspect of the development of the Tuggerah Lakes CMP. Engagement with stakeholders and community members has been undertaken with consideration for:

- The Community and Stakeholder Engagement Strategy developed for the Tuggerah Lakes CMP Scoping Study (Appendix A)
- Stakeholder engagement strategy for Tuggerah Lakes floodplain risk management study and plan (WBMA Water, 2014), and the Coastal Zone Management Plan (Bio-analysis, 2006)
- Council's Community Strategic Plan -2018-28 (2021)
- Council's Engagement Framework (2017)
- Council's Community Participation Plan (2019)
- The International Association of Public Participation (IAP2) Public Participation Spectrum
- The Entrance Place Plan (2021)
- The Coastal Management Act (2016) and the NSW Coastal Management Manual requirements.

A summary of previous stakeholder and community consultation regarding the entrance management of Tuggerah Lakes is summarised in Section 2.3.3. The outcomes, learnings, and community values identified in earlier community engagement for the Tuggerah Lakes entrance have informed the community and engagement undertaken to inform the development of the Tuggerah Lakes options.

Consultation about management options and the evaluation process will:

- Raise awareness of the strategic and staged approach to management of the Tuggerah Lakes Entrance.

- Ensure residents and key stakeholders are informed and have contributed to how Tuggerah Lakes is managed in the future.
- Provide council with early feedback about actions and priorities that are acceptable to local communities and the overall population of the LGA and its visitors. Ensure there are 'no surprises' by engaging early with key stakeholders and the community to understand and work through any key concerns and identified opportunities. This should streamline Stage 3.
- Clarify the agency roles and public authority position on actions that require a collaborative effort, for instance around dredging and natural defences actions.
- Ensure the management option evaluation process undertaken through Stages 2 and 3 of the CMP (feasibility, viability (costs and benefits) and acceptability) is transparent and communicated effectively and clearly.
- Build on previous consultation undertaken for the CMP under the previous studies. Ensure that communities feel that their previous feedback was heard and taken on board.

The key engagement activity undertaken as part of the preparation of this report included the Community Focus Group and the community online survey. Details of the Community Focus Group are provided in Section 3.2. The outcomes of the online survey are provided in Section 5.3.1, with a brief overview provided in Section 3.3.

Further community engagement will be undertaken when the options report is made available for public comment. Additional stakeholders will be engaged through targeted stakeholder meetings.

3.1 Community and Stakeholder Engagement Plan

A Community & Stakeholder Engagement Plan (CSEP) has been prepared (see Appendix A) which sets out the strategy to engage with the community and stakeholders as part of the Tuggerah Lakes Estuary CMP (Stage 2 Assessment) as required by the CM Act 2016 and the Coastal Management Manual 2018.

The key objectives of the CSEP are to:

- **Confirm** the key community values, uses and vision for the management of Tuggerah Lakes through a review of earlier entrance management strategies, and historical community engagement.
- **Educate and inform** the community about the coastal processes impact on the entrance and the CMP development process.
- **Identify** risks and barriers to success by ensuring awareness of the CMP across the whole community and facilitate residents' feedback, ideas and concerns about acceptable risk and around how Tuggerah Lakes is managed in the future.
- **Clarify and deliver** the CMP over the next 10 years by fostering understanding of the priorities of the CMP.

A stakeholder matrix has been developed and is presented in Appendix A to identify relevant stakeholders, and their relative level of interest, influence and impact on the CMP. The outcomes of this analysis identifies the suitable level of consultation based on the IAP2 consultation spectrum.

A range of engagement methods have been developed based on the requirements of the CM Act and CM Manual, the objectives of the consultation and the level of consultation identified for each of the stakeholders. These engagement methods included:

- Media releases and Enews

- Technical workshops with relevant Council staff
- Stakeholder workshops with relevant State Agency representatives
- Community online survey
- Community focus group.

Further community and agency consultation will be completed through the development of the Tuggerah Lakes CMP and development of the Entrance Management Strategy.

3.2 Tuggerah Lakes Community Focus Group

The Tuggerah Lakes Community Focus Group (CFG) was established in December 2022. Community members were invited by Council to express their interest in being involved in the group to help develop the Tuggerah Lakes entrance management options and to ensure community attitudes and values were considered and represented.

A member selection process was undertaken by Council to achieve diversity and community representation (as best possible). Fourteen members were selected and formed the CFG. All members agreed to the Terms of Reference (ToR). These ToR outlined the group purpose, background, role of the CFG, membership and responsibility of members.

Three CFG meetings were held in person at Council's administration building in Wyong, during December 2022 – February 2023 (see photograph from final meeting in Figure 37). The CFG membership included representatives from across the local community and were encouraged to seek and provide feedback to the group from the broader community so:

- Council could better understand the concerns of the community with regards to the management of the entrance at Tuggerah Lakes, and
- Meaningful feedback could be incorporated into the development of the management solutions for the Tuggerah Lakes entrance.

Representatives from the NSW Government were also in attendance at the CFG Meetings, including representatives from the Department of Planning and Environment (DPE, now DCCEEW). In addition, numerous Council staff members, including senior management, attended the CFG meetings to listen to community feedback and provide advice.

Figure 37: Photograph taken during final CFG meeting.

The CFG has been integral to the development of the Tuggerah Lakes entrance management option assessment. The feedback provided by the CFG members was also intended to directly inform the development of an Entrance Management Strategy during Stage 3 of the CMP.

The agenda for each CFG meeting was developed in consultation with the CFG members. Following the conclusion of each CFG meeting, members were invited to provide their feedback including any suggested topics for discussion at future meetings.

Each CFG meeting included an interactive session, providing opportunities to foster greater understanding between members and the project team of:

- shared misconceptions,
- any concerns and opportunities when exploring the coastal processes within the entrance compartment and estuary,
- identified community values, and
- various management options.

Council and the broader project team recognises the contribution of the community representatives who donated their time and knowledge. These insights have been highly beneficial to the project.

A summary of the agenda for each meeting is summarised in Table 10.

Table 10: Agenda Items for CFG Meetings.

CFG Meeting 1 – 14 December 2022	CFG Meeting 2 – 1 February 2023	CFG Meeting 3 – 22 February 2023
Meeting purpose (including Terms of Reference) Project background, overview, and socio-economic assessment Interactive workshop: Tuggerah Lakes community values and issues identification.	Values and issues Outcomes of the socio-economic assessment Tuggerah Lakes Processes – exploring key issues raised by the community and common misconceptions. Overview of potential entrance management options Entrance coastal processes Break out groups to discuss management options.	Overview of project objectives and outcomes of CFG CFG member comment Socio-economic assessment update Outcomes of the assessment of the long list of options and draft short list of options assessment Feedback session Brainstorming on community education needs and opportunities

3.3 Community online survey

A community engagement survey was undertaken to obtain an understanding of community use relating to the estuary and entrance. The survey included multiple choice, scaled responses and open-ended responses to the question focusing on how individuals use the lakes and open coast region and what they valued about the region.

The survey asked the following questions:

- What is the postcode of your primary place of residence?
- What do you most value about the natural environment at the entrance to Tuggerah Lakes?
- Have you visited a beach or lake in the Tuggerah Lakes catchment area in the past 12 months?
- In the past 12 months, how many times have you visited the following beach or lake areas?
    - Tuggerah Lake
    - Entrance to Tuggerah Lakes
    - Budgewoi Lake
    - Lake Munmorah
    - North Entrance Beach
    - Entrance Beach
- Why do you choose to visit the entrance to Tuggerah Lakes over other locations?
- How long would you usually spend at the beach/lake and surrounds each visit?
- How do you usually get to the beach/lake area you visit most frequently?
- For the location you visit most frequently, how much money do you normally spend preparing for the visit (e.g., buying picnic food or drinks) and at the lake/ beach (e.g. spending at local businesses)?

- For the location you visit most frequently, why do you choose to visit it over other lakes/ beaches in the area?
- Do you want to keep the Tuggerah Lakes Entrance open?
- If the Tuggerah Lakes entrance is closed, how does it affect your use?
- Do you own or work for a commercial activity that uses (e.g., sailing lessons) or interacts with the lake and its foreshore (e.g. paddleboard hire, tourism accommodation)? If so, which best describes the business? If so, how dependent is your commercial activity on the Tuggerah Lakes entrance being open?
- Where have you previously sought information on coastal issues?

Further, a map of key locations (Figure 38) was provided to respondents as a reference.

Figure 38: Map provided to survey respondents showing the locations of key areas.

There were 164 responses received to the survey. Details on the outcomes of the survey relate to the socio-economic assessment and are provided in Section 5.3.1.

3.4 Outcomes of engagement

The CFG meetings and community online survey supported the identification and assessment of entrance management options, this process is outlined in Figure 39 and included:

- The online survey and first CFG meeting contributed to an understanding of community values and expectation to inform the identification of management issues and priorities, which in turn informed the identification of potential management options (draft longlist of options). In addition, these engagement activities identified a range of misconceptions, impacting expectations on entrance management.
    - Key values included recreational activities, access to open space, protection of wildlife and heritage values, and the social value associated with water view and the coastal / lake setting.
    - Key management issues included berm management for flood mitigation purposes, impact of wrack on amenity, water quality issues, odour issues associated with low estuary levels, and maintenance of recreational assets.
    - Key misconceptions included exaggerated expectation in the impact of entrance management on flood risk, perception of a strong connection between water quality across the lakes and the entrance condition, and a lack of understanding of the ecological impacts associated with artificial interference with the entrance.
- The second CFG meeting assisted the project team in identifying a range of management options for inclusion in the options assessment process (long list of options). Amongst a range of inputs received during discussions, of note were that:
    - Overall, there was stronger support by the CFG members for options not including structures (such as groynes and training walls). However, inclusion of structural options in the long list was considered appropriate for a balanced outcome and completeness.
    - The concept of encouraging a closed entrance condition was raised by members for consideration in terms of maintaining elevated water levels in the estuary resulting in favourable outcomes in terms of odour control (of exposed foreshore areas during low estuary levels) and reduction of seaweed growth (and associated wrack) due to reduced light penetration into deeper water.
    - Infrequent entrance management for flood mitigation rather than regular or permanent entrance management for recreational or water quality outcomes was considered a key objective. Entrance management is likely to have limited impact on water quality improvement and incur significant environmental impacts.
- The third CFG meeting involved collaborative evaluation of options to determine a short list of feasible options for further assessment by the project team. Some of the key matters raised and outcomes of the meeting included:
    - Members wanted any socio-economic evaluation of the lakes and options to be treated with caution as the estuary are a complex system with a number of processes that are difficult to understand or allocate an economic value to.

- Public education is key in gaining acceptance by the community on entrance management outcomes. These need to address misconceptions and explain the complex processes involve in and potentially impacted by entrance management.
- Option evaluation should consider impacts on estuary health as the critical factor.

- The online survey was also a key input to the socio-economic assessment by providing estuary use and visitation information. This is discussed in more detail in Section 5.

The broader community will have the opportunity to provide their feedback on the Tuggerah Lakes entrance management options assessment when further community consultations is undertaken throughout development of the Tuggerah Lakes CMP.

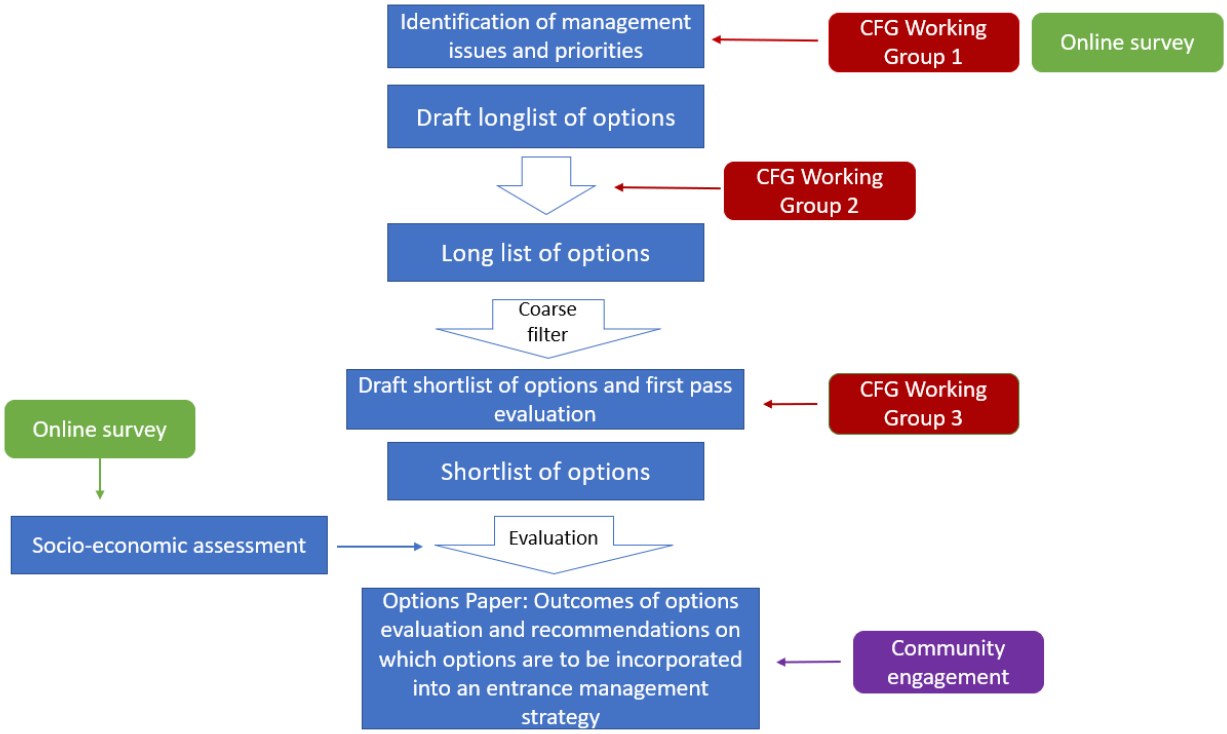


Figure 39: Overview of entrance management options assessment process and engagement activities.

4. Coastal processes assessment

4.1 Overview

This assessment focusses on providing a clear understanding of the coastal processes that shape the entrance to Tuggerah Lakes and the influence these processes have on the estuary's functional zones (see Section 2.5.1). It is informed by the study context (including the engineering history of the area, literature review and existing environment). Its outcomes inform the review of entrance management options. The assessment involves the following:

- Local entrance sand budget analysis incorporating a morphological review of shoal dynamics.
- Review of entrance and estuary dynamics.
- Groyne impact assessment.
- Conceptual model showing key processes and sand (or other sediment) movement pathways.

4.2 Entrance sand budget

4.2.1 Approach

A sediment budget is a quantitative analysis of the movement and distribution of sediment within a coastal region. In the context of a tidal entrance, a sediment budget can be used to identify the long-term rate of entrance infilling (or net export) as well as shorter term entrance dynamics in response to floods, waves and coastal storms.

The analysis herein focuses on the entrance to the Tuggerah Lakes estuary from the nearshore upstream to The Entrance bridge (see Figure 40). This corresponds to an area of the flood tide delta reasonably well covered by entrance surveys, noting that some surveys used have larger extents. It also corresponds to the area that is typically dredged as part of the historical entrance management practices (see Section 2.2.2). Sediment sampling in this area of the flood tide delta shows that the surface sediments are predominately fine to medium grained sand with an average fines content of less than 7% (see Section 2.5.3). Given the sandy nature of the sediments, the term sand budget has been adopted.

An assessment of the change in the sand volumes within the entrance compartment was undertaken adopting the analysis cells shown in Figure 40. The extents and division of the analysis cells were defined in consideration of the available data extents, observed processes and morphology. The analysis maps historical sand volume changes in ten lower entrance cells covering the flood tide shoals and entrance berm. The surveyed volume changes have not been adjusted for the quantities of sand removed from the entrance by dredging.

The adjacent coastal analysis cells form part of a separate coastal sand budget analysis being undertaken as part of the Central Coast LGA coastal hazard assessment. Bluecoast (2023) reports on this inclusive of a:

- regional coastal sand budget for the open coast of the Central Coast LGA
- local coastal sand budget for The Entrance – Tuggerah Beach compartment covering the coastal analysis cells shown in Figure 40.

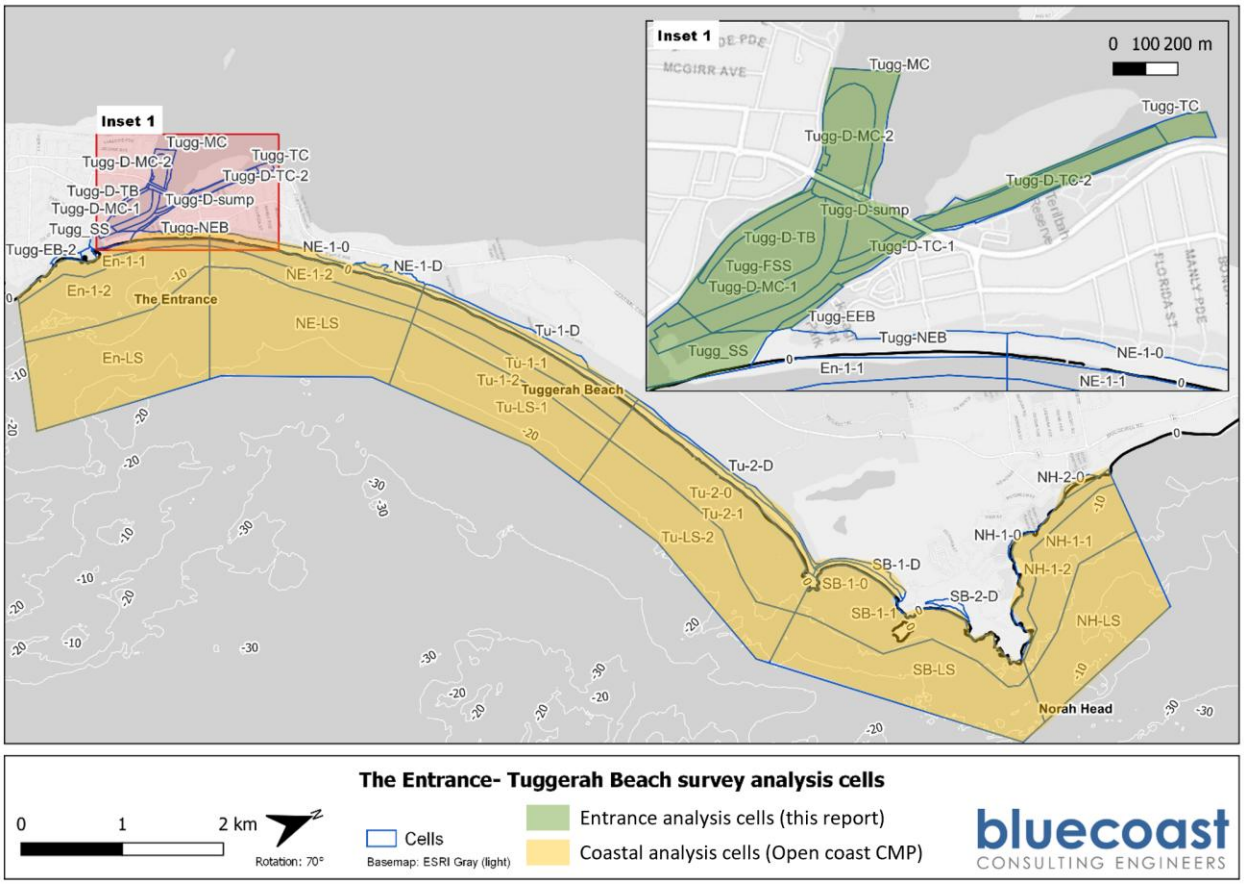


Figure 40: Entrance analysis cells (shaded green) adopted for the development of the entrance sand budget.

Note: The local Entrance – Tuggerah Beach compartment coastal analysis cells (shaded yellow) are reported in Bluecoast (2023), with a summary provided herein.

4.2.2 Results

Volume change was determined from surveyed differences in the seafloor relative to the 2018 coastal LiDAR survey. Where survey coverage allowed, volumes were determined for the adopted entrance analysis cells. The results are presented as:

- survey difference maps for the entrance area with selected surveys each relative to the 2018 coastal LiDAR survey are shown in Figure 41 and Figure 42.
- survey difference maps for the entrance area with selected surveys shown in sequence (i.e., sequential order).
- timeseries of sand volumes changes over the lower entrance (seaward of bridge), entrance berm cells and total (entrance and berm) is shown in Figure 43. Also shown in this figure is timeseries of Wyong River stream flows and entrance dredging activity.

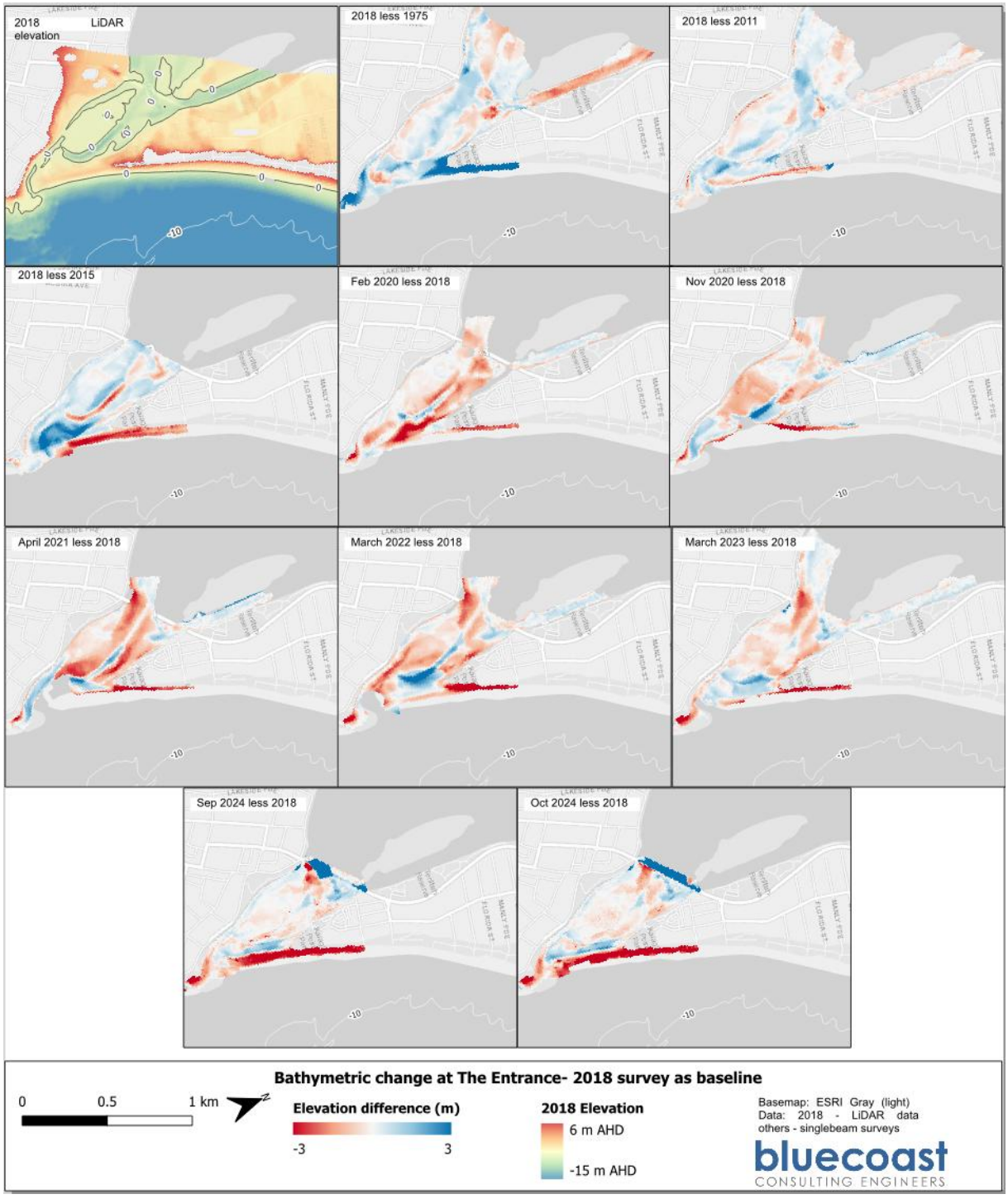


Figure 41: Seabed elevation change within the entrance compartment relative to 2018 survey.

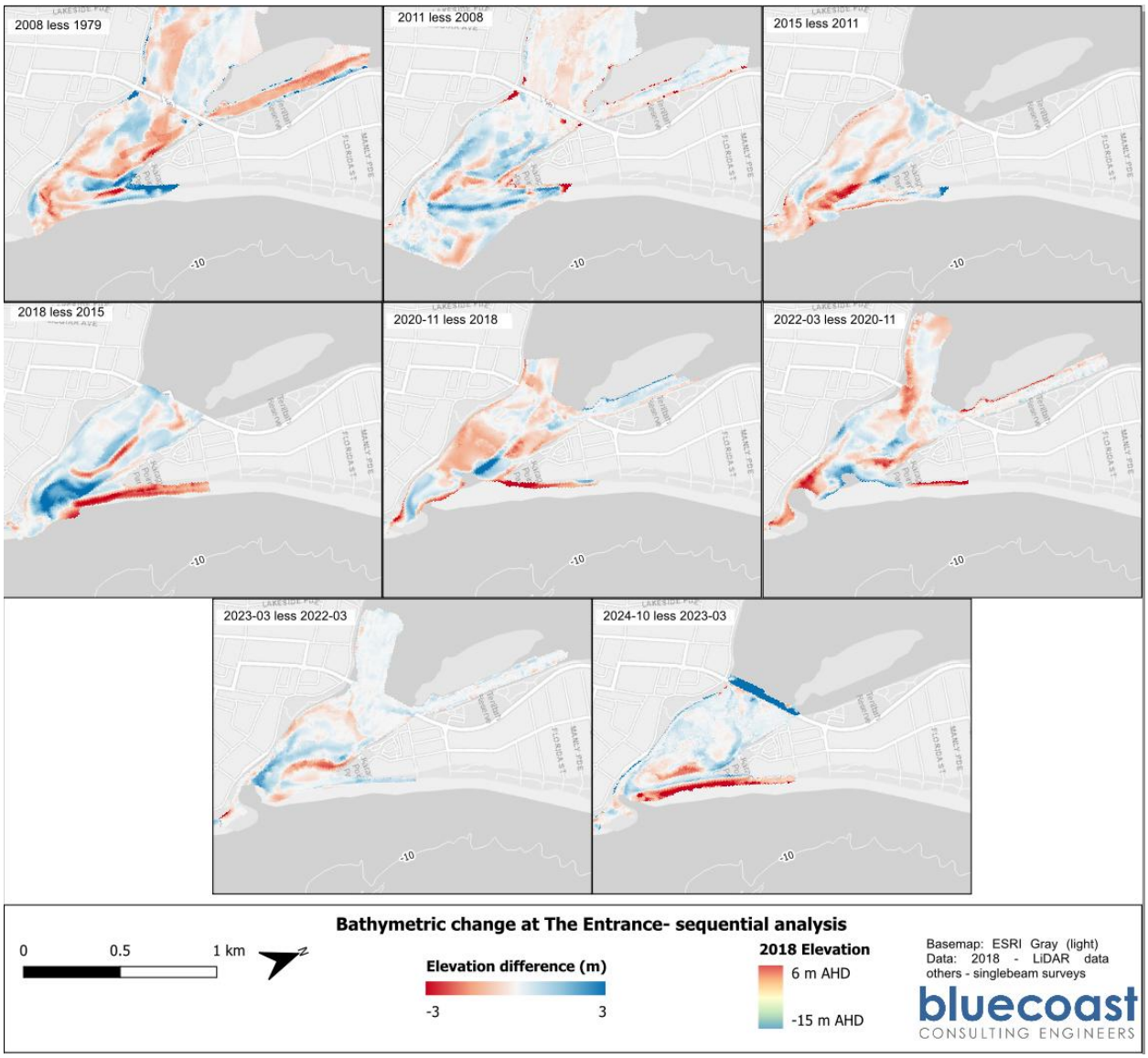


Figure 42: Sequential analysis of the seabed change within the entrance compartment.

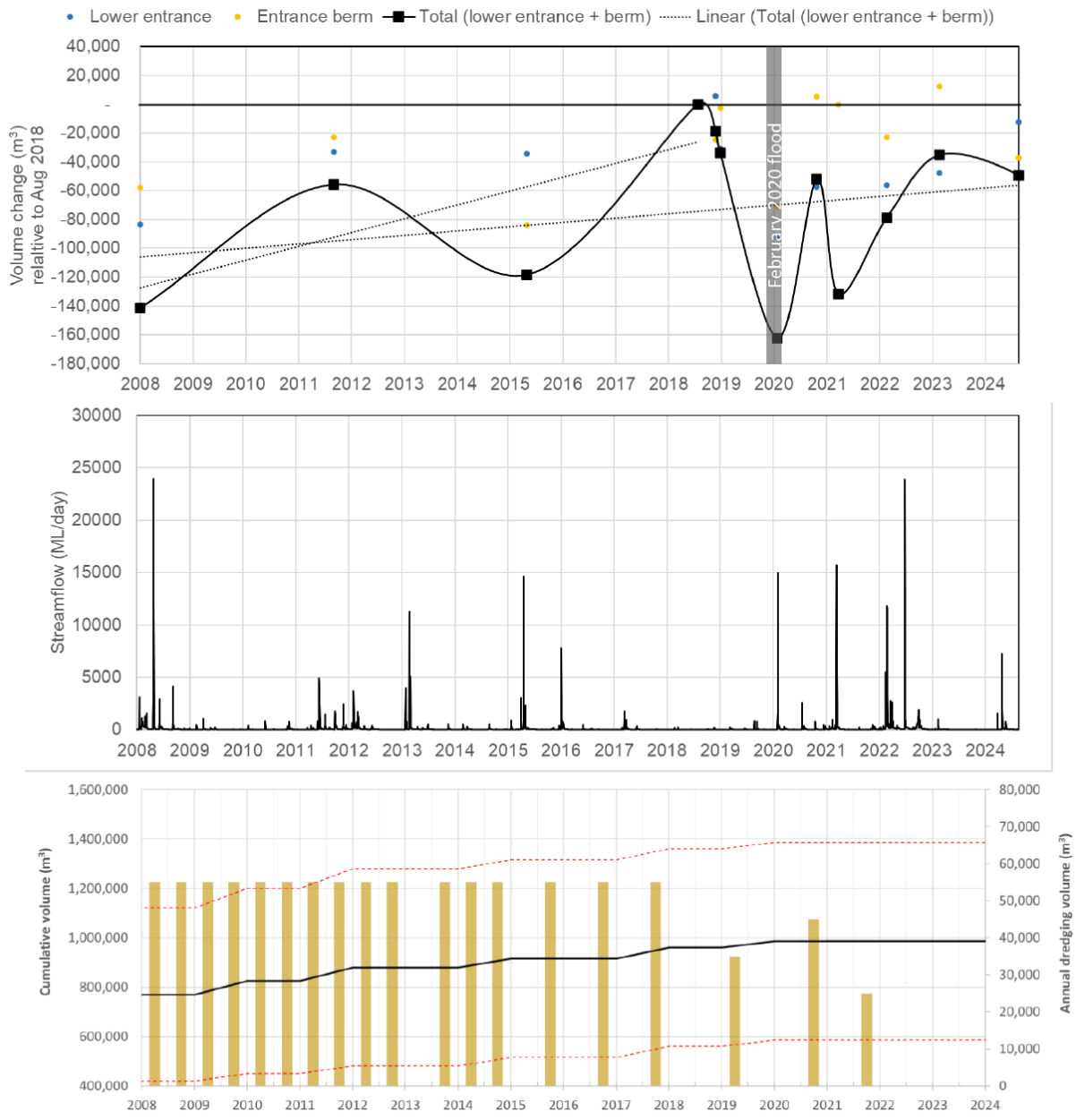


Figure 43: (top) timeseries of sand volume changes in the entrance area, (centre) Wyong River stream flow and (bottom) entrance dredging activity.

4.2.3 Discussion

The key outcomes of the entrance sand budget analysis are:

- Net infilling of the entrance area (i.e., in addition to infilling of dredged areas) appears to be marginal. Infilling rates over the lower entrance and berm are:
  - Negligible when taken as trend between 1975 and 2024
  - 2,500m³/year when taken as the trend between 2008 and 2024
  - 10,000m³/year when taken as the trend between 2008 and 2018, which was a period of generally low flow between major floods.

- That is, if the effects of floods are considered, the morphology of the lower entrance area (i.e. between berm and The Entrance bridge) appears to be in balance. Between 2008 and 2024, dredging activities removed an estimated 195,000m^3 of sand from the entrance. The survey analysis shows that volume all infilled, with a slight net increase of around 35,000m^3 above that (i.e., effectively 230,000m^3 of sand moved into the entrance with an estimated 195,000m^3 removed by dredging).

  The lack of growth of the upstream sections of the flood tide delta, particularly the 'drop-overs', provide further evidence to support a stable or marginally infilling entrance delta (see Figure 44). It is further noted that upstream of the bridge the flood tide shoals are covered in seagrasses. Glamore et al. (2020) notes that the flood tide delta upstream of the bridge is no longer active but was formed by net flood tide sand movements in the past. Umwelt (2011) suggests that these upper areas of the flood tide shoal ceased to be active in or around the 1970's and linked this to development of sandy dunes around Curtis Parade (and a reduction in wind-blown sand inputs) as well as to dredging of the channels which reduced sand movements over the shoals and encouraged colonisation by marine vegetation.

- The volume of sand stored within the lower entrance is primarily controlled by stream flow conditions. Extended periods of low stream flow allow sand to accumulate and the entrance to infill, whereas high stream flow and flood events result in scour and sand removal. By comparison, coastal storms and previous dredging activities have a lessor effect on observed sand volumes in the lower entrance area. .

- Flood scour, or a net export of:

  - 130,000m^3 of sand was inferred for the February 2020 flood[6] which had a peak flood flow of 12,608 ML/day at Wyong River's Yarramalong gauge and a peak estuary water level of 1.652m AHD at the Long Jetty tide gauge.

  - 80,000m^3 of sand was inferred for the March 2021 flood[7] which had a peak flood flow of 14,480ML/day at Wyong River's Yarramalong gauge and a peak estuary water level of 1.494m AHD at the Long Jetty tide gauge.

  Prior to the February 2020 event, a dredged ebb channel through the flood shoal was in place, however the entrance was full of sand and with an almost continuous berm across the entrance (i.e., heavily constricted). The greater export of sand and higher lake water level for the lower stream flow February 2020 event provides evidence that the preceding entrance condition resulted in a slightly higher lake level and effected the morphological response of the entrance and vice versa. MHL (2022) documents the entrance channel management measures undertaken by Council prior and during each of these events. It is further noted that other factors, such as tailwater conditions (ocean tides, storm surge and waves), rainfall patterns, catchment storages and initial lake water level have not yet been compared for the two events and may influence this outcome.

- Following the February 2020 event, 110,000m^3 of sand infilled the entrance compartment in the 5-months between sequential surveys. This equates to an annualised infilling rate of 265,000m^3/year, demonstrating that when the entrance berm is open, wave action can infill the entrance at a rate much greater than historical dredging rates.

[6] Based on survey differences between January 2019 and a post-flood survey in late February/early March 2020.
[7] Based on survey differences between November 2021 and a post-flood survey in April 2021.

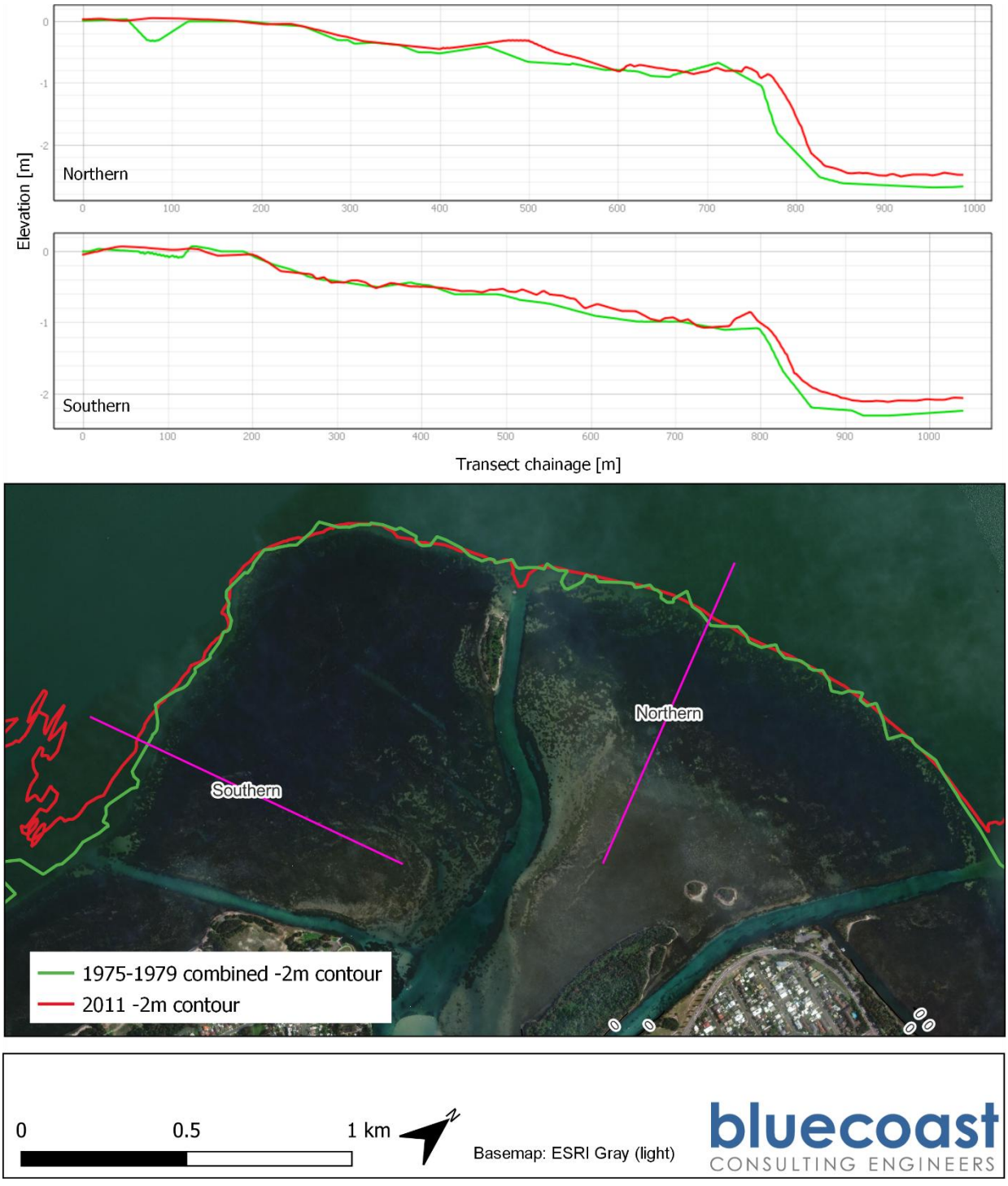


Figure 44: Comparison of the -2m AHD contour and profiles for the 1970's survey and 2011 survey on the flood tide delta edge (or 'drop-overs').

4.3 Entrance and Tuggerah Lakes dynamics

4.3.1 Approach

The entrance to the Tuggerah Lakes is a dynamic system, prone to physical changes in the short and long-term. In this section, available data has been analysed to assess any trends between entrance width and the potential flow-on effects to the wider estuary, including the functional zones within the estuary. An entrance behaviour assessment has been undertaken and used to map out the interrelationships with the estuary and other factors pertinent to informing entrance management.

To map the entrance channel width and location, survey data, aerial imagery and an open-source tool known as 'InletTracker' (Heimhuber, et al, 2021) was utilised. This tool uses Landsat and Sentinel-2 satellite imagery to track the width of the entrance over time. This entrance width can then be related to other variables within the functional zones of the estuary.

4.3.2 Results

The entrance channel was open the entirety of the analysed dataset (1992 – 2022). The analysis shows a very narrow entrance at times (<20m) while at other times the opening width can be over 500m. An example of a typical along-berm elevation profile based on survey data for a constricted and wide open entrance (post flood) is shown in Figure 45. The survey data captured the scoured flood channel from the February 2020 flood and clearly shows the effect of the Karagi Point rock shelf limiting channel scour in the southern entrance area.

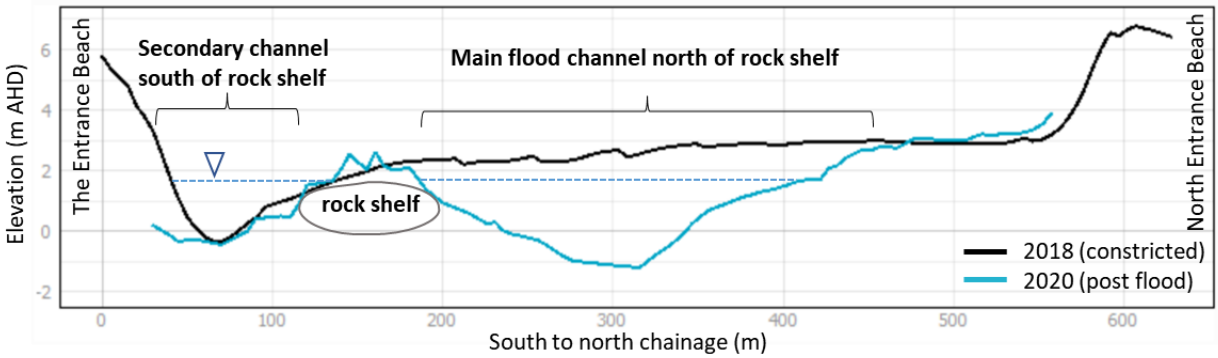


Figure 45: Along-berm elevation profile at Tuggerah Lakes entrance based on survey data.

Figure 46 shows this entrance width and location and compares this to several key physical drivers or estuarine variables (e.g. tidal levels, rainfall). A summary of the relationships between variables is provided below:

- There appears to be a positive relationship between high rainfall anomaly and resulting estuary inflows from runoff and entrance width. The recent La Niña period since 2020 highlights this relationship. High rainfall anomalies and a series of significant floods have occurred, including February 2020 and March 2021, leaving a much wider entrance. A wider entrance is also visible in the 2007 La Niña period following a significant flood in June of that year. The relationship between La Niña and wider entrance states is less clear during some La Niña periods (for example 1999 – 2001, 2010 – 2014), and it is proposed that this is likely due to the lack of significant flooding events during these La Niña periods. Persistent rainfall that may occur during a La Niña period, without a significant event, is unable to generate the flow velocities capable of significant bed scour of the entrance channel due to the lack of hydraulic grade from the estuary to the ocean.

- The inverse of the relationship is also visible during recent El Niño periods, typically with much lower rainfall than average, between 2002 – 2006, 2010, 2014 – 2016 and 2019 showing a minimal entrance width at times.
- The entrance width shows a correlation with the spring tidal range at Long Jetty, with larger tidal range when the entrance channel is wider. This is utilised by Council's Interim Entrance Management Procedure (MHL, 2022), where real-time monitoring of the M2 tidal constituent (in conjunction of camera monitoring of entrance throat width) defines the entrance state (wide open, moderately open, moderately constricted or heavily constricted – see Figure 48) and prescribes berm management procedures during a flood event.
- The entrance width shows no clear correlation with monthly mean water level in the lake. The mean water level appears to be seasonal in nature, with higher inflows during wet season (and vice versa in dry season) dominating the mean water level fluctuations.
- Also shown in Figure 46 is the nearshore wave energy, wave direction and extreme wave events at the site. There does not appear to be a clear relationship that can be drawn between the nearshore wave energy and the entrance width or location. Some major coastal storm events do align with widening of the entrance, however it is proposed that this is typically due to rainfall and subsequent flooding event associated with the coastal storm, not due to wave energy from the coastal storm opening the entrance. In fact, waves are more likely to be responsible for shoaling by assisting flood currents transport sand into the entrance.

The overall result is that the entrance channel is more likely to be open during a period of high rainfall anomaly and related flooding, which are typically associated with a La Niña period. During some periods of La Niña without significant floods, the entrance channel width can remain narrow. There does not appear to be a major influence on the entrance width and location resulting from ocean waves or storms.

The water quality of the functional zones has been incorporated into the assessment for the period that monthly water quality data has been provided by Council (2012 – 2021), as shown in Figure 47. To compare the water quality of the functional zones, Chlorophyll-a data for the lake basins (functional zone 1) and nearshore soft sediment zone at The Entrance (functional zone 2) has been compared to entrance width. Chlorophyll-a is thought to be a key functional water quality indicator for the estuary, as the key water quality issues identified by the community (seaweed growth, algal blooms, ooze) are correlated to the Chlorophyll-a value. A higher Chlorophyll-a value generally suggests more nutrients have entered the estuary, indicating a decline in water quality. To summarise the results:

- In general, water quality in the lake basins (functional zone 1) appears to show a strong relationship to water level anomaly within the estuary. As established above, water levels in the lake typically fluctuate with wet and dry seasons, suggesting water quality is typically worse in the lake basins during a wet season due to incoming nutrients.
- There is not enough data to confirm the hypothesis that the lake basins (functional zone 1) show a significant improvement in water quality after flood events. The water quality data provided only covers two significant flood events (April 2015 and February 2020). The year following the April 2015 flood event shows a slight improvement in water quality. Minimal data points have been provided post February 2020 event. However initial indications suggest a slight improvement in water quality. The latest health of the estuary report card for 2021/22 suggests minimal change in water quality in the lake basins despite this period of La Niña and several flood events.
- In general, the same relationship is visible for the lake nearshore site analysed at The Entrance (functional zone 2), with water quality generally decreasing during wet seasons. However, this nearshore zone does, at times, de-couple from the fluctuations experienced in water quality in lake basins. An example of this is during the recent La Niña period since 2020, where The Entrance

nearshore site experiences an improved water quality compared to the lake basins. Other sites within the nearshore zones (not shown in Figure 47) also show a de-coupling from the water quality, with some higher Chlorophyll-a and nutrient readings than recorded in functional zone 1.

- Overall, the water quality in the lake basins (functional zone 1) appears to be related to inflowing water, and not the width of the entrance. While it is not clear the influence flooding has on water quality with only two significant floods during the period of regular water quality monitoring, it appears that flooding (and associated significant widening of the entrance) does not have a long-lasting effect on the water quality of the lake basins.
- There also appears to be a similar relationship for the nearshore zones, with water quality in the nearshore also related to the inflowing water. The nearshore zones (functional zone 2 and 3) are also more variable and prone to greater fluctuations in water quality. This may make the nearshore zones more prone to algal blooms and other water quality issues.
- No water quality data is available within the entrance compartment (functional zone 4), however community observations, and tidal gauging of the entrance (MHL, 1993) suggest water quality of this zone is highly likely influenced by the width of the entrance. Without water quality data it is not clear how far this influence extends into the flood tide delta but evidence based on aerial imagery (shown in Figure 35 earlier in this report) suggests the entire entrance compartment (at least as far west as The Entrance bridge) is well flushed by tidal waters.
- There appears to be a southward trend in the location of the entrance commencing in around 2021. In recent years the entrance has remained at an atypically south location. This southward location has only occurred once previously within the data record (1999) and for a short duration. The current south location has been experienced consistently over the last two years of the data record (2023 – 2025). The cause of this trend cannot be confidently determined due to the short period over which it has been observed. Some signals of a southward trend can be observed following construction of the groyne in 2017. Works were undertaken by Council in 2020 to close the southern channel, which resulted in accretion along the southern shoreline, which helped keep the channel north, temporarily masking this southward trend.

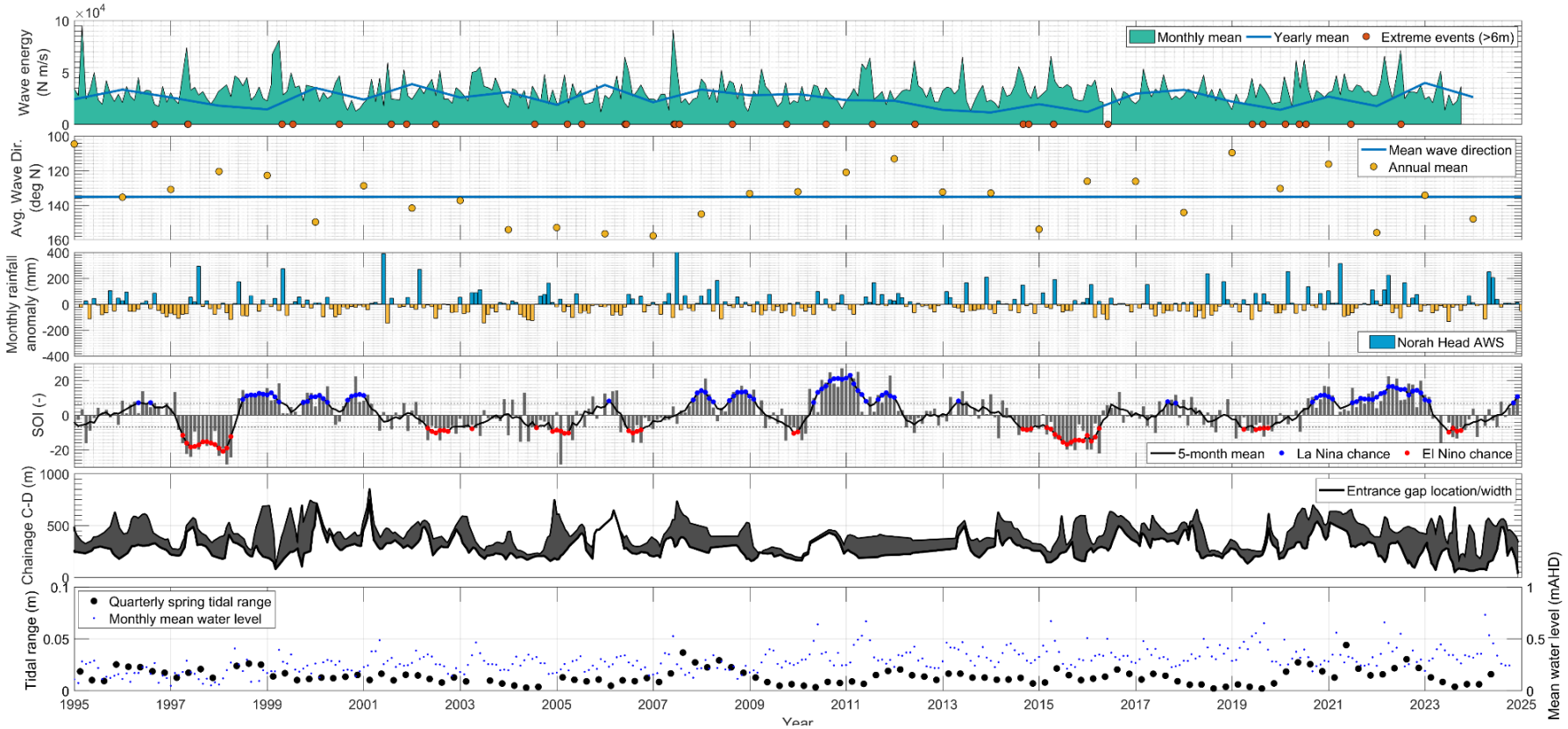


Figure 46: Timeseries of (bottom) Long Jetty quarterly spring tidal range and mean water level, (2nd panel) entrance channel behaviour* (3rd panel) SOI condition, (4th panel) monthly rainfall anomaly at Norah Head (5th panel) mean wave direction (top panel) offshore mean wave energy.

Note: *the width of the entrance gap is depicted as the grey-coloured band based on satellite imagery, with the location of the entrance being presented along an alongshore chainage from the southern embankment (0m) to the northern embankment (1000m). It should be noted that the frequency of satellite imagery used by InletTracker varies to over time as new satellites are deployed, and the best quality data available is shown in Figure 46. This means that recent time periods show a much higher frequency of imagery and more variability – it should not be interpreted that the older data is less variable.

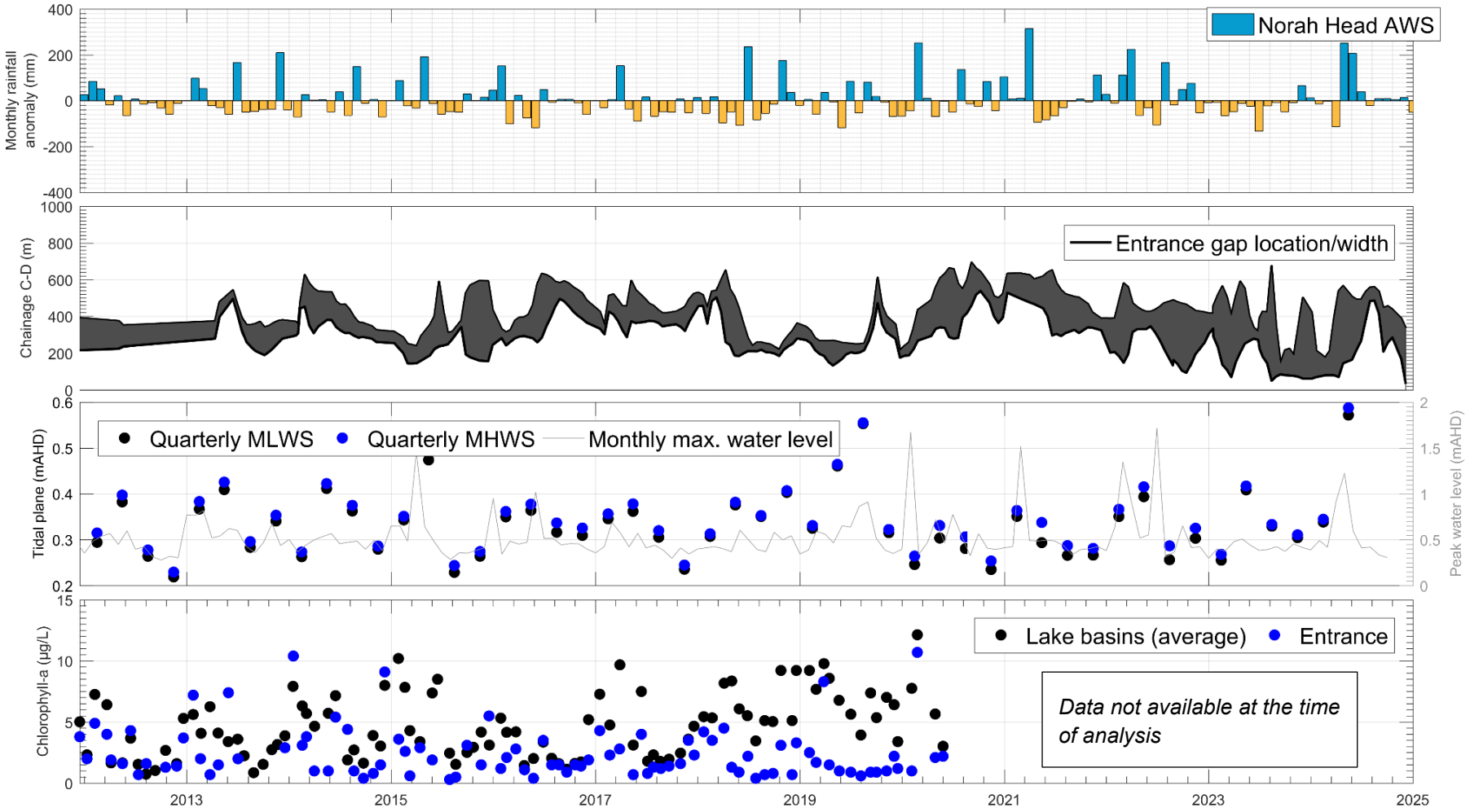


Figure 47: Timeseries of (bottom) Lake basin and The Entrance nearshore zone Chlorophyll-a monthly monitoring results, (2nd panel) Long Jetty tidal range and mean water level (3rd panel) entrance condition, (top) monthly rainfall anomaly at Norah Head.

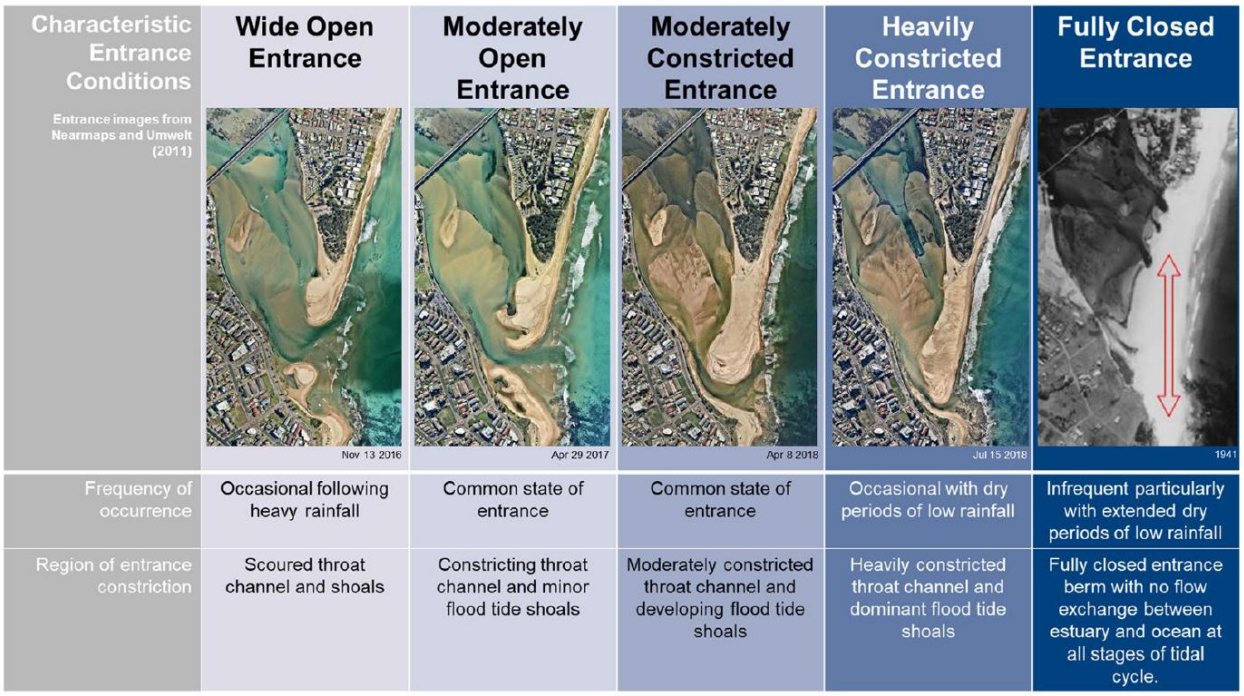


Figure 48: Entrance states as previously defined by MHL (2022).

4.4 Groyne impact assessment

4.4.1 Background

In 2017 NSW Department of Primary Industries constructed a rock groyne south of the entrance channel. The intent of the groyne was to assist in retaining sand on The Entrance Beach, directly to the south of the estuary's entrance. The beach was also nourished at this time.

On behalf of Maritime Infrastructure Delivery Office (MIDO), the asset owner, Salients (2021, 2022 and 2024) undertook a review on the performance of the groyne, including assessing aerial imagery and hydrographic and beach profile surveys. The review found that whilst there was not enough post-groyne data available to establish definitive trends, initial indications are that of a reduction in recession rate on The Entrance Beach. The review also noted that the beach to the north of the groyne is highly variable due to the dynamic nature of the entrance, with a maximum width between 100 to 130m prior to groyne construction and a consistent decrease in beach width since.

Salients (2024) suggest that the groyne's construction has reduced sand supply to the entrance from the south, allowing the entrance channel to migrate further south. In this configuration, tidal flows are observed to concentrate between the rock shelf and a somewhat permanent (over recent years) scoured area immediately north of the groyne which keeps the entrance marginally open but with limited ocean exchange.

The impacts of the groyne on shoreline and entrance behaviour have been further assessed in this study and results are provided in the following sections. To further assess the impacts of the groyne:

- Digital Earth Australia's (DEA) mean annual shorelines for the period 1988 to 2021 were analysed. These shorelines are generated by combining satellite data and tidal modelling to produce an average yearly shoreline at mean sea level (see Figure 49).
- Sand volume changes in the cells updrift and downdrift of the groyne (see analysis cells in Figure 49), as derived from the sand budget analysis, were assessed (see Figure 52).

- A review of aerial imagery was undertaken (see Figure 53).

4.4.2 Shoreline impacts

The historic mean annual shoreline behaviour (based on DEA) pre- and post-construction of the groyne is shown in Figure 49. Prior to groyne construction, The Entrance Beach had a mean annual beach width in the range of 14 to 51m (measured to the revetment in front of The Entrance Surf Club), with a median width of approximately 35m. Between the construction of the groyne and the latest available data (2023), the mean annual beach width has remained approximately at that median beach width, with minimal change. Cardno (2015) reporting on the groyne estimated a 7 to 10-year period before additional nourishment at The Entrance Beach would be required (from a 5 year period without groyne). This small improvement in beach stability is difficult to identify over the short time period of the analysis.

Immediately north of the groyne, on the southern side of the entrance channel, the available data shows considerable shoreline recession over this period exposing the foreshore rock revetment as evident in the photograph presented in Figure 50. The data indicates the mean annual beach width at this location has reduced from a typical beach width range of 95 – 120m, to 30 – 40m in more recent years along an alongshore distance of up to around 150m north of the groyne. In the year following construction of the groyne (2018) there was around 25m recession in the mean annual shoreline position.

Figure 51 provides a comparison of surveys relative to 2018 (shortly following construction of the groyne). This shows a consistent reduction in subaerial and subaqueous beach levels north of the groyne following its construction. Figure 52 provides a timeseries of surveyed sand volume changes either side of the groyne. Similar to the DEA shorelines, it shows that the groyne appears to have had a stabilising effect on the southern (updrift) beach. Downdrift (north) of the groyne, a prior (2006 to 2014) trend of sand volume reduction appears to have accelerated following the introduction of the groyne. In general, there is a high variability in downdrift sand volumes which is likely influenced by periodic flood scour of the entrance area as well as entrance management works by Council, including nourishment of the southern entrance in 2020 (see Section 2.2.2). While the results of this analysis indicate a reduction in sand volumes downdrift of the groyne, it is noted that the time period for the analysis (2017 to 2024) is likely insufficient to fully isolate such impacts from longer term climate drivers of entrance behaviour discussed in Section 4.2 and 4.3. The aerial imagery presented in Figure 53 show the significant evolution of the entrance since construction of the groyne in 2017. Council's entrance management works in 2020 which led to an opening of the entrance channel to the north followed by southward migration of the entrance can be observed.

In summary, the analysis of imagery, survey data and mean annual shoreline positions suggest that the installation of the groyne has reduced the amount of sand reaching the beach north of the groyne, including the berm that typically overlies the rock shelf. As per Salients (2024), this has led to recession of this section of beach. This is a typical pattern of erosion that occurs downdrift of shore perpendicular structures. While it is apparent that downdrift realignment of the shoreline has occurred due to the presence of the groyne, it is expected that the beach conditions at Karagi Point and along the southern entrance area continue to be heavily influenced by the wider entrance behaviour. The processes driving variability in the entrance behaviour have been described earlier in this report.

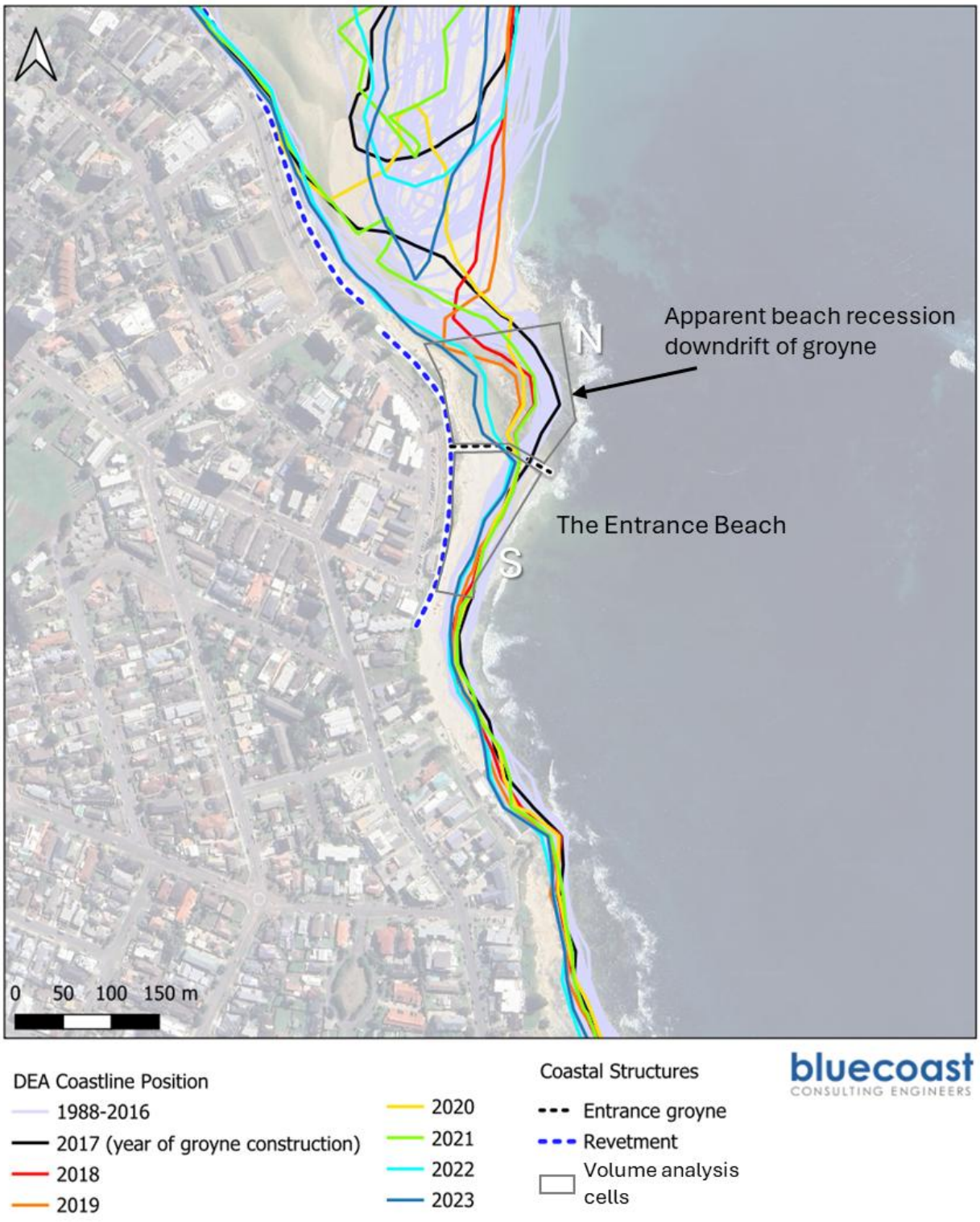


Figure 49: Historic DEA shorelines from satellite imagery – highlighting pre and post-groyne construction.

Figure 50: Photograph showing eroded area downdrift (north) of groyne and opened pilot channel in May 2025 (source: Chris Drummond/ DCCEEW).

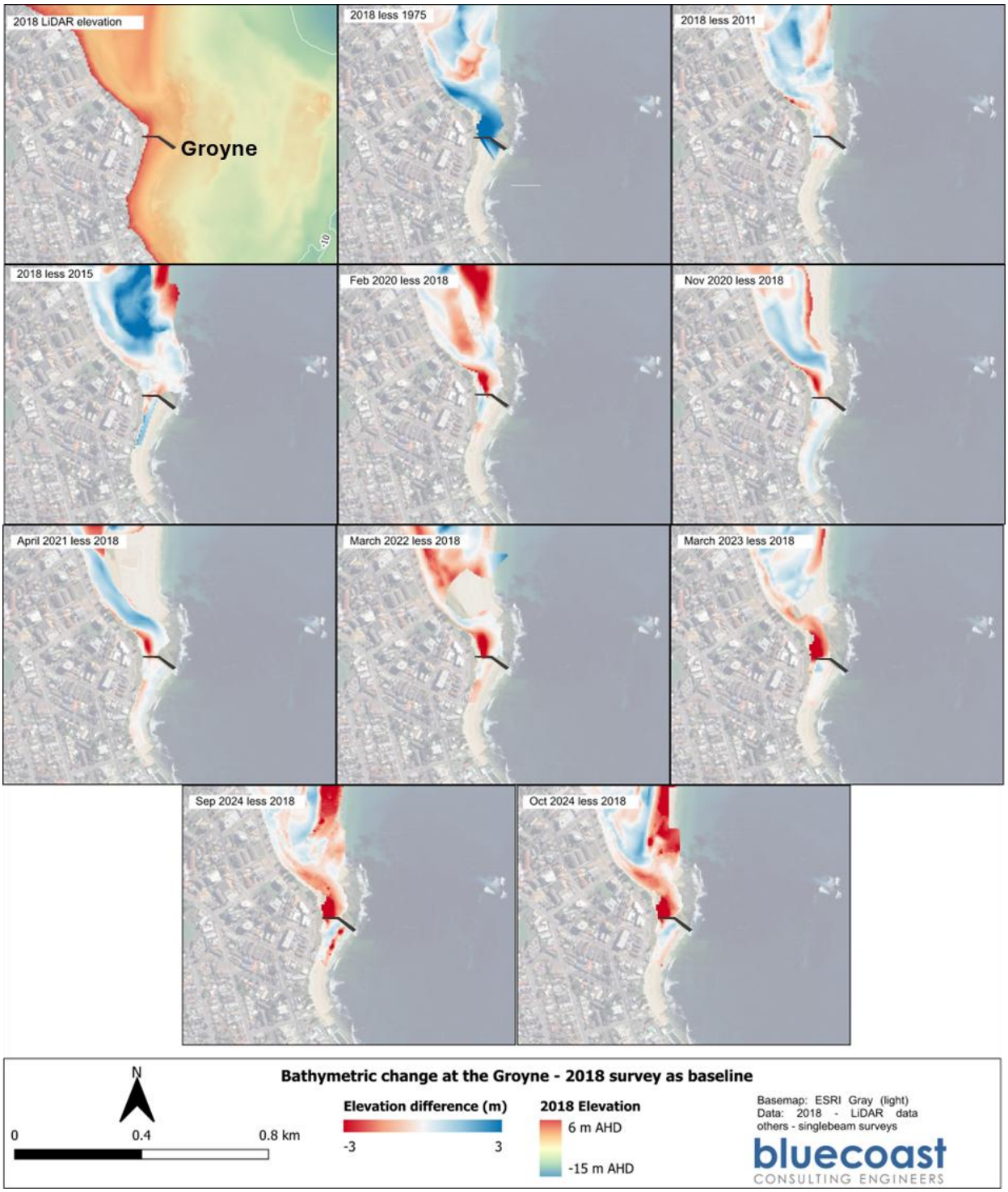


Figure 51: Seabed elevation change around the groyne relative to 2018 survey.

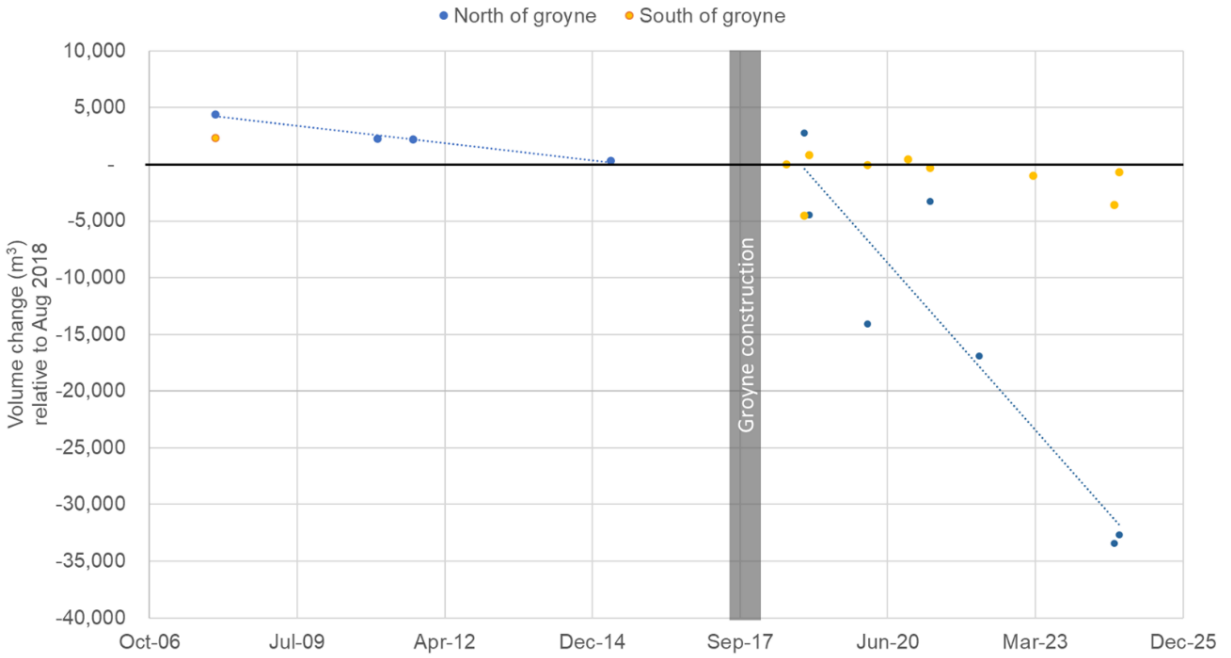


Figure 52: Timeseries of sand volume change either side of the groyne (analysis cells shown in Figure 49).

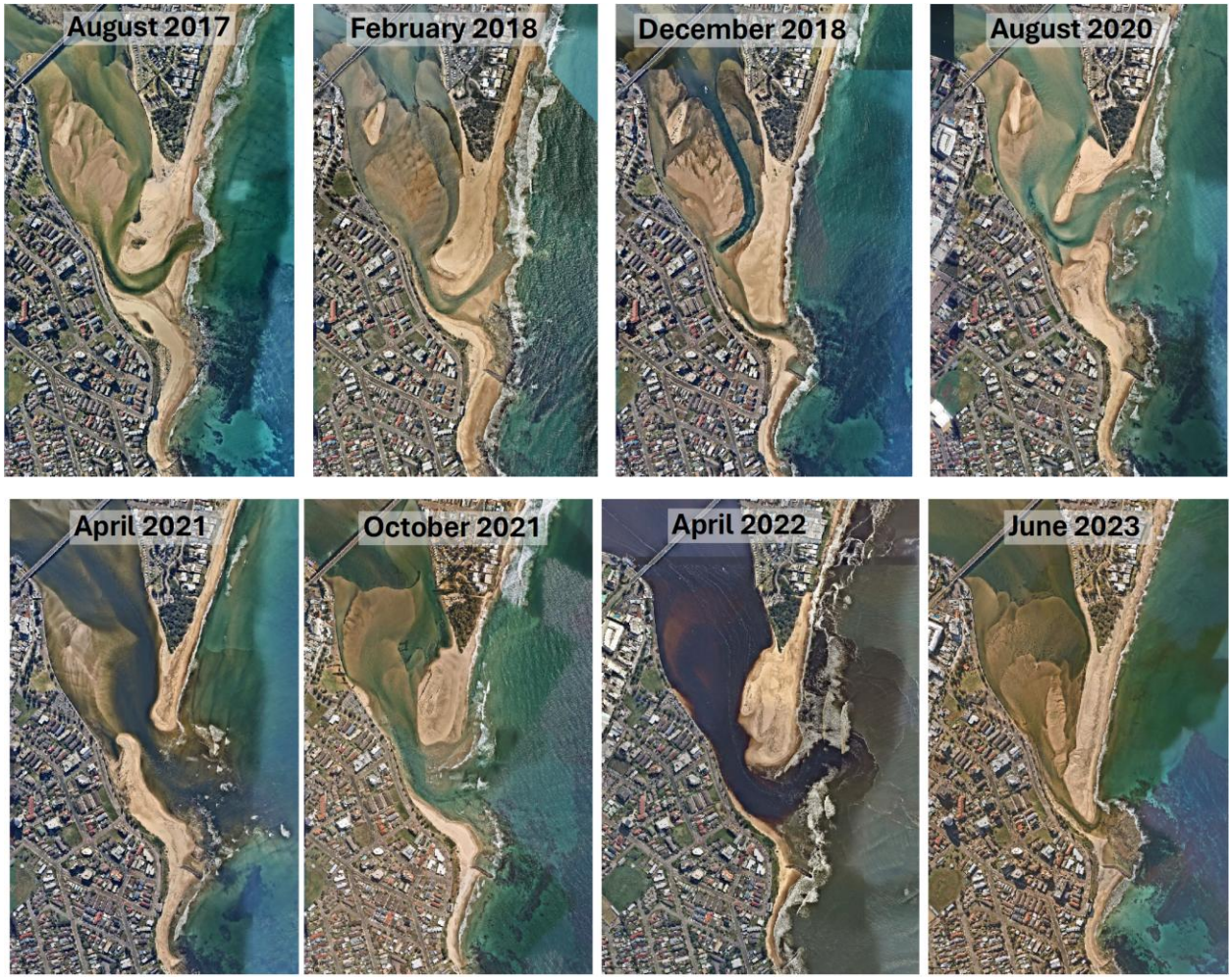


Figure 53: Aerial imagery showing various entrance conditions since construction of groyne in 2017.

4.4.3 Entrance location

The groyne construction may have the potential to influence the location of the entrance channel's discharge location. As described earlier in the report, Salients (2024) suggest that the groyne's construction has reduced sand supply to the entrance from the south, allowing the entrance channel to migrate further south in more recent years.

Review of satellite imagery since 1995 using the InletTracker tool (as presented in Figure 46), provides some initial evidence of the entrance channel trending towards a more southerly location following installation of the groyne. The recent location of the entrance channel is at the most southerly location observed in several decades (see example photographs in Figure 54 and Figure 55), despite having cycled through various drought and floods over this period. This location has been consistent since 2023 whilst previous occurrences of a southern entrance location (1999) have been short-lived (refer Figure 46). The location of the channel is influenced by a range of factors which cannot be isolated from the analysis over a period of only 8 years since construction of the groyne. Hence, a permanent or more frequent entrance channel location at a more southerly location since the construction of the groyne cannot yet be concluded.

Glamore, et al (2020) note that ICOLL entrances tend to migrate (over millennia time periods) to locations where more coastal protection is afforded, in the case of Tuggerah Lakes estuary this entrance migration has resulted in the entrance channel typically located in the shadow of the raised Karagi Point rock shelf providing protection from south-easterly swells. It is possible that, over a long time period, the groyne could also provide some of this swell protection, resulting in a more permanent long-term shift to the south.

Council staff (personal comms, 2022) also noted that recent flood events, especially the 2020 event, discharged further south than usual (see Figure 53). This results in more of a bend in the downstream section of entrance channel and a reduction in hydraulic efficiency. The entrance channel discharging further south also results in discharging water hitting the Karagi Point rock shelf (which cannot be scoured unlike the sand further north), further reducing the hydraulic efficiency of the entrance during flood events. With a pre-flood entrance channel location on or to the south of the rock shelf, it is expected that during large flood events the main flood channel would eventually (naturally) form north of the rock shelf (see Figure 45 above). However, this may result in a slightly delayed scouring process when compared to a pre-flood entrance channel located to the north of the rock shelf which could have implications on the magnitude and duration of peak flood levels within Tuggerah Lakes. Similarly, this may impact moderate flood events that usually have lower natural scouring potential. However, confirming the sensitivity of peak flood levels within Tuggerah Lakes to the pre-flood entrance channel location and the scouring processes influenced by the groyne requires detailed flood modelling.

A key element in MHL's (2022) Interim Entrance Management Procedure is berm scraping to encourage the entrance channel to scour and accelerate natural northward migration. However, with the channel currently occupying its recent southern alignment around the rock shelf, the procedure requires Council to excavate a pilot channel to redirect it northward (pers. comms., 2025). If the groyne continues to promote a more southerly channel position, this is likely to necessitate more frequent and more extensive intervention works.

Figure 54: Photographs of southern channel location in (left) February and (right) March 2025 (source: CCC).

Figure 55: Example aerial imagery showing entrance in 'heavily constricted' conditions over past 50 years (source: NSW Government and Nearmap).

4.5 Quantified conceptual sand movement model

Figure 56 and Figure 57 provide a graphical overview of the quantified conceptual model of sand movements (quantified model) for the northern Central Coast and Tuggerah Lakes entrance. The models are based on the Tuggerah Lakes sand budget (described in Section 4.2), and additional regional analysis undertaken as part of the Central Coast LGA coastal hazard assessment (Bluecoast, 2023).

The observed sand movements and key processes were identified based on observational data, previous literature, available numerical modelling results and/or coastal processes knowledge. Wherever possible, multiple lines of evidence have been used to cross-check, validate and provide greater confidence in the findings.

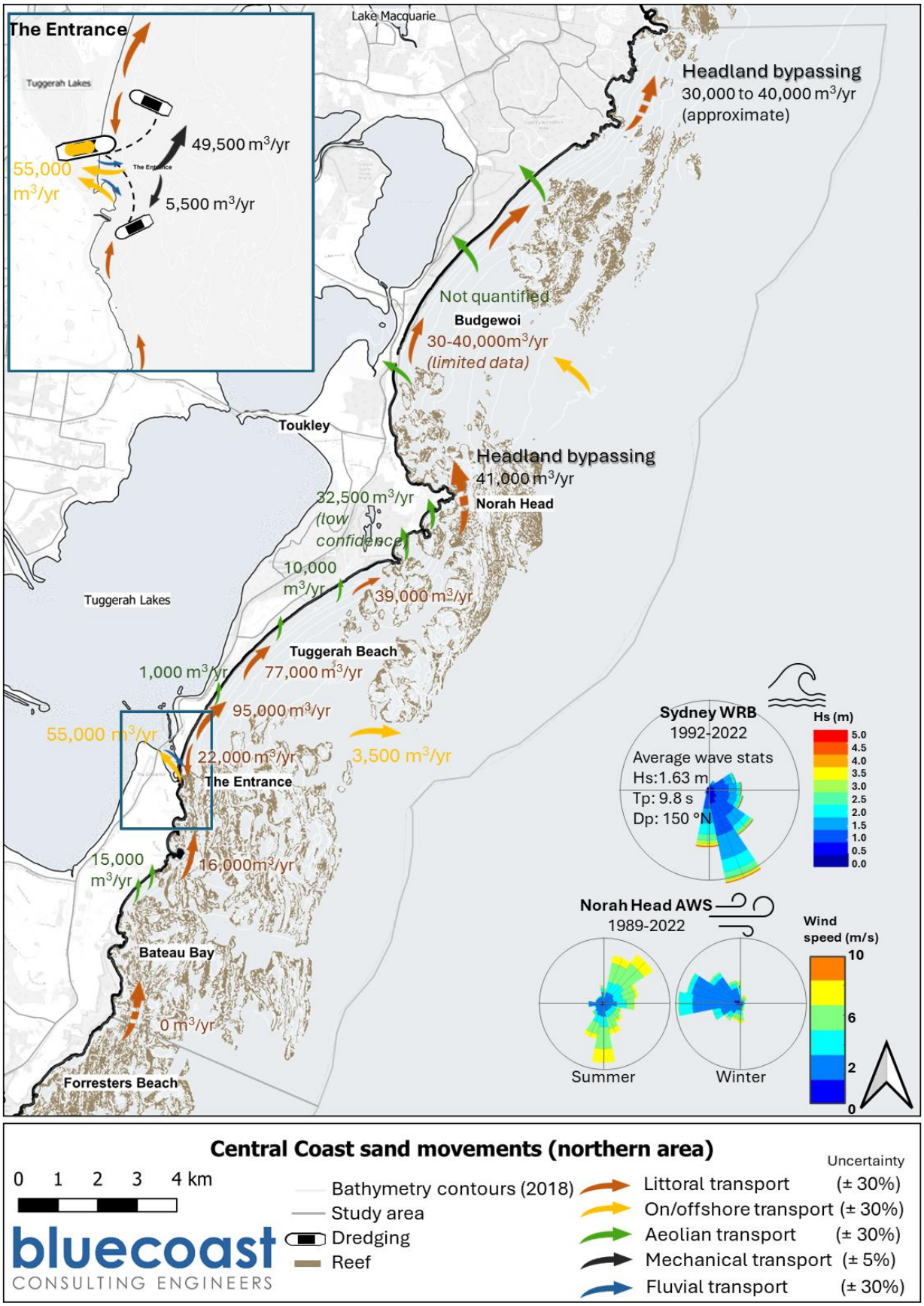


Figure 56: Quantified conceptual model of contemporary sand movements for the northern Central Coast.

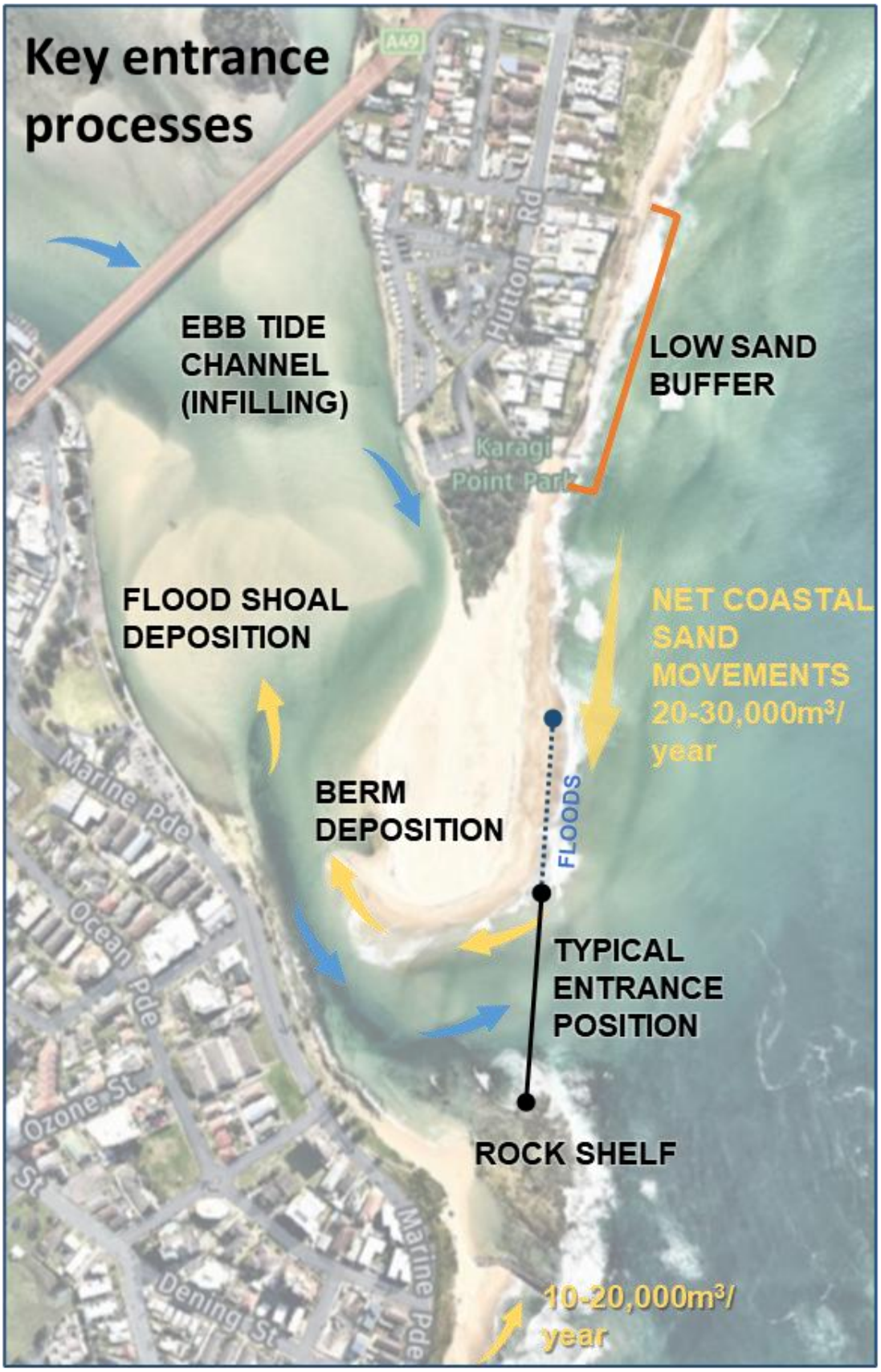


Figure 57: Key contemporary coastal and estuarine processes identified at Tuggerah Lakes entrance.

5. Socio-economic assessment

5.1 Overview

This section provides an overview of the socio-economic aspects of the Tuggerah Lakes estuary, as well as a high-level valuation of the estuary and the potential dependency of this value upon entrance state, in particular, entrance channel water clarity and flow conditions. This valuation will help inform management options for the entrance.

The valuation was undertaken in consideration of both **use** and **non-use** values. Use values derived from both survey and historic data, focused on which activities visitors conducted on a typical trip and how frequently these activities occurred. Non-use values were estimated based on literature review and previous economic studies of existence and conservation values, regardless of use or access. Also included in the non-use valuations were considerations of the associated ecosystem services such as possible flood mitigation benefits.

5.1.1 Objective

Th objective of the Socio-economic assessment was to explore the values community place on Tuggerah Lakes entrance, and what potential impacts particular management actions may have on these places and values and in particular to quantify the benefits of a clear and flowing channel.

5.2 Social and economic context

The Tuggerah Lakes project's area of social influence is potentially vast given the array of social, environmental, and socio-economic interdependencies between the Tuggerah Lakes estuary, the open coast, and the economies and communities of NSW. It is important to recognise that the current condition of the Tuggerah Lakes estuary has a significant influence on tourism and maritime activity in the region, with users varying from local through to regional and interstate individuals. As such any social impact assessment needs to consider the full extent of potential users and associated drivers. For the purposes of this preliminary study, the focus has been upon regional and local users and drivers, as these represent the majority of individuals interacting with the Lakes and potentially affected by changes to entrance conditions.

The project area of social influence is described in this sub-section in terms of:

- Land and natural resources present, and how they are used
- Housing and business structures that characterise the area
- Population welfare, health and freedoms (including health, crime and education)
- Infrastructure and public services present, and their utilisation
- Livelihoods and activities
- Community, social supports and political context (including opinion regarding the project)
- Vulnerable groups
- Indigenous peoples.

5.2.1 Land and natural resources and their utilisation

The study area provides a diversity of land and natural resources that support the livelihood of many residents and businesses in the region. These resources can be described through the ecosystem services provided to affected communities and individuals. Key ecosystem services provided by the estuary and the associated shoreline that support local communities include:

- Provisioning services –
    - Food from fish – Habitats provided by the estuary and open coast play a critical part in ecosystem function, with the close connection between, and structural complexity of, saltmarsh and seagrass habitats supplying shelter and protection for larval and juvenile aquatic species, after which some remain in the estuary and move out to coastal waters. Recreational and commercial fisheries operating on the estuary and along the open coast are dependent upon this function.
- Regulation and maintenance services – Regulation and maintenance services mediate key processes that maintain our marine and coastal environments. For the Tuggerah Lakes estuary this includes –
    - Regulation of base flows and extreme events. Extreme events such as coastal storms result in coastal inundation and beach erosion, which can cause damage to coastal infrastructure including houses, roads and bridges. The entrance to Tuggerah Lakes partially serves to attenuate wave energy and protect the shoreline from erosion from storms and mitigate the loss of coastal land from chronic erosion and inundation. The estuary stores and conveys floodwaters from the catchment to the coast, reducing the costs of flooding across an array of rainfall events.
    - The Tuggerah Lakes also supports the processing of wastes of anthropogenic origin, whereby plants, algae and other organisms' cycle and assimilate nutrients and other pollutants (e.g. wastewater and heavy metals), reducing the incidence of broader adverse effects on the environment, especially in and along the coast.
    - Estuarine macrophytes, like saltmarsh and seagrass have been identified as being extremely efficient at sequestering carbon per unit area, more so than terrestrial vegetation.
    - The estuary provides a sand resource through the periodic build-up of sand in and around the entrance to the estuary. In the past this has been dredged by Council and moved to sites where sand nourishment is required.
- Cultural services –
    - For both residents and tourists, the physical and experiential interactions with the natural environment support substantial socio-cultural activities. Birdwatching, fishing, beach-going and water sports are key activities conducted on the lake and the open coastline. The social value of these activities is high, with physical and psychological benefits from activities undertaken including improved cardiovascular condition, reduced obesity, improved mood and attention, and reduced levels of stress.
- Community value to the Darkinjung People – the landscape has and will continue to be actively used and managed by the Darkinjung and other Indigenous people.

Estuary and Open Coast access

Access to and from the Tuggerah Lakes, as well along its foreshore is substantial and is provided through numerous formal paths, roads, and informal bush trails, including over twenty public reserves near to Tuggerah Lakes.

Lands adjacent to the estuary include a combination of private and public lands. In addition to the reserves mentioned above, there are several national and state parks present including Wyrrabalong National Park, Tuggerah Nature Reserve, Munmorah State Conservation Area along with other smaller parklands.

When broken down further, private lands bordering the lakes are in the vast majority residential (650 properties), with about 106 commercial operations bordering the estuary and its tributaries.

There are 20 public boat ramps that allow individuals to launch vessels within the estuary. Moreover, numerous private properties maintain private jetty access to the estuary, particularly around Lake Haven and Toukley.

In terms of access to coastal waters and beaches, the existing sandbanks at the entrance to the estuary are used by locals and tourists for recreation depending on their condition.

Open coast beaches adjacent to the Tuggerah Lakes are accessible via a variety of roads, boardwalks and both informal and formal trails. There is no authorised public vehicle access on the beaches or the Tuggerah Lakes foreshore. However, limited authorised access (e.g., for Council, commercial fishers, surf lifesaving etc.) exists to support management and operations.

5.2.2 Housing and business structures

Housing and business structures provide insight into the residential and commercial landscape of the area. This information helps in understanding the distribution of property ownership, the density and type of housing, and the availability of commercial services, all of which are crucial for planning and management. By assessing these aspects, it is possible to identify the trends and the economic health of the communities surrounding the Tuggerah Lakes.

Table 11 summarises the housing stock and ownership status for key areas in the investigation area. It is noticeable that the coastal communities, particularly Budgewoi, Buff Point, Halekulani, Lake Munmorah and Mannering Park have higher rates of residential ownership than other lake-side communities. The Entrance is an outlier due to its high proportion of medium to high density housing stock, reflecting one of the few high-rise areas in the Central Coast LGA.

Table 11: House Stock and Ownership for SA2* areas surrounding the Tuggerah Lakes.

Attribute	The Entrance	Toukley, Norah Head	Bateau Bay, Killarney Vale	Chittaway Bay, Tumbi Umbi	Tuggerah, Kangy Angy	Wyong	Gorokan, Kanwal, Charmhaven	Budgewoi, Buff Point, Halekulani	Blue Haven, San Remo	Lake Munmorah, Mannering Park
Housing Stock										
Freestanding house	47.8%	73.4%	84.5%	89.3%	80.2%	79.7%	80.9%	93.3%	97.8%	97.8%
Medium to high density	50.8%	25.1%	15.3%	10.6%	19.8%	19.0%	17.6%	5.4%	2.0%	1.6%
Other (e.g., caravan, houseboat)	1.4%	1.4%	0.1%	0.1%	0.0%	1.3%	1.5%	1.4%	0.2%	0.6%
Housing Ownership										
Owned	31.6%	38.7%	33.6%	33.8%	28.6%	28.8%	33.6%	40.5%	25.8%	48.8%
Purchasing	19.7%	24.4%	36.7%	43.7%	38.7%	28.7%	31.4%	31.6%	41.4%	30.2%
Renting	44.6%	32.3%	24.6%	18.2%	29.8%	39.0%	30.1%	23.7%	29.6%	17.1%

*SA2 = Statistical Area 2 – the statistical areas adopted by the Australian Bureau of Statistics to aggregate socio-economic data, approximately equivalent to suburb area/extents and population size.

Across the LGA, approximately 9.5 per cent of households are in housing stress; that is, spending more than 30 per cent of their gross household income on either rent or mortgage repayments (excluding high income households) (ABS, 2016). Of those with mortgages, approximately 7 per cent face mortgage stress, compared to a regional NSW state average of 12 per cent. Of those renting, 12 per cent are in rental stress, compared to a regional NSW state average of 35 per cent. The stress associated with housing is also a function of rising housing prices. The average price for a house ($690,000) and unit ($491,000) level properties in the Central Coast LGA are lower compared to Greater Sydney and the NSW average. However, over the five years prior to COVID-19, the Central Coast LGA has consistently exceeded the growth rate of the Greater Sydney and NSW average housing price rises. This comparative increase in housing and rental prices is likely to increase the occurrence of housing stress in the region in the future census (2022/23).

The increasing demand for housing is also reflected in increased development activity in the region. Over 8,275 building approvals were issued in the LGA in the last five years, 20 per cent of which were issued in 2019. Of the SA2's bordering the Tuggerah Lakes, Gorokan – Kanwal – Charmhaven area had 311 developments, whilst The Entrance had 340 and Chittaway Bay – Tumbi Umbi had 265 within the past five years. Developments within the Tuggerah Lakes region have been significantly hampered by the rise in the cost of labour, economic downturn, and the historic floods, reducing the capacity of the construction sector within the region.

The key industry in the Tuggerah Lakes area is Health Care and Social Assistance, which out of the ten SA2 areas leads employment in nine of them, with the only differing SA2 being the construction industry leading employment in the Lake Munmorah, Mannering Park Area.

The high proportion of rental, hiring and real estate services on the Central Coast is likely associated with the proximity to Greater Sydney. Coupled with the higher proportion of the private ownership of properties within the coastal communities, this industry trend is suggestive of the common scenario observed across the NSW coast of higher socio-economic ownership in high tourist demand communities, in which property owners do not reside permanently in the region but have a holiday home there. This is highlighted by the high visitation to the Central Coast LGA, with over 5.2 million individual trips per year to the coastline (National Visitor Survey 2022). A vast majority of these trips are from Sydney and Newcastle (70%). In terms of Tuggerah Lakes, this assessment has estimated approximately 1 million tourist trips per year.

With the higher socio-economic presence in the area, there are greater numbers of purchases of goods and services (e.g., going out to eat), and greater participation by communities in recreational activities which require greater expenditure like boating. This participation is comparatively larger than the states average, not due to the socio-economic status of the communities but the ease of access to waterways and other natural assets.

5.2.3 Population welfare, health, and freedoms

The Central Coast LGA has an estimated population of 358,826 in 2021, which is forecast to grow to 414,615 by 2036 with an average annual growth rate of 1.55 per cent (idcommunities, 2022). One of the largest SA2 by population, Bateau Bay – Killarney Vale has 25,400 residents in 2022, and forecasted to increase by 8 per cent by 2036. However, the greatest forecasted growth area is for the Warnervale-Wallarah-Bushells Ridge statistical area, in which the population is set to increase sevenfold by 2036. This large growth is forecast due to the large-scale housing developments in the district. Table 12 summarises key demographic characteristics of the communities surrounding Tuggerah Lakes.

Table 12: Population Characteristics for SA2 areas surrounding the Tuggerah Lakes.

Attribute	The Entrance	Toukley, Norah Head	Bateau Bay, Killarney Vale	Chittaway Bay, Tumbi Umbi	Tuggerah, Kangy Angy	Wyong	Gorokan, Kanwal, Charmhaven	Budgewoi, Buff Point, Halekulani	Blue Haven, San Remo	Lake Munmorah, Mannering Park
Population	15,925	10,341	22,656	15,739	5,478	9,286	22,796	9,843	11,319	11,291
Average household size	2.1	2.2	2.6	3.1	3.1	3.0	3.0	2.8	3.1	2.8
Age Structure (%)										
0-19 years old	20.3	21.9	25.9	26	26.9	26	24.7	22.5	30.8	20.3
20-59 years old	46.6	45	47.3	49.7	51.8	50	47.5	45.8	50.2	42.2
60+ years old	33.2	33.4	26.6	24.1	21.3	24.3	27.6	31.6	19.2	37.5
Main method of Travel to Work	Car (74.7%)	Car (76.2%)	Car (77.9%)	Car (77.8%)	Car (72.7%)	Car (73.3%)	Car (76.0%)	Car (77.4%)	Car (80.8%)	Car (79.0%)
Unemployment (% unemployed)	8.2	8.0	6.3	5.9	6.4	10.0	9.0	8.8	9.3	7.5

The car is the main method of transport to access work (as a driver or a passenger), reflecting the geographic isolation of many of the centres, as well as the low availability of public transport options. Boat ownership is high in comparison to the state average, with the Central Coast area having an ownership percentage of 4.6 per cent, whilst the state average is 2.8 per cent.

The Central Coast LGA unemployment rate is almost the same as the regional NSW average (4.6 per cent) at 4.7 per cent. The level of unemployment also strongly reflects the socio-economic welfare of the communities within the region. The region contains pockets of relatively low socio-economic welfare communities, as estimated by the Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Disadvantage (Table 13). Aside from Tuggerah- Kangy Angy, all SA2 areas in the investigation area are in the bottom 45 per cent of all communities across Australia in terms of their relative socio-economic disadvantage, with Toukley, Norah Head and Gorokan, Kanwal, Charmhaven in the lowest 15 per cent. There exists significant opportunity for improvement regarding the socio-economic welfare of the region.

Table 13: Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Disadvantage for Tuggerah Lakes SA2 Areas.

Area	2016 Index	Percentile
The Entrance	994.6	42
Toukley, Norah Head	926.3	15

Area	2016 Index	Percentile
Bateau Bay, Killarney Vale	994.9	42
Chittaway Bay, Tumbi Umbi	989.2	39
Tuggerah, Kangy Angy	1,023.9	60
Wyong	945.7	20
Gorokan, Kanwal, Charmhaven	912.7	12
Budgewoi, Buff Point, Halekulani	940.5	19
Blue Haven, San Remo	943.1	20
Lake Munmorah, Mannering Park	960.8	25
Central Coast Council LGA	989.0	39
Regional NSW	971.0	29

In terms of crime, the region has above average robbery and theft rates. The LGA reported 1,616 domestic violence-related assaults and 1,390 non-domestic violence-related assaults between July 2021 and July 2022 (NSW Government 2022). The most common drug offence in the Central Coast district is cannabis use and/or possession, followed by amphetamines and cannabis.

The study area is located within the Central Coast Local Health District (CCLHD), with the Wyong Public Hospital the major emergency service provider in the area. Co-located with the health service is the Berkeley Vale Private Hospital, Public Dental Clinic, Mental Health Service and Drug and Alcohol Service, incorporating the Methadone Treatment Unit.

In terms of disabilities, 7.0 per cent of the population of the Central Coast LGA need help or assistance with core activities (i.e., over 24,400 individuals). This is marginally higher than the NSW average of 5.4 per cent.

5.2.4 Infrastructure and public services

The Local and State Governments support an array of public infrastructure and services in the region. In terms of housing, the LGA contains over 4,475 social housing residential dwellings, the majority of which were Public or Community Housing.

Central Coast Council provides water supplies across the LGA, from a system comprising of three dams, three weirs and over 50 reservoirs. Council also provides sewage services across the region. While reticulated services for both water and sewage are extensive, some more rural areas and properties are not serviced and rely on stormwater harvesting or private river extraction for water supply and septic tanks for storage. However, the vast majority of residences are connected to the Council services.

There are a few public transport options for travel to Tuggerah Lakes within the Central Coast LGA. The Central Coast and Newcastle Train Line which runs through Tuggerah, Wyong and Warnervale stations,

is adjacent to the Lakes area. There are 16 bus routes that provide accessibility to the Tuggerah Lakes area, with services provided by Red Bus Services and Busways.

An array of public (roads, footpaths, buildings, stormwater drainage etc.) and private (housing, fencing, etc.) infrastructure exists in proximity to the estuary and are exposed to flood damages. The total tangible flood damages for residential properties, commercial properties and the public sector were estimated as part of the Wyong River Catchment Floodplain Risk Management Study & Draft Plan (Catchment Simulation Solutions, 2019) prepared for Central Coast Council. An average annual flood damage of $2,200,000 was estimated.

5.2.5 Livelihoods and activities

The Central Coast Council LGA supports over 120,000 jobs and has an annual economic output of $15.14 billion (idEconomics 2022). The interdependencies of the Tuggerah Lakes and local economy include not only direct employment benefits, but leisure and recreational values. It is estimated that there are 2.5 million trips to the Tuggerah Lakes and open coast region per year with approximately 1.5 million of these trips being from local communities. Recreational activities are widely diverse with the most common activities being walking (670,000 trips), general leisure (1 million trips), fishing (300,000 trips), cycling (420,000 trips), swimming (162,000 trips) and boating (11,000 trips). For further information refer to section 5.3**.**

A number of key industries do have either direct or indirect dependences on the estuary. Industries directly dependent on environmental values associated with the estuary include agriculture, fishing and tourism. Examples of existing commercial and community organisations with direct dependencies upon the estuary include:

- Wallarah Bay Recreation Club
- Toukley Sailing Club
- Central Coast Dragon Boat Club
- Rotary club of Northlakes Toukley
- Chittaway Point Community Hall
- The Entrance Surf Club
- North Entrance Surf Life Saving Club
- Uniting Burnside Northern Lakes Neighbourhood Centre
- Commercial Fisherman’s Co-operative Tacoma
- Lake Munmorah Community Hall.

The estuary and open coast dependent industries primarily consist of the Accommodation and Food services, Rental and Hiring and Real Estate Services and Tourism Industries.

- Accommodation and food services play a significant role in the wider economy of the Central Coast, employing almost 10 per cent of the workforce and producing $900 million in economic output. This is especially significant as the majority of these earnings are concentrated in holidaying periods of the year. This sector relies on the popularity of natural features on the Central Coast, including the open coast beaches and lakes. Hence, investment into infrastructure to benefit the usage of the Central Coast’s natural landscape is anticipated to have indirect positive effects on the accommodation and food services sector.

- Rental and Hiring and Real Estate Services is another sector of the local economy that has a dependency upon the natural features of the Central Coast. The sector is the third largest by economic output, with revenue reaching $3.3 billion a year.
- Tourism accounts for approximately 8 per cent of local employment yet has an output of $1 billion. The tourism industry is intrinsically linked to the above sectors by way of direct economic flow-on effects. The open coast beaches (especially The Entrance Beach) and the Tuggerah Lakes are focal points for the tourism industry, with both on-water (cruises, fishing tours, active recreation) and foreshore (active and passive recreation) activities representing key drawcards for the region.
- The indirect economic value-add and employment to associated industries (e.g., food and beverage, accommodation, and real estate) associated with these uses tourist activities within the region.

5.2.6 Vulnerable groups

The social locality includes a number of potentially vulnerable groups, including:

- People on low incomes and suffering housing stress – approximately 9 per cent of households are in housing stress.
- People living with disabilities, chronic medical conditions or in poor health requiring access to services – in terms of disabilities, 7.0 per cent of the population of the LGA need help or assistance with core activities (i.e., over 24,400 individuals). This is marginally higher than the NSW average of 5.4 percent.
- People who are homeless or in insecure housing – the LGA contains over 4,475 social housing residential dwellings, the majority of which were Public or Community Housing.

Moreover, the coastal towns of Lake Munmorah, Mannering Park, The Entrance, Toukley and Norah Head have a higher proportion of older workers and retirees, with over 20 per cent of their populations being over the age of 70 (also refer Table 12). As the population of the LGA ages, increased demand for health services and concerns for the safety of the elderly are likely to increase. This is already evident in the Health Care and Social Assistance sector, which has an economic output of $2.6 billion (2018/2019).

The proportion of families from non-English speaking backgrounds in the Central Coast LGA (7.1 per cent) is greater than for regional NSW average proportion (5.7 per cent). However, it is still noted that low proportionate representation of non-English speaking community members can increase the vulnerability of these families and groups, as they can be less visible within the community and have fewer support services targeted towards them.

5.2.7 Indigenous peoples

For the local Aboriginal community, continued connection to culture associated with the Central Coast includes ongoing visitation to traditional sites for sharing and learning cultural knowledge and engaging in traditional practices, as well as being used historically for work, fishing, transport and resource gathering. The Tuggerah Lakes catchment was and is important for the Traditional Custodians, who used and use the area for resource gathering and campsites. This is attested to by the array of Aboriginal sites and artefacts present within the region. There are 48 registered Aboriginal Sites, ceremonial sites, and other culturally significant locations and landscape features, within the Tuggerah Lakes area as listed on OEH's Aboriginal Heritage Information Management System. Some of these sites can be seen on guided tours by the Traditional Custodians.

5.3 Utilisation of Tuggerah Lakes and its entrance channel

5.3.1 Community engagement survey

A community engagement survey was undertaken to obtain an understanding of community use relating to the estuary and entrance. Details of the survey questions are provided in Section 3.3. This section provides a summary of key results relevant to understanding the socio-economic value of the entrance.

There were some 164 responses received to the survey. Of these, 140 were from four postcodes immediately adjacent to the lakes: postcodes 2261 (The Entrance), 2259, 2262, 2263 (Figure 58). While the level of response is significant, as with all online surveys the extent to which the responses can be considered representative of the community as a whole is uncertain. Alternative survey methods (e.g., randomly issued postal surveys) are typically more effective at generating unbiased representation of community opinion. It is likely that a portion of respondents to the survey have a higher vested interest in the estuary and entrance condition (as suggested by the location of the respondent's residence location and responses, as discussed further below) than the community more generally. The presence of such bias does not undermine survey results, but supports caution in interpretation and extrapolation of results, particular in terms of valuation.

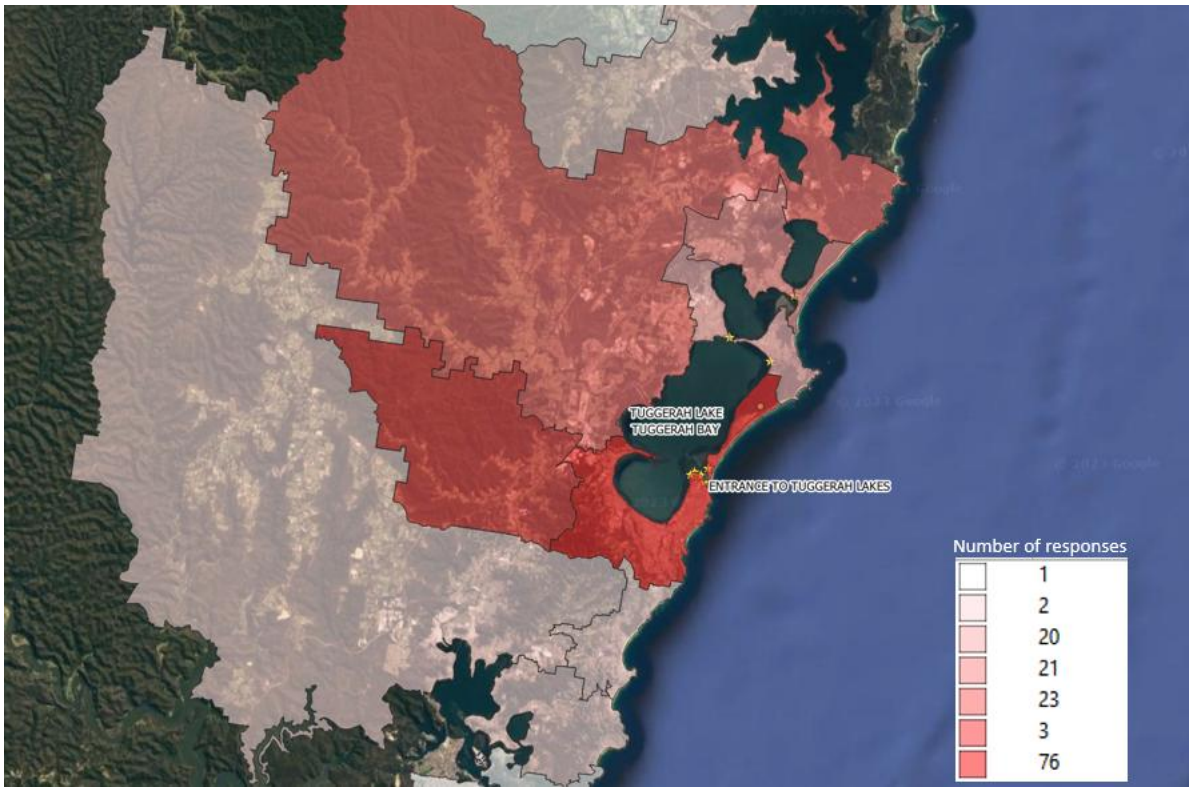


Figure 58: Survey responses by postcode.

In terms of aspects of the estuary and entrance that were appreciated by respondents, the highest ranked aspects were typically those associated with the presence of marine life and wildlife, the beauty of the natural areas, and the clarity of the water. The three aspects are somewhat inter-related, representing aspects that may be appreciated by both direct estuary users (e.g., boaters, swimmers etc.) as well as foreshore users. Figure 59 to Figure 61 demonstrate the response profile for key locations, showing a consistency in valuation of response for these three aspects, above others, across user frequency of visitation and locations. The degree to which changing entrance conditions affects these values is likely to be a key factor in determining the economic value of any entrance management option and its impacts to users.

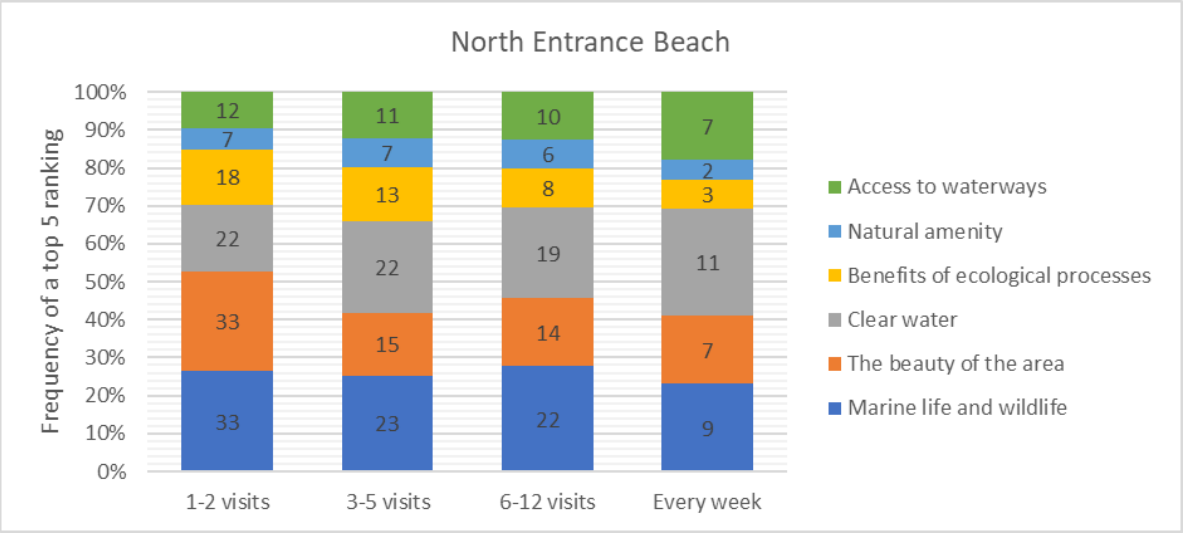


Figure 59: Aspects valued by users of North Entrance Beach by frequency.

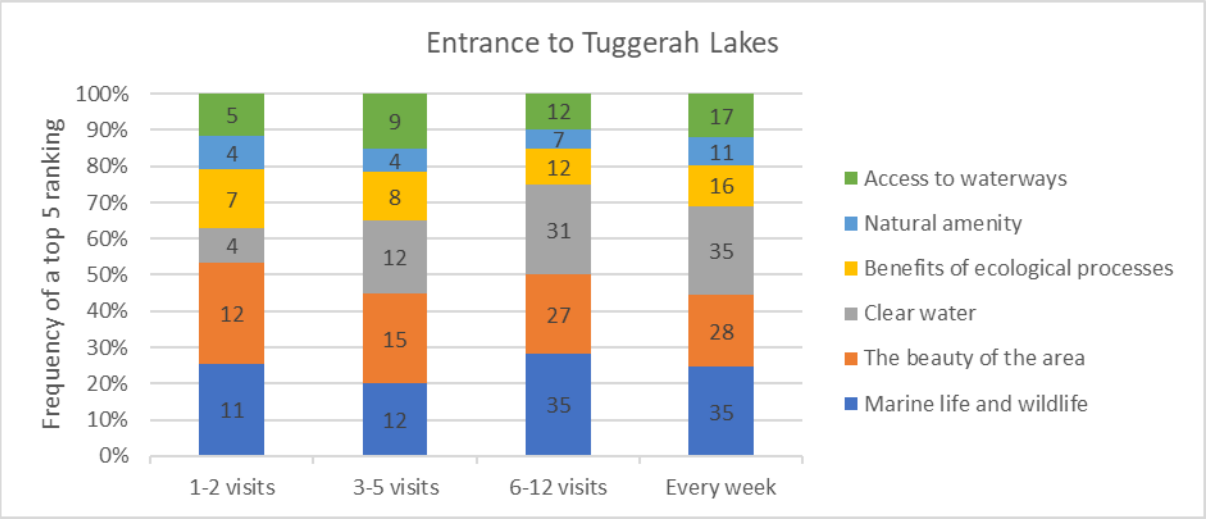


Figure 60: Aspects valued by users of the entrance to Tuggerah Lakes by frequency.

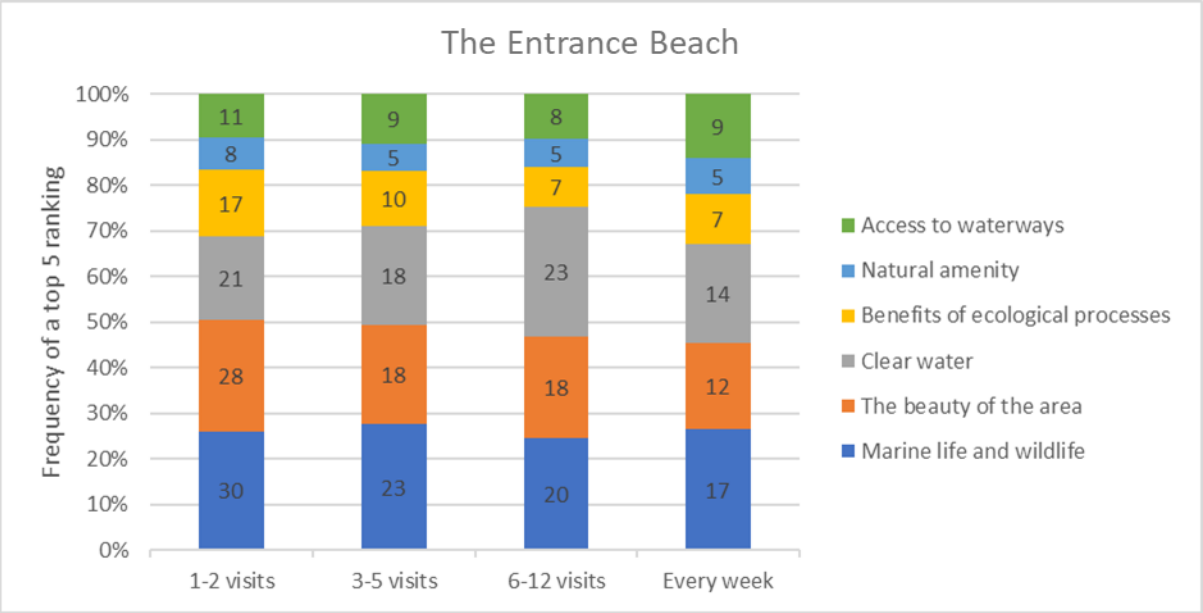


Figure 61: Aspects valued by users of The Entrance Beach by frequency.

Figure 62 explores further how the frequency of use of an area by a respondent, varied their responses regarding values. It can be seen that regarding the clarity of water, a key potential outcome of the project, the respondents who utilise the area most frequency typically valued this aspect more highly than less frequent visitors to the region for both the entrance to Tuggerah Lakes and general lake users. However, the same trend was not observed for The Entrance Beach users. Such trends are significant in that:

- It may suggest that the respondents who frequently utilise the areas have differing drivers/activities shaping their values and/or that the areas provide differing services/opportunities for use, and
- They inform the likely benefit distribution of any works to strengthen the particular value in question. For example, improving clarity and the entrance to Tuggerah Lakes is likely to add most value to the proportion of the community that frequently utilise the entrance. Less frequent users are more indifferent to the water clarity of the entrance.

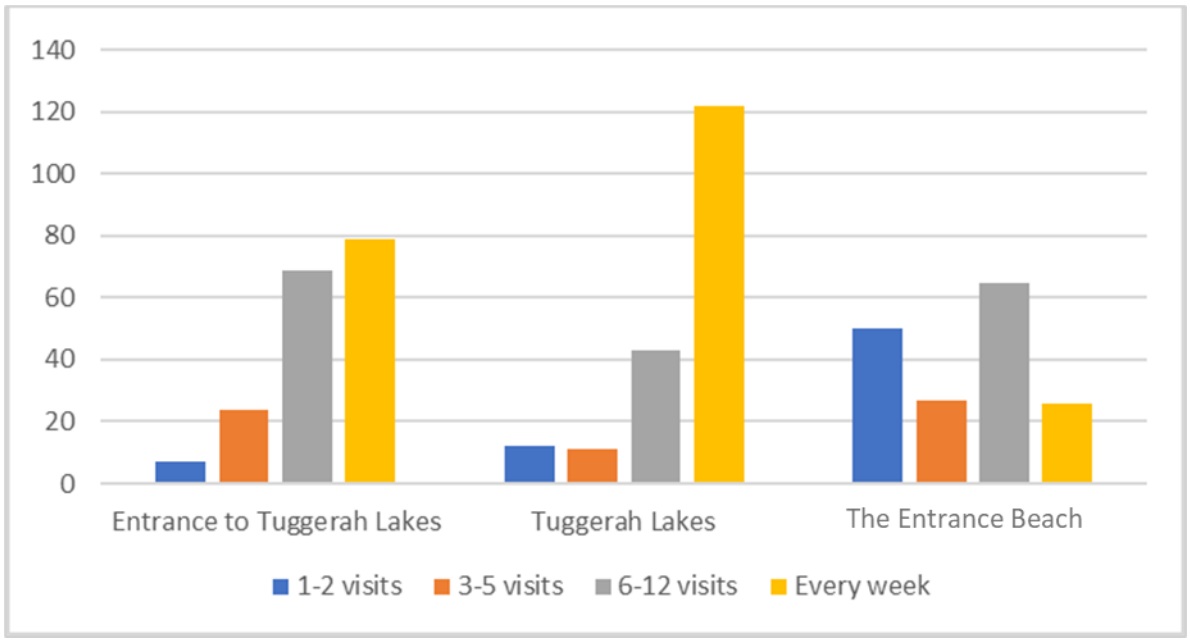


Figure 62: The prioritisation of clear water by respondent use frequency.

Figure 63 breaks down the prioritisation of values by users of the entrance to the lakes, in terms of their preference regarding keeping the entrance permanently open. There is a large difference in a number of values (lower scores indicate higher ranking) between respondents in terms of their management preference for the entrance, with those who wish to keep the entrance open, valuing recreational opportunities, clear water and foreshore cleanliness more so than those less concerned about entrance condition, who tended to value ecological processes, natural amenity and cultural interactions more highly.

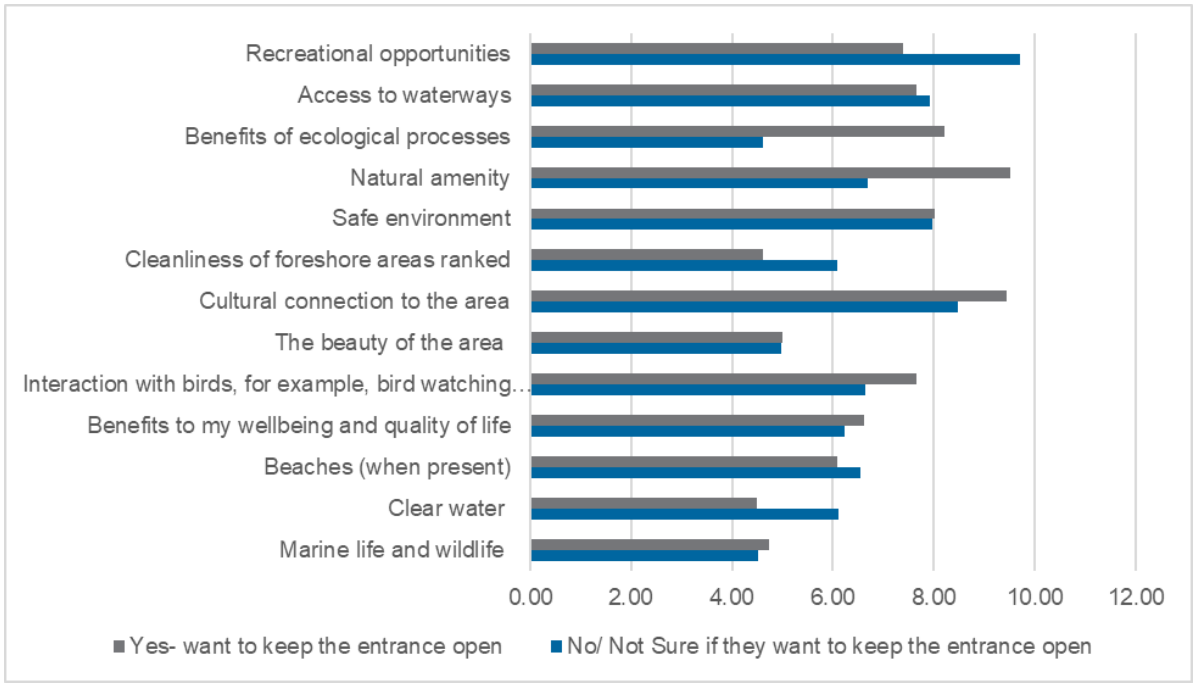


Figure 63: Average value rankings (lower scores reflect higher values).

In terms of frequency of visitation, 79 percent of respondents indicated that they visited one or more areas (Tuggerah Lakes, entrance to Tuggerah Lakes, Budgewoi Lake, Lake Munmorah, North Entrance Beach, The Entrance Beach) at least six times per year (“frequently”), with the remaining 21 percent visiting less frequently. This result may reflect the nature of respondents to the survey, and it is unclear as to the extent to which this is representative of the broader community. Overall, the entrance to Tuggerah Lake itself was the most visited areas, with 57 percent of respondents choosing to visit it at least six times per year.

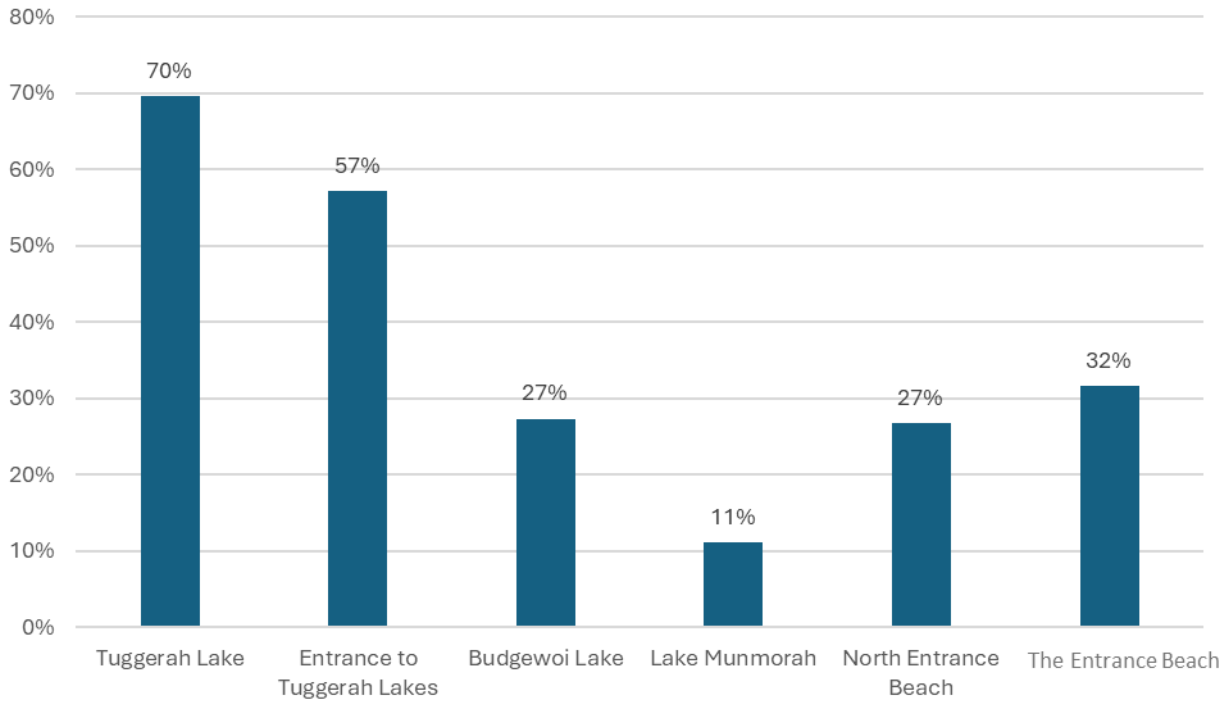


Figure 64: Frequent visitation to areas of the estuary (at least six times per year).

The reasons for visiting the entrance to Tuggerah Lakes as opposed to other areas was seen to vary significantly between frequent and infrequent users, with infrequent users choosing the entrance due to its commercial areas (shopping, eating, accommodation) more so than frequent users who appreciated the sand shoals, safety for kids and fishing opportunities.

From the survey, 90 of the 161 respondents said they want to keep the entrance open, citing flood risk, clean water, smell, and leisure as their main reasons, as shown in Figure 65.

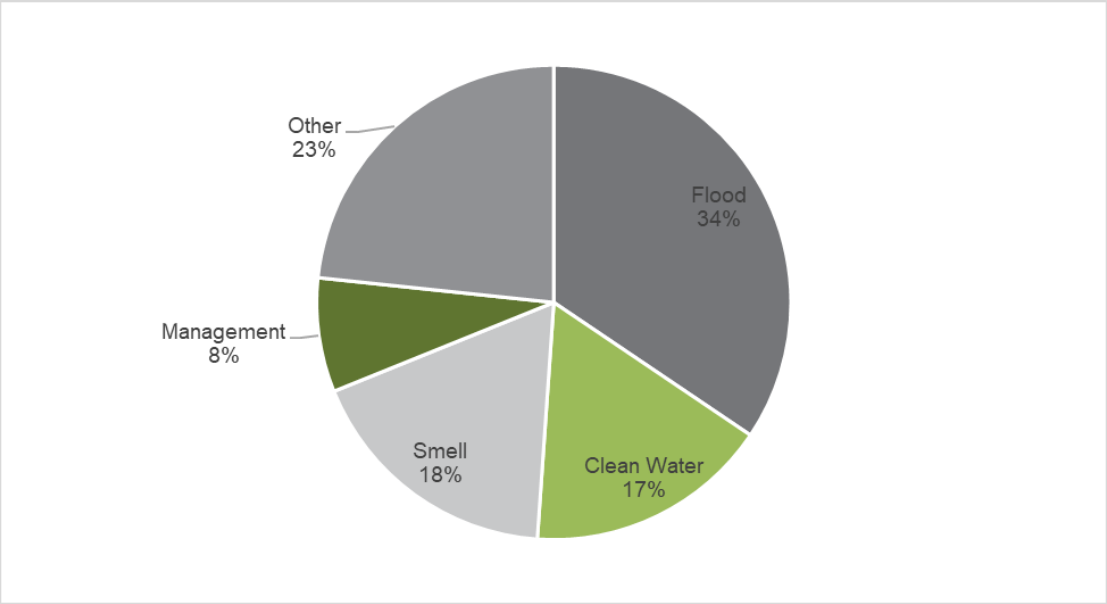


Figure 65: Reasons given for why respondents want to keep the entrance open.

The 25 who answered “No” (10) or “Not Sure” (15) to the question were either unsure about the environmental impact or thought that nature should be left to its devices and would sort problems without human intervention. Further, as shown in Figure 66, many of the reasons cited for not visiting Tuggerah Lakes by those wanting to keep the entrance open were independent of the entrance quality.

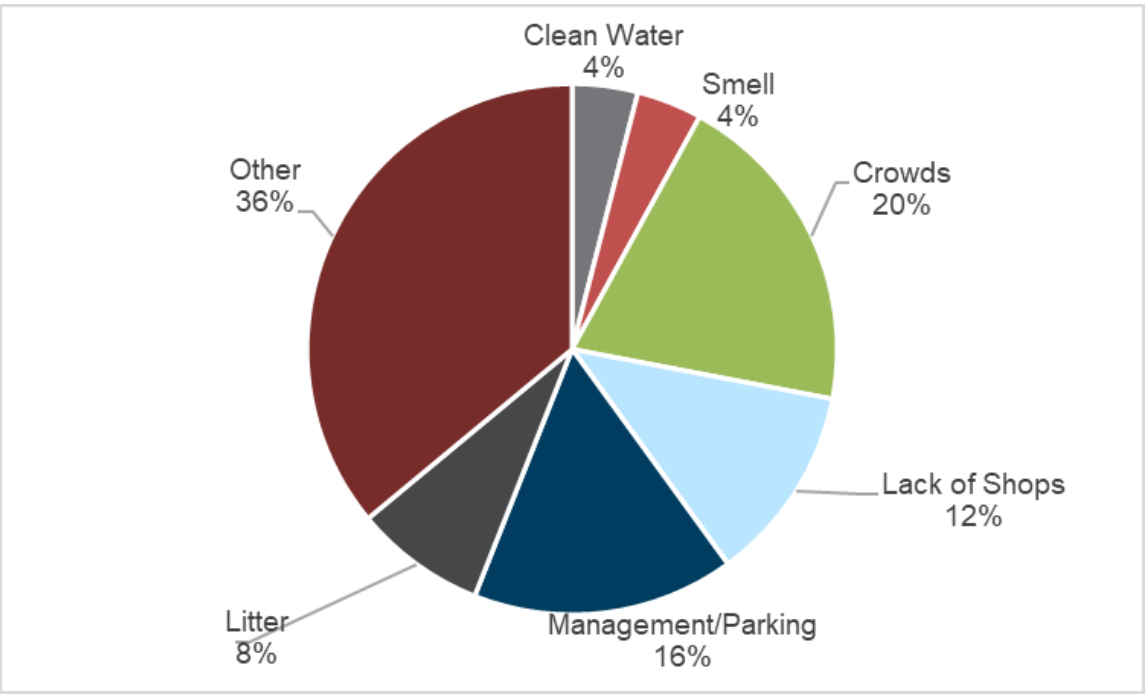


Figure 66: Reasons cited for not visiting Tuggerah Lakes by those wanting to keep the entrance open.

The diversity in responses regarding the open entrance reflects key drivers behind choices. Frequent users of the entrance are more concerned about water clarity and quality compared to less frequent users. The understanding of what an "open entrance" means, such as its effects on flooding, health, and

smell, varies among respondents. While the survey reveals valued opinions, these opinions likely differ based on education on the issue and frequency of use.

5.3.2 Site inspection and historical aerial analysis

The community survey (Section 5.2.1) provided useful information regarding how and why individuals choose to utilise the entrance to Tuggerah Lakes as well as the estuary more broadly. However, the survey only captured responses from a portion of the community, particularly those with sufficient interest in the topic to complete the survey. As such extrapolation from the results of the survey to the broader community to obtain a full understanding of users and ultimately values relating to the entrance and its condition is challenging.

In the absence of a full user count and activity surveys and for the purposes of this study, snapshot data of person counts and activities were combined with observed historical carparking practices to try and estimate total entrance and estuary utilisation on an annual basis.

A snapshot, in-person survey was conducted on 24th of January 2023. Across eight locations, at various times throughout the day, user counts and associated activities recorded included walking, fishing, boating, cycling, swimming, and general leisure activities. At eight locations (Figure 67:), observations of activities were tallied in 10-minute intervals at various times throughout the day. Simultaneously, adjacent carpark vacancy/utilisation was recorded at the time of observation in order to create a comparative ratio between user presence and carpark usage. This ratio was considered plausible as the results of the community survey indicate that the vast majority (81%) of visitations to the region were via private vehicle (as per the survey results). However, it is recognised that not all visitors travelling by car necessarily utilise the car parks that were able to be monitored during the site inspection (i.e., park in other locations or on the street) and that snapshot data points permit limited understanding of results variance or accuracy.

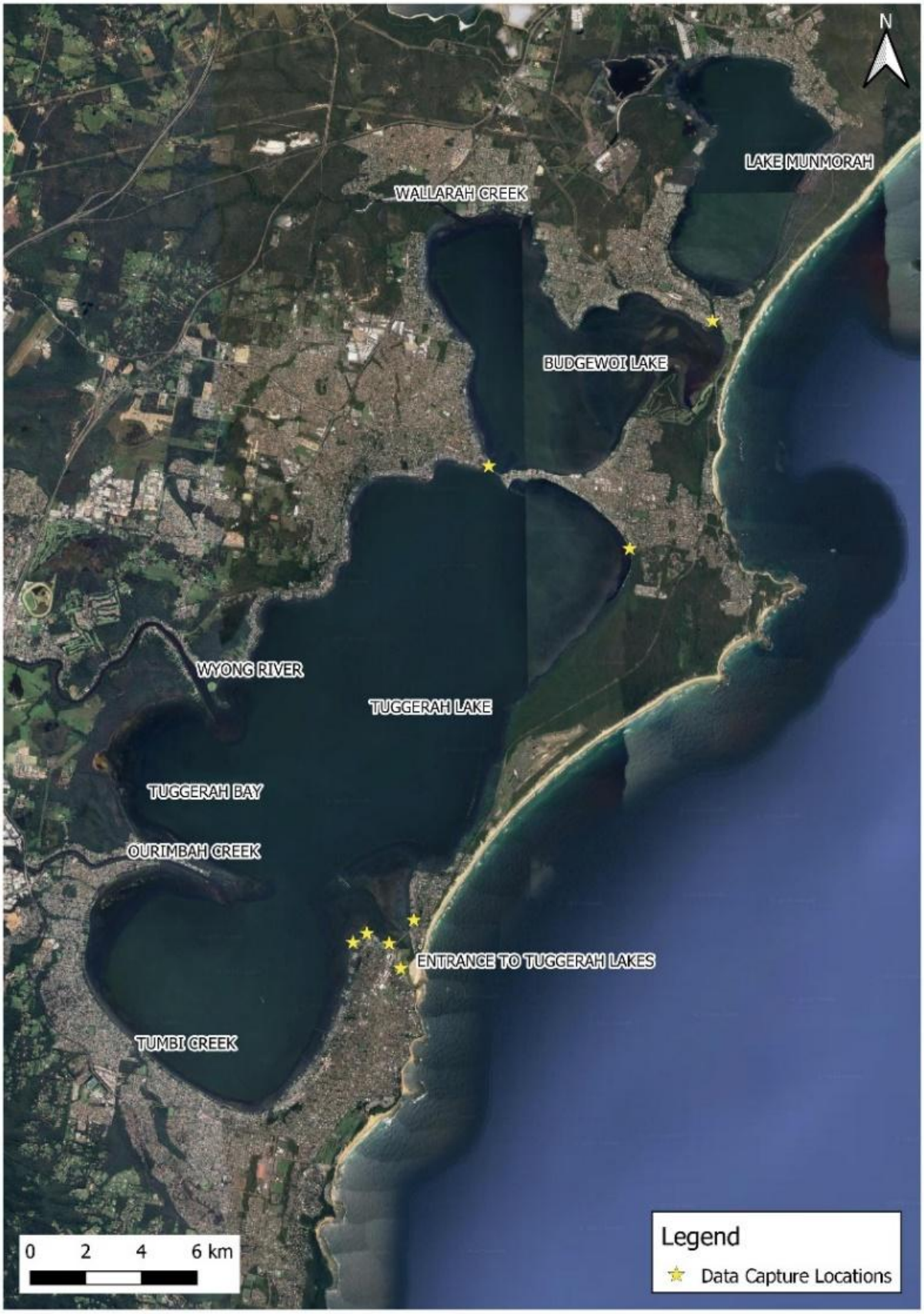


Figure 67: Data capture locations.

Following the field component and the observed ratio between carparking volumes an historic aerial photograph review of other major carparks in the region was undertaken to try and extrapolate total usage and activity estimates. Ten carparks were selected based on their proximity to the foreshore, their size and their facilities (e.g. boat ramp). A 2.5 km buffer was applied to each of the carparks in order to estimate the activity coverage of carparks over the study area (as seen in Figure 68 below). It is noted that approximately 32.7 percent of the shoreline is not covered by these buffer lines, hence a conservative factor of 1.3 was placed on all activity totals for each day to accommodate for this limitation, noting that the car parks tend to be located in areas of higher demand.

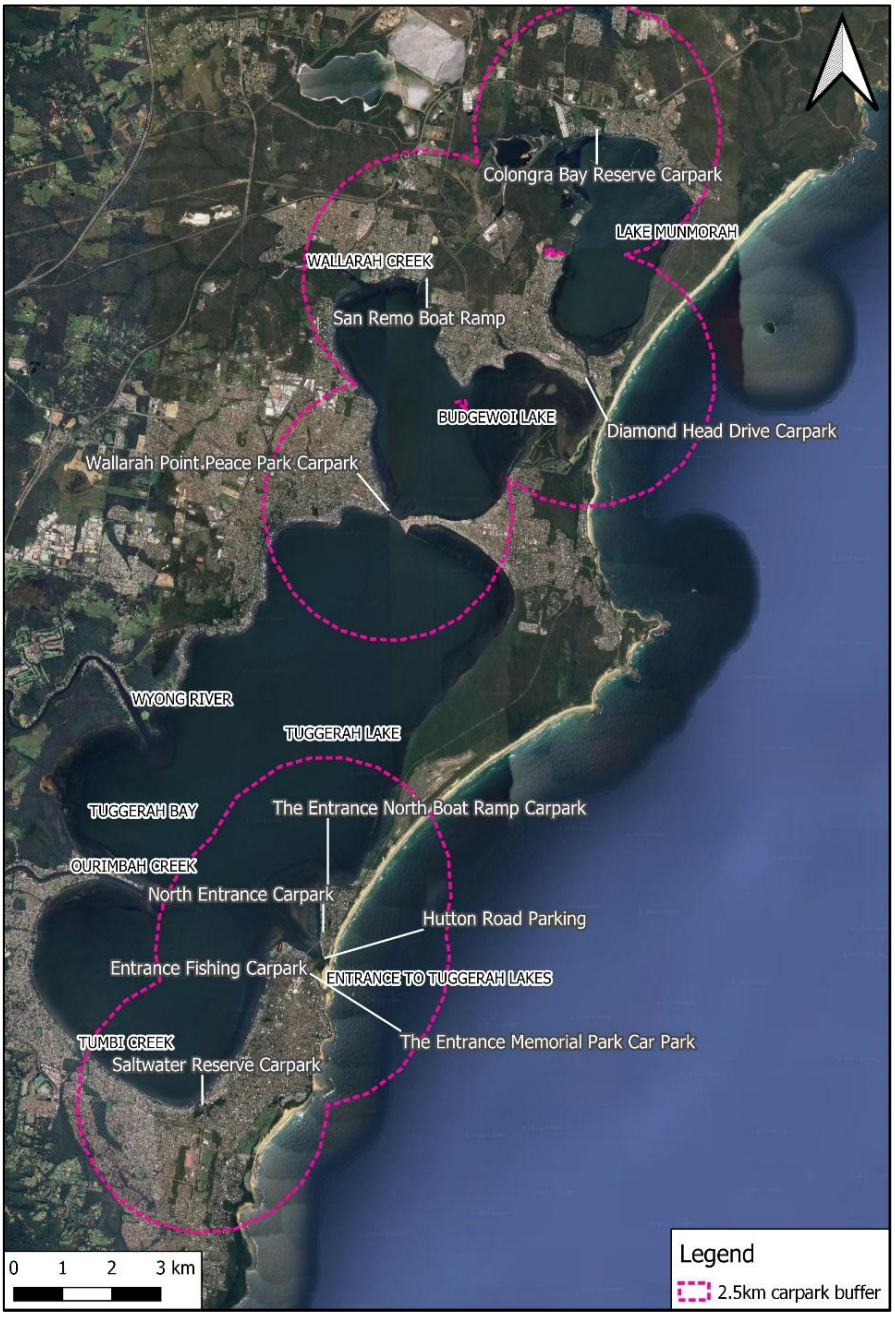


Figure 68: Surveyed carparks with 2.5 km buffer zones.

Historical aerial photographs (Nearmap, 2023) of carpark usage assessed over a 3-year span was reviewed to estimate a yearly average car park patronage and utilisation of the lakes and foreshore. Ten

images were examined from December 2020 to July 2022 at each location. A summary of results for each carpark are in Table 14 below. From each aerial photo it was possible to extrapolate activities frequency in order to obtain a daily total[8].

Table 14: Carpark daily occupancy.

Carpark	Cars per weekday	Cars per weekend day
The Entrance Memorial Park Car Park	64.2	103.3
Hutton Road Parking	8.8	19.0
Entrance fishing Carpark	11.6	27.8
North Entrance Car Park	9.8	25.8
The Entrance North Boat Ramp Carpark	6.7	19.0
Wallarah Point Peace Park Carpark	16.5	23.6
Diamond Head Drive Carpark	5.3	13.3
Colongra Bay Reserve Carpark	6.3	4.8
Saltwater Reserve Carpark	42.6	47.6
San Remo Boat Ramp	2.6	10.6

The ratio of activity to a singular occupied parking spot for each carpark is outlined below in Table 15. For carparks that were not visited in person, the same ratio was taken from carparks visited with similar features and size.

Table 15: Carpark occupancy to activity ratios.

Carpark	Walking	General Leisure	Fishing	Cycling	Swimming/Surfing
The Entrance Memorial Park Car Park	1.42	2.13	0.29	0.08	0.20
Hutton Road Parking	0.28	0.28	0.76	1.93	0.38
Entrance fishing Carpark	0.36	0.36	1.01	2.55	0.50

[8] For the purposes of consistency, and in the absence of site specific turnover information, car park volumes expansion factors of six and four were applied for the weekday and weekend periods respectively. The reported figures are not intended to represent actual utilisation but represent comparative demand between the sites, which is then able to be used to scale activity use observed during the snapshot surveys undertaken in January 2023. As it is the ratio between the chosen car parks and the number of users / activities observed during site inspection (Table 15), the specific car parks used is not significant to the analysis. It is recognised that other car parks are commonly used to support beach activities (e.g. Coral St carpark) and these have not been assessed in the analysis as their activity ration was captured by other carparks assessed.

Carpark	Walking	General Leisure	Fishing	Cycling	Swimming/Surfing
North Entrance Car Park	0.31	0.31	0.85	2.15	0.42
The Entrance North Boat Ramp Carpark	0.21	0.21	0.58	1.46	0.29
Wallarah Point Peace Park Carpark	0.25	0.25	0.69	1.75	0.35
Diamond Head Drive Carpark	0.25	0.50	1.12	0.00	0.00
Colongra Bay Reserve Carpark	0.20	0.20	0.54	1.37	0.27
Saltwater Reserve Carpark	2.51	3.77	0.51	0.15	0.36
San Remo Boat Ramp	0.08	0.08	0.22	0.55	0.11

By combining the cars per day and the activity ratios above, it was possible to calculate an estimate of the total annual volumes of each activity (as shown in Table 16). It can be seen that walking/general leisure represent the vast majority of activities. Those engaging directly with the water (e.g., swimming/surfing, boating, fishing etc.) represent a smaller proportion (19%). This is consistent with the results of the community survey which identified a range of drivers behind utilisation and value. It is likely that those activities which directly interact with the water are likely to receive greater benefits from improvements in water quality and flow conditions.

Table 16: Trips per activity per year to Tuggerah Lakes.

Activity	Weekdays (246 per year)	Weekend days (105 per year)	Holidays (14 per year)	Total
Walking	305,652	185,642	24,752	670,860
General Leisure	448,535	270,384	36,051	981,461
Fishing	126,128	92,186	12,291	299,787
Cycling	169,344	136,353	18,180	421,041
Swimming / Surfing	70,161	48,489	6,465	162,650
Boating	4,699	5,460	728	10,887
Total				**2,546,686**

As indicated in Section 5.1, it is estimated that there are approximately one million tourist trips to the Tuggerah Lakes from outside the LGA per year, suggesting a further 1.5 million of trips per year generated within the LGA. This is equivalent to approximately 14 trips per household per year. For comparison, the community survey indicates respondents visit the estuary an average of 74 times a year. This suggests that the respondents of the survey were approximately five times more likely to visit the entrance. This is likely because the survey targeted a high usage sector of the community, and carries significant bias as compared to the general population.

Utilising the results from the community survey allowed for an estimate of the total number of trips to the entrance to Tuggerah Lake and associated activities as well (Table 17). Visitation and activities at the entrance comprise approximately 35 percent of all coastal visitation activities. The nature of the survey (basically an origin/destination survey) does not pick up boating trips at the entrance in this regard as no boat launching was observed at the entrance; of the 10,887 estimated boating activities undertaken per year (Table 16) it is assumed these trips will launch at other locations within the estuary (and were captured within value estimates accordingly). A portion of these trips may choose to pass through the entrance. However, data regarding vessel navigation through the entrance was not available for the purposes of this study.

Table 17: Trips per activity per year at the entrance to Tuggerah Lakes.

Activities	Weekdays	Weekends	Holidays	Total
Walking	134,173	92,225	12,297	310,302
General Leisure	201,259	138,338	18,445	465,454
Fishing	27,229	18,716	2,496	62,973
Cycling	7,893	5,425	723	18,253
Swimming/surfing	19,060	13,101	1,747	44,081
Boating	0	0	0	0
Total				**901,063**

5.4 Valuation of Tuggerah Lakes

The 2020 report of the Tuggerah Lakes Expert Panel (Glamore et al., 2020) recommended an assessment of the value of “a clear and flowing entrance” to the local community. The community survey and historic data analysis outlined in Section 5.2 are formative in understanding what the community may value about the entrance and how changes to its conditions may affect the choices of some entrance users. However, converting such impacts to dollar terms is challenging. The problems in estimating such a value, from an economic perspective, is one of both definition and methodology.

5.4.1 Definition

A clear and flowing entrance is a term that means different things to different people and is hard to define. In its current configuration the entrance will naturally close/open and have variable clarity and flow in response to tides, coastal processes, storms, rainfall, upstream catchment activities, etc. There will be times when it is not clear and flowing and times when it is open and flowing quickly. Even for the approximately 34 percent of survey respondents that visit the entrance on at least a weekly basis, the ability to get a full picture of entrance condition is relatively limited. Moreover, even with significant infrastructure investment to keep the entrance open (e.g., a large dredging program or entrance training structures) there will still be variation in condition due to catchment and coastal processes and the entrance would not be clear and flowing all of the time (Section 4). As such the community understanding of what constitutes an acceptably “clear and flowing entrance” is hard to define.

5.4.2 Methodologies

Natural assets require management and investment to support sustainable use, consequently there is a significant array of economic methodologies and literature regarding the best ways to value such non-market goods and justify investment. The two key frameworks used to value environmental non-market goods are its **use** and **non-use** values.

Use values reflect the utilisation and engagement of society with a specific environmental asset in question. The Tuggerah Lakes and open coast region supports a wide array of recreational, commercial and passive use activities through its land and maritime infrastructure and varied environments. A significant proportion of residents chose to live in this area due to the benefits that derive from being in close proximity to the coast and estuary. This is indicative that the community is likely to have high use values of the local natural resources and is likely to be the value type most responsive to changes in entrance conditions. There are three main approaches that are typically used to quantify such use benefits:

- Stated Preference Approach

  Under this approach, stakeholders are effectively asked as to their relative preference of one good over another in order to ultimately link the goods back to an already known market good with an agreed value. This is often undertaken as a choice experiment or willingness to pay survey, requiring significant investment in survey development, particularly in scenarios in which stakeholders have varied understanding about the definition of the asset in question (Section 5.3.1). Additional complexity is introduced where, an individual may for example, not value clear and flowing water in and of itself, but rather values a by-product of the clear and flowing water, such as fishing. Such surveys are complex and require clear disambiguation of what the endpoint value is.

- Revealed Preference Approach

  In contrast to a stated preference approach, this methodology observes behaviour of individuals (rather than asking them to state a preference) that may reveal their actual preference for one asset over another. The Travel Cost Methodology (TCM) is the most common such approach, equating the amount people spend on accessing a location as a minimum bound to the actual benefit they get out of it. This approach was adopted as the basis of estimation for this study. However, it is noted that this approach is effective in valuing the current (or historic) conditions and does not readily allow for an understanding of how this value would vary with entrance condition (i.e. more or less clarity and flow). A detailed data set showing the relationship between individuals travelling to the entrance (and their associated costs) and the variation in water clarity and flow over time would be required to accurately discern such a value. A series of sensitivity tests to the

results of the TCM assessment undertaken (Section 5.4.3) were applied to try and address this short-coming.

- Benefit Transfer

  Benefit transfer approaches, recognise the short-comings of both the Stated Preference and Revealed Preference approaches as they seek to apply outcomes based on similar questions/studies explored elsewhere in the world and apply such outcomes to the project in questions. A number of Willingness to Pay (WTP) surveys regarding waterway quality and clarity have been undertaken in Australia and New Zealand, which are of relevance to the project, including:

  - Van Bueren and Bennett (2000) who identified a national WTP of $0.08 per household per year for every 10km of waterway restored for fishing or swimming.
  - Windle and Rolfe (2004) They found a WTP of between $0.08 to $0.11 per household per year over 20 years for each kilometre of waterway remaining in good health over this period.
  - Marsh and Baskaran (2009) undertook a study for the Karapiro Catchment in New Zealand. This study is particularly useful given that it provided an understanding of the WTP under different water quality conditions, identify that for each additional metre of water depth clarity you might generate $20 per benefiting households.

  As a point of comparison, application of the Marsh and Baskaran (2009) values to the entrance to Tuggerah Lakes was applied as a sensitivity check (Section 5.5) to the TCM approach adopted herein.

Non-use valuation methodologies are less well established within the industry at this point in time. For the purposes of this study, a Benefit Transfer approach has been adopted as detailed in Section 5.4.3.

5.4.3 Values of use

A Travel Cost Methodology (TCM) for the project was undertaken in two ways to allow for internal validation of the assessment:

- Once based on average costs estimates per trip derived from literature elsewhere across NSW
- Once based on estimated travel costs based on the results of the community survey.

Two primary literature sources were used as the basis of the statewide evaluation:

- Pascoe and Doshi (2018)
- Victorian Fisheries Authority (2020)

Pascoe and Doshi's (2018) analysis focused on a survey of 1,414 NSW coastal residents as to activities undertaken and the associated cost of travel and time to complete the activities. The Victorian Fisheries Authority's estimation focused on fishing activities which typically incur higher activity specific costs and was derived through survey of on-water users in Victoria. This trip value per person, includes the trip expenditure and the annual costs associated with boat maintenance, licenses and gear. Table 18 summarises the resultant minimum consumer surpluses derived through the array of activities assessed in dollars per trip from these two studies.

Table 18: Travel cost activity based consumer surplus.

Activity	Consumer surplus ($) / trip
All uses (average)	$ 23.63
Passive use/ General Leisure + additional activity value of:	$ 21.62
Swimming	$ 7.77
Walking	$ 9.70
Fishing	$ 27.51
Surfing	$ 40.11
Boating	$443.00*
Cycling	$ 15.66

*Victorian Fisheries Authority (2020) data, all other data from Pascoe and Doshin (2018)

Applying these rates to the estimated number of trips of that type per year (Table 17), indicates an annual usage value of Tuggerah Lakes to be approximately $83 million per year (Table 19) below. When these trips are narrowed down to just the entrance to Tuggerah Lakes, these show an annual use value in the order of $26 million per year (Table 20). Although, it is noted that this approach underestimates the value of boating, a significant majority of boats will utilise the entrance, but are not captured under this approach as their destination utilised in the TCM was to access boat ramps in other locations within the estuary.

Table 19: Activity Value Method valuations at Tuggerah Lakes.

Activity	Total	Value per visitation	Total Use Value
Walking	670,860	$31.32	$21,012,345
General Leisure	981,461	$23.63	$23,187,024
Fishing	299,787	$49.13	$14,728,403
Cycling	421,041	$26.47	$11,145,172
Swimming / Surfing	162,650	$51.01	$8,296,608
Boating	10,887	$443.00	$4,822,764
Total	**2,546,686**		**$83,192,315**

Table 20: Activity Value Method valuations for the entrance to the Tuggerah Lakes.

Activity	Total	Value per visitation	Total Use Value
Walking	310,302	$31.32	$9,718,671.69
General Leisure	465,454	$23.63	$10,998,669.16
Fishing	62,973	$49.13	$3,093,870.25
Cycling	18,253	$26.47	$483,159.12
Swimming / Surfing	44,081	$51.01	$2,248,581.82
Boating	0	$443.00	$-
Total	**901,063**		$26,542,952.03

As a way of validating this estimate, an alternative travel cost estimate was also derived by utilising the result of the community survey to determine a Tuggerah Lakes specific cost per trip/activity. The survey gave an indication of where visitors to the lakes were coming from, the mode of transport, how much money they would spend preparing for a trip and where in the lakes and open coast region they visited and how frequently.

From this it was possible to calculate the time travel and associated costs individuals were willing to pay to access the lakes/undertake their activities. Postcodes from within the Central Coast LGA were drawn from the community engagement survey. The travel time from the most populated area within each postcode, to each of the six key locations within the study area was estimated using google maps and an associated average time taken with minimal traffic to reach the key location. A summary of each postcode's average return trip time and valuation are outlined in Table 21 below. The average travel time cost basis of $24.98 per hour per person (TfNSW Economic Parameter Values, 2022) was used to derive the average travel time cost per trip.

Table 21: Travel duration (min) from suburb to destination.

Postcodes	Tuggerah Lakes/ entrance	Entrance to Tuggerah Lakes	Budgewoi Lake	Lake Munmorah	North Entrance Beach	Entrance Beach	Average time	Average Travel Time Value
2262	40	50	16	26	46	50	38	$15.82
2261	30	20	56	54	24	20	34	$14.16
2263	30	46	14	30	44	46	35	$14.57
2259	46	50	24	38	48	50	43	$17.77
2251	70	60	94	96	62	60	74	$30.68

Postcodes	Tuggerah Lakes/ entrance	Entrance to Tuggerah Lakes	Budgewoi Lake	Lake Munmorah	North Entrance Beach	Entrance Beach	Average time	Average Travel Time Value
2250	68	70	74	78	72	68	72	$29.84
2258	40	50	50	52	54	50	49	$20.54
2257	92	92	98	100	94	92	95	$39.42
2260	62	42	76	80	44	42	58	$24.01

In addition to travel time, travel cost methods include Vehicle Operating Costs (VOC). VOC incorporates average speed and a myriad of other coefficients associated with vehicle type. For the purposes of this assessment, it was assumed that all private vehicles used are classified as “light vehicles” and that the average speed of travel is 50 km/h. These assumptions amount to an average VOC of $0.32 per km. This is likely to be conservative in light of the high proportion of trips utilising trailerable boats and larger vehicles.

In addition to VOC, the value of preparation for each trip made was also considered and derived directly from the community engagement survey. Each individual was asked if they spend either; less than $20, $20-50, $50-100 or over $100, resulting in an average of $34 per trip.

Based on these estimate costs per trip and the estimated number of annual trips (11,512) to the six most popular sites within Tuggerah Lakes[9] was determined (Table). This resulted in a total annual use value of approximately $90 million. When applied solely to the number of trips to the entrance this value reduces to $33.5 million.

Table 22: Travel Cost Method calculations.

Postcodes	Value per trip	Total trips per postcode (survey)	Total trips per postcode (extrapolated)	Total Value of Travel time per postcode
2262	$31.10	1,944	408,681	$12,707,940
2261	$37.39	6,046	1,271,031	$47,525,785
2263	$43.10	1,518	319,124	$13,752,913
2259	$30.77	1,613	339,096	$10,432,712
2251	$119.90	65	13,665	$1,638,335
2250	$119.39	74	15,557	$1,857,336
2258	$39.38	238	50,034	$1,970,411

[9] Due to the number of potential destinations, estimation of travel cost for all trips was seen to be unwarranted.

Postcodes	Value per trip	Total trips per postcode (survey)	Total trips per postcode (extrapolated)	Total Value of Travel time per postcode
2257	$0	14	0	$0
2260	$121.78	36	7,568	$921,656
Total		**11,512**		**$90,807,089**

The two travel cost methodologies adopted provide results within the same order of magnitude, giving confidence to the estimate use value, noting that the results are both highly dependent upon the estimated total visitation to the lakes and foreshore areas. It is considered that more detailed survey and monitoring of utilisation would allow for refinement of this visitation estimate.

5.4.4 Non-use Values

Non-use values are the intrinsic value assigned by individuals to an environmental asset such that there is worth in it continuing to exist, independent of personal use or benefit. Utilising categorised natural asset areas, as defined by Department of Planning and Environment land use shapefiles (Oct-2022), the array and area of environmental assets present was determined.

In order to value each natural asset area, a benefit transfer approach from other literature was applied. Pascoe and Doshi (2018) combined a range of techniques (revealed and stated preference, choice experiments and analytic hierarchy processes) to determine a per household range of potential values per hectare of environmental asset present. The resultant non-use values per hectare of asset type (Table) are based on non-Sydney residents and are scaled in accordance with income levels of the Central Coast LGA.

Table 23: Natural asset non-use valuation.

Natural asset	$ per household per hectare per year
Sandy beach	$1.83
Headland	$1.41
Rocky shoreline	$1.22
Dunes	$1.38
Adjacent scrubland	$1.09
Freshwater lakes	$1.83
Estuary	$1.01
Saltmarsh	$1.00
Mangroves	$1.83
Seagrass	$1.73
Reefs	$1.72
Sandy seabed	$1.83

The above values effectively represent a household base willingness to pay to continuously preserve the natural asset types present. However, it is noted that there is an array of other non-use aspects not captured within such conservation-based approaches. Such benefits include the ecosystem services associated with physical, chemical and biological systems and which often underly both the non-use and use values of an asset. Given the potential for double counting in this regard, such values are often conservatively removed from estimates of value. However, for the purposes of this study, attention is drawn to the ecosystem service role that estuaries play within flooding and drainage. The cost of flooding to the local community is estimated to be an Average Annual Damage (AAD) of $2.64 million per year[10] based on a relatively open channel scenario (Tuggerah Lakes Floodplain Risk Management Study and Plan, 2014).

Non-use Results

Non-use values were calculated by totalling the areas of each natural asset and multiplying this by the number of households within the Central Coast LGA and by the relevant coefficients stated above in Table 23. Table 24 outlines the total area for asset per location.

As of March 2023, there are 133,779 households in the LGA. For the purposes of the non-use value calculation, the total area of each natural asset of the lakes has been reduced by 90 percent to better represent the value of the foreshore areas. The Pascoe and Doshi (2018) methodology is highly sensitive to the population assumed to have interest in the intrinsic value of the estuary. Given the extent of the LGA and the size of the estuary the coarse methodology adopted is likely to over-estimate the non-use values in this regard.

Table 24: Non-use value calculations.

Natural Asset	Tuggerah Lake	Lake Munmorah	Budgewoi Lake	The Entrance and Open Coast beaches	Total Area	Total Non-use Cost
Freshwater lakes	5797.8	796.8	1360.4	0	795.5	**$194,750,495**
Adjacent scrubland	999.8	28.4	85.6	18.9	1132.6	**$165,157,759**
Sandy beach	0	0	0	21.3	21.3	**$5,215,573**
Saltmarsh	19.6	10.6	0	0	30.2	**$4,034,133**
Total						**$369,157,961**

The magnitude of this benefit reflects the broad extent of natural assets present in the region and the population present that appreciate its presence. The magnitude of flooding impacts in relation to these values is relatively minor.

[10] The Floodplain Risk Management Study and Plan reported an Average Annual Damage of $2.2 million in 2014. Adjusted for inflation, this results in $2.64 million

5.5 Discussion

The use and non-use values outlined in Section 5.4 indicate the magnitude of value potentially at risk through anthropogenic changes to the entrance condition. However, it is noted that the value that any entrance change would generate/lose is entirely a function of the degree to which a management option affects the use and non-use values of the community/users and how sensitive they are to the changes induced by the entrance conditions.

Typically, non-use values are inelastic to minor changes in asset condition, but very sensitive to large scale changes in asset extent (e.g., a small decay in ecological condition may not alter non-use values, but entire loss of habitat effectively loses all value). In this instance, changes to the hydrodynamic functioning of the entrance to Tuggerah Lakes may have an array of impacts to upstream conditions. For example, a more restrictive channel could result in generally higher estuary levels most of the time and greater depths affecting the location and distribution of ecological communities within the waters and along the foreshore. A less restrictive channel could result in a generally lower lake level which could exacerbate nearshore water quality issues, introduce challenges regarding wrack management (e.g., lifting it on or off fringing wetlands and foreshores etc.). There may be both positive and negative existing / non-use impacts associated with such changes. The complexity in forecasting such impacts is difficult. However, it is considered unlikely that Council would proceed with any options which would materially generate significant adverse environmental impacts.

In particular, the non-use value calculations outlined in the preceding section, are fundamentally based on areas present of habitat types. Should the entrance be maintained in a very open and flowing state it is likely that this will lead to:

- A reduction in total estuary area
- A reduction in the beach area immediately adjacent to the entrance channel (i.e., along the entrance berm which would be lost due to a wide channel)
- An increase in foreshore areas (including beaches/rocky/areas/scrubland)
- Changes to the distribution and extent of saltmarsh (noting that ecological distributions will adapt to changed water levels over time).

The reduction in estuary and beach areas may be offset entirely or partially by gains elsewhere. However, it is not possible to assess this level of change with available information for the purposes of understanding magnitude of benefit. If the project was to lead to a net 5 percent increase in sandy beach area, it would result in an increase of $260,000 per year in non-use benefit. Modelling of specific management option across the estuary in terms of its impacts would be required to determine the realism of such an increase.

In contrast, use values are likely to be more sensitive to small changes in asset condition. The community survey undertaken indicated:

- 56 percent of total respondents say they would like the entrance to be “permanently open”
- 39 percent of total respondents say that they alter their activities when the entrance is “closed” (noting the level of change is assumed to be a reduction, but insufficient data is available to determine the magnitude of reduction per degree of closure)
- 93 percent of respondents who said that it affects their use also want the entrance to be kept open
- 67 percent of respondents who said that they would like it to be kept open also said it would affect their use

- 20 percent of respondents identified issues associated with poor water quality, odour and channel condition as the primary reason they may choose not to utilise the entrance to Tuggerah Lakes.

It is also noted that of the observed activities through the snapshot sampling:

- Approximately 19 percent of activities undertaken involve direct water interaction (fishing, swimming, boating etc.)
- 81 percent of activities involved indirect water interactions (e.g., walking, cycling etc.).

The survey results suggest:

- A correlation exists between frequent direct users of the entrance and the likelihood of a change in utilisation as a result of entrance conditions
- The reasons held by the community for keeping the entrance open extend to more than its utilisation (e.g., perceived flood mitigation)
- The community considers that entrance opening will positively impact on an array of estuary issues including clarity, odour, channel depth, ecology and flooding
- A concentration of foreshore and entrance activities at the entrance to Tuggerah Lakes itself, with the majority consisting of foreshore-based activities (e.g., walking, running) often associated with the presence of other community assets (e.g., shopping, café, play areas etc.).

A more detailed behavioural survey would be required to estimate the extent of the relationship; however, it is considered reasonable to assume that in the order of 20-40 percent of respondents may alter their utilisation of the estuary as a result of a material change to entrance conditions (e.g. reduce or shift utilisation type when the entrance closes; increase or shift utilisation type when it becomes more open). However, it is not possible from the survey results to understand the degree of such changes, nor the extent to which an individual may consider the entrance to be closed or open (Section 5.3.1). For example, in comparison to the channel's existing level of constriction (and natural variability therein), would an "improved" scenario result in a 1 percent, 10 percent or 100 percent increase in the number of days an individual may go swimming?

Given this data constraint, for the purposes of this assessment, a series of sensitivity tests to the base economic value estimates were undertaken to provide indications as to the magnitude of value at risk/potentially realised by interventions at the entrance to Tuggerah Lakes (Section 6). The following sensitivity scenarios were run and associated net increase in use values derived:

- 20 percent of users increase their frequency of use by 50 percent $3,357,106 per annum.
- 40 percent of users increase their frequency of use by 10 percent $1,342,842,62 per annum.
- Increased swimming, walking, fishing and boating by 20 percent $3,012,302 per annum.
- Increased swimming, walking, fishing and boating by 40 percent $6,024,605 per annum.

As noted in Section 5.3.2, the results presented above are based on the adopted revealed preference, travel cost estimation methodology. An alternate approach is to adopt a Benefit Transfer approach, pulling on literature and studies undertaken elsewhere to the entrance to Tuggerah Lakes. Marsh and Baskaran (2009) undertook a study for the Karapiro Catchment in New Zealand, focussing on understanding of the Willingness to Pay (WTP) of local communities under different water quality conditions. A summary of the results from the Marsh and Baskaran (2009) study are shown in Table 25. These were adjusted to 2023-dollar equivalents, and a preliminary estimate of the annual value for the catchment was estimated based on the number of users of the estimated annual number of entrance users (45,053).

The mean secchi depths (a common measure of clarity) at the entrance are not known at this point in time. However, as clarity is a commonly listed concern, it could be argued that clarity could be improved at times. As seen from Table 25, assuming the entrance would improve in water clarity[11] by approximately 0.5m secchi depth (level 1 to level 2) as a result of intervention works, benefiting stakeholders would be willing to pay in the order of $19 per year to achieve and maintain such a benefit. Applying this to the estimated number of individual users of the entrance to Tuggerah Lakes per year (45,053 individuals), and assuming that each individual represents an individual household, this is equivalent to approximately $856,010 per year as a result of clarity improvements. This is at a similar order of magnitude as the use case presented above.

Table 25: Willingness to Pay (per household per year) results for Marsh & Baskaran (2009)[12].

Benefit		Base Case	Level 1	Level 2	Level 3
Suitability for Swimming and Recreation	Condition	Every summer there is a 50% chance of health warnings for 1 – 2 weeks due to algal blooms.	20% Chance	10% change	2% chance
	WTP (2009NZD)		$68	$139	$125
	WTP (2023AUD)		$115	$233	$210
Water Clarity	Condition	You can usually see up to 1 metre underwater. This was reportedly the NZ standard for safe swimming.	1.5 metres	2 metres	4 metres
	WTP (2009NZD)		$4*	$21*	$66
	WTP (2023UD)		$7	$36	$111
Ecological Health	Condition	Less than 40% of readings are excellent.	50% are excellent	60% are excellent	More than 80% are excellent
	WTP (2009NZD)		$82	$41	$126
	WTP (2023AUD)		$138	$68	$212

**not statistically significant*

[11] The WTP survey was not based on technical secchi depths but community perception of visible depths.
[12] WTP values adjusted to 2023 dollars, based on the exchange rate between NZD and AUD in 2009, and then adjusted by the difference in annual earnings between the 2009 study area and current Australian 2023 averages.

6. Entrance management options

6.1 Preamble

Following the coastal and estuarine processes assessment and establishing the socio-economic context, potential opportunities for management of the entrance to Tuggerah Lakes are explored. This section presents a range of entrance management options, including a shortlisting of potentially feasible options. The shortlist is evaluated for each option's potential benefits and impacts. Entrance management options are limited to the Tuggerah Lakes entrance compartment and its specific management areas as shown in Figure 69. The term 'option' refers to a single coastal management element (likely for a specific area) which ultimately may or may not form part of a greater management scheme.

The findings of this evaluation will inform Council's approach to managing the entrance channel. The key findings and further recommendations on shortlisted entrance management options will be prepared during Stage 3 of the Tuggerah Lakes CMP to assist further community engagement and to inform development of the Entrance Management Strategy.

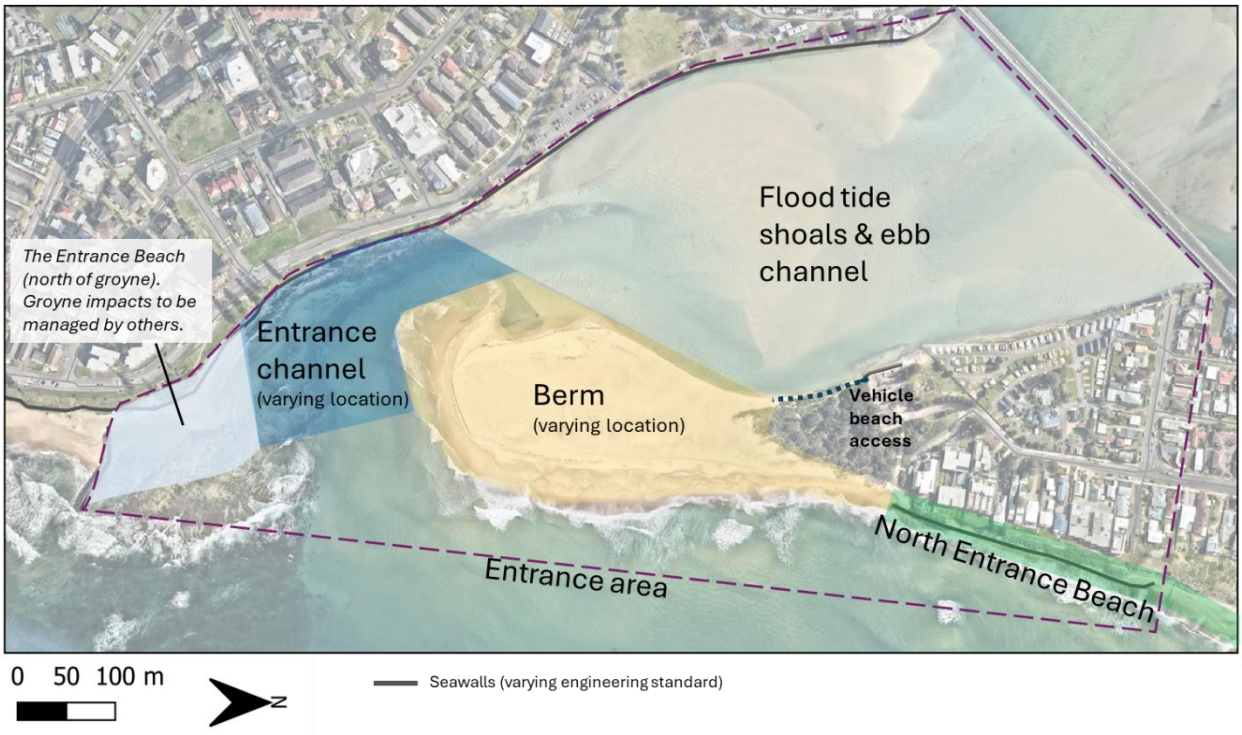


Figure 69: Entrance management areas considered in the options assessment.

6.2 Management objectives

Management of the Tuggerah Lakes entrance requires careful consideration of impacts on the estuary's natural processes and ecosystems, its recreational value, and public safety during flood events. The management objectives have been developed in collaboration with Council in consideration of their wider Coastal Management Program (CMP) objectives and are informed by the outcomes of the community engagement survey and the Community Focus Group workshops. The objectives have also been developed to ensure alignment with the NSW Coastal Management Act 2016 (*CM Act*). Those considerations are further discussed in the following sections.

6.2.1 Coastal Management Act 2016

The *CM Act* establishes a legislative framework for managing NSW coastal zones. The objects of this Act are to manage the coastal environment of NSW in a manner consistent with the principles of ecologically sustainable development for the social, cultural and economic well-being of the people of the State. Part 2 of the Act provides management objectives for different types of coastal management areas including:

- the coastal wetlands and littoral rainforests area
- the coastal vulnerability area
- the coastal environment area
- the coastal use area.

Management of Tuggerah Lakes entrance could impact areas which meet each of these categorisations and as such the management objectives should consider objectives for each. Table 26 presents the objectives for each of these coastal areas as described in the *CM Act*.

Table 26: Objectives for management of coastal areas defined in the NSW Coastal Management Act 2016.

Coastal wetlands and littoral rainforests area	Coastal vulnerability area	Coastal environment area	Coastal use area
• to protect, including the biological diversity and ecosystem integrity, • to promote the rehabilitation and restoration, • to improve the resilience to the impacts of climate change, including opportunities for migration, • to support the social and cultural values, • to promote the objectives of State policies and programs	• to ensure public safety and prevent risks to human life, • to mitigate current and future risk from coastal hazards by considering the effects of coastal processes and climate change, • to maintain natural features, considering the beach system operating at the relevant place, • to maintain public access, amenity and use, • to encourage land use that reduces exposure to risks from coastal hazards, • to adopt coastal management strategies that reduce exposure to coastal hazards in the first instance and wherever possible, by restoring or enhancing natural defences • if taking that other action to reduce exposure to coastal hazards • to avoid significant degradation of biological diversity and ecosystem integrity, and • to avoid significant degradation of or disruption to ecological, biophysical, geological and geomorphological coastal processes, and • to avoid significant degradation of or disruption to beach and foreshore amenity and social and cultural values, and • to avoid adverse impacts on adjoining land, resources or assets, and	• to protect and enhance the coastal environmental values and natural processes and enhance natural character, scenic value, biological diversity and ecosystem integrity, • to reduce threats to and improve resilience, including in response to climate change, • to maintain and improve water quality and estuary health, • to support social and cultural values, • to maintain the presence of natural features, considering the beach system operating at the relevant place, • to maintain and, where practicable, improve public access, amenity and use.	• to protect and enhance the scenic, social and cultural values of the coast by ensuring that - • the type, bulk, scale and size of development is appropriate for the location and natural scenic quality of the coast, and • adverse impacts of development on cultural and built environment heritage are avoided or mitigated, and • urban design, including water sensitive urban design, is supported and incorporated into development activities, and • adequate public open space is provided, including for recreational activities and associated infrastructure, and • the use of the surf zone is considered, • to accommodate both urbanised and natural stretches of coastline.

Coastal wetlands and littoral rainforests area	Coastal vulnerability area	Coastal environment area	Coastal use area
	• to provide for the restoration of a beach, or land adjacent to the beach, if any increased erosion of the beach or adjacent land is caused by actions to reduce exposure to coastal hazards, • to prioritise actions that support the continued functionality of essential infrastructure during and immediately after a coastal hazard emergency, • to improve the resilience of coastal development and communities by improving adaptive capacity and reducing reliance on emergency responses.		

6.2.2 Tuggerah Lakes Estuary Coastal Management Program Scoping Study

In accordance with the NSW Coastal Management Framework, Central Coast Council published the *Tuggerah Lakes Estuary Coastal Management Program Scoping Study* in 2021. The CMP aims to provide a long-term strategy and short-term actions to manage the estuary in an ecologically sustainable manner, for the benefit of the wider community by working towards the following objectives:

- Maintain and improve the ecological health of the estuary and its coastal environment, by protecting the natural processes, natural variability, environmental assets, ecosystem integrity and water quality of the estuary.
- Support community connection with and use of the estuary, in an ecologically sustainable and culturally sensitive manner.
- Improve coordination of public authorities that manage the estuary waterway and its catchment.
- Identify areas for improved management and facilitate good decision making.
- Acknowledge the cultural value and indigenous use of the system and protect areas and items of cultural heritage significance.
- Align coastal management planning with local and regional planning, and vice versa.
- Manage coastal and climate risks proactively, strategically and with consideration of future generations.
- Collaborate with government and community to manage the estuary and its catchment, through improved collective knowledge and understanding, capacity building, and collective action.
- Support the overarching strategy for coastal management, objects of the Coastal Management Act 2016 and objects of the Marine Estate Management Act 2014.

These objectives are for the entire estuary which is broader than the scope of the entrance management strategy. Given the entrance management strategy can impact on the wider estuary, these objectives must be considered.

6.2.3 Community and stakeholder engagement

A clear objective of the Coastal Management Act 2016 is to support social and community values as well as maintain public access and amenity. Community and stakeholder engagement was undertaken for this project as discussed in Section 3. The development of entrance management objectives was undertaken to address the key issues and key values that were identified in the community engagement results (see Section 5.3.1) and findings of the study's economic assessment (see Section 5.4).

6.2.4 Adopted management objectives

Management objectives for the Tuggerah Lakes entrance have been developed in collaboration with Council, based on the *CM Act 2016*, Tuggerah Lakes Estuary Coastal Management Program Scoping Study (CCC, 2021) and community and stakeholder feedback.

Key considerations guiding the development of entrance management objectives include the following:

- Flood mitigation was a key reason (34% of all reasons) that the community is supportive of entrance management interventions. Modelling undertaken by MHL (2022) confirmed that modest flood mitigation benefits can be realised through entrance management actions. Taking action to avoid the impacts of coastal hazards is an objective for coastal areas identified in *CM Act 2016*. Hence flood mitigation has been adopted as a primary management objective for the assessment.

- *CM Act 2016* identifies protection of biological diversity and ecosystem integrity and maintaining natural features and protection natural processes as objectives for coastal areas. In the community engagement survey 65% of respondents identified marine life and wildlife in their top 5 values of the natural environment at Tuggerah Lakes entrance whilst 28% identified benefits to ecological processes. Ecological health is also clearly identified in estuary management objectives (CCC 2021). Preserving estuary health has been adopted as a primary management objective.
- The NSW Government generally only supports minimal interference with ICOLL entrances and encourages natural processes being allowed to operate to the greatest extent possible. Any proposals for entrance management, including artificial opening, of ICOLLs must seek the approval or concurrence under the Fisheries Management Act 1994. The artificial opening of an ICOLL is typically not supported unless Council can demonstrate that the social, environmental and economic benefits greatly outweigh any potential adverse impacts. For Tuggerah Lakes entrance this means that management approach should endeavour to allow the entrance to behave as a natural ICOLL and protect natural habitats (including Little Terns). In the community engagement survey 55% of respondents identified the beauty of the area, 44% identified beaches and 34% identified interaction with birds in their top 5 values of the natural environment at Tuggerah Lakes entrance. Preserving beach health has been adopted as a primary management objective.
- The area is highly valued for waterway activities such as boating, swimming and fishing and as such the entrance management strategy should aim to maintain or enhance the amenity provided for these activities. In the community engagement survey 30% of respondents identified access to waterways and 56% identified clear water in their top 5 values of the natural environment at Tuggerah Lakes entrance. The survey results suggest that approximately 19% of recreational activities undertaken at the entrance involve direct water interaction. The economic assessment shows that changes in the recreational usage realised by interventions at the entrance can significantly change the economic value. Further, the *CM Act 2016* identifies maintaining public access, amenity and use as an objective for coastal areas. As such waterway amenity has been adopted as a secondary management objective.
- The beaches adjacent to Tuggerah Lakes entrance such as The Entrance Beach and North Entrance Beach are popular for recreation and provide a sandy buffer for infrastructure behind. In the community engagement 44% of respondents identified beaches in their top 5 values of the natural environment at Tuggerah Lakes entrance. Taking action to avoid the impacts of coastal hazards is an objective for coastal areas identified in *CM Act 2016*. These outcomes are reflected in the beach amenity and protection management objective. However, benefits to these areas are considered secondary to the overall entrance management strategy as management of these areas is predominantly addressed in Council's Open Coast CMP.

Management of Tuggerah Lakes entrance requires careful consideration as it impacts the estuary's natural processes and ecosystems, its recreational value and public safety during flood events. The adopted aspirational management objectives are defined as follows:

- **Flood mitigation:** Reduction in flood risk to the public and infrastructure along the estuary foreshore.
- **Estuary health:** Improve estuary water quality and ecological health of the estuary and its coastal environment.
- **Beach health:** Avoid disturbance of natural entrance features to maintain health of the natural habitats (including Little Tern habitat).

- **Waterway amenity:** Improve cultural, social and/ or recreational use of the Tuggerah Lakes entrance.
- **Beach amenity and protection:** Support coastal protection and increase beach amenity of adjacent areas.

These management objectives form the basis for developing, shortlisting and evaluating entrance management options for the Tuggerah Lakes entrance.

6.3 Basecase

The basecase assumes the entrance behaves entirely as it would under natural conditions (i.e., opening and closing under coastal and estuarine processes) prior to any potential impacts of the groyne constructed in 2017 (see Section 4.4) and without any entrance management intervention, specifically:

- No berm management (scraping and/or pilot channel)
- No dredging
- Retention of existing coastal structures
- Impacts of the groyne are outside Council's responsibilities and are assumed to be managed by others.

The basecase allows to compare the effectiveness of the management options with what would occur without intervention. Under the basecase, there is no improvement to the estuary amenity, no improvement to estuary water quality issues or reduction of the exposure to the natural hazards (flooding, erosion).

6.4 Overview of potential entrance management options (longlist)

Feasible management options should constitute integrated solutions that improve the value of the entrance of Tuggerah Lakes and more broadly of the functional zones of the estuary (see Section 2.5.4). However, it is noted that based on the key findings discussed earlier in this report (in Section 2 and Section 4) that there are significant constraints with what is achievable with entrance management interventions for a large, shallow, modified and degraded estuary where flooding cannot be eliminated. This is also emphasised in Glamore et al. (2020).

An overview of the potential options for entrance management of Tuggerah Lakes is provided in Table 27 to Table 29. The potential options were identified through review of previous options assessments for Tuggerah Lakes, community engagement outcomes (including Community Focus Group feedback) and experience by the project team. Potential management options were characterised under three key themes based on the way they affect sand movements at the Tuggerah Lakes entrance:

- **'Flood mitigation options'** – these options consist of allowing the entrance to behave as much as possible as it does under existing conditions. Management options are limited to emergency situations or minimal change in the configuration of existing structures to alleviate the immediate risks to public and infrastructure (flooding and erosion). There is no intervention tailored to provide any improvement to the lake amenity or estuary water quality issues. Under this theme, the following options were considered:
    - New southern training wall (modification of The Entrance Beach groyne)
    - Event-based berm management (for flood mitigation only).
- **'Keep the sand out"** – these solutions work by limiting the sand ingress into the entrance by slowing down longshore sand transport rates via shoreline control structures. They often provide a

net improvement of foreshore and waterways amenity. Due to the obstruction created in the net flow of sand, these solutions would also likely cause an updrift sand build-up which would increase the sand buffer at North Entrance Beach. Such structures may however have adverse impacts on the estuary including increasing flooding risks around the estuary (including nuisance flooding from elevated ocean water levels), depending on their location and dimensions. Under this theme, the following options were considered:

  - Training walls
  - Northern groyne
  - Artificial reef/ ship wreck
  - Closing the berm.

- **'Keep sand moving'** – these solutions work by periodically removing the sand from the entrance and replacing it on North Entrance Beach where it comes from. The constriction state of the entrance and benefits to waterway amenity would depend on the sand removal rates; a wide and open entrance would require sand removal rates to match the increased infilling rate. Removed sand would in turn be available to top up the sand buffer at North Entrance Beach or eroded foreshore areas to improve access or amenity, or enhance little tern habitat, depending on the needs at the time. No downdrift erosion impacts would be expected as these solutions are aimed at 'keeping sand moving' (i.e., they work with nature) however, a wide and open entrance would likely lead to shallower estuary water depths and associated decrease of water quality as well as risk of nuisance flooding from ocean water levels. Under this theme, the following options were considered:
  - Routine berm management
  - Programmed dredging
  - Excavation and trucking to the beach
  - Sand transfer system
  - Entrance channel fluidiser
  - Second lake entrance.

Lastly, a fourth management theme (i.e., **'complementary estuary management'**) comprises options that are complementary to longlist options and address wider estuary issues but do not consist of entrance management works or are not feasible/acceptable on their own. These options are not further evaluated herein, however should be considered during development of the final entrance management strategy and wider estuary management in Council's CMP. These consist of:

  - Stormwater treatment
  - Wetland rehabilitation
  - Catchment management
  - Floating wetlands
  - Nature-based solutions.

Table 27: Flood mitigation options.

ID	Option	Example
A1	**'New southern training wall'** A training wall is constructed in the southern entrance immediately north of the rock shelf for promoting a more efficient channel that allows unconstrained self-scouring and alleviate flood waters more rapidly. Most likely this would be a relocation of the existing rock groyne at the Entrance Beach.	 View of southern entrance area with existing groyne and rock self
A2	**'Event- based berm management'** The entrance berm is monitored and mechanically opened/ lowered prior to a flood event to allow alleviating flood waters more rapidly and includes prescribed actions tailored to different channel states. This option is similar to Council's Interim Entrance Management Procedure (see Section 2.2.1).	 Pilot channel preparation prior to flood

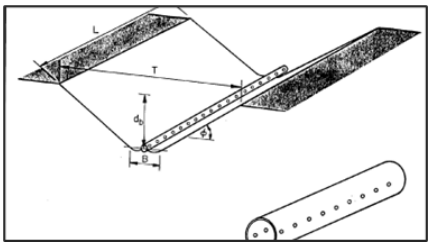
Table 28: List of 'keep the sand out' options.

ID	Option	Example
B1	**Training walls** Two training walls are constructed in the entrance immediately north of the rock shelf for keeping a permanent open tidal entrance to the estuary. Sand build up on the northern side of the northern breakwater is expected to be rapid. Maintenance dredging to offset sand bypassing likely required.	 Trained entrance at Tweed Heads NSW
B2	**Northern groyne** A groyne is constructed on the northern side of the entrance that constitutes a barrier to southward longshore sand transport aiming to limit sand ingress into the entrance and reduce level of constriction. This groyne(s) would retain sand on updrift beach and maintain the sandy	

ID	Option	Example
	buffer on North Entrance Beach. Efficiency dependent on length of groyne and sand bypassing.	 Quinns Beach rock groyne, Western Australia
B3	**Artificial reef / ship wrecks** Wave breaking on reef/ wreck reduces energy at the beach and slows down longshore sand transport (locally). This promotes updrift (northern) sand build up and limits sediment ingress in the entrance. Sand berm and shoals behave naturally but with a decreased constriction level.	 Palm Beach artificial reef, Gold Coast

Table 29: Longlist of 'keep the sand moving' options.

ID	Option	Example
C1	**Routine berm management** This option consists of ongoing berm scraping of a designated region of the entrance berm to maintain low sand levels and pilot channel excavation using land-based equipment. A designated region of the entrance berm is monitored, and its height is maintained below a design elevation via routine mechanical beach scraping. In addition, a pilot channel through the berm would also be routinely maintained at a given depth and width.	 Beach scrapping at Main Beach, Byron Bay
C2	**Programmed dredging** This option consists of regular programmed dredging of entrance flood shoal similar to Council's previous practice (see Section 2.2.2). "Programmed" dredging refers to works undertaken under established approvals and with allocated budget. Dredging is typically carried out every one to two years, triggered when entrance constriction and shoal growth threaten the stability or openness of the ebb and flood channels.	 Maintenance dredging at the Tuggerah Lakes entrance
C3	**Berm excavation and trucking to the beach** This option consists of routine excavation of the entire entrance berm using land-based equipment to maintain design sand levels below a certain level. Sand would be trucked to North Entrance Beach to increase sand buffer.	 Excavating and trucking of sand on beach
C4	**Sand transfer system** A sand transfer system with mobile intake pumps sand from the entrance to North Entrance Beach attempting to keep the entrance permanently open and manage the berm.	 Discharge pump at Woorim Beach, Queensland

ID	Option	Example
C5	**Entrance channel fluidiser** Fixed fluidiser system at southern entrance channel location. Pipe buried in channel allowing injection of fluid to fluidise sandy seabed. Slurry is transported out of the entrance channel via ebb tide current. The effectiveness of this option may be impacted by the presence of rock around/in the entrance including the current entrance location.	 Channel fluidiser concept sketch
C6	**Second lake entrance** This option consists of excavating the ancient marine delta south of Budgewoi township to create a second entrance to the estuary. During the Pleistocene and Holocene periods, Budgewoi entrance gradually infilled with rising sea levels sand and closed about 2000 years ago. Such works would involve extensive excavation and civil works including a bridge along the Central Coastal Highway.	 Narrow coastal dunes fronting Budgewoi Lake south of Budgewoi township
C7	**Closing the berm** Mechanical closing of the entrance berm to maintain/ increase estuary water levels during periods of low catchment inflows. Unlike the other options that aim to widen the entrance, this option serves mainly to manage estuary water quality during low estuary water levels and would only apply in limited situations. This option can supplement other sand management options in this category and may need mechanical entrance opening after a set period or when catchment inflows raise estuary water levels to acceptable levels.	 Mechanical closure of an estuary entrance, Sunshine Coast

6.5 Coarse filter assessment

6.5.1 Framework

A coarse filter was applied to identify a shortlist of options to be the focus for further development from those that could be dismissed early in the process. The filter applied a traffic light type assessment where 'Go', 'Slow', 'Stop' were assigned based on expected performance against mandatory criteria. Progression of options was considered as follows:

- 'Stop' options were not progressed further. These were options that were identified if any of the three mandatory assessment criteria to be scored as a 'stop'.
- 'Go' options were deemed feasible. These were options that did not score a 'stop' against any of the three mandatory assessment criteria. Where 'slow' was assigned to one or more mandatory criteria, this may trigger additional investigation to understand if the option is feasible/ acceptable.

Elements of the 'complementary management' group have not been assessed as these are equally beneficial to all entrance management options considered herein.

Three mandatory criteria were adopted that helped identify the most feasible entrance management options. Scoring against the mandatory assessment criteria was undertaken based on accepted coastal engineering research and understanding of Tuggerah Lakes processes. Scoring and ranking of the longlist of the options was also workshopped with the Community Focus Group on 1 February 2023.

With the mandatory criteria set out in Table 30 the coarse filter answers the following key questions:

- **Is it practical (i.e., can it be done?)**
  - Is the option acceptable from an engineering, constructability, and operability/ maintenance perspective?
  - Does it align with the roles and responsibilities of the Central Coast Council?
  - Is it financially possible?
- **Is it acceptable? (i.e., should it be done?)**
  - Does it have acceptable environmental impacts?
  - Is it legal? Is it possible to seek planning approvals for it?
  - What is the expected level of community support for this option?
- **Is it effective? (i.e., will it work?)**
  - Does it perform against the management objectives (flood mitigation, estuary health, beach health, waterway amenity)?
  - What is the level of confidence in the solution?
  - Is the option adaptable to changing condition?

Table 30: Assessment criteria used in coarse filter.

Score	Is it practical? (i.e., can it be done?)	Is it acceptable? (i.e., should it be done?)	Is it effective? (i.e., will it work?)
Go	Clear design and implementation pathway	Enhances the Tuggerah Lakes environment/ no adverse impacts	Responds adequately and sustainably to the management objectives
Slow	Likely feasible but identified unresolved difficulties	Likely acceptable with manageable impacts	Likely minimal benefits or high uncertainty or inconsistency
Stop	Not practical	Unacceptable impacts	Performs poorly

6.5.2 Coarse filter results

The results of the coarse filter assessment of potential entrance management options is provided in Table 31. As outlined in Section 6.5.1 any management options that were assigned ‘stop’ were dismissed and are not further considered. Five shortlisted entrance management options were considered most feasible for Tuggerah Lakes entrance.

Table 31: Coarse filter assessment results.

Description	Is it practical? (i.e., can it be done?)	Is it acceptable? (i.e., should it be done?)	Is it effective? (i.e., will it work?)	Assessment outcome
A1 – New southern training wall	Yes, a geobag or rock training wall could be designed and constructed. There would be a significant cost.	To gain planning approval, a significant social or economic justification is required (e.g., new/support for industry) which is unlikely.	To a degree. A southern training wall will slightly concentrate flows and lead to a deeper channel after flood. The channel will still infill.	**Stop**
A2 – Event-based berm management	Regular monitoring and emergency resources on standby – similar interim procedures already in place (MHL, 2022).	Impacts are likely to be manageable and may include the disruption of operations on environmental receptors.	Improvement to flood mitigation only.	**Go**
B1 – Training walls	Excessive costs unlikely to be financially viable. Extensive approvals would be required from multiple consent authorities.	Potential impact on lake habitats and ecology (increase in salinity and decrease in mean estuary water levels). Runaway estuary response triggered leading to larger tidal ranges in the estuary and potential impacts on foreshore and assets.	Potential increase in flooding levels, efficiency dependent on length of breakwaters. Dredging may be required periodically.	**Stop**

Description	Is it practical? (i.e., can it be done?)	Is it acceptable? (i.e., should it be done?)	Is it effective? (i.e., will it work?)	Assessment outcome
B2 – Northern groyne	Similar to the existing (southern) groyne suggesting that structure could be built at North Entrance Beach.	Potential impact on berm condition and sand dune habitats of North Entrance Beach.	Moderately reduces shoaling (improves flood conveyance) but degree of reduction subject to further investigation. Could improve beach resilience at North Entrance Beach.	**Go**
B3 – Artificial reef / ship wreck	Artificial reefs or scuttling of ship would be expensive to implement and are unlikely to be financially possible.	While environmental impacts are likely to be acceptable these structures have a challenging planning approvals process in NSW. Would rely on CMP outcomes.	Relatively low alongshore rates of net sand movement and steep coastal profile means this is unlikely to be effective against management objectives.	**Stop**
C1 – Regular berm management	High cost with minimal benefit over event-based berm management (A2) – high sand infilling rates.	Potential impact on natural habitats and nuisance of operations to the community.	May improve flooding risk if works can keep up with high sand infilling rates.	**Slow**
C2 – Programmed dredging	Long-history of dredging proving dredging is practically feasible.	Potential impact on natural habitats (sediment plume) and nuisance during operations.	Improves flushing (largely limited to entrance compartment) and waterway amenity. Benefits to reducing flooding risk by maintaining	**Go**

Description	Is it practical? (i.e., can it be done?)	Is it acceptable? (i.e., should it be done?)	Is it effective? (i.e., will it work?)	Assessment outcome
			ebb tide channel requires further investigation.	
C3 – Excavation and trucking to the beach	Approvals dependent on community and environmental impact level.	Nuisance of operations (i.e., noise) to the community. Impact on sand dune habitats (including Little Terns) on the berm and North Entrance Beach.	Expected to improve flushing (largely limited to entrance compartment). Benefits to reducing flooding risks requires further investigation (option not modelled).	**Stop**
C4 – Sand pumping transfer system	High capital and operations costs.	Requires further investigation. Impacts on beach and estuary habitats likely could be managed due to flexibility in operations.	Providing that the entrance is wide enough and pump capacity set to match infilling rate.	**Go**
C5 – Entrance channel fluidiser	This system is considered novel on the east coast of Australia. Trials would be required. Developing the technology falls outside Council's remit.	As C4. Generally, sand management strategies around coastal entrances are accepted.	If proven, it could provide a positive benefit to flood mitigation & beach health. Little effect on waterway amenity. Low level of confidence.	**Stop**

Description	Is it practical? (i.e., can it be done?)	Is it acceptable? (i.e., should it be done?)	Is it effective? (i.e., will it work?)	Assessment outcome
C6 – Second lake entrance	Excessive costs unlikely to be financially viable. Low confidence in technical feasibility and extensive approvals would be required from multiple consent authorities.	Profound impact on lake ecosystem, disruption of road traffic.	Potential limited efficacy (constriction of existing entrance).	**Stop**
C7 – Closing the berm	Yes, during low flow / heavily shoaled conditions sand could be used to mechanically close the berm.	Likely only acceptable in combination with other entrance management procedures to mitigate elevated risk of flooding and changes to estuary health (e.g., decrease in salinity and increase in mean estuary water levels).	Aspects of estuary health would improve while there would be a flood risk that would need to be managed.	**Go**

6.5.3 Summary

Five standalone entrance management options passed the coarse filter (i.e., were not assigned a 'Stop') and therefore progressed to further development and assessment in Section 6.6. These include:

- Event-based berm management (Option A2)
- Northern groyne (Option B2)
- Regular berm management (Option C1)
- Programmed dredging (Option C2)
- Sand pumping transfer system (Option C4)

The closing the berm option (C7) which was assigned 'Go' was incorporated into Options A2 and C1 as it may provide additional benefit to these options in limited situations where low estuary water levels periodically reduce estuary health. Similarly, the entrance channel fluidiser option (C5) was assigned 'Stop' as a standalone option however could be considered as part of the sand transfer system option (C4) due to the similar nature of such system. Should options A2, C1 or C4 become preferred entrance management solutions, further investigation into incorporating options B4 and C5, respectively, into a greater entrance management scheme may be warranted. Options B4 and C5, have not been further developed in this study.

6.6 Shortlisted management options

In this section a description, conceptual layout, high level cost estimate and socio-economic context for a design lifetime of 20 years are provided for each option. Consistent with the early design stage, relatively simple methods were used to develop the shortlisted options. Methods included reviewing available literature, data and precedent projects which was used to inform selected design configurations for each of the shortlisted options. In general, conservative assumptions and approaches have been adopted for the design of the main elements. More thorough approaches should be used during later design phases to better resolve and optimise the preferred option(s).

6.6.1 Event-based berm management (Option A2)

The rationale behind event-based berm management is that the level of constriction of the entrance influences the magnitude of flooding around the estuary (i.e., a wide open entrance reduces estuary flood levels and minimises flood damages along the estuary foreshore) and that flood levels can be reasonably predicted using modelling and monitoring tools sufficiently early to mechanically reduce the level of entrance constriction prior to a flood event.

Figure 70 provides a layout of the conceptual design of this option while Table 32 provides a description of its main elements and outcomes.

Table 32: Description of event-based berm management (Option A2).

Design parameter	Description
Strategy	The entrance berm is monitored and mechanically opened prior to a predicted flood event to reduce flood risk. This option largely represents the existing Interim Entrance Management Procedure as per MHL (2022) with the addition of formalised beach nourishment to increase the buffer against storm erosion at vulnerable areas, primarily along North Entrance Beach or eroded foreshore areas as required.

Design parameter	Description
Scheme	The following steps are involved in this scheme: • Ongoing prediction and monitoring of lake levels/ entrance condition using MHL Flood Information Tool (MHLFIT) as well as regular site inspections (see flow Chart A in MHL, 2022). MHL FIT considers entrance constriction while incorporating near real-time gauge data, Bureau of Meteorology (BoM) rainfall forecasts, tide and antecedent moisture content into its automated predictions of lagoon level for up to four days into the future (MHL, 2022) If exceedance of estuary water level trigger of +1.3m AHD is predicted, implement a suite of berm management procedures depending on level of entrance constriction (see Procedures A to E in MHL, 2022). Berm preparation works should ideally be undertaken around low tide windows within the 1 to 3 days prior to flooding and would consist of: • Berm scraping works (A, see Figure 70) to lower the berm levels adjacent to existing channel opening south. Pilot channel end plugs (estuary and ocean) kept in place. • Excavation of the pilot channel (B, see Figure 70) is to be undertaken after measured estuary levels are at least +1.1 m AHD but depending on the coastal conditions as assessed using MHLFIT decision support. • Minor nourishment (C, see Figure 70) using excavated sand at approved placement areas (e.g., North Entrance Beach). • Assumed one berm management event every five years based on historical water level exceedance (see Section 2.5.5). *Optional [not scored]:* closing of berm to maintain estuary water level during drought conditions to periodically manage water quality but this would require detailed investigations as this could also have potential undesired effects (e.g., reduced flushing in entrance compartment). In addition, if required, scraping of section of berm may be undertaken for the purpose of beach nourishment.
Implementation requirements	• Machinery consists of bulldozers, excavators, and dump trucks. Suitable machinery required to be on standby to intervene at short notice during a storm event. • Access to the entrance berm from the Hutton Road carpark, Council is to regularly maintain access. • OHS procedures should control risk during operations on entrance berm in difficult weather conditions. • Berm and pilot channel preparation work and access locations should be determined based on present shorebird nesting areas during the nesting periods. The nesting periods are typically between October to March depending on shorebird species. Additional controls may be required to minimise impacts including buffer distance from nesting areas. • Trigger value would need to be periodically reviewed based on performance evaluation and adaptation to rising sea levels.
Flood mitigation	Flood mitigation is the primary benefit of this management option with berm based management targeted prior to certain flood events to reduce backwater flooding. Flood level reductions associated with the procedure were modelled in the development of the procedure. Modelling indicates flood level reductions are expected to be small (typically less than 0.2m, varying depending on antecedent entrance conditions and flood

Design parameter	Description
	severity), however, are considered beneficial in assisting to reduce flood damages (MHL, 2022). While the economic value of flood risk mitigation at Tuggerah Lakes was not assessed herein, the socio-economic assessment (Section 5) identified that flood mitigation was a key reason (34% of all reasons) that the community is supportive of entrance management interventions.
Estuary health	No significant changes to estuary health are anticipated from the implementation of the management option. Management actions are restricted to berm scraping and excavation of a pilot channel. Whilst this represents an interruption to natural processes it would not be expected to significantly impact conveyance outside of significant flood events. Hence, impacts to estuary health and water quality indicators would not be expected.
Beach health	This management option minimises intervention outside of event-based activities. Hence, outside of these activities the berm and entrance will be allowed to behave as a natural ICOLL. Impacts to habitat and beach health may be experienced during management activities which involve heavy machinery on the berm. Shorebird nesting periods occur from October to March which require consideration during operations. Potential for some benefit via targeted sand placements to support habitat management.
Waterway amenity	No significant changes to waterway amenity would be anticipated due to this management approach. Management actions are targeted to the berm and are limited to scraping and establishment of a pilot channel. Hence, no benefits to waterway-based activities such as swimming, fishing or boating would be anticipated.
Beach amenity and protection	A small amount of sand is excavated during event-based berm management activities through berm scraping and excavation of a pilot channel and is available for nourishment of adjacent beaches. However, these volumes are minimal and unlikely sufficient to provide a measurable benefit against storm erosion. Targeted sand placements may improve access, amenity and provide ecological benefits.

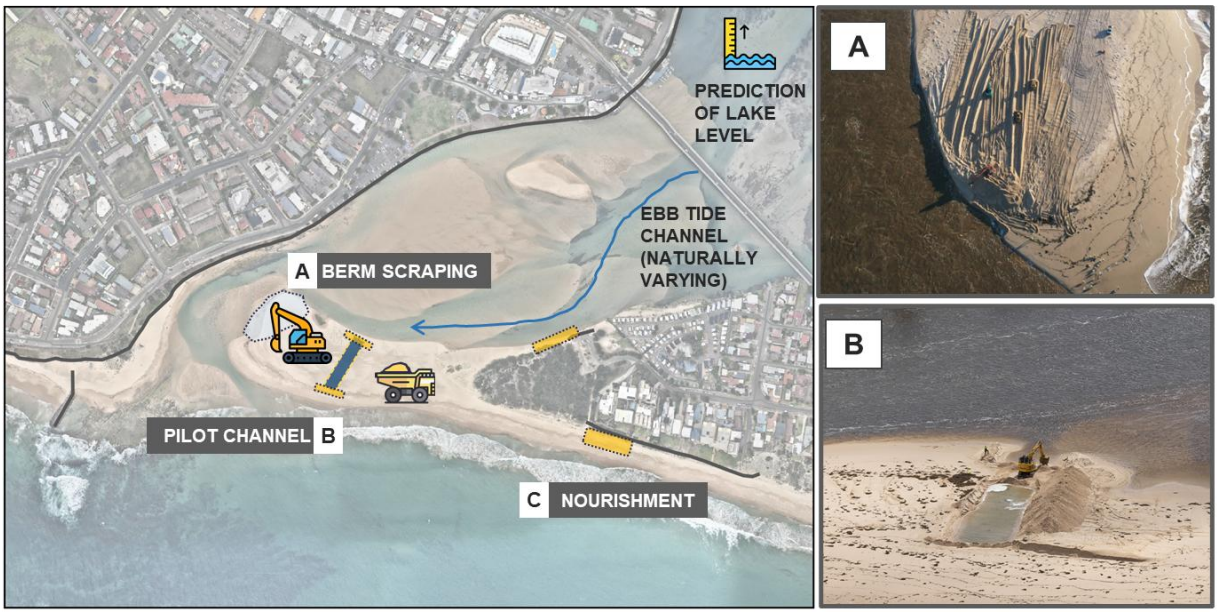


Figure 70: Event-based berm management (Option A2) conceptual design layout.

6.6.2 Routine berm management (Option C1)

The rationale behind routine berm management is to regularly maintain a low level of constriction of the entrance to reduce the flood levels in the estuary. The berm levels are regularly monitored, and mechanical interventions are frequently implemented attempting to maintain the berm in a configuration favourable to conveyance of flood waters to minimise flood damages along the estuary foreshore. Such works would be required to keep up with natural sand infilling rates due to coastal processes.

Figure 71 provides a layout of the conceptual design of this option while Table 33 provides a description of its main elements and outcomes.

Table 33: Description of routine berm management (Option C1).

Design parameter	Description
Strategy	This option largely represents Option 5 as per MHL (2022). The entrance berm is monitored and routinely opened to maintain a maximum berm height and pilot channel (similar to A2 but more proactive and labour intensive) to reduce flood risk during flood events.
Scheme	The scheme would include the following steps: • Monitoring of entrance condition (berm height, level of constriction) If monitoring records exceed trigger levels (e.g., berm height exceeds +1.8m AHD), the following berm maintenance works are implemented: • Regular scraping of berm to keep a predefined section below target level of +1.5m AHD (A, see Figure 71). Pilot channel end plugs (lake and ocean) kept in place. • Regular excavation of pilot channel to maintain target dimensions with a natural berm plug on its estuary and seaward edges to prevent infilling during dry weather (B, see Figure 71). These plugs would be excavated in the lead up to a flood event allowing ocean outflow and inflow.

Design parameter	Description
	• Nourishment at approved placement area (C, see Figure 71). • Assumed six berm management events required every year based on MHL (2020). • *Optional [not* scored*]:* closing of berm during drought conditions to maintain estuary water level to periodically manage water quality but this would require detailed investigations as this could also have potential undesired effects (e.g., reduced flushing in entrance compartment).
Implementation requirements	• Berm monitoring techniques could vary from drones, on-ground surveys, or LiDAR. • Machinery for berm works consists of bulldozers, excavators, and dump trucks. • Access to the entrance berm from the Hutton Road carpark. A formalised access path and procedures would be required to reduce erosion and ecological impacts. • OHS procedures should control risk during operations on entrance berm. Works should be performed at low tide and preferably in good weather conditions. • Work and access locations should be determined to avoid present shorebird nesting areas during the nesting periods. The nesting periods are typically between October to March depending on shorebird species. Additional controls may be required to minimise impacts including buffer distance from nesting areas.
Flood mitigation	Flood mitigation is the primary benefit of this management option with regular berm scraping and pilot channel excavation undertaken to maintain a consistent berm condition which has been designed to enable scouring during flood events to reduce backwater flooding. Similarly to event-based berm management flood level reductions are expected to be small. While the economic value of flood risk mitigation at Tuggerah Lakes was not assessed herein, the socio-economic assessment (Section 5) identified that flood mitigation was a key reason (34% of all reasons) that the community is supportive of entrance management interventions.
Estuary health	No significant changes to estuary health are anticipated from the implementation of the management option. Management actions are restricted to berm scraping and excavation of a pilot channel. Whilst this represents an interruption to natural processes it would not be expected to significantly impact conveyance outside of significant flood events. Hence, impacts to estuary health and water quality indicators would not be expected.
Beach health	Due to the dynamic nature of the berm management activities are likely to be required regularly. These activities may influence the natural behaviour of the ICOLL and berm processes. Impacts to habitat and beach health may be experienced during regular management activities involving heavy machinery working on the berm. Shorebird nesting periods occur from October to March which may limit operations.
Waterway amenity	No significant changes to waterway amenity would be anticipated due to this management approach. Management actions are targeted to the berm and are limited to scraping and establishment of a pilot channel. Hence, no benefits to

Design parameter	Description
	waterway-based activities such as swimming, fishing or boating would be anticipated.
Beach amenity and protection	A small amount of sand is excavated during routine berm management activities through berm scraping and excavation of a pilot channel and is available for nourishment. While higher sand volumes compared to event based berm management would be available, these volumes are still unlikely sufficient to provide a measurable benefit against storm erosion.

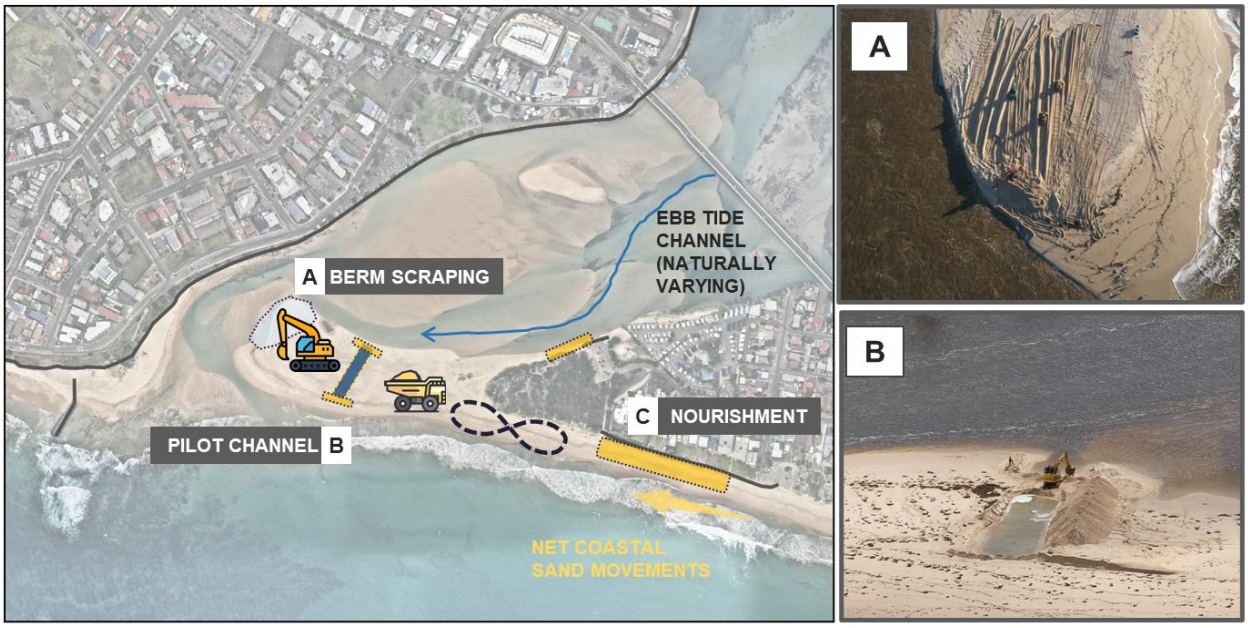


Figure 71: Routine berm management (Option C1) conceptual design layout.

6.6.3 Sand transfer system (Option C4)

The rationale behind the sand transfer system is to continuously maintain a flood ready entrance condition using a sand transfer system. This is similar to options A2 and C1 but using a mobile sand pumping system to reduce manual labour. Figure 72 provides a layout of the conceptual design of this option while Table 34 provides a description of its main elements and outcomes.

Table 34: Description of sand transfer system (Option C4).

Design parameter	Description
Strategy	Periodic removal of sand from entrance to provide flood mitigation, entrance clearance and beach nourishment using a sand transfer system.
Scheme	The sand transfer system would consist of:

Design parameter	Description
	• Mobile jet pumps (e.g., sand shifter or DOP pumps) remove sand from the berm including pilot channel (see 'A' in Figure 72). A mobile intake is used to overcome issues with dynamic entrance behaviour. • The pumps are connected to a fixed slurry pump station and seawater intake located in a sheltered location at Hutton Rd carpark (see 'B' in Figure 72). • Permanent (buried) pipeline and outlet to North Entrance Beach (C and D, see Figure 72) *Optional [not scored]:* connection for dredger for use of permanent pipe/outlet for beach nourishment at North Entrance Beach. The sand transfer system could also be used for closing of berm to maintain estuary water level but this groyne would require detailed investigations as this could also have potential undesired effects (e.g., reduced flushing in entrance compartment). The system should be designed to cope with time varying ingress of sand into the entrance. A production capacity of 60m^3/hr (600m^3/day) would likely be required with a yearly average transfer of up to 30,000m^3 to balance the southward oriented longshore sand transport in this area.
Implementation/ operational requirements	• Prior to full scale operations, geotechnical and design investigations as well as trial tests using mobile sand transfer station to determine optimum system configuration (e.g., number and positions of pumps) and definition of controls to limit impact of wrack on performance. • The sand transfer system would consist of a slurry pump station and high-pressure water pump, mobile jet pumps, pipelines (around 1km above-ground and 500m buried), excavator to change position of pumps and above-ground pipes (occasionally). Consideration of safeguards and mitigation measures regarding noise from pump station.
Flood mitigation	The sand transfer system would provide in-situ infrastructure for more significant berm and flood shoal management. By pumping up to 30,000m^3 each year this will limit the growth of the berm and flood shoal by removing sand from the entrance. Flood mitigation is a benefit of this management option with a less constricted enhancing conveyance. Flood mitigation benefits of this approach are expected to be greater compared to event-based and routine berm management options due to the larger and more consistent reduction in entrance constriction. The risk of nuisance flooding from elevated ocean water levels entering the less constricted entrance would require further assessment. The economic value of flood risk mitigation at Tuggerah Lakes was not assessed herein, but the socio-economic assessment (Section 5) identified that flood mitigation was a key reason (34% of all reasons) that the community is supportive of entrance management interventions.
Estuary health	The reduction in entrance constriction arising from more significant sand management activities could lower the typical water levels of the estuary impacting overall estuary health and water quality indicators. Due to the potential impacts on estuary health a reduction in the economic value of the estuary is plausible. Assuming 20% of users would decrease their frequency of use by 50% due to a potential decrease in estuary health and worsened smell associated with decomposing organic matter (due to lowering of estuary water level), this could result in an estimated loss of $3.4M per annum (see Section 5.4.5).

Design parameter	Description
	The reduced constriction can also support tidal flushing however this would be limited to the entrance compartment. No correlation has been found between the level of constriction of the entrance and water quality in the wider estuary (Glamore et al., 2020).
Beach health	This management option represents a significant interruption to the natural behaviour of the entrance as an ICOLL. Impacts to habitat may be experienced during construction and operation of the management option, including activities involving heavy machinery. Shorebird nesting periods occur from October to March which may limit operations. Operation of the sand transfer system involves the pumping of sand from the berm inhibiting the natural behaviour of the ICOLL. Reductions in berm size would be expected impacting beach health and habitat.
Waterway amenity	The reduced constriction of the entrance arises from the removal of sand from the berm. This may also result in some changes to the flood shoals but predicting the effect of this on waterway amenity would require detailed assessment. Greater hydraulic connectivity may lead to scouring/ lowering of the flood shoal increasing navigability in some areas. However, this may also increase currents and wave exposure reducing the safety for water-based activities such as boating, swimming and fishing.
Beach amenity and protection	Sand removed from the entrance (up to 30,000 m^3/ year) could be placed on North Entrance Beach. This additional sand would support beach amenity providing additional space for recreation and a level of buffer against storm erosion. The economic benefit associated with an increased sand buffer at North Entrance Beach was not quantified in this study but could be significant.

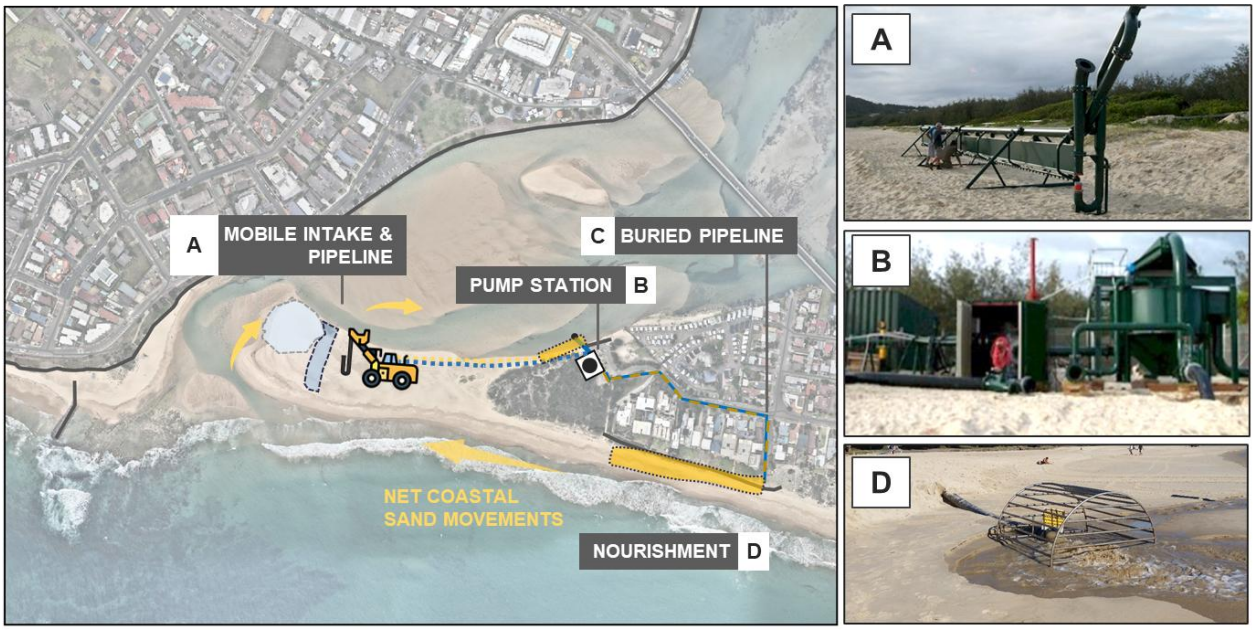


Figure 72: Sand transfer system (Option C4) conceptual design layout.

6.6.4 Programmed dredging (Option C2)

The rationale behind programmed dredging (Option C2) is reducing the entrance compartment sand volume at the flood shoals, maintaining a connection between the estuary and the ocean (i.e., ebb channel through flood shoal) and limiting full closure of the entrance while deepened areas provide recreational waterway opportunities (e.g., boating). Dredging within the entrance has historically been undertaken for various purposes (either using Council's previously owned dredge and more recently via external contractors). It is noted that the approach to recent dredging campaigns was amended to fulfil requirements set out by the NSW Environment Protection Authority (EPA) which significantly reduced productivity. For the purposes of this option evaluation, it was assumed that the dredging approach could be improved during further development of this option to achieve higher productivity while satisfying EPA requirements.

Previous studies are inconclusive on the benefits of past dredging on flood risk reduction (Glamore et al., 2020) and this requires further assessment. Recent flood modelling in MHL (2022) did not specifically assess benefits of maintaining an ebb channel for flood risk mitigation. That is, all MHL's modelling assumed a flow connection across the flood tide shoals (i.e., a scoured and/or dredged channel).

Figure 73 provides a layout of the conceptual design of this option while Table 35 provides a description of its main elements and outcomes.

Table 35: Description of programmed dredging (Option C2).

Design parameter	Description
Strategy	Routine dredging of the ebb channel and flood shoal primarily for waterway amenity and potentially help alleviating flooding risk (effects to be investigated further). "Programmed" dredging refers to works undertaken under established approvals and with allocated budget.
Scheme	The scheme would involve: • Cutter Suction Dredge removing sand at flood shoal to maintain flow connection between Tuggerah Lake basin and the lower entrance (see 'A' in Figure 73). • Dredged sand pumped to North Entrance Beach or other approved placement area via temporary pipeline for beach nourishment. • *(optional) [not scored]* beach profiling along North Entrance Beach to enhance sand buffer and profile shape (see 'B' and 'C' in Figure 73). • Assumed one dredging campaign every year of up to 30,000m^3 based on estimated infilling rates (Section 4.2) and dredging volumes of previous campaigns (optimal dredging program subject to refinement during design phase).
Implementation/ operational requirements	• Additional targeted modelling to study the effects of the flood tide shoals/ebb channel restrictions on flood risk and optimise dredging plan for flood mitigation. • Plant/ equipment: cutter suction dredger, pipelines (typ. 0.8km floating/ temporary and 250m permanent buried pipe). • Environmental controls to limit fines dispersion to meet EPA requirements (see the Review of Environmental Factors - RHDHV, 2020).

Design parameter	Description
	• Safety controls (e.g., buoys) and optimised dredge design as narrow dredged channel can pose risk to waterway usage.
Flood mitigation	Flood mitigation impacts arising from this management option require modelling to determine expected efficacy. Dredging is limited to navigable areas including the flood shoal and ebb channel. Investigation and modelling would be required to design the dredging to train the flow in these locations with the goal to assist scouring of the berm during flood events. This may result in some improved flood mitigation. The economic value of flood risk mitigation at Tuggerah Lakes was not assessed herein, but the socio-economic assessment (Section 5) identified that flood mitigation was a key reason (34% of all reasons) that the community is supportive of entrance management interventions.
Estuary health	The reduction in entrance constriction arising from dredging activities may improve hydraulic connectivity and conveyance. These changes may lower the typical water levels of the estuary impacting overall estuary health and water quality indicators. Due to the potential impacts on estuary health a reduction in the economic value of the estuary is plausible. Assuming 20% of users would decrease their frequency of use by 50% due to a potential decrease in estuary health and worsened smell associated with decomposing organic matter (due to lowering of estuary water level), this would result in an estimated loss of $3.4M per annum (see Section 5.5). The reduced constriction can also support tidal flushing however this would be limited to the entrance compartment. No correlation has been found between the level of constriction of the entrance and water quality in the wide estuary (Glamore et al., 2020).
Beach health	Operation of the dredge is limited to the flood shoal having minimal impact on berm behaviour outside of flood events. However, improvements in hydraulic connectivity and conveyance may impact the natural behaviour of the entrance as an ICOLL. Dredge operations could be undertaken to limit usage of heavy machinery in habitat/ sensitive areas on the beach/ berm. However, some disruptions to habitat and health may occur during placement of dredged material.
Waterway amenity	Dredging involves the removal of sand from the ebb channel and flood shoal. This increases the depth of the water providing additional depth and space for waterway-based activities such as fishing, boating and swimming in the entrance. An increase in waterway amenity due to a less shoaled entrance compartment and deepened channels has the potential to increase water-based activities. Assuming a 40% increase in such activities, this could result in an estimated additional economic benefit of $6M per annum (see Section 5.5).
Beach amenity and protection	Dredged sand removed from the entrance could be placed on North Entrance Beach. This additional sand would support beach amenity providing additional space for recreation and a level of buffer against storm erosion. The economic benefit associated with an increased sand buffer at North Entrance Beach was not quantified in this study but could be significant.

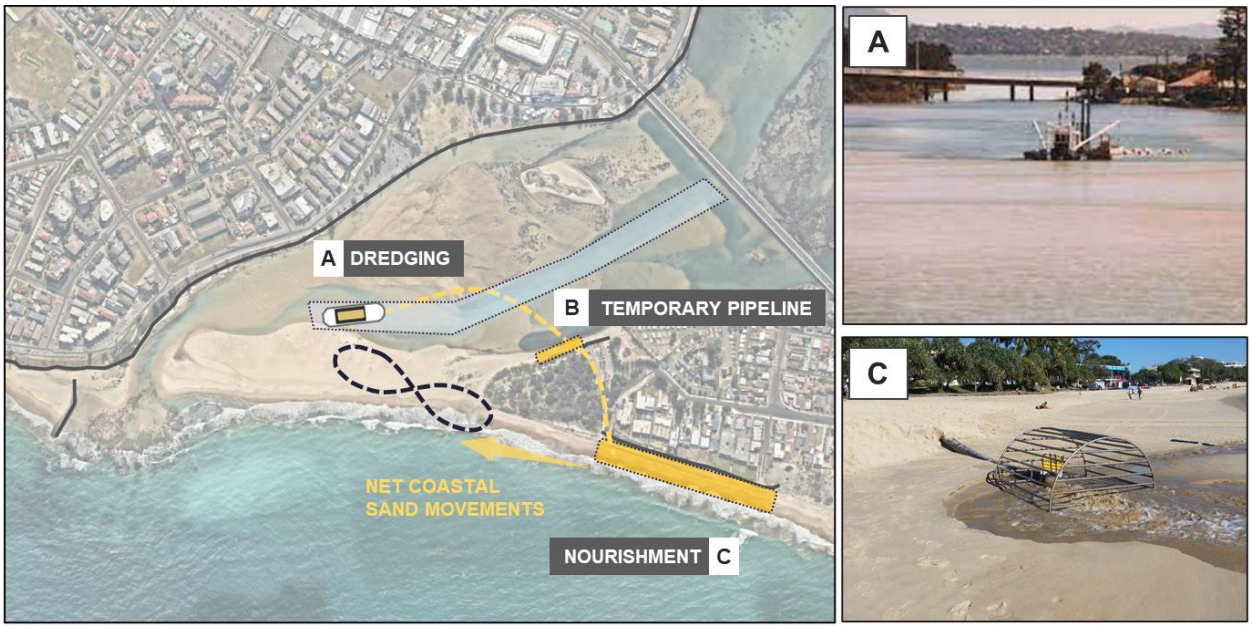


Figure 73: Programmed dredging (Option C2) conceptual design layout.

6.6.5 Northern groyne (Option B2)

The rationale behind the northern groyne option (B2) is that the estuary entrance infills primarily with sand being transported alongshore from the north under the wave induced longshore sand transport. This option aims to block sand updrift prior to deposition in the entrance, therefore maintaining a more open entrance which would promote conveyance of floodwaters and increase the typical sand buffer along North Entrance Beach.

Figure 74 provides a layout of the conceptual design of this option while Table 36 provides a description of its main elements and outcomes.

Table 36: Description of northern groyne (Option B2).

Design parameter	Description
Strategy	Groyne on the northern side of the entrance to interrupt net southward sand movements, reducing the volume of sand on the entrance berm providing flood mitigation and stabilisation of North Entrance Beach.
Scheme	The scheme would consist of: • Construction of trial groyne using geotextile sand containers, if successful, future option to replace with permanent rock groyne to reduce maintenance (see 'A' in Figure 74). • Periodic mechanical profiling of sand along North Entrance Beach to reduce sand bypassing around groyne (see 'B' in Figure 74). • Performance of trial groyne would determine the final optimal length and position of the permanent rock groyne.
Implementation requirements	• Detailed investigations required to evaluate performance and impacts including on flooding risk mitigation.

Design parameter	Description
	• Detailed design investigations including rock sizing and rock sourcing studies and environmental studies. • Materials: a 100m groyne would typically require up to 3,000T of rocks or 2,000 geotextile sand containers (2.5m^3 size). A smaller trial groyne would be constructed using geotextile sand containers. • Machinery: suitable excavator for construction and bulldozer for regular beach profiling to limit sand bypassing.
Flood mitigation	Flood mitigation impacts arising from this management option require modelling to determine expected efficacy. A groyne on the northern side of the entrance would act to keep sand out of the entrance reducing the growth of the berm. This could reduce the entrance constriction and reduce backwater flooding. Hence, a modest reduction in peak flood levels would be expected. The risk of nuisance flooding from elevated ocean water levels entering the less constricted entrance would require further assessment. The economic value of flood risk mitigation at Tuggerah Lakes was not assessed herein, but the socio-economic assessment (Section 5) identified that flood mitigation was a key reason (34% of all reasons) that the community is supportive of entrance management interventions.
Estuary health	The reduction in entrance constriction arising is likely to improve hydraulic connectivity and conveyance. These changes may lower the typical water levels of the estuary impacting overall estuary health and water quality indicators. Due to the potential impacts on estuary health a reduction in the economic value of the estuary is plausible. Assuming 20% of users would decrease their frequency of use by 50% due to a potential decrease in estuary health and worsened smell associated with decomposing organic matter (due to lowering of estuary water level), this would result in an estimated loss of $3.4M per annum (see Section 5.5). The reduced constriction can also support tidal flushing however this would be limited to the entrance compartment. No correlation has been found between the level of constriction of the entrance and water quality in the wide estuary (Glamore et al., 2020).
Beach health	This management option represents a significant interruption to the natural processes of the berm and entrance to behave as an ICOLL. Impacts on habitat during construction and operation would be expected as the entrance and adjacent shorelines respond to the intervention. Downdrift erosion/ destabilisation would lead to a reduction in the entrance berm size which could impact dune health and sensitive habitat. To maintain efficacy regular beach profiling north of the groyne would be required potentially causing ongoing impacts to beach health and habitat.
Waterway amenity	This approach would limit the ingress of sand into the entrance and slow the growth of the northern berm reducing entrance constriction as shown in Figure 74. This may also result in some changes to the flood shoals but predicting the effect of this on waterway amenity would require detailed assessment. Greater hydraulic connectivity may lead to scouring/ lowering of the flood shoal increasing navigability in some areas. However, this may also increase currents and wave exposure reducing the safety for water-based activities such as boating, swimming and fishing.

Design parameter	Description
Beach amenity and protection	Sand kept out of the entrance would be retained on the northern side of the groyne leading to an increase in beach width at this location. This additional sand would support beach amenity providing additional space for recreation and a level of buffer against storm erosion. The economic benefit associated with an increased sand buffer at North Entrance Beach was not quantified in this study but could be significant. However, impacts (including downdrift erosion and visual amenity) could result in an overall loss of economic value. The natural amenity, beauty of the area and benefits to ecological process and wildlife are key values important to the community (Section 5.3.1).

Figure 74: Northern groyne (Option B2) conceptual design layout.

6.7 Comparative assessment of shortlisted options

6.7.1 Technical evaluation approach

To compare their expected performance, the shortlisted management options were assessed against non-economic criteria. The assessment criteria are aligned with the management objectives described in Section 6.2 and are presented in Table 37. The weighting of each assessment criteria is separated into primary and secondary criteria based on outcomes of the community engagement and consultation with Council as well as objectives in the *CM Act 2016* and Tuggerah Lakes Estuary coastal management program scoping study (CCC, 2021). Flood mitigation, estuary health and beach health are primary criteria and weighted higher than the secondary criteria of waterway amenity and beach amenity and protection.

Each shortlisted option was evaluated against the basecase by asking:

- Compared to the basecase, how much better or worse is the considered option at achieving each criteria?

The adopted scoring scale is presented in Table 38. The shortlist of options and assessment was workshopped with the Community Focus Group on 22 February 2023 (see Section 3 for further results from the community engagement).

Table 37: Shortlist assessment criteria.

Criteria [weighting]	Target	Measure
Flood mitigation **[24%]**	Reduction in flood risk.	Reduction in peak flood level during severe flood events.
Estuary health **[24%]**	Avoid disturbance of natural estuary behaviour and maintain water quality and ecological health.	Behaviour of the estuary relative to a natural ICOLL entrance state. Improvements in water quality indicators such as chlorophyll, salinity and turbidity.
Beach health **[24%]**	Avoid disturbance of natural entrance features to maintain health of the natural habitats (incl. Little Tern habitat).	Behaviour of the berm relative to a natural ICOLL entrance state. Frequency, duration and beach/ foreshore area impacted by temporary plant and equipment.
Waterway amenity **[18%]**	Improve cultural, social and/ or recreational use of the estuary entrance.	Space and depth of water available for waterway activities including fishing, boating or swimming.
Beach amenity and protection **[10%]**	Support coastal protection and increase beach amenity of adjacent areas.	Sand volumes available for nourishment activities at beaches in the vicinity of the entrance.

Table 38: Adopted scoring scale for shortlist evaluation.

Score	Description
+3	Much better than basecase
+2	Moderately better than basecase
+1	A little better than basecase
0	Same as basecase
-1	A little worse than basecase
-2	Moderately worse than basecase
-3	Much worse than basecase

6.7.2 Technical evaluation results

The results of the comparative technical performance assessment of the shortlisted management options along with a relative ranking are provided in Table 39. The scores are reflective of the relative performance of each option against the adopted criteria as described in Section 6.6 and are based on the best information available for use in the project. The available information was considered adequate for this high-level comparative assessment. Conservative assumptions were made where confidence in an option's performance was low (i.e., assuming lower benefits or higher impacts).

More detailed assessments may be necessary to refine scoring for lower-ranking options should these be considered as part of Council's entrance management strategy. For example, modelling was undertaken by MHL to inform the event-based berm management approach and hence the understanding of the flood mitigation benefits are more advanced. This is not the case for other options such as the sand transfer system, programmed dredging or northern groyne.

The ranking shown in Table 39 is not intended to provide the preferred management approach for implementation. Rather, the results present the relative technical capability of the different management options to achieve adopted management objectives. The results are intended to inform Council's next steps for progressing development of an entrance management strategy, including consideration of combinations of options assessed herein.

The implementation of a preferred entrance management strategy would be contingent on approval of a business case/ funding submission by Council. A cost benefit analysis of the entrance management strategy is recommended following further technical studies to develop the preferred approach.

As shown in Table 39 the technical evaluation has identified the following ranking of options:

1. Equal highest scoring options
    a. event-based berm management
    b. programmed dredging
2. Third highest scoring option is routine berm management
3. Equal lowest scoring options
    a. sand transfer system
    b. northern groyne

Table 39: Summary of technical evaluation results and ranking.

Performance (relative to base case) -3 -2 -1 0 +1 +2 +3 Worse Better	Base Case	Technical evaluation: Event-based berm management (A2)	Routine berm management (C1)	Sand transfer system (C4)	Programmed dredging (C2)	Northern Groyne (B2)
Flood Mitigation [24%]						
Estuary health [24%]						
Beach health [24%]						
Waterway amenity [18%]						
Beach amenity and protection [10%]						
Rank (weighted)		1	3	4	1	4

The event-based berm management approach achieves high scores as it has been developed to mitigate flooding utilising modelling undertaken by MHL (2022) providing confidence in modest flood mitigation outcomes. In addition, the utilisation of an event-based only approach limits the impacts to beach health and habitat associated with management activities including berm scraping and pilot channel excavation. It also enables the entrance to behave in a largely natural ICOLL state, in line with NSW guidance.

Programmed dredging scores highly as it may support indirect flood mitigation whilst performing well against secondary management objectives. Dredging can provide significant benefits to waterway amenity allowing navigation within the entrance which is a popular recreational activity without diminishing other recreational activities in other areas of the entrance such as swimming. Dredging activities are limited to the flood shoal which allows the berm to largely behave like a natural ICOLL. Available information does not support dredging being effective in achieving the flood mitigation objectives as a standalone entrance management option. Hence, this management option could be considered as an element of the entrance management strategy to maximise benefits in achieving secondary management objectives.

The lower scoring options (routine berm management, sand transfer system and northern groyne) were found to result in likely unacceptable impacts on the beach health and habitat during construction or operation. For example, these activities involve significant construction/ operational activities that are likely to disturb little tern habitat or other sensitive environmental receptors. The sand transfer system and northern groyne involve a significant inhibition of the entrance to behave as a natural ICOLL.

6.7.3 Cost comparison

A summary of high level cost estimates for the entrance management options is provided in Table 40. A comparison and ranking of the relative cost over a 20-year design life are provided in Table 41. These costs are initial high-level estimates based on industry benchmark rates for comparable works. The costs are presented for comparative purposes only and should not be utilised to inform budgetary estimates.

As shown in Table 41 event-based berm management is the lowest cost option followed by routine-berm management. The more significant interventions including sand transfer system, programmed dredging and the northern groyne incur greater costs. The sand transfer system and northern groyne are most expensive including significant upfront capital investment for infrastructure construction.

Table 40: Cost summary of management options (2025 dollars).

Management option	High level cost and assumptions
Event-based berm management (A2)	• Initial: $200,000 (detailed design and approvals) • Operation & maintenance (annually): $12,000/year including, $50,000 per event once every 5 years based on previous berm management works*
Routine berm management (C1)	• Initial: $200,000 (detailed design and approvals) • Operation & maintenance (annually): $300,000/year (six interventions per year at $50,000 per event based on previous berm management works*)
Sand transfer system (C4)	• Initial: $4.6M including, $0.9M for preliminary investigations, $1.5M for water supply, $1.6M for the pump station, high-pressure pump and SCADA/PLC, $180,000 for jet pumps and $0.5M for pipelines based on benchmarking against similar projects (e.g. Noosa Sand Recycling System)

Management option	High level cost and assumptions
	• Operation & maintenance (annually): $385,000/year including, $345,000 for the transfer of 30,000m^3/year ($11.50/m^3 x 30,000m^3/year) and $40,000/year for maintenance
Programmed dredging (C2)	• Initial: $400,000 for detailed modelling studies and long-term contracts execution costs (e.g., 2 x 10-year contracts). • Operation & maintenance (annually): $0.75M/year including, $0.51M of operational dredging costs ($17.25/m^3 x 30,000m^3/year) and $0.23M/year of mobilisation costs (annual campaign – subject to refinement during design)
Northern groyne (B2)	• Initial: $3.1M including, detailed design and approvals ($0.4M), construction and removal of a test geotextile groyne ($0.46M) and permanent rock groyne ($2.53M) • Operation & maintenance (annually): $57,000 (1-2% of capital construction cost per year)

**The typical cost is estimated from past berm management works (provided by CCC) but does not reflect the increased expenses now required due to the southern channel location - an issue likely related to groyne impacts (see Section 4.4).*

Table 41: High level whole of life cost comparison of management options (incl. 20% contingency*, 2025 dollars).

Cost	Cost comparison				
	Event-based berm management (A2)	Routine berm management (C1)	Sand transfer system (C4)	Programmed dredging (C2)	Northern Groyne (B2)
Initial	$200k	$200k	$4.6M	$400k	$3.1M
Annual ongoing	$12k	$302k	$385k	$751k	$57k
Total over 20 years (incl. contingency)	$0.5M	$7.5M	$17.2M	$18.5M	$5.2M
Rank	1	3	4	5	2

**A 40% contingency was applied to sand transfer system(C4) due to relatively higher implementation risk.*

7. Summary and recommendations

7.1 Summary

This report supports the development of Council's Tuggerah Lakes Estuary Coastal Management Program (CMP) and aims to gather and simplify information relating to the coastal processes shaping the entrance to Tuggerah Lakes and the impacts of past, current, and proposed management intervention. The outcomes of this report will inform development of Council's entrance management strategy as part of Stage 3 of the CMP.

The study area focuses on the Tuggerah Lakes estuary on the Central Coast, NSW, particularly the lower estuary east of The Entrance Bridge. The estuary is a complex system influenced by river flows, wind, tides, waves, human modification, and bio-geochemical processes. The report adopts a data-driven approach and draws on previous literature covering estuarine processes in the project area.

The primary objectives of the study are to inform the community and stakeholders about entrance management at Tuggerah Lakes, provide a scientific and social-economic basis for future decision-making, and support the development and implementation of an entrance management strategy. The study also aims to provide a clear understanding of the entrance coastal processes, socio-economic aspects of the estuary, and feasible entrance management options.

Community and stakeholder engagement was undertaken including community focus group workshops, an online survey and a technical stakeholder workshop. Outputs of this engagement was utilised to inform the socio-economic assessment which established values for the entrance to Tuggerah Lakes and informed the options assessment approach undertaken.

A coastal processes assessment was undertaken including the development of a conceptual model for the entrance and adjacent areas. Further, a targeted assessment of the impacts of the groyne constructed in 2017 south of the entrance at The Entrance Beach was undertaken. The installation of the groyne has impacted the coastal dynamics at the entrance, resulting in reduced sand supply to the beach north of the groyne and subsequent recession, noting that this area continues to be heavily influenced by the wider entrance behaviour. Recent observations suggest that the entrance channel has shifted to a southern position not seen in many decades, potentially affecting hydraulic efficiency during flood events.

A range of entrance management options were identified for consideration in developing Council's entrance management strategy. A course filter assessment was undertaken to shortlist five options for more detailed comparative technical evaluation and cost considerations. The five options assessed included event-based berm management, routine berm management, a sand transfer system, programmed dredging and a northern groyne. For each of the five options a high level implementation approach was developed to enable technical evaluation against a 'do nothing' basecase. The technical evaluation involved assessment of the performance of each option against adopted management objectives developed, in collaboration with Council, based on community engagement, legislative requirements (*CM Act* 2016) and the Tuggerah Lakes Estuary CMP scoping study (CCC, 2021). The five management objectives included flood mitigation, estuary health, beach health, waterways amenity and beach amenity and protection.

The technical evaluation identified event-based berm management and programmed dredging as the highest scoring options. Event-based berm management scores highly due to confidence in modest flood mitigation outcomes with minimal impacts on beach health and habitat associated with management activities, including berm scraping and pilot channel excavation. It also allows the entrance to remain in a largely natural ICOLL state.

Programmed dredging is considered useful as it may indirectly support flood mitigation while aligning with secondary management objectives. Dredging can enhance waterway usability by enabling navigation within the entrance for recreational purposes without impacting other activities such as swimming. The dredging operations are limited to the flood shoal, allowing the berm to function similarly to a natural ICOLL. Current information does not show that dredging alone meets flood mitigation objectives. Therefore, this approach could be part of an entrance management strategy to optimise benefits in achieving secondary management goals.

High level cost estimates developed for the five options identified event-based berm management as the lowest cost option followed by the northern groyne option. The more significant interventions including sand transfer system, programmed dredging and the routine berm management incur greater costs. The

programmed dredging and sand transfer system options are most expensive. Both, the sand transfer system and northern groyne include significant upfront capital investment for infrastructure construction.

A summary of the technical and cost evaluation outcomes is presented in Table 42.

Table 42: Summary of technical and cost performance ranking.

	Rank	
Entrance management option	**Technical performance**	**Cost performance**
Event-based berm management (A2)	1 (equal)	1
Routine berm management (C1)	3	3
Sand transfer system (C4)	4	4
Programmed dredging (C2)	1 (equal)	5
Northern Groyne (B2)	4	2

7.2 Recommendations

Based on the findings of this report it is recommended that Council considers undertaking the following:

1. Develop a comprehensive entrance management strategy, focusing on event-based berm management, including monitoring and regular performance reviews of these interventions.
2. Consider inclusion of programmed dredging for the purpose of enhancing waterway amenity and nourishment of adjacent beaches. Undertake investigation to improve operations to fulfill EPA requirements while maintaining high production rate.
3. Undertake flood modelling with sensitivity tests of flood shoals and ebb channel configurations to determine the benefits of dredging of ebb channel/ flood shoal on flood risk mitigation.
4. Undertake flood modelling with sensitivity tests of the entrance scouring to the pre-flood entrance channel location considering influence of the groyne to determine impacts on flood risk. As required, incorporate findings to maximise the effectiveness of the adopted entrance management strategy.
5. Undertake permanent water quality monitoring (Chlorophyll-a, turbidity) within the entrance (for example between The Entrance Bridge and Karagi Point Reserve and at selected estuary stations used for report cards) as well as regular topo-bathymetric surveys of the entire lower entrance (typically every 6-12 months and following large flood events covering the area between The Entrance Bridge and as far as possible seaward of the entrance berm) to improve understanding of the entrance morphodynamics and associated effects on water quality.
6. Undertake ongoing coastal monitoring of The Entrance Beach south and north of groyne as well as North Entrance Beach (from top of dune down to depth of closure) to better understand sand movements, impact of coastal structures and effectiveness of beach nourishment.
7. Undertake ongoing full user count and activity monitoring of the entrance foreshore and waterway to establish a socio-economic baseline dataset for future management decisions.

8. References

Bio-Analysis Pt Ltd, 2005. Tuggerah Lakes estuary Management Study.

Bio-Analysis Pt Ltd, 2006. Tuggerah Lakes estuary Management Plan.

Bluecoast Consulting Engineers [Bluecoast], 2023. Central Coast Open Coast & Coastal Lagoons Coastal Management Program – Stage 2 Coastal hazard report. Report in-preparation for Central Coast Council.

BMT WBM, 2010. Tuggerah Lakes Catchment Scenario Assessment. Prepared for DECCW.

BMT, 2018. Review of the Wyong Coastal Zone Hazard Study. Prepared for Central Coast Council.

Boyd, R.; Dalrymple, R.; Zaitlin, B. A. 1992. Classification of clastic coastal depositional environments. Sedimentary Geology, Vol. 80, Issues 3 – 4, pp. 139 – 150.

Cardno, 2013. Tuggerah Lakes – The Entrance Morphodynamic Modelling. Entrance Beach Management Investigations.

Cardno, 2013. Tuggerah Lakes – The Entrance Morphodynamic Modelling.

Cardno, 2015. Additional Morphological Modelling - The Entrance.

Catchment Simulation Solutions, 2019. Wyong River Catchment Floodplain Risk Management Study & Draft Plan

Central Coast Council, 2017. Engagement Framework.

Central Coast Council, 2019. Community Participation Plan.

Central Coast Council, 2020. Tuggerah Lakes estuary Management Plan – Summary of Implementation 2008 – 2020.

Central Coast Council, 2021a. Tuggerah Lakes Estuary Coastal Management Program – Scoping Study.

Central Coast Council, 2021b. Central Coast Waterways Report Card 2020-21.

Central Coast Council, 2021. Community Strategic Plan -2018-28.

Central Coast Council and Artscape, 2021. The Entrance Place Plan.

Coastal Zone Management and Planning, 2021. Review of Central Coast Council's Lagoon and Lake Entrance Management, Policies and Practices. Report No. 2021/3. Coastal Zone Management and Planning.

Dalrymple, R. W.; Zaitlin, B. A.; Boyd, R. 1992. Estuarine Facies Models: Conceptual Basis and Stratigraphic Implications. Journal of Sedimentary Petrology, Vol. 62, No. 6, pp. 1130 – 1146.

Department of Planning and Environment, 2023. Coastal Management Manual.

Erskine, 2013. Flood-tidal and fluvial deltas of Tuggerah Lakes, Australia: Human impacts on geomorphology, sedimentology, hydrodynamics and seagrasses.

Eysink, 1990. *Morphologic response of tidal basins to changes*. 22nd International Conference on Coastal Engineering, ASCE.

GHD, 2019. The Entrance Channel Dredging Operations Feasibility Review.

Glamore, W. C.; Waters, S.; Wainwright, D.; Ferguson, A.; Dafforn, K.; Maher, D.; Ramilo, N.; Fawcett, S. 2020. Tuggerah Lakes Water Quality Independent Expert Panel Review.

idcommunities, 2022. Central Coast Council area.

International Association of Public Participation, 2023. Public Participation Spectrum.

Kinsela, M.A., Morris, B.D., Linklater, M. and Hanslow, D.J., 2017. *Second-Pass Assessment of Potential Exposure to Shoreline Change in New South Wales, Australia, Using a Sediment Compartments Framework.* Journal of Marine Science and Engineering Volume 5, 61.

Lawson & Treloar Pty. Ltd, 1992. Tuggerah Lakes Flood Study. Compendium of Data.

Lawson & Treloar Pty. Ltd, 1994. Tuggerah Lakes Flood Study. Flood Forecasting System.

Lawson & Treloar Pty. Ltd,1994. Tuggerah Lakes Flood Study.

Lawson and Treloar, 1999. Recalibration of Tuggerah Lakes model and Evaluation of The Entrance Dredging Impacts.

Manly Hydraulics Laboratory, 1995. Tuggerah Lakes Entrance Tidal Surveys January and December 1993. Report MHL680.

Manly Hydraulics Laboratory, 2002. MHL2750 – Tuggerah Lakes catchment February 2020 flood summary and historical comparison.

Manly Hydraulics Laboratory, 2022. Tuggerah Lakes Entrance Management Study. Report MHL2781.

Marsh, D. and Baskaran, R., 2009. Valuation of water quality improvements in the Karapiro catchment: a choice modelling approach.

Brennan, K. Sanderson, B. Ferguson, A. Weber, T. Claus, S. 2010. Tuggerah Lakes estuary Modelling Report CPA/157279. Department of Environment, Climate Change and Water.

NSW Bureau of Crime Statistics and Research, 2023. Crime Statistics in the Central Coast

NSW DPI, 2016. Review of Environmental Factors - The Entrance Rock Groyne. NSW Department of Primary Industries - Crown Lands.

NSW Government, NSW Legislation – Coastal Management Act, 2016.

NSW Office of Environment and Heritage, 2013a. An assessment of 'Tuggerah Lakes Restoration Project' as a shoreline restoration strategy.

NSW Office of Environment and Heritage, 2013b. Recommendations for Management of Ooze in Tuggerah Lakes.

NSW Office of Environment and Heritage, 2023, Coastal Management Manual.

NSW Public Works Department, 1978. Tuggerah Lakes – the Future of the Waterway. Interdepartmental committee contributions from multiple agencies.

NSW Public Works Department, 1987. Jet pump systems for maintaining tidal entrances, NSW Public Works Department.

NSW Public Works Department, 1988. Tuggerah Lake Entrance Improvements – Entrance Restraining Wall, NSW Public Works Department.

NSW Public Works Department, 1992. Tuggerah Lakes Flood Study. Compendium of Data, NSW Public Works Department.

NSW SES, 2013., Wyong Shire Local Flood Plan. NSW State Emergency Services.

Pascoe and Doshi, 2018. Estimating coastal values using multi-criteria and valuation methods

Patterson Britton and Partners, 1994. Tuggerah Lakes, Entrance Training Walls: Technical Discussion.

Roper, T., Creese, B., Scanes, P., Stephens, K., Williams, R., Dela-Cruz, J., Coade, G., Coates, B., Fraser, M., 2011. Assessing the condition of estuaries and coastal lake ecosystems in NSW - Monitoring, evaluation and reporting program. State of NSW Office of Environment and Heritage.

Salients, 2021. The Entrance Rock Groyne Impact Assessment Study. Prepared for Maritime Infrastructure Delivery Office, Transport for NSW.

Salients, 2022. The Entrance Groyne Impact Assessment: Addendum 1. Prepared for Maritime Infrastructure Delivery Office, Transport for NSW.

Salients, 2024. The Entrance Groyne Impact Assessment: Addendum 2. Prepared for Maritime Infrastructure Delivery Office, Transport for NSW.

Sanderson, B., 2009. Preliminary 3D modelling of Tuggerah Lakes.

SMEC, 2011. Longshore Sand Transport and Tidal Inlet Stability Study for The Entrance and The Entrance North.

Shirley Consulting Engineers, 2010. Report on the Geotechnical Issues associated with the Coastline Hazard Management Study [CPA # 170951] for the Wyong Shire Council.

Swanson, R., 2018. Tuggerah Lakes Nearshore Data Synthesis. Prepared for Central Coast Council.

Tourism Research Australia, 2022. National Visitor Survey.

Transport for New South Wales, 2022. Economic Parameter Values.

Umwelt Pty Limited, 2011. Entrance Dynamics and Beach Condition at The Entrance and North Entrance Beaches.

Umwelt Pty Limited, 2011. Coastal Zone Management Plan for the Wyong Coastline.

Heimhuber, V. Vos, K. Fu, W. Glamore, W. 2021. InletTracker: An open-source Python toolkit for historic and near real-time monitoring of coastal inlets from Landsat and Sentinel-2. Georphology, Vol. 389 15 September 2021, 107830.

Van Bueren, M. and Bennett, J., 2000. Estimating community values for land and water degradation impacts. Final Report, Project, 6(4), p.66.

Victorian Fisheries Authority, 2020. Victorian Fisheries Authority Annual Report

Webb McKeown & Associates, 1992. Sensitivity analysis The Entrance Tuggerah Lake Final Report.

Windle, J. and Rolfe, J., 2004. Assessing values for estuary protection with choice modelling using different payment mechanisms.

WMAwater, 2014. Tuggerah Lakes Floodplain Risk Management Study and Plan.

Wyong Shire Council, 2001. Tuggerah Lakes estuary Process Study. Prepared by D. E. Roberts from Strategic Planning Department.

WorleyParsons, 2009. The Entrance Dredging Project Review of Environmental Factors.

Appendix A: Community and Stakeholder Engagement Plan

Tuggerah Lakes Estuary Coastal Management Program (Stage 2)

Community and Stakeholder Engagement Plan

Contact Information

Rhelm Pty Ltd
ABN : 55 616 964 517
50 Yeo Street
Neutral Bay NSW 2089
Australia

Lead Author:
Emma Maratea
contact@rhelm.com.au

Document Control

Rev	Effective Date	Description of Revision	Prepared by:	Reviewed by:
00	August 2022	First draft to provide engagement context and scope	Caitlin Brookes (Rhelm)	Emma Maratea (Rhelm)
01	October 2022	Update: feedback from Council	Caitlin Brookes (Rhelm)	Emma Maratea (Rhelm)
02	July 2023	Update: project milestone 3 complete	Caitlin Brookes (Rhelm)	Emma Maratea (Rhelm)

Prepared For: Central Coast Council

Project Name: Central Coast CMP (Stage 2)

Rhelm Reference: J1688

Document Location: C:\Dropbox (Rhelm)\J1600-J1699\J1688 - Tuggerah Lakes Social Economics\5. Engagement\Engagement Plan\Tuggerah Lakes Estuary CMP CSEP_Rev02.docx

COPYRIGHT NOTICE

DISCLAIMER

Table of Contents

Attachments

Tables

1 Context

This Community & Stakeholder Engagement Plan (CSEP) aims to set out the strategy to engage with the broader community and stakeholders as part of the Tuggerah Lakes Estuary CMP (Stage 2 Assessment) as required by the CM Act 2016 and the Coastal Management Manual 2018, including:

- Local, State and Federal Government Agencies (including surrounding local councils, NSW State agencies and State and Federal Members of Parliament (MPs).
- Local and State Government working groups and committees:
  - Catchments to Coast Advisory Group.
- Local Aboriginal community:
  - Local Aboriginal Advisory Committee e.g. Cultural Heritage Advisory Committee
  - Local Aboriginal Land Councils (LALC's)
  - Elders and members of the community who can speak on behalf of Country.
- The broader Tuggerah Lakes community, facilitated through community focus groups.
- A wide range of demographics, contacted through community associations including youth organisations e.g. Youth Leaders Council and other users of the lake.
- Private organisations.
- Affected Landholders and residents.
- Visitors to the area.
- Local Chamber of Commerce and the business community.

The CSEP aligns with IAP2 principles and Council's Community Engagement Framework, as well as the requirements of the CM Act (2016) and the Coastal Management Manual (2018). These engagement principles are set out in **Section 3**.

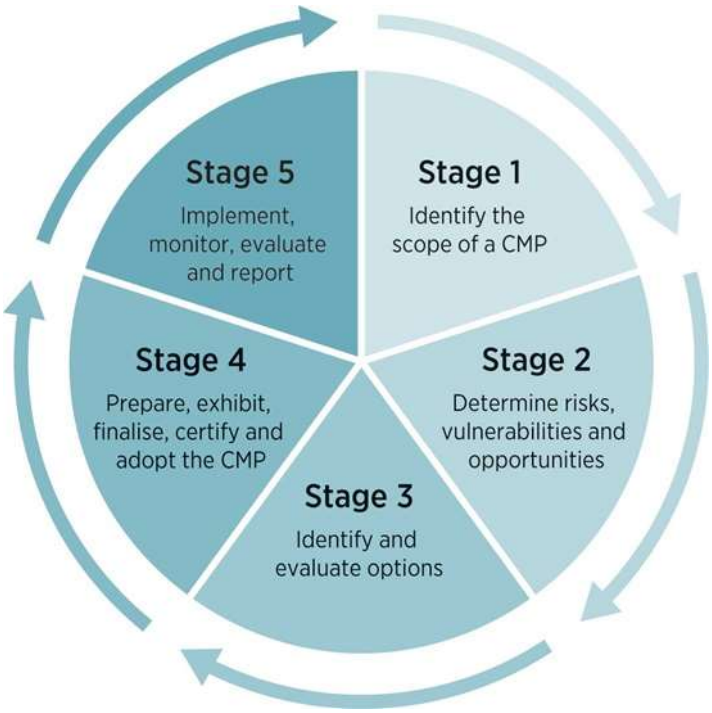


Figure 1. The five stages of the Coastal Management Program (CMP) process

1.1 Background

Central Coast Council has embarked on the CMP for the Tuggerah Lakes Estuary which aims to provide a long-term strategy and short-term actions to manage the estuary in an ecologically sustainable manner, for the benefit of the wider community.

For Stage 2 of the CMP for Tuggerah Lakes Entrance, estuary entrance management studies (primarily focussed on non-flood periods) are required. These studies will inform an Entrance Management Strategy, which will be developed during Phase 3 of the CMP, detailing entrance management actions, with respect to physical intervention and monitoring **(see Figure 2).**

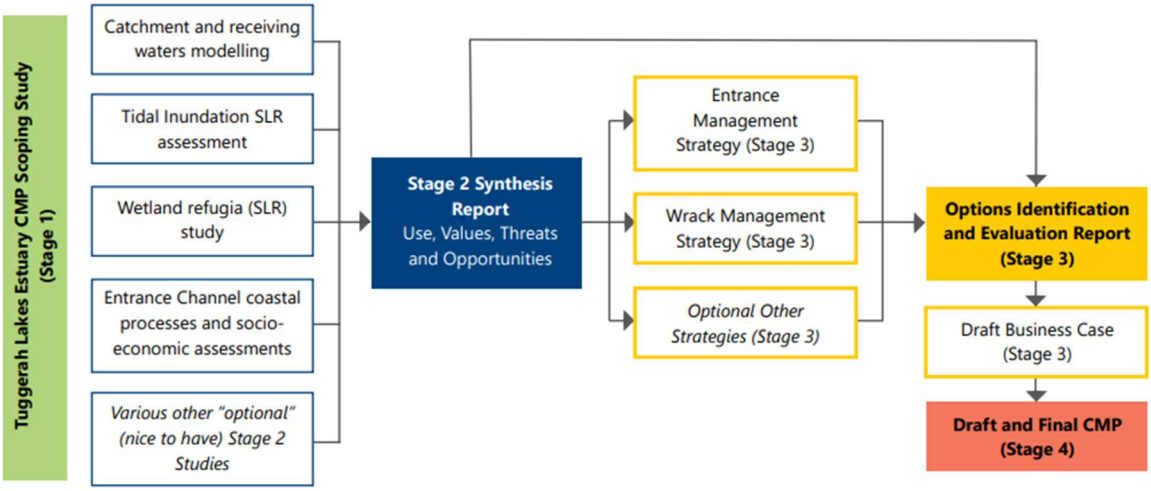


Figure 2: Tuggerah Lakes estuary CMP workflow (extract from CMP Stage 1 [Central Coast Council, 2021]).

To inform the development of the CMP numerous technical studies were developed and a range of stakeholder and community engagement activities were undertaken as part of these previous studies. A summary of the previous engagement activities is provided in **Attachment A**.

1.2 Supporting Studies and Investigations

A range of investigations have been undertaken to date that will support and inform the Tuggerah Lakes Estuary CMP, below is a summary of the key studies and investigations:

- The Entrance Management Study including an Interim Entrance Management Procedure (completed in August 2022) will provide the basis for interim measures to maintain the channel open while a formal entrance management strategy is decided through the CMP.
- The Tuggerah Lakes Coastal Management Program Scoping Study (2021) defines a pathway for achieving the council vision based on the community values.
- The recent community and stakeholder engagement for the CMP (stage 1) and the Entrance Place Plan will be used as a starting point for the Stage 2 socio-economic assessment.
- Stakeholder engagement strategy for Tuggerah Lakes floodplain risk management study and plan (WBMA Water, 2014), and the Coastal Zone Management Plan (Bio-analysis, 2006).

As part of the process of developing these studies, extensive community consultation has been undertaken over the years, which can be used to inform our understanding of what the community expects when it comes to the management of Tuggerah Lakes. The Tuggerah Lakes Estuary CMP will consider current land use, coast dependent economic activity, Aboriginal cultural heritage and capture the views and expectations within the community of how Tuggerah Lakes is to be managed now and into the future. A summary of the previous engagement activities is provided in **Attachment A**.

2 Purpose and Objectives

The key objectives of the CSEP are to:

1. Confirm	Confirm the key community values, uses and vision for the management of Tuggerah Lakes through a review of earlier entrance management studies and historical community engagement.
2. Educate and inform	Educate and inform the community about the coastal processes impact on the entrance and the CMP development process.
3. Identify	Identify risks and barriers to success by ensuring awareness of the CMP across the whole community and facilitate residents' feedback, ideas and concerns about acceptable risk and around how Tuggerah Lakes is managed in the future.
4. Clarify and deliver	Clarify and deliver the CMP over the next 10 years by fostering understanding of the priorities of the CMP.

Consultation about management options and the evaluation process will:

- Raise awareness of the strategic and staged approach to management of the Tuggerah Lakes Entrance.
- Ensure residents and key stakeholders are informed and have contributed to how Tuggerah Lakes is managed in the future.
- Provide Council with early feedback about actions and priorities that are acceptable to local communities and the overall population of the shire and its visitors. Ensure there are 'no surprises' by engaging early with key stakeholders and the community to understand and work through any key concerns and identified opportunities. This should streamline Stage 3.
- Clarify the agency roles and public authority position on actions that require a collaborative effort, for instance around dredging and natural defences actions.
- Help identify groups that require more targeted engagement in the coming months (in the lead up to and during the consultation on the options paper) to facilitate conversations and gain feedback on the management options and legal implications.
- Ensure the management option evaluation process (feasibility, viability (cost benefit) and acceptability) is transparent and communicated effectively and clearly.

- Build on previous consultation undertaken for the CMP under the previous studies. Ensure that communities feel that their previous feedback was heard and taken on board.

3 Engagement Principles

This Tuggerah Lakes CMP CSEP is aligned with the principles within Council's Community Engagement Framework included within Council's:

- Community Participation Plan (CPP) (November 2019), and
- Central Coast Engagement Framework (2017).

Council's CPP is designed to make participation in planning clearer for the Central Coast community. It does this by setting out in one place how and when community members and stakeholders participate in the planning system, Council functions and various proposals.

Central Coast Council's Engagement Framework (2017) is designed to support Council's values and guide its approach to all community engagement activities by following the engagement principles.

Council's engagement framework has been considered when designing this CSEP by incorporating the principles into the design. Engagement with key stakeholders and the community throughout the delivery of this plan will adhere to the following principles:

- **Respect and Transparency** – ensure, with consideration for the IAP2 spectrum, that engagement is undertaken at a level appropriate to the possibility the community has to influence. Communication of the engagement intent will be transparent and will be done in a manner that ensures respect and that we are listening to the community. The community will be encouraged to work with the project team and Council staff in an atmosphere of mutual respect.
- **Access and Inclusion** –encourage a diversity of views and perspectives through the involvement of those groups that can be deemed as harder to reach. The engagement will endeavour to remove the barriers to participation by using various engagement methods and techniques.
- **Clarity** –clearly articulate the intention of the engagement, its scope and outcomes. The project team will work with Council to ensure the communication and engagement materials are clear and will be easily understood by the community and stakeholders.
- **Accountability and Improvement** – seek to uncover engagement with key stakeholders being undertaken concurrently and identify opportunities to combine or alter consultation opportunities to avoid consultation fatigue.
- **Capacity** – seek to empower the community in their capacity to contribute, by encouraging a two-way dialogue. Recognise the importance of building mutual trust and respect, by listening to a diversity of perspectives and encouraging participation and feedback.

3.1 International Association for Public Participation – IAP2

International Association for Public Participation (IAP2) is a key international organisation advancing the practice of public participation. Its mission is to advance and extend the practice of public participation through professional development, certification, standards of practice, core values, advocacy and key initiatives with strategic partners around the world.

IAP2 Australasia is a member association incorporating individuals, governments, institutions, and other entities that affect the public interest throughout the world.

IAP2 has developed tools that are widely used and acknowledged. These include the **Core Values for Public Participation** for use in the development and implementation of public participation processes;

and the **IAP2 Public Participation Spectrum** which assists with the selection of the level of participation that defines the public's role in any community engagement program. Additionally, the **Quality Assurance Standard for Community and Stakeholder Engagement** is recognised as the international standard for public participation practice.

This CSEP has been prepared in consideration of the IAP2 tools and guidelines.

3.2 Coastal Management Act (2016) and Coastal Management Manual

The *Coastal Management Act (2016)* set out the following requirements for preparing a CMP.

Before adopting a coastal management program, a local council must consult on the draft program with:

- *a) the community, and*
- *b) if the local council's local government area contains:*
  - *(i) land within the coastal vulnerability area, any local council whose local government area contains land within the same coastal sediment compartment (as specified in Schedule 1), and*
  - *(ii) an estuary that is within 2 or more local government areas (as specified in Schedule 1), the other local councils, and*
- *c) other public authorities if the coastal management program:*
  - *(iii) proposes actions or activities to be carried out by that public authority, or*
  - *(iv) proposes specific emergency actions or activities to be carried out by a public authority under the coastal zone emergency action subplan, or*
  - *(v) relates to, affects or impacts on any land or assets owned or managed by that public authority.*

The coastal environment area means the land identified by a State environmental planning policy to be the coastal environment area for the purposes of this Act, being land containing coastal features such as the coastal waters of the State, estuaries, coastal lakes, coastal lagoons and land adjoining those features, including headlands and rock platforms.

(2) The management objectives for the coastal environment area are as follows—

(a) to protect and enhance the coastal environmental values and natural processes of coastal waters, estuaries, coastal lakes and coastal lagoons, and enhance natural character, scenic value, biological diversity and ecosystem integrity,

(b) to reduce threats to and improve the resilience of coastal waters, estuaries, coastal lakes and coastal lagoons, including in response to climate change,

(c) to maintain and improve water quality and estuary health,

(d) to support the social and cultural values of coastal waters, estuaries, coastal lakes and coastal lagoons,

(e) to maintain the presence of beaches, dunes and the natural features of foreshores, taking into account the beach system operating at the relevant place,

(f) to maintain and, where practicable, improve public access, amenity and use of beaches, foreshores, headlands and rock platforms.

The Coastal Management Manual provides guidance on how to undertake engagement with stakeholders and the community to achieve the requirements of the CM Act. This guidance has been considered in the preparation of this CSEP.

4 Stakeholder Analysis

It is important to ensure that all those who need to be involved in coastal management (i.e. those with responsibility for managing the coast, community members who use and enjoy the amenity of the coast, and those with a vested interest in its management, such as property owners) are kept informed and invited to contribute to the process to establish a common understanding of coastal management and how decisions are made.

Stakeholders may tend to make judgements about coastal management based solely on their own perceptions. These perceptions can vary due to differences in values, needs, assumptions, concepts, concerns and degrees of knowledge. Stakeholders' views can have a significant impact on how they interpret the decisions made through the coastal management process, so it is important that differences in their perceptions of risk be identified, recorded and addressed.

A stakeholder matrix has been developed to identify relevant stakeholders, and their relative level of interest, influence and impact on the CMP. The outcomes of this analysis identify the suitable level of consultation based on the IAP2 consultation spectrum (**Table 4-1**).

The stakeholder matrix is provided in

Table 4-2. The matrix also indicates the suggested engagement method selected for each stakeholder based on the outcomes of the stakeholder analysis. Further details on the engagement methods are provided in **Section 5**.

Table 4-1 IAP2 Spectrum of Public Participation

	Inform	Consult	Involve	Collaborate	Empower
Participation Goal	To provide the stakeholders and community with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain stakeholder and community feedback on analysis, alternatives and/or decisions.	To work directly with the community and stakeholders throughout the process to ensure that their concerns and aspirations are consistently understood and considered.	To partner with the community and stakeholders in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public or stakeholders.
Promise	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how stakeholder and community input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how stakeholder and community input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Table 4-2 Stakeholder Matrix

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
Councils	Central Coast Council (Project Manager)	Empower	Regular project meetings	Regular project meetings to be held.	Ongoing
	Central Coast Council (Councillors)	Empower	Briefing 1	Arranged by Council, to ensure Councillors are aware of the engagement timeframes and approach and key risk mitigations.	Ongoing
			Media Releases and Enews content.	To inform of project progress and to encourage participation in the engagement process.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	To be drafted as required to ensure key questions and responses are available on Council's website.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
	Central Coast Council (other Council Staff)	Involve	Technical Workshops 1-3	Technical workshops to ensure technical review and early stakeholder engagement. Initial interviews were held with Council staff on entrance management activities, constraints and opportunities and any ideas for the future entrance management strategy were sought. Later workshops to involve key stakeholders.	Late 2022, then two additional workshops to be held in mid to late 2023.
			Interviews	To gather information on available data, previous studies, and engagement activities to gain an appreciation of the issues to be assessed in this study	Aug-22
			Email/phone direct contact to seek input on specific issues, as required	Contact with the project manager and engagement team (phone and/or email) to seek specific input on issues, as required.	Ongoing
	Lake Macquarie Council	Inform	Media release and Enews content.	Media Releases - To inform of project progress and to encourage participation in the engagement process. Enews content - to be drafted for inclusion in Council's newsletter.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
	Hawkesbury Council	Inform	Media release and Enews content.	As above, see Media releases and Enews content.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
	Hornsby Council	Inform	Media release and Enews content.	As above, see Media releases and Enews content.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
	Northern Beaches Council	Inform	Media release and Enews content.	As above, see Media releases and Enews content.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
State/ Federal Government Agencies	Department of Planning, Environment	Collaborate	Regular project meetings	Project meetings to be held as required and as warranted to ensure DPE are well informed of project progress and any issues requiring escalation.	Ongoing
			Technical Workshops 2-3	These workshops will aim to discuss the findings of the technical assessments (entrance coastal processes assessment and socio-economic assessment) and incorporate specialist inputs from the consulted agencies and groups.	Two workshops to be held in 2023.
	Department of Planning, Environment – Crown Lands	Collaborate	Email/phone direct contact to seek input on specific issues, as required	Early engagement to seek advice/input on specific issues, as required.	August 2022- February 2023

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
			Technical Workshops 2-3	As above, see technical workshops.	Two workshops to be held in 2023.
	Department of Primary Industries – Fisheries	Collaborate	Email/phone direct contact to seek input on specific issues, as required	Early engagement to seek advice/input on specific issues, as required.	August 2022- February 2023
			Technical Workshops 2-3	As above, see technical workshops.	Two workshops to be held in 2023.
	National Parks and Wildlife Services	Collaborate	Email/phone direct contact to seek input on specific issues, as required	Early engagement to seek advice/input on specific issues, as required.	August 2022- February 2023
			Technical Workshops 2-3	As above, see technical workshops.	Two workshops to be held in 2023.
	Transport for NSW	Collaborate	Email/phone direct contact to seek input on specific issues, as required	Early engagement to seek advice/input on specific issues, as required.	August 2022- February 2023
			Technical Workshops 2-3	As above, see technical workshops.	Two workshops to be held in 2023.
	NSW Environment Protection Authority	Inform	Council / DPE to notify, as required	Additional targeted letters to inform community and stakeholders will be used to communicate project updates and other issues related to the project.	Before the drop-in sessions are held.
	National Parks Association of NSW (NPA)	Inform	Council / DPE to notify, as required	As above.	Before the drop-in sessions are held.
	NSW Local Land Services	Inform	Council / DPE to notify, as required	As above.	Before the drop-in sessions are held.
	NSW Police	Inform	Council / DPE to notify, as required	As above.	Before the drop-in sessions are held.
	Australian Defence Force	Inform	Council / DPE to notify, as required	As above.	Before the drop-in sessions are held.
	NSW SES	Inform	Council / DPE to notify, as required	As above.	Before the drop-in sessions are held.
	RFS	Inform	Council / DPE to notify, as required	As above.	Before the drop-in sessions are held.
Advisory	Catchments to Coast Advisory Group	Involve	Presentation	Presentation (30 minutes) to present the entrance management options and seek input on the project options.	Ongoing

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
Traditional Land Owners	Aboriginal Advisory Committee (e.g. Cultural Heritage Advisory Committee)	Collaborate	Technical Workshops 2-3	These workshops will aim to discuss findings of the technical assessments (entrance coastal processes assessment and socio-economic assessment) and incorporate specialist inputs from the consulted agencies.	Two workshops to be held in 2023.
	Darkinjung LALC		Technical Workshops 2-3	These workshops will aim to discuss findings of the technical assessments (entrance coastal processes assessment and socio-economic assessment) and incorporate specialist inputs from the consulted agencies.	Two workshops to be held in 2023.
Community Organisations	Community Organisations within and involved in the study area	Involve	Community and Stakeholder survey	An online survey which we will seek feedback on: 1. The level of understanding of natural processes in the estuary 2. What activities do individuals undertake and 3. How frequently they are undertaken 4. What costs and expenses are associated with the activity 5. Why they are undertaken and what values/appreciation is generated through the activity 6. The willingness of the community to protect its estuarine/coastal assets 7. How utilisation may alter into the future and with entrance conditions. The questions developed will closely align with the consultation objectives. The survey will include demographic questions which will enable us to dissect the information collected for community characteristics.	Friday 18 November 2022 – Tuesday 17 January 2023
			Media release	As above, see media releases.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
			Community Focus Group meetings 1-3	Community Focus Group meetings 1-3: Meetings held in person at Councils Administration Building with involvement from community members registered as interested participants and key stakeholders. The CFG will ensure the community has a direct line of contact with the project team to ask questions and raise issues. Relevant options will be presented to the members for comment.	14 December 2022, 1 February and then 22 February 2023

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
			Drop in sessions	Drop in sessions (two) in person. These meetings (held during and after business hours) will provide an update on project progress and seek input on the options paper (through maps and imagery) and an outline of the project timeline. They will also provide the opportunity for two-way communication and Q&A's between Council and the project team. These meetings will be notified to the public via the project website and a letterbox notification to nearby residents.	Following the completion of the draft Coastal Processes and Socio-Economic Report.
Youth Organisations	Youth Leaders Council (and Youth groups to be identified by Council)	Involve	Council / DPE to notify, as required	The methodology for the engagement plan considers the importance of engaging with young people to ensure they have various opportunities to contribute their views. Early notification with the Youth Leaders Council and utilising social media channels to encourage their participation in providing their feedback.	November- January 2023
			Drop in sessions	See above, Drop in sessions.	Following the completion of the draft Coastal Processes and Socio-Economic Report.
Private Organisations	Private Organisations within and involved in the study area	Involve	Media releases	Media Releases -As required, to inform of project progress and to encourage participation in the engagement process.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
			Drop in sessions	See above, Drop in sessions.	Following the completion of the draft Coastal Processes and Socio-Economic Report.
Business community	Local businesses	Involve	Community and Stakeholder online survey	See above, Community and Stakeholder online survey.	Friday 18 November 2022 – Tuesday 17 January 2023

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
			Media releases	As above, see media releases.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
			Drop in sessions	See above, Drop in sessions.	Following the completion of the draft Coastal Processes and Socio-Economic Report.
	Wyong Tuggerah Chamber of Commerce	Involve	Community and Stakeholder online survey	See above, Community and Stakeholder online survey.	Friday 18 November 2022 – Tuesday 17 January 2023
			Media releases	As above, see media releases.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
Individuals	Landowners and residents	Involve	Community and Stakeholder online survey	See above, Community and Stakeholder online survey.	Friday 18 November 2022 – Tuesday 17 January 2023

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
			Media releases	As above, see media releases.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
			Site walk-over/inspection	A two-day site walk-over and inspection providing the opportunity for ground truthing and ad-hoc engagement with users (as encountered)	Dec-22
			Drop in sessions	See above, Drop in sessions.	Following the completion of the draft Coastal Processes and Socio-Economic Report.
	Community members (registered)		Community and Stakeholder survey	See above, Community and Stakeholder online survey.	Friday 18 November 2022 – Tuesday 17 January 2023
			Community Focus Group meetings 1-3	See above, Community Focus Group meetings.	14 December 2022, 1 February and then 22 February 2023
			Media releases	As above, see media release.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.

		Stage 2 - Technical Studies			
Type	**Organisations**	**IAP2**	**Methods**	**Purpose / Details**	**Timing**
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
			Site walk-over/inspection	A two-day site walk-over and inspection providing the opportunity for ground truthing and ad-hoc engagement with users (as encountered)	Dec-22
			Drop in sessions	See above, Drop in sessions.	Following the completion of the draft Coastal Processes and Socio-Economic Report.
	Visitors		Community and Stakeholder survey	See above, Community and Stakeholder online survey.	Friday 18 November 2022 – Tuesday 17 January 2023
			Media release	As above, see media release.	January 2023 - Enews content. Media releases issued in August 2022 and May 2023, recommend Media Releases to be drafted before and after the drop in sessions.
			FAQs	As above, see FAQs.	After the completion of the February CFG meeting. Also, during the consultation period, when drop in sessions are held.
			Site walk-over/inspection	A two-day site walk-over and inspection providing the opportunity for ground truthing and ad-hoc engagement with users (as encountered).	Jan-23
			Drop in sessions	See above, Drop in sessions.	Following the completion of the draft Coastal Processes and Socio-Economic Report.

5 Engagement Methods

A range of engagement methods have been developed based on the requirements of the CM Act and CM Manual, the objectives of the consultation (**Section 2**) and the level of consultation identified for each of the stakeholders (

Table 4-2**).**

A description of the engagement methods, including a summary of the outcome of each method is provided in **Table 5-1**.

5.1 Social Media Strategy:

Council will reach out to the community throughout the CMP process at key stages using the following social media and media channels:

- Updates on Councils Tuggerah Lakes estuary website page and *Your Voice, Your Coast* website page,
- Council's Facebook and LinkedIn page,
- Media Release,
- Relevant council operated newsletters – e.g. Council newsletter, at critical milestones to stakeholders that have registered an interest.

Through these channels, we can disseminate updates, for example, access to the values survey and map, and seek feedback on key aspects of the CMP.

Table 5-1 Engagement Methods and Outcomes

Engagement Method	Details	Stakeholders Involved	Level of Engagement	Timing	Outcomes
Councillor Briefing	• Arranged by Council, to ensure Councillors are aware of the engagement timeframes and approach and key risk mitigations.	• Central Coast Councillors • Central Coast Council Staff	Empower	• Ongoing	A briefing was held at the inception of the project, further briefings will be held throughout the project to ensure Councillors are informed and can appropriately respond to any community enquiries.
Community Focus Group (CFG) Meetings	• The Community Focus Group was formed and is comprised of 14 members, representatives from Council and the Department of Planning and Environment were also in attendance. Three meetings have been held and were integral to the development of the Tuggerah Lakes Option Paper and Entrance Management Strategy.	• Community Focus Group members • The Department of Planning and Environment (DPE) • Central Coast Council Staff	Involve	• 14 December 2022 • 1 February 2023 • 22 February 2023	These meetings helped to identify a range of misconceptions, key management issues, and key values. These key insights have been incorporated in the evaluation of the options which will be incorporated into an Entrance Management Strategy.
Technical Workshops 1-3	• **Council Staff Interviews (Workshop 1)** To gather information on available data, previous studies, and engagement activities to gain an appreciation of the issues to be assessed in this study. • **Key Stakeholders (Workshops 2-3)** These workshops will aim to discuss the findings of the technical assessments (entrance coastal processes assessment and socio-economic assessment) and incorporate specialist inputs from the consulted agencies and groups.	• Council Staff • Council Staff • DPE • National Parks and Wildlife Services • Crown Lands • Department of Primary Industries – Fisheries • TNSW • Darkinjung Local Aboriginal Land Council (LALC)	Involve - Collaborate	• August 2022 • To be confirmed	Eleven interviews were held with Council staff. The key insights received from Council staff were considered as the project progressed in our engagement approach and also in the development of the management approach. Key stakeholder workshops are planned to be held before and during the upcoming consultation period.
Community and Stakeholder Survey	An online survey to obtain an understanding of community use relating to the estuary and entrance seeking feedback on: 1. The level of understanding of natural processes in the estuary 2. What activities do individuals undertake and 3. How frequently they are undertaken 4. What costs and expenses are associated with the activity 5. Why they are undertaken and what values/appreciation is generated through the activity 6. The willingness of the community to protect its estuarine/coastal assets 7. How utilisation may alter into the future and with entrance conditions. The questions developed will closely align with the consultation objectives. The survey will include demographic questions which will enable us to dissect the information collected for community characteristics.	• Community Members	Involve	• Friday 18 November 2022 – Tuesday 17 January 2023	The online survey was a key input to the socio-economic assessment by providing estuary use and visitation information. There were 164 responses received to the survey. A summary of the responses received is included in the Coastal Processes and Socio-Economic Report for the Tuggerah Lakes Estuary.

Site walk-over and inspection	• A two-day site walk-over and inspection providing the opportunity for ground truthing and ad-hoc engagement with users (as encountered).	• Observations of Community members	Inform	• January 2023	An in-person observational survey was conducted across eight locations, at various times of the day, user counts and recording of associated activities were undertaken alongside carpark vacancy and utilisation was observed and recorded. The analysis of this survey is included in the Coastal Processes and Socio-Economic Report for the Tuggerah Lakes Estuary.
Community Project Updates: E-newsletter	• Community project updates are drafted for inclusion in Council's electronic newsletter.	• Community Members	Inform	• December - January 2023 and ongoing	Two newsletter articles were sent out during the project to update the community on the survey. Further project updates will be circulated through future newsletters to update the community as the project progresses.
Media Releases	• To inform of project progress and to encourage participation in the engagement process.	• Community Members and Media Outlets	Inform	• At each project milestone.	• Media Release - Council releases Interim Entrance Management Procedure (August 2022) • Media Release -Tuggerah Lakes and The Entrance Channel Update (May 2023) • Media Release - Sand transfer works to commence at the Entrance channel (May 2023)
Frequently Asked Questions (FAQs)	• FAQs are drafted as required to ensure key questions and responses are available on Council's website.	• Community Members	Inform	• After the completion of the CFG meeting in February 2023. • During the consultation period, when drop-in sessions are held.	Council has updated its website to include FAQs on the project, these are informed by earlier consultation with the CFG and key stakeholders. An evaluation of the FAQs will be included after the consultation period has concluded.
Catchments to Coast Advisory Group - Presentation	• Presentation (30 minutes) to present the entrance management options and seek input on the project options.	• Catchments to Coast Advisory Group Members	Involve	• To be confirmed.	It is anticipated presentations to the Catchments to Coast Advisory Group will be held. The dates of the meetings are to be confirmed.
Drop in sessions	• Drop in sessions (two) will be held in person. These meetings (held during and after business hours) will provide an update on project progress and seek input on the Coastal Processes and Socio-Economic Report for the Tuggerah Lakes Estuary (through maps and imagery) and an outline of the project timeline. They will also provide the opportunity for two-way communication and Questions and Answers between Council and the project team. These meetings will be notified to the public via the project website and a letterbox notification to nearby residents.	• Community Members • Key Stakeholders • Local Businesses • Visitors • Community Organisations • Youth Organisations	Involve	• Following the completion of the draft Coastal Processes and Socio-Economic Report.	These drop-in sessions are yet to be held and will be evaluated after they are completed.

6 Monitoring and Evaluation

Evaluation is an integral part of engagement. It provides the opportunity to reflect and review the engagement as it is progressing and enables changes to be made, if necessary, through the engagement (between and within the CMP stages).

The evaluation of the CMP engagement, including a review of engagement tasks that have been undertaken is presented within **Table 5-1.** and an evaluation of how well they achieved the desired level of engagement is identified in the Stakeholder Matrix in **Table 4-2.** At project completion, further evaluation will be conducted to assess the effectiveness of the overall engagement program.

A1 Community and stakeholder engagement for the CMP (Stage 1)

Between 30 March and 15 June 2021 Central Coast Council hosted the first phase of community consultation to inform the development of the CMP. Key touchpoints in the first phase of engagement included:

- Key interest focus groups
- A dedicated project webpage
- An online waterways survey
- Community pop-up information stalls

Communications activity during the phase one consultation achieved:

- 3,918 visits to the Your Voice Our Coast project page
- 1,168 survey responses received
- 14 ads across Facebook and Instagram, reaching 62,011 unique users and achieving 263,341 impressions and 2,074 link clicks
- Snap chat ads, generating 128,212 paid impressions
- 8 Google display ads, generating 815,340 impressions and 819 clicks
- 2 e-news articles distributed, reaching more than 12,000 subscribers – generating 97 click throughs
- Over 350 respondents have entered the focus group candidate pool
- Over 220 stakeholder emails sent
- 3 focus groups hosted with over 20 participants
- Over 400 community members reached at pop up events
- Over 500 postcards distributed

Council's round one consultation survey focused on:

- the management of waterways
- use of waterways
- views on waterways
- obtaining a demographic profile of survey participants.

The information collected was then used to inform the development of the three CMP actions, but also the education and implementation for the CMPs.

The phase one – Our Coast, Our Waterways – survey delivered the following results:

- 94.5% of participants agree that waterways are a significant reason they live on the Central Coast
- 98% of participants agree that waterways contribute to their personal health and wellbeing (e.g. fitness, relaxation, happiness, lifestyle, sense of place, cultural heritage)
- 88.7% of respondents agree that if waterway access, safety or condition declined significantly they would reduce the frequency they visit and use waterways.
- 65.6% of respondents agree that if waterway access, safety or condition declined significantly they would consider moving away from the Central Coast to another location

- 96.5% of respondents agree that more should be done to protect and enhance the natural aspects of waterways such as the cleanliness of water, health of coastal vegetation, and the protection of wildlife
- 69.2% of respondents would support more resources being used for the management of our waterways and coast, even if it meant a very small increase in their property rates or rent a further 13.6% neither agreed or disagreed

The degree of participation in the community survey is testament to the level of community interest in our local waterways and the values placed upon them.

When asked what participants value about our waterways, the top three topics covered in these comments were:

- Recreational opportunities and access to waterways 28.1%
- Beauty and aesthetic 15.8%
- Environment and natural amenity 11.2%

When asked what the top three focus areas for Coastal Management Programs should be, respondents advised:

- Reducing pollutant loads (sediment, nutrients and microbes) entering waterways 16.6%
- Improving and maintain water quality 15%
- Restoring and maintaining key habitats 12.5%

423 comments were received when additional comments on waterways were requested, the top three topics covered in these comments were:

- Wamberal Seawall 13.3%
- Quality of life 3.5%
- Love waterways 2.6%

The Tuggerah Lakes Expert Panel was appointed by the NSW Minister for the Environment in February 2020 to undertake an independent assessment of water quality in Tuggerah Lakes. This included representative consultation with community and stakeholders, which anecdotally was well received by the local community. Whilst the scope of the CMP is broader than water quality alone, the Panel's report provided useful input and insights into the current situation and Council will continue to seek out opportunities to work with Expert Panel members to integrate their recommendations into the CMP.

The Tuggerah Lakes Coastal Management Program (CMP) Scoping Study integrates the recommendations of the Tuggerah Lakes Expert Panel and builds on the successes and learnings from the Tuggerah Lakes Estuary Management Plan (EMP) (Bio-Analysis, 2006). It provides a summary of the strategic, environmental, heritage and future contexts, identifies the purpose, scope, vision and objectives of the CMP and maps out a series of forward planning tasks and milestones which will assist with filling key knowledge gaps and gathering sufficient information to establish an effective and implementable CMP.

The Tuggerah Lakes Expert Panel highlighted the fundamental importance of working collaboratively with the local community to develop strategic and measurable plans for Tuggerah Lakes and to integrate them into the CMP. It is clear there is a strong appetite from the community and key stakeholders to

work collaboratively with Council and to co-design any future management strategies for Tuggerah Lakes.

Specific community engagement and communication recommendations included:

- "Focus engagement on learning together rather than solving 'the problem' or 'fixing' the Lakes."
- "Work with the community to grow a shared understanding of the Lakes' management dilemmas – what is actually going on and what makes managing the Lakes so difficult."
- "Build on the dilemma work to co-create a shared picture of the realistic and preferred outcomes for the Lakes."
- "Work with the community to design and agree to a decision-making process to determine potential and prioritised management actions, and to implement them."

An engagement strategy was prepared by Twyfords (2021) to support the Tuggerah Lakes Estuary Coastal Management Program. The strategy was used as guide for ongoing community and stakeholder collaboration throughout the development (Stages 1-4) and implementation (Stage 5) of the Tuggerah Lakes Estuary Coastal Management Program (CMP). During the development of the scoping study targeted focus groups were held to provide guidance on the engagements, reach and barriers.

The Strategy includes suggested key messages, stakeholder mapping analysis and proposed engagement methods to use throughout the development of the CMP. We have considered this earlier strategy in the development and refinement of our CSEP.

A2 The Entrance Place Plan (2021)

The Place Plan is a guiding document that helps Council and the Community work together to re-imagine and kick start The Entrance for the better. The Place Plan takes the documents, strategies, plans and reports previously prepared for the town and overlays new expectations and constraints identified in 2020.

This information is used to create a series of projects that can be delivered by Council and the Community - independent and in collaboration. The Place Plan provides a shared goal and vision for the town. This helps Council to understand what they are trying to achieve and why. Most importantly, the plan gives Council and the community a framework to deliver projects.

Engagement for the Place Plan was undertake using three (3) methods:

Method 1: Historical Engagement drawing together the studies, reports, data, plans produced for the Central Coast and The Entrance for the past ten years. All these past processes included detailed engagement. Key themes, ideas, constraints and opportunities were drawn from those reports and used to inform the Place Plan.

Method 2: One on one meetings and workshops- Individual or small group meetings were held during the engagement process. The meetings were with individuals who live and work in the area, know the area well or have businesses or business ties. All participates were also strongly encouraged to participate in Method 4 - Online Engagement.

Method 3: Online Engagement -Online engagement was held between 13 July and 2 August 2020 and was located on Councils www.yourvoiceourcoast.com. This included an Ideas Wall which

encouraged the community to put forward their ideas and start discussions about other people's ideas. A video explaining the process and initial ideas was placed on the engagement platform and on social media. The project was further promoted on social media and in window displays.

Key messages were called out during the engagement process. These ideas, concerns and opportunities have been integrated into this Place Plan. The following key messages from the community were identified:

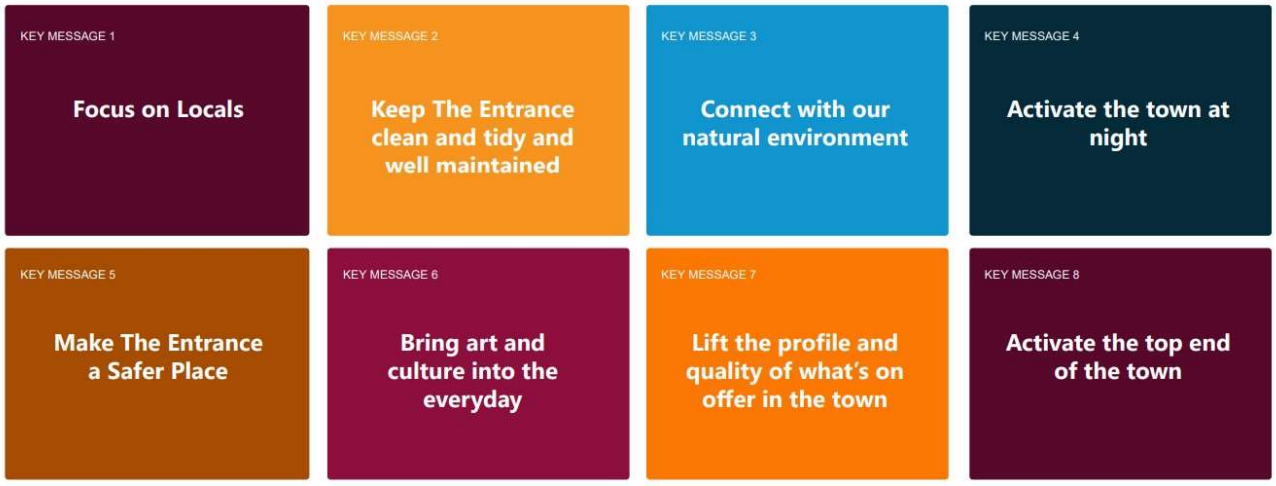


Figure A1: Key Messages identified during the Place Plan (2021) engagement process.

From all the projects and activations suggested by the community for The Entrance, there were three consistent threads. These three threads will form the basis for Actions that will form part of the Principles for the Place Plan Framework.

Figure A2: Key threads identified during the Place Plan (2021) engagement process.

From the Place Plan, as part of the Ideas Generator, the Coast to Tuggerah Lake scenic walk project was envisaged. This is an opportunity that was identified through the engagement process and is likely to be an opportunity that is again raised by the community during the consultation on this project.

The Entrance Place Plan will inform our socio-economic assessment and recommended engagement approach.

A3 Tuggerah Lakes Estuary Management Plan (2006)

Wyong Shire Council (now Central Coast Council), in partnership with the Department of Natural Resources (now DPE), developed an estuary management programme for the Tuggerah Lakes. The programme involved the preparation of an Estuary Process Study and an Estuary Management Study.

It was identified by the Department of Natural Resources and Council that the long term success of the Estuary Management Plan needs to be "owned" by all stakeholders including the community, business groups and State agencies. These stakeholders were consulted extensively at all key stages of the Estuary Process Study and Estuary Management Study.

At the time this plan was developed Wyong Shire Council was exploring ways of increasing funding for estuary management activities. The preferred funding source was through the establishment of a new stormwater levy. As this marries estuary management with an increased charge to residents, it was more important than ever to consult with the community.

Consultation was achieved through numerous methods; a summary can be found in **Table A1**.

Table A1: Consultation Methods – Tuggerah Lakes Estuary Management Plan

Consultation Methods
Open days at Lakehaven, Westfield Tuggerah and Bay Village shopping centres
Poster displays at Council chambers and local libraries
Advertorials on key lakes issues in local newspapers
Community input called for in newspapers, on display posters and through media interviews on local radio
Guiding local media on a tour of the estuary to discuss issues
Workshops with technical, community and business focus groups
Ongoing liaison with the Tuggerah Lakes Estuary, Coastline and Floodplain Management Committee
Engaging local school children to assist with developing a logo for the lakes
Public Exhibition of the draft Estuary Management Plan
Field Day Sessions held at three locations around the estuary

A4 Tuggerah Lakes floodplain risk management study and plan (WBMA Water, 2014)

Council was responsible for the initial consultation phase of the Floodplain Risk Management Study, including:

- A survey posted to all of the residential and commercial properties located in the 1% AEP flood extent,
- The survey was also available on Council's website for download or submission electronically,
- Presentations were undertaken at all of the Precinct and/or Progress Associations located around the Tuggerah Lakes foreshores,
- Ongoing advertising in local papers on the above communication methods.

The survey aim was to understand the existing flood knowledge in the community, the community's experience with previous flood events in Tuggerah Lakes, and what management measures the

community thought should be used to manage the flood risk. Additional general commentary was also sought.

At the conclusion of the consultation period, Council had received 1,285 responses. 90% of respondents were owner occupiers of their property, and the average age was 30 years of age. Only 33% had not experienced flooding at their property. Of the remaining, 18% had experienced floodwaters in the house or work, and 58% had experience floodwaters entering their backyard. **Table A2** summarises the survey responses regarding floodplain risk management measures suitable for use in the Tuggerah Lakes catchment. Respondents were asked to rank these options in order of preference. Number 5 indicated the most preferred method and number 1 the least preferred method. The survey highlighted the fact that 36% of respondents had not looked for information in relation to their property.

Table A2: Summary of Community Views on Management Measures

	Most Preferred		Least Preferred	
	Rank	**%**	**Rank**	**%**
Recognition of natural flowpath	5	59%	2,4	7
Vegetation Control	5	45%	2,4	5%
Building Development Controls	5	42%	2,4	5%
Educating the Community	5	42%	2,4	6%
Flood forecasting, flood warning, evacuation planning and emergency response	5	34%	2,4	8%
Floodgates or levee banks	5	23%	2,4	9%
Opening or dredging the entrance channel	5	68%	2,4	3%
Voluntary house purchase	1	24%	2,4	9%
House raising	3	24%	2,4	11%

Rhelm Pty Ltd

ABN 55 616 964 517

ACN 616 964 517

Head Office

Level 1, 50 Yeo Street

Neutral Bay NSW 2089

contact@rhelm.com.au

+61 2 9098 6998

www.rhelm.com.au