

REPORT

Lake Conjola Coastal Management Program Stage 2 Determine Risks, Vulnerabilities and Opportunities

Report C - "Entrance Processes and Entrance
Management Options"

Client: Shoalhaven City Council

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HASKONING AUSTRALIA PTY LTD.

Level 15
99 Mount Street
North Sydney NSW 2060
Water & Maritime
Trade register number: ACN153656252

+61 2 8854 5000 **T**
project.admin.australia@rhdhv.com **E**
royalhaskoningdhv.com **W**

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Author(s): Greg Britton
Drafted by: Greg Britton

Checked by: Matt Potter

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Approved by: Greg Britton

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Executive Summary

This report has been prepared as part of Stage 2 of development of the Lake Conjola Coastal Management Program (CMP). The aim of the report is to provide the basis for, and an outline of, options for management of the entrance to Lake Conjola to be assessed during Stage 3 of the CMP process.

The report sets out the following:

- an overview of the main coastal and estuary processes that influence entrance management;
- the history of entrance management, including previous options, plans and policies, and the current interim entrance management policy and licence;
- a description of historical records and selected events, including mechanical openings, flooding and dredging, that influence consideration of future entrance management; and
- the entrance management options proposed to be considered and assessed during Stage 3.

Based on a review of relevant background information it is evident that:

- Government Departments would not support any entrance management policy or need for entrance works based around water quality triggers except in exceptional circumstances. Studies carried out as part of this CMP also indicate that lake water quality should not be considered a driver for mechanical intervention at the entrance in normal circumstances. Managing the risk associated with flooding is the primary reason for entrance management; and
- the condition of the entrance is dependent on the interaction of a range of natural physical processes which cannot be controlled e.g. tides, wave action, rainfall, and beach rotation. On the basis of the lake entrance being managed with as minimal interference to natural processes as practicable, consistent with the NSW Government position, it can be expected there will be occasions when the entrance will close. Historical records have shown that complete closure of the entrance to Lake Conjola occurs on average for about 12% to 15% of the time which is a relatively low percentage of time in comparison to other similar systems in NSW, e.g. Narrabeen Lagoon entrance which is closed a minimum of approximately 25% of the time and is more actively managed.

The options for management of the entrance to Lake Conjola are considered to fall into four categories, involving progressively greater intervention, as follows:

- Category 1: The entrance area is allowed to behave naturally. Mechanical intervention in the form of excavation of a pilot channel occurs only in response to certain triggers;
- Category 2: The entrance area is managed by way of a dry notch approach whereby the sand levels in the entrance area (above water level) are regularly mechanically groomed to facilitate an easier mechanical opening when required, i.e. less excavation is necessary to open the lake when trigger levels are met;
- Category 3: The entrance area is managed by way of occasional dredging whereby a channel is sustained in the position of the natural ebb tide channel, aligned behind the sand spit and directed towards the Cunjurong shoreline. Excavation of a pilot channel would also form part of this approach. It could also be combined with maintenance of a dry notch. The aim of this approach is to avoid loss of the ebb tide channel, which would otherwise necessitate a much longer pilot

channel thereby impacting adversely on response times and effectiveness of a mechanical breakout; and

- Category 4: Engineering works are constructed in the entrance area, such as entrance breakwaters, to create a permanently open entrance, in which case there would be no requirement for a pilot channel.

The construction of engineering works at the entrance has been raised a number of times at community forums and on social media. While this approach would not be expected to be supported by Government Departments and would have a number of adverse impacts on the ecological and recreation values of the lake, it has been included for completeness to 'book end' the range of management approaches.

Within each category of options, consideration would be given to a number of key factors that influence the outcome of a mechanical intervention. These influencing factors are listed below together with the range of values proposed to be considered in numerical modelling of entrance options in Stage 3 of the CMP:

- trigger water level for mechanical opening: 0.8, 1.0, 1.2 and 2.0m AHD¹;
- dimensions and level of a pilot channel:
 - width: 5 and 10m,
 - bed level: 0m AHD,
- width and level of a dry notch:
 - width: 50m,
 - level: 1.0 and 1.2m AHD,
- location of a pilot channel: mid spit zone and northern spit zone;
- location of a dry notch and pilot channel: northern spit zone; and
- timing of a mechanical opening: Initiation of breakout flow typically at ocean high tide, but with sensitivity testing for other timings.

A range of lengths for a pilot channel would be considered, between 50m and 300m depending on the category of entrance management option. Category 1 and Category 2 options could be associated with pilot channel lengths over the full range of lengths from 50m to 300m depending on the water level trigger adopted and the configuration of the entrance channels at the time. Category 3 options would be expected to be associated with a pilot channel length no greater than approximately 150m, due to the approach of sustaining an ebb tide channel behind the sand spit and directed towards the Cunjurong shoreline.

Pilot channel length is an important factor as it affects the response time for mechanical intervention (quantity of sand to be excavated) and the effectiveness of a mechanical breakout event (scouring of the channel), all other factors being equal.

¹ AHD = Australian Height Datum, which is approximately the level of mean sea level at present.

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1 Introduction

This report has been prepared as part of Stage 2 of the development of the Lake Conjola Coastal Management Program (CMP). The aim of the report is to provide the basis for, and an outline of, options for management of the entrance to Lake Conjola to be assessed during Stage 3 of the CMP process.

The report is set out in the following way:

- **Section 2** provides an overview of the main coastal and estuary physical processes that influence entrance management;
- **Section 3** sets out the history of entrance management including previous options, plans and policies, and the current interim entrance management policy and licence;
- **Section 4** sets out a description of historical records and selected events, including mechanical openings and flooding, that influence consideration of future entrance management; and,
- **Section 5** outlines the entrance management options proposed to be considered and assessed during Stage 3 of the CMP process.

2 Overview of Main Coastal and Estuary Physical Processes

2.1 General

The main coastal and estuary physical processes active within, and at the entrance to, Lake Conjola have been investigated in a number of previous studies, most notably:

- Shoalhaven City Council (1996), Lake Conjola – Stage 1: Estuary Processes Study Draft, August 1996;
- Patterson Britton & Partners (1999), Lake Conjola Entrance Study, prepared for Shoalhaven City Council, Issue No. 2, May 1999;
- BMT WBM (2007), Lake Conjola Flood Study, Final Report R.N0758.004.05, July 2007;
- BMT WBM (2013a), Lake Conjola Floodplain Risk Management Study and Plan, Final Report R.N1778.001.04, February 2013; and,
- BMT WBM (2013b), Lake Conjola Floodplain Risk Management Study and Plan: Entrance Sensitivity Report, Final Report R.N1778.002.00, April 2013.

A description of the key physical processes is set out in the following sections based on information within the above documents, together with information from more recent sources and studies carried out as part of preparation of the Lake Conjola CMP.

The key physical processes described comprise:

- astronomical tide;
- coastal water level;
- wave climate and wave driven processes;
- sedimentary processes at the entrance;
- beach rotation; and,
- flood behaviour.

2.2 Astronomical Tide

Astronomical tide is a key ‘forcing’ mechanism for water movement and sediment movement in the lake entrance area and further upstream within the inlet channel (refer **Figure 2-1**). The other key forcing mechanism is freshwater discharge from the lake at times of rainfall. During dry periods, freshwater flows are insignificant and tidal and wave driven processes dominate entrance behaviour.



Figure 2-1: Aerial view of Lake Conjola showing the entrance area and the inlet channel

Astronomical tide refers to the periodic rise and fall of water along the coast due to the gravitational interactions between the moon, sun and the earth. The moon has a greater effect on tides than the sun due to its proximity to the earth even though it has vastly less mass.

When the moon, sun and the earth are in line their combined attraction is stronger and the ocean tidal range (height difference between high tide and low tide) is greater. This is referred to as spring tides and occurs on approximately a fortnightly cycle around the time of the new moon and full moon. Neap tides (lower tidal range) occur when the sun and moon are at right angles relative to the earth and their gravitational effects act in opposition. The neap tide follows seven days after a spring tide, during the first and third quarters of the moon. The above astronomical tidal behaviour along the coast is depicted in **Figure 2-2**.

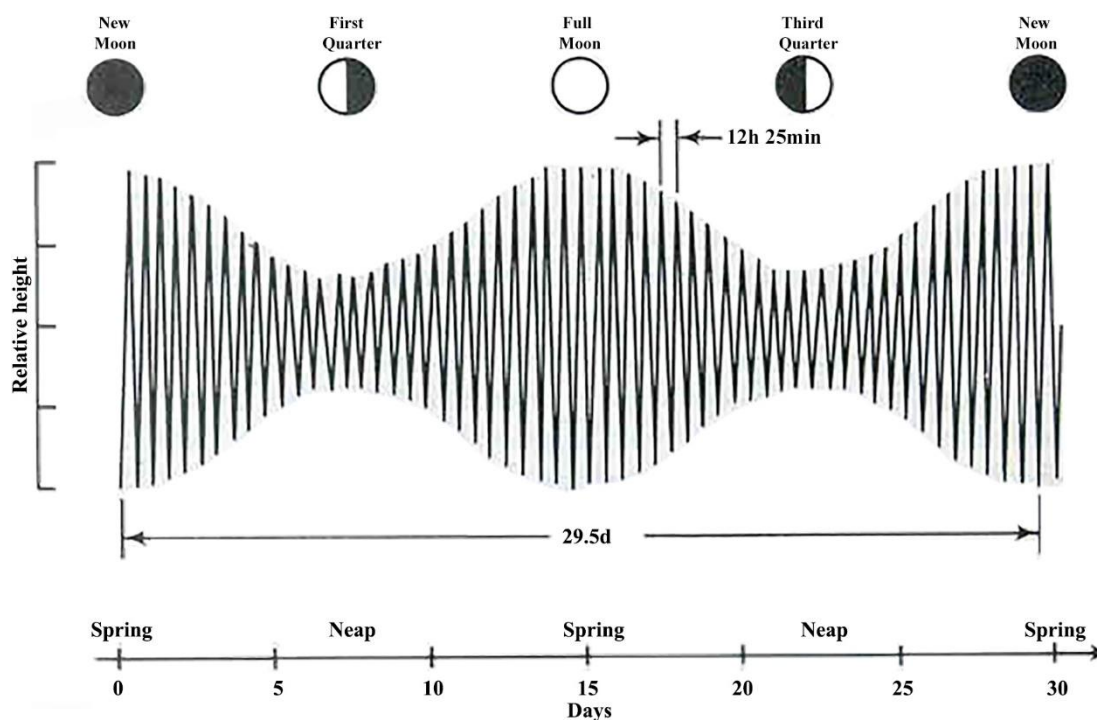


Figure 2-2: Astronomical tide behaviour in the ocean

Tides along the NSW coast are semi-diurnal, meaning there are two high tides and two low tides daily. The tide can also exhibit significant diurnal inequality, meaning a significant difference between the heights of two successive high or low tides in a day.

The closest open coast water level recorder to Lake Conjola is located within Ulladulla Harbour approximately 10km to the south. Tidal planes determined at Ulladulla Harbour and reported in Manly Hydraulics Laboratory (2012) are set out in **Table 2-1** relative to Australian Height Datum (AHD)². These tidal planes would be representative of the ocean tide at the entrance to Lake Conjola.

Table 2-1: Tidal planes at Ulladulla Harbour

Tidal Plane	Level (m AHD)
High High Water Solstices Springs (HHWSS)	0.960
Mean High Water Springs (MHWS)	0.617
Mean High Water (MHW)	0.510
Mean High Water Neaps (MHWN)	0.403
Mean Sea Level (MSL)	0.040
Mean Low Water Neaps (MLWN)	-0.325
Mean Low Water (MLW)	-0.431
Mean Low Water Springs (MLWS)	-0.538
Indian Spring Low Water (ISLW)	-0.783

² Australian Height Datum is approximately the level of mean sea level at present.

When the entrance to Lake Conjola is open to the sea, tides cause a periodic flow into the lake (flood tide) and flow out of the lake (ebb tide). Due to 'shallow water effects' caused by the restricted depth at the entrance, and frictional resistance to the tidal flow caused by the bed of the lake, the tidal behaviour within the lake exhibits a number of specific characteristics that are different to the ocean tide. These characteristics are illustrated by way of example in **Figure 2-3** which shows an actual lake water level record in June 2008 captured by the water level recorder situated adjacent to Council's Holiday Haven Caravan Park near the entrance to the lake, compared to the ocean tide (represented by the Ulladulla Harbour tide gauge)³. The actual water level record was at a time of spring tides with significant diurnal inequality and no significant rainfall.

The characteristics of the lake water level are described below:

- tidal range in the lake is significantly reduced compared to that in the ocean;
- the half tide level in the lake (average mid point between high tide level and low tide level) is elevated relative to mean sea level, i.e. the average lake water level is 'perched' above mean sea level;
- the rate of rise of the water level in the lake during the flood tide is greater than the rate of fall of the water level in the lake during the ebb tide, i.e. the duration of the flood tide is shorter than the duration of the ebb tide;
- the diurnal inequality in the ocean tide is reflected in the lake water level record; and,
- during spring tides the average water level in the lake increases, followed by a lowering of average lake water level during neap tides, i.e. the lake is 'pumped up' during springs and then subsequently 'drains' during neaps in a weekly cycle.

The configuration of the entrance channel and shoals has an effect on tidal behaviour within the lake since they influence the shallow water effects and frictional resistance. When the entrance is well scoured following a freshwater flooding event, the tidal range in the lake is increased and the average water level is less elevated relative to mean sea level, due mainly to diminished shallow water effects. On the other hand, when the entrance is heavily shoaled, the tidal range is reduced and the average water level is more elevated relative to mean sea level. These features are illustrated in **Figure 2-4**.

³ The water level recorder situated adjacent to Council's Holiday Haven Caravan Park is operated by Manly Hydraulics Laboratory (MHL) on behalf of Council. It has been operational since 1992.

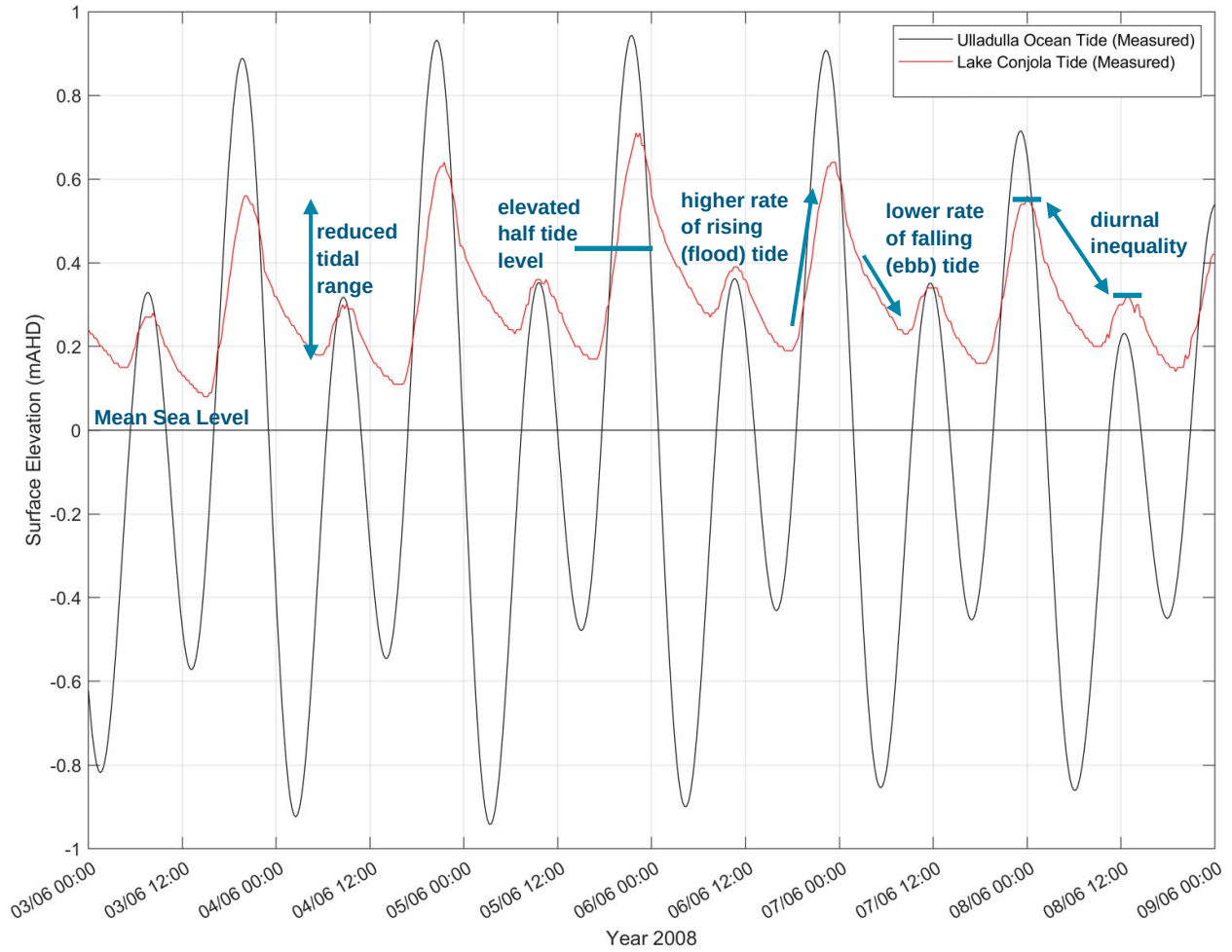


Figure 2-3: Water level behaviour in Lake Conjola compared to the ocean

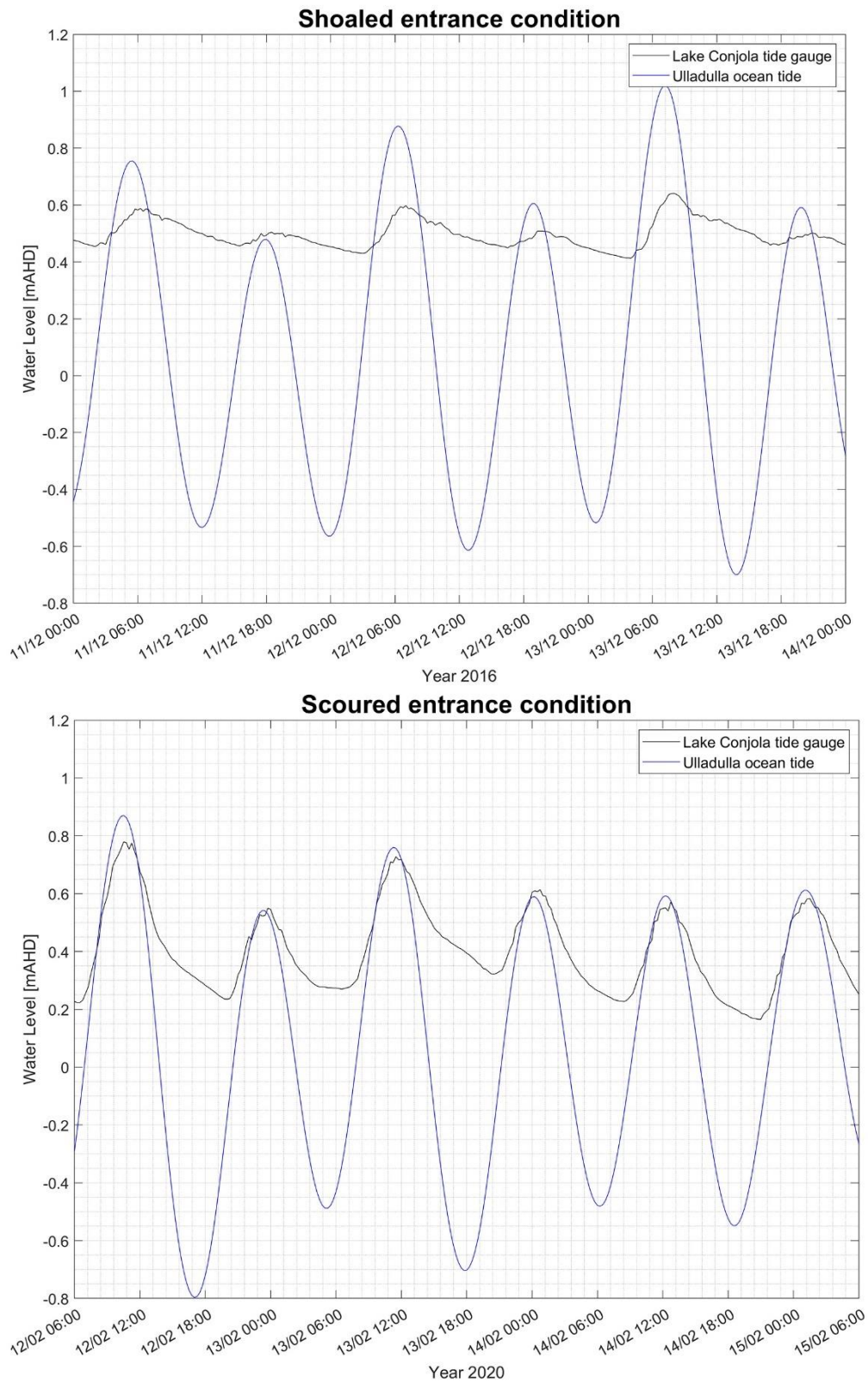


Figure 2-4: Tidal behaviour for a scoured entrance condition following the February 2020 flood event (top panel) and for a heavily shoaled condition in December 2016 (bottom panel)

Due to the dependence between lake water level behaviour and entrance condition, Manly Hydraulics Laboratory (MHL) has developed a tool for Council which monitors a component of the variation in lake water level (being the M2 tidal constituent⁴) as a proxy for the various stages of the entrance closure of Lake Conjola (refer **Figure 2-5**). Plotting of the M2 tidal constituent can be used as a remote monitoring indicator of the degree of lake entrance constriction, and potential for closure. As illustrated on **Figure 2-5**, a higher M2 value indicates a well-scoured open entrance condition and a reduction in M2 value indicates progressive shoaling and possible imminent closure of the entrance.

The dependence between lake water level behaviour and entrance condition also means that any entrance management practices that modify natural entrance conditions will have an effect on lake water level. In turn this has the potential to impact on factors such as the degree of inundation of the foreshore and lake ecology.

⁴ M2 is the principal lunar, i.e. determined by the moon, semi-diurnal constituent of the tide.

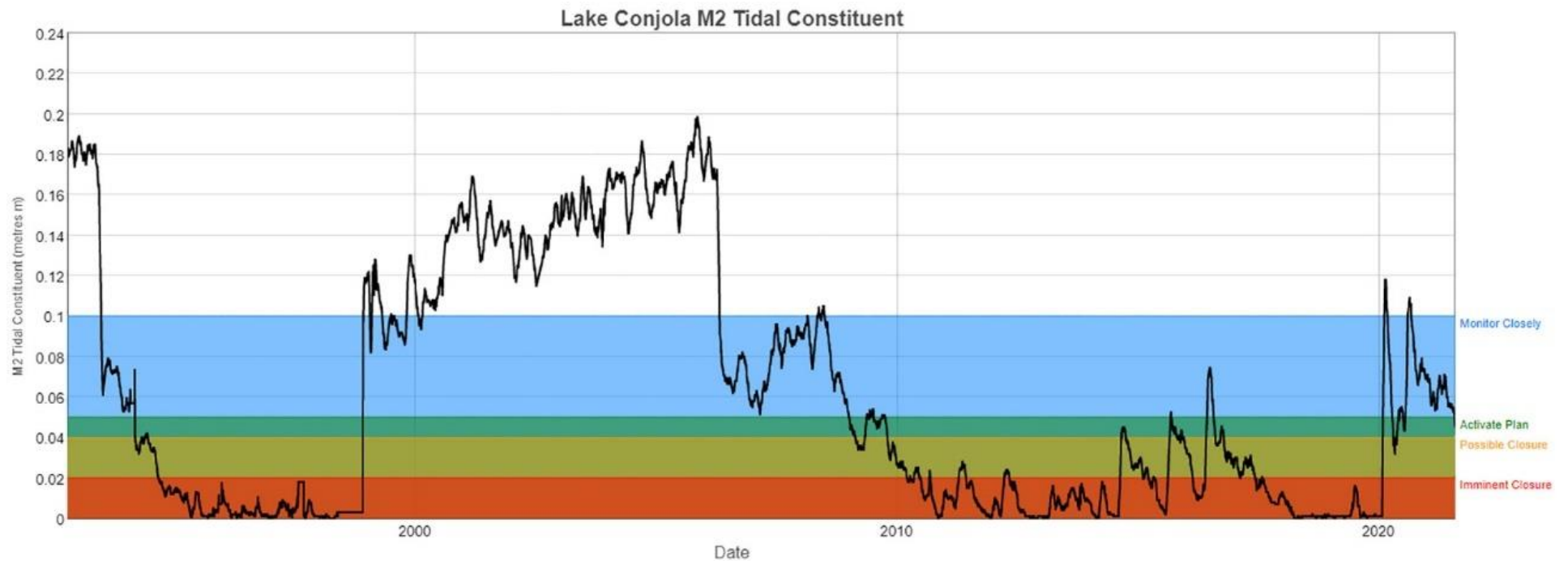


Figure 2-5: Lake Conjola M2 tidal constituent time – series and associated guidance on entrance closure
(from: <https://mhlfit.net/users/ShoalhavenCityCouncil-LakeConjolaM2>)

2.3 Coastal Water Level

At times of coastal storms, the water level along the open coast becomes elevated above astronomical tide due to the effects of storm surge, wave setup and wave runup. These factors are illustrated diagrammatically in **Figure 2-6** and discussed below.

Storm surge is made up of two components; a rise in mean sea level due to low air pressure (inverted barometric pressure effect) and a rise in water level at the shoreline due to strong onshore winds (wind setup). The combined effect of storm surge and astronomical tide is sometimes referred to as storm tide.

Wave setup is a further rise in water level inshore of the wave breaking zone due to the conversion of the kinetic energy of the waves to potential energy.

Wave runup is the vertical distance above mean water level reached by the uprush of individual waves across a beach or up a structure. Where a beach and dune system, or structure, does not extend vertically to the limit of wave runup, the full wave runup would not be realised. In such cases the wave runup may 'fold over' the dune or structure and continue as sheet flow at shallow depth, spreading out and infiltrating into the ground.

An understanding of the duration of the above additional water level components above astronomical tide level is also important for assessment of potential impacts and consequences. Storm surge is essentially a steady phenomenon, lasting for hours, whereas wave setup has a significantly lesser duration measured in minutes. Wave runup is a transient phenomenon and occurs at the frequency of the waves themselves, typically in the order of every 10 to 15 seconds during storms.

When the entrance to Lake Conjola is open and an ocean storm occurs, inundation levels around the lake foreshore are increased above astronomical tidal levels due to the effects of storm surge and wave setup at the entrance. The magnitude of wave setup at the entrance may be less than the value along the adjacent open coast due to some transmission of wave energy through the entrance, i.e. not all the kinetic energy of the waves is converted to potential energy. The ocean wave runup component is not considered in determining the inundation level around the lake foreshore due to the generally limited penetration of ocean waves beyond the entrance and the transient nature of the runup.

Typical magnitudes of storm surge in severe storms are 0.3 to 0.5m. Wave setup along the open coast is much more significant and in severe storms is in the range 1 to 1.5m.

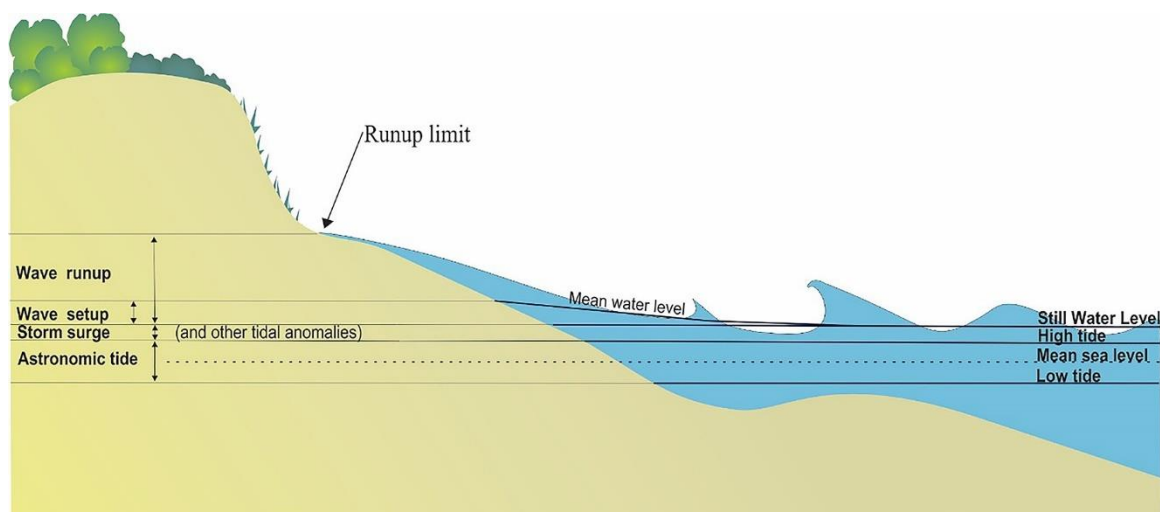


Figure 2-6: Components of coastal water level

2.4 Wave Climate and Wave Driven Processes

Waves play a key role in entrance behaviour in several respects. Waves transport sand to the entrance area via alongshore (littoral) wave-driven currents and contribute to the transport of sand into the lake as a result of storm washover processes and the suspension of sand into the water column for transport by the flood tide (refer **Section 2.5**). Waves also elevate coastal water levels (wave setup) which affects shoreline response at the entrance.

A waverider buoy station was commissioned offshore of Batemans Bay (approximately 55km from the Lake Conjola entrance) in May 1986 and upgraded with a directional waverider buoy in February 2001 (Glatz et al, 2017). Data from this buoy provides a good understanding of the wave climate offshore from Lake Conjola.

Figure 2-7 presents a wave rose (percent occurrence of significant wave height and direction) for the Batemans Bay waverider buoy station based on 18.9 years of directional wave data⁵. This figure demonstrates that the majority of waves, and the highest waves, recorded offshore of Batemans Bay are from the south-east (SE) and south-south-east (SSE). This predominant wave direction and wave height, and the generally north-east alignment of the coastline at the Lake Conjola, gives rise to a net northerly sand transport (littoral drift) along Conjola Beach and explains the sand spit growth at the entrance from south to north thereby forcing the entrance channel against the northern shoreline at Cunjurong Point (refer **Section 2.5**).

⁵ Significant wave height is the average height of the highest one third of waves in a wave record. It was defined mathematically to equal the wave height estimated on the ocean by a trained observer. The wave direction is the direction the waves come from.

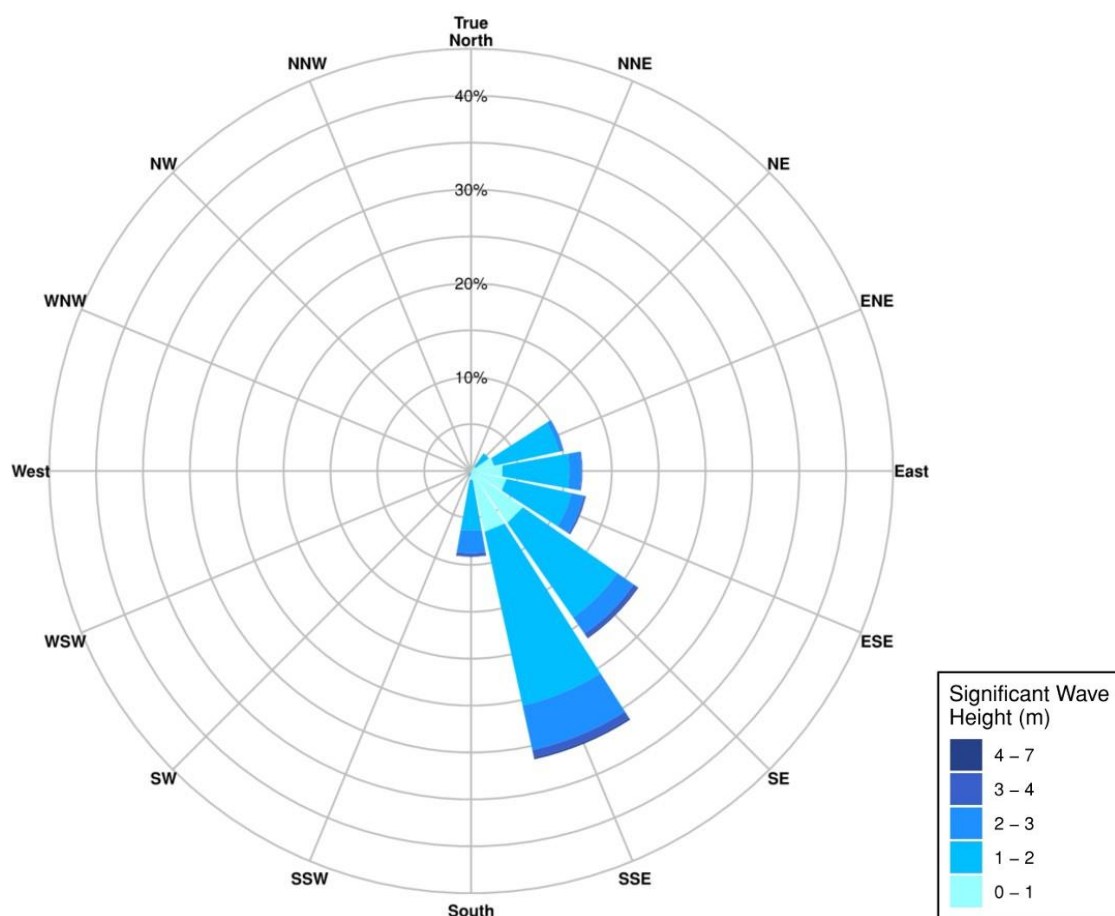


Figure 2-7: Wave rose for the Batemans Bay waverider buoy station (source: Manly Hydraulics Laboratory)

2.5 Sedimentary Processes at the Entrance

2.5.1 General

An understanding of sediment movement at the entrance to Lake Conjola and the underlying physical processes that cause this movement is fundamental to consideration of how the entrance may be most appropriately managed and the potential impacts of different approaches or options.

The most comprehensive understanding of sedimentary processes at the entrance to Lake Conjola is that presented in Patterson Britton (1999). This understanding was developed based on a number of studies including, significantly, the interpretation of historical vertical aerial photographs covering the period 1944 to 1997 and various sediment transport analyses. The vertical aerial photographs examined in Patterson Britton (1999), together with the annotations made at the time, have been reproduced in **Appendix A**⁶.

Additional vertical aerial photography is now available covering the period 1999 to 2021. In all there are a further 26 dates of vertical aerial photographs available. Review of this additional photography has indicated that the physical processes operating at the entrance to Lake Conjola have not materially

⁶ The annotations include a comment on the entrance condition or 'entrance state'. A description of the characteristic entrance states defined in Patterson Britton (1999) is set out in the following Section 2.5.2.

changed since the descriptions included in Patterson Britton (1999). The additional vertical aerial photographs reviewed, including annotations made as part of this study, are included in **Appendix B**.

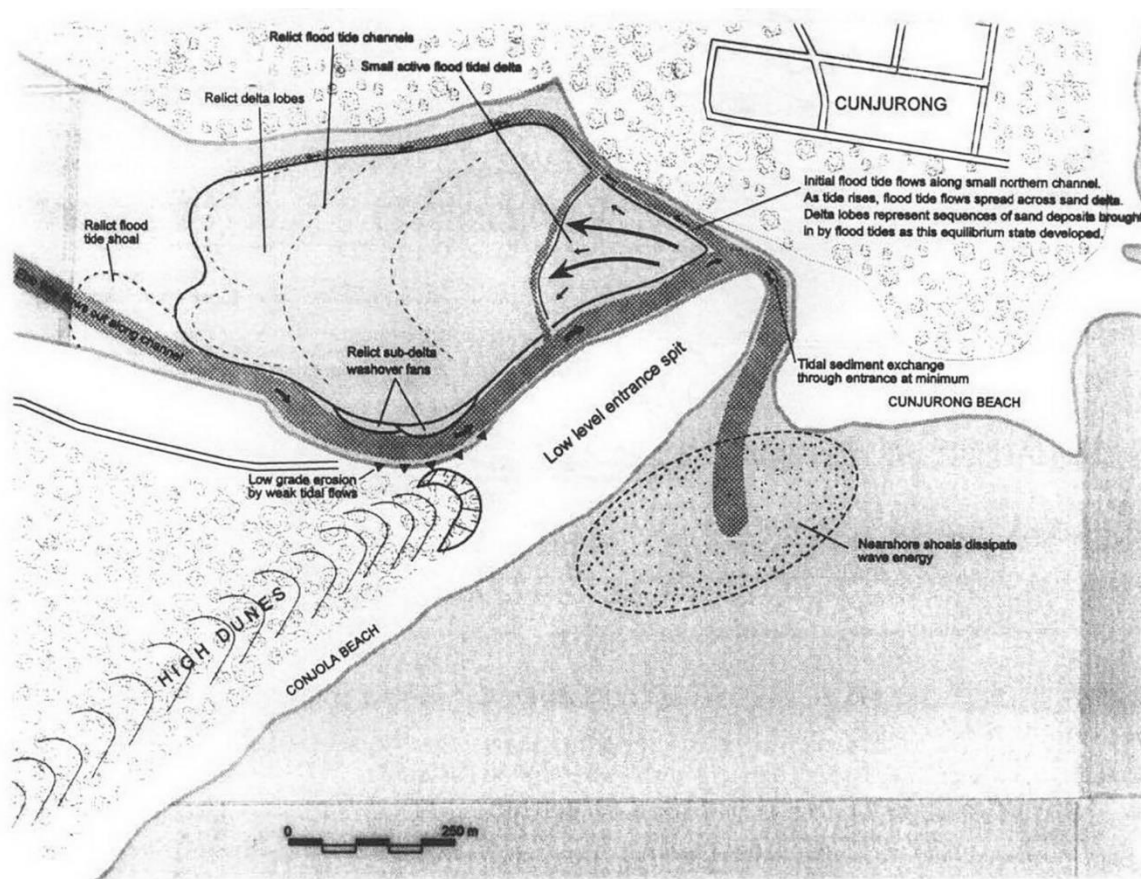
The descriptions in the following sections are taken largely from Patterson Britton (1999) with additional notes included where considered appropriate.

2.5.2 Basic characteristic entrance states

Four basic characteristic entrance states for Lake Conjola were identified and described in Patterson Britton (1999) as set out in **Table 2-2** and illustrated in **Figure 2-8** to **Figure 2-11**.

Table 2-2: Characteristic entrance states for Lake Conjola

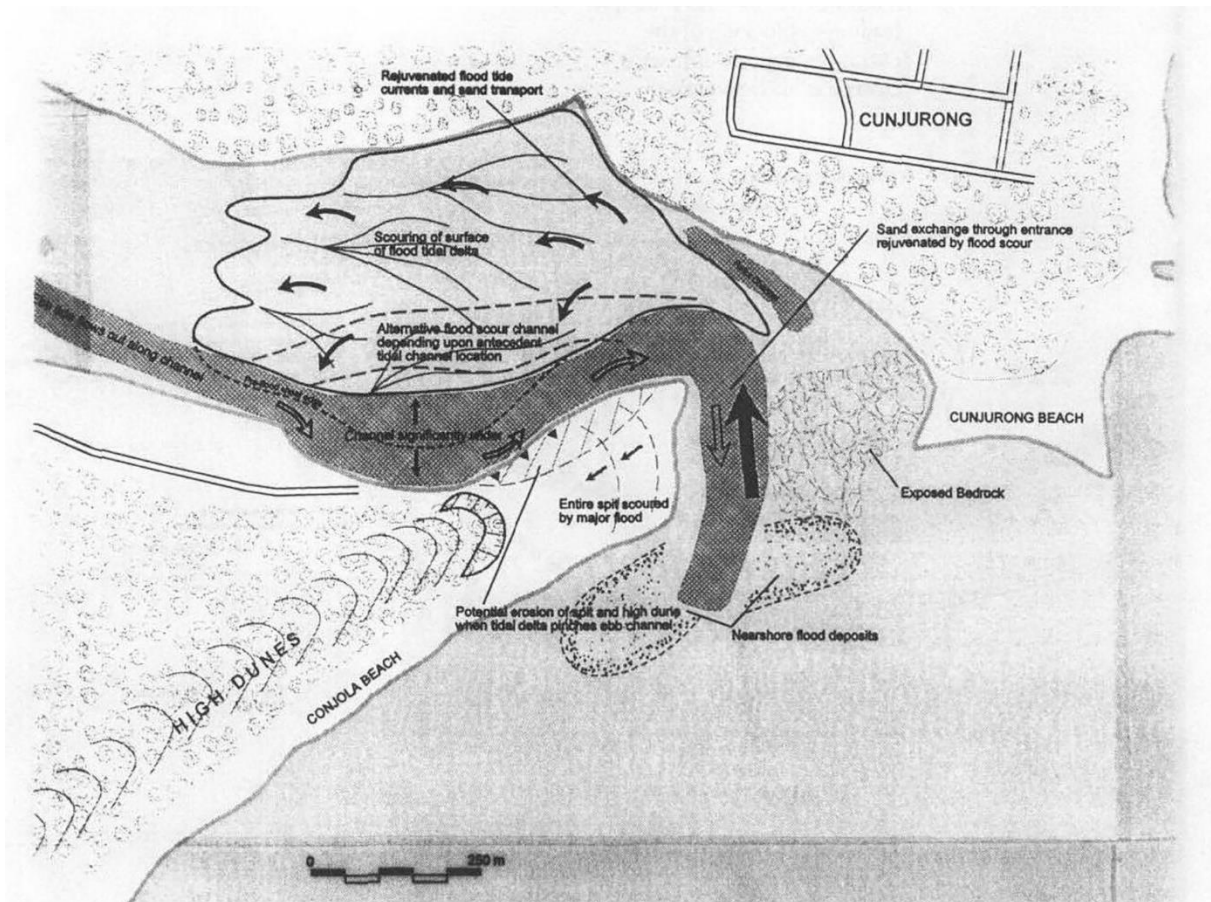
Characteristic entrance state	Description
Regime Entrance State	A steady end state that the entrance naturally and gradually establishes in the absence of any sudden changes caused by major floods and ocean storms. This is a state of near dynamic equilibrium. Refer Figure 2-8 .
Flood Scoured Entrance State	The entrance state resulting from a sudden change caused by a significant flood leading to a net loss of sand from the entrance shoals and widening of the entrance. Refer Figure 2-9 .
Intermediate Entrance State	The entrance state associated with relatively rapid infilling of entrance shoals after a major flood and before the regime state is reached. The intermediate state was considered to progress to the regime state over a period of 1 to 2 years. Refer Figure 2-10 .
Storm Washover Entrance State	The entrance state associated with a sudden change caused by major to severe ocean storm waves washing sand over the entrance sand spit leading to blocking of the entrance channel. Entrance closure is likely to ensue from this state. Refer Figure 2-11 .



Regime Entrance State - Broad features:

- entrance is hard against the northern shoreline and the channel is quite narrow;
- small tidal exchange with limited tidal range in lake – average lake level is elevated well above mean sea level;
- flood tide delta and low level entrance spit relatively stable but prone to instability from:
 - floods cutting through spit and opening up lake and rejuvenating tidal exchange,
 - severe coastal storm overtopping the entrance sand spit and pushing large deposits of sand westwards and potentially closing the entrance,
 - lengthy dry spell (several years) allowing windblown sand to slowly close off the narrow entrance channel.

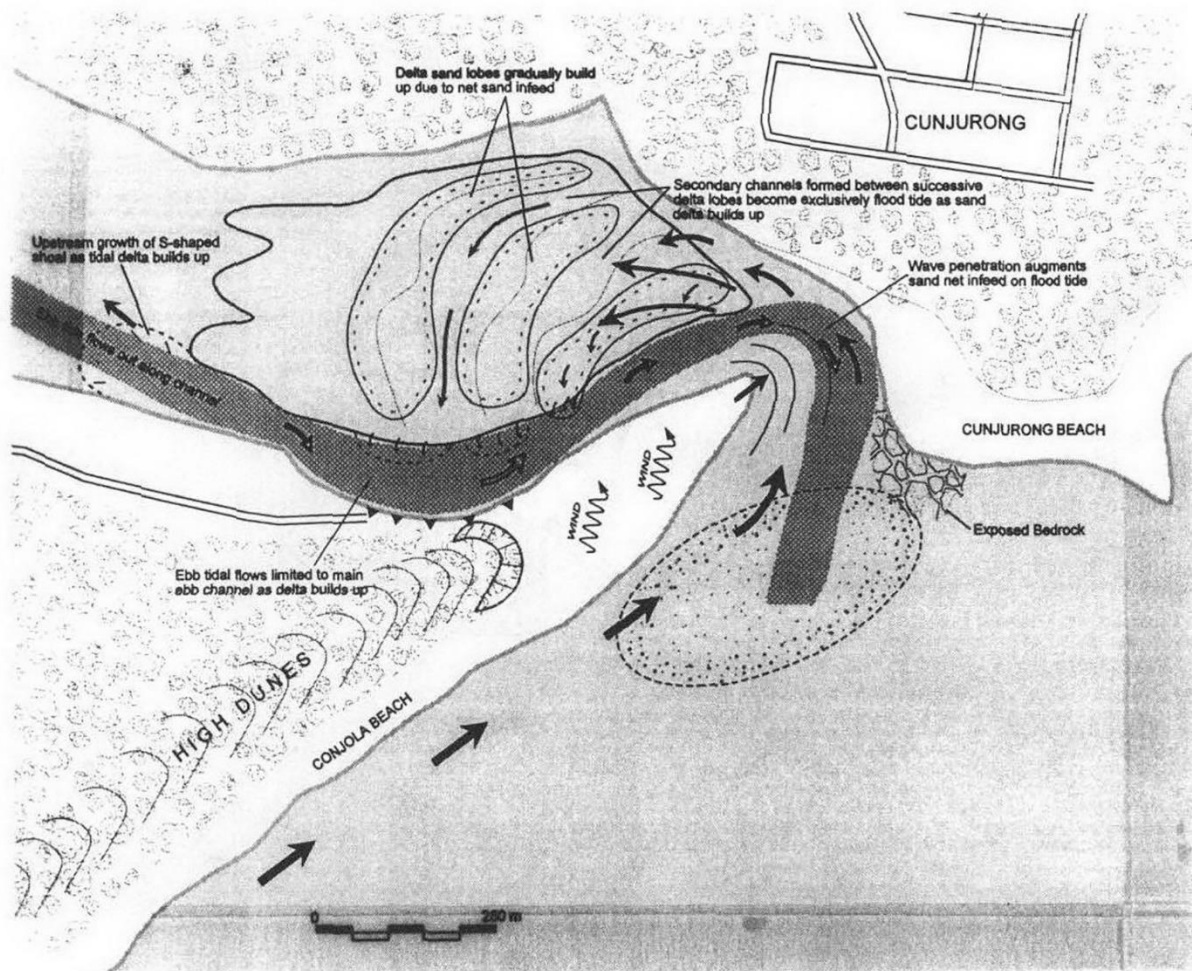
Figure 2-8: Regime entrance state



Flood Scoured Entrance State - Broad features:

- scour expands entrance throat, enlarging channel more to the south;
- flood tide delta scoured at southern edge and over entire surface (evidenced by channelling pattern);
- flood scour deposits placed in nearshore zone as large shallow bar;
- due to proximity of flood sediment deposits and increased tidal flows, the entrance is primed for:
 - rapid onshore movement of previously flood scoured deposits combined with normal longshore transport of sand from Conjola Beach into the entrance area,
 - pronounced net infeed of sediment thereby increasing shoal build-up across flood tidal delta.

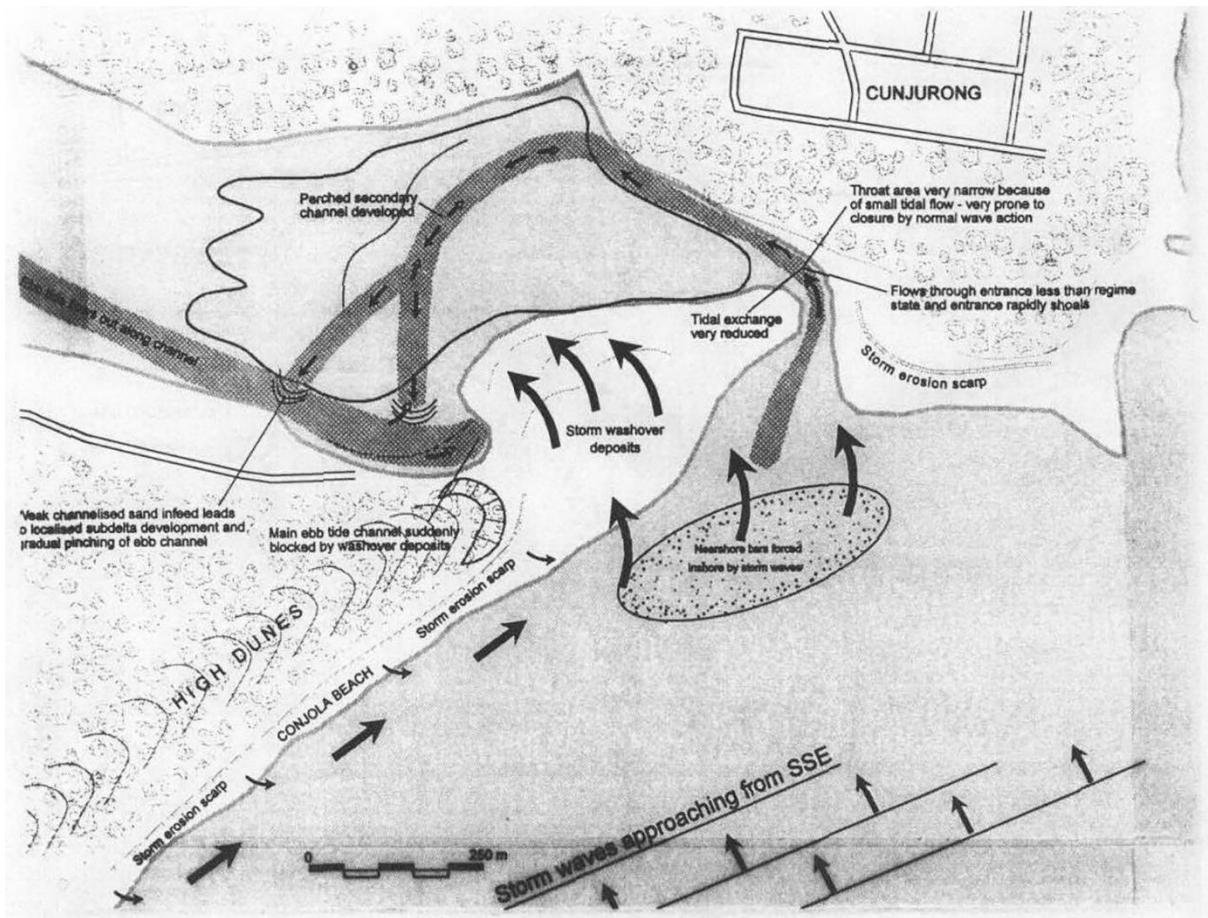
Figure 2-9: Flood scoured entrance state



Intermediate Entrance State - Broad features:

- sediment has mobilised into entrance via onshore movement of flood deposits as well as longshore and wind transport, viz:
 - entrance spit has migrated northwards,
 - flood tidal delta lobes have built up significantly,
- these changes combine to reduce tidal flows, though there is still a net infeed of sediment;
- entrance will gradually reduce unless reopened by a flood;
- closure may be catalysed by storm supply of large amount of sediment.

Figure 2-10: Intermediate entrance state



Storm Washover Entrance State - Broad features:

- washover deposits i.e. 'fans' cut off fluvial channel/primary ebb channel;
- ebb channel becomes perched on flood delta lobes leading to suddenly and substantially diminished tidal flows;
- flood tide tends to re-establish northern perimeter channel;
- sediment infeed is reduced but continues to pinch primary ebb channel which eventually disappears;
- further washover leads to closure.

Figure 2-11: Storm washover entrance state

2.5.3 Conceptual model of entrance sedimentary processes

A detailed conceptual model of sedimentary processes operating at the entrance to Lake Conjola was prepared in Patterson Britton (1999). A simplified version of this conceptual model was included in a Coastal Fact Sheet – Lake Conjola Management prepared by Council in 2018 (refer **Appendix C**).

Detailed conceptual model

The detailed conceptual model included in Patterson Britton (1999) is reproduced in **Figure 2-12**. The key features of the conceptual model are summarised below. Quantification of the various sedimentary processes was also included in Patterson Britton (1999) but this level of detail is not presented here.

- northerly net longshore transport along Conjola Beach drives northwards growth of the entrance spit and forces the entrance channel against the northern shoreline at Cunjurong Point;
- because of the net northerly longshore transport, there are always extensive nearshore shoals adjacent to the entrance spit and entrance channel. These shoals produce a wide surf zone and considerable dissipation of wave energy;
- the northern shoreline exhibits reduced exposure to waves due to the wave shadow caused by Green Island and the dissipative effects of the nearshore shoals;
- there is a northerly leakage of longshore sand transport between Green Island and Cunjurong headland, occurring as sand 'slugs' during southerly storms;
- the entrance spit is always low and therefore susceptible to storm washover. Storm washover fans are the trigger for entrance closure;
- windblown sand from Conjola Beach is a significant supply for the build-up of the entrance spit, entrance dunes and tidal delta shoals. Windblown sand can build-up the entrance to 3 to 4m above sea level, requiring a major flood to scour a closed entrance;
- significant reversals in longshore transport direction are rare but are evident in the photographic records. These can add additional sand infilling to the entrance;
- wave stirring of the seabed enhances flood tide sand transport so that there is a net infeed of sand every tide;
- when the entrance is well scoured, tidal range is greatest and tidal flows are strong, causing sand to be transported to the western extremity of the delta shoals;
- as the entrance shoals build-up, tidal range and tidal flows reduce and the area of active sand transport retreats towards the entrance;
- floods periodically scour the surface of the tidal delta and expand the entrance channel, thereby rejuvenating tidal flows and sediment infeed;
- secondary flood tide channels convey sand towards the southern edge of the tidal delta, in the vicinity of the boat ramp near the Holiday Haven Caravan Park. Southerly growth (progradation) of the delta in this area deflects the ebb tide and flood flow against the landward side of the high dunes, causing bank erosion; and,
- the indented shoreline in the southern boat ramp area, including the large bay and beach to the east in the vicinity of the beach access walkway, is present in the earliest photos of the area. It has evolved due to repeated southerly progradation of the tidal delta during periods of sustained delta build-up.

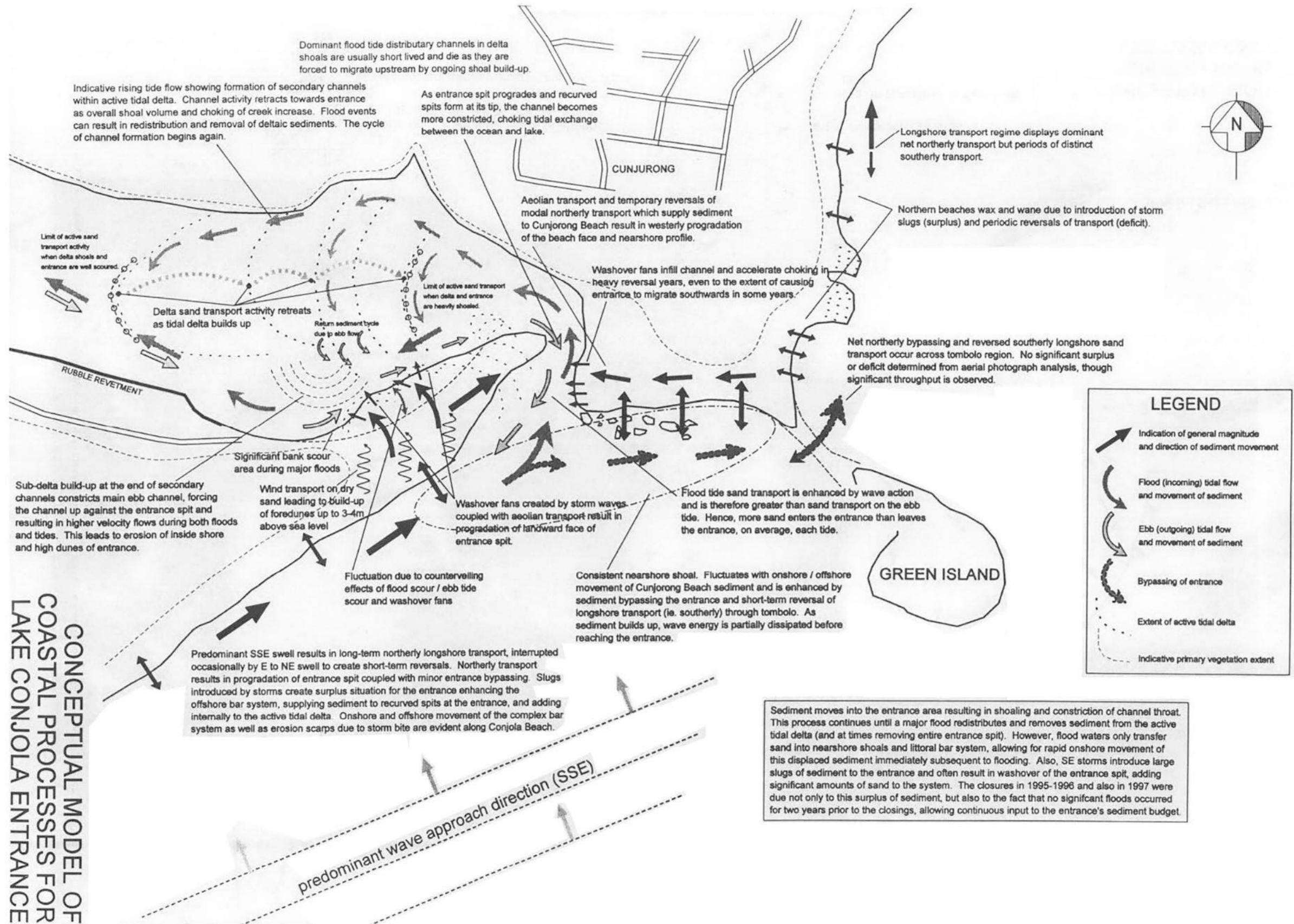


Figure 2-12: Conceptual model of sedimentary processes at Lake Conjola entrance (from Patterson Britton, 1999)

Simplified conceptual model

The simplified conceptual model of sedimentary processes operating at the entrance to the lake included in Council's Coastal Fact Sheet – Lake Conjola Management (refer **Appendix C**) is reproduced in **Figure 2-13**. This shows the main sediment transport pathways.



Figure 2-13: Simplified model of sedimentary processes at Lake Conjola entrance (from Coastal Fact Sheet, 2018)

2.5.4 Entrance stability (open or closed)

Entrance stability over the period 1937 to 1999 was investigated in Patterson Britton (1999). The findings of this investigation were summarised as follows. Particular data analysis that underpinned the findings is included in **Appendix D**:

- between the period 1937 to 1999 the entrance closed 8 times;
- in every case, closure was triggered by a severe coastal storm, i.e. storm washover deposits blocked the entrance channel;
- entrance closures often lasted for several years until a large flood scoured a substantial entrance channel (in the absence of any mechanical intervention by Council); and,
- over the 62 year period 1937-1999 the cumulative durations (total percentages of time) of main entrance states were as follows:

- entrance closed: 15%,
- entrance open (including heavily shoaled): 85%⁷.

On the basis of the analysis in Patterson Britton (1999) it was concluded that:

- entrance closures are caused by severe storms;
- periods of entrance stability correspond with periods of little storm activity; and,
- the key to improving entrance stability (reducing the likelihood of entrance closure) is reducing the destabilising impact of severe storms, i.e. preventing or mitigating storm washover deposits⁸ (refer **Figure 2-14** which shows dune stabilisation works completed by Council in 2004 in response to conclusions in Patterson Britton (1999)).



Figure 2-14: Dune revegetation at Lake Conjola entrance (source: DPE)

A historical record of the entrance condition, whether open or closed, is also available for the period 1916 to 2019 on a monthly basis from Council spreadsheet records compiled by Isabelle Ghatti (former Natural Resources and Floodplain Manager, Shoalhaven City Council). These records are included in

⁷ The 85% of the time was made of 62% when the entrance was in either a regime state, flood scoured state or intermediate state, and 23% when the entrance was in a heavily shoaled or storm washover state.

⁸ The occurrence of ocean storms cannot be controlled of course, hence in effect this meant reducing the surface area of the sand spit and/or increasing the elevation of the spit and/or stabilising the spit through increasing the vegetation cover.

Appendix E and indicate that the entrance was open for 88% of all the months and closed for 12%, which is a similar result to the assessment in Patterson Britton (1999).

The percentage of time Lake Conjola entrance is open is relatively high in comparison to other NSW intermittently closed and open lakes and lagoons (ICOLLS). For example, it is noted in the Coastal Fact Sheet – Lake Conjola Management that about 70% of ICOLLS in NSW are closed most of the time (i.e. greater than 50% of the time). Narrabeen Lagoon on Sydney's northern beaches, as a specific example, is open approximately 75% of the time and closed 25% of the time. Major entrance clearance operations are carried out approximately every four years at Narrabeen Lagoon entrance as part of entrance management practices, which skew the natural entrance behaviour, hence the percentage of time the lagoon would be open under natural conditions would be actually less than 75% compared to the Lake Conjola figure of approximately 85 to 88%.

2.6 Beach Rotation

A potential factor influencing entrance condition and stability at Lake Conjola, not considered in past studies, is beach rotation. This refers to the cyclic erosion and accretion at opposite ends of long beaches controlled by the irregular 2 to 7 year cycles of the El Nino – Southern Oscillation climate oscillation, or ENSO.

Beach rotation can occur independently of other beach processes such as short term cycles of erosion and accretion along the entire beach in response to individual ocean storms, long-term shoreline recession or progradation trends due to net sand loss or gain respectively, or long-term shoreline recession due to sea level rise.

Beach rotation along Collaroy-Narrabeen Beach in Sydney has been examined to explain the variation in beach width at the northern end of the beach which affects the stability of Narrabeen Lagoon entrance (WRL, 2019)⁹.

A so-called Beach Orientation Index (BOI) has been developed for Collaroy-Narrabeen Beach as a measure of the orientation of the beach on any given day relative to the long-term average. A positive BOI means the beach has a more clockwise rotation relative to the long-term average, i.e. wider beach at the northern end at Narrabeen Lagoon entrance (El Nino phase) and a negative BOI highlights a more anti-clockwise rotation, i.e. narrower beach at the northern end (La Nina phase).

Figure 2-15 shows the time series of the BOI at Collaroy Narrabeen Beach for the period 1976-2019. The extreme clockwise rotation evident in the 1990s and in recent years has coincided with increased risk of closure of Narrabeen Lagoon entrance and difficulty of entrance management (maintaining an open entrance).

⁹ A wider beach at the northern end increases the likelihood of closure of the lagoon entrance due to the greater availability of sand for washover and windblown transport into the entrance.

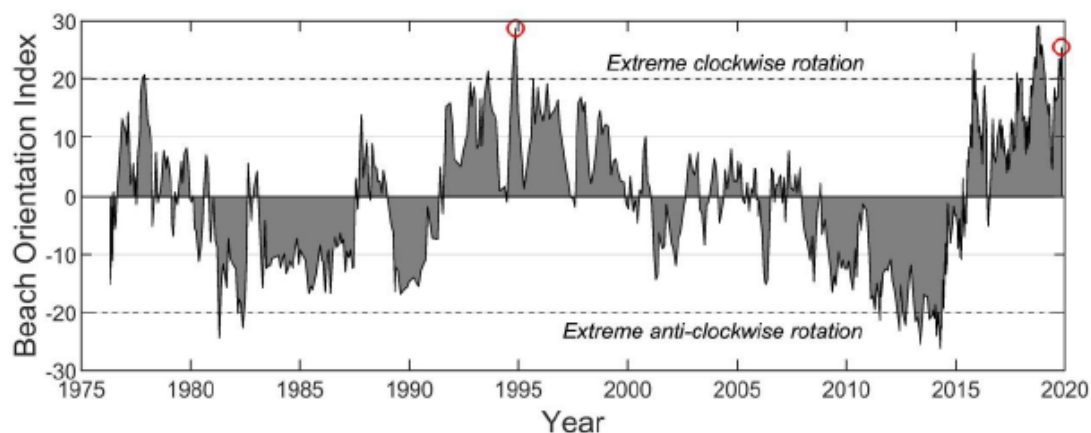


Figure 2-15: Time-series of the Beach Orientation Index at Collaroy-Narrabeen Beach (1976-2019). The November 1994 and November 2019 periods of extreme clockwise rotation are indicated in red.

A similar beach rotation phenomenon to that observed for Collaroy-Narrabeen Beach is considered likely to occur for the long stretch of beach from Narrawallee in the south to the entrance to Lake Conjola in the north, a distance which exceeds 4km (noting Collaroy-Narrabeen Beach has a length of approximately 3.5km).

Figure 2-16 shows the position of the water line along the beach near the entrance to Lake Conjola over the period 1990 to 2019, mapped from satellite imagery as part of this study. It is evident that the most clockwise alignment of the beach is in the years 1996 and 2019. These two years correspond to the strong clockwise rotation observed at Collaroy-Narrabeen Beach and which also correspond to periods of closure of Lake Conjola entrance based on the Council spreadsheet records referred to in **Section 2.5.4** and included in **Appendix E**.

The phenomenon of beach rotation is a natural process and cannot be controlled, similar to other natural processes which cannot be controlled such as ocean storms and rainfall/flooding, which also affect the entrance state at Lake Conjola.

In addition to affecting beach rotation, cycles of ENSO also affect rainfall. Higher than average rainfall is experienced during a La Nina phase and lower than average rainfall is experienced during an El Nino phase. Accordingly, generally speaking, a La Nina phase is more conducive to entrance stability (higher rainfall, anti-clockwise beach rotation) than an El Nino phase (lower rainfall, clockwise beach rotation). Having said that, the occurrence of an ocean storm when the entrance is in a vulnerable state such as an intermediate entrance state or storm washover entrance state could lead to entrance closure regardless of the particular state of beach rotation.



Figure 2-16: Selected plots of water line position along the beach near the entrance to Lake Conjola over the period 1990-2019 from satellite imagery

Studies of the behaviour of the open coast beaches in the Shoalhaven LGA, including Conjola Beach, are currently underway as part of the Open Coast and Jervis Bay CMPs, being prepared on behalf of Council by Water Technology. Preliminary findings in relation to beach rotation have been discussed with Water Technology and indicate the following (pers. comm., Christopher Beadle, Principal Engineer):

- clear examples of beaches with high confidence rotation signals include Mollymook Beach and Culburra Beach;
- some rotation could be detected (albeit with low confidence due to limited data) at beaches close to Conjola Beach; namely Inyadda Beach and Manyana Beach to the north, and Narrawallee Beach to the south; and
- there is a paucity of data available for Conjola Beach, however the occurrence of beach rotation would be expected.

2.7 Flood Behaviour

2.7.1 General

The general flood behaviour of Lake Conjola is described in the Lake Conjola Flood Study (BMT WBM, 2007). The general flood behaviour together with management of the flood risk, is also discussed in the Lake Conjola Floodplain Risk Management Study and Plan (BMT WBM, 2013a). In addition, a supplementary report to the Lake Conjola Floodplain Risk Management Study and Plan was prepared, providing further detail on the relative sensitivity of design flood conditions to entrance conditions (BMT WBM, 2013b).

A summary of the general flood behaviour based on these three documents is provided in the following sections, with some emphasis on the influence of the lake entrance conditions on flood behaviour. A number of comments are also included, generally by way of footnotes.

2.7.2 Lake Conjola Flood Study (2007)

BMT WBM (2007) noted that flooding in Lake Conjola can be caused by one, or both, of the following mechanisms:

- intense rainfall within the catchment, resulting in large volumes of surface runoff discharging into the lake. If the entrance channel is heavily shoaled or even closed, water levels would be potentially high. In these circumstances, maximum flood levels would be controlled by the condition of the sand berm at the entrance and the nature of the scour of the berm by flood waters; and,
- severe ocean conditions comprising barometric storm surge and wave setup due to a large offshore wave climate. Once again, the extent of inundation would be dependent on the entrance conditions, but in this case, a shoaled entrance would attenuate the flood ingress and minimise the overbank impacts¹⁰.

It was also noted that, at a local level, flooding between Pattimores Lagoon and the lake could be exacerbated by the afflux (refer **Figure 2-17**) caused by the restriction at the Lake Conjola Entrance Road bridge.

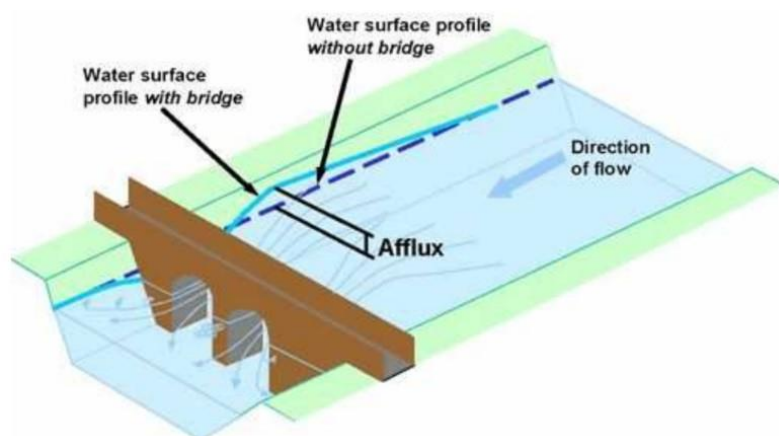


Figure 2-17: Afflux at a bridge crossing

Three historical flood events were selected for calibration of a flood model and were selected due to the number of recorded flood marks available for these events. The events were the February 1971 flood, March 1975 flood, and the February 1992 flood:

¹⁰ Strictly speaking, storm surge is made up of not only a barometric effect but also wind setup (refer **Section 2.3**). Note that while a shoaled entrance may, on the one hand, attenuate the (oceanic) flood ingress, it can also increase the amount of wave setup at the entrance which is a significant contribution to elevated coastal water levels (refer **Section 2.3**).

- the 1971 flood is the largest flood on record, with lengthy and intense rainfall being the contributing factors, in conjunction with a closed entrance. The sand berm became overtopped and eroded resulting in re-opening of the lake. The sand berm level, time of overtopping, entrance channel conditions, and ocean water levels are unknown;
- the 1975 event was again associated with intense rainfall but in this case the entrance was open, although shoaled; and,
- the February 1992 event was not particularly significant in terms of total rainfall (ranking 15th for the period 1971 to 2007) but a significant amount of information was available for the event making it useful for a calibration. The condition of the entrance was not stated in the BMT WBM (2007) report but an image showing the entrance condition adopted for the event indicates the entrance was open although shoaled.

Modelling carried out for the calibration events and for the subsequent design events incorporated a geomorphologic model in addition to a digital elevation model (providing ground levels and bed levels in the lake), hydrological model (rainfall-runoff processes), and hydraulic model (water flow behaviour). The geomorphologic model simulated sand transport in the lake entrance area, thereby allowing the entrance area to erode/scour during the flooding event which in turn affects flow behaviour and water level¹¹.

It is noted that a range of assumptions had to be made during the calibration process, as a conventional calibration of the hydrologic and hydraulic flood models was not possible due to the complexities and unknown historical conditions associated with key model inputs for the historical events, such as the sand berm levels and initial water levels in the lake at the start of the floods.

Design flood conditions were estimated for a range of Annual Exceedance Probabilities (AEPs) from 20% to 1%, and for the Probable Maximum Flood (PMF). Due to the significance of entrance channel geometry on flood levels, it was necessary to consider the geometry that should be adopted for catchment flooding and for ocean flooding.

For catchment flooding and bearing in mind the 'managed entrance' policy which applied at the time in 2007, the adopted entrance channel condition was that representative of the maximum degree of shoaling within the entrance corresponding to the trigger conditions for entrance management¹². A channel bed level of -0.5m AHD was considered reasonable. A 'low ocean tailwater level' was adopted for the catchment flooding simulations for all AEP events (being a neap high tide, 0.6m AHD) except for the PMF where a 100 year Average Recurrence Interval (ARI) elevated ocean water level was adopted (2.6m AHD).

For ocean flooding, the adopted entrance channel condition was that after entrance dredging in accordance with the 'managed entrance' policy; namely, an entrance channel having a bed level of -2.5m AHD and an alignment as per the then applicable Entrance Management Plan (MHL, 2003a). The ocean tailwater level was varied from 5 year ARI (1.89m AHD) to 100 year ARI (2.60m AHD) and combined in each case with a 20% AEP catchment event. The PMF for ocean flooding was represented by the 100 year ARI ocean tailwater level combined with the probable maximum precipitation in the catchment.

¹¹ Having said that, for the calibration events, it was noted in BMT WBM (2007) that an un-erodable bed level was introduced into the model below the sand berm (approximately 1m below the initial entrance channel bed level) defining the maximum extent of the vertical erosion which was allowed in the geomorphologic model. Definition of the un-erodable bed level was calculated iteratively by providing a cross-sectional conveyance within the entrance at the peak of the historical floods to match the calculated flood levels with the historical flood mark records.

¹² The assumption being that the entrance would not become more shoaled, or close, if the 'managed entrance' policy was being adhered to. Refer to **Section 3.3** for a description of the 'managed entrance' approach.

Flood maps were produced which showed the 'worst case' conditions at each location in the model for a given ARI event, taking into consideration both flooding from the catchment and flooding from the ocean. Consequently, the flood maps do not represent a particular instant in time.

2.7.3 Lake Conjola Floodplain Risk Management Study and Plan (2013a)

General

BMT WBM (2013a) outlined three causes of flooding within Lake Conjola:

1. catchment flooding from the local catchment rainfall;
2. ocean inundation as a result of high ocean tides plus storm surge plus potential future sea level rise¹³; and,
3. low-level persistent flooding due to elevated lake level during periods of entrance closure.

The third cause of flooding was an added cause since the 2007 flood study and is understood to have been promoted by the local community.

Catchment flooding

It was noted that the condition of the entrance, being either open, closed or heavily shoaled, has some impact on peak flood conditions in the lake for catchment flooding. This was more pronounced for lower order flood events which produce less flow and less scour leading up to the peak of the flood. For major floods, e.g. the 1% AEP event, it was considered that significant scouring of the entrance channel by the catchment flows would be expected by the time the flood peak is conveyed through the system and that, accordingly, the resulting impact of starting berm condition on the peak flood levels is relatively minor for large flood events. This is further outlined and quantified in Section 2.7.4.

A number of inconsistencies were noted in the Floodplain Risk Management Study and Plan in relation to the adopted entrance conditions for the design flood. These inconsistencies were resolved in a supplementary report (refer **Section 2.7.4**).

Ocean flooding

It was noted that the condition of the entrance could also impact on ocean flooding behaviour. It is evident that an open entrance was adopted for the ocean flooding simulations but the form of this entrance is not explicitly stated. Presumably it is based on the conditions adopted in the earlier flood study (BMT WBM (2007)). If so, the basis for the ocean flooding in BMT WBM (2013a) may now be conservative as the open entrance conditions modelled in the flood study comprised a channel bed level of -2.5m AHD and channel alignment as per the Entrance Management Plan (MHL, 2003a), which are no longer Council policy. It should be noted that this previous work has now been superseded by the coastal inundation modelling undertaken as part of this CMP.

¹³ This description should also include wave setup, which is a significant contribution to elevated coastal water levels at times of severe ocean storms as noted earlier (refer **Section 2.3**).

Low-level persistent flooding

This form of flooding is associated with a gradual and prolonged build up in lake water level when the entrance is closed and the trigger level for a mechanical break out has not been reached. As such it pertains to flooding up until a level of around 1.0 to 1.2m AHD.

No above floor flooding to residential property is experienced at these levels, however inundation of foreshore land takes place and waterfront infrastructure such as boat ramps and jetties are impacted. As such, this form of flooding is a concern to the local community.

2.7.4 Supplementary report to Lake Conjola Floodplain Risk Management Study and Plan (2013b)

General

The purpose of this supplementary report (BMT WBM, 2013b) was to provide further detail on the sensitivity of design flood conditions to entrance conditions. It resolved some of the inconsistencies in BMT WBM (2013a) relating to adopted entrance conditions for the design flood conditions, as noted in **Section 2.7.3** above.

The supplementary report considered catchment flooding only. Two entrance conditions were considered, an open entrance and a closed entrance, simulated as follows:

- open entrance: This was taken to be represented by an approximate 30m wide channel with an invert level of -0.5m AHD, carved through the entrance shoals as defined by 'normal bathymetry'. This situation was considered to be similar to maintaining a dredged channel¹⁴; and,
- closed entrance: This was represented by a sand barrier to a level of 1m AHD across the front of the entrance. The level of 1m AHD was selected as a general representation of 'the entrance management policy triggers.'¹⁵ The further interesting point is that the width adopted for the barrier at 1m AHD was 250m for all AEP events, which seems very wide for the relatively low level of 1m AHD for the sand barrier¹⁶.

The modelling included application of a morphodynamic model to simulate the breach (breakout) behaviour at the lake entrance so that the effect of entrance scour on flood conditions could be represented, as was the case in the earlier flood study and floodplain risk management study and plan (in these studies this model was referred to as a geomorphologic model).

Influence of adopted entrance conditions on design flood levels

Table 2-3 sets out the peak flood level results for a range of design flood events from the 20% AEP event up to the PMF for both the open and closed entrance conditions as described above. Two peak flood levels are provided; the first being along the entrance channel near the Council Holiday Haven Caravan

¹⁴ Maintaining a dredged channel is not current Council policy but the description of the adopted entrance channel geometry for the open entrance condition is useful to understand the significance of the results as part of development of the CMP.

¹⁵ This would appear to be a reference to the Council policy of mechanical opening of the Lake at a water level of around 1m AHD.

¹⁶ BMT WBM acknowledged that when the entrance is closed the beach berm can build naturally to over 2m AHD given an extended period of suitable climatic conditions and no intervention. Adoption of the combination of 1m AHD elevation and 250m width may have been influenced by consideration of the Council entrance management policy at the time, but is considered non-conservative, i.e. would overstate the actual available conveyance in a catchment flood.

Park, and the second within the main lake waterbody upstream of the limit of the inlet channel, about 3.5km from the lake entrance (a location known as ‘The Steps’) (refer **Figure 2-18**). The difference (flood level increase) between the peak flood levels for the closed entrance case versus the open entrance case, for each design flood event, is also shown in the table.

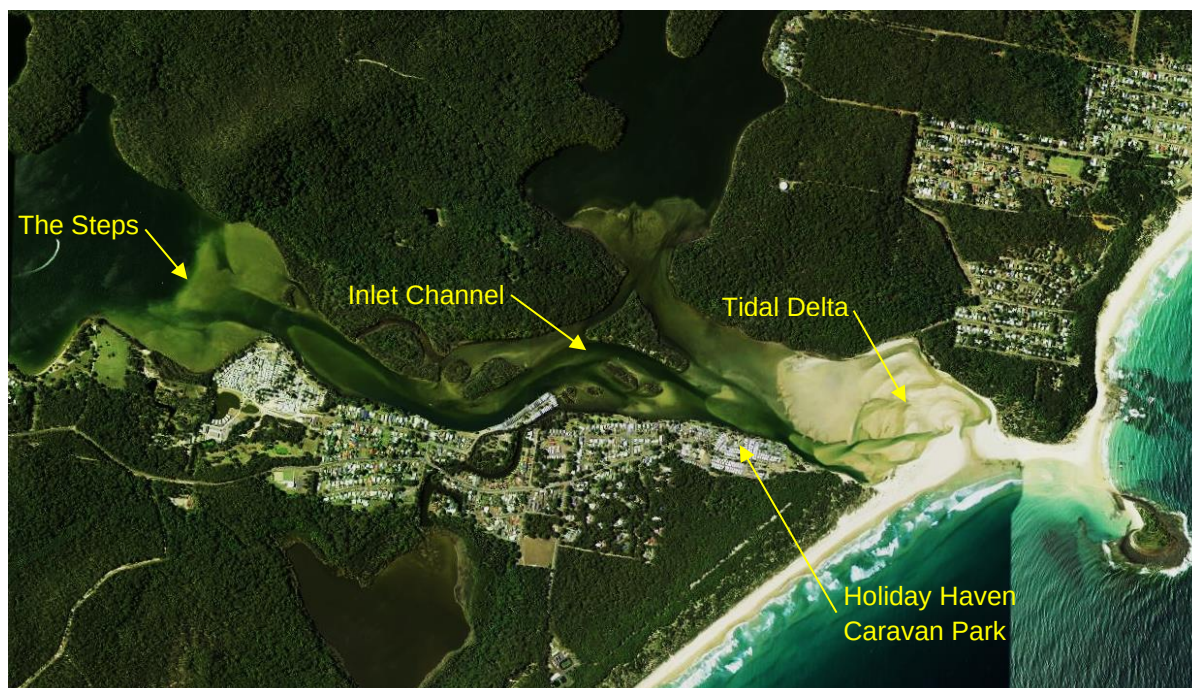


Figure 2-18: Lake Conjola inlet channel extending from the lake entrance approximately 3.5 km upstream to ‘The Steps’

BMT WBM concluded on the basis of the results in **Table 2-3** that:

- for flood events up to and including the 1% AEP flood event, there is little difference in peak flood levels attained between the closed and the open entrance conditions; and,
- an open entrance condition has more of an impact on reducing peak flood levels at the lower order events, i.e. the more frequent events such as the 20% AEP and 10% AEP events, however even so the differences in peak flood levels were relatively small; up to 0.16m.

BMT WBM attributed the small differences to two main factors:

- the active scour of the entrance once overtopping occurs starts to increase the conveyance through the entrance by the time the flood peak comes through; and,
- the flood levels upstream along the entrance channel are largely driven by the conveyance capacity of the channel itself (separate from the entrance berm condition).

The above findings are noted but are contingent on the underlying assumptions, particularly in relation to the geometry adopted for a closed entrance condition, being a flat berm at an elevation of 1m AHD and some 250m wide. If this berm was higher and/or narrower the expectation would be that the impact of a closed entrance condition on peak flood levels would be more significant.

It is noted, for example, that the average level of the berm when the entrance was closed at the commencement of the February 2020 flood was 2.05m AHD (this event is discussed in more detail later in **Section 4.4**).

BMT WBM (2013b) does provide some insight into the potential impact on peak flood levels of a 2.0m AHD berm (250m wide) for the case of a 1% AEP flood event (closed entrance condition). These results are set out in **Table 2-4**. Again, two peak flood levels are provided, the first along the entrance channel near the Council Holiday Haven Caravan Park and the second in the main lake waterbody (refer **Figure 2-18**). The increase in peak flood levels at these two locations are 0.21m and 0.11m respectively.

BMT WBM acknowledged that if the entrance berm did approach 2m AHD such conditions would start to influence peak flood levels significantly in the broader entrance area (for the 1% AEP event, refer **Figure 2-19**). Impacts would be expected to be of greater significance for more frequent events such as the 20% AEP and 10% AEP events, based on the results presented in **Table 2-3**.

The increase in peak flood level for a closed entrance with a berm level of 2m AHD versus an open entrance, for the 1% AEP event, is shown in **Figure 2-19**. At the downstream limit of the Council Holiday Haven Caravan Park this increase is 0.2 to 0.3m.

Table 2-3: Simulated peak flood levels for closed and open entrance conditions (from BMT WBM, 2013b)

Event	Peak Flood Level (m AHD)		Flood Level Increase (m)
	Open	Closed	
20% AEP	1.81 2.25	1.93 2.41	0.12 0.16
10% AEP	1.94 2.47	2.03 2.59	0.09 0.12
5% AEP	2.09 2.74	2.14 2.83	0.05 0.09
2% AEP	2.21 2.98	2.24 3.04	0.03 0.06
1% AEP	2.33 3.23	2.35 3.25	0.02 0.02
PMF	3.28 4.54	3.30 4.54	0.02 0.00

Table 2-4: Comparison of peak 1% AEP flood level for a closed berm level of 1.0m AHD and 2.0m AHD (from BMT WBM, 2013b)

1% AEP Peak Flood Level (m AHD)		Flood Level Increase (m)
Berm level 1.0m AHD	Berm level 2.0m AHD	
2.35	2.56	0.21
3.25	3.36	0.11

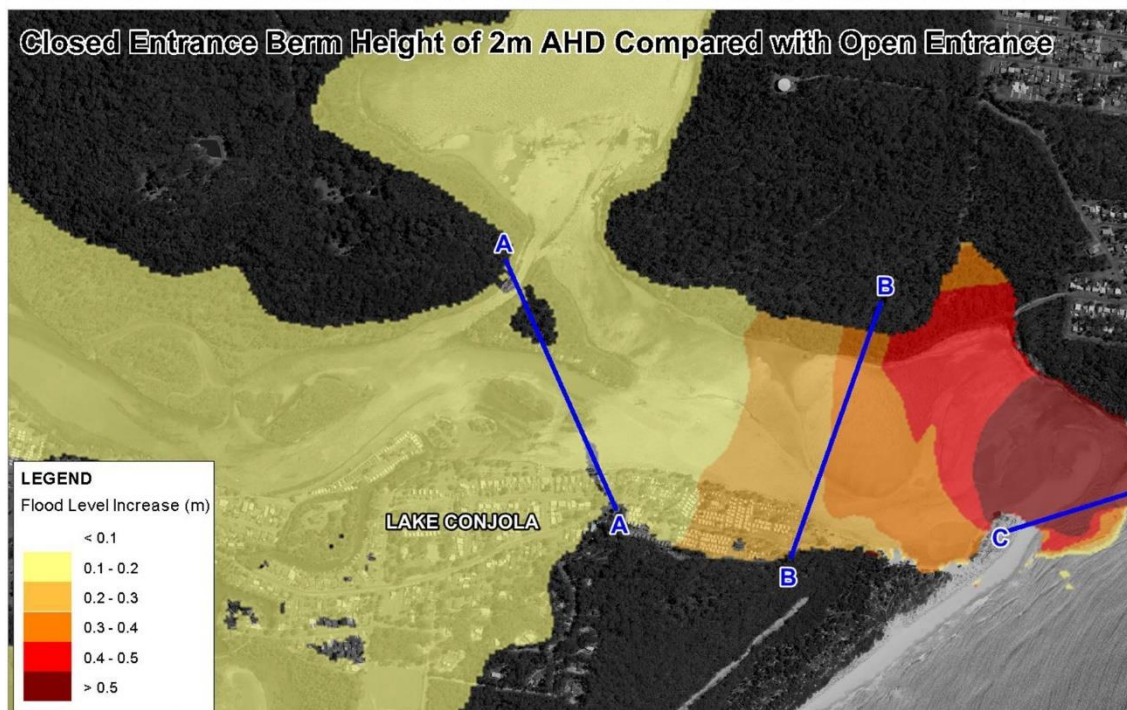


Figure 2-19: Impact on peak flood level of closed entrance with berm level of 2m AHD compared to open entrance for 1% AEP event (from BMT WBM, 2013b)

2.7.5 Implications for entrance management

BMT WBM (2013a and 2013b) made a number of statements in relation to flooding behaviour and entrance management that are useful to note, and are presented below in **Table 2-5** along with commentary from RHDHV.

Table 2-5: Implications for entrance management

BMT WBM 2013a and 2013b Conclusions	RHDHV Commentary
The nature of flooding in Lake Conjola is such that severe flooding problems can occur with very little warning.	This suggests that strategies to mitigate flooding risk need to have a short response time, noting that severe catchment flooding can occur at night and on weekends, e.g. the flooding event in February 2020.
The sensitivity analysis of entrance conditions has highlighted that for major flood events the condition of the entrance does not have a significant impact on peak flood levels within the system given that the entrance condition has only minimal influence on design peak flood condition, the value of entrance management in terms of reducing flood risk is limited.	This statement is considered overly simplistic. The reasonableness of the assumptions for the closed entrance conditions needs to be tested. In addition, there may be merit in considering entrance management options that could mitigate the impacts of less rare events which are of concern to the community; for example the 10% AEP event causes above floor flooding of 70 properties (BMT WBM, 2013a).

BMT WBM 2013a and 2013b Conclusions	RHDHV Commentary
The threat posed by ocean flooding to Lake Conjola is as significant as major catchment flooding. Under ocean flooding scenarios an open entrance allows for a greater penetration of ocean water through the inlet into the lake. As such, a wide open entrance condition may in fact exacerbate the ocean flooding risk for some event conditions.	This statement is considered to be somewhat of an exaggeration in that a large component of the ocean flooding level is astronomical tide which is independent on the storm event, i.e. a low tide will follow 6 hours or so after any high tide. Hence ocean flooding is not sustained in the same way as catchment flooding. In addition, a wide open entrance may reduce the wave setup component of the elevated ocean water level, which can be a significant component. Ocean storms can also be predicted well in advance allowing for mitigation strategies to be put in place. Furthermore, it is noted that the peak flood level for ocean flooding is some 1m lower than the peak flood level for catchment flooding, for the 1% AEP and 5% AEP events (BMT WBM, 2013a).
Future entrance management should consider the maintenance of a 'dry notch' to maintain a maximum berm saddle height. The maintenance of a dry notch provides some control on the entrance breakout location and at a level to limit the flood risk.	Maintenance of a dry notch is considered a potential option for future management of the entrance to Lake Conjola and is discussed further later in this report (refer Section 5).

3 History of Entrance Management – Options, Plans and Policies

3.1 General

It is useful to summarise the various entrance management options, plans and policies that have been considered for Lake Conjola over the years leading up to the Policy which is currently in place, prior to discussion of proposed entrance management options to be evaluated under the Lake Conjola Coastal Management Program.

3.2 Lake Conjola Estuary Management Plan (Shoalhaven City Council, 1998)

The purpose of this Plan was to provide a comprehensive and integrated set of strategies to restore, protect and conserve the natural resources of the lake and to ensure their use is ecologically sustainable in the long term.

Six management areas were identified comprising water quality, erosion and sedimentation, flooding, lake ecology, recreation and tourism, and entrance management. In terms of entrance management, the key issues were:

- concern of lake closure and impacts on water quality, ecosystem health and flooding; and,
- appropriate opening policy.

It is relevant to note that at the time of the 1998 Estuary Management Plan there was no reticulated sewage system and wastewater treatment plant for the Lake Conjola communities; septic tank disposal systems were in place and the inundation of these systems when the entrance was closed, together with the absence of tidal flushing at such times, was a significant issue¹⁷.

A formal entrance management policy did not exist in the late 1990s. Accordingly, three strategies in relation to entrance management (denoted EM1, EM2 and EM3) were included in the Plan as follows:

- EM1: Develop an appropriate management policy for the lake entrance;
- EM2: Investigate effects of artificial opening of the lake entrance on lake ecology and water quality; and,
- EM3: Increase community awareness of possible advantages and disadvantages of frequent artificial lake openings.

3.3 Lake Conjola Entrance Study (Patterson Britton, 1999)

Part of the scope of this study was to identify and assess options to improve entrance stability, with the aim of alleviating community concerns regarding flooding and water quality (noting again the absence of a reticulated sewage system at this time). The study followed on from the 1998 Estuary Management Plan referred to above.

¹⁷ The Conjola Wastewater Treatment Plant (WWTP) subsequently commenced operations in 2008 as part of the Conjola Regional Sewerage Scheme (CRSS). The WWTP is located south of Lake Conjola and discharges treated effluent into a dune exfiltration system.

Six basic options for management of the entrance to Lake Conjola were identified:

- entrance breakwaters;
- stub groyne and internal training wall;
- stub groyne and internal groyne field;
- stub groyne with partial spit stabilisation;
- managed entrance; and,
- existing opening policy.

The existing opening policy or protocol was described as excavation of a pilot channel to artificially open the lake when the water level reached 1.0m AHD. This water level had been chosen historically based on residential floor levels (to mitigate flooding impacts to residential properties) and the levels of septic tanks (to mitigate inundation and water quality impacts), and with the aim of achieving as large an entrance as possible during the breakout so that the lake would not close again too quickly (i.e. not having the trigger water level 'too low' whereby the artificial breakout would be less effective in scouring a channel).

The managed entrance option involved four main elements and is depicted schematically in **Figure 3-1**:

- stabilise the entrance sand spit to reduce storm washover¹⁸;
- maintain a 'fuse plug' at the northern tip of the sand spit to accommodate flood flows¹⁹;
- monitoring of entrance conditions; and,
- at times when the entrance channel may be close to closure, dredging of a new channel having dimensions of approximately 40m wide by 2m deep to alleviate the risk of closure. The alignment of the dredged channel would follow the path of historical flood scour through the entrance area.

¹⁸ Storm washover was considered the dominant factor in entrance closures, as noted earlier in **Section 2.5**.

¹⁹ The fuse plug comprised an unvegetated area at the northern tip of the sand spit of sufficient dimensions such that scour could occur during flooding events and release flood waters to mitigate flood impacts.

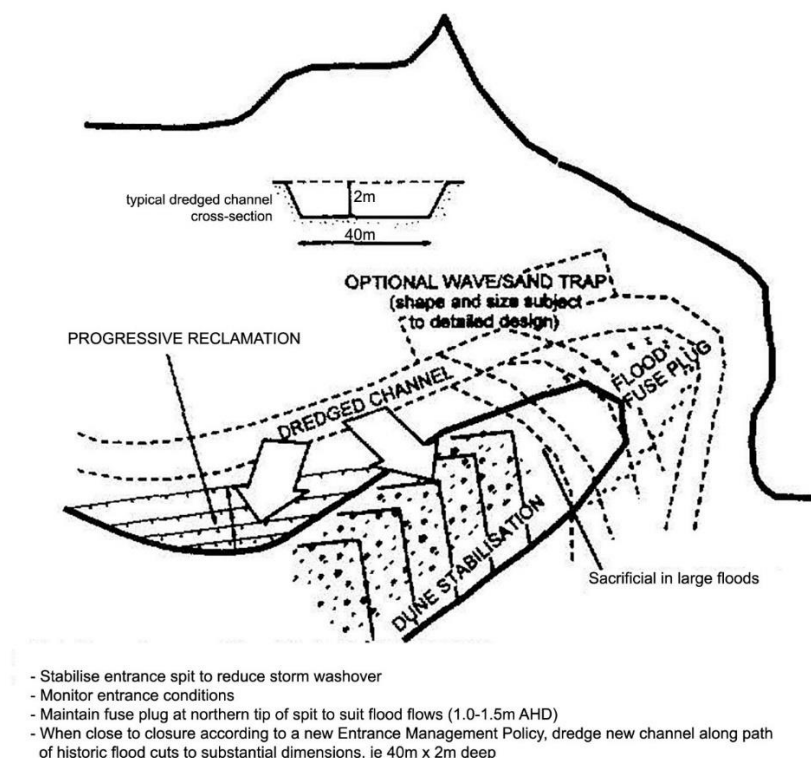


Figure 3-1: Schematic of the 'managed entrance' option considered in Patterson Britton (1999)

The remaining entrance management options all involved permanent physical engineering works (rock structures), combined with stabilisation of the sand spit to reduce storm washover in common with the managed entrance option.

The six options were evaluated in regard to a range of factors including achievement of entrance stability, flood mitigation potential, water quality improvement potential, ease of implementation, and present value of benefits and costs. Entrance stability was essentially the ability to keep the entrance open or reduce the risk of closure. Costs included capital costs and periodic maintenance costs distributed over a 50 year period. Benefits were assessed in terms of flood mitigation potential and water quality improvement potential.

The managed entrance option, which had a relatively low cost and a positive flood mitigation benefit, was the only option which was found to have a benefit : cost ratio greater than 1.0..

3.4 Lake Conjola Entrance Management Plan (MHL, 2003a)

This Entrance Management Plan described the procedures for managing Lake Conjola entrance under a Managed Entrance policy, which had been adopted by Shoalhaven City Council and the then Lake Conjola Estuary Management Task Force following the Patterson Britton (1999) entrance study.

Significantly, the aim of the policy was to ensure a permanently open entrance, while having minimal interference with natural environmental processes. Under the policy, the constriction of the entrance channel would be monitored and entrance works implemented when necessary to prevent closure. The works would comprise dredging a volume of sand from the entrance channel and placing it on the

entrance sand spit. The manner of the placement and stabilisation of the placed sand would aim to reduce storm washover into the channel.

The Entrance Management Plan included a decision support system (DSS). The purpose of the system was to provide advanced warning of entrance closure so that the essential activities that have to be carried out prior to entrance works can be set in train to enable dredging to commence before closure. A key element of the DSS was tracking of the principal lunar semi-diurnal constituent M2 of the lake tide, which had been shown to provide a good indicator of tidal constriction (refer to **Section 2.2** and **Figure 2-5**).

The Entrance Management Plan was supported by a Review of Environmental Factors (MHL, 2003b).

The 2003 Entrance Management Plan was subsequently replaced by an Interim Entrance Management Policy (GHD, 2013), for a number of reasons as outlined in the next section.

3.5 Lake Conjola Interim Entrance Management Policy (GHD, 2013)

This Policy was developed in consultation with Shoalhaven City Council, relevant NSW Government authorities, consultants, and the Lake Conjola community. The purpose of the Policy was to provide updated direction to Council in managing Lake Conjola entrance based on new information and changed circumstances since the adoption of the 2003 Entrance Management Plan (MHL, 2003a).

In developing the Policy, consideration was given to a range of factors including:

- NSW Government guidelines in relation to coastal and estuary management;
- Council's available resources and funding;
- ecological diversity and water quality within the lake; and,
- inundation as a result of catchment flooding and storm surge inundation.

The Policy was endorsed by Council on 24 September 2013.

The Policy was supported by a Discussion Paper included in Appendix A of the Policy (GHD, 2012). The Discussion Paper provided a summary of the processes occurring within Lake Conjola, the requirements of NSW Government guidelines, and the desires of the Lake Conjola community.

Some key points from the Discussion Paper are summarised below prior to an outline of the Policy itself:

- entrance physical processes were described based on Patterson Britton (1999);
- over the 20 year period 1991-2011, the entrance was mechanically opened six times;
- a shift away from the aim of a permanently open entrance as set out in the 2003 Entrance Management Plan was outlined, driven by two factors:
 - a change in the approach to management of ICOLLs by the NSW Government, whereby the long term goal was to retain or progressively reinstate natural entrance behaviour and to progressively remove, relocate, or modify assets or activities that are affected by inundation if the entrance is allowed to return to a natural regime,
 - the commencement of operations of the Conjola Wastewater Treatment Plant in 2008 which was considered to have alleviated water quality concerns for the lake,
- matters raised by the community included:

- the trigger level for mechanical opening of the lake of 1.0m AHD is too high and adoption of a lower trigger level of 0.8m AHD should be considered,
- dredging of the lake should be carried out,
- innovative methods of funding sand removal should be investigated,
- water quality of the lake is a concern,
- mechanical opening of the lake to the south should be considered,
- the lake should be restored to its natural regime,
- the impact of sea level rise should be considered.

The Policy set out triggers and procedures for mechanical opening of the entrance and the monitoring which should be carried out. It also outlined ongoing management actions, consideration of revised trigger levels over time, and long term targets.

Two triggers were identified that would justify mechanical opening of the entrance, a planned opening at a lake water level of 1.0m AHD and an emergency opening at a lake water level of 1.2m AHD, as summarised in **Table 3-1**. Water levels are measured at the water level recorder located adjacent to the Holiday Haven Caravan Park operated for Council by Manly Hydraulics Laboratory as previously noted in **Section 2.2**.

Procedures for the planned opening differed depending on the time of year, specifically whether the opening was to take place during the threatened shorebird species nesting season (September through to March inclusive) or outside of this season (April to August inclusive). In particular, during the nesting season, only a northern pilot channel alignment was to be adopted.

Table 3-1: Interim Entrance Management Policy (2013) triggers for mechanical opening of the entrance

Trigger	Description
Planned opening at 1.0m AHD	• place plant and equipment on standby at 0.8m AHD; • if moderate or heavy rainfall is ongoing or predicted and water level reaches 0.9m AHD, prepare pilot channel for opening; and • commence opening when water level is at or exceeding 1.0m AHD.
Emergency opening at 1.2m AHD	• water levels are rising rapidly and a flood event is occurring or predicted; • open entrance in the shortest and quickest way possible, if situation permits, at a water level above 1.2m AHD.

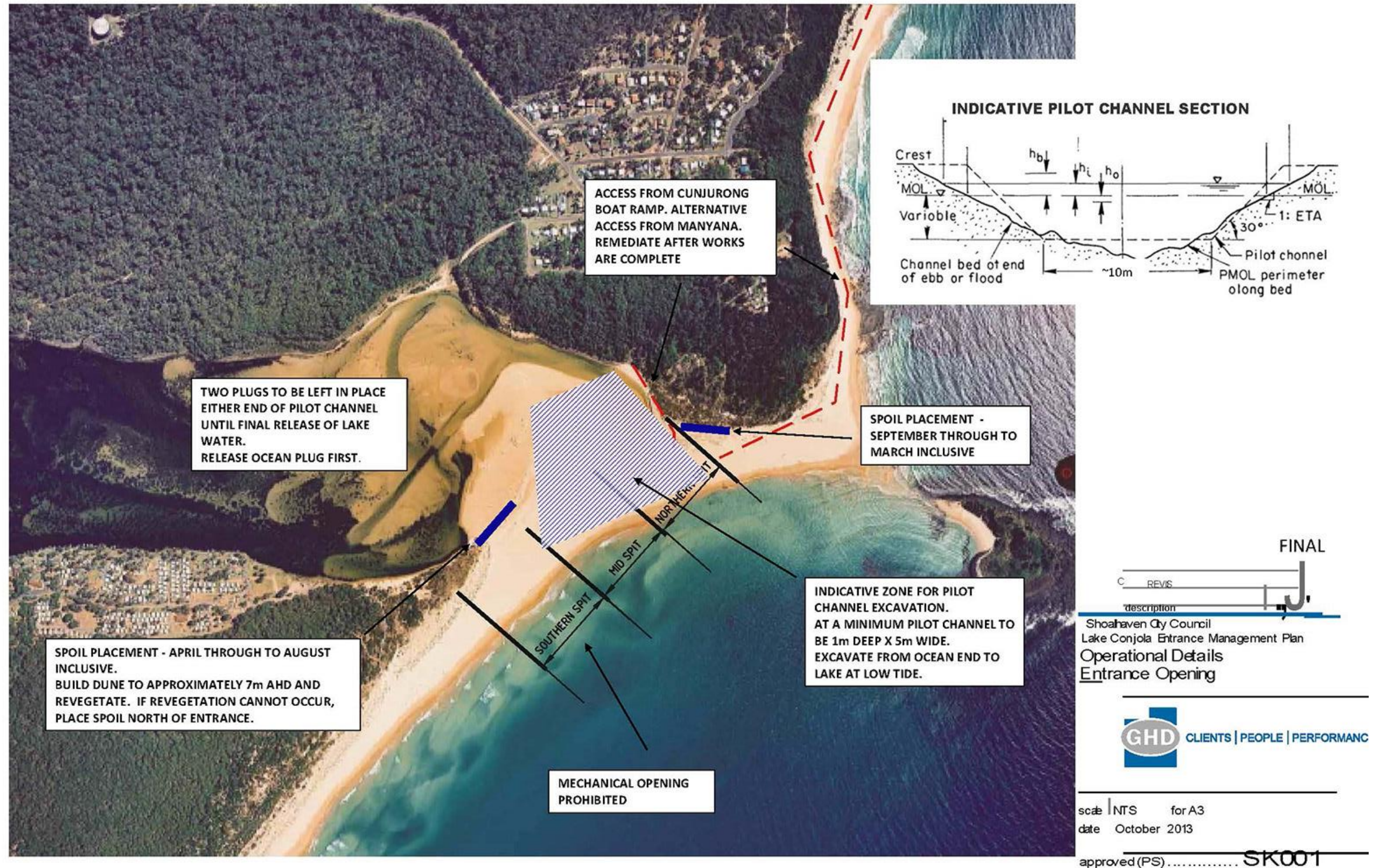
Appendix C of Interim Entrance Management Policy set out 'Operational Details' for implementation of the Policy, comprising an aerial photograph of the entrance area marked up with operational notes and is reproduced in **Figure 3-2**. Some key points in the operational details are as follows:

- the entrance area was divided into three zones – a southern spit, mid spit and northern spit. Mechanical opening was only permitted in the mid spit and northern spit (due to dune stability and threatened species issues in the southern spit zone); and,
- the typical width for the pilot channel was 10m. The depth was variable depending on the sand berm level. The minimum dimensions of the pilot channel were 1m deep by 5m wide.

Monitoring activities included in the Policy were related to water level, rainfall, regular survey of the entrance, water quality, the preparation of a description of opening events (natural and artificial), and trials for different opening procedures. Trials were to consider:

- opening location (northern and mid point zones on the sand spit);
- tide level – high, low, mid tide;
- lake water level at time of opening;
- pilot channel dimensions; and,
- excavation sequence – working from lake to ocean or ocean to lake.

Ongoing management actions included in the Policy are briefly summarised in **Table 3-2**.



NOTE: PILOT CHANNEL DIMENSIONS WILL CHANGE DEPENDING ON LEVEL OF BERM AT TIME OF EXCAVATION

Figure 3-2: Operational details included in the Interim Entrance Management Policy (GHD, 2013)

Table 3-2: Interim Entrance Management Policy (2013) – brief summary of ongoing Management Actions

Process/Development	Management Action
Storm washover	Nourishment and vegetation of sand spit
Windblown sand	Vegetation of sand spit
Water quality	Water quality monitoring, vegetation, bank stabilisation
Flooding	Flood Risk Management Plan, flood Development Control Plan (DCP), evacuation plan
Wastewater and sewage overflows	Establish emergency procedures during times of power outage and pump problems
Community awareness	Community noticeboard, webpage
Development consent and lake entrance management	Implement Flood Risk Management Plan development controls
Opening protocol	Inform contractors of alternate methods of pilot channel excavation, investigate environmental levy to increase funding for entrance opening procedures, investigate government funding options

In terms of revised trigger levels over time and long term targets the Policy noted:

- consideration should be given to increasing trigger levels (raising the trigger water level) as a result of future climate change and to progressively return the lake to as natural a regime as is possible with fewer artificial entrance openings; and,
- in the long term, the Policy seeks to restore the lake to a point where natural breakouts occur and artificial entrance interference is unnecessary.

3.6 Five Year Crown Lands Licence to Open Lake Conjola (Crown Lands, 2021)

3.6.1 General

In response to a state of closure of Lake Conjola entrance after April 2018, resulting in prolonged elevated lake levels in the range 0.75 to 0.9m AHD, Council resolved on 5 February 2019 to seek a short term licence from the NSW Government (the then Department of Industry – Crown Lands) to construct a pilot channel in the northern zone on the spit to effect an opening of the lake below the planned opening trigger level of 1.0m AHD set out in the Interim Entrance Management Policy (GHD, 2013). This licence application was refused.

Following ongoing representations from the community, Council continued to consult and make application to Crown Lands for a short term licence to open the lake below the level of 1.0m AHD. Some of the issues identified at the time by the community in their representations to Council were as follows, as set out in a Review of Environmental Factors (REF) in support of the licence application (Shoalhaven City Council, 2019):

- submersion and failure of foreshore assets including seawalls, jetties, boat ramps and pathways²⁰;

²⁰ It is noted that these issues were raised by the community but were not investigated or confirmed by Council. In addition, the affected assets could have been either authorised or unauthorised foreshore structures.

- saturated foreshore conditions resulting in erosion, ground slumping, die-back of vegetation particularly trees causing significant safety issues;
- submersion of foreshore structures causing boating safety issues²¹;
- community stress related to the perception of heightened flood risk and reduced evacuation options as a result of the elevated lake levels reducing the capacity of the lake to endure significant rainfall events;
- a policy cannot have regard to every scenario and trigger levels may not always be the appropriate determinant for management; and,
- overarching objectives of entrance management need to be given significant weight, particularly relevant were considered to be:
 - minimising risk to public safety associated with excessive inundation of foreshores and associated infrastructure as a result of low-level flooding,
 - minimising interference to the local ecological community,
 - satisfying local community values.

Following a number of revisions to the application and the supporting REF, Council was granted a licence by Crown Lands in October 2021, for a five year period, to mechanically open the entrance at lower trigger levels than those stated in the Interim Entrance Management Policy (GHD, 2013) providing certain conditions are satisfied. The key terms and conditions in the five year licence (Licence: RN625288) are outlined in **Section 3.6.2**.

As part of consideration by Crown Lands of Council's applications, Crown Lands sought advice from the then Department of Planning Industry & Environment (DPIE) and the Department of Primary Industries Fisheries (DPI Fisheries). The advice provided by these Departments outlines their position in relation to management of the entrance to Lake Conjola and is important for consideration in the development of the Lake Conjola CMP. This advice is summarised in **Section 3.6.3**.

During the course of the licence applications to Crown Lands, an emergency mechanical opening of Lake Conjola entrance was carried out by Council on the morning of 10 February 2020. Prior to the opening, the lake water level had reached a level slightly above 2m AHD, influenced by the average sand berm level at the time of approximately 2m AHD, and substantial flooding of private properties and Council assets had occurred. As described in **Section 4.3.2**, a relatively short pilot channel, only some 20m to 30m in length, was quickly excavated to initiate the breakout due to the high lake water level. The lake has remained open since February 2020.

The lake water level preceding and following the mechanical opening on 10 February 2020 is shown in **Figure 3-3**. It shows the very rapid rise in water level during the evening of 9 February and morning of 10 February over a period of approximately 15 hours (7pm to 10am), the rapid lowering of the water level over a similar period following the opening, and the subsequent strong tidal response through the scoured entrance.

The February 2020 flood is further discussed in **Section 4**.

²¹ It is noted that this issue was raised by the community but were not investigated or confirmed by Council. In addition, the affected assets could have been either authorised or unauthorised foreshore structures.

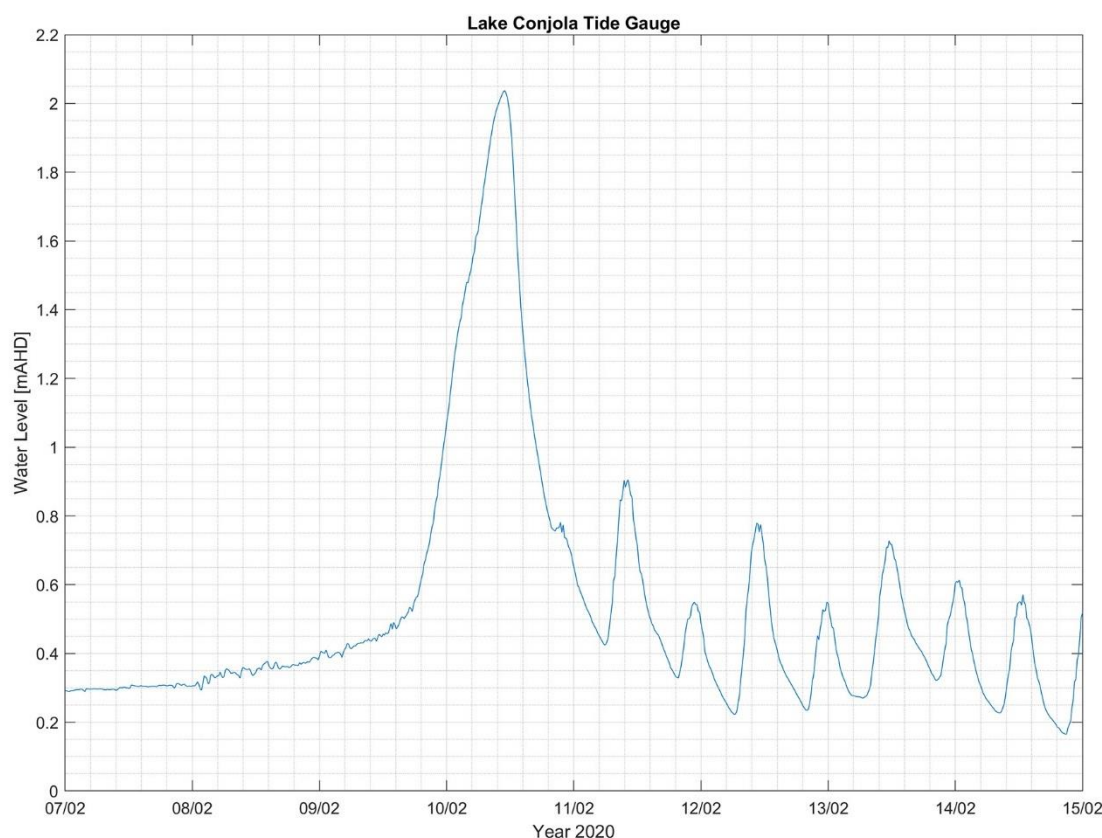


Figure 3-3: Lake water level over the period 7-14 February 2020 showing the breakout on 10 February

3.6.2 Relevant extracts from Crown Lands Licence

The relevant extracts from the five year licence are Schedule 2 and Schedule 3. Schedule 2 sets out the intervention trigger levels which are to be adhered to, and certain other additional terms and conditions. Schedule 3 includes a map of the Licence Area, which is provided at the end of this section.

Three specific scenarios are defined in the Licence for which intervention can take place:

- prolonged low-level inundation;
- possible flooding; and,
- evidence of water quality risks and hazards.

The scenarios and corresponding intervention trigger levels are summarised in **Table 3-3**.

The 'prolonged low-level inundation' scenario and the 'evidence of water level risks and hazards' scenario are new scenario categories. The 'possible flooding' scenario is similar to the planned opening scenario in the Interim Entrance Management Policy (GHD, 2013), however the 'get ready' trigger level of 0.7m AHD is slightly lower than the 'standby' trigger level in the Interim Policy (0.8m AHD, refer **Table 3-1**), and the 'prepare pilot channel' trigger level of 0.8m AHD is again slightly lower than the 'prepare pilot channel' level in the Interim Policy (0.9m AHD, refer **Table 3-1**).

Table 3-3: Five year Crown Lands licence intervention trigger levels

Scenario	Action	Intervention Trigger
Prolonged low-level inundation	Planning for an opening Open lake to sea	The lake stabilises at or above 0.8m AHD for a period of three consecutive months 10-day-mean water level is reached or exceeded and maintained at or above 0.8m AHD for more than three consecutive months
Possible flooding (refer Note 1)	Get ready Prepare Pilot Channel Planned Opening	0.7m AHD 0.8m AHD 1.0m AHD
Evidence of water quality risks and hazards	Liaison with DPI-Fisheries and Crown Lands Open lake to sea	Red alert as described in Guidelines for Managing Risks in Recreational Water (NHMRC, 2008) (refer Note 2) Red alert level (NHMRC, 2008) and concurrence from DPI-Fisheries and Crown Lands has been received

Notes:

1. Possible flooding means – ‘high lake water levels, and heavy rain of more than 150mm in 24 hours or more than 300mm over 3 days is forecast and likely to impact the Lake Conjola catchment or which has been received in the catchment’. It is of interest to assess the approximate Average Recurrence Interval (ARI) of these two rainfall triggers based on Bureau of Meteorology data for the Lake Conjola catchment. This indicates that 150mm in 24 hours is approximately a 2 to 5 year ARI event and 300mm over 3 days is approximately a 10 year ARI event. This suggests that the 150mm in 24 hours is more likely to potentially trigger the ‘possible flooding’ scenario.
2. The ‘red alert’ is the ‘red level (action mode)’ in the National Health and Medical Research Council (NHMRC) Guidelines and is triggered when the presence of certain algae and cyanobacterium exceed specified levels. At such times the local authority and health authority are required to warn the public that the water body is considered to be unsuitable for primary and secondary contact recreational use.

An assessment has been made of whether the intervention trigger for prolonged low-level inundation would have been activated over the period of time for which lake water data is available, namely the period from 1992 to 2021. **Figure 3-4** shows the 10-day-mean water level over this period of time calculated by two methods. It is evident there are only two occasions when the intervention trigger was approached (not reached), being during the period December 2018 to June 2019.

A zoomed-in view of the lake water level over the period December 2018 to June 2019 is shown in **Figure 3-5**. The second elevated water level period March-June is slightly longer than the first period December-March but is just below the trigger duration of 3 consecutive months. Accordingly, the intervention trigger for prolonged low-level inundation, as defined in the Crown Lands Licence: RN625288, would not have been activated over the 29 year period 1992-2021.

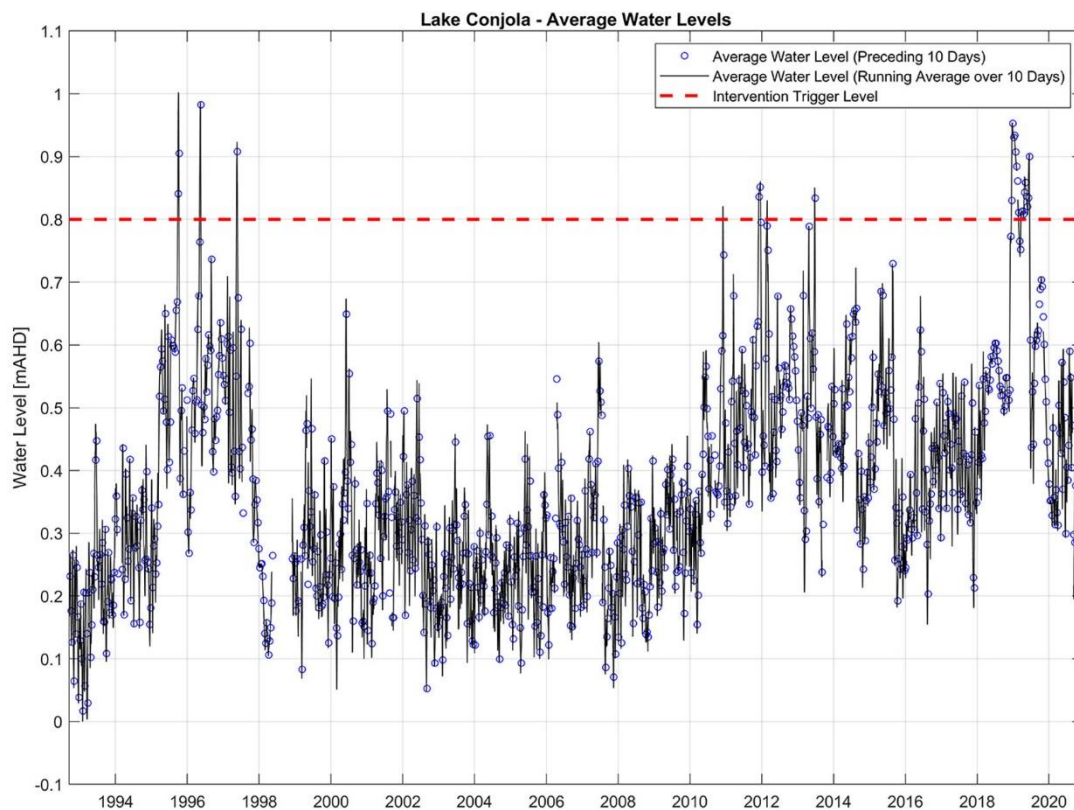


Figure 3-4: Variation in 10-day-mean lake water level over the period 1992-2021

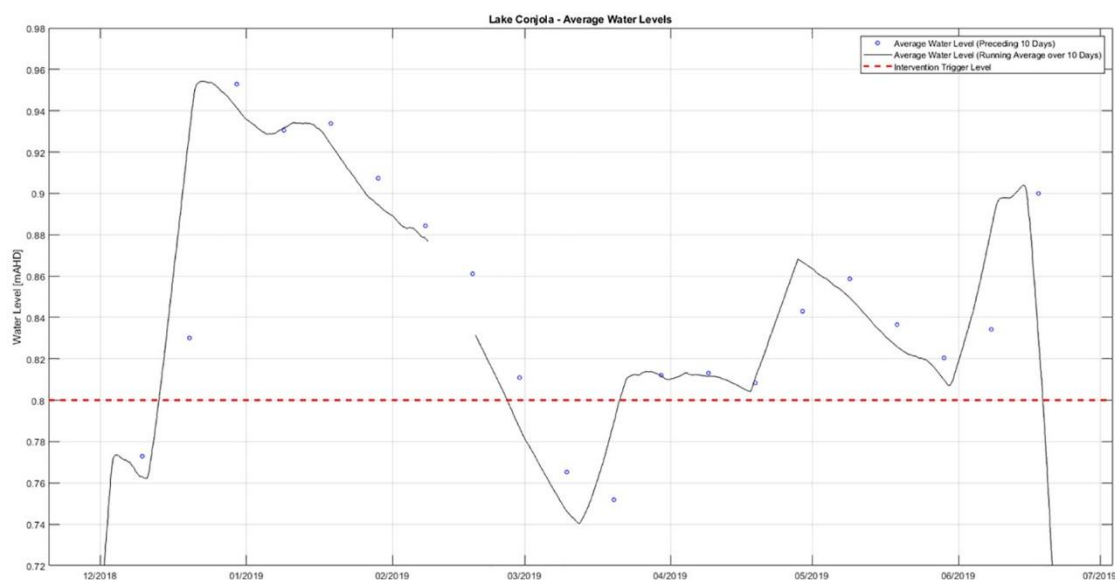


Figure 3-5: Zoomed-in lake water level over the period December 2018 - June 2019

Water quality data collected by Council does not include the algae and cyanobacterium species on which the 'evidence of water quality risks and hazards' intervention trigger is based. Algae and cyanobacteria testing would be necessary to allow comparison to guideline values in NHMRC (2008), allow grading of the water body, and to consider the need for intervention. The terms and conditions of the licence in fact require a water quality monitoring program inclusive of algae and cyanobacteria.

Additional terms and conditions outlined in Schedule 2 of the licence include, but are not limited to:

- maintaining records of water levels;
- maintaining a water quality monitoring program;
- maintaining fringing vegetation surveys;
- development of a conceptual model/project logic defining the likely impacts of the artificial opening on estuarine processes, water quality within the lake, and fringing vegetation communities;
- evaluation of entrance management; and,
- protection of migratory shorebirds.

The map included in Schedule 3 of the Licence showing the Licence Area is reproduced in **Figure 3-6**. The area extends within the lake from the Cunjurong foreshore to the Conjola foreshore and upstream over a large portion of the flood tide delta, extends to the south of the entrance along Conjola Beach, and extends northwards around Cunjurong Point and along Manyana Beach. The extent of the Licence Area takes into account potential disposal areas for excavated sand in addition to the potential excavated channel locations.

3.6.3 Advice from NSW Government Departments to Crown Lands

Three rounds of advice to Crown Lands from NSW Government Departments are available, two from DPIE dated 26 June 2020 and 8 June 2021, and one from DPI Fisheries dated 10 June 2021.

DPIE, 26 June 2020

This advice was prepared by the Biodiversity and Conservation Division within DPIE (DPIE-BCD) in regard to the REF titled 'Management of Lake Conjola Entrance 2020/2021 to 2024/2025'. The advice was grouped under a number of key themes. Main points within the advice are summarised below under each key theme.

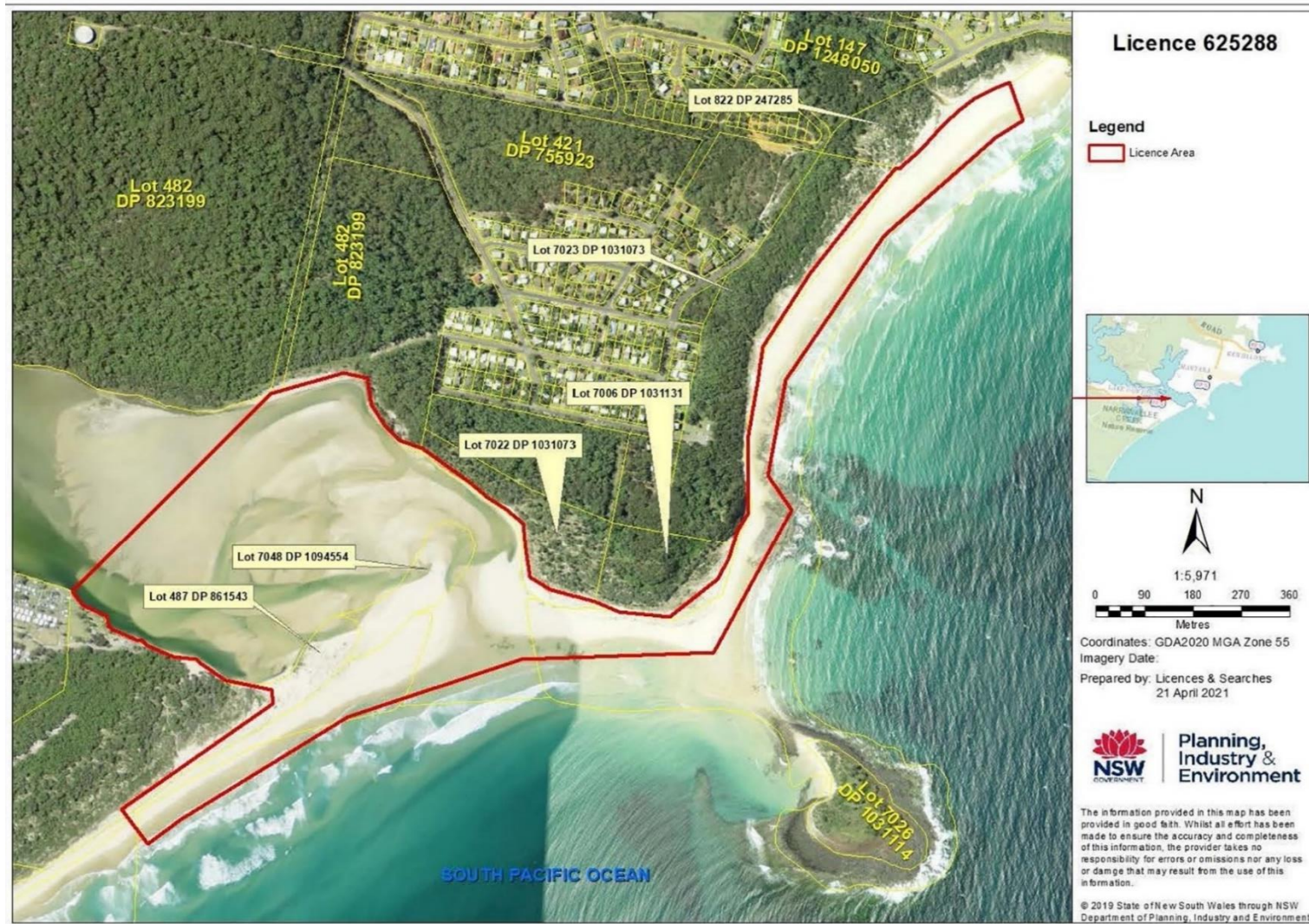


Figure 3-6: Extent of Licence Area in Schedule 3 of five year Crown Lands Licence

Consistency with Council and Agency Policies and Legislation

- DPIE-BCD do not support ongoing excavation and dredging works at the Lake Conjola entrance as it is inconsistent with the Lake Conjola Interim Entrance Management Policy (GHD, 2013);
- mechanical excavations and openings that are inconsistent with entrance management policies, particularly openings at lower water trigger levels, increase the risk of environmental impacts and as such are inconsistent with the objectives of government policy and legislation;
- nothing has changed since 2013 that has led to an increased risk of inundation of low-lying assets around Lake Conjola that would warrant opening the entrance at water levels lower than those outlined in the current (2013) policy;
- a review of Council's current interim entrance management policy will be a component of the Lake Conjola CMP and is the recommended pathway to enable the full range of management options and impacts to be assessed; and,
- the REF lacks adequate detail on the location(s) of sand proposed to be removed by dredging/excavation, as well as the sand disposal quantity, placement and stabilisation.

Water quality and amenity

- opening entrances of ICOLLs to try and improve water quality has been consistently shown time and again to be unsuccessful. This is because water quality in ICOLLs like Lake Conjola is significantly influenced by catchment runoff which contains pollutants like sediment and nutrients, and flushing of these pollutants is generally limited to the immediate entrance channel area;
- the REF does not include any comprehensive analysis of water quality, nor does it clearly demonstrate that the lake is experiencing critical short or long-term impacts due to water quality;
- review by DPIE-BCD of historical and more recent water quality data (12 months preceding June 2020) clearly shows the water quality is generally good irrespective of whether the entrance is open or closed, and periods of poorer water quality are associated with rainfall events, consistent with other ICOLLs; and,
- DPIE-BCD would not support any entrance management policy or need for entrance works based around water quality triggers except in exceptional circumstances.

Legislative basis for the works

- it is recommended that Council obtain legal advice regarding the correct approvals pathway having regard to various considerations including the interpretation of 'emergency works', 'environmental management works' and 'extractive industry'²².

Shorebirds and other threatened species and ecological communities

- entrance management practices that are inconsistent with Council's current policy (GHD, 2013) are likely to increase the frequency at which residents of Lake Conjola are brought into conflict with nesting shorebirds, which is a situation that needs to be avoided;

²² DPIE-BCD questioned whether the entrance management works may require development consent as opposed to an approval under State Environmental Planning Policy (Infrastructure) 2007 (Infrastructure SEPP).

- reference to a nesting period for threatened shorebirds of generally November to February significantly underestimates the duration of the breeding season, particularly for Pied Oystercatcher and Hooded Plover (the correspondence letter refers to the period October – March for the breeding season);
- a minimum 20m buffer applied to identified shorebird nesting areas from construction activities is not adequate to avoid impact on nesting shorebirds studies have recommended buffer zones with widths ranging from 165 to 255m;
- disposal of dredge spoil on ocean beaches north and south of the entrance has a high likelihood of damaging nesting and foraging areas for Pied Oystercatchers and Hooded Plovers; and,
- changed hydrological regimes due to entrance management practices would impact on saltmarsh and swamp oak ecological communities and, through estuarine vegetation changes, impact on foraging and roosting habitat for threatened and migratory shorebirds.

DPIE-BCD concluded that it was supportive of entrance management policies that are prepared under the coastal management framework, accordingly it was stated that the agreed pathway to update the Lake Conjola Entrance Management Policy is through the Lake Conjola CMP.

DPIE, 8 June 2021

This advice was prepared by DPIE-BCD in respect of an updated REF titled Review of Environmental Factors – Management of Lake Conjola Entrance, 17 May 2021. DPIE-BCD made a number of general comments and specific comments, and also referred to comments in its earlier letter of 26 June 2020 (summarised above). Main points are summarised below.

General comments

- DPIE-BCD does not support allowing openings below the current water level triggers in Council's adopted entrance management policy (GHD, 2013). The rationale for openings after prolonged periods of lake water levels below 1m AHD would be best evaluated through the CMP process that is currently underway, to enable the cost, benefits and detail on assets impacted below 1m AHD to be properly assessed and quantified;
- past openings at lake water levels lower than 1m AHD have resulted in the entrance closing quickly, e.g. in December 2018 the entrance was opened at 0.97m AHD and it closed 2 days later, as such openings do not generate sufficient scour;
- the lack of sufficient scour was the reason why a lower trigger level was ruled out when the current entrance policy was developed in 2013;
- the wording and intervention trigger for the 'possible flooding' scenario are not supported since:
 - the ability to initiate a rapid opening at water levels lower than 1m AHD is likely to be difficult,
 - cutting a pilot channel will require a significant amount of sand to be moved, taking a minimum 3 to 5 days to achieve, meaning it would be impractical to prepare a pilot channel a week in advance of heavy rainfall when forecasts can change,
 - excavation of pilot channels which are not utilised due to a change in forecast, leads to unnecessary cost and disturbance to migratory shorebirds,

- DPIE-BCD recommend that instead of preparing a pilot channel, berm crest lowering to 1.2m AHD is completed in advance of heavy rain;
- DPIE-BCD is supportive of Council trialling maintaining a berm 'dry notch'²³ as long as the dry notch is maintained at a minimum of 1m AHD (with higher areas of the berm crest left undisturbed);
- further assessment of both berm crest lowering prior to heavy rain and maintenance of a berm dry notch should be evaluated through the CMP process; and,
- opening based on degradation of water quality is not supported as there is no evidence that water quality will be improved by opening the entrance (as noted in the correspondence of 26 June 2020).

Specific comments

- opening of the lake will only have benefit for the water quality in the immediate entrance area;
- a 20m buffer is not considered adequate to mitigate impacts on nesting areas;
- disposal of sand on the dunes south of the entrance, and revegetation, is supported. It is recommended that primarily *Spinifex sericeus* should be used for the revegetation;
- source control still remains the only effective and feasible way to manage water quality; and,
- management of water quality should focus on the sources of water quality impacts that existed prior to bushfires, such as cleared agricultural areas with limited riparian zones where stock have direct access to the lake edge, and drains that convey urban runoff directly into the lake.

DPI Fisheries, 10 June 2021

The advice by DPI Fisheries was prepared in response to the REF dated 17 May 2021, as for the second round of advice prepared by DPIE-BCD referred to above. Main points in the advice are summarised below.

Interim approach proposed in the REF and Licence term

- DPI Fisheries supports development of an entrance management plan for Lake Conjola as part of the formal legislative CMP process under the *Coastal Management Act*;
- DPI Fisheries stated that the decision to open an ICOLL should be made on the basis of factual data such as verified water levels, the nature and extent of associated flooding impacts and quantitative evidence of changes to relevant water quality parameters; and,
- DPI Fisheries concurs that the risk associated with response times to rapidly rising water levels and subsequent flooding to be something that warrants more flexibility than is currently provided in the current Lake Conjola Interim Entrance Management Policy (GHD, 2013), and that sufficient information has been provided to demonstrate support for interim entrance management triggers to address this risk prior to completion of the CMP.

²³ A dry notch refers to an area within a beach berm or dune system that is maintained at a relatively low level by mechanical means to reduce the burden of the quantity of sand required to be removed at the time of a flood emergency and/or to control the location of a breakout channel.

Comment on proposed interim triggers

- as an interim measure while the CMP is being prepared, DPI Fisheries is specifically supportive of the creation of a dry notch to facilitate managed entrance openings, providing its level is not lower than 1.0m AHD. This measure should also incorporate triggers to lower the berm height of the dry notch to 1.2m AHD ahead of predicted heavy rainfall to improve emergency preparedness and reduce flood risk²⁴;
- it is unclear why both a dry notch and a pilot channel is proposed in the REF, as it is stated in the REF (Appendix C) that preparation and maintenance of a dry notch would eliminate the need for a pilot channel arrangement (with which DPI Fisheries agrees)²⁵;
- DPI Fisheries does not support the proposed lowering of the planned (pilot channel) opening trigger from 1.0m AHD to 0.9m AHD;
- DPI Fisheries supports the assessment of perceived impacts such as submersion of low-lying infrastructure and land, as part of the CMP process. Quantification of such impacts should occur as part of this process;
- DPI Fisheries is not supportive of opening Lake Conjola for perceived impacts to water quality or amenity; and,
- DPI Fisheries does not support the proposed interim water quality entrance opening measure in the REF.

Additional comments on REF

- the REF has not considered potential visual or scenic impact associated with spoil disposal sites; and,
- harm to small patches of seagrass situated near Cunjurong boat ramp should be avoided by locating the entrance opening works away from this seagrass.

²⁴ The berm height of the dry notch would refer to the higher sand level on the seaward side of the notch which serves as a 'plug' or 'headwall'.

²⁵ For a number of reasons it is considered that a pilot channel would also form part of a general dry notch approach (refer **Section 5.3**).

4 Description of Historical Records and Selected Events

4.1 General

A number of key historical records of entrance conditions are available for Lake Conjola, as follows:

- an aerial photograph analysis/interpretation of the entrance area covering the period 1944 to 1997 included in Technical Appendix 1 of Patterson Britton (1999), with notation as to the main physical features visible in the photographs;
- an analysis of entrance stability included in Technical Appendix 9 of Patterson Britton (1999) covering the period 1937 to 1998 on a year by year basis, set out in tabular form and including notes in relation to:
 - entrance condition accordingly to the four basic characteristic entrance states defined in Patterson Britton (1999) and referred to in **Section 2.5.2** of this report, namely regime state (R), flood scoured state (F), intermediate state (I) and storm washover state (W), plus two further states of heavily shoaled (SH) and closed (C),
 - whether the entrance had been manually opened by Council,
 - monthly rainfall,
 - occurrence of ocean storms (severe or major),
- an extension of the above analysis of entrance stability in tabular form covering the period 1999 to 2011, understood to have been completed by Council staff. A copy of the complete tabular analysis for the period 1937 to 2011 is included in **Appendix D**;
- a history of the state of the entrance set out in GHD (2012), but this would appear to be a direct copy of the information in the tabular summaries referred to above;
- a historical record of the entrance condition, whether open or closed, covering the period 1916 to 2019 on a monthly basis compiled by Council staff, referred to in **Section 2.5** of this report and included in **Appendix E**; and,
- a chronology of Lake Conjola management prepared by the Conjola Community Association covering the period 1985 to 2019.

A number of key points from the above information, some of which have been previously noted earlier in this report, are as follows:

- over the period 1916 to 2019, the entrance to the lake has been open (including heavily shoaled) about 85 to 88% of the time. That is not to say the entrance cannot be closed for extended periods, including for several years at a time;
- mechanical openings of the lake are reported to have been carried out on the following occasions over the 74 year period 1937 to 2011 (10 individual years in 74 years but with multiple attempts in four of the years; 1967, 1996, 1997 and 2010):
 - March 1939,
 - May 1943,
 - three occasions including 29 September 1967,
 - March 1970,
 - 1996 (several attempts),
 - 1997,
 - August 1998,

- November 1999,
- May, September and December 2010,
- March 2011,
- December 2011,
- over the period 2012 to 2022 mechanical openings are understood to have been carried out or attempted on five occasions at the following times. Significant flooding immediately preceded the mechanical opening in February 2020:
 - March 2014,
 - August 2014,
 - December 2018,
 - June 2019, and,
 - February 2020,
- dredging within the entrance area is known to have taken place on two occasions, November 1999 and May to September 2016.

The following sections set out a review of certain historical records and events to assist with the formulation of future entrance management options, namely:

- vertical aerial photography covering the period 2012 to 2021 (following on from the tabular summary of entrance conditions covering the period 1937 to 2011 included in **Appendix D**);
- lake water level, catchment rainfall, and ocean water level over the period 1995 to 2020 with a focus on natural breakouts and mechanical openings;
- flood event of February 2020; and,
- dredging within the entrance area.

4.2 Analysis of Entrance Stability

An analysis of entrance stability covering the period 2012 to 2021 has been completed with the findings presented in the same tabular format as that adopted for the analysis of entrance stability covering the earlier period 1937 to 2011.

The findings of the analysis for the period 2012 to 2021 are set out in **Table 4-1**. The findings of the analysis for the period 1937 to 2011 are included in **Appendix D**, as noted earlier.

The monthly rainfall records in **Table 4-1** are for the Milton (Sarah Claydon Village) Bureau of Meteorology (BoM) site, as was the case for the earlier 1937 to 2011 analysis, unless records were not available in which case the rainfall records are from the Bendalong Sewage Treatment Plant (STP) BoM site.

The Category 'X' and Category 'A' ocean storms are based on the definition in Blain Bremner and Williams (1985) as was also the case in the earlier 1937 to 2011 analysis. The classification is based on the recorded offshore significant wave height (H_s), as set out below. Wave data for the period 2012 to 2021 was examined from the Batemans Bay directional waverider buoy.

- Category 'X' storm: H_s greater than 6.0m
- Category 'A' storm: H_s 5.0 to 6.0m

The overall results of the analysis of entrance stability have been examined for the period 1971 to 2021 to assess whether there are any significant trends for entrance stability in relation rainfall and ocean storms. Consideration has also been given to any potential influence of cycles of the El Nino and La Nina phases of the Southern Oscillation Index (SOI) which can affect beach rotation and the stability of the entrance of a coastal lake, as noted in **Section 2.6**²⁶.

The period from 1971 to 2021 was selected since it includes long periods of entrance open conditions (1971 to 1993, and 1999 to 2010), periods of entrance closure (1994 to 1998, and 2018 to 2020), comprises a relatively long length of record (50 years), and includes a period when offshore waverider buoy data is available (1986 to 2021).

A number of observations are set out below, followed by some concluding remarks:

- period 1971 to 1993 (entrance open):
 - during the period 1974 to 1976 a number of ocean storms were experienced (three Category 'A' storms and one Category 'X' storm), however rainfall was above average, indicating the significance of rainfall for keeping the entrance open,
 - during the period 1979 to 1982 rainfall was below average, however there were no Category 'X' or Category 'A' storms and the entrance stayed open, indicating that the entrance can remain open even if rainfall is low providing there is an absence of ocean storms,
 - in the period 1989 to 1992, like the first point above, a number of ocean storms were experienced (three Category 'A' storms and one Category 'X' storm), however rainfall was above average indicating the significance of rainfall in keeping the entrance open,
 - a La Nina phase of the SOI (index above +7) occurred in the period 1973 to 1976 and may have influenced the entrance open condition,
 - an El Nino phase of the SOI (index below -7) occurred in the period 1991 to 1995 and may have influenced the entrance closed condition outlined below.
- period 1994 to 1998 (entrance generally closed):
 - during this period a large number of storms were experienced (four Category 'X' and two Category 'A' storms) and rainfall was below average, indicating this combination is problematic for entrance stability,
 - an El Nino phase occurred during 1997 and 1998 and may have influenced the entrance closed condition.
- period 1999 to 2010 (entrance open):
 - during this period rainfall was generally at or below average, there were two Category 'X' and seven Category 'A' storms, however the entrance did not close,
 - during the early years (1999, 2000) and the later years (2007, 2008, 2010, 2011) a La Nina phase occurred which may have influenced entrance open conditions, there was no distinct sustained El Nino phase,

²⁶ Generally speaking, rainfall is a mechanism for keeping the entrance open, ocean storms can close the entrance due to washover of the spit. A sustained El Nino phase can cause clockwise beach rotation and exhibit lower than average rainfall (increased tendency to entrance closure), and a sustained La Nina phase can cause anti-clockwise beach rotation and exhibit higher than average rainfall (decreased tendency for entrance closure).

- dredging was also carried out in 1999 to enhance the ebb tide channel with sand placed on the spit to reduce storm washover, which may have mitigated the risk of entrance closure during the period 1999 to 2010 (refer **Section 4.5.2**).
- period 2018 to 2020 (entrance closed):
 - during the period of closure, rainfall was below average, a Category ‘A’ storm occurred and an El Nino phase was evident, all of which would have contributed to closing of the entrance.

The assessment of the results of the analysis of entrance stability leads to a number of conclusions:

- rainfall is a key mechanism for keeping the entrance open, or causing the entrance to open if it is closed, however even in below average rainfall years the entrance can stay open in the absence of significant ocean storms;
- ocean storms are the key mechanism for closing the entrance, due to storm washover of the sand spit, but high rainfall years can dominate over ocean storms; and,
- the El Nino and La Nina phases of the SOI can influence entrance conditions, all other things being equal, with the El Nino phase tending to influence entrance closure (lower than average rainfall, clockwise rotation of the beach) and the La Nina phase tending to influence entrance open conditions (higher than average rainfall, anti-clockwise rotation of the beach).

4.3 Analysis of Lake Water Level 1992 – 2020 with a Focus on Natural Breakouts and Mechanical Openings

4.3.1 General

Lake water level data from the MHL recorder near the entrance was examined from the commencement of records in 1992, to 2020, to identify those times when the lake may have been heavily shoaled or closed and an opening occurred, either naturally or mechanically, so as to assist with an understanding of entrance behaviour. At the times of an opening the following data was also obtained and plotted on a common time axis with the lake water level over a period of typically 10 days:

- ocean tide level, from Jervis Bay ocean tide gauge;
- daily rainfall, from the BoM Bendalong STP site; and,
- offshore significant wave height, from the Batemans Bay waverider buoy and the Port Kembla waverider buoy.

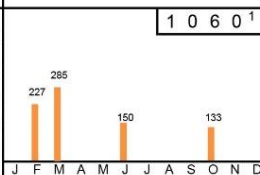
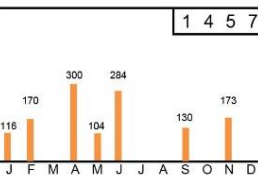
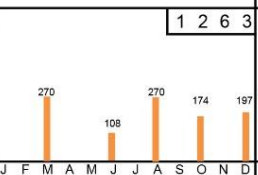
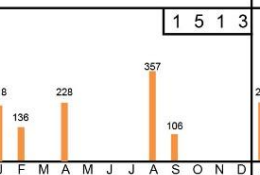
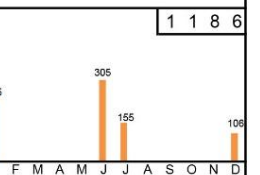
In all, 22 instances of an opening were identified and reviewed. These are listed in **Table 4-2** together with a notation of whether the opening is known to have been a mechanical opening by Council, based on available Council records.

Section 4.3.2 describes examples of mechanical openings by Council.

Section 4.3.3 describes an example of a natural opening (breakout).

Section 4.3.4 summarises a number of features of the mechanical openings and natural openings, and provides some concluding remarks.

Table 4-1: Entrance conditions analysis for the period 2012 to 2021

YEAR		2012	2013	2014	2015	2016
ENTRANCE CONDITIONS		Open (R) and closed	Open (R) and closed	Open and closed	Open (R, SH) and closed	Open (R, SH) and closed
NOTES: Aerial photos available Jan 2012, Oct 2013, Aug 2015, Nov 2015, Feb 2016, Mar 2016, Aug 2016, Jul 2018, Sep 2018, Jan 2020, Jul 2020, Apr 2021. Council records of entrance open/closed available on a monthly basis from 1937 to 2019.		Open Jan Closed Feb Open Mar-May Closed Jun (?) Open Jul-Dec Openings would be due to rainfall Feb-Mar, and Jun	Open Jan-Feb Closed Mar (?) Open Apr-May Closed Jun Open Jul-Dec High rainfall year	Open Jan-Jun (closed Mar?) Closed Jul Open Aug-Dec Rainfall in Mar and Aug led to openings	Open Jan-May Closed Jun-Jul Rainfall in Aug led to opening High rainfall year	Closed Jan-May (?) Open Jun-Dec Rainfall in June led to significant increase in tidal exchange
MONTHLY RAINFALL* (annual mm totals in boxes)	600mm 500mm 400mm 300mm 200mm 100mm	1 0 6 0 1	1 4 5 7	1 2 6 3	1 5 1 3	1 1 8 6
Source: Met. Bureau (Milton records unless otherwise stated) *only amount > 100mm shown						
OCEAN STORMS "X"= severe, "A"= major Source: Batemans Bay Wavender Buoy (from Australian Ocean Data Network-Open Access to Ocean Data)	CATEGORY "X" "A"	Nil				

¹ Bendalong

² Records extend to April 2021 only

Mean annual rainfall:

- Milton (1876-2018): 1,251mm
- Bendalong (1939-2021): 1,228mm

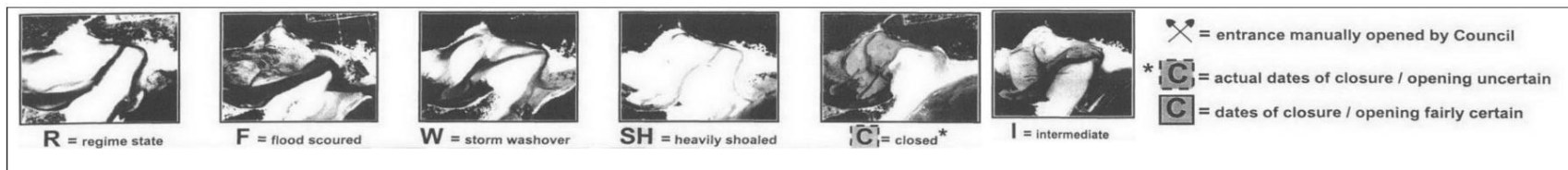
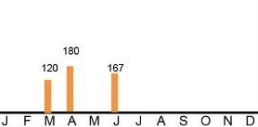
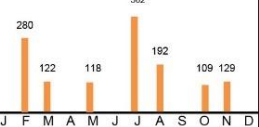
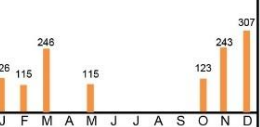


Table 4-1: Entrance conditions analysis for the period 2012 to 2021 (cont'd)

YEAR		2017	2018	2019	2020	2021
ENTRANCE CONDITIONS		Open	Open and closed ✂	Open and closed ✂	Open and closed ✂	Open
NOTES: Aerial photos available Jan 2012, Oct 2013, Aug 2015, Nov 2015, Feb 2016, Mar 2016, Aug 2016, Jul 2018, Sep 2018, Jan 2020, Jul 2020, Apr 2021. Council records of entrance open/closed available on a monthly basis from 1937 to 2019.		Large rainfall event in Feb-Mar, but generally low rainfall year, no significant ocean storms.	Open Jan-Mar Closed Apr-Dec Low rainfall year, no significant ocean storms. Mechanical opening Dec, lake remained open only 2 days.	Closed Jan-May Open Jun-Jul (Council records cease Jul 2019). Mechanical opening in Jun which lasted 3 months, entrance closed Sep 2019. Generally low rainfall year.	Open Jan Open Feb-Dec Mechanical opening Feb after large rainfall event, high rainfall year	Open Jan-Dec High rainfall year
MONTHLY RAINFALL* (annual mm totals in boxes) Source: Met. Bureau (Milton records unless otherwise stated) *only amount > 100mm shown	600mm 500mm 400mm 300mm 200mm 100mm	9 1 8	9 0 3 ¹	8 1 9 ¹	1 5 2 9 ¹	1 4 9 0 ¹
						
OCEAN STORMS "X" = severe, "A" = major Source: Batemans Bay Waverider Buoy (from Australian Ocean Data Network-Open Access to Ocean Data)	CATEGORY "X" "A"	Nil	Nil			Nil ²

¹ Bendalong

² Records extend to April 2021 only

Mean annual rainfall:

- Milton (1876-2018): 1,251mm
- Bendalong (1939-2021): 1,228mm

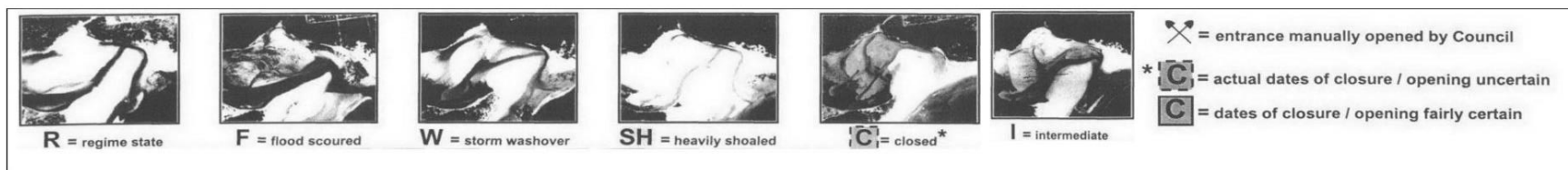


Table 4-2: Identified openings of Lake Conjola over the period 1992 to 2020 (refer Note to Table)

Date	Known Council mechanical opening (✓ = Yes, x = No)
19 May 1995	x
18 May 1996	✓
02 September 1996	✓
16 February 1997	✓
06 March 1997	✓
25 May 1997	✓
28 June 1997	✓
26 September 1997	✓
07 December 2010	✓
21 March 2011	✓
23 December 2011	✓
28 February 2012	✓
08 March 2012	x
06 June 2012	x
28 February 2013	✓
21 April 2013	x
27 March 2014	✓
19 August 2014	✓
26 August 2015	x
06 June 2016	x
19 June 2019	✓
10 February 2020	✓

Note: In some cases where a natural opening was identified, the entrance may not have been fully closed but was heavily shoaled with only a very weak tidal signal.

4.3.2 Examples of mechanical openings by Council

Seven examples of known mechanical openings by Council have been selected for illustration and discussion:

- 7 December 2010;
- 21 March 2011;
- 23 December 2011;
- 27 March 2014;
- 19 August 2014;
- 19 June 2019; and,
- 10 February 2020.

Mechanical opening 7 December 2010

According to the records of entrance stability included in **Appendix D**, three mechanical openings were undertaken in 2010; an opening in May which failed to trigger a persistent channel due to a coastal storm (three coastal storms can be identified in the Batemans Bay waverider buoy record in May, with H_s varying from approximately 4m to 5.5m), a second attempt in September however coastal storms closed the lake, and the opening on 7 December.

The records of water level, rainfall, and offshore wave height prior to and following the opening on 7 December 2010 are shown in **Figure 4-1**. A number of features are evident:

- the water level in the lake slowly increased over the days prior to the opening, reaching a level of approximately 1.1m AHD at the time of the opening;
- only relatively minor rainfall preceded the opening;
- the offshore wave climate was mild at the time of the opening (H_s in the range 1.5 to 2m);
- the lake water level dropped by 0.55m, from 1.1m AHD to 0.55m AHD, over a period of about 2.5 days following the opening (0.35m/day); and,
- the tidal response in the lake following the opening was relatively minor (tidal range less than 0.1m) indicating the breakout channel was not particularly well developed. According to the records of entrance stability, the entrance closed in early March 2011 after a period of about three and a half months and an emergency opening had to be completed on 21 March 2011 (refer **Appendix D**).

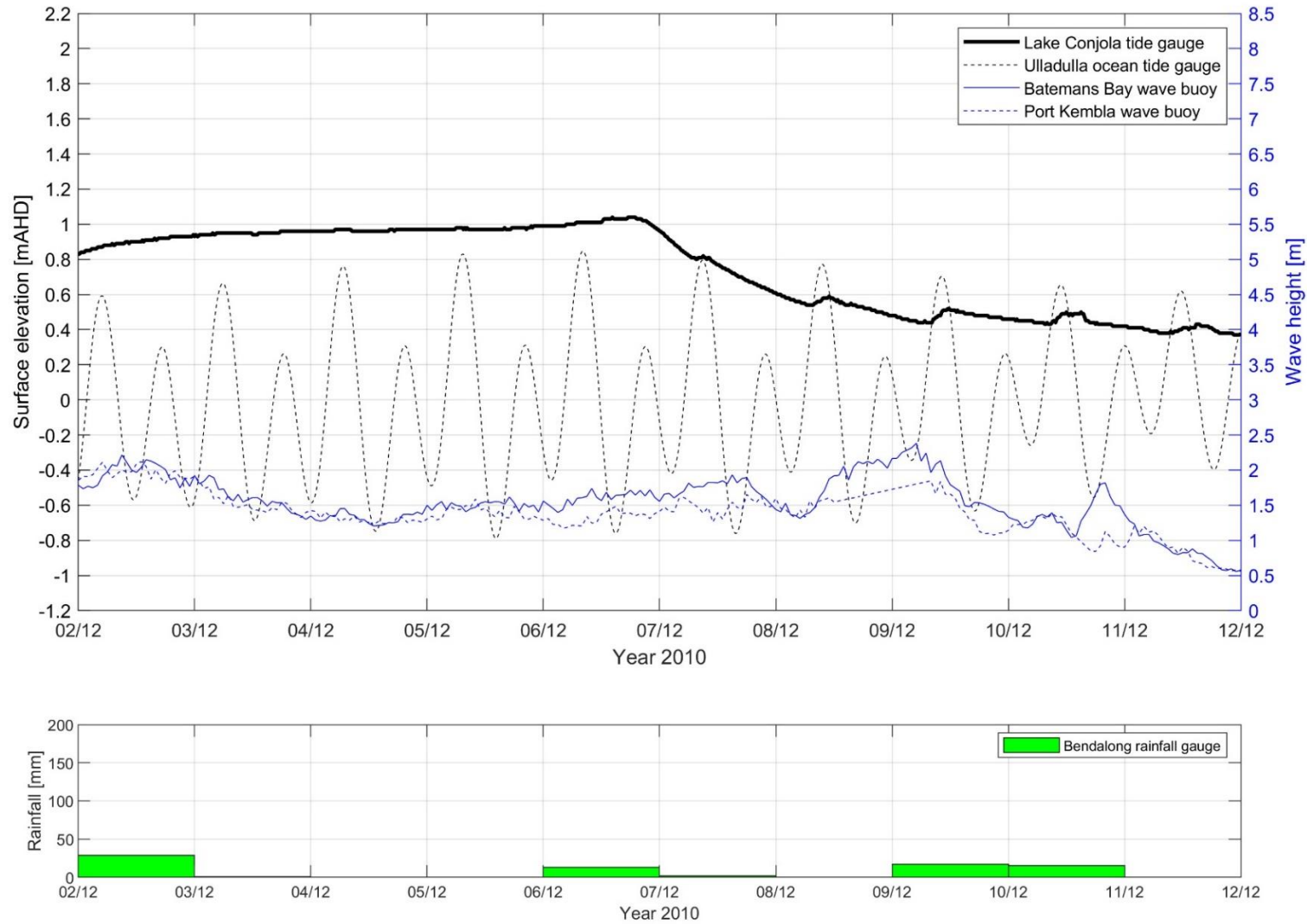


Figure 4-1: Water level, rainfall, and wave records for the mechanical opening on 7 December 2010

Based on the above, it would seem that an opening can be achieved at an initial lake level of 1m AHD providing the wave climate is mild, but the channel may not be well developed and the entrance opening could be relatively short lived.

Mechanical opening 21 March 2011

The records of water level, rainfall, and offshore wave height prior to and following the opening on 21 March 2011 are shown in **Figure 4-2**. A number of features are evident:

- the water level in the lake was initially around 0.6m AHD but rose in response to rainfall and reached a peak of approximately 1.3m AHD at the time of the opening;
- the offshore wave climate was relatively mild at the time of the opening (H_s in the range 1.5 to 2.5m), although H_s increased to approximately 3.5m after the opening;
- the lake water level dropped by 0.7m, from 1.3m AHD to 0.6m AHD, over a period of 1.5 to 2 days following the opening (0.4m/day), so at a greater rate than for the opening on 7 December 2010, indicating a stronger breakout flow; and,
- the tidal response in the lake following the opening was stronger than for the opening on 7 December 2010 (tidal range 0.1 to 0.2m), also indicative of a more well developed breakout channel (less shallow water effects on tidal propagation).

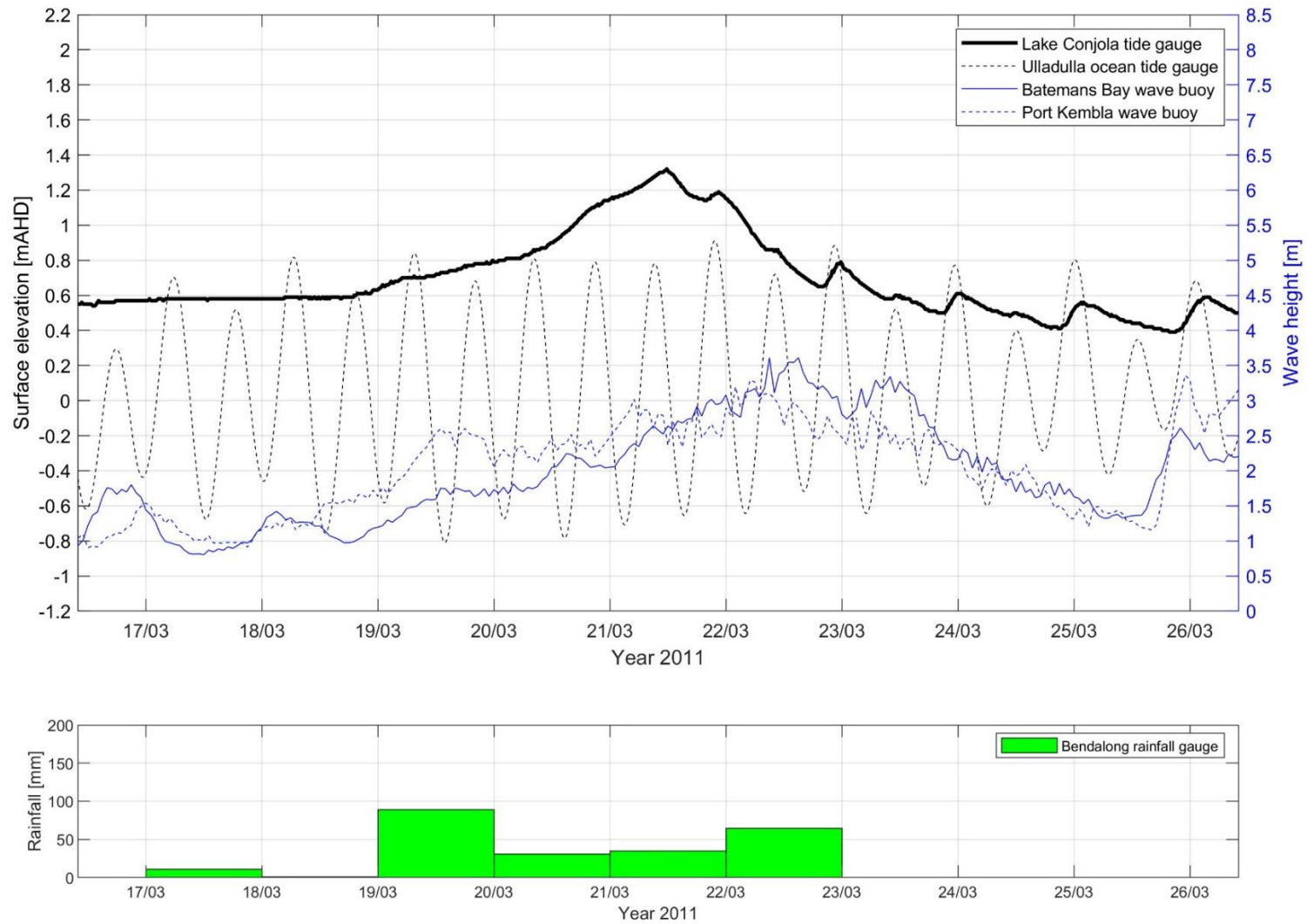


Figure 4-2: Water level, rainfall, and wave records for the mechanical opening on 21 March 2011

The above outcome indicates the benefit of a higher initial lake water level at the time of an opening in generating greater scour and a more well developed channel, which may have been assisted in this case by continuing rainfall generating discharge through the entrance following the opening.

The period of time for which the entrance remained open is not documented but it is apparent from aerial photographs that the entrance was heavily shoaled in September 2011 some six months after the opening (refer **Figure 4-3**).

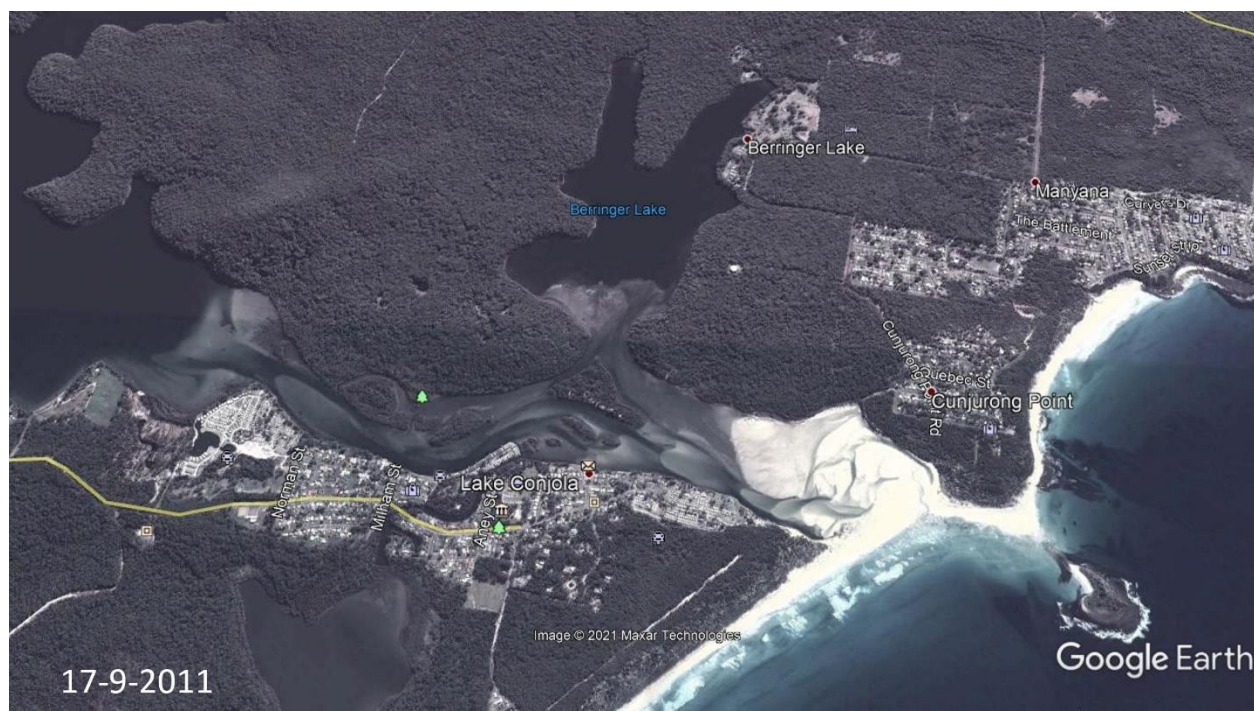


Figure 4-3: Heavily shoaled entrance condition on 17 September 2011 following the mechanical opening on 21 March 2011

Mechanical opening 23 December 2011

This opening is not noted to be a 'known' mechanical opening in **Table 4-2** but is believed to be a mechanical opening since the opening was preceded by minimal rainfall²⁷.

The records of water level, rainfall, and offshore wave height prior to and following the opening on 23 December 2011 are shown in **Figure 4-4**. A number of features are evident:

- the water level in the lake was in the range 0.8m to 0.9m AHD at the time of the opening;
- minimal rainfall preceded the opening;
- the offshore wave climate was very mild at the time of the opening (H_s less than 1.5m) although H_s increased to above 2m following the opening;
- the lake water level dropped by approximately 0.3m, from around 0.9m AHD to 0.6m AHD, over a period of about 1.5 days following the opening (0.2m/day); and,

²⁷ In records supplied by Council the cause of the opening is prescribed by the letter 'U' meaning Unknown.

- the tidal response in the lake following the opening was relatively minor (tidal range 0.1m or less).

Based on Council records, it is apparent the lake closed a short time after the opening, in February 2012, but subsequently was open in March 2012. This subsequent opening would have been due to the high rainfall experienced in February and March 2012 (227mm and 285mm respectively, refer **Table 4-1**).

The short lived open entrance conditions following the mechanical opening in 23 December 2011 would appear to be another example where the entrance channel did not become well developed even though the offshore wave climate was mild, probably as a consequence of the low initial lake water level and absence of rainfall contributing to the discharge through the entrance.

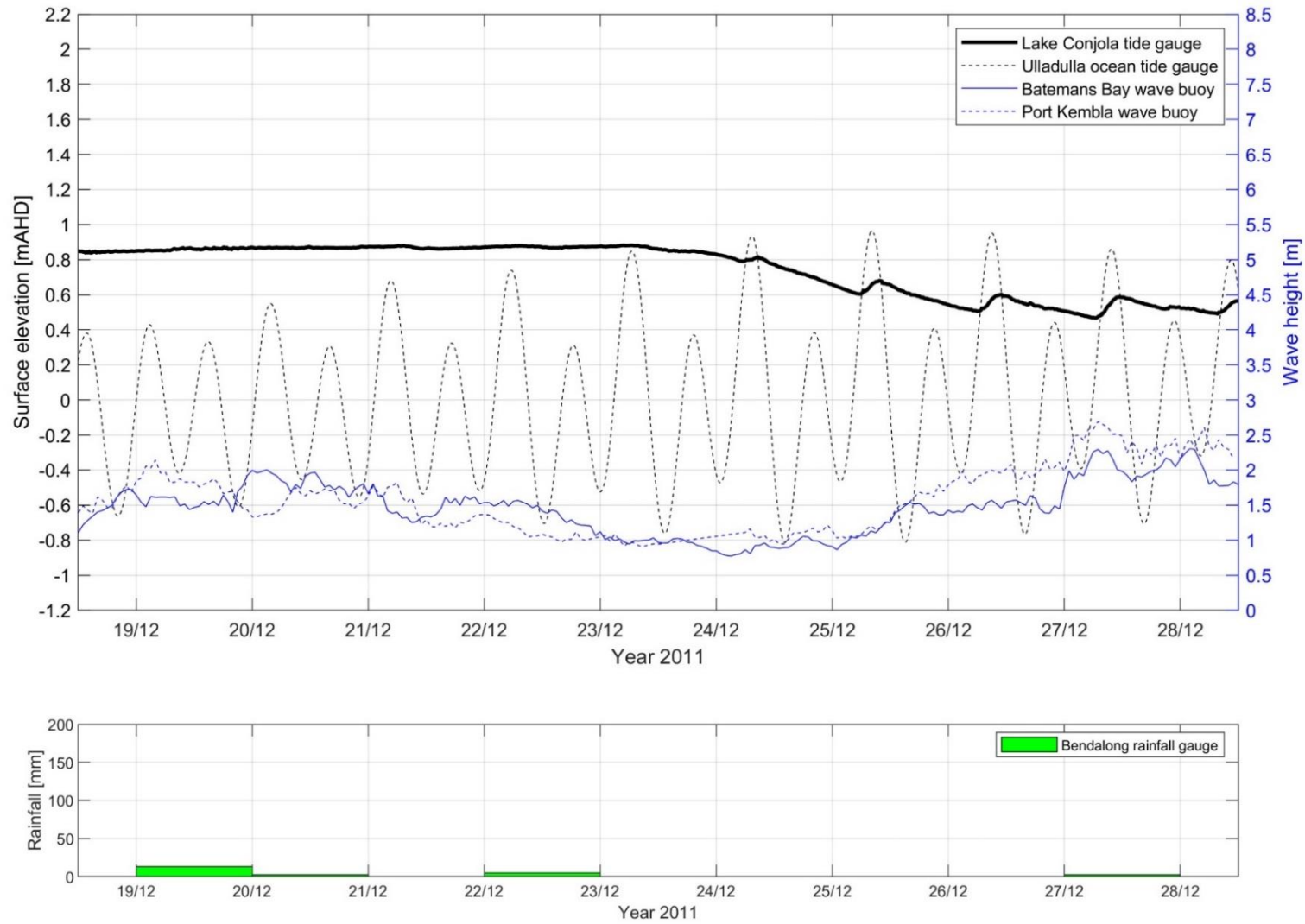


Figure 4-4: Water level, rainfall and wave records for the mechanical opening on 23 December 2011

Mechanical opening 27 March 2014

The records of water level, rainfall, and offshore wave height prior to, and following, the opening on 27 March 2014 are shown in **Figure 4-5**. A number of features are evident:

- the water level in the lake increased slowly over the days prior to the opening in response to rainfall, rising from 0.4m AHD to a maximum level of 1m AHD;
- the offshore wave climate was mild at the time of the opening (H_s in the range 1 to 2m);
- the lake water level dropped by approximately 0.45m, from 1m AHD to about 0.55m AHD over a period of about 20 hours following the opening (about 0.5m/day); and,
- the tidal response in the lake following the opening was relatively minor (tidal range typically less than 0.1m) indicating the channel was not particularly well developed. According to the records of entrance stability, the entrance was closed some 4 months later, in July 2014, shortly after which it was again opened mechanically, as outlined below.

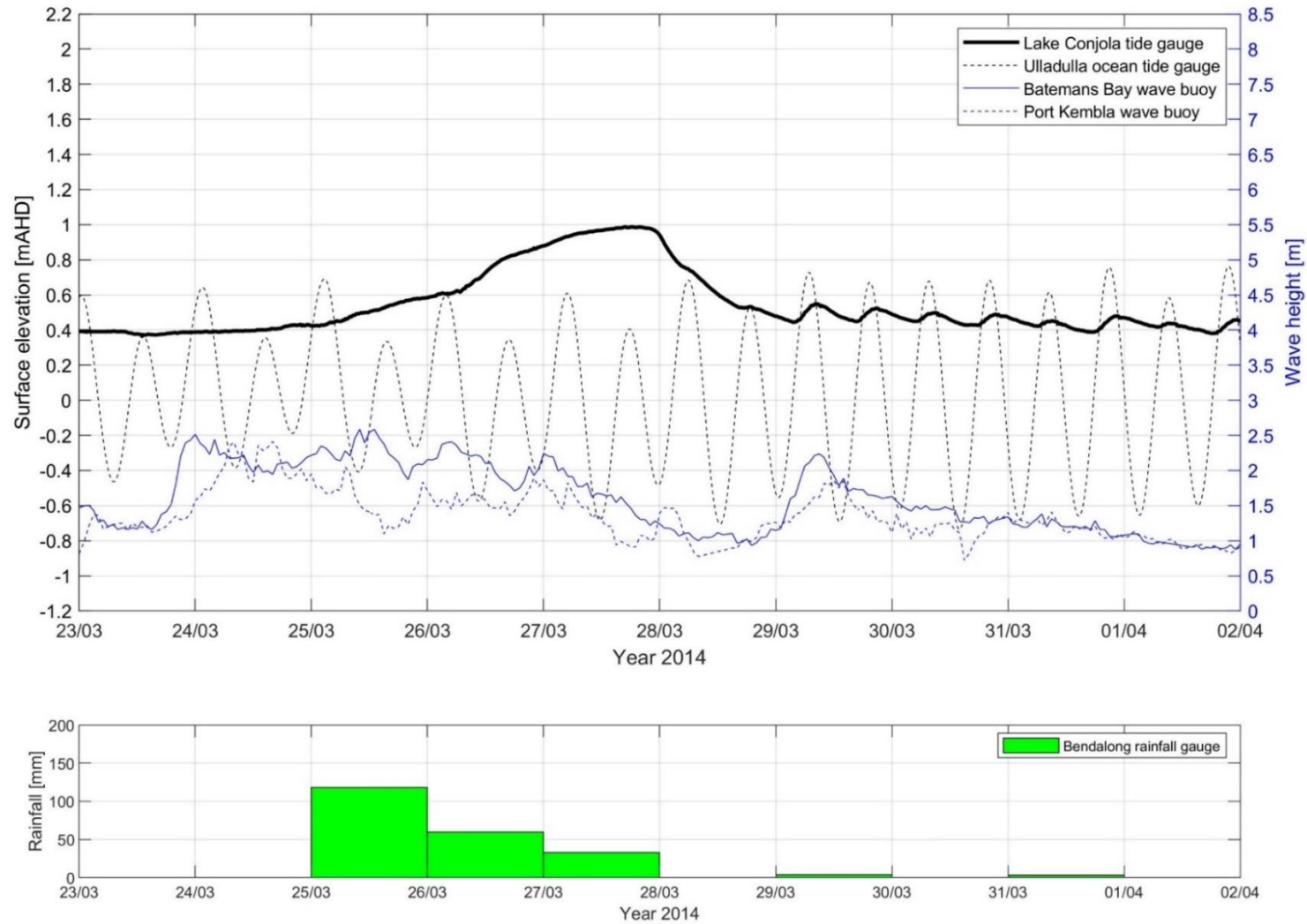


Figure 4-5: Water level, rainfall, and wave records for the mechanical opening on 27 March 2014

Mechanical opening 19 August 2014

The records of water level, rainfall, and offshore wave height prior to, and following, the opening on 19 August 2014 are shown in **Figure 4-6**. A number of features are evident:

- the water level in the lake increased over the days prior to the opening in response to rainfall, rising from 0.6m AHD to a maximum level of 1.2m AHD;
- a significant ocean storm occurred in conjunction with the rainfall (H_s increasing to 5.5m corresponding to a Category 'A' storm), but the rainfall dominated the ocean storm to produce a breakout event;
- the lake water level dropped by approximately 0.65m, from 1.2m AHD to about 0.55m AHD, over a period of about 14 hours following the opening (about 1.1m/day); and,
- the tidal response in the lake following the opening was minor to moderate (tidal range 0.1 to 0.2m) indicating the channel is likely to have been more well developed than for the opening on 27 March 2014, possibly due to the higher initial lake water level. The lower ocean high tide may have also been a factor. According to the records of entrance stability, the entrance remained open for a period of 10 months, closing again in June 2015.

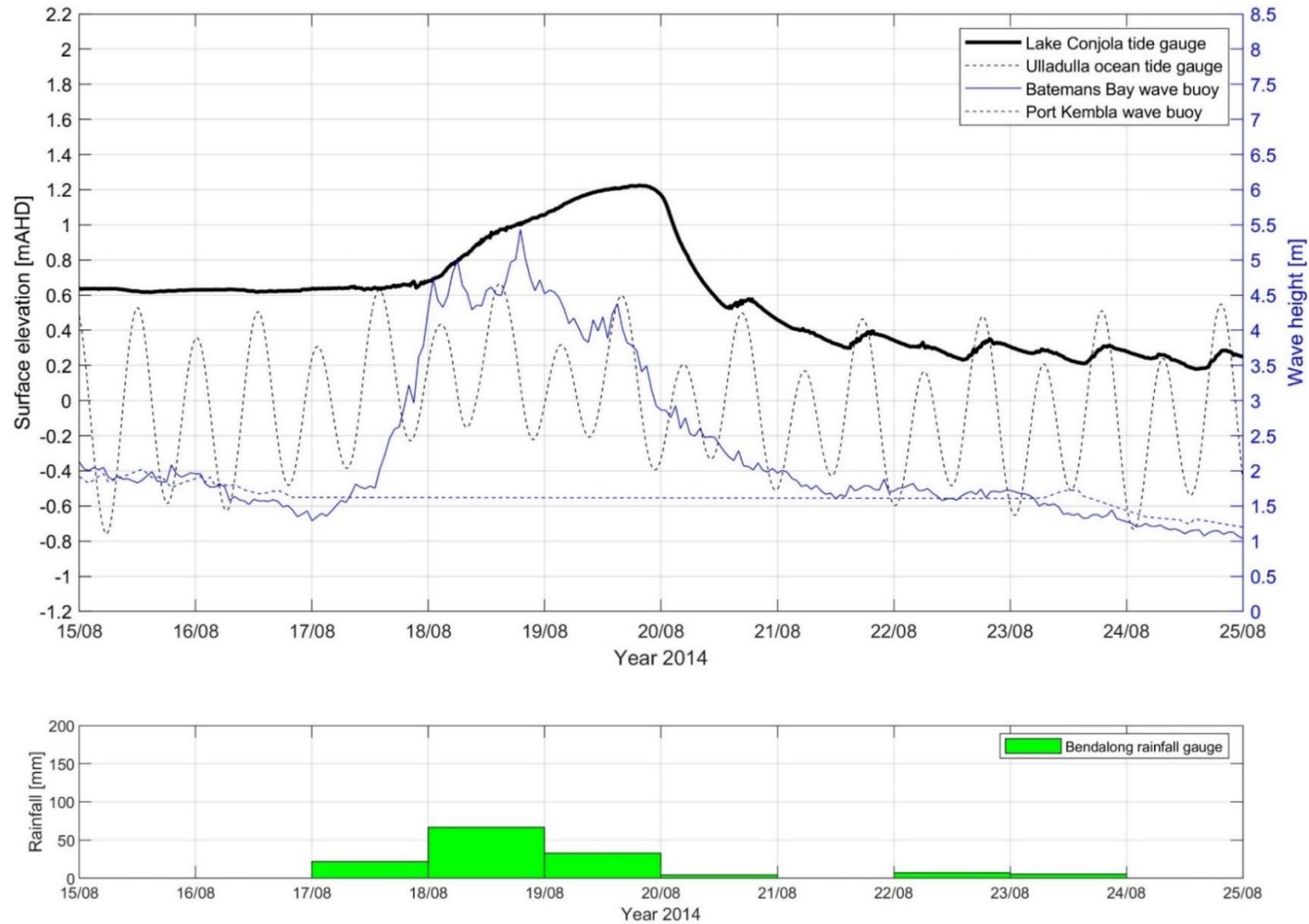


Figure 4-6: Water level, rainfall, and wave records for the mechanical opening on 19 August 2014

Mechanical opening 19 June 2019

The records of water level, rainfall, and offshore wave height prior to and following the opening on 19 June 2019 are shown in **Figure 4-7**. A number of features are evident:

- the water level in the lake was at 0.92m AHD at the time of the opening;
- minimal rainfall preceded the opening;
- the offshore wave climate was mild at the time of the opening (H_s 1.5 to 2.0m);
- the lake water level dropped by approximately 0.3m, from just above 0.9m AHD to about 0.6m AHD, over a period of around 1 day following the opening (approximately 0.3m/day); and,
- the tidal response in the lake following the opening was relatively minor, with tidal range around 0.1m initially then reducing further as the tides approached a neap period.

This particular opening ended up being a dredging operation to which Council received a warning letter from Crown Lands. A pilot channel was dug for 4 days prior to 19 July when it was opened, but machinery stayed digging until at least 12 July cutting additional channels and digging in the main ebb channel guided by members of the community. A total of 22,600m³ of sand was ultimately removed and placed on the sand hill to the north of the entrance at a cost of \$140,000, as conveyed in a Council report on the operation.

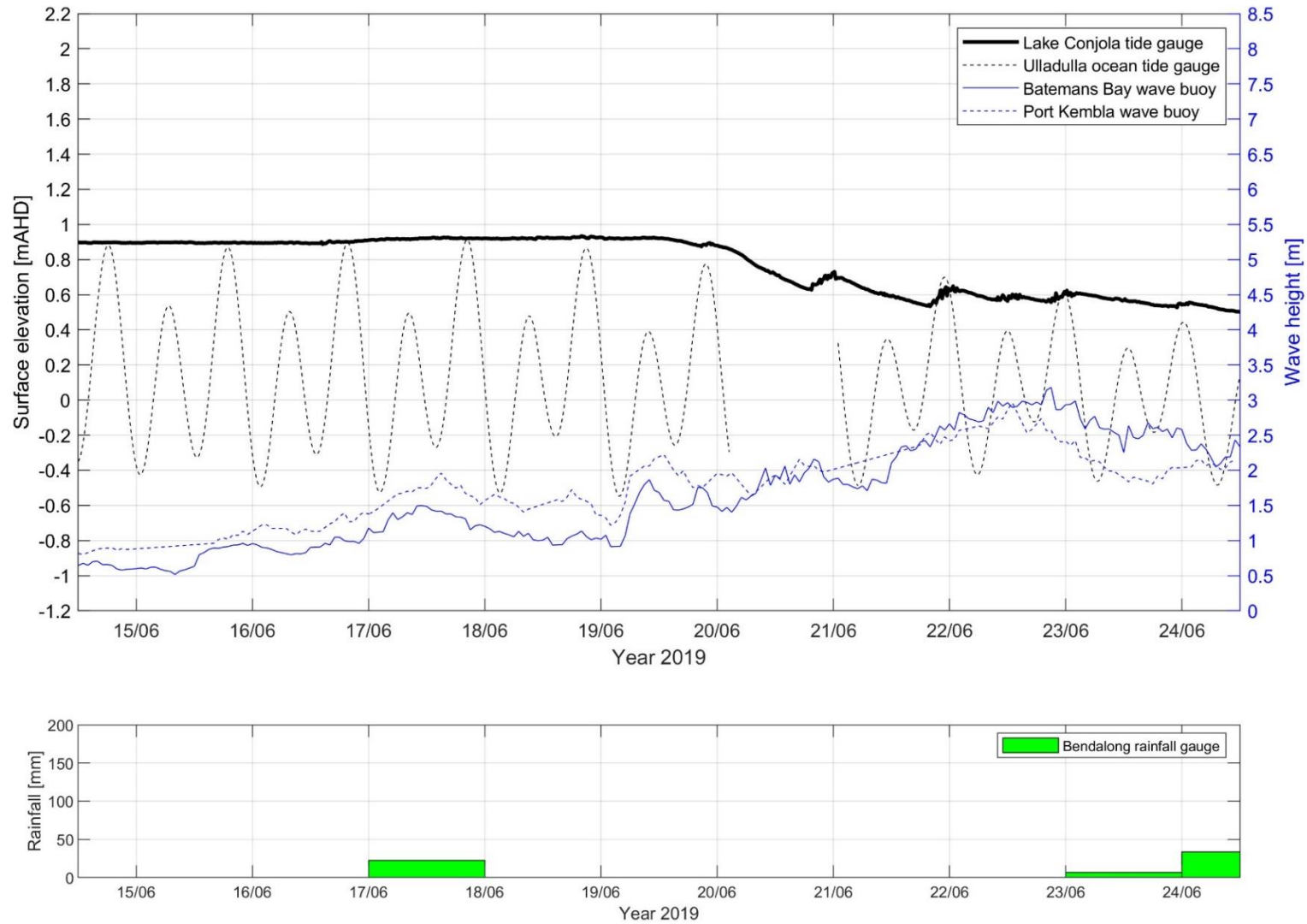


Figure 4-7: Water level, rainfall and wave records for the mechanical opening on 19 June 2019

Following the opening in June 2019, the entrance remained open for a period of three months, closing in September 2019²⁸.

Some notes in relation to the 19 June 2019 mechanical opening have also been provided by Mr Daniel Wiecek of the Department of Planning and Environment (DPE). These notes are summarised below:

- the lake was opened at high tide around 10am on 19 June 2019. Water did not flow out of the lake with wave runup resulting in some water being pushed back into the entrance of the lake at that time;
- the pilot channel was located further to the south in a more central location within the entrance area compared to prior openings, including the unsuccessful opening in December 2018; and,
- water began flowing out of the lake once tide levels dropped during the afternoon.

The mechanical opening in June 2019 and the earlier opening in December 2018 would appear to be further examples of the importance of ensuring a relatively high initial lake water level at the time of a mechanical opening, potentially associated with rainfall, in order to achieve a well scoured entrance channel.

Images of the excavated pilot channel in the June 2019 opening are shown in **Figure 4-8** and **Figure 4-9**. The width of the channel is estimated to be approximately 10 to 12m. The bed of the channel intercepted the water table and is estimated to have been at a level of approximately 0m AHD.

Ground level oblique views of the pilot channel are shown in **Figure 4-10**.

A view of the excavated sand from the pilot channel being placed on the northern side of the entrance area is shown in **Figure 4-11**.

The plant used on the beach for excavation of the pilot channel typically comprises an excavator (visible in Figure 4-10). Access to the beach is normally via the Cunjurong boat ramp unless access to the beach from the ramp is not possible due to the lake water level and/or foreshore conditions, in which case access is obtained from Manyana to the north. Transport of excavated material across the beach is achieved by use of Moxy dump trucks (visible in **Figure 4-11**).

²⁸ It is also worth noting that Council had attempted to open the entrance on 21 December 2018, however in that instance the lake entrance quickly closed within 48 hours due to natural processes. The initial water level in the lake for this attempted opening was relatively low at 0.97m AHD. Council had also prepared a more significant pilot channel in early January 2019 (12,000m³ excavation at a cost of \$60,000), however Council did not proceed to open the lake due to a change in rainfall prediction.



*Figure 4-8: Oblique north-south aerial image - Lake Conjola mechanical entrance clearance works - June 2019
(source: Shoalhaven City Council)*



Figure 4-9: Oblique west-east aerial image - Lake Conjola mechanical entrance clearance works - June 2019 (source: Shoalhaven City Council)



Figure 4-10: Mechanical opening of Lake Conjola entrance near high tide around 10am 19 June 2019, with water observed flowing out of the lake from around 1:45pm 19 June 2019 (source: D. Wiecek, DPE)



Figure 4-11: Contractors placing sand near northern dunes after removing it from the entrance of Lake Conjola on 13 June 2019 (source: Illawarra Mercury)

Mechanical opening 10 February 2020

The records of water level, rainfall, and offshore wave height prior to, and following, the opening on 10 February 2020 are shown in **Figure 4-12**. A number of features are evident as outlined below. As noted earlier, significant flooding immediately preceded the mechanical opening in February 2020. The rainfall experienced (the magnitude of which in places was not predicted), Council actions, and the extent of flooding are further discussed in Section 4.4:

- the water level in the lake was steady at between 0.2m AHD and 0.4m AHD before rising rapidly in response to rainfall, in particular the rainfall late on Sunday 9 February and early on 10 February, to reach a peak of approximately 2m AHD;

- the offshore wave climate was equivalent to a Category 'A' storm prior to the opening (H_s 5.0 to 6.0m) before reducing to an H_s less than 4.0m at the time of the opening;
- the lake water level dropped by 1.6m, from 2m AHD to 0.4m AHD, over a period of approximately 20 hours following the opening (1.9m/day), the highest rate of fall of lake water level for the five mechanical openings described, being some 5 to 10 times the rate of fall of the other mechanical openings, indicating a very strong breakout flow²⁹; and,
- the tidal response in the lake following the opening was stronger than all other mechanical openings (maximum tidal range 0.5 to 0.6m), also indicative of a well developed breakout channel (reduced shallow water effects on tidal propagation).

The above outcome again indicates the relationship between a high initial lake water level and the generation of significant scour and a well developed channel, although in this case the initial lake water level of 2m AHD led to substantial flooding at Lake Conjola, as described in **Section 4.4**.

Due to the very high lake water level at the time of initiation of the mechanical opening, the excavated pilot channel was relatively short, estimated to be only some 20 to 30m in length. This allowed a rapid opening of the lake once the plant was mobilised on the beach and emphasised the significance of pilot channel length on the ability to initiate a breakout flow in a timely manner.

The width of the pilot channel was also relatively narrow, at only approximately 2m. Due to the high initial lake water level this narrow channel width was all that was necessary to commence strong natural scour.

Figure 4-13 shows excavation of the pilot channel taking place, viewed from an elevated position on Cunjurong Point. **Figure 4-14** shows a close-up view of the channel shortly after commencement of the breakout flow.

The lake has remained open since the mechanical opening on 10 February 2020 to the present time (December 2022), influenced by the establishment of a well developed channel but also as a consequence of the above average rainfall experienced in 2020, 2021 and 2022.

²⁹ This very strong breakout flow would have been the consequence of the combination of high initial lake water level (giving a large head difference between the lake water level and the ocean), the short length of pilot channel, and possibly the ongoing rainfall runoff entering the lake and discharging through the entrance channel.

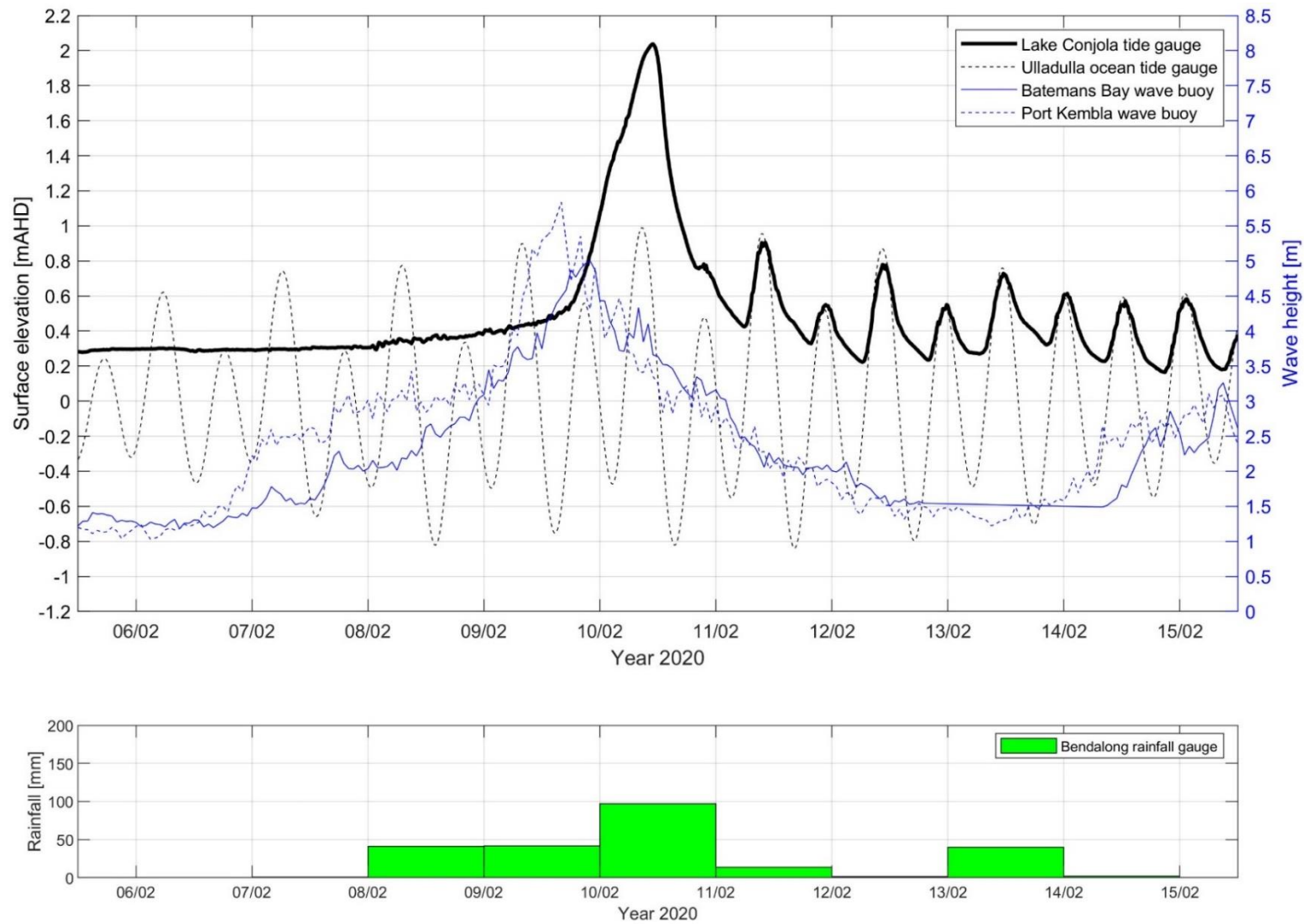


Figure 4-12: Water level, rainfall, and wave records for the mechanical opening on 10 February 2020



Figure 4-13: View of excavation of pilot channel in February 2020 from Cunjurong headland (source: D. Wiecek, DPE)



Figure 4-14: Close up view of excavated pilot channel in February 2020 with outflow occurring (source: D. Wiecek, DPE)

4.3.3 Examples of natural breakouts

One example of a natural opening has been selected for illustration and discussion:

- 25 August 2015.

Natural opening 25 August 2015

The records of water level, rainfall, and offshore wave height prior to, and following, the opening on 25 August 2015 are shown in **Figure 4-15**. A number of features are evident:

- the water level in the lake increased relatively rapidly over approximately 12 hours during the day of the opening in response to heavy rainfall, from 0.6m AHD to a peak level above 1.9m AHD. Heavy rainfall continued following the opening;
- an ocean storm occurred in conjunction with the rainfall (H_s 4.0 to 4.5m), but the rainfall dominated the ocean storm to produce a breakout event;
- the lake water level dropped by approximately 1m, from above 1.9m AHD to around 0.9m AHD over a period of about 18 hours following the opening (about 1.3m/day); and,
- the tidal response in the lake following the opening was relatively strong (tidal range greater than 0.2m), indicating a well developed channel, probably due to the high initial lake water level and ongoing rainfall runoff entering the lake and discharging through the entrance channel. According to records of entrance stability, the entrance remained open for a period of 4 months, closing again in January 2016.

Council email correspondence to agencies at the time confirmed that the lake opened well before the peak of the flood, but the lake water level continued to rise after the opening due to the continuing heavy rainfall (pers. comm Danny Wiecek, Department of Planning and Environment).

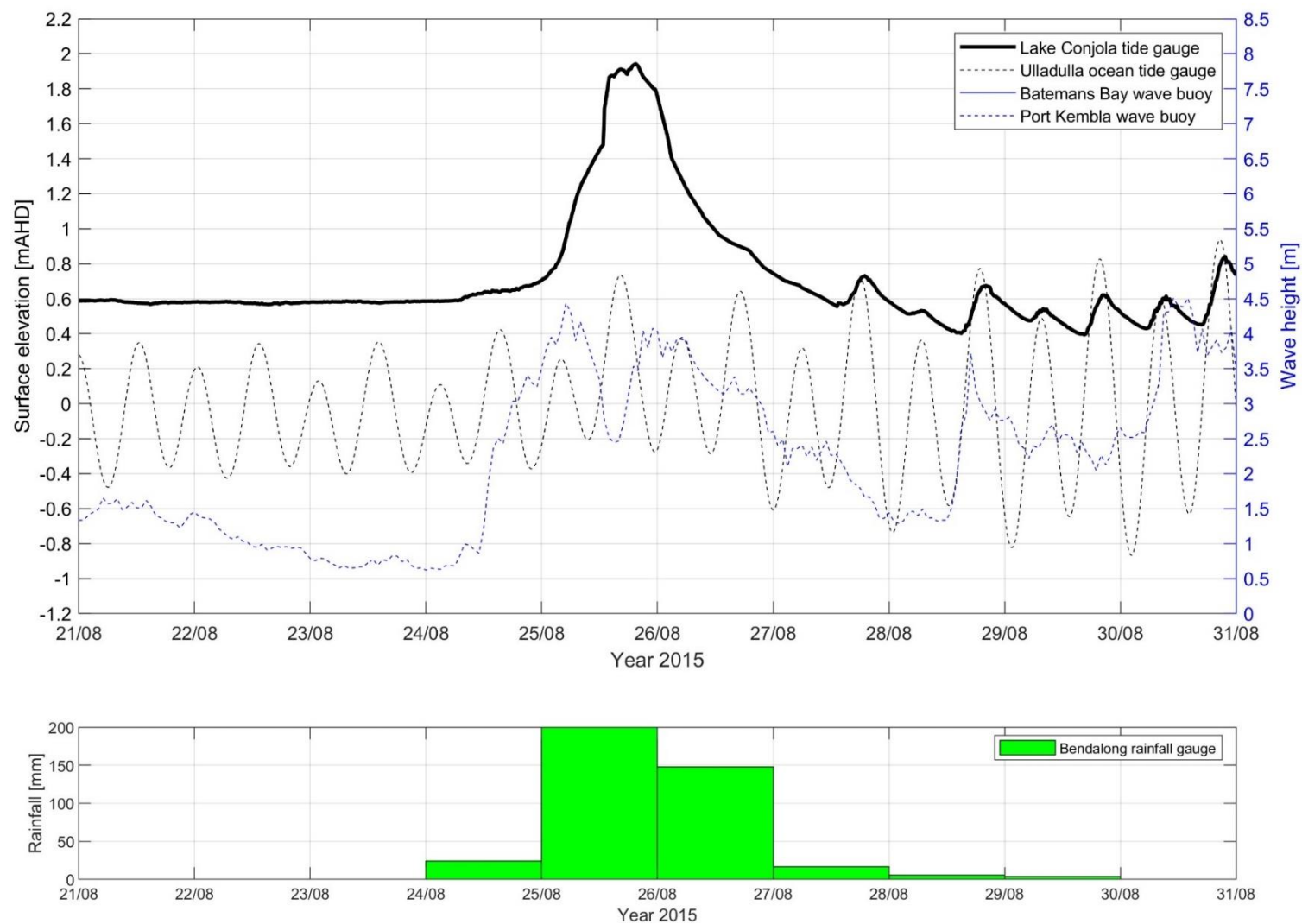


Figure 4-15: Water level, rainfall, and wave records for the natural opening on 25 August 2015

4.3.4 Summary of features of the openings and concluding remarks

Table 4-3 sets out a summary of a number of features of the mechanical openings by Council and the natural opening, as described in the previous sections. Based on this summary and observation of the relationships between water level, rainfall, and wave records in **Figure 4-1, Figure 4-2, Figure 4-4, Figure 4-5, Figure 4-6, Figure 4-7, Figure 4-12 and Figure 4-15**, the following general concluding remarks can be made:

- there is a strong dependency between the initial lake water level at the time of an opening and the effectiveness of the channel which forms, not unexpected due to the influence of head difference between the lake and the ocean, as indicated by the rate of drop in lake water level and the subsequent tidal response. Openings at a lake level less than around 1.1m AHD would in particular appear to be problematic, recognising that a range of other factors can also influence the effectiveness of opening events, e.g. continuing rainfall and occurrence of ocean storms;
- natural openings are obviously created by substantial rainfall events. It is not unusual for rainfall events and ocean storms to be coincident, generated by the same weather system, but rainfall would appear to generally dominate ocean storms in achieving a breakout event³⁰;
- a higher initial lake water level would also in effect mean a shorter channel length (excavated pilot channel or naturally scoured channel) which has the benefit of a steeper hydraulic gradient (greater scour) and quicker excavation duration for a mechanical opening. This is evident in the 10 February 2020 mechanical opening, but of course the high lake water level in this case led to substantial flooding of Lake Conjola Village; and,
- the initial lake water level at times of natural openings is obviously controlled by the sand berm level at the lake entrance. It is evident that when the entrance is closed and the berm level becomes relatively high, and heavy rainfall occurs quickly as was the case in August 2015 (refer Figure 4-15), the lake level can rise rapidly to high levels before natural breaching of the sand berm can occur, being a level of 1.9m AHD in that case. The only way to manage the flooding risk for this type of situation would be to manage the level of the sand berm, e.g. by way of a dry notch.

Table 4-3: Summary of features of lake openings

Date of opening	Type of opening	Initial lake water level (m AHD)	Rate of drop in lake water level (m/day)	Subsequent tidal response (range) (m)
7 December 2010	Mechanical	1.1	0.35	< 0.1
21 March 2011	Mechanical	1.3	0.4	0.1 – 0.2
23 December 2011	Mechanical	0.8 – 0.9	0.2	< 0.1
27 March 2014	Mechanical	1.0	0.5	< 0.1
19 August 2014	Mechanical	1.2	1.1	0.1 – 0.2
25 August 2015	Natural	1.9	1.3	> 0.2
19 June 2019	Mechanical	0.9	0.3	0.1
10 February 2020	Mechanical	2.0	1.9	0.5 – 0.6

³⁰ Ocean storms causing washover of the sand spit remain the primary mechanism for entrance closure.

4.4 Flood Event February 2020

It is useful to summarise the circumstances of the flood event which occurred in Lake Conjola on Monday 10 February 2020 and to assess any implications for entrance management. This was a significant recent event with the lake water level at the entrance reaching 2.0m AHD, corresponding to approximately a 10% AEP event, and with an estimated 34 habitable floors impacted³¹. The flooding immediately preceded the mechanical opening of the lake (refer **Section 4.3.2**).

An internal Council report describing the 10 February 2020 flood event was prepared and the following points are summarised from that report:

- a peak water level of 2.0m AHD was recorded at the entrance as noted above;
- rainfall within and immediately adjacent to the catchment was highly variable with the following AEPs estimated at three local rainfall gauges:
 - Lake Conjola: 50% AEP,
 - Fishermans Paradise: 20% AEP,
 - Porters Creek Dam: 5% AEP,
- rainfall had occurred on Saturday 8 February and Sunday 9 February 2020 but as at 8.33pm Sunday night the lake water level was at 0.6m AHD, below the planned and emergency trigger levels in the adopted Interim Entrance Management Policy (GHD, 2013) of 1.0m AHD and 1.2m AHD respectively;
- recorded rainfall at Lake Conjola was below the BoM predicted value, but significantly greater rainfall than predicted occurred overnight on Sunday and early on Monday further upstream in the catchment at the Fishermans Paradise and Porters Creek Dam rainfall gauges as indicated above;
- due to the higher than predicted rainfall, the lake water level reached the emergency trigger level in the early hours of Monday morning, which had not been expected;
- at 3.55am on Monday 10 February Council staff issued an emergency opening notification with the instruction to open Lake Conjola in accordance with the Interim Entrance Management Policy;
- Council's contractor for opening the lake could only transport the excavator used for this purpose during daylight hours to comply with Transport for NSW laws;
- the normal means of access to the beach for the excavator, from Cunjurong Point boat ramp, could not be used and it was necessary to gain access via the northern end of Manyana Beach (Sunset Strip) some 1.8km to the north; and,
- the excavator commenced digging the pilot channel at 10.55am on Monday 10 February and the lake was open at 11:25am.

The situation experienced in February 2020 demonstrates that rainfall can be unpredictable and variable, conditions can change quickly in a relatively small system such as Lake Conjola, and that water level triggers can be reached over weekends and at night, outside of normal working hours.

In such circumstances, for purposes of flood mitigation, consideration could be given to an entrance management approach whereby a natural opening could be initiated 'early' and/or reduced time is required to complete a mechanical opening. Maintenance of a dry notch at the entrance would satisfy

³¹ The estimated AEP of the water level at the entrance, and the estimated number of habitable floors impacted, is based on information in BMT WBM (2013a).

such an approach. This was recognised in the Council post-flooding report, however maintenance of a dry notch did not form part of the adopted Interim Entrance Management Policy.

Images of the February 2020 flood are shown in **Figure 4-16**, **Figure 4-17** and **Figure 4-18**.

Following the February 2020 flood, the Conjola Community Association (CCB) prepared a document which contained stories from residents, holiday home and caravan owners, and visitors at Lake Conjola, of their experiences before, during, and after the flood (CCB, 2020).

This document noted that the February 2020 flood was the 10th flood experienced at Lake Conjola since 2011. It also included reference to the flooding which occurred at the time of the natural opening on 25 August 2015 (refer **Section 4.3.3** and **Figure 4-15**). In respect of the flood on 25 August 2015 it was stated that the lake opened naturally at a level of 1.2m AHD and the lake water level reached 2.14m AHD³².

The stories in CCB (2020) contained substantial anger and frustration at the flooding and a call for improved management of the entrance for flood mitigation benefit.

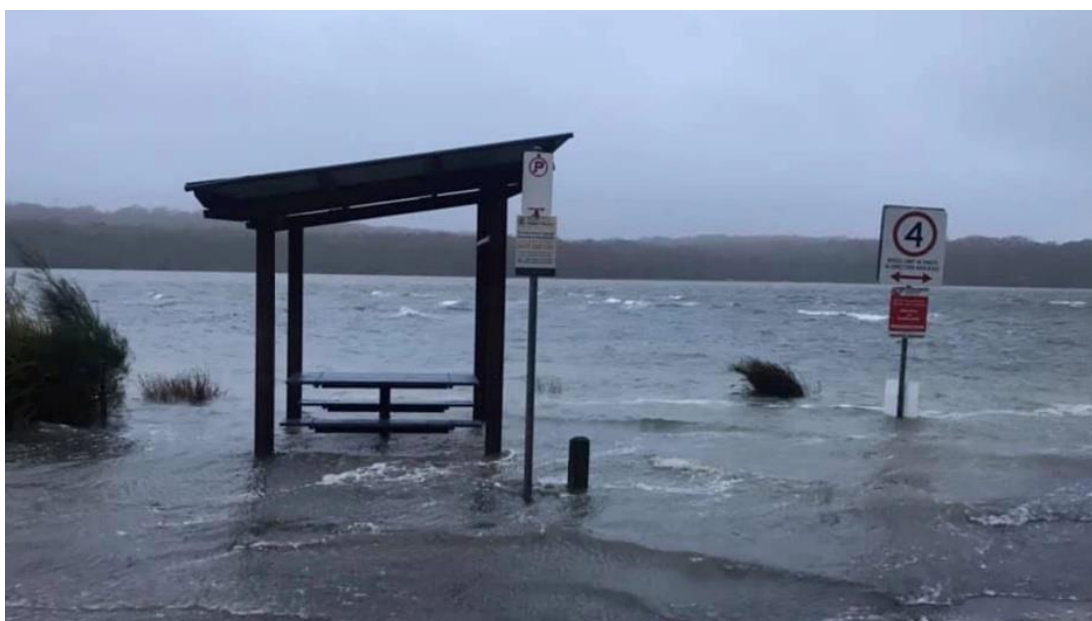


Figure 4-16: Flooding near the entrance to Lake Conjola on 10 February 2020 (dailytelegraph.com.au)

³² The peak water level recorded near the entrance on the MHL recorder was approximately 1.9m AHD as indicated in **Figure 4-15**; the level of 2.14m AHD is likely to have been further upstream. It is also noteworthy that the lake is stated to have opened at a level of 1.2m AHD yet the water level reached 2.14m AHD, indicating that the rate of rainfall runoff into the lake in that event exceeded the discharge capacity of the naturally scoured channel.



Figure 4-17: Flooding of one of the upstream caravan parks at Lake Conjola on 10 February 2020 (www.sbs.com.au)



Figure 4-18: Flooding of houses in Lake Conjola Village on 10 February 2020 (courtesy of Ms Kristen Bird)

4.5 Dredging within the Entrance Area

4.5.1 General

Two dredging campaigns have been carried out in the entrance area of Lake Conjola over the past approximately 20 years; namely, Stage 1 (Interim works) dredging carried out during the period November to December 1999, and dredging carried out for navigation access improvements during the period May to September 2016.

These two dredging campaigns are outlined briefly below, to provide some possible insights for dredging as a potential component of entrance management.

4.5.2 Stage 1 (Interim works) dredging in 1999

These works were a recommendation of the Patterson Britton (1999) Entrance Study. The objectives of the works were to:

- decrease the current (1999) risk of closure of the entrance by storm washover of the spit;
- realign the main ebb tide channel; and,
- arrest the erosion of the southern shoreline of the entrance area.

The interim works were carried out from November to December 1999. The location of the works are shown in **Figure 4-19** and involved the following main elements:

- realignment of the main ebb tide channel (A) – the channel was dredged through the internal marine sand delta shoals in alignment with the southern boat ramp and the northern entrance channel adjacent to the Cunjurong shoreline. The volume of dredging was approximately 9,500m³;
- dredge material disposal area (B) – a portion of the dredge material was pumped to a disposal area along the southern shoreline, widening and raising this area to a level of 1.0m AHD as an erosion mitigation measure;
- creation of an artificial entrance dune (C) – the entrance sand spit was raised to a crest level of 3.0 to 3.5m AHD with side slopes of 1V:5H over a length of approximately 200m to mitigate storm washover of the spit. Approximately 6,500m³ of sand was incorporated into the dune sourced from dredging of the ebb tide channel; and,
- northern boat ramp access channel (D) – navigation access to the northern boat ramp at Cunjurong Point was improved by dredging a channel between the ramp and the entrance channel.

The dredging in 1999 is considered by the Conjola Community Association to be the main reason why an open entrance in the 'regime entrance state' was sustained for 11 years between 1999 and 2010, and that there was no reported major flooding during this time (CCB, 2017).

As storm washover is a clear mechanism for entrance closure, raising of the sand spit to reduce this process would have been a factor in sustaining an open entrance, noting that during this 11 year period there were two Category 'X' and seven Category 'A' storms and rainfall was generally at or below average (refer **Section 4.2**).

A further contributing factor may also have been cycles of the El Nino and La Nina phases of the Southern Oscillation Index (SOI), as during the early years (1999 and 2000) and the later years (2007, 2008, 2010 and 2011) a La Nina phase occurred which may have influenced entrance open conditions and there was no distinct sustained El Nino phase (refer **Section 4.2**).

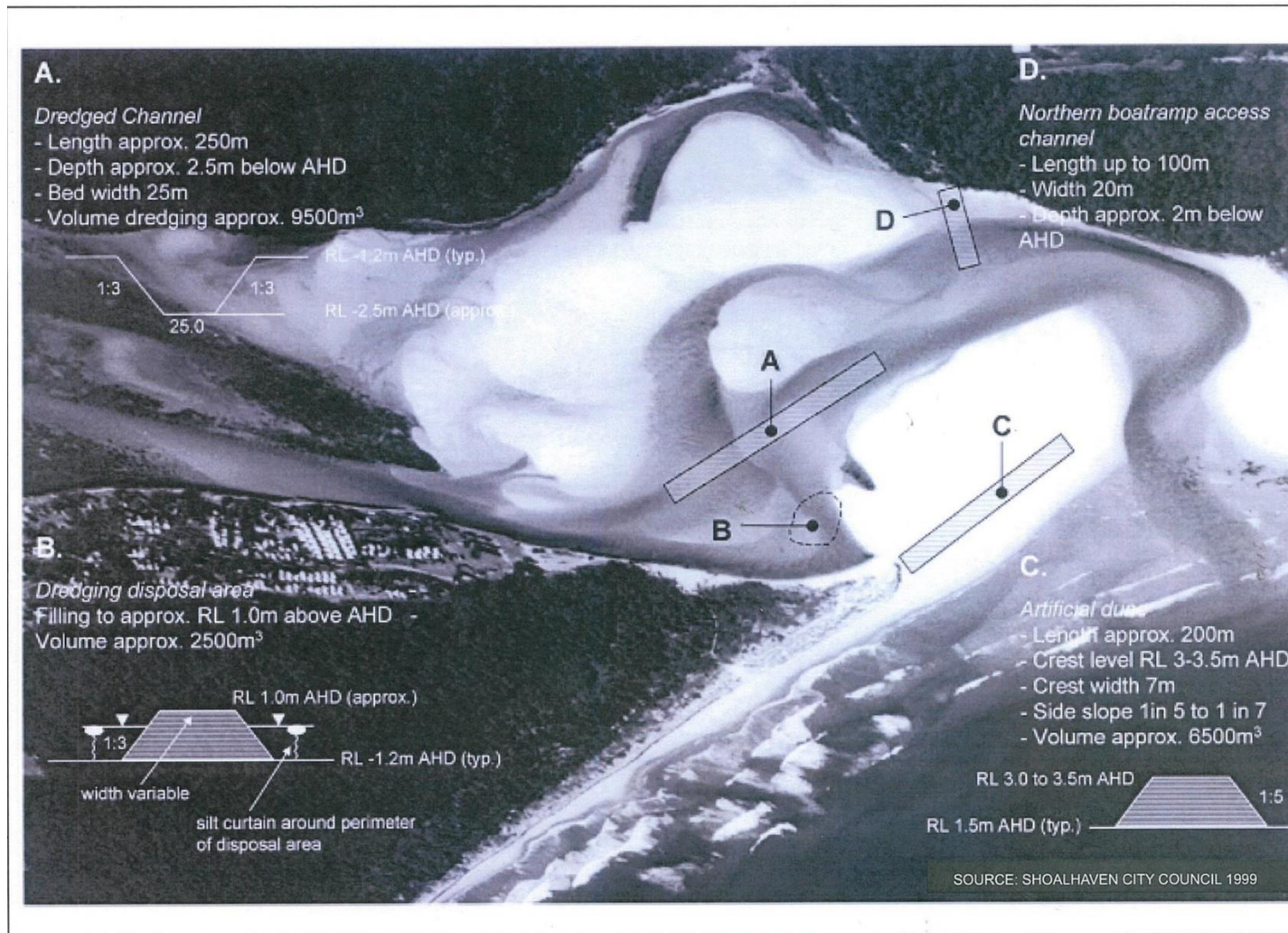


Figure 4-19: Stage 1 (Interim Works) dredging and dredge material disposal November to December 1999

4.5.3 Navigation access dredging in 2016

In response to an increased frequency of lake entrance closures and associated low level flooding events, in 2013 a petition was signed by more than 3,000 local residents and tourists requesting the entrance be dredged again (CCB, 2017). Other affected communities surrounding waterways within the Shoalhaven Local Government Area (LGA) also expressed their concerns regarding the need for dredging and in 2013 Council commissioned the Shoalhaven Citywide Dredging Feasibility Study (Peter Spurway and Associates, 2014).

The local community also successfully sought to have trial configuration dredging included in the Estuary Management Plan Review (GHD, 2015). The aim of the trial dredging was to emulate the natural ebb and flood tide channels in the entrance area in order to maintain a more persistent opening.

NSW Government grant funding was successfully sought by Council under the 'Rescuing our Waterways' program for Citywide dredging, including Lake Conjola. However, in order to satisfy program funding criteria, the original aim of the trial dredging in Lake Conjola was altered to that of improving navigation access to the Cunjurong boat ramp.

It is noted that despite a major flood event occurring in August 2015 to open the entrance (refer **Section 4.3.3**) the entrance was closed again prior to dredging commencing in May 2016. Dredging was completed in September 2016. A rainfall event in June 2016 opened the entrance and the entrance remained open until April 2018 (refer **Table 4-1**).

The dredging plan and typical section is shown in **Figure 4-20**. According to CCB (2017), a total of approximately 20,000m³ of sand was dredged for the channel improvements, with approximately 13,500m³ placed along the southern shoreline to address erosion and form a beach, and approximately 6,500m³ exported to various sites within the LGA for beneficial reuse including nourishment of Mollymook Beach north of Blackwater Creek.

Figure 4-21 and **Figure 4-22** show images of the dredging in 2016.

In October 2016 and August 2017, the Conjola Community Association (CCB) conducted two audits into the outcomes of the dredging, evaluating the outcomes in relation to the eight management areas of the Estuary Management Plan (Shoalhaven City Council, 1998) and the eight management areas of the Interim Entrance Management Policy (GHD, 2013), as described in CCB (2017).

In both audits the CCB reported notable improvements in those areas of most concern to the community; namely, water quality, biodiversity, flood mitigation and an open entrance, among other things. The audits did reveal restricted tidal access through the dredged northerly navigation channel, a gradual constriction of the channel width, and erosion of the adjacent foreshore. It should be noted that the audits were undertaken independently by CCB and the methodology and outcomes of the audits were not verified or confirmed by Council.

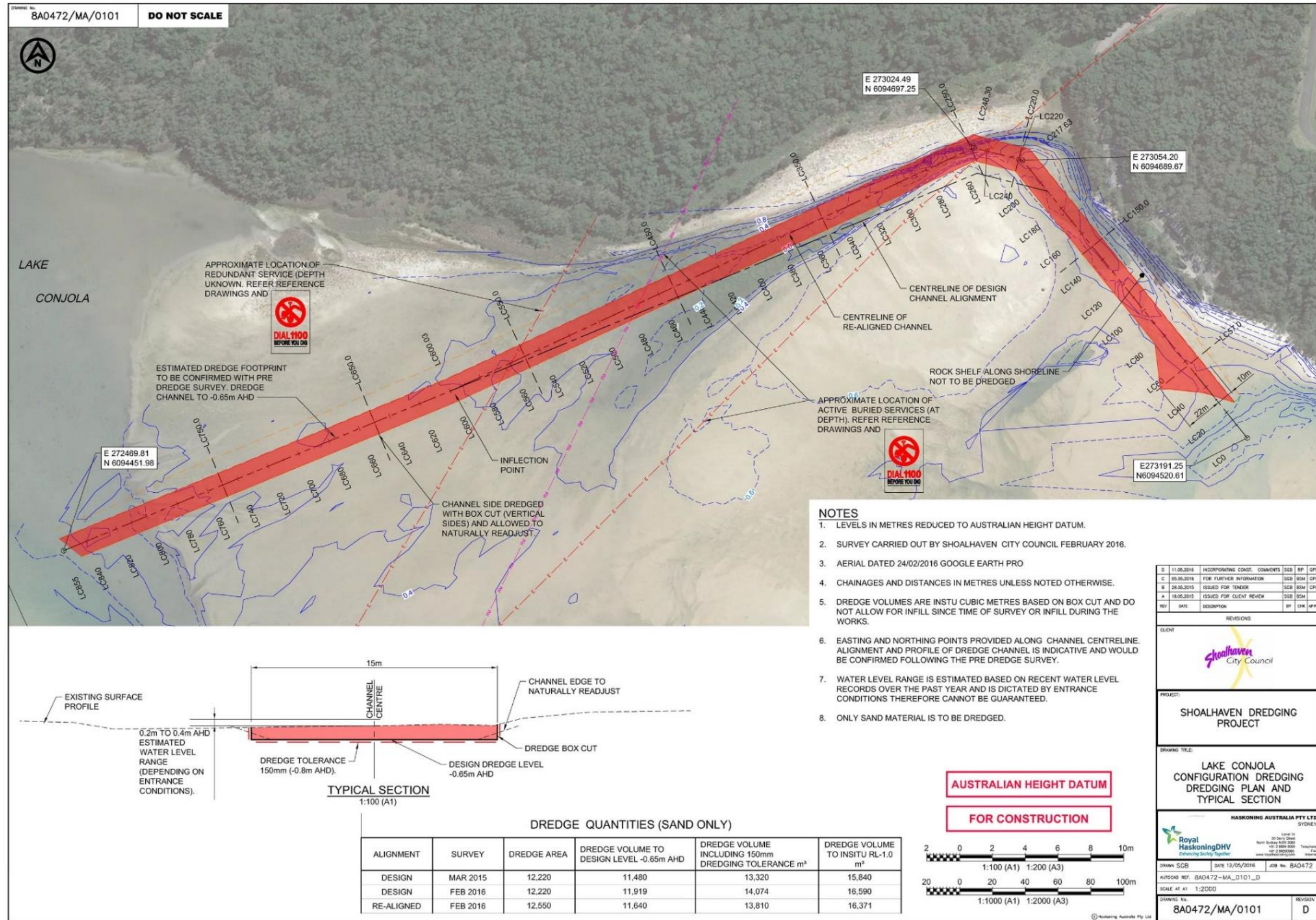


Figure 4-20: Dredging plan and typical section for navigation access dredging in 2016



Figure 4-21: View looking westwards over the entrance area showing the dredged channel in the background and natural channel in the foreground (CCB, 2017)



Figure 4-22: View of the sand placement area along the southern shoreline

5 Consideration of Entrance Management Options for Assessment in Stage 3 of the CMP

5.1 General

It is evident from the discussion in **Section 3** and an understanding of physical processes in the entrance area that:

- Government Departments would not support any entrance management policy or need for entrance works based around water quality triggers except in exceptional circumstances. Studies carried out as part of this CMP also indicate that lake water quality should not be considered a driver for mechanical intervention at the entrance in normal circumstances (refer Stage 2 Report B RHDHV, 2022). Managing the risk associated with flooding is the primary reason for entrance management; and,
- the condition of the entrance is dependent on the interaction of a range of natural physical processes which cannot be controlled, e.g. tides, wave action, rainfall, and beach rotation. On the basis of the lake entrance being managed with as minimal interference to natural processes as practicable, consistent with the NSW Government position, it can be expected there will be occasions when the entrance will close. Historical records have shown that complete closure of the entrance to Lake Conjola occurs on average for about 12% to 15% of the time which is a relatively low percentage of time in comparison to other NSW ICOLLs, e.g. Narrabeen Lagoon entrance which is closed a minimum of approximately 25% of the time and is more actively managed (refer **Section 2.5.4**).

It is also evident that there are differing views in the relation to a number of key influencing factors for any mechanical intervention at the entrance, including:

- trigger lake water level for mechanical opening;
- location of any pilot channel or dry notch;
- dimensions of any pilot channel or dry notch; and,
- timing of a mechanical breakout relative to ocean tide.

A discussion of these influencing factors is included in **Section 5.2**.

The options for management of the entrance to Lake Conjola are considered to fall into four categories involving progressively greater intervention, as summarised below. Further details are set out in **Section 5.3**:

- Category 1: The entrance area is allowed to behave naturally. Mechanical intervention in the form of excavation of a pilot channel occurs only in response to certain triggers. This is essentially a continuation of the current approach taken in the Interim Entrance Management Policy (GHD, 2013) and the Five Year Crown Lands Licence to Open Lake Conjola (Crown Lands, 2021), although noting the trigger water levels differ between the Policy and the Licence and the Licence includes a water quality trigger in addition to water level triggers;
- Category 2: The entrance area is managed by way of a dry notch approach whereby the sand levels in the entrance area (above water level) are regularly mechanically groomed to facilitate an easier mechanical opening when required, i.e. less excavation is necessary to open the lake when

trigger levels are met. For reasons noted in **Section 5.3**, it is considered that excavation of a pilot channel would still form part of the general dry notch approach;

- Category 3: The entrance area is managed by way of occasional dredging whereby a channel is sustained in the position of the natural ebb tide channel, aligned behind the sand spit and directed towards the Cunjurong shoreline. Excavation of a pilot channel would also form part of this approach. It could also be combined with maintenance of a dry notch.

The required frequency of the occasional dredging would be subject to further consideration in Stage 3 of the CMP but based on review of past entrance behaviour, would be expected to be in the order of every 10 years or so on average.

The approach is a modification of the 'managed entrance' option considered in Patterson Britton (1999); the difference being that in that option the aim was to keep the entrance permanently open (the imperative at that time) whereas in the modified managed entrance approach it is accepted the aim is just to try and keep the entrance open for longer on average and avoid loss of the ebb tide channel which would necessitate a much longer pilot channel (impacting adversely on the timing of a response and effectiveness of a mechanical breakout, hence flood risk). A loss of a distinct ebb tide channel due to storm washover deposits followed by build up of the surface level of the deposits under wind action has occurred in the past as indicated in **Figure 5-1**; and,

- Category 4: Engineering works are constructed in the entrance area, such as entrance breakwaters, to create a permanently open entrance, in which case there would be no requirement for a pilot channel³³.

³³ For a combination of reasons (to be subsequently explained) this category of entrance management options is not considered appropriate. It has been included as agreed with Council and DPE to 'book end' the range of possible entrance management options and to enable demonstration of the consequences of a permanent entrance. The option has been raised a number of times at community forums and on social media.



Figure 5-1: Loss of distinct ebb tide channel due to storm washover – September 2011 (top) and September 2018 (bottom)

5.2 Key Influencing Factors

The key influencing factors listed in **Section 5.1** are discussed below with a view to establishing suitable values for numerical modelling of options.

The modelling scope for the CMP required building and calibrating a three dimensional (3D) hydrodynamic model to help assess entrance management options. The model was to be capable of allowing assessment of tidal regime changes, tidal flushing and water quality, ecological changes, entrance morphology changes, and impacts on inundation.

5.2.1 Trigger lake water level for mechanical opening

Pilot channel

The Interim Entrance Management Policy (GHD, 2013) sets a trigger level for a planned opening at 1.0m AHD and a trigger level for an emergency opening at 1.2m AHD (refer **Table 3-1**).

The Five Year Crown Lands Licence to Open Lake Conjola (Crown Lands, 2021) sets trigger levels as low as 0.8m AHD in the case of the 'prolonged low-level inundation' scenario (refer **Table 3-3**).

Sections of the community have advocated for a trigger level of 0.8m AHD (refer **Section 3.5**).

For purposes of modelling the effectiveness of a mechanical breakout via a pilot channel, it is proposed that the following lake trigger levels be considered:

- 0.8m AHD;
- 1.0m AHD;
- 1.2m AHD; and,
- 2.0m AHD³⁴.

It is necessary to adopt a general berm level in conjunction with the lake water level and pilot channel dimensions. Based on available survey data when the lake entrance is closed, a berm level of 2m AHD has been adopted.

Dry Notch

DPIE-BCD and DPI Fisheries have noted their support for a dry notch providing its level is not lower than 1.0m AHD. DPI Fisheries have added that the berm level seaward of the notch could be lowered to 1.2m AHD ahead of predicted heavy rainfall to improve emergency preparedness and reduce flood risk.

The lake trigger levels of 0.8m AHD and 1.0m AHD referred to above would not initiate a breakout for a dry notch level of 1.0m AHD. For this reason, and others (refer **Section 5.3**), it is considered that a pilot channel would need to form part of a general dry notch approach. Accordingly, it is proposed to consider the same lake trigger levels for the dry notch as for the pilot channel discussion above.

5.2.2 Location of any pilot channel or dry notch

The operational details included in Appendix C of the Interim Entrance Management Policy (GHD, 2013) noted that any pilot channel should be located in either the mid spit or northern spit zones (within the period April to August inclusive – outside shorebird nesting season) or the northern spit zone only (within the period September to March – during shorebird nesting season) (refer **Figure 3-2**).

Patterson Britton (1999), based on entrance process studies and investigation of the causes of past entrance closures, considered that the channel should be located towards the north on the basis that:

³⁴ The value of 2.0m AHD represents a water level that could be reached naturally if the lake is not opened to manage inundation impacts on built assets. It has also been adopted in consultation with Council and DPE to fully explore the sensitivity of head difference between the lake and ocean on the effectiveness of a mechanical breakout.

- the northern foreshore has least exposure to wave energy because of the Green Island wave shadow and the wave energy dissipation caused by the nearby nearshore shoals; and,
- a channel in the north represented a steady end state (regime state) that the entrance naturally and gradually establishes in the absence of any sudden changes caused by major floods and storms (refer **Figure 2-8**).

The REF prepared by Council in support of the application for a five year licence from Crown Lands, dated 17 May 2021, in reference to the location of a dry notch in **Appendix C**, indicated a location in the north but this was based on the condition of the entrance in a survey dated 3 March 2019. The expectation was that the location of a dry notch would vary and would be in accordance with the location of a pilot channel in either the mid spit or northern spit as per the Interim Entrance Management Policy (GHD, 2013) (refer **Figure 3-2**).

In practice, it is likely a dry notch would need to be located in the northern spit zone if it had to be regularly maintained, due to the issue of disturbance to threatened shorebird species.

The location of the dry notch would affect the length of a pilot channel, e.g. if the dry notch had to be located in the northern spit due to the shorebird nesting season for threatened shorebird species and the internal channel within the lake to which the pilot channel had to connect was 'stranded' well to the south by entrance infilling due to storm washover, the excavated channel would be 'long'.

For modelling purposes, it is proposed to consider a pilot channel (no dry notch) in either the mid spit zone or the northern zone, and a dry notch plus pilot channel in the northern spit zone only.

5.2.3 Dimensions of any pilot channel or dry notch

Pilot channel

The operational details included in Appendix C of the Interim Entrance Management Policy (GHD, 2013) showed an indicative pilot channel having a width of 10m and variable depth, and a minimum width and depth of 5m and 1m respectively (refer **Figure 3-2**).

Patterson Britton (1999) found that the pilot channel width and depth for an effective breakout was dependent on the width of the entrance berm (or in other words the length of the channel). For example, for a pilot channel 200m long, the width of the pilot channel would need to be no smaller than about 10m wide and have a bed level at 0m AHD, assuming a lake water level at breakout of 1.0m AHD.

For modelling purposes, it is proposed to consider pilot channel widths of 5m and 10m, and a bed level of nominally 0m AHD near the inlet (upstream end) of the pilot channel. There is also a practical limit on the initial width of the pilot channel that can be simulated in the numerical model, due to model run times. This has influenced the adopted minimum width of 5m. This width can either be thought of as the initial width established by the excavator or the width shortly after commencement of the breakout flow when some scour (slumping) of the channel banks has occurred.

Dry notch

The REF prepared by Council in support of the application for a five year licence from Crown Lands, dated 17 May 2021, in reference to the width of a notch in Appendix C, indicated a width of 20m if located in the central spit and a width of 50m if located in the northern spit.

It is noted that the width of the dry notch maintained at the entrance to the Shoalhaven River for flood mitigation purposes is 50m (Shoalhaven City Council, 2006).

For modelling purposes, it is proposed to consider a width for a dry notch of 50m and a minimum surface level of 1.0m AHD in accordance with the advice of DPIE-BCD and DPI Fisheries (refer **Section 3.6.3**). A surface level for the notch of 1.2m AHD would also be considered.

5.2.4 Timing of a mechanical opening relative to ocean tide

Patterson Britton (1999) investigated the timing of the 'point of breakout' relative to the phase of the ocean tide. The 'point of breakout' was defined as the time at which the breakout channel is scouring vertically and horizontally at its greatest rate.

It was concluded that for maximum effectiveness (scouring) of the breakout channel the 'point of breakout' should coincide with ocean low tide, based on a pilot channel length of 200m and width of 10m. In practice, this generally means an initiation of the mechanical opening (commencement of the breakout flow) at around ocean high tide.

It is understood that the intention of Council is to initiate the mechanical opening around ocean high tide, subject to other factors such as safety of operations on the beach, as in practice this has generally proven to be the most effective from an ocean tide phasing perspective, i.e. provides a well scoured entrance and longer period of open entrance conditions.

For modelling purposes, it is proposed to primarily initiate mechanical opening at ocean high tide, but also consider a few variations to test the sensitivity of the breakout to different timing relative to ocean tide. For example, initiation of an opening at ocean mid tide falling, ocean mid tide rising, and ocean low tide, would be considered.

In practice, predicted ocean tides can be affected by tidal anomalies such as storm surge and wave setup from large swell conditions can also increase ocean water levels, so it is important in the execution of a mechanical opening to monitor the actual ocean tide and wave conditions.

5.3 Summary of Management Options for Assessment

The following sections summarise the entrance management options proposed to be considered under each of the four categories referred to in **Section 5.1**, including the values proposed to be adopted in the numerical modelling for the key influencing factors. Some preliminary modelling results are also presented for the Category 4 permanent entrance channel in **Section 5.3.4**.

5.3.1 Category 1 options – natural entrance behaviour (pilot channel)

As noted earlier, in this category the entrance area is allowed to behave naturally. Mechanical intervention in the form of excavation of a pilot channel occurs only in response to certain triggers.

The proposed modelling parameters are summarised in **Table 5-1**.

Table 5-1: Modelling parameters for Category 1 entrance management options

Modelling Parameter	Values
lake water level triggers	0.8, 1.0, 1.2 and 2.0m AHD
berm level at entrance	2m AHD
location of pilot channel	mid spit and northern spit zones
length of pilot channel	50m, 100m, 200m and 300m
width of pilot channel	5m and 10m
bed level of pilot channel	0m AHD
timing of initiation of mechanical opening	ocean high tide primarily but with some sensitivity testing

Figure 5-2 shows the proposed positions for modelling of the pilot channels in the mid spit zone and in the northern spit zone. The northern extent of the pilot channel in the northern spit zone corresponds to the location of exposed bedrock in the seabed profile. It is considered unlikely the pilot channel would be excavated further to the north.

The lengths of the pilot channels are annotated commencing from a 2m AHD contour along the beach determined from a 2018 survey when the entrance was closed. The air photo included in **Figure 5-2** as a base is dated 24 February 2016 and depicts an open entrance in a Regime state (refer **Section 2.5.2**). The air photo is included for context and scale only.

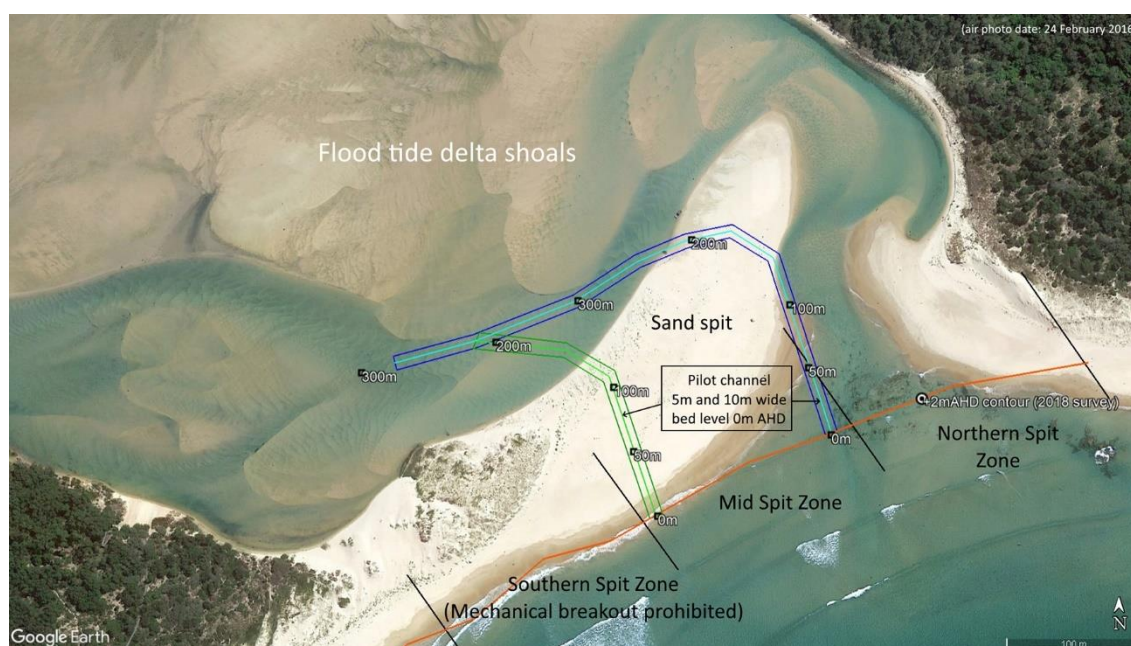


Figure 5-2: Diagram summarising modelling approach for Category 1 entrance management options

5.3.2 Category 2 options – dry notch (with pilot channel)

As noted earlier, in this category the entrance area is managed by way of a dry notch approach whereby the sand levels in the entrance area (above water level) are regularly groomed to facilitate a mechanical opening. The approach would be similar to that adopted at the entrance to the Shoalhaven River for flood mitigation purposes at Shoalhaven Heads (Shoalhaven City Council, 2006).

It is of interest to note that in the case of the dry notch at the entrance to the Shoalhaven River the original Public Works Department (PWD) concept that the notch (weir) would be breached when it was overtopped with flood waters, i.e. without mechanical intervention, did not prove to be practical. Mechanical opening came to be advantageous and is the current practice for a number of reasons, for example (Shoalhaven City Council, 2006):

- the location of the entrance breach can be controlled;
- the level of the berm on the seaward side of the maintained notch level can naturally rise and fall over short time periods in response to sea conditions and it is not practical or desirable to attempt to maintain this berm crest at the same (lower) level as the notch. Hence, mechanical intervention is required to remove the higher seaward berm;
- the notch behind the higher berm may be infilled by unfavourable weather/sea conditions just prior to a flood, despite a monitoring and notch maintenance strategy; and,
- there may be, in certain circumstances, advantages in terms of reducing flood impacts and improving operator safety if the entrance is opened at a lower river level than the maintained notch level.

Accordingly, mechanical opening of Lake Conjola including excavation of a pilot channel would be the practical expectation for a dry notch management approach.

The proposed modelling parameters are summarised in **Table 5-2**.

Table 5-2: Modelling parameters for Category 2 entrance management options

Modelling Parameter	Values
lake water level triggers	0.8, 1.0, 1.2 and 2.0m AHD
berm level at entrance	• notch area, 1.0 and 1.2m AHD • seaward of notch, 2.0m AHD (assumed to have been removed to 1.0m AHD at initiation of the mechanical opening)
location of pilot channel	northern spit zone
length of pilot channel	50m, 100m, 200m and 300m
width of dry notch	50m
width of pilot channel	5m and 10m
bed level of pilot channel	0m AHD
timing of initiation of mechanical opening	ocean high tide primarily but with some sensitivity testing

Figure 5-3 shows the proposed position for modelling of the pilot channel and notch, located in the northern spit zone only (same position as northern pilot channel in **Figure 5-2**). In this case, for illustration, the base for the figure is the bathymetry (bed level) file in the numerical model. The bed level is colour coded relative to AHD.

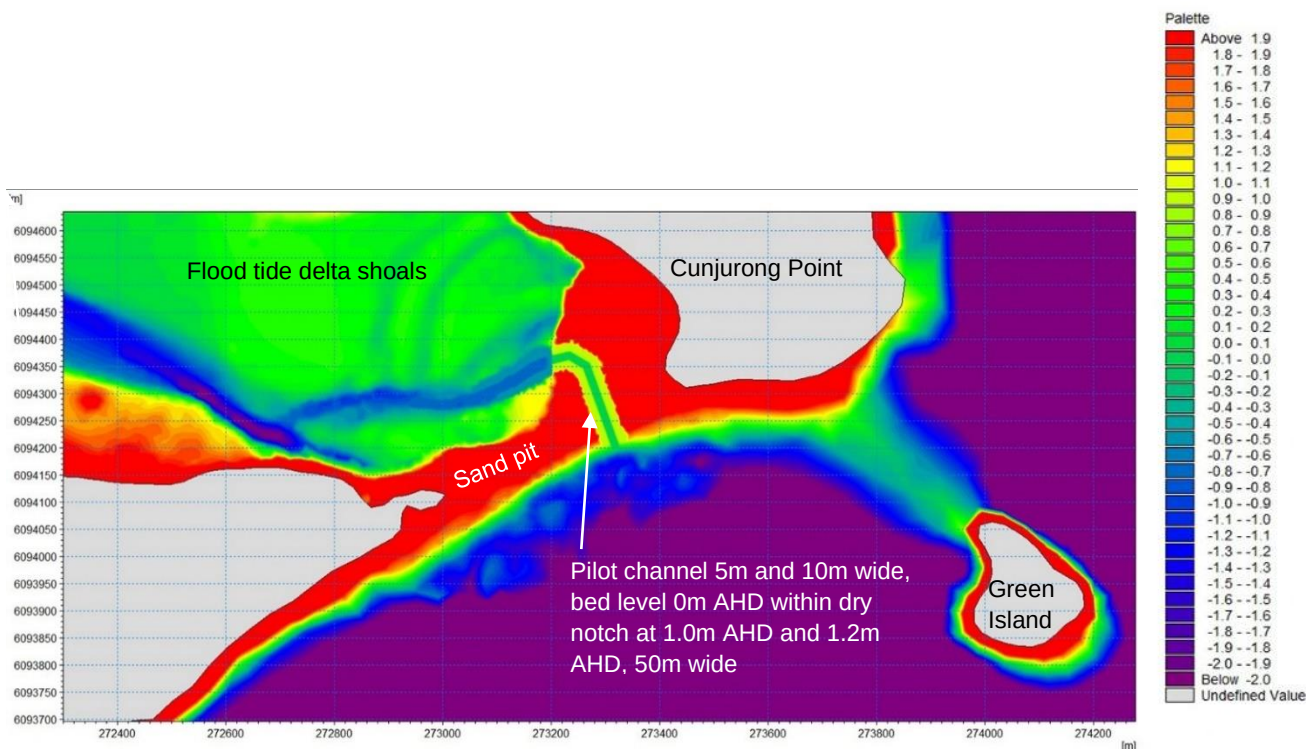


Figure 5-3: Diagram summarising modelling approach for Category 2 entrance management options

From a modelling perspective, the only significant difference between the Category 2 and Category 1 options is the elevation level of the berm in Category 2 (1.0 and 1.2m AHD) versus Category 1 (2.0m AHD).

In practice, the dry notch approach would involve less excavation to create the pilot channel, hence the ability to achieve a more rapid response to initiation of a mechanical opening to mitigate the flood risk, all other things being equal. Operator safety would also be improved due to less time required on the beach.

5.3.3 Category 3 options – modified ‘managed entrance’ (pilot channel)

As noted earlier, in this category the entrance area is managed by way of occasional dredging whereby a channel is sustained in the position of the natural ebb tide channel, aligned behind the sand spit and directed towards the Cunjurong shoreline.

Since it is not possible to ensure the entrance never closes, a pilot channel would also form part of this approach.

From a modelling perspective, the only significant difference between the Category 3 and the Category 1 options is the length of the pilot channel, since, if the ebb tide channel behind the spit is sustained, it

should be possible to avoid the need on occasions for excavation of a 'long' pilot channel. For this reason, the maximum length of pilot channel proposed to be modelled is 150m.

In practice, the occasional dredging of the ebb tide channel would involve less excavation of the pilot channel than for Category 1 options, on those occasions when otherwise for Category 1 options the channel would be 'long'. Hence on such occasions there could be a more rapid response to initiation of a mechanical opening to mitigate the flood risk, all other things being equal.

It would also be possible to combine the Category 3 options (occasional dredging of the ebb tide channel) with the Category 2 options (dry notch), but that is not considered at this stage.

The proposed modelling parameters are summarised in **Table 5-3**.

Table 5-3: Modelling parameters for Category 3 entrance management options

Modelling Parameter	Values
lake water level triggers	0.8, 1.0, 1.2 and 2.0m AHD
berm level at entrance	2m AHD
location of pilot channel	mid spit and northern spit zones
length of pilot channel	50m, 100m and 150m
width of pilot channel	5m and 10m
bed level of pilot channel	0m AHD
timing of initiation of mechanical opening	ocean high tide primarily but with some sensitivity testing

The dimensions of the ebb tide channel have been selected to correspond to those evident in a typical Regime entrance state and are as follows:

- channel width : 20m
- channel bed level : -0.8m AHD

Figure 5-4 shows the proposed modelling approach for the Category 3 entrance management options superimposed on the 14 September 2018 aerial photo corresponding to a time when a distinct ebb tide channel did not exist due to storm washover deposits.



Figure 5-4: Diagram summarising modelling approach for Category 3 entrance management options (Air photo date 14 September 2018)

It will also be necessary to consider in Stage 3 of the CMP the method of dredging and the method of disposal of the dredged material. Consideration would be given to both hydraulic and mechanical methods of dredging. Disposal of the dredged material would have regard to beneficial reuse options, such as addressing any foreshore erosion issues within the lake and nourishment of beaches on the adjacent open coast.

5.3.4 Category 4 options – engineering works (permanent channel)

The engineering works at the entrance selected to demonstrate the consequences of a permanent entrance to the lake are twin rock breakwaters similar to that examined in Patterson Britton & Partners (1999), having the following key dimensions:

- entrance channel width : 50m
- entrance channel bed level: -2m AHD

The conceptual arrangement of the twin entrance breakwaters is shown in **Figure 5-5**.

It is noted that this permanent entrance concept is on a lesser scale than the permanent entrance opening adopted in BMT WBM (2013a) as a possible flood mitigation option. In that study an entrance channel width of 125m and entrance bed level of -4m AHD was adopted.

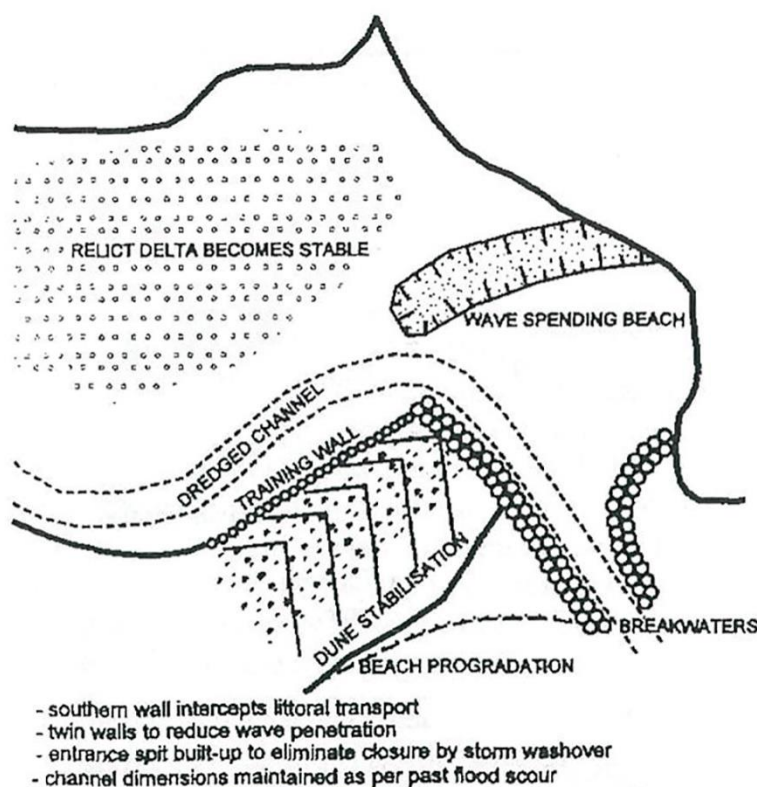


Figure 5-5: Conceptual arrangement of twin entrance breakwaters adopted to demonstrate a permanent entrance channel

Some preliminary modelling of the implications of a permanent entrance channel was carried out as part of Stage 2 of the CMP. The results of the preliminary modelling are shown in **Figure 5-6** in the form of the lake water level response (tidal range) over a six week period of actual ocean tides in June-July 2017. The cross-hatched area indicates the range between high tide and low tide in the lake without a permanent entrance channel. The shaded area indicates the range between high tide and low tide in the lake if a permanent channel is in place having the dimensions referred to above, i.e. channel width 50m and channel bed level -2m AHD.

It is evident from **Figure 5-6** that the effect of a permanent channel would be as follows:

- the tidal range would increase;
- the average water level in the lake would be lower;
- the low tide level would be significantly lower as a consequence of the above factors, by around 0.2m, reducing the water depth at low tide.

The above outcomes are due to the reduction in shallow water effects and reduced friction that result from the deeper permanent channel.

The water level and associated water depth changes in turn would have an impact on ecology and recreation within the lake. These matters would be further assessed in Stage 3 of the CMP.

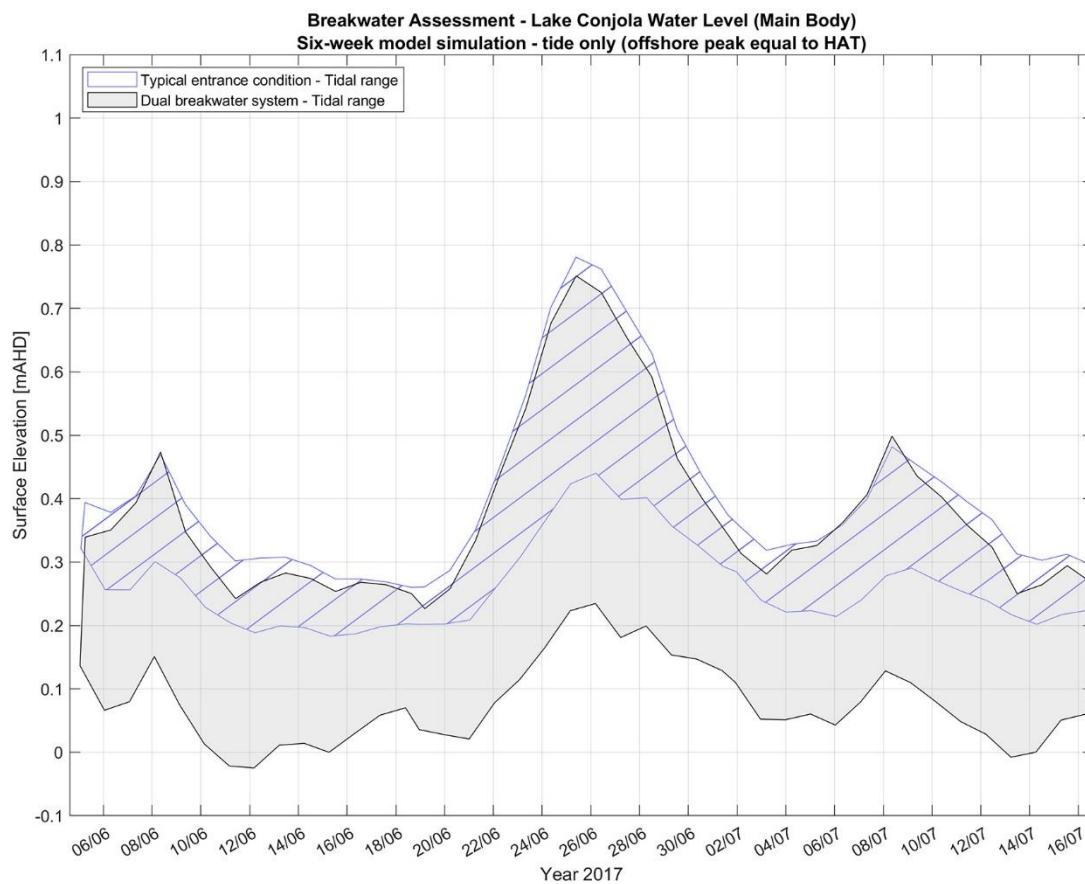


Figure 5-6: Modelled effect of a permanent entrance channel on lake water level

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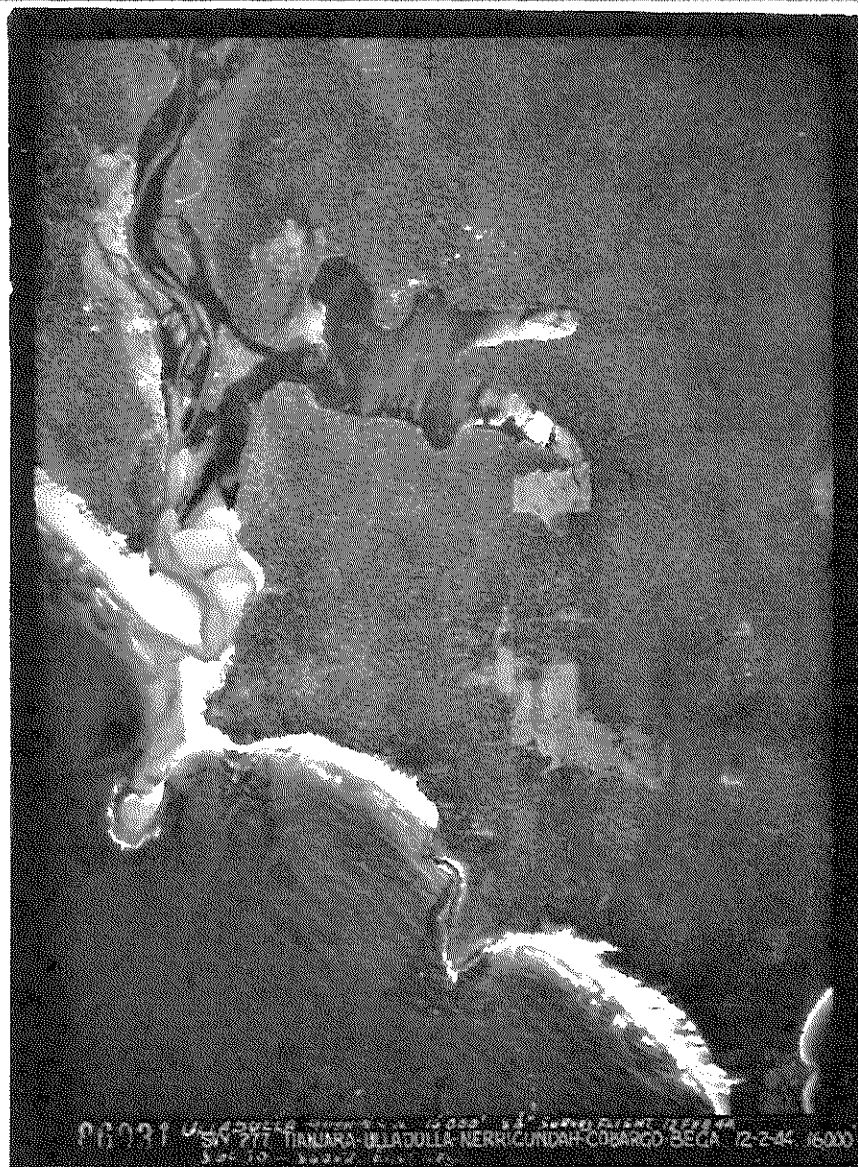
Shoalhaven River Entrance Management Plan for Flood Mitigation

Version: adopted November 2006, SCC File No. 9825

Shoalhaven City Council (2019)

Addendum to Review of Environmental Factors – Lake Conjola Entrance Manual Opening, 6 June 2019

Appendix A – Vertical Aerial Photograph Analysis 1944 to 1997 from Patterson Britton (1999)



- Entrance condition = Intermediate/regime
- 1944 was the driest year on record
- No major storms for 18 months
- Entrance stayed open, slowly migrating to the north
- Relatively small active flood tidal delta

Feb-44 DPIE

open

Vertical

No



- Entrance condition = Heavily shoaled
- Rejuvenated by April & June floods
- April & June storms caused washover deposits
- Entrance channel has migrated north
- More sand in nearshore profile

Mar-45 DPIE

open

Vertical

No

02-1-17 SVY 274 156-18 INDIANILLA 30-3-45 16,000' 51" RESTRICTED



- Entrance condition = Washover/heavily shoaled – entrance almost closed
- Three major storms in 1948
- Substantial storm washover emanated from N to S through tombolo
- December storm almost closed entrance
- Significant accretion along Cunjurong Beach due to storm wave action

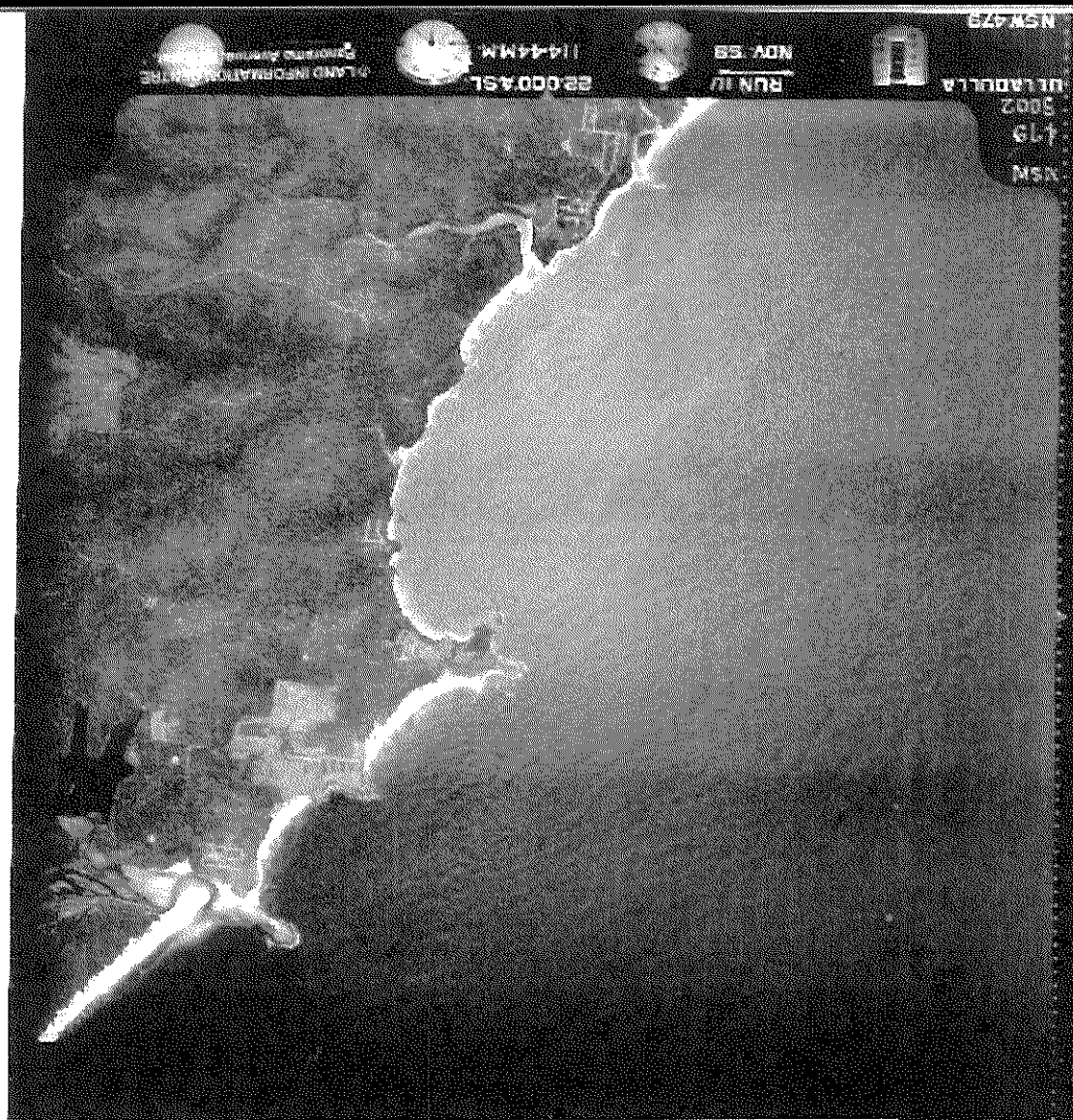
Dec-48 DPE

open

Vertical

No

030 15,000' 2-12-48



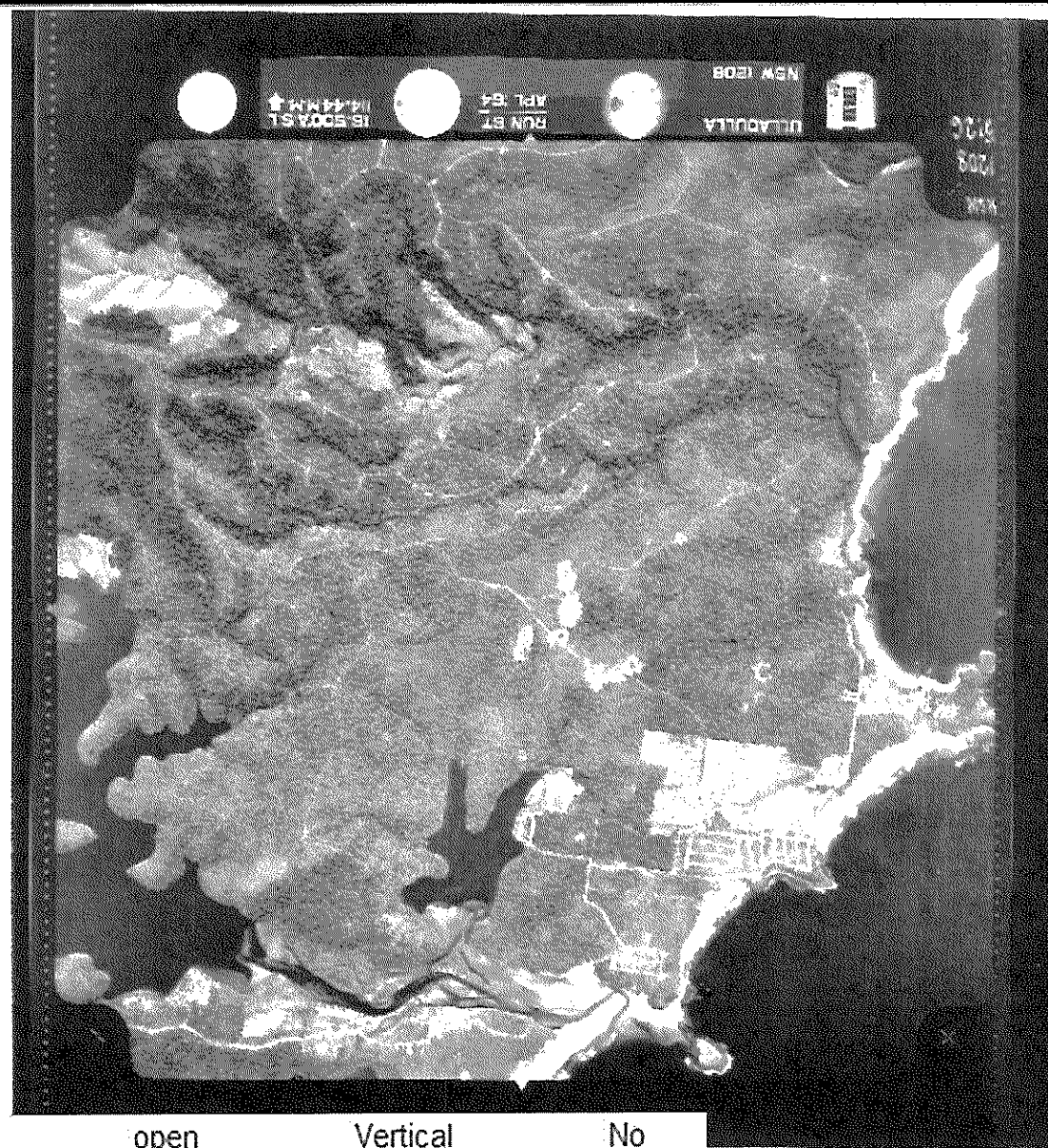
- Entrance condition = Washover/flood scoured
- Three major storms in 1959 created washover deposits
- October flood scoured the entrance
- Flood deposit seen SE of entrance spit

Nov-59 DPE

open

Vertical

No



- Entrance condition = Regime state
- Entrance up against northern side
- Slightly flood scoured after > 300mm rainfall in April
- No major storms

Apr-64 DPE

open

Vertical

No



1967 DPIE

closed

Vertical

no

- Entrance condition = Closed/opened by Council
- Entrance effectively closed by severe May 1966 storm
- Opening attempts by Council on three occasions in 1967
- Minor freshes only
- Remained heavily shoaled/closed until Feb 71 flood



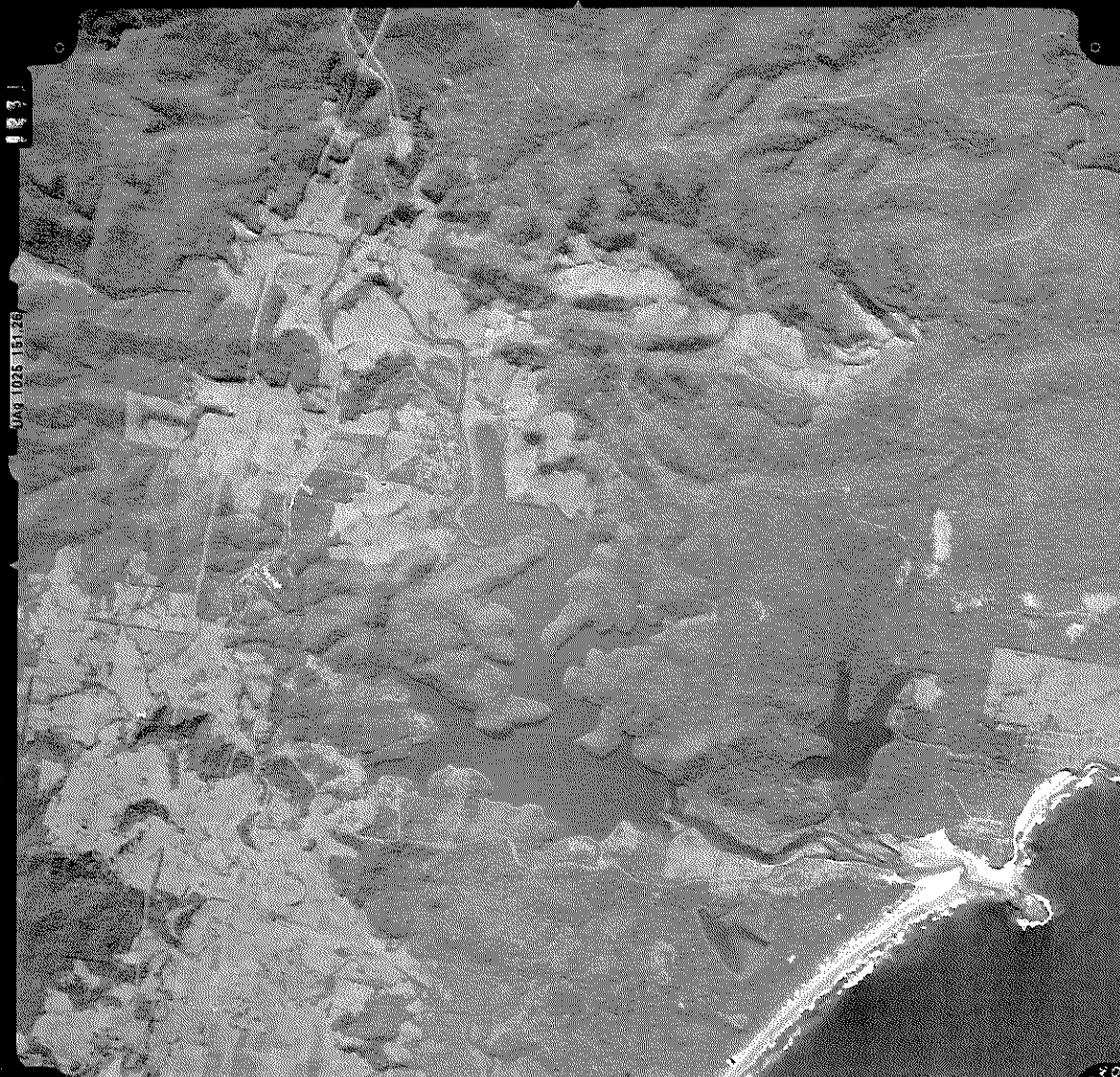
- Entrance condition = Flood scoured
- Major flood in February scoured the entrance
- No major storms in 1971
- Flood deposit SE of entrance spit
- Dune plantings and sand fences evident

Apr-71 DPIE

open

Vertical

No



- Entrance condition = Flood scoured
- Major flood in February scoured the entrance
- No major storms in 1971
- Flood deposit SE of entrance spit
- Longshore transport reworking flood material to the north

1971 DPIE

open

Vertical

no



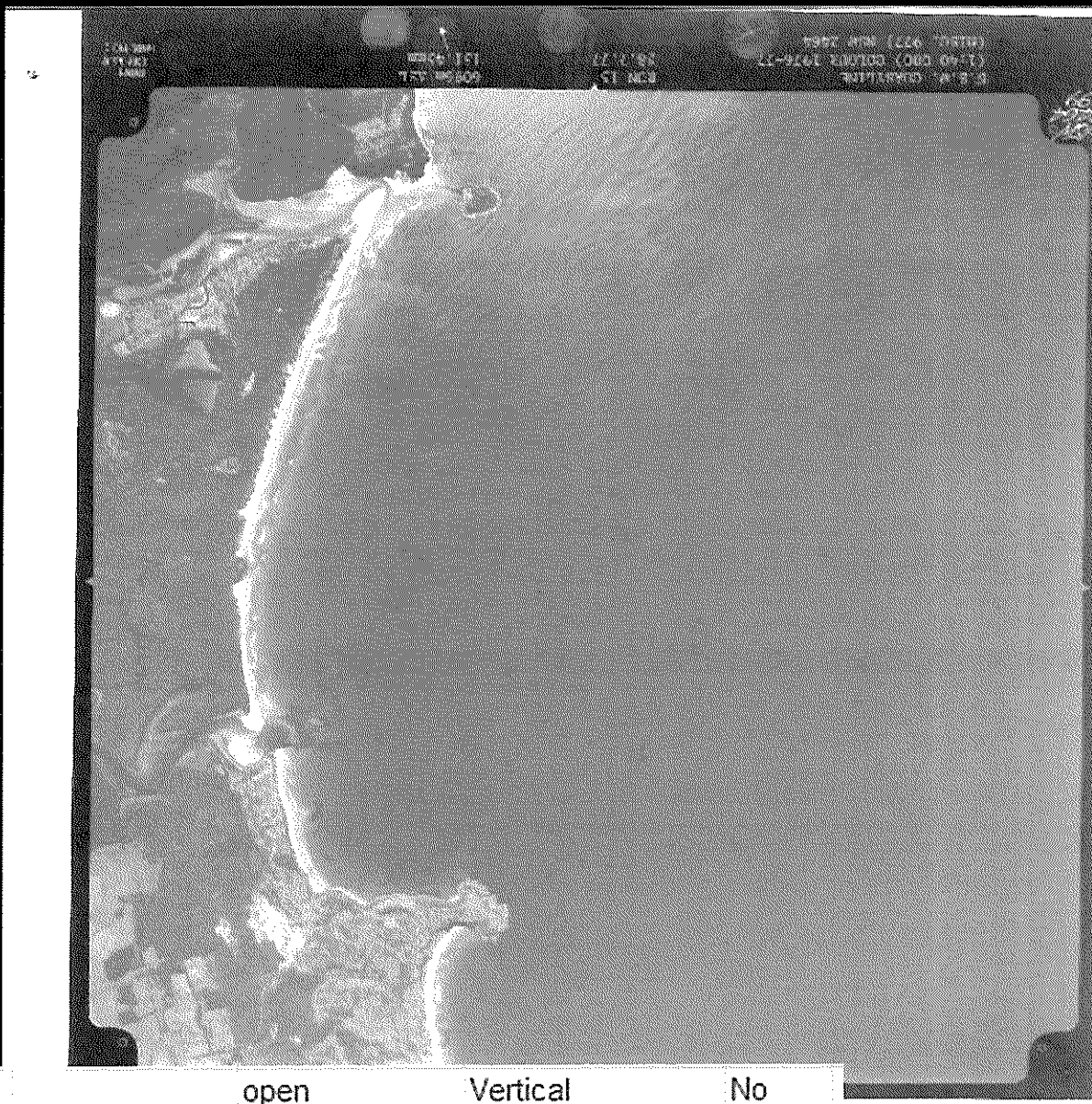
- Entrance condition = Regime state
- Entrance spit prograded north quickly after 1971 flood event
- Narrow entrance channel located to the north
- Very dry year

Jun-72 DPIE

open

Vertical

No



- Entrance condition = Flood scoured, moving towards regime state
- Entrance throat not constricted due to heavy flows

Jul-77 DPIE

open

Vertical

No



- Entrance condition = Intermediate/Regime state
- No major storms
- Entrance throat becoming more constricted
- Freshes maintain regime channel

Jan-79 DPIE

open

Vertical

No

An aerial photograph of a river delta system, likely the Mississippi River Delta. The image shows a complex network of channels and distributaries. A grid of lines is overlaid on the upper portion of the image, possibly for measurement or mapping purposes. The date "JUN 1981" is printed in the top right corner.

JUN 1981

- Entrance condition = Regime state
- No major storms
- Delta infilling – shoals prograding across delta surface
- Freshes maintain regime channel
- Delta build up pinching ebb channel and causing entrance spit to scour



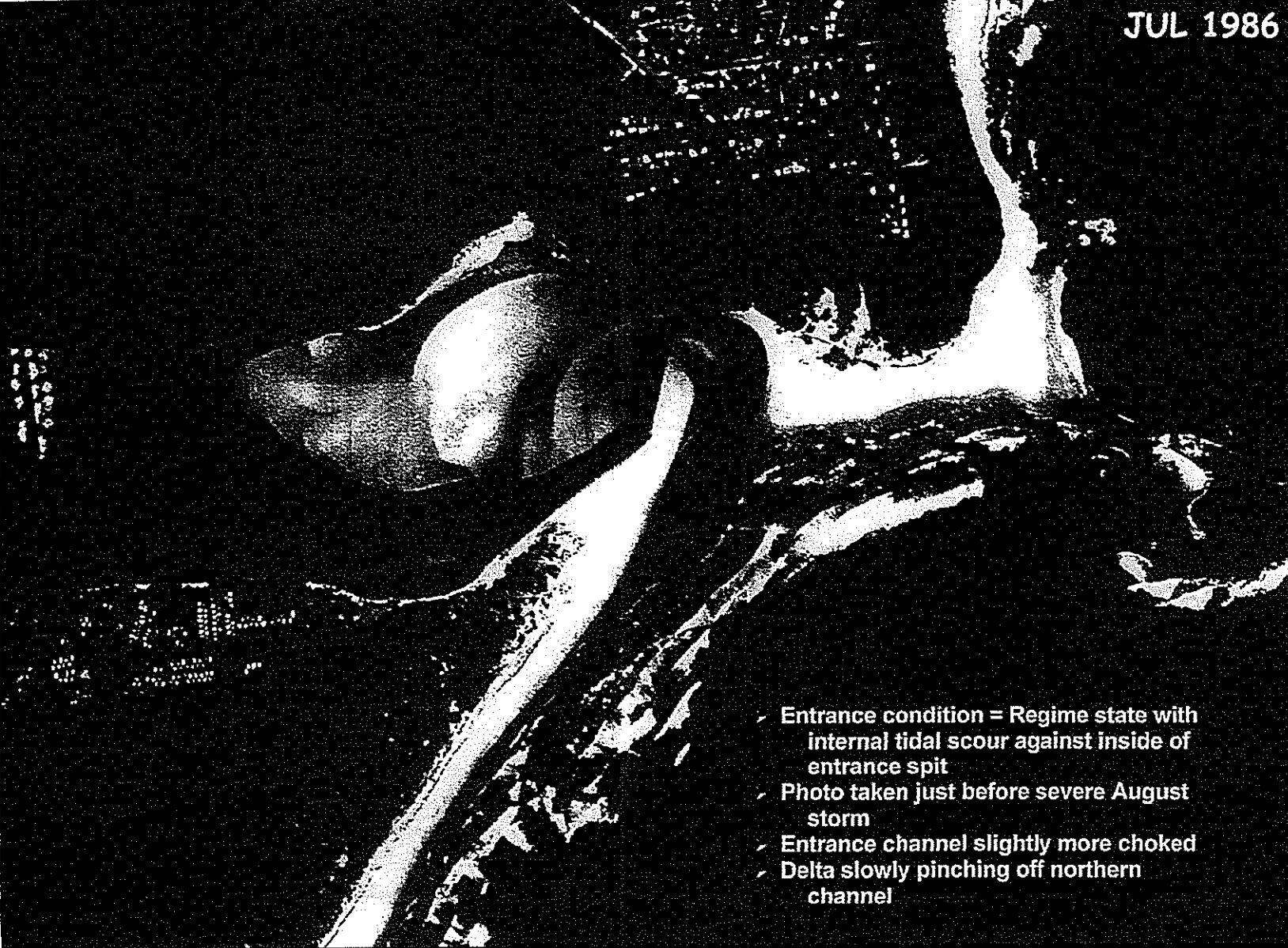
- Entrance condition = Regime state
- Two previous storms in 1984
- Delta continues to infill and pinch flow against inside of entrance spit
- Freshes maintain regime channel

Jan-85 DPIE

open

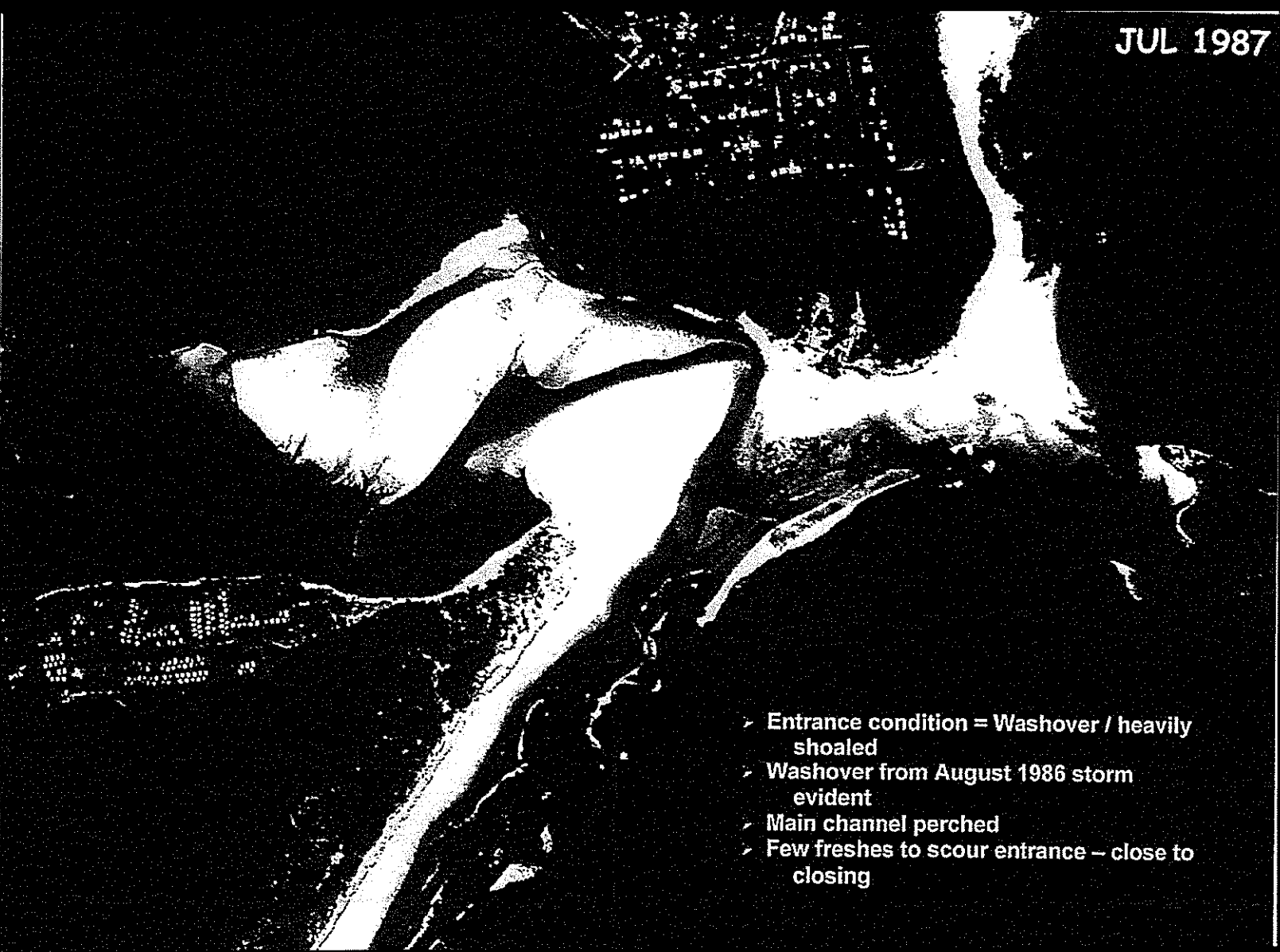
Vertical

No



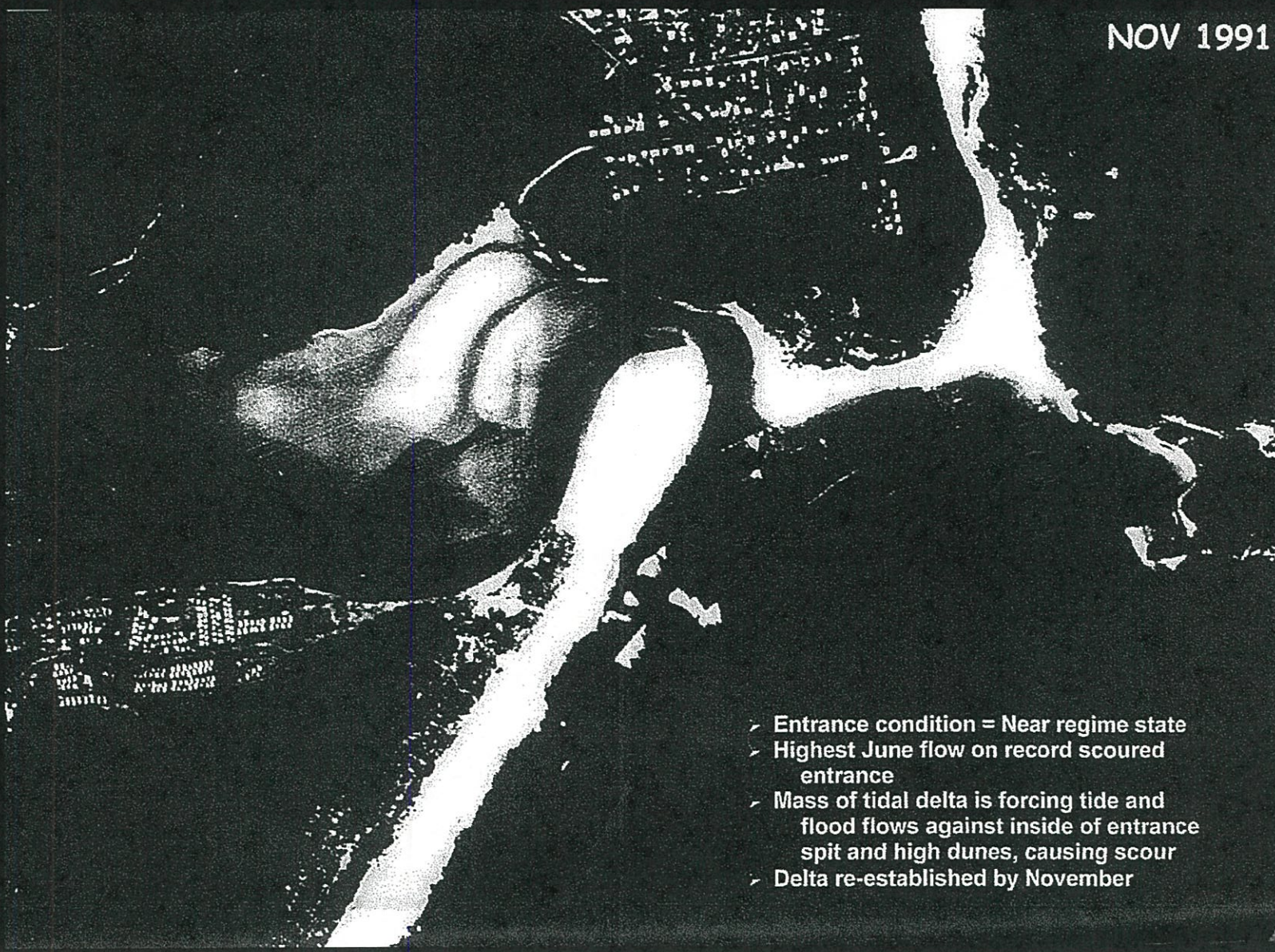
JUL 1986

- Entrance condition = Regime state with internal tidal scour against inside of entrance spit
- Photo taken just before severe August storm
- Entrance channel slightly more choked
- Delta slowly pinching off northern channel



JUL 1987

- Entrance condition = Washover / heavily shoaled
- Washover from August 1986 storm evident
- Main channel perched
- Few freshes to scour entrance – close to closing



NOV 1991

- Entrance condition = Near regime state
- Highest June flow on record scoured entrance
- Mass of tidal delta is forcing tide and flood flows against inside of entrance spit and high dunes, causing scour
- Delta re-established by November



- Entrance condition = Regime state
- Internal tidal scour against high dune
- Regular freshes throughout 1992 and 1993 have kept entrance open
- No major storms

May-93 DPIE

open

Vertical

Yes



- Entrance condition = Closed/Storm washover
- Large washover by March 94 storm blocked main channel and forced perched tidal channel around northern perimeter
- Entrance closed towards end of 94
- Since closure, wind blown sand building up entrance spit
- Severe storms in September 95 and September & November 96 added further washover deposits
- Minor freshes only
- Internal channels heavily shoaled

Jan-97 DPE

closed

Vertical

Yes

- 
- Entrance condition = Opened by Council/storm washover/heavily shoaled
 - Additional severe storm May 1997 resulted in more overwash
 - Minor freshes only
 - Primary channel around perimeter of delta (ie. relict 94 channel)

1997 DPIE

open

Vertical

no

Appendix B – Vertical Aerial Photograph Analysis 1999 to 2021



- Entrance condition = Flood Scoured/Intermediate
- Heavy rainfall January – February 1999 (total 318mm)
- No significant storms since 1996/1997
- Strong recurved spit in centre of entrance area, ebb tide channel well landward

Feb-99 DPIE

open

Vertical

Yes

- Entrance condition = Regime
- Spit growth has extended northwards from February 1999 to April 2001
- Significant rainfall February 2001 (162mm), single storm June 2000



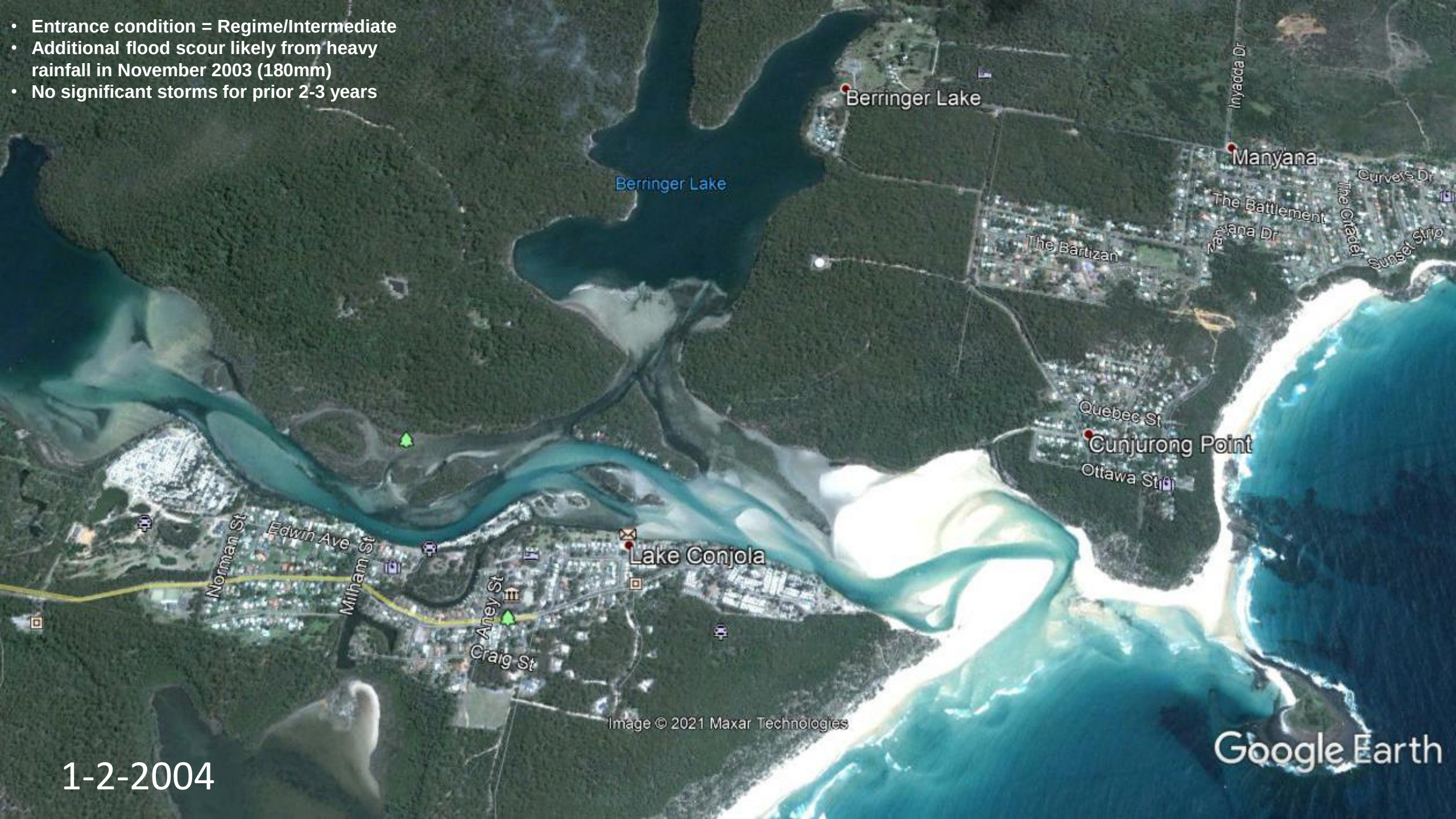
Apr-01 DPIE

open

Vertical

Yes

- Entrance condition = Regime/Intermediate
- Additional flood scour likely from heavy rainfall in November 2003 (180mm)
- No significant storms for prior 2-3 years



1-2-2004

- Entrance condition = Regime/Intermediate
- Similar entrance configuration to that in 1-2-2004 image
- No significant heavy rainfall February – July 2004, or storms



Image © 2021 Maxar Technologies

Google Earth

13-7-2004

-
- COASTAL SURVEILLANCE 2005
STANWELL PARK - BATEMANS BAY
CONJOLA
NSW4893 (M246d)
01-02-05
20:48
- RUN 6
162.75 mm
Approx. Scale
1:12 000
- | | | |
|------|----------|-----|
| open | Vertical | Yes |
|------|----------|-----|

Yes



- Entrance condition = Regime
- Further infill of ebb tide channel apparent
- Three significant storms in 2005 (June, July, November) since image in February 2005, however heavy rainfall in June – July 2006 (total 438mm) and in February 2007 (214mm) would have assisted with keeping entrance open

Mar-07	DPIE		open	Vertical	Yes
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- Entrance condition = Regime
- Two storms occurred in June 2007 but also heavy rainfall in June 2007 (306mm)
- Entrance remained open even though 2008 and 2009 were below average rainfall years, possibly due to absence of storms after June 2007

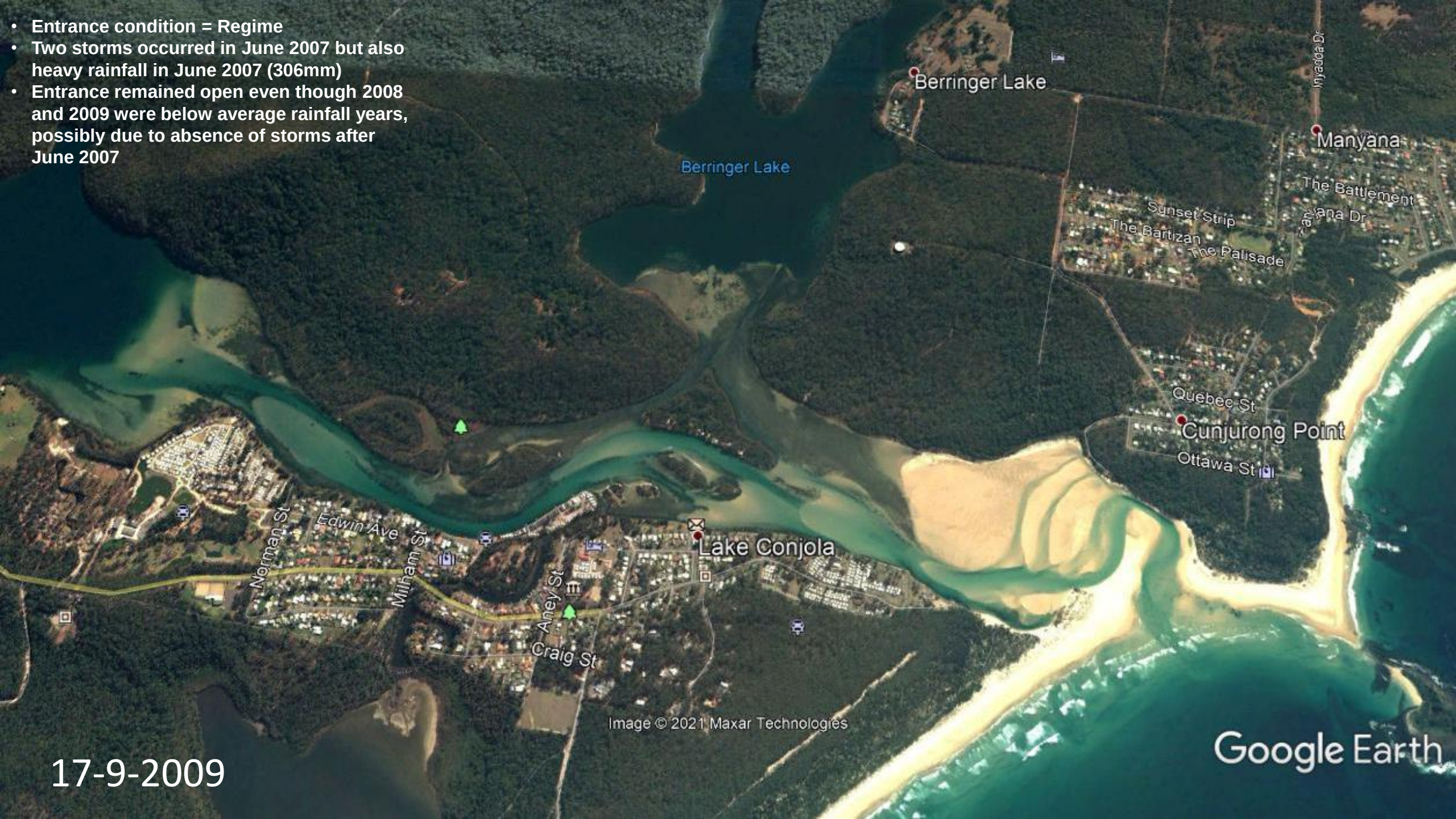
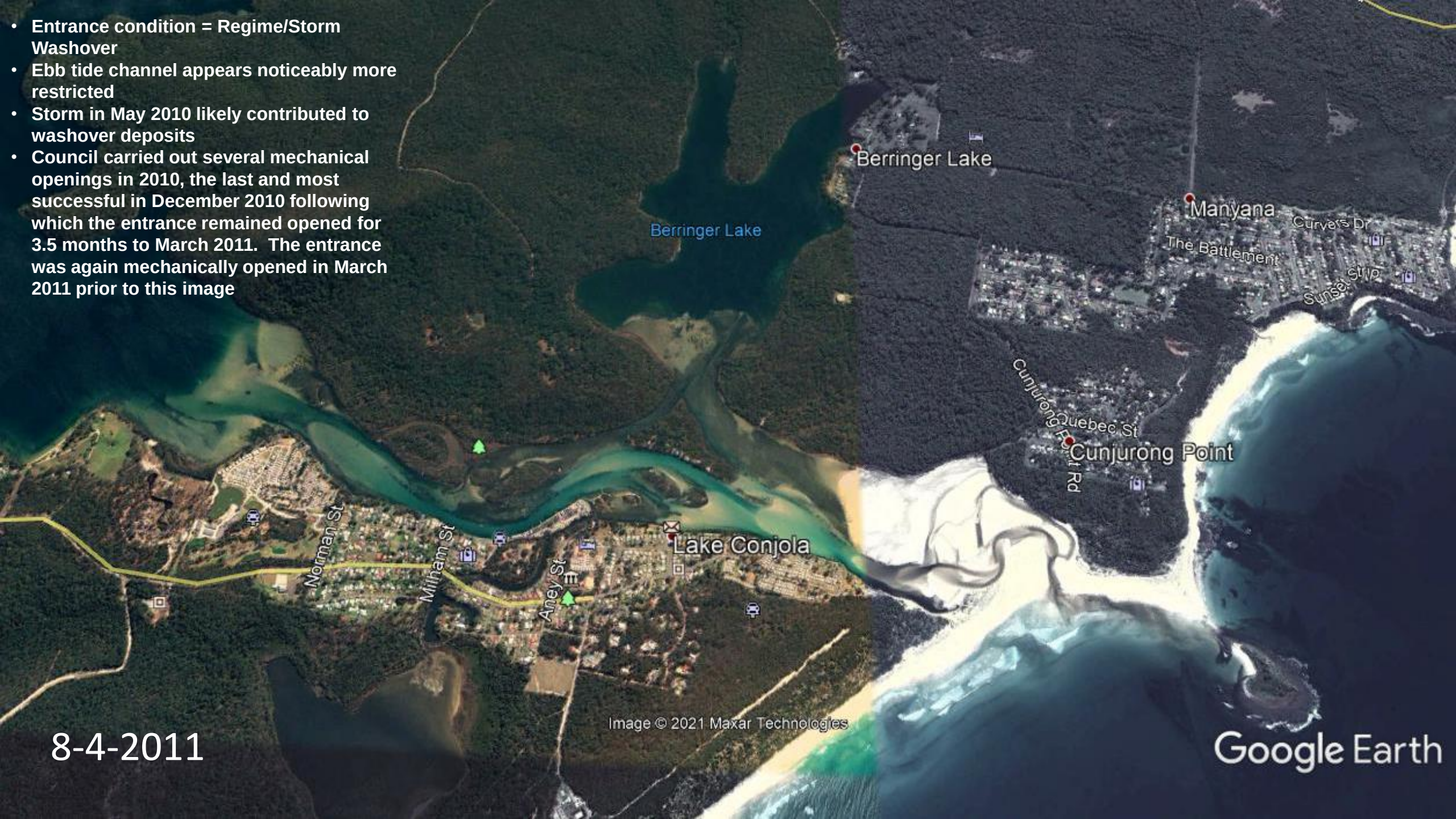


Image © 2021 Maxar Technologies

Google Earth

17-9-2009

- Entrance condition = Regime/Storm Washover
- Ebb tide channel appears noticeably more restricted
- Storm in May 2010 likely contributed to washover deposits
- Council carried out several mechanical openings in 2010, the last and most successful in December 2010 following which the entrance remained opened for 3.5 months to March 2011. The entrance was again mechanically opened in March 2011 prior to this image



8-4-2011

Image © 2021 Maxar Technologies

Google Earth

- Entrance condition = Storm Washover/Closed (?)
- Extensive washover deposits and channel infilling, probably due to the storm in July 2011
- Effect of the mechanical opening in March 2011 largely lost



Image © 2021 Maxar Technologies

Google Earth

6-9-2011

- Entrance condition = Closed
- Closure of the entrance probably influenced by relatively low rainfall in late 2011
- Mechanical opening of the entrance was carried out shortly after this image, on 23 December 2011, but was short lived, reported as closed in February 2012



Image © 2021 Maxar Technologies

21-12-2011

Google Earth

- Entrance condition = Intermediate/Regime
- Entrance was mechanically opened on 23 December 2011
- Entrance reported as closed in February 2012, open again in March, probably due to heavily rainfall February/March 2012 (total 512mm)
- Multiple channels within flood tide delta



Jan-12 nearmap

open

Vertical

Yes

- Entrance condition = Regime
- Entrance recorded as closed in March 2013, open in April (heavy rainfall, 345mm), closed in June, possibly due to storm in June, open again by July (heavy rainfall, 274mm)
- Multiple channels within flood tide delta

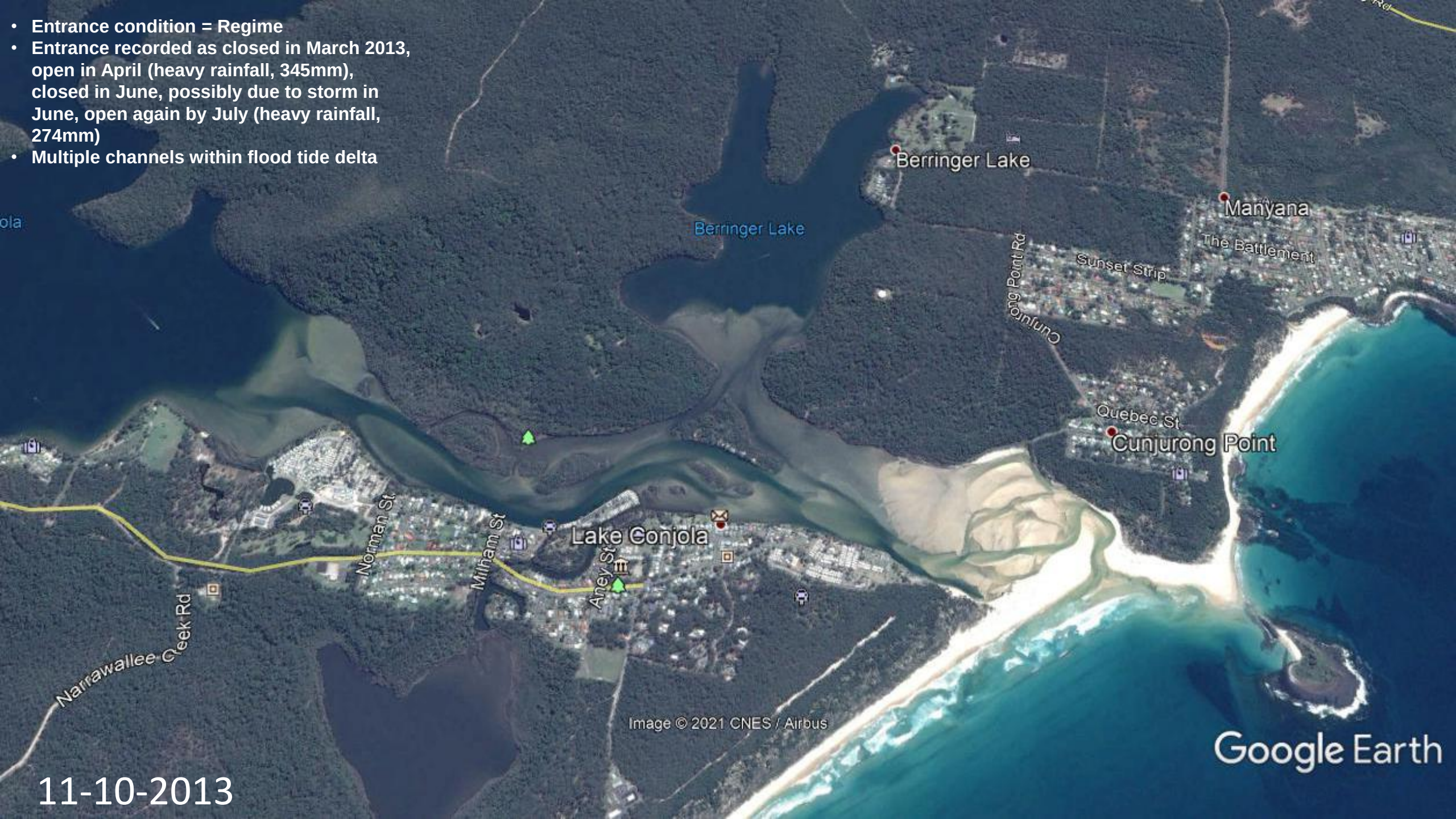
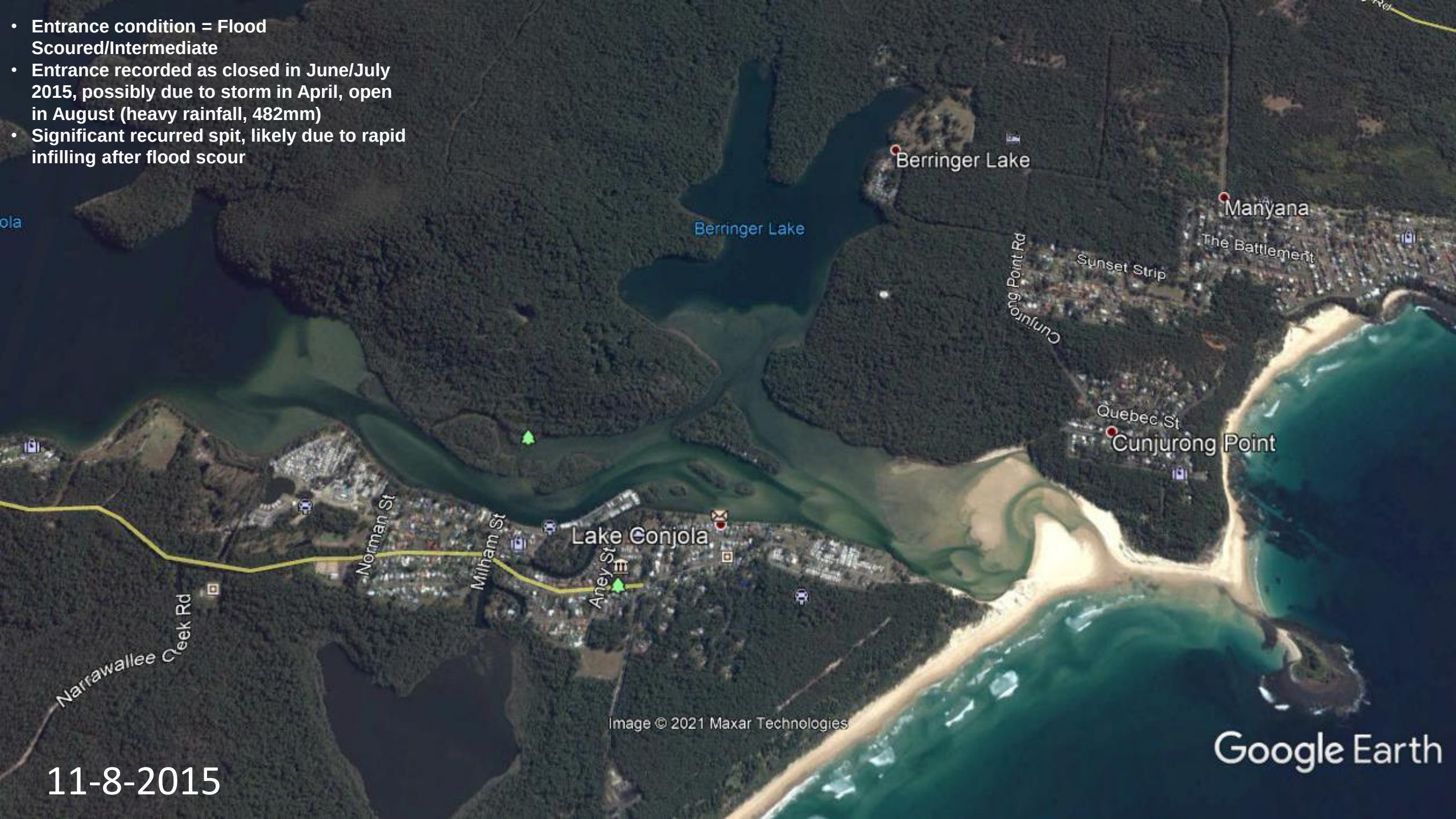


Image © 2021 CNES / Airbus

Google Earth

11-10-2013

- Entrance condition = Flood Scoured/Intermediate
- Entrance recorded as closed in June/July 2015, possibly due to storm in April, open in August (heavy rainfall, 482mm)
- Significant recurred spit, likely due to rapid infilling after flood scour



11-8-2015

Image © 2021 Maxar Technologies

Google Earth

- Entrance condition = Intermediate/Regime
- Entrance trending to Regime
- Generally low rainfall and no storms
- Ebb tide has scoured the recurved spit evident in August 2015 image

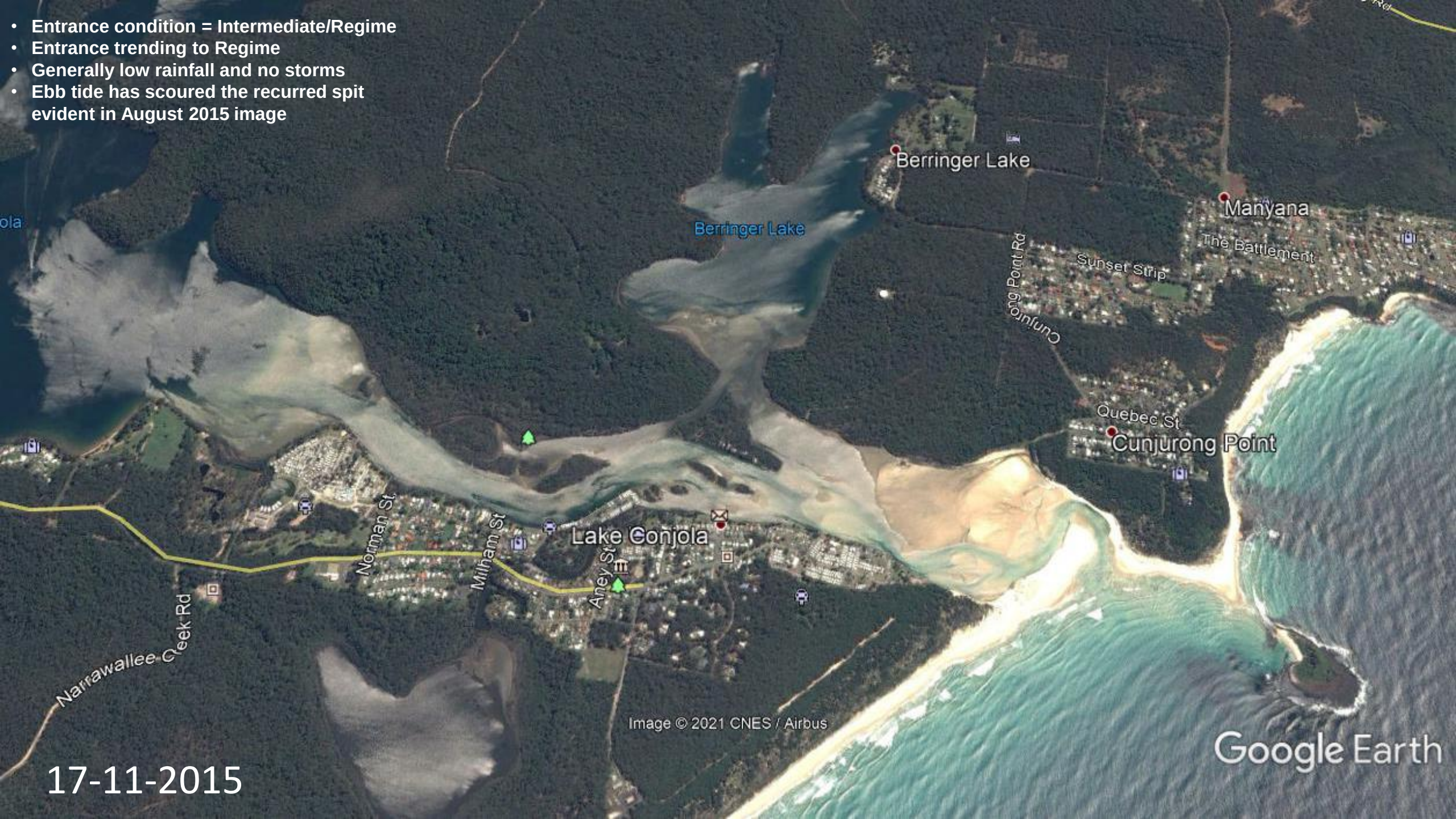


Image © 2021 CNES / Airbus

Google Earth

17-11-2015

- Entrance condition = Intermediate/Regime
- Entrance trending further towards Regime
- Heavy rainfall in January (240mm) would have assisted in keeping entrance open, no storms



Image © 2021 CNES / Airbus

Google Earth

12-2-2016

- Entrance condition = Regime / Storm washover
- Entrance exhibiting signs of shoaling/constriction
- Flood tide shoals appear more emergent
- More apparent spit/tombolo growth to Green Island

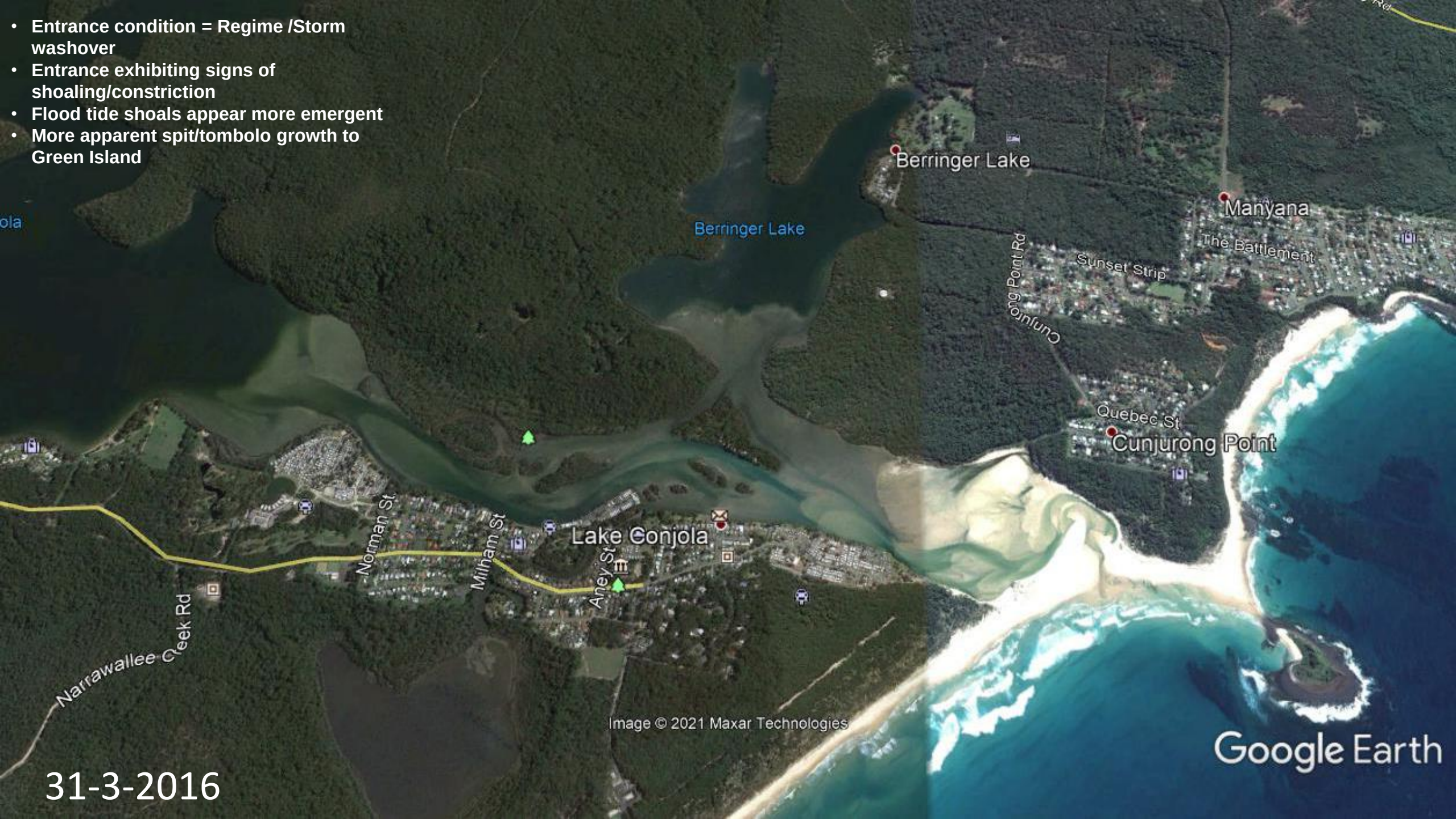


Image © 2021 Maxar Technologies

Google Earth

31-3-2016

- Entrance condition = Intermediate/Regime
- Heavy rainfall in June/July (total 504mm) has led to an increase in entrance channel dimensions and scour of entrance spit compared to 31-03-2016 image, notwithstanding a storm in July
- Dredged navigation channel evident at upstream limit of flood tide delta

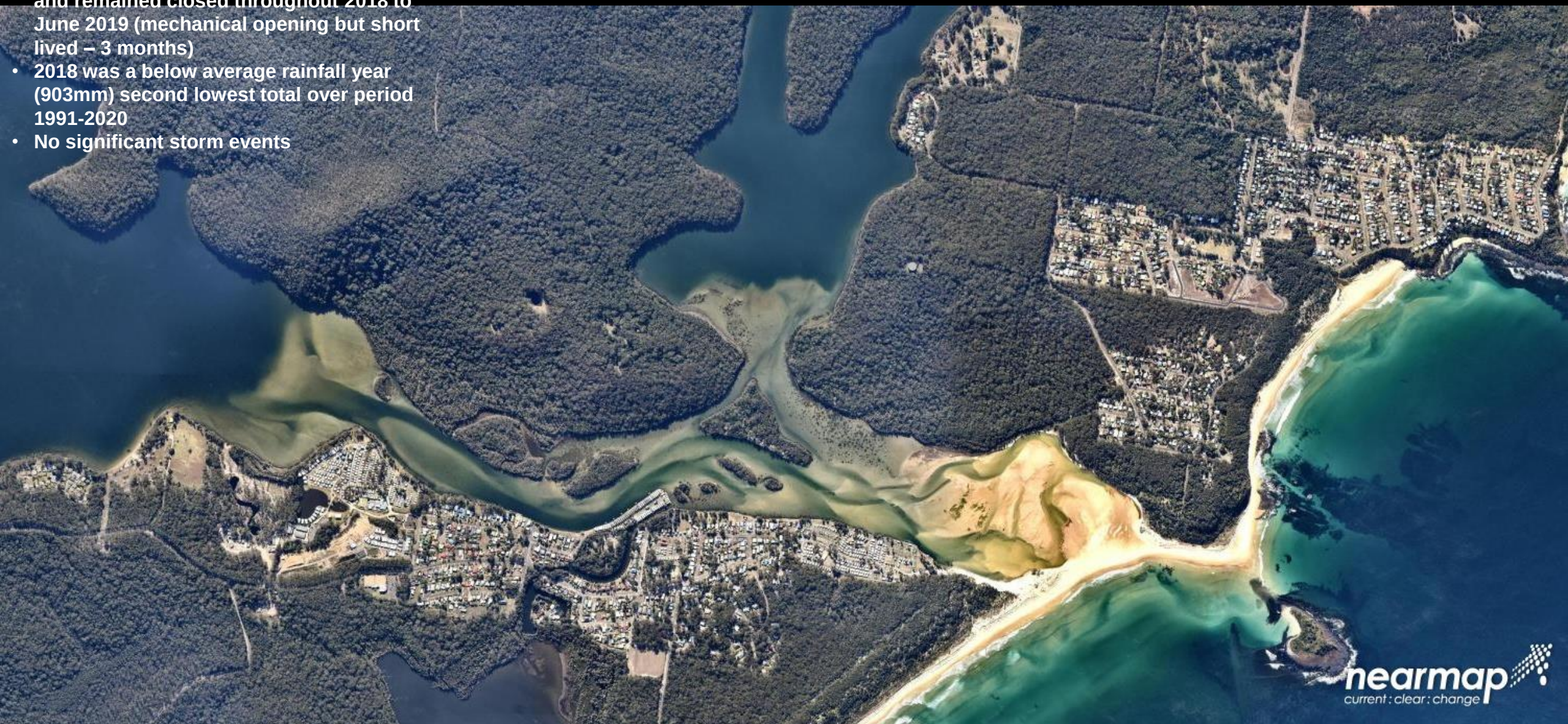


Image © 2021 Maxar Technologies

Google Earth

16-8-2016

- Entrance condition = Closed
- Records indicate entrance closed in April and remained closed throughout 2018 to June 2019 (mechanical opening but short lived – 3 months)
- 2018 was a below average rainfall year (903mm) second lowest total over period 1991-2020
- No significant storm events



nearmap
current : clear : change

15/7/2018

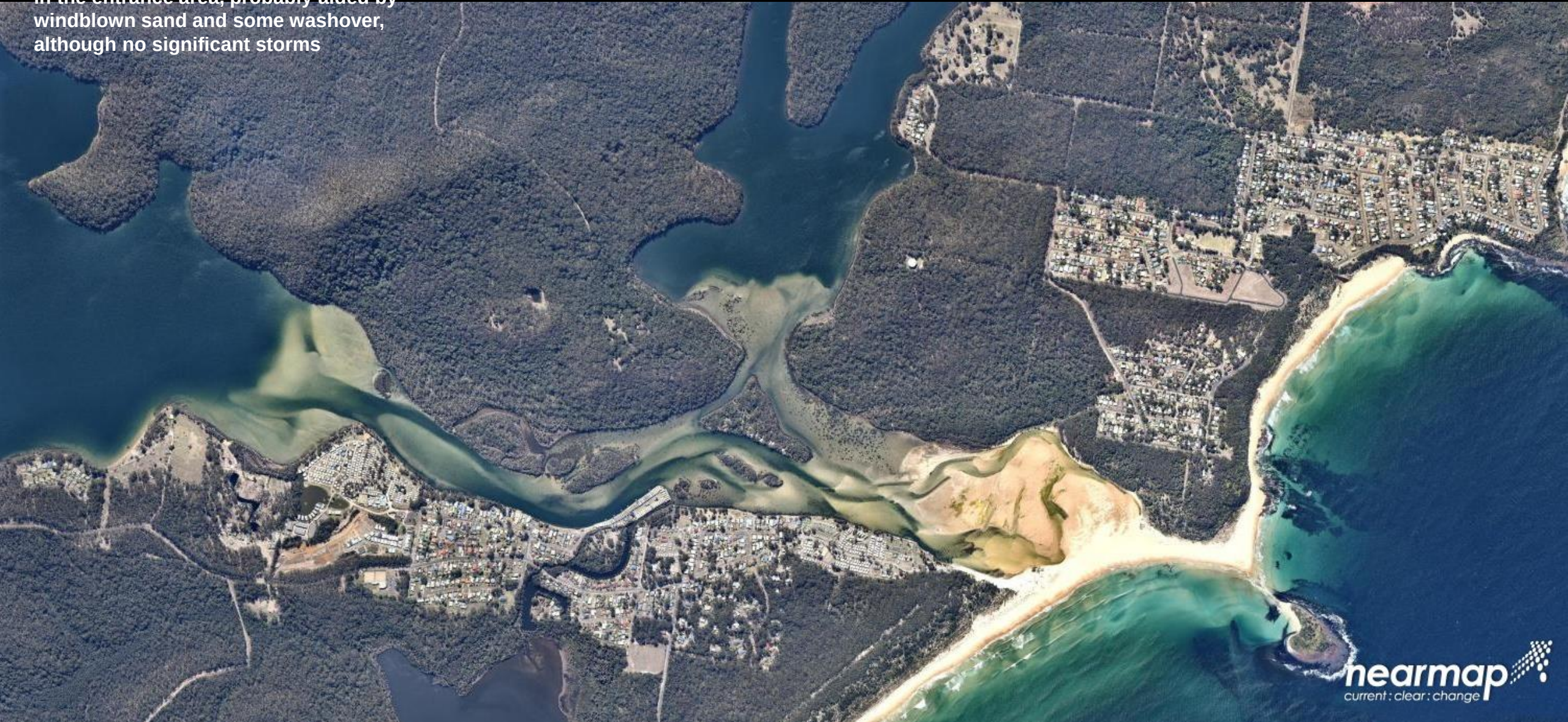
nearmap

closed

Vertical

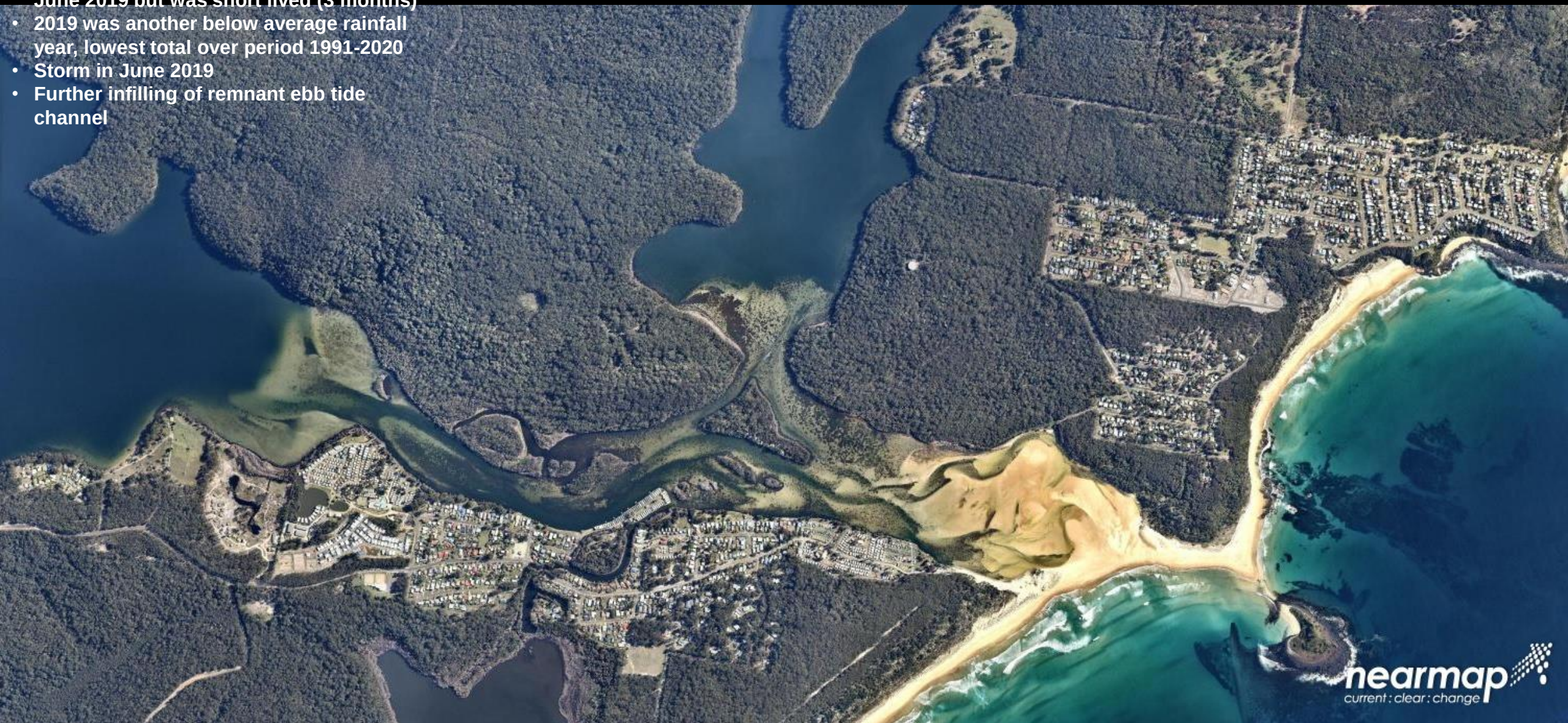
Yes

- Entrance condition = Closed
- Noticeable further build up of sand shoals in the entrance area, probably aided by windblown sand and some washover, although no significant storms



nearmap
current : clear : change

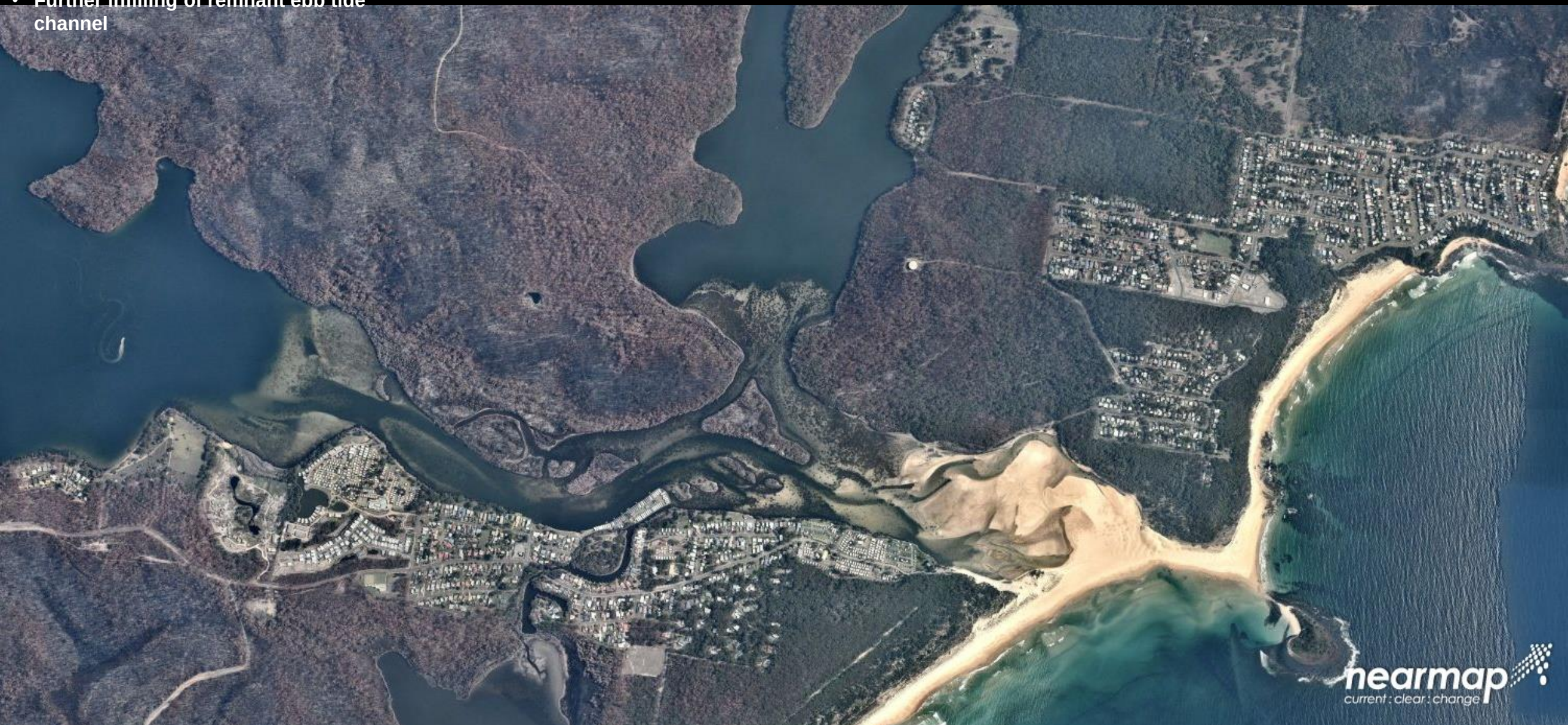
- Entrance condition = Closed
- A mechanical opening was carried out in June 2019 but was short lived (3 months)
- 2019 was another below average rainfall year, lowest total over period 1991-2020
- Storm in June 2019
- Further infilling of remnant ebb tide channel



nearmap
current : clear : change

14/9/2019	nearmap	closed	Vertical	Yes
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- Entrance condition = Closed
- No significant antecedent rainfall in 2019
- Further infilling of remnant ebb tide channel



nearmap
current : clear : change

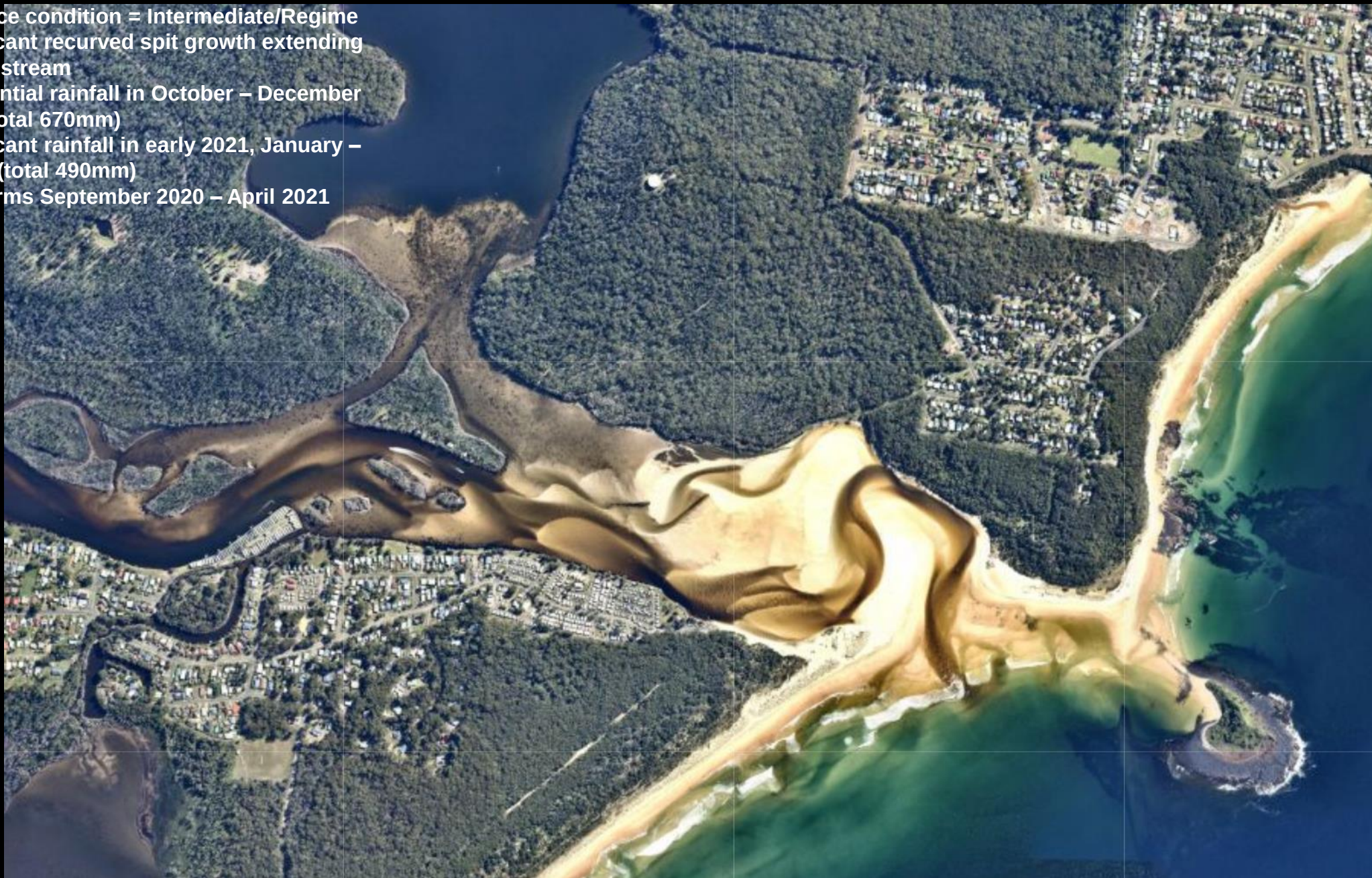
31/1/2020	nearmap	closed	Vertical	Yes
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- Entrance condition = Intermediate
- Mechanical opening/significant rainfall and flooding on 10 February 2020
- 2020 a high rainfall year (1529mm)
- Sand migration into the entrance and spit growth at the entrance evident
- Ebb tide channel trending towards a Regime state
- Several storms May – August 2020



nearmap
current : clear : change

- Entrance condition = Intermediate/Regime
- Significant recurved spit growth extending well upstream
- Substantial rainfall in October – December 2020 (total 670mm)
- Significant rainfall in early 2021, January – March (total 490mm)
- No storms September 2020 – April 2021



01-Apr-21

nearmap

Open

Vertical

Yes

Appendix C – Coastal Fact Sheet – Lake Conjola Management

Coastal Fact Sheet

Lake Conjola Management



Many coastal lakes open and close naturally. They are known as

ICOLLS –

Intermittently Closed and Open Lakes and Lagoons.

World-wide, ICOLLS are quite rare. The NSW south coast is home to most of Australia's ICOLLS.

Shoalhaven has a number of ICOLLS including Swan Lake, Burrill Lake, Tabourie Lake and Lake Conjola. ICOLLS are very sensitive to human disturbance. This makes them one of the most complex and difficult coastal environments to manage.

Council must comply with NSW Government legislation, and the management of ICOLLS is undertaken in partnership with Government agencies and the community.



Why is the Lake closed?

It's natural for the Lake to be closed at times. In NSW, about 70% of ICOLLs are closed most of the time.

Lake Conjola entrance is constantly changing, from being open to the ocean after a big flood, to being completely closed due to drought and severe coastal storms. In between these events, the entrance channel naturally drifts north until it's against Cunjurong Point.

These changes are caused by water and wind constantly moving sand into, and around, the entrance. These effects include:

Water

- Coastal storms with big swells wash offshore sand over the spit and into the entrance
- Rainfall in the catchment may 'refresh' the channel by increasing flows that scour sand build up in the entrance and carry some sand offshore

- Floods dramatically and quickly wash sand out to sea, and scour a more central channel
- Wave action carries sand from south to north along the beach (littoral drift), pushing the entrance channel north
- Tides carry sand in and out of the Lake entrance. The flood (in-coming) tide carries more sand in, than the ebb (out-going) tide carries out, resulting in a nett gain in sand volume in the entrance

Wind

- The wind, which blows predominantly from the south-east, carries large amounts of sand into the entrance.

The combination of storm wash-over, littoral drift, wind and tides, carries approximately 68,000 cubic metres of sand into the entrance every year.



*Lake Conjola
Circa 1964*

Why doesn't Council keep the Lake open?

- An open entrance lets the ocean in (both normal tides and storm surge) and ocean flooding is as big a risk to Lake Conjola as catchment flooding. The April 2013 flood demonstrated this when the Lake naturally opened, and flooding occurred from both the ocean and the catchment
- Flood models show that only modest reductions in peak flood levels are achieved with an open entrance (Flood Risk Plan 2013)
- A more permanently open entrance will change the Lake's natural ecology. Possible impacts include loss of seagrass and saltmarsh, mangrove colonisation and decline in recreational species such as prawns
- Increased tidal flushing does not necessarily mean overall improvement to water quality or water clarity, as water quality is largely a function of catchment runoff
- The natural vegetation around the Lake is adapted to changing water levels and protects the foreshores. Lower water levels would expose additional foreshore and potentially lead to erosion, as well as impacting saltmarsh that is dependent on periods of higher water levels.
- An open entrance would reduce low level flooding in the short term. This flooding is already managed by **The Entrance Management Plan**. In the longer term, sea level rise will lead to increased water levels and inundation of low lying areas (Flood Risk Plan 2013)

For these reasons, the millions of dollars required for training walls and dredging to maintain an open entrance, is difficult to justify. The NSW Marine Estate Threat (2013) and Risk Assessment identified the modification of coastal estuary entrances as the third highest risk to the health of the estuaries, behind agricultural runoff and storm water.

The long-term goal of the NSW Government is, as far as possible, to progressively allow ICOLL entrances to return to their natural processes.

When does Council open the Lake?

In order to address flooding, when the Lake is closed, Council's adopted Entrance Management Plan allows for mechanical opening at trigger levels of between 1.0m AHD (planned) and 1.2m AHD (Emergency Opening).

Prior to intervention Council must gain approval from relevant NSW government agencies.

Mechanical openings are generally short lived due to two factors:

- the water level at the time of opening is too low to create the surge required for effective scouring of the channel. Opening the Lake at a level lower than the trigger level will lead to an even more rapid closure. The better the scour, the longer the Lake stays open

- storm wash-over carries offshore sand back into the entrance

What's the best location for a mechanical opening?

A central to northern location is favoured because

- Green Island protects the northern area from wave energy and storm wash-over
- littoral drift causes the spit to move northwards, naturally forcing the entrance channel towards Cunjurong Point
- with a channel located along a rocky shoreline, such as Cunjurong Point, there are benefits to both scouring and persistence of the opening
- threatened migratory shorebirds nest on the sand spit at Lake Conjola and are endangered. During the nesting season from September to March, Council must minimise disturbance to the nesting area. Only a northern intervention can be considered at this time.

Mechanical intervention is only used to alleviate low level, flooding



What about the fish?

Fish stocks in ICOLLs are adapted to periods of entrance closure, which allows species such as prawns, mullet and bream to grow and reach maturity, enhancing survival and reproductive success. When the entrance opens they head for the ocean to reproduce and younger fish and prawns enter the Lake to mature.

These are natural cycles.

ICOLLs on the south coast can remain highly productive systems, even after extended periods of closure.

The water looks dirty, is it safe?

It's natural for ICOLLs to be closed at times. During long periods of closure the water can change colour. This doesn't mean that the Lake is dirty or unhealthy.

When the Lake is closed, weekly water quality monitoring is undertaken by Council at three locations and results are posted on Council's website. For the period of Lake closure during 2018, test results consistently rated as 'Good' which indicates that the water is suitable for swimming.

If test results indicate that water quality is unsafe, then Council will advise the community.

Sediment and pollutants are washed into the Lake by heavy rain and water quality is affected whether the entrance is open or closed. For this reason it's best to avoid swimming for at least a day after heavy rain, especially near storm water outlets.

Council, residents and visitors all play a part in keeping the catchment and the Lake clean and healthy.





FLOOD SCoured

During a flood the Lake breaks out in a central location.



REGIME STATE

Due to the influence of 'littoral drift', the Lake entrance moves north to Cunjurong Point.



CLOSED

Over time, in the absence of heavy rain, waves, tides and wind, transport sand back into the entrance.

Lake Conjola Entrance
Management Plan 2013

Lake Conjola Floodplain Risk
Management Study and Plan 2013

Management of Coastal Lakes and
Lagoons DPI

Brochure update in 2018.

For further information contact
Shoalhaven City Council's Natural
Resources & Floodplain Unit on
4429 3392.

Address all correspondence to

The General Manager, PO Box 42, Nowra NSW 2541 Australia

DX5323 Nowra Fax 02 4422 1816

council@shoalhaven.nsw.gov.au

Bridge Rd, Nowra NSW 2541 02 4429 3111

Appendix D – Tabular Summary of Entrance Conditions Analysis for the Period 1937 to 2011

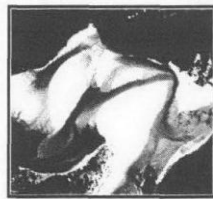
YEAR		1937	1938	1939	1940	1941
ENTRANCE CONDITIONS		C			F → R	
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		June, 1937 -“Worst storm since 1927”	March, 1938 -“Entrance still closed. -Lake colour of black tea. -Previous closures from time to time”.	March, 1939 -“Flood caused water to rise 6ft above high tide” -“Locals got cracking with a battery of shovels and some mechanical equipment”		-Closure due to dry conditions and occurrence of major storm Oct 41 or March 42
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	1249	939	992	688	773
OCEAN STORMS “X”= severe “A”= major Source: DPWS/MHL & Blain et al 1985	CATEGORY “X” “A”		NO MAJOR STORMS	NO MAJOR STORMS	NO MAJOR STORMS	



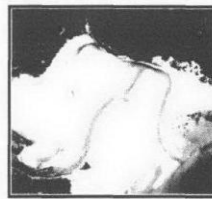
R = regime state



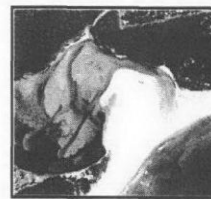
F = flood scoured



W = storm washover



SH = heavily shoaled



C = closed*



I = intermediate



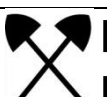
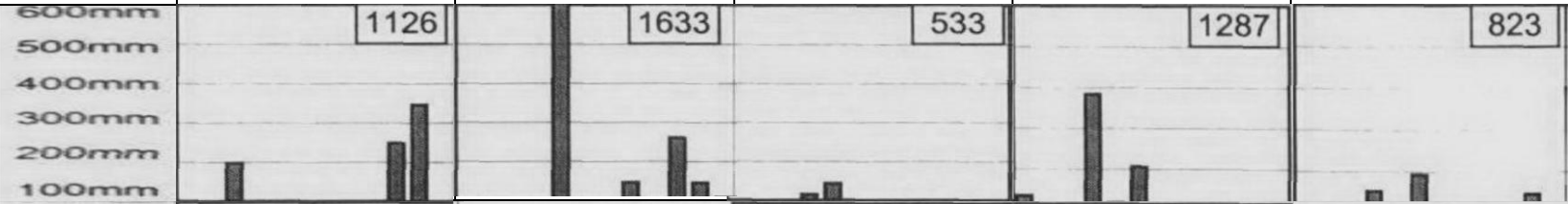
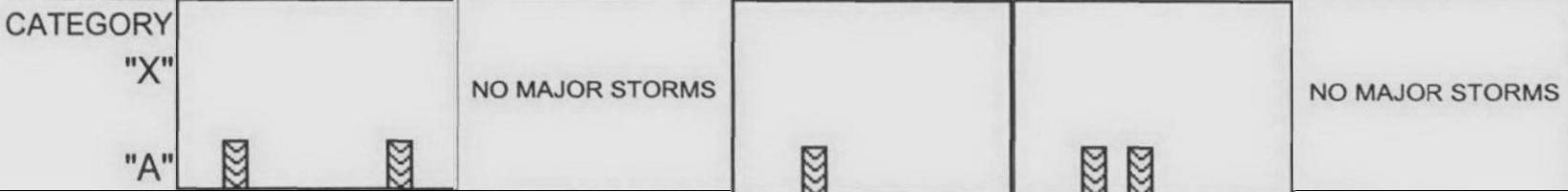
= entrance manually opened by Council



* = actual dates of closure / opening uncertain

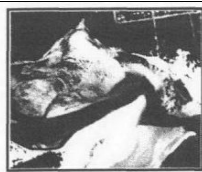


= dates of closure / opening fairly certain

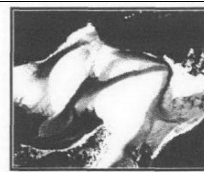
YEAR		1942	1943	1944	1945	1946
ENTRANCE CONDITIONS			 			
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-“Entrance was blocked”.	May, 1943 -631mm rainfall when: -“...The blocked entrance was manually opened up” -“...opened south side and took 2 years to get to north side”.	-Driest year on record. -No severe storms between March 44 and March 45, hence entrance stayed open. -“Lovely entrance for years”.	March, 1945 -Entrance heavily shoaled. -Entrance rejuvenated by April and June floods.	-DRY YEAR -Fishes maintain regime state.
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.						
OCEAN STORMS “X”= severe “A”= major Source: DPWS/MHL & Blain et al 1985	CATEGORY “X” “A”					



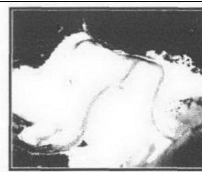
R = regime state



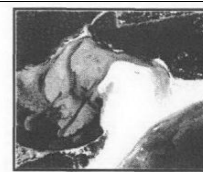
F = flood scoured



W = storm washover



SH = heavily shoaled



[C] = closed*



I = intermediate



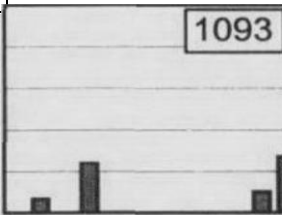
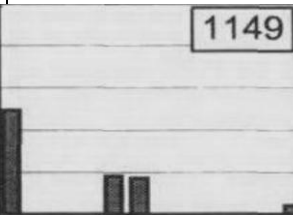
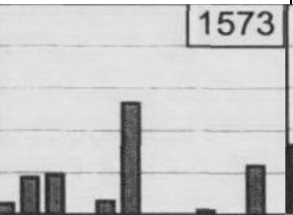
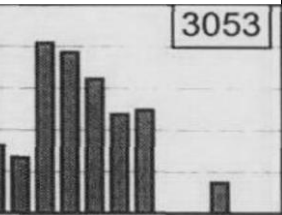
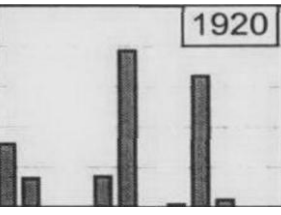
= entrance manually opened by Council



* = actual dates of closure / opening uncertain

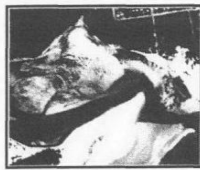


= dates of closure / opening fairly certain

YEAR		1947	1948	1949	1950	1951
ENTRANCE CONDITIONS			 →  → 			
NOTES:	Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.	-Freshes maintain regime state.	-Several storm washover deposits. -December 48 storm almost closed entrance.	-Wet year and numerous freshes keep entrance open.	-Wettest year on record with over 3m of rainfall. -Entrance scoured.	-Wet year. -Various floods. -Entrance scoured.
Monthly Rainfall*	(annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.					
OCEAN STORMS	"X" = severe "A" = major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" NO MAJOR STORMS "A"	CATEGORY "X" NO MAJOR STORMS "A"	CATEGORY "X" NO MAJOR STORMS "A"	CATEGORY "X" NO MAJOR STORMS "A"	CATEGORY "X" NO MAJOR STORMS "A"



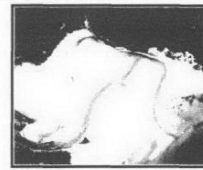
R = regime state



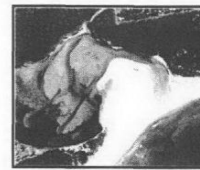
F = flood scoured



W = storm washover



SH = heavily shoaled



C = closed*



I = intermediate



= entrance manually opened by Council



* = actual dates of closure / opening uncertain



= dates of closure / opening fairly certain

YEAR		1952	1953	1954	1955	1956
ENTRANCE CONDITIONS		F		W / SH	F	F
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-Wet year.- Numerous floods. -Entrance scoured	-Rainfall 49 – 52 and May 53 would have kept entrance open. -As precipitation decreases, entrances moves from flood scoured state towards regime state.	-entrance open but heavily shoaled by February 54 storms.	-Entrance rejuvenated.	
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.						
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"					



R = regime state



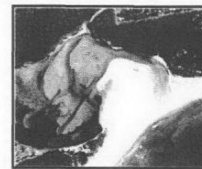
F = flood scoured



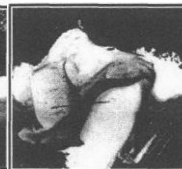
W = storm washover



SH = heavily shoaled



C = closed*



I = intermediate



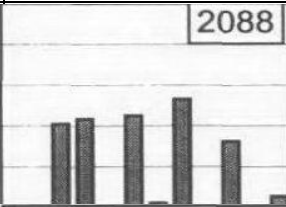
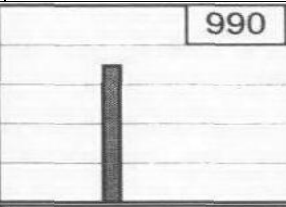
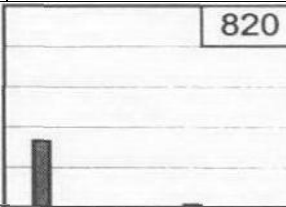
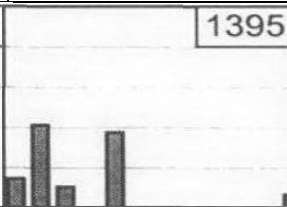
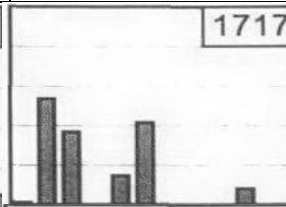
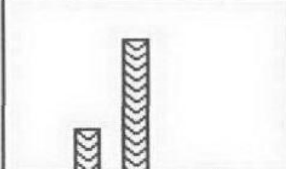
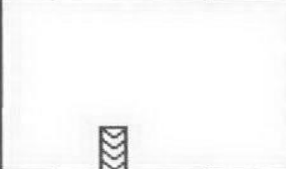
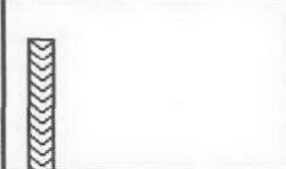
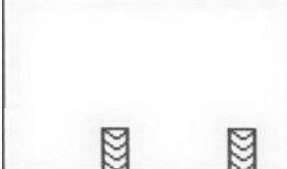
= entrance manually opened by Council



* = actual dates of closure / opening uncertain



= dates of closure / opening fairly certain

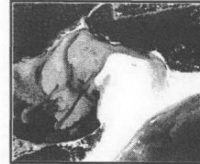
YEAR		1952	1953	1954	1955	1956
ENTRANCE CONDITIONS		F		W / SH	F	F
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-Wet year.- Numerous floods. -Entrance scoured	-Rainfall 49 – 52 and May 53 would have kept entrance open. -As precipitation decreases, entrances moves from flood scoured state towards regime state.	-entrance open but heavily shoaled by February 54 storms.	-Entrance rejuvenated.	
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	2088 	990 	820 	1395 	1717 
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"					


R = regime state


F = flood scoured


W = storm washover


SH = heavily shoaled


C = closed*


I = intermediate

✂ = entrance manually opened by Council

* **C** = actual dates of closure / opening uncertain

C = dates of closure / opening fairly certain

YEAR		1957	1958	1959	1960	1961	
ENTRANCE CONDITIONS		SH	C	F	W I F	SH	F
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-Entrance closed by August 57 storm. -"In the 50s the entrance was reduced to a chain of ponds – pools 3 ft deep and 10 ft wide linked by 2 inch rapids" -"Virtually closed for six months".	-Rainfall in February and March reopened entrance naturally.	-Washover deposits by several storms. -October flood scoured entrance.	-Major storms would have choked entrance.	-WET YEAR -Several floods scoured entrance.	
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	867	1400	1863	1199	2142	
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"						



R = regime state



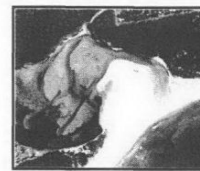
F = flood scoured



W = storm washover



SH = heavily shoaled



C = closed*



I = intermediate

✂ = entrance manually opened by Council

*C = actual dates of closure / opening uncertain

C = dates of closure / opening fairly certain

YEAR		1962	1963	1964	1965	1966
ENTRANCE CONDITIONS						
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.			-Consistent rainfall over past three years maintained regime state or better.	-Slightly flood scoured. -Close to regime condition.	-DRY YEAR -Entrance would have shoaled. -Entrance prone to closure by storm.	-Entrance effectively closed by May storm. -12 th October 1966 "Now entrance closed..."
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm					
OCEAN STORMS "X" = severe "A" = major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"	NO MAJOR STORMS	NO MAJOR STORMS	NO MAJOR STORMS		



R = regime state



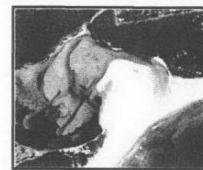
F = flood scoured



W = storm washover



SH = heavily shoaled



C = closed*

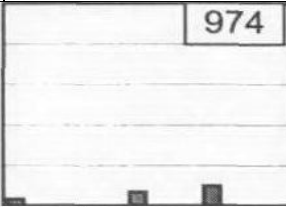
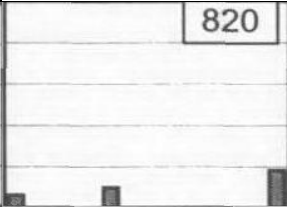
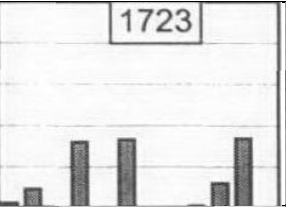
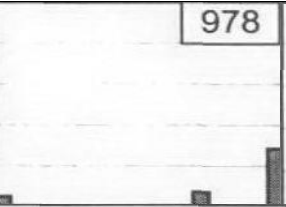
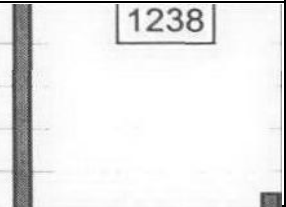
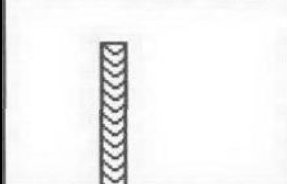
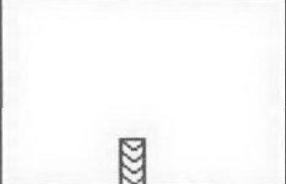


I = intermediate

= entrance manually opened by Council

* = actual dates of closure / opening uncertain

= dates of closure / opening fairly certain

YEAR		1967	1968	1969	1970	1971
ENTRANCE CONDITIONS		 C  	SH 	 C 	 SH 	C F 
NOTES:		- DRY YEAR - Opened on three occasions. - Opened 29 September. - Dredge attempted to make a channel for four months.	- DRY YEAR - 4th July 1968 - "Entrance virtually closed" By severe May storms.	- "Has been closed for some considerable time" - Dune stabilisation-heavy wind blown sand.	- DRY YEAR - Opened March 1970 - October 1970 – "Again closed completely".	- Flood in February 1971 – Scoured entrance. - Very dry after February floods.
Sources: Land Information Centre / Shoalhaven City Council.						
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	 974	 820	 1723	 978	 1238
OCEAN STORMS "X" = severe "A" = major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"					NO MAJOR STORMS



R = regime state



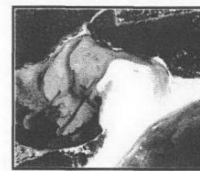
F = flood scoured



W = storm washover



SH = heavily shoaled



C = closed*



I = intermediate

 = entrance manually opened by Council

* **C** = actual dates of closure / opening uncertain

C = dates of closure / opening fairly certain

YEAR		1972	1973	1974	1975	1976
ENTRANCE CONDITIONS		→ R	R	F / W	F	F
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-VERY DRY YEAR -Internal tidal scour of split – entrance reached regime state.	-Combination of moderate rainfall and lack of significant storms – entrance remained open in regime state.	-“Entrance dunes destroyed by severe storms” in 1974 – 75 -Numerous floods.	-Numerous floods would have kept entrance scoured.	Major rainfall over past three years keeping entrance open.
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	727	1306	2148	1419	1929
OCEAN STORMS “X”= severe “A”= major Source: DPWS/MHL & Blain et al 1985	CATEGORY “X” “A”		NO MAJOR STORMS			



R = regime state



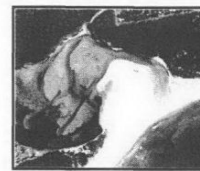
F = flood scoured



W = storm washover



SH = heavily shoaled



C = closed*

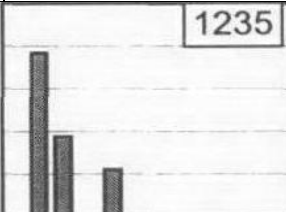
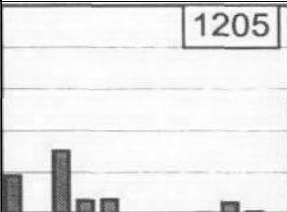
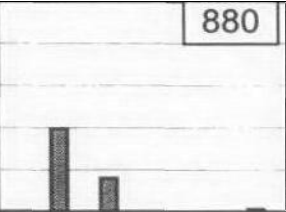
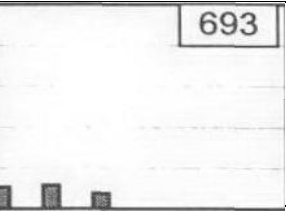
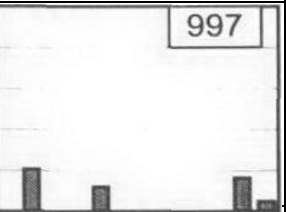


I = intermediate

✂ = entrance manually opened by Council

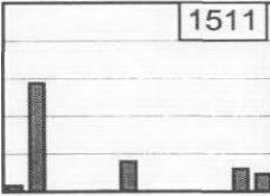
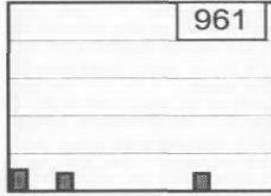
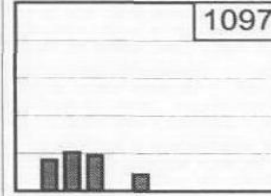
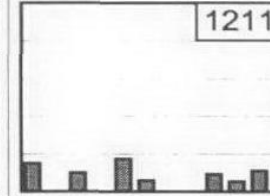
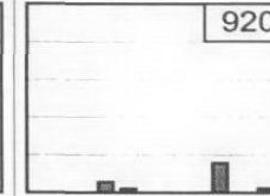
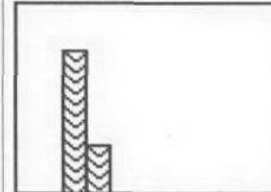
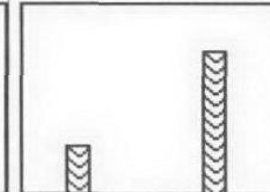
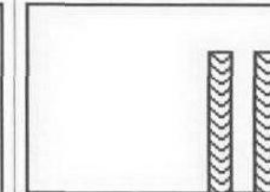
* **C** = actual dates of closure / opening uncertain

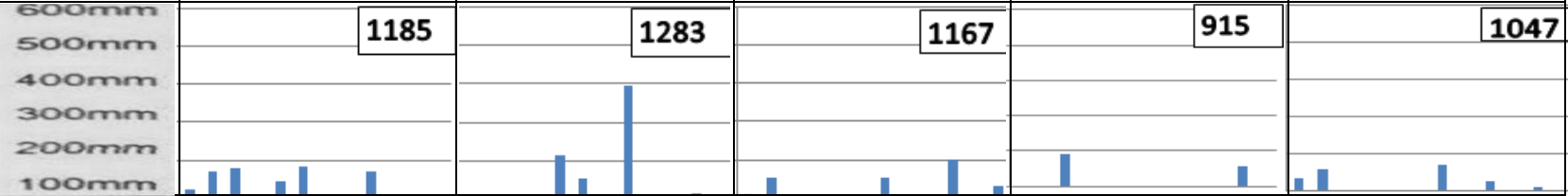
C = dates of closure / opening fairly certain

YEAR		1977	1978	1979	1980	1981
ENTRANCE CONDITIONS		F	→	I / R	→	R
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.				-Jan 79 – entrance channel close to regime state. -Freshes maintain regime channel.	-DRY YEAR. Delta infilling.	-DRY YEAR. -Delta infilling.
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	 1235	 1205	 880	 693	 997
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"	NO MAJOR STORMS		NO MAJOR STORMS	NO MAJOR STORMS	NO MAJOR STORMS

YEAR		1982	1983	1984	1985	1986
ENTRANCE CONDITIONS		→ SH	F A I	F A I → R	R W SH	
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-VERY DRY YEAR. -Continued infilling due to longshore transport and flood tidal transport. -Very little rainfall to flush entrance.	-Several floods rejuvenated entrance.	-Several floods. -Storms would have caused sediment infeed.	-Tidal delta growth restricted to immediate entrance area.	-DRY YEAR -internal tidal scour -Shoal build up pinching inside of spit -August storm caused large washover deposit and blocked ebb channel
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	571	1529	1739	1304	944
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"	NO MAJOR STORMS	NO MAJOR STORMS		NO MAJOR STORMS	

YEAR		1987	1988	1989	1990	1991
ENTRANCE CONDITIONS		→ SH	F SH	F → W		F
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-Channel perched -Few freshes to scour entrance -Entrance close to closing	-April flood unlikely to rejuvenate entrance in face of storm in 87&88	-WET YEAR -several floods would have probably scoured entrance	-Severe storms would have washed over spit and choked entrance	-Highest June flow on record scoured entrance -By November delta shoals re- established -Internal flood scour against high dune
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	571	1529	1739	1304	944
OCEAN STORMS "X" = severe "A" = major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"	NO MAJOR STORMS	NO MAJOR STORMS		NO MAJOR STORMS	

YEAR		1992	1993	1994	1995	1996
ENTRANCE CONDITIONS		→ R	→ W	SH	C	C W
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-Pronounced erosion of high dune by February 1992 flood	-Internal scour	-washover fan from March/April storms closed ebb channel -Entrance almost closed by storms -Shallow, choked secondary ebb channel formed -entrance closed towards end of 94	-Freshes not enough to open entrance -Storm Washover caused by Sept 95 storm	-Several council attempts to open entrance -Major storm washover in Sept and Nov -Minor freshes only -Wind blow up sand build up
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	 1511	 961	 1097	 1211	 920
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"	NO MAJOR STORMS	NO MAJOR STORMS			

YEAR		1997	1998	1999	2000	2001
ENTRANCE CONDITIONS						
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-Major washover by May 1997 storm (mother's day storm) -Minor freshes -Wind blown up sand build up	-August –artificial opening in south -August flood scoured entrance -Flood scoured high dune	-Nov dredging of app 8500m² of sand -spit raised to reduce storm washover	-high waves form a storm event infilled the entrance, which quickly recovered	-no major storms and a few freshes maintained the entrance opened -however entrance progressively shoaling
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.		1185	1283	1167	915	1047
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"					

YEAR		2002	2003	2004	2005	2006
ENTRANCE CONDITIONS					W	W SH
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		February freshes and low storm activity maintained the entrance open	Freshes and low storm activity maintained the entrance open	-freshes and tidal flushing maintained the entrance opened	-storm washover -lake slowly shoaling towards closure	-storm wash over -significant coastal storm combined with an unusual 0.5m storm surge which washed over the beach and heavily shoaled the eastern ebb channel. -lake close to closure
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	600mm 500mm 400mm 300mm 200mm 100mm	929	1233	1089	1112	850
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"					

YEAR		2007	2008	2009	2010	2011																																																								
ENTRANCE CONDITIONS		SH	SH		C																																																									
NOTES: Aerial Photographs from: Feb 44, Mar 45, Dec 48, Nov 59, Apr 64, Mar 67, Apr 71, May 71, Jun 72, Jul 77, Jan 79, Jun 81, Jan 85, Jul 86, Nov 91, May 93, Jan 97, Sep 97 Sources: Land Information Centre / Shoalhaven City Council.		-freshes and tidal flushing maintained entrance opened	Very large storm 'Pasha Bulker Storm') And very low rainfall lead to a heavily shoaled entrance close to closure	May moderate north east storm formed second channel and improved efficiency of the entrance -end 2009 single channel along the northern rock wall.	May intervention operation failed to trigger a persistent channel due to a coastal storm Second attempt in September – but coastal storms closed the lake. Pre Christmas intervention at lake level 1 mAHD	-closure early march -emergency mechanical opening following heavy rainfalls on 21 st march lake level 1.32mAHD.																																																								
Monthly Rainfall* (annual mm totals in boxes) Source: Met. Bureau (Milton records) *only amounts >100mm shown.	<table><caption>Monthly Rainfall Data (mm)</caption><thead><tr><th>Year</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Total</th></tr></thead><tbody><tr><td>2007</td><td>200</td><td>50</td><td>50</td><td>380</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>1317</td></tr><tr><td>2008</td><td>100</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>867</td></tr><tr><td>2009</td><td>200</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>50</td><td>746</td></tr></tbody></table>	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	2007	200	50	50	380	50	50	50	50	50	50	50	50	1317	2008	100	50	50	50	50	50	50	50	50	50	50	50	867	2009	200	50	50	50	50	50	50	50	50	50	50	50	746	1317	867	746		
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total																																																	
2007	200	50	50	380	50	50	50	50	50	50	50	50	1317																																																	
2008	100	50	50	50	50	50	50	50	50	50	50	50	867																																																	
2009	200	50	50	50	50	50	50	50	50	50	50	50	746																																																	
OCEAN STORMS "X"= severe "A"= major Source: DPWS/MHL & Blain et al 1985	CATEGORY "X" "A"																																																													

Appendix E – Lake Conjola Open-Closed History 1916-2019 (Ghetti and Dodimead)

Ref: Isabelle Ghatti Spreadsheets from Ken Dodimead

												Open	Closed		
												% Status	89%	11%	
												Total # Mths :	1104	139	
Year	J F M A M J J A S O N D												# Mths		
													Open	Closed	
1916-36	O	O	O	O	O	O	O	O	O	O	O	O	252	0	
1937	C	C	C	C	C	C	C	C	C	C	C	C	0	12	
1938	C	C	C	C	C	C	C	C	C	C	C	C	0	12	
1939	C	C		O	O	O	O	O	O	O	O	O	10	2	
1940	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1941	O	O	O	O	O	O	O	O	O	O		C	C	10	2
1942	C	C	C	C	C	C	C	C	C	C	C	C	0	12	
1943	C	C	C	C	C		O	O	O	O	O	O	7	5	
1944	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1945	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1946	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1947	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1948	O	O	O	O	O	O	O		O	O	O	O	12	0	
1949	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1950	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1951	O	O	O	O	O	O	O	O	O	O	O	O	12	0	
1952	O	O	O	O	O	O		O	O	O	O	O	12	0	
1953	O	O	O	O	O	O	O		O	O	O	O	12	0	
1954	O	O	O	O	O	O	O		O	O	O	O	12	0	
1955	O	O	O	O	O	O	O		O	O	O	O	12	0	
1956	O	O	O	O	O	O	O		O	O	O	O	12	0	
1957	O	O	O	O	O	O	O		C	C	C	C	C	7	5
1958	C		O	O	O	O	O		O	O	O	O	O	11	1
1959	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1960	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1961	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1962	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1963	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1964	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1965	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1966	O	O	O	O	O	O	O		O		C	C	C	9	3
1967	C	C	C	C	C	C	C	C		O	O	O	O	4	8
1968	O	O	O	O	O	O		C	C	C	C	C	C	6	6
1969	C	C	C	C	C	C	C	C	C	C	C	C	C	0	12
1970	C	C		O	O	O	O	O	O		C	C	C	7	5
1971	C		O	O	O	O	O	O	O	O	O	O	O	11	1
1972	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1973	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1974	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1975	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1976	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1977	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1978	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1979	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1980	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1981	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1982	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1983	O	O	O	O	O	O	O		O	O	O	O	O	12	0
1984	O	O	O	O	O	O	O		O	O	O	O	O	12	0

Ref: Isabelle Ghatti Spreadsheets from Ken Dodimead

[illegible]

Ref: Isabelle Ghatti Spreadsheets from Ken Dodimead

	Open	Closed
% Time	89%	11%
# Mths	1104	139

[illegible]

Lake Conjola Entrance Status

Ref: Isabelle Ghetti Spreadsheets from Ken Dodimead

	Open	Closed
% Lake Status:	88%	12%
Hrs Lake Status:	1094	149

Year	Start of Yr	Closed	Open	# Months		Duration	
				Open	Closed	Open	Closed
1916	Open			252		252	
1937	Closed				12		
1938	Closed				12		26
1939	Closed		Mar	10	2	32	
1940	Open			12			
1941	Open	Oct		10	2		18
1942	Closed				12		
1943	Closed		May	8	4		
1944	Open			12			
1945	Open			12			
1946	Open			12			
1947	Open			12			
1948	Open			12			
1949	Open			12			
1950	Open			12		172	
1951	Open			12			
1952	Open			12			
1953	Open			12			
1954	Open			12			
1955	Open			12			
1956	Open			12			
1957	Open	Aug		8	4		6
1958	Open		Feb	10	2		
1959	Open			12			
1960	Open			12			
1961	Open			12			
1962	Open			12		104	
1963	Open			12			
1964	Open			12			
1965	Open			12			
1966	Open	Oct		10	2		
1967	Closed		Sep	3	9	9	9
1968	Open	Jul		6	6		24
1969	Closed				12		
1970	Closed	Oct	Mar	6	6	6	
1971	Closed		Feb	10	2		
1972	Open			12			
1973	Open			12			
1974	Open			12			
1975	Open			12			
1976	Open			12			
1977	Open			12			

Year	Start of Yr	Closed	Open	# Months		Duration	
				Open	Closed	Open	Closed
1978	Open			12		277	
1979	Open			12			
1980	Open			12			
1981	Open			12			
1982	Open			12			
1983	Open			12			
1984	Open			12			
1985	Open			12			
1986	Open			12			
1987	Open			12			
1988	Open			12			
1989	Open			12			
1990	Open			12			
1991	Open			12		10	
1992	Open			12			
1993	Open			12		7	
1994	Open	Mar		3	9		18
1995	Closed		Sep	3	9	159	
1996	Open	May	Jun	7	5		
1997	Open	May	Sep	7	5	26	16
1998	Closed		Jun	6	6		
1999	Open			12			
2000	Open			12			
2001	Open			12			
2002	Open			12			
2003	Open			12			
2004	Open			12			
2005	Open			12			
2006	Open			12			
2007	Open			12			
2008	Open			12			
2009	Open			12			
2010	Open			12			
2011	Open	Mar	Apr	9	3		
2012	Open	Feb/Jun	Mar/Jun	10	2	2 & 3 & 5	1 & 1
2013	Open	Mar/Jun	Apr/Jun	10	2	3 & 2 & 5	1 & 1
2014	Open	Jul	Aug	10	2	6 & 4	2
2015	Open	Jun	Aug	9	3	5 & 4	3
2016	Open	Apr	Jun	10	2	1	2
2017	Open			12			
2018	Open	Apr		4	8	1	14
2019	Closed		Jun	1	6		



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