alluvium

FINAL REPORT:

North Creek Coastal Management Program – Stage 1 scoping study

Dec 2019

ballina shire council

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The project team would also like to acknowledge and thank all stakeholders who provided input and feedback on the scoping study.

Executive summary

Ballina Shire Council has commenced the development of a Coastal Management Program (CMP) for the North Creek catchment. This report outlines the Stage 1 scoping study of the CMP development process, and sets the forward program for Stages 2 – 5 (of the 5 stage process).

The North Creek catchment extends north from the confluence with the Richmond River in Ballina. North Creek includes an extensive estuary system, and over two thirds of the catchment is tidally influenced.

The North Creek CMP is one of the first CMPs for a catchment-estuary system (no direct open coastline). The approach to the North Creek CMP development has an integrated focus on catchment and coastal processes, with a vision for:

"A healthy estuary, resilient ecosystems, and a sustainable, productive catchment."

Management objectives are associated with enhancing estuary and wetland health, promoting sustainable industries and liveable communities.

The Bundjalung people are the traditional custodians of the land, having cared for and lived off the land for thousands of years. In the past century the North Creek catchment has undergone rapid changes since European settlement. The vast swampy floodplain and wetlands into which the small coastal catchment creeks flowed have been extensively drained to allow for agricultural and urban development. Now, over half the catchment area is used for agriculture including grazing and sugarcane cultivation and just over 10 % of the catchment urbanised for residential development.

The catchment has a recent history of management challenges related to poor water quality and drainage, with adverse impacts on estuary health as well as agricultural and fisheries industries. Key knowledge gaps are linked to complex surface water, ground water and tidal dynamics.

Priority management issues for the North Creek catchment have been identified through a synthesis of previous work and research (Section 3), stakeholder and community engagement process (Section 3.14), and a first past risk assessment (Section 5). The priority issues for the North Creek CMP are:

1. Catchment runoff
    - This includes - agricultural diffuse runoff, diffuse urban stormwater and acid sulfate soils runoff. For the purposes of the scoping study, these stressors are combined and referred to collectively as catchment runoff.

2. Altered hydrology
    - This includes – changing patterns of surface and groundwater interactions, and altered drainage patters across the catchment.

3. Climate change
    - This focuses on the implications of climate change on sea level rise and increasing tidal inundation across the catchment.

4. Sand mining and dredging
    - This includes sand mining activities in the catchment, and dredging in the lower estuary reaches.

Recommended studies for including into the Stage 2 CMP work program include:

- Collection of high-resolution topographic data to 0.1 m vertical resolution of the entire catchment

- Bathymetric survey of all key drains and the estuary channel

- Development of a hydrodynamic model of the catchment to assess flow dynamics and drainage pathways and impacts on existing land uses. A coupled catchment-coastal model including tidal and storm tide inundation.

- Implementation of a North Creek Water Quality Monitoring Program (WQMP) which will include ambient and event-based monitoring for over 18 months across different areas of the catchment

- Development of a Source Catchment model of surface and groundwater pathways using outputs from the hydrodynamic model and WQMP to assess pollutant pathways through the catchment.

A range of additional studies of benefit to the health of the catchment and estuary have also been identified, which can be delivered as part of the Stage 2 CMP development, or later stages / as part of the CMP program implementation (or linked into other relevant strategies).

The proposed forward work program for Stages 2 – 5 of the CMP development runs over Jan 2020 to Dec 2021. The nominated program budget, including priority studies for Stage 2, is in the order of $600,000 - $700,000.

The preliminary economic assessment for the CMP scoping study has indicated that there is a strong case for investing in the CMP priority studies and CMP development for North Creek. This is based on consideration of the potential implications of tidal inundation impacts on agriculture alone being in the order of up to $14 million (loss) by 2050. The ecosystem services value of natural assets in the catchment (that may be impacted by known issues) is also in the order of up to $1 million per annum. Actions through the CMP will assist to mitigate losses and facilitate adaptation.

Strong stakeholder partnerships exist to support the CMP development and implementation, including an Agency Reference Group who have collaborated to inform the vision, objectives and direction of the CMP developed during the scoping study. There is also strong community support and interest in the CMP development.

The North Creek CMP will enable a holistic and collaborative approach to the management of key issues impacting on the health and resilience of the catchment and estuary ecosystems, while supporting sustainable and productive industries and liveable communities.

North Creek estuarine reach

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1 Introduction

1.1 Scoping study purpose

Ballina Shire Council has commenced the development of a Coastal Management Program (CMP) for the coastal catchment of North Creek. The scoping study is the first stage in the process of preparing a CMP. The scoping study assists council to (OEH 2018b):

- Identify the community and stakeholders and prepare an engagement strategy
- Determine the strategic context of coastal management
- Establish the purpose, vision and objectives
- Determine the key coastal management issues and the spatial extent of management areas
- Review current coastal management arrangements
- Establish roles, responsibilities and governance
- Determine where action is required through a first-pass risk assessment
- Identify knowledge gaps and information needs
- Prepare a preliminary business case
- Determine whether a planning proposal will be prepared to amend coastal management area maps and the Local Environmental Plan
- Develop a forward program for subsequent stages of the coastal management program, including a fast-tracking pathway (if applicable).

This document sets out the scoping study for the North Creek catchment CMP. The scoping study establishes the program of work to be completed for the CMP and is completed in accordance with the requirements of the NSW Government Coastal Management Manual (OEH 2018), and with regard to the Coastal Management Act 2016 and Coastal Management State Environmental Protection Policy (SEPP) 2016.

North Creek estuarine reach

1.2 The study area

Ballina Shire

Ballina Shire is located in the Northern Rivers of the Far North Coast of New South Wales (Figure 1). The Shire covers an area of 485km^2, with over 32 km^2 of coastline including sandy beaches, rocky headlands, and the major estuary system and coastal floodplains of the Richmond River system.

Ballina Shire Council have undertaken several investigations in recent years in relation to the management of the open coast environment, including the development of a Coastal Zone Management Plan (CZMP) focused on managing beach erosion, shoreline recession and coastal inundation (Ballina Shire Council and GeoLink 2016). Prior to this, the Ballina Shire Coastline Management Study and Management Plan (2003) was also completed, looking at values of the coast and management options. A CZMP has also been completed for the Richmond River Estuary (Hydrosphere 2011) outlining action to address management issues affecting the estuary, along with a recent study on governance arrangements to enhance delivery of coordinated management efforts (Ballina Shire Council 2018).

North Creek is a tributary of the Richmond River estuary, and has not been the subject of a CZMP or similar detailed planning investigations to date. The catchment has a history of management challenges related to poor water quality and drainage, with adverse impacts on estuary health as well as agricultural and fisheries industries. Setting a forward program for integrated catchment management in the North Creek coastal catchment is a current priority for Ballina Shire Council. Therefore, the North Creek catchment is the focus area for this first CMP to be completed by Ballina Shire under the new legislation.

North Creek catchment

The North Creek catchment extends north from the confluence with the Richmond River in Ballina (Figure 1). The catchment is situated parallel to the coastline, and is bordered by the Alstonville plateau to the north west and the coastal dunes and headlands to the east near Lennox Head. The total catchment area is in the order of 122 km^2, and North Creek itself flows south for approximately 28 km, with an extensive estuarine reach in the lower catchment area.

The intertidal flats of lower North Creek and the Richmond River provide a sheltered environment for recreation, threatened migratory shorebirds, juvenile fish and other fauna. The mid to lower zones of North Creek are highly valued by tourists and locals for swimming, boating and fishing. A designated recreational fishing haven is situated within the lower estuary, except for the commercial mullet fishery at its mouth which is operated seasonally. Commercial oyster culture occurs in North Creek and within the Richmond River in Mobbs Bay.

The upper catchment supports agriculture such as sugarcane, macadamia plantations and livestock where tidal influence is limited. A complex network of drainage infrastructure has been installed to allow these agricultural developments. The Ballina Nature Reserve occupies a large area of the mid-section of North Creek and provides habitat for flora and fauna, including threatened species. Ongoing urban development is occurring within the catchment on the fringes of both Ballina and Lennox Head.

Figure 1. *The North Creek catchment to the north of Ballina*

1.3 Report structure

This North Creek catchment CMP scoping study is structured as follows, reflecting the scope of the CMP as defined previously in Section 1.1.

- **Section 2 – Program context:** An overview of the strategic and legislative context to the NSW CMPS, and for the North Creek catchment specifically.
- **Section 3 – Strategic context of coastal management:** A literature and data review - supplemented with new targeted desktop analysis and field assessments - on the relevant context and management challenges for the North Creek catchment. Including: environmental context, social and economic context, legal and planning context, review of Coastal Management Areas extents, current coastal management arrangements (existing plans), and potential barriers and enablers for effective management.
- **Section 4 – Purpose, vision and objectives:** Clarification of the purpose, and a preliminary vision and objectives of the North Creek catchment CMP.
- **Section 5 – Scope of the CMP – key management issues and areas:** First pass risk assessment on priority issues, and recommendations to address key knowledge gaps.
- **Section 6 – Preliminary business case and forward program:** A business case for the CMP including activities across CMP stages 2 – 3, costs, roles and responsibilities – lead applicant and established partnerships, as well as timeframes and any requirements for an amended planning proposal.
- **Attachment A –** A Community and Stakeholder Engagement Plan (C&SEP) prepared as a document that is part of this scoping study and can also be a stand-alone document for ease of reference throughout the CMP process.
- **Attachment B –** EPBC report
- **Attachment C –** First ARG meeting minutes
- **Attachment D –** North Creek CMP survey responses
- **Attachment E –** Relevant policy summaries
- **Attachment F –** Water Quality Monitoring Program

North Creek catchment - rural landscape

2 Program context

2.1 NSW Coastal Management Framework

Overview

Recent coastal management reform led by the Office for Environment and Heritage and the Department of Planning and Environment has involved the release of several key pieces of legislation, policies and guidance material over the last six years (Figure 2). These changes have been developed under the supervision of the responsible ministers and the Coastal Expert Panel with the aim to manage the coastal environment in a manner consistent with the principles of Ecologically Sustainable Development (ESD), i.e. for the 'social, cultural and economic wellbeing of the people of the State'.

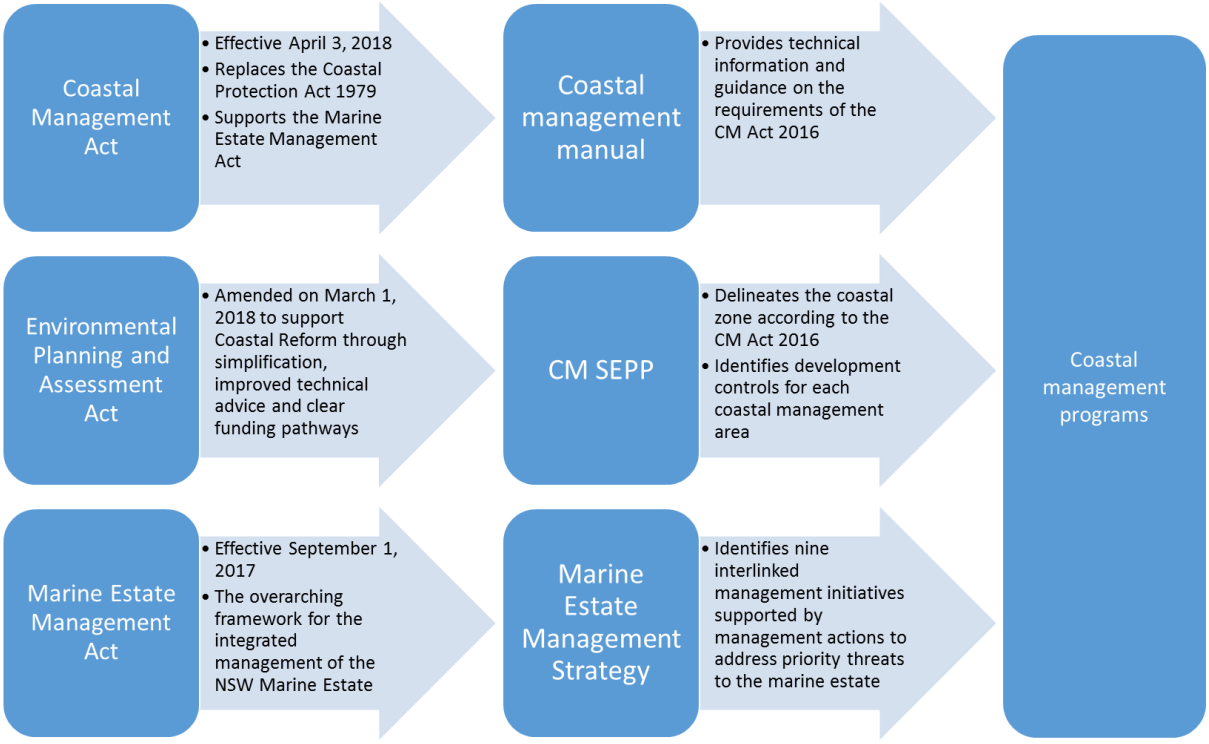


Figure 2. *An overview of the legislation, policies and guiding material involved in NSW coastal management reform*

Four key component documents / programs that provide direct influence / guidance for the Coastal Management Program are summarised further in Figure 3.

North Creek main channel – mid-catchment (rural)

Coastal Management Act 2016	•This Act divides the coastal zone into four management areas which are to be used by local councils to achieve the objectives of the Act through the implementation of their respective Coastal Management Programs. The guidance for this process is provided for by the Coastal Management Manual (OEH 2018a) through a five-stage approach (see Table 1 below).
State Environmental Planning Policy (Coastal Management) 2018	•Updated in 2018, the Coastal Management State Environmental Planning Policy (Coastal Management) 2018 (CM SEPP) supports the Coastal Management (CM) Act 2016 through provision of the development controls specific to each of these coastal management areas. These controls are supported by the Environmental Planning and Assessment (EP&A) Act 1979.
Marine Estate Management Act 2014	•A key objective of the Marine Estate Management (MEM) Act 2014 is improved co-ordination by public authorities in relation to their responsibilities to the Marine Estate. This integration, critical to the delivery of outcomes for both the Marine Estate Management Strategy (MEMS) 2018 and the Coastal Management Program, is supported by the Coastal Management Act, which 'support(s) the objects of the MEM Act 2016'.
Coast and Estuary Grants Program	•Funding support for local councils has been made available by the State government for this reform process through the Coastal and Estuary Grants Program, which is part of a greater $83.6 million funding package for coastal management in NSW from 2016-to 2021. In developing the CMP, councils are required to clearly identify and balance competing interests and priorities within the coastal zone (OEH 2018).

Figure 3. *Summary of several key documents / programs that have influenced the CMP process*

2.2 Coastal Management Programs

The five recommended stages to preparing a CMP as set out in the Coastal Management Manual (OEH 2018a) are shown in Figure 4 and Table 1. When progressing through this approach, Councils are required to report on progress, outcomes and achievements in line with reporting requirements under the Integrated Planning and Reporting (IP&R) framework (OEH 2018a).

Completion of the Stage 1 scoping study involves a review of the existing understanding of the catchment, examining progress on the management of coastal issues, developing a shared understanding amongst stakeholders of the issues at hand, identifying the key knowledge gaps and risk, and developing recommendations for future studies/investigations and a forward program of work to complete the CMP.

Figure 4. *Five stages to preparing a CMP (OEH 2018a)*

Table 1. An overview of the five-stage process of a Coastal Management Program (OEH 2018a)

CMP stage	Key steps	Key outputs
	• Identify key stakeholders and prepare an engagement strategy • Determine the strategic context of coastal management • Establish the purpose vision and objectives • Identify key coastal management issues and review coastal management arrangements • Determine where action is required through a first pass risk assessment	• Identification of the key knowledge gaps and how to bridge them • Established roles responsibilities and governance • Determination on whether a planning proposal will be prepared to amend coastal management areas and the Local Env Plan • A forward program for the Stage 2 and Stage 3 of the coastal management program • A preliminary business case for recommended studies
	• Define the socioeconomic characteristics such as demographics, coast dependent economic activity, land use patterns and future development scenarios • Improve the understanding of the complexity of the issues and community perspectives • Ensure different perspectives are incorporated in the analysis of consequences and likelihood • Understand the range of potential future scenarios and the local community's attitude to risk	• Quantification of the nature and the extent of threats to public and private assets (both natural and built). • Context and data to support the identification and evaluation of management options in Stage 3. • Identification of opportunities to reduce risks and enhance the environmental, social and economic values. • The detailed information necessary for a planning proposal to amend the mapping of the coastal management areas
	• Confirm the strategic direction for the catchment • Identify potential options for integrated management of all coastal management areas. • Evaluate the feasibility, viability and acceptability of management actions • Engage public authorities about implications for their assets and responsibilities • Evaluate mapped coastal areas and implications if a planning proposal is prepared	• Identify pathways and timing of actions • A business plan for implementation
	• Prepare a Coastal Management Program (CMP) • Submit the draft CMP to the Minister for certification • Review and adopt the draft CMP	• Exhibition of the draft CMP and any related planning proposal • Publishing of the certified CMP in the Gazette
	• Implement actions in the published CMP through the IP & R framework and land use planning system • Implement actions in partnership with adjoining councils and public authorities where relevant • Implement an effective monitoring, evaluation and reporting program • Monitor indicators, trigger points and thresholds	• Amendments, a review of and updates to the CMP • A report to stakeholders and the community on progress and outcomes through the IP&R framework

2.3 Towards the North Creek CMP

The final North Creek catchment CMP will provide a framework for the future management of the catchment and coastal areas

Management challenges at a glance – the need for a CMP
Over time, the ability of the North Creek catchment to support a functioning ecosystem has been significantly compromised to the extent that several environmental, social, legal and planning issues now exist. Some of the key management challenges facing the North Creek catchment centre around the following:

- Altered hydrology
- Impacts of climate change
- Catchment runoff and the impacts on water quality
- Weeds and pests
- Governance
- Ongoing urbanisation
- Sand mining

North Creek has experienced significant historical changes to land use and hydrology as a result of European settlement. The change is ongoing, with urban development continuing on both sides of the mid-catchment. As development increases and agricultural practices change, complex governance arrangements add to the complexity of managing legacy issues associated with altered hydrology and water quality.

The low relief of the majority of the catchment also exposes agricultural and urban areas (including Ballina) to the risk of tidal inundation from projected sea-level rise. Despite relatively minor community concern, this ingress has the potential to significantly impact catchment and community values in the next 20, 50 and 100 years. As the population continues to grow and land use pressures increase, there is a need to quantify the threats and risks to the local communities.

With the new coastal management framework, the appropriate legislation is now in place to provide councils with the support to deal with complex issues associated with management of coastlines and coastal catchments. It is envisaged that the final North Creek catchment CMP will provide a framework for the future management of the catchment and coastal areas. Bridging key knowledge gaps on the social, environmental and economic impacts of altered hydrology, poor water quality and tidal inundation in the catchment are key to the success of the CMP, and concurrently, gaining support for the adoption of the CMP from stakeholders and the community is essential.

Policy context
The statutory framework supporting the management of the North Creek catchment is complex. In addition to the regulatory and policy documents discussed as part of the coastal reform (Figure 3.), several other federal, state and local legislation, policies and management plans and guidance material complete the policy and planning context for the North Creek catchment. This is illustrated and summarised in

Further details of how objectives from local, regional and state policy and planning documents relate to the key management issues facing the North Creek catchment are discussed later in this document.

Figure 5. *Relevant federal, state and local legislation, policies and management plans and guidance material which comprise the statutory landscape for the North Creek CMP*

3 Strategic context of coastal management

The following section provides a review of the background information relating to the existing management practices and studies that have been conducted in the North Creek catchment and Ballina Shire. This includes a literature review and summary narratives that incorporate the following elements:

Landscape context and physical processes shaping the landcape

Climate

Values and threats (environmental, social, economic).

3.1 Setting, geology and soil-landscapes

Key points

- Much of the catchment is of very low elevation representing formerly freshwater and estuarine wetland locations in a back-barrier environment.
- Over 50 % of the North Creek catchment has been identified as at risk from acid sulfate soils (potential or known)

Landscape setting

The North Creek catchment consists of a mosaic of landscapes which have been sculpted over time by the interplay of coastal and terrestrial geomorphic processes. The dominant topography of the catchment comprises of weathered basaltic flows known as the Alstonville Plateau, Skennars Head and Lennox Head. Over time, sediments shed off these flows, plus those delivered from the coastal margin, have deposited in a series of intercalated marine and terrestrial sequences within the adjacent low-lying areas. Once heavily forested, these low-lying coastal swamps and intertidal wetlands have now been extensively modified for agriculture.

The main stem of North Creek runs along a series of agricultural drains which are gated to restrict tidal ingress which can now extend up to two thirds of this modified catchment (Ryder et al. 2015). A considerable portion of highly modified tidal wetland remains along the lower half of the creek (Ballina Nature Reserve) before it widens to a broader estuary system. Lower North Creek flows through the urban areas of Ballina and Ballina East and has high recreational value for the local community.

Coastal processes

The adjacent coastline outside the North Creek Catchment boundary extends from Ballina to the north past Broken Head. The coast is situated within one main sediment compartment, with predominantly sandy shores interspersed with hard rock shores around the several headlands (NCCARF 2018). Erosion (storm bite) and long-term recession with sea level rise are ongoing processes along the open coast areas, and may put increased pressure on development in the North Creek catchment as the future development focus may shift inland.

For North Creek catchment itself, tidal inundation is the main coastal process impacting on the catchment form and function. Predicted sea level rise with climate change is expected to substantially increase the extent

of tidal ingress up into the North Creek catchment area by 2050 and 2100 (NCCARF 2018), bring increased management challenges for the catchment in relation to agricultural productivity, drainage and water quality, and ecosystem dynamics (discussed in later sections).

Geology context

The geologic setting for North Creek is one in which the coastal fringe meets the tertiary basalts of the Alstonville Plateau in a dynamic environment. Much of the catchment is of very low elevation representing formerly freshwater and estuarine wetland locations in a back-barrier environment. Around Broken Head lie metamorphosed sediments forming the north-eastern catchment boundary. The north-western and western catchment divide consists of the Lismore Basalts, which also form outliers at Skennars Head and around East Ballina in the vicinity of the Missingham Bridge.

Originally the catchment consisted of both estuarine and aeolian sediments behind coastal dunes. This would have been a freshwater environment transitioning to a brackish one with intermittent openings to the estuarine waters at very high tides and during storm events. Different climates have also contributed to the development of the sediments and soils on which North Creek lies today. It is likely that the low-lying areas of the catchment were inundated by estuarine waters altogether during the Holocene 'sea-level high stand' some 2000 to 2500 years ago, with the presence of coastal sands deposited inland indicating that the local sea level was approximately 1 to 1.5 m higher at that time (Lewis et al. 2013).

A snapshot of the underlying geology of the catchment demonstrates the complex nature of its coastal landscape location (Figure 6).

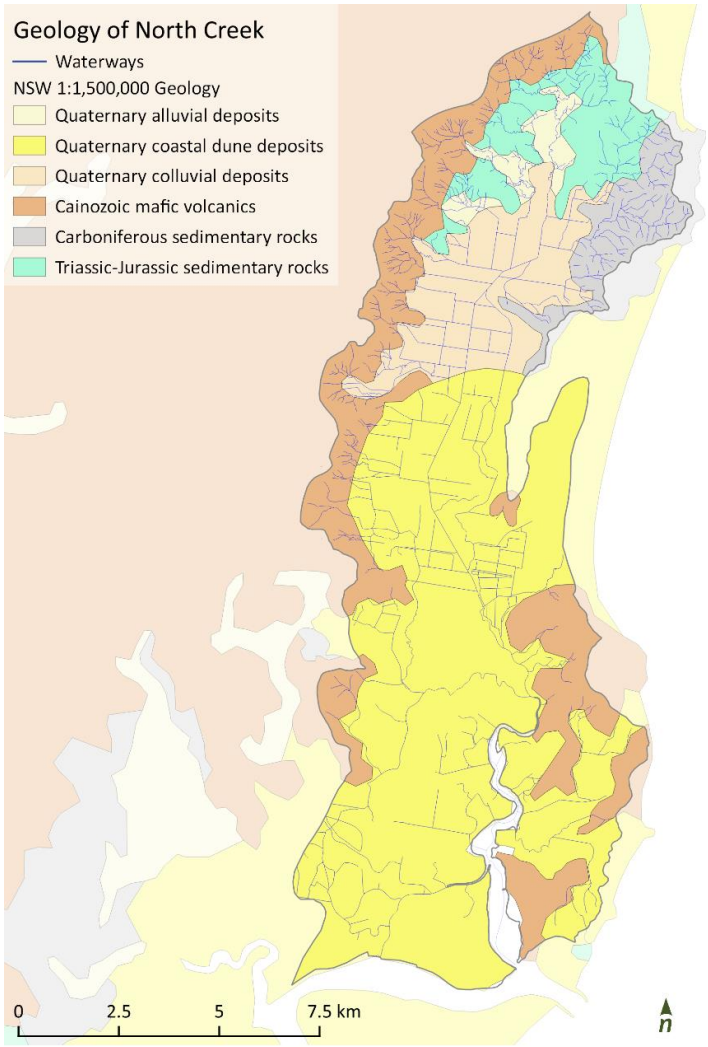
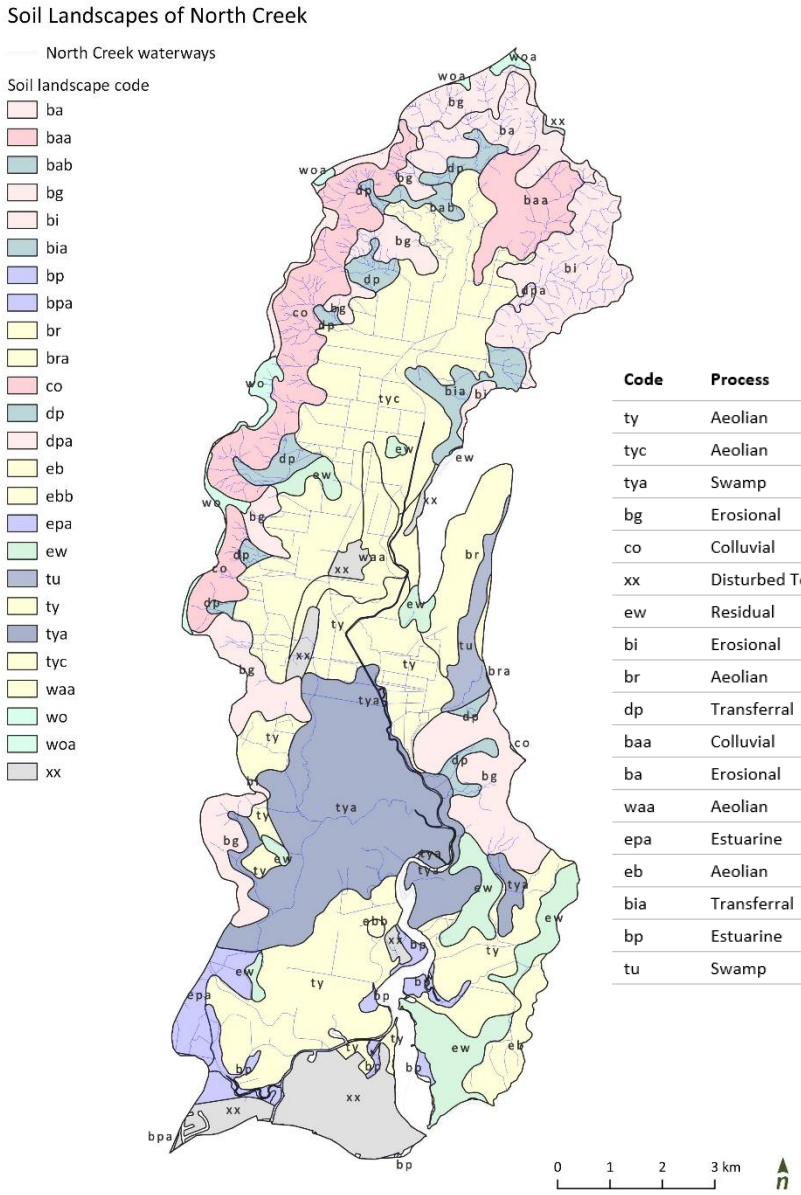


Figure 6. *The surface geology of the North Creek catchment (DPE 2015)*

Soil landscapes

The 'soil-landscapes' mapping by the state government provides an integration of soil and topographic factors to assist with identifying potential limitations for urban and rural development. The soil-landscapes within the North Creek catchment are shown in Figure 7.



Code	Process	Name	% Total area
ty	Aeolian	Tyagarah	16%
tyc	Aeolian	Tyagarah variant c	15%
tya	Swamp	Tyagarah variant a	13%
bg	Erosional	Bangalow	10%
co	Colluvial	Coolamon	7%
xx	Disturbed Terrain	Disturbed Terrain	6%
ew	Residual	Ewingsdale	5%
bi	Erosional	Billinudgel	4%
br	Aeolian	Black Rock	3%
dp	Transferral	Disputed Plain	3%
baa	Colluvial	Bagotville variant a	3%
ba	Erosional	Bagotville	2%
waa	Aeolian	Wardell variant a	2%
epa	Estuarine	Empire Vale variant a	2%
eb	Aeolian	East Ballina	1%
bia	Transferral	Billinudgel variant a	1%
bp	Estuarine	Burns Point	1%
tu	Swamp	Tuckean	1%

Figure 7. *The soil landscapes of North Creek (OEH 2017b)*

DPIE Environment, Energy and Science (EES) utilises soil landscapes mapping to provide an integration of soil, topography, aspect and other geomorphic processes. A soil landscape can be defined as an area of land that has "recognisable and specifiable topographies and soils...and that can be described by concise statements" (Northcote, 1978). Soil profiles are not necessarily uniform within the landscape.

Soil classification

There are other methods of describing soils, such as the Australian Soil Classification (CSIRO).The Australian Soil Classification classifies the soils as they occur in situ which has a relationship to the parent material and geomorphic processes acting upon them, whereas the Soil Landscapes describe those processes and the types

of soils that you find within them. A map of corresponding soil types as described under the Australian Soil Classification is provided in Figure 8.

Together, both classification approaches (soil types and soil landscapes) provide a catchment wide appreciation of both the soils *in situ* and how they have developed. There is an observable relationship between soil types and acid sulfate soil risk (Figure 8).

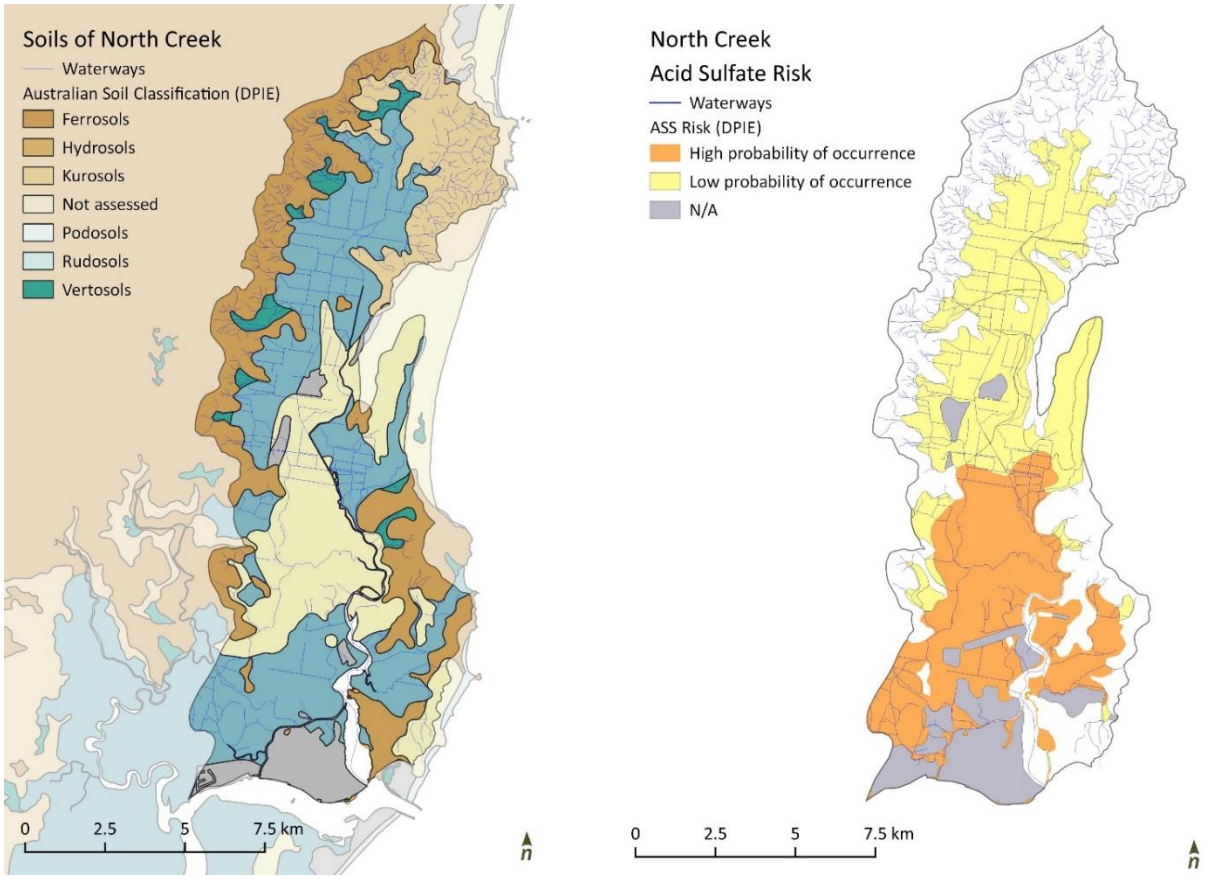


Figure 8. *The soils and acid sulfate risk of the North Creek catchment - note that mining operations and drainage works have confirmed the existence of acid sulfate soils within the low probability zone.*

With regard to acid sulfate soil risk, Morand (1994) notes that acid sulfate soil material was identified near the vicinity of the original course of Deadmans Creek. Studies investigating quarry remediation on the upper North Creek floodplain have found that even sediments identified as Low Risk for acid sulfate soil, such as those in water held in former quarries - are discharging low pH (acid) water. It is unclear whether this is due to the acid nature of the Tyagarah soils or acid sulfate soil material. Morand (1994) also notes very localised acid sulfate soils in old estuarine areas which may be contributing.

A summary of soil types and implications for management in the North Creek catchment are provided in Table 2. Over 50 % of the catchment is likely to be at risk from acid sulfate soils (potential or known).

Table 2. Soil types and associated management issues within the North Creek catchment, including potential acid sulfate soils (PASS) and known/expected acid sulfate soils (ASS).

Soil Type	Description	Management issues to consider	Catchment percentage	Catchment location	Approximate elevation (m)
Hydrosol	Waterlogged soils of varied compositions. High levels of organic matter. PASS	Disturbance likely to oxidise iron sulphides. PASS	35 %	Permanently inundated areas	0-2
Ferrosol	Well structured, deep, Fe rich and well-draining. A high value agricultural soil.	Development pressures on high quality agricultural soil	23 %	Slopes and ridges	10-100
Podosol	B horizon dominated by the accumulation of organic matter, aluminium and/or iron	Metal toxicity in the event of acute acid discharge, PASS	21 %	Flood plain areas and foot slopes	1-10
Kurosol	Texture contrast soils. Sandy surface and clay sub-surface.	Dispersive varieties have high erosion risk	12 %	Slopes and ridges	10-90
Not assessed	Soils predominantly overlain by development	High probability of PASS or ASS	6 %	6 %	1-10
Vertosol	Swelling clays can cracks >5mm when dry Often have dispersive subsoils	Minimise sub-soil exposure	3 %	3 %	1-15

North Creek – mid-catchment swampy areas: potential acid sulfate risk for inundated and floodplain areas

3.2 **Climate**

Key points

- The climate of the North Creek catchment is regulated by its proximity to the sea
- A relatively short record of temperature and rainfall is available for the Ballina Shire
- The catchment has experienced a number of significant flooding events in recent history
- Sea level rise is likely to have an increasing impact across the catchment

The North Coast region of NSW generally experiences a sub-tropical climate. The main atmospheric factors affecting the climate are the slow, easterly-moving high-pressure systems, low pressures systems associate with cold fronts and the occasional tropical cyclone which drifts south (DECCW 2010). North Creek's climate is regulated by its proximity to the sea, which moderates the extremes in temperature experienced further inland.

Temperature and rainfall

Mean summer highs are approximately 28°C from December through to February and average winter lows reach approximately 9°C in June and July (BOM 2018) (Figure 9.). Approximately 1800 mm of rain falls annually, with the majority falling during rapid and intense rain periods in the summer (BOM 2018) (Figure 10).

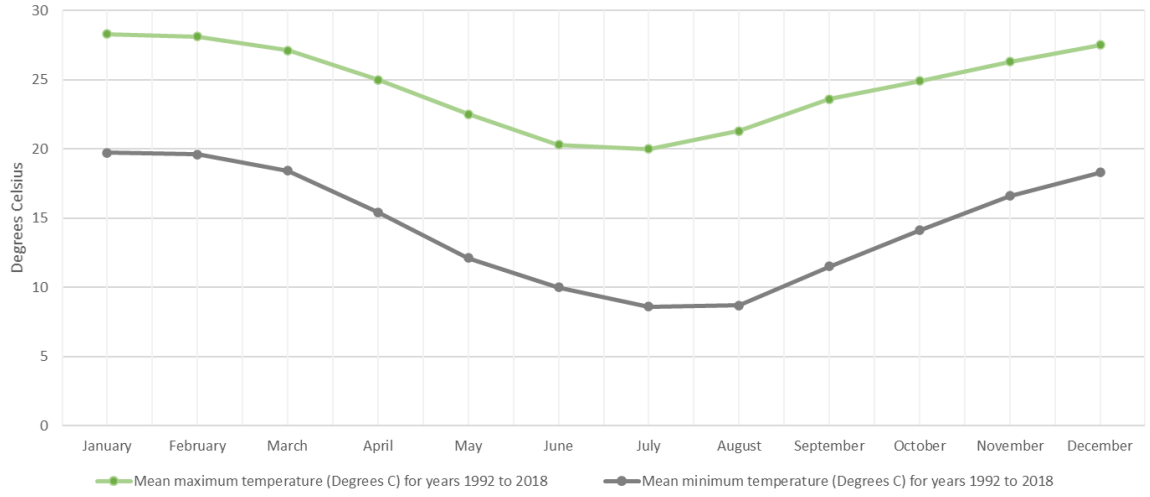


Figure 9. *Mean maximum and minimum temperatures for Ballina airport from 1992 to 2018 (BOM 2018)*

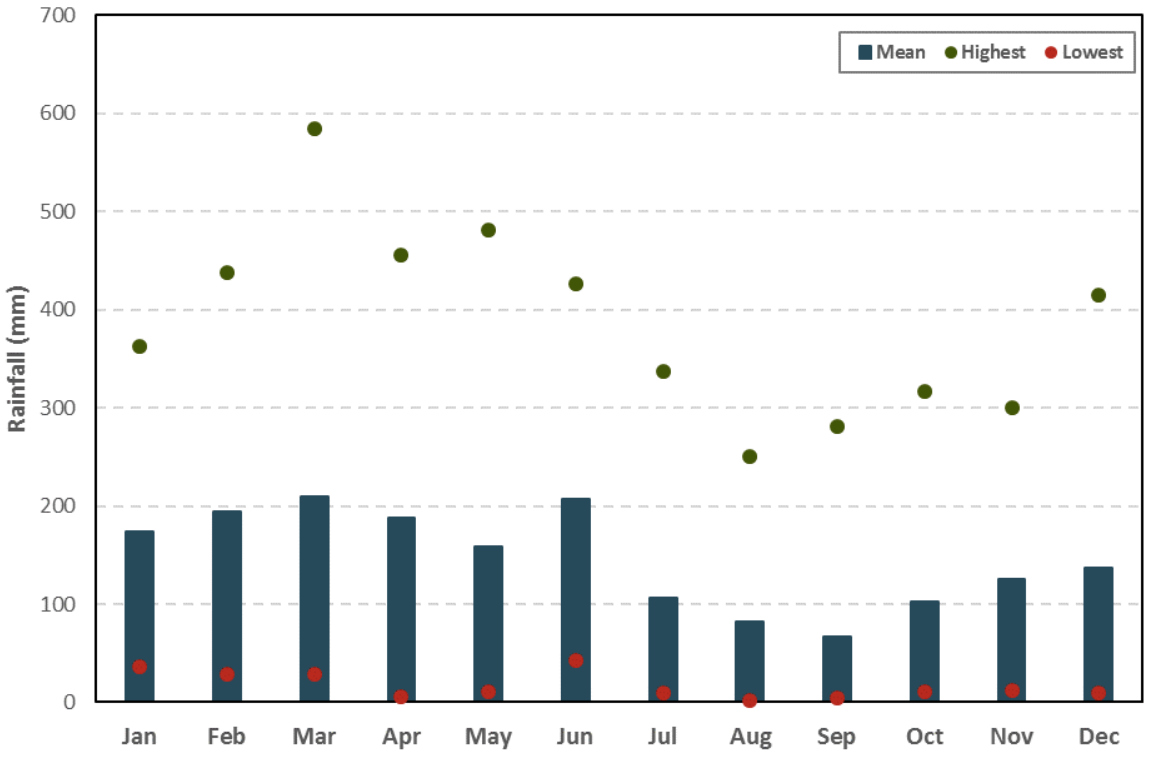


Figure 10. *Highest, lowest and mean monthly rainfall from 1992 – 2018 from Ballina Airport (BOM 2018)*

Significant storm events

The Richmond river catchment has been subject to significant flooding in the past. Since 1900 the largest floods in the catchment were in 1954 and 1974 (WBM 2012). In more recent times significant flooding has occurred in 2001 and 2006 and 2008, all of which were both associated with moderate to major fish kills (Wong et al. 2018). Oyster harvest areas in the Lower Richmond and North Creek were also closed during these times.

A changing climate and implications for Ballina Shire

Climate change is influencing changes in regional sea level, rainfall patterns, and temperature, with a range of implications for coastal management including estuaries and catchments.

Temperature and rainfall

Climate projections for the north coast of NSW depict a warming of 0.7 degrees by 2020-2039 which will reach 2 degrees by 2060-2079. Maximum temperatures also increase with reduction in potential frost risk. Rainfall is projected to increase in autumn in spring and decrease during the winter. Fire weather is also projected to increase in summer and spring, along with severe fire weather days (Mummery 2016).

The CoastAdapt support tool employs eight climate models to predict temperature and rainfall extremes at a Local Government Area level. The projected changes in temperature extremes for the Ballina region are shown in Figure 11. These projected increases in hot day, warm nights and heatwaves have the potential to impact the liveability and productivity of the catchment. These increases could test the climate for which facilities such as retirement homes have been designed. Primary production may also be at risk, particularly those industries sensitive to climatic change. These industries may include intensive horticulture and oyster culture.

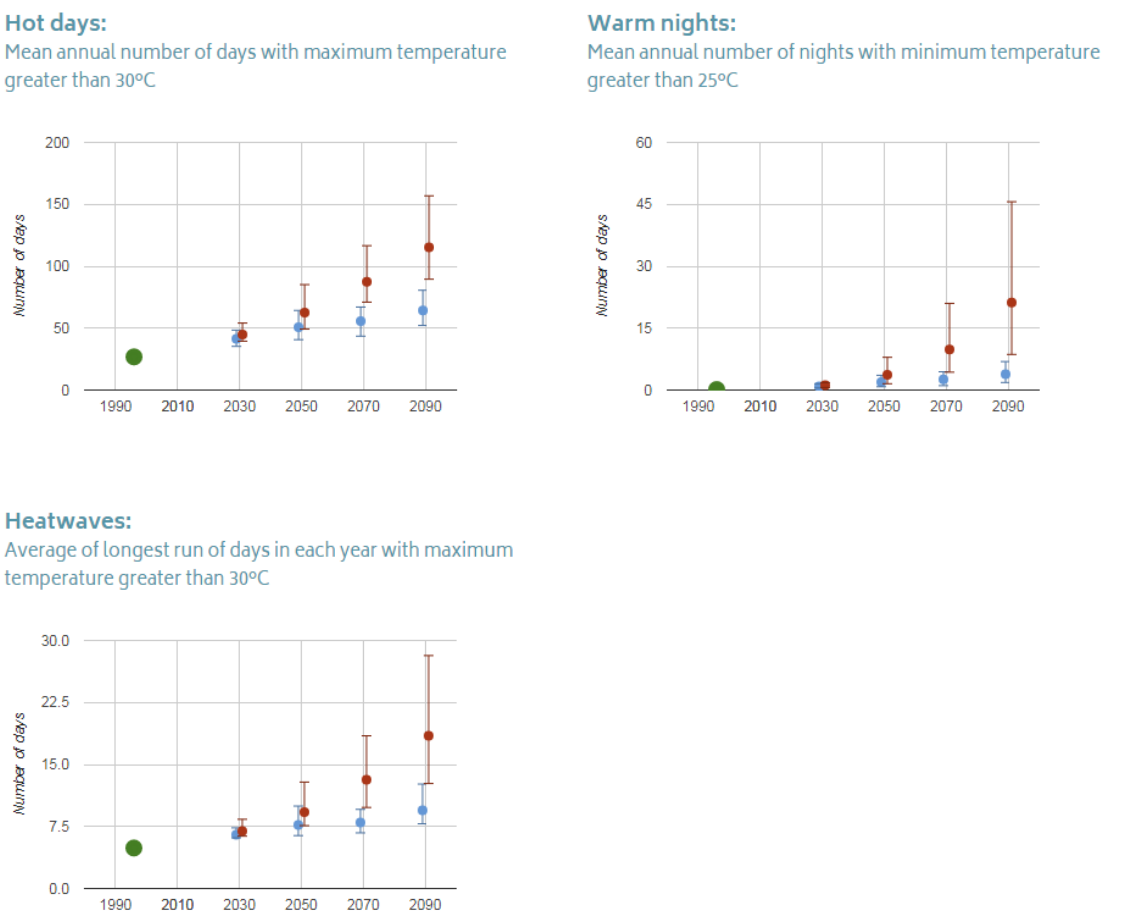


Figure 11. *Temperature extremes plot for the Ballina Region. The green dot represents observed conditions based on 1981-2010 data and the bars indicate future (modelled conditions for four time slices up to 2090. The red dots delineate the highest greenhouse gas scenario (RCP8.5) and blue represent the low (RCP4.5) scenario. The dot is the mean across the eight climate models, the upper end of the bar is the maximum value from the eight models and the lower end of the bar the minimum. (NCCARF 2018).*

The potenital changes in rainfall that could occur as a result of climatic change are presented in Figure 12. These changes indicate a mild reduction of rainfall in the near (2030), mid (2050) and long term (2090). Such changes may impact the viability of marginal primary production, aquifer recharge rates and the resilience of marginal ecosystems within the catchment/region.

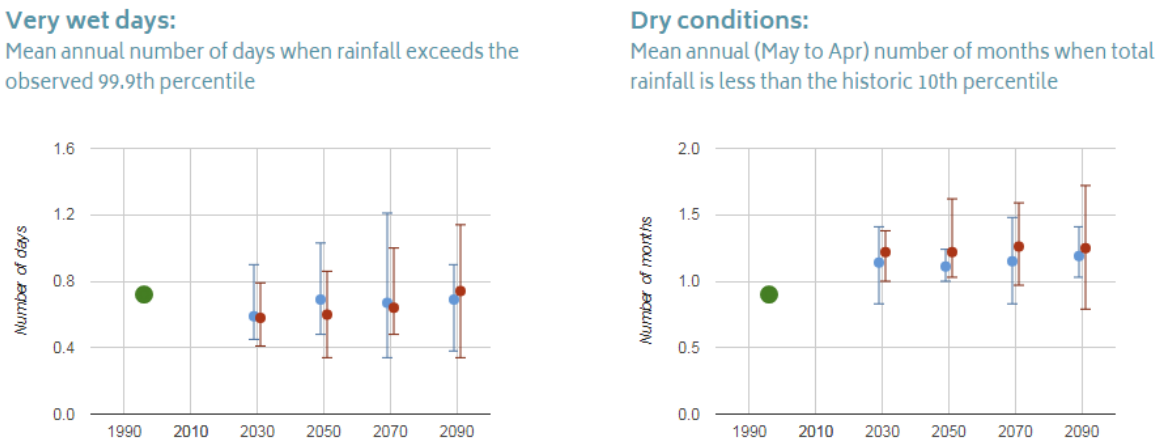


Figure 12. *Extreme rainfall plots for the Ballina Region. Very wet days which are the mean annual number of days when rainfall exceeds the historic 99.9th percentile, and Dry conditions which are the mean annual (May to April) number of months when total rainfall is less than the historic 10th percentile. The green dot represents observed conditions based on 1981-2010 data and the bars indicate future (modelled conditions for four time slices up to 2090. The red dots delineate the highest greenhouse gas scenario (RCP8.5) and blue represent the low (RCP4.5) scenario. The dot is the mean across the eight climate models, the upper end of the bar is the maximum value from the eight models and the lower end of the bar the minimum. (NCCARF 2018).*

Sea level rise and tidal inundation

The NSW government 2009 sea level rise policy statement provided state-wide benchmarks of projected sea level rise to ensure consistent adaptation by coastal councils, namely a 0.9 m increase by 2100. The Ballina Development Control Plan has factored these benchmarks into its flood planning levels (BSC 2012). These benchmarks were also employed in the 2015 WBM Newrybar Swamp drainage and flood mitigation study (discussed further below) which modelled climate change scenarios for the lower and mid catchment.

In the recent NSW coastal legislation reform, the 2009 sea-level rise policy has been adjusted in favour of flexibility for councils to determine their own sea level rise projections. Likely global mean sea-level rise by 2100 has been projected to exceed the 0.9 m benchmark (by 0.08 m) in the highest emissions scenario. The IPCC also suggest the possibility of greater rises should unfavourable conditions prevail, such as ice sheet collapse (OEH 2018d).

The CoastAdapt risk management framework provided by the National Climate change Adaptation Research Facility (NCCARF) has been recently developed as a support tool for local government to assess the risk posed by predicted sea level rise. Four different Representative Concentration Pathways (RCPs) are available to understand how climate change may impact sea levels, as presented in Figure 13. (NCCARF 2018).

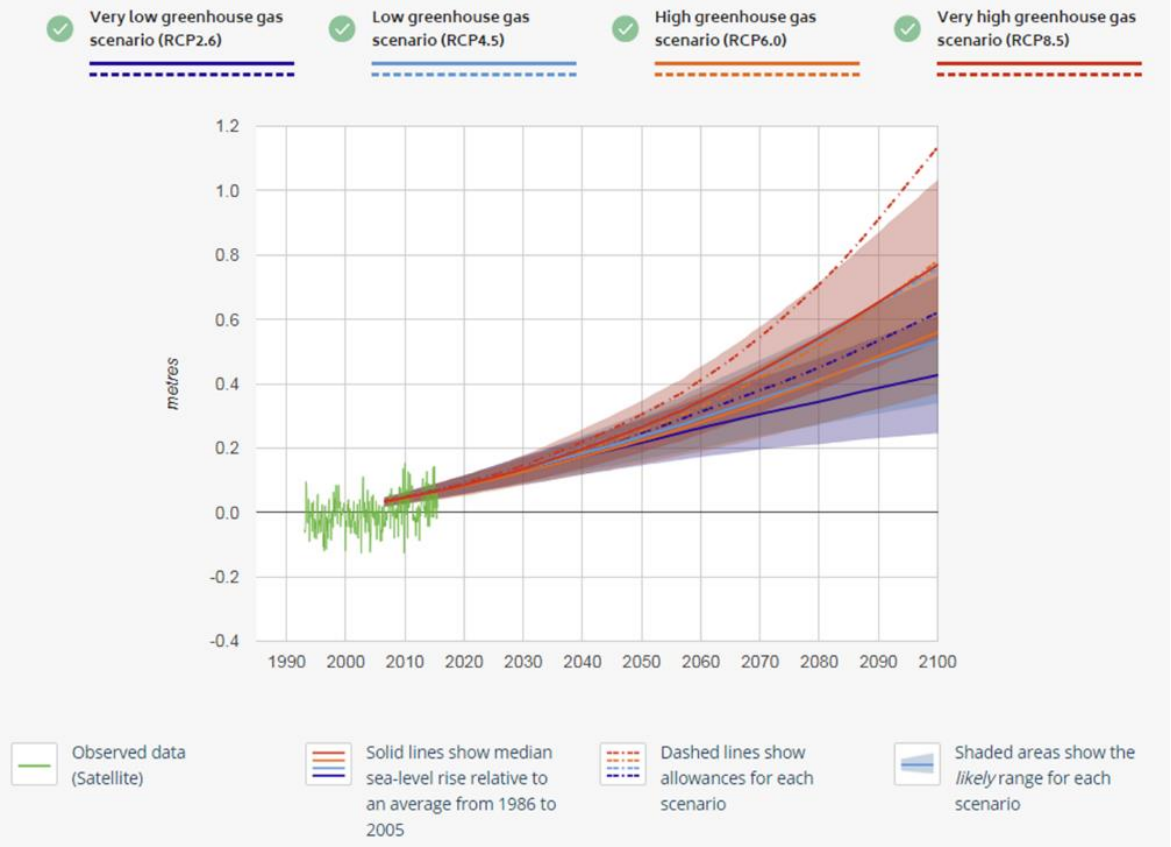


Figure 13. *Predicted sea level rise scenarios under very low to very high greenhouse gas scenarios (NCCARF 2018).*

As current emissions are tracking close to the RCP 8.5 pathway, a high level of adaptation at a high cost is expected (NCCARF 2018). The dashed 'allowance' lines in Figure 13. indicate the corresponding height coastal defences would need to be raised to provide the same level of protection as they do today.

A summary of predicted sea level rise from 2030 to 2090 within the Ballina region and the corresponding allowances required to protect at risk development are provided in Table 3 and Table 4.

Table 3. Predicted sea level rise along the Ballina coastline relative to an average calculated between 1986 and 2005 (NCCARF 2018)

	Greenhouse Gas scenario (RCP)			
Date (unit)	Very Low (RCP 2.6)	Low (RCP 4.5)	High (RCP 6.0)	Very High (RCP 8.5)
2030 (m)	0.09 - 0.18	0.09 - 0.18	0.09 - 0.17	0.09 - 0.18
2050 (m)	0.15 - 0.29	0.17 - 0.32	0.15 - 0.30	0.19 - 0.35
2070 (m)	0.20 - 0.42	0.24 - 0.48	0.23 - 0.46	0.31 - 0.58
2090 (m)	0.23 - 0.55	0.31 - 0.65	0.32 - 0.66	0.46 - 0.88
Rate of change at 2100 (mm/yr)	1.6 - 6.5	3.2 - 8.7	4.7 - 10.5	7.6 - 16.1

Table 4. Corresponding allowances for predicted sea level increase under different RCPs (NCCARF 2018)

	Greenhouse Gas scenario (RCP)			
Date (unit	Very Low (RCP 2.6)	Low (RCP 4.5)	High (RCP 6.0)	Very High (RCP 8.5)
2030 (m)	0.14	0.15	0.14	0.15
2050 (m)	0.25	0.27	0.26	0.31
2070 (m)	0.38	0.44	0.42	0.55
2090 (m)	0.54	0.65	0.65	0.92

The predicted inundation levels for the highest modelled emissions pathway (RCP 8.5) in 2050 and 2100 is illustrated in Figure 14.. This model imposes the predicted sea level rise shown in Figure 13. on the highest astronomical tide (HAT) for the Ballina region. The model uses a simple 'bucket fill', and the result is an approximation only, the model does not consider existing seawalls or barriers, the consequences of erosion, storm surge and wave height. Technical guidance material on the data and methodologies used to produce these maps is available in Church et al. (2016).

Despite the constraints of the model, it provides an indication of the potential increase in tidal inundation expected by the 2100 planning horizon. As such, it supports the first pass risk assessment as part of this scoping study (see Section 5).

The NCCARF model indicates an increase in sea level of approximately 1.2 m by 2100 when compared to baseline 1981-2010 data. This contrasts with the benchmarks currently employed by the BFRMP and the subsequent Development Control Plan (DCP), which employ a 1990 mean sea level as baseline. At the very least, there is a 0.3 m difference in the two 2100 benchmarks which the BFRMP and DCP will need to consider. The tidal extent of North Creek is also susceptible to storm tide inundation. Storm surges and the other factors excluded from the bucket fill model will need to be taken into consideration with future modelling.

Within the North Creek catchment tidal inundation is the main coastal hazard. Large areas of the lower catchment have a low elevation and will be increasingly exposed to tidal inundation associated with sea level rise. Urban and agricultural areas will be increasingly exposed to tidal inundation by 2100.

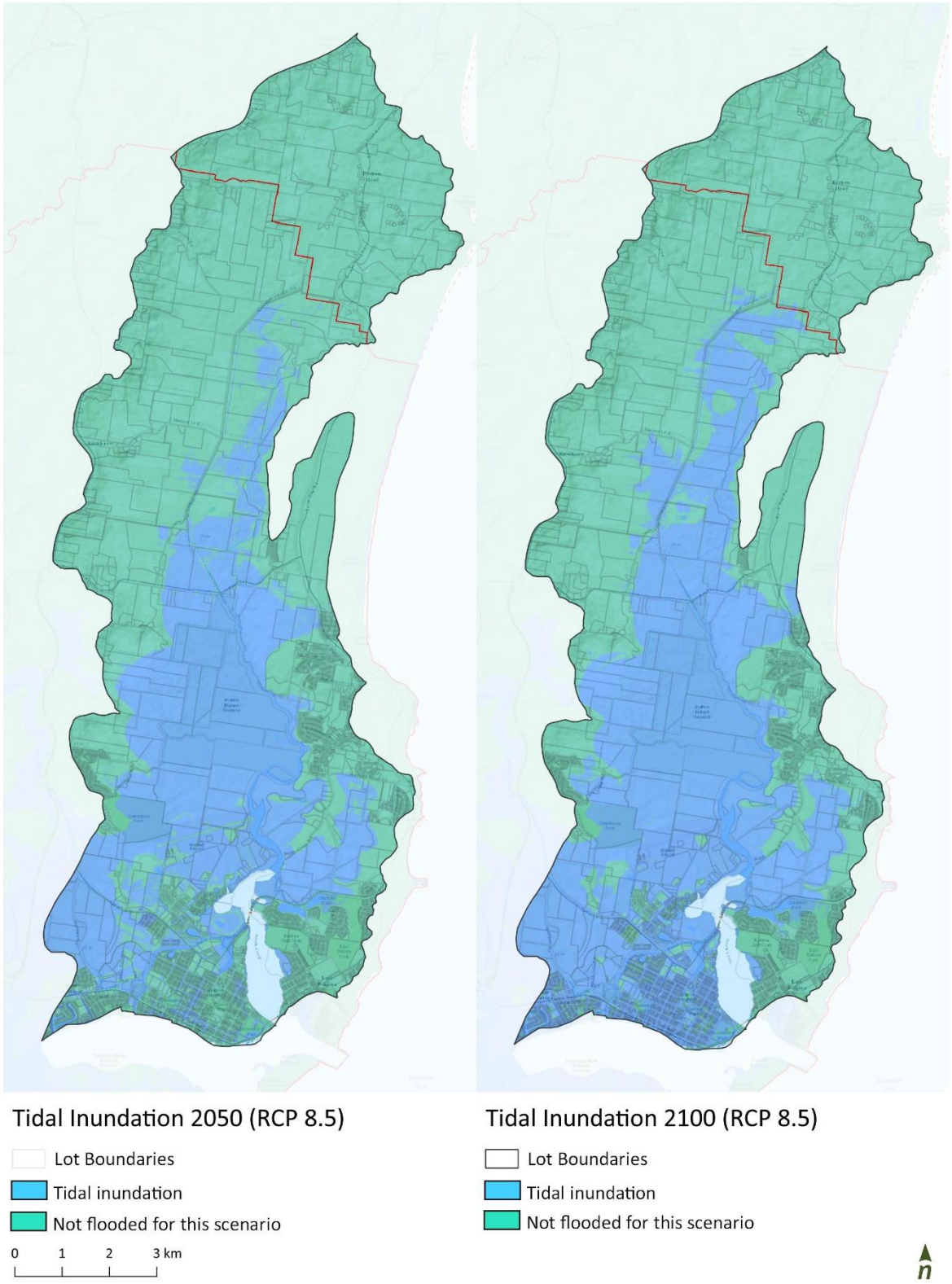


Figure 14. *Modelled tidal inundation extents for North Creek in the highest emissions scenario for 2050 (left) and 2100 (right) (otherwise known as the Representative Concentration Pathway 8.5 or RCP 8.5) (NCCARF 2018).*

The CoastAdapt risk assessment tool provides for the initial screening of climate change hazards and implications. This tool has been applied to the North Creek catchment and considers the climate hazards relevant to the North Creek catchment under a 2100 planning horizon assuming a RCP 8.5 scenario. A summary of the potential climate hazards and implications identified within the catchment are provided in Table 5.

Table 5. Summary table of potential climate hazards in the North Creek catchment within the 2100 timeframe

Potential hazard	Have these occurred in the past?	Likely future direction of the hazard?	Which geographic area/sector/assets/ecosystems can be impacted?
Storm surge inundation	Yes	Increase	All low-lying areas within and adjacent to the tidal 2100 extent of North Creek as depicted in Figure 29.
Entrance instability	Yes	Increase	Any training walls and entrance management (including dredging) which did not take 2100 projected sea level rise (and associated sediment transport impacts) into consideration during construction.
Tidal inundation of estuary and surrounding area	Yes	Increase	All low-lying areas within the catchment which intercept the projected tidal inundation levels for years 2050 and 2100 at RCP 8.5. Refer to Figure 35.
Erosion within estuary	Yes	Increase	All exposed or poorly vegetated banks along North Creek and the estuary as outlined in low lying areas within the catchment at risk of inundation are also at risk of increased erosion.
Saline intrusion in estuary	Yes	Increase	Estuarine macrophytes, especially those at the upper end of the tidal extent, groundwater dependent ecosystems, groundwater dependent industry/agriculture. Low lying green spaces and recreation spaces. Primary industry (macadamias, sugar, grazing etc) through groundwater intrusion.
Prolonged summer heatwave	Yes	Increase	Entire catchment, especially townships (urban heat island effect), young and elderly, Primary industry (macadamias, sugar, grazing etc)
Increased number of hot days and nights	Yes	Increase	Entire catchment, especially townships (urban heat island effect), young and elderly, Primary industry (macadamias, sugar, grazing etc)
Surface water flooding	Yes	Increase	All low-lying areas within the catchment, including Ballina Island and proximal low-lying developed areas. Primary industry (macadamias, sugar, grazing etc)
Drought	Yes	Increase	Entire catchment, Primary industry (Macadamias, sugar, grazing etc), Water sensitive threatened ecological communities (Swamp oak forest and Littoral Rainforest)
Erosion induced by excessive rainfall	Yes	Increase	All areas within the catchment with exposed soil.
Bushfire	Yes	Increase	Well vegetated areas and/or grasslands which are prone to drying out due to seasonality or drought.

Knowledge gaps

A detailed understanding of impacts from climate change, in particular tidal inundation, in the North Creek catchment are largely unknown. While the projected sea level rise reflected in the bathtub model provided through CoastAdapt is a good indication of potential inundation, it is a broad estimate only. The bathtub model does not account for the dynamic estuarine environment and model precision is limited by the resolution of the baseline DEM used in the model.

Key knowledge gaps exist around:

- Tidal inundation extent within the catchment.
- The socio-economic impact of inundation, including vulnerability mapping to inform floodplain and land use planning.
- How coastal wetlands will respond to tidal inundation.
- How groundwater systems will respond to tidal inundation and how this will impact primary industry.
- How projected changes in climate will impact ecosystems, primary industry and liveability within the catchment.

A hydrodynamic model incorporating tidal and storm tide inundation for the present and future time frames (20, 50 and 100 years) would assist to improve understanding of sea level rise impacts across the catchment. This model will need to take into consideration the construction of training walls at the mouth of the Richmond River, the installation of drainage infrastructure, future dredging scenarios and the possibility of subsidence of areas built on reclaimed land, all of which can increase tidal amplitude and influence.

3.3 Historical changes to the catchment

Key points

- The Bundjalung people are the traditional owners of the land
- Extensive drainage works have modified catchment hydrology, surface water, groundwater and tidal interactions

An overview narrative

Prior to European settlement, the North Creek catchment was occupied by traditional owners, the Bundjalung nation. The catchment itself was a seasonal source of food and shelter, affording a rich supply of oysters, fish and traditional medicines.

This pre-European ecosystem comprised of an extensive and diverse array of vegetation communities and flora. Expansive tidal wetlands, sandy shoals and seagrass meadows formed the lower sections of the catchment. Further upstream, these tidal wetlands gave way to increasingly fresh water melaleuca swamp across the lowland flats and coastal heath towards the barrier dunes. The low hillslopes which rose from the swamp bore thickets of subtropical and littoral rainforest and stands of red cedar, which extended to the elevated slopes of the catchment boundary.

Changes since the displacement of the Bundjalung people have been extensive. Floodplain clearing for timber resources paved the way for settlement and agriculture in the 1860s. North Creek itself provided the main means of transport for settlers, who began to install drainage works with Newrybar Swamp as early as 1888 to cultivate the floodplain. Drainage works accelerated in the 1900s to protect agricultural exploits from flooding and tidal inundation (Hydrosphere 2011).

In the late 1970s, the Richmond River County Council constructed a large flood mitigation drain which facilitated widespread floodplain cultivation of sugarcane (WBM 2015). Ad hoc drainage work by landholders has also continued throughout the catchment, leaving behind a complex and poorly understood drainage pattern.

More recently housing developments continue to extend along the hillside fringes of the floodplain north and east of Ballina. Figure 15, Figure **16**. and Figure 17. highlight some of the major changes to the North Creek catchment since the 1967.

North Creek – drainage channel in upper catchment (2018)

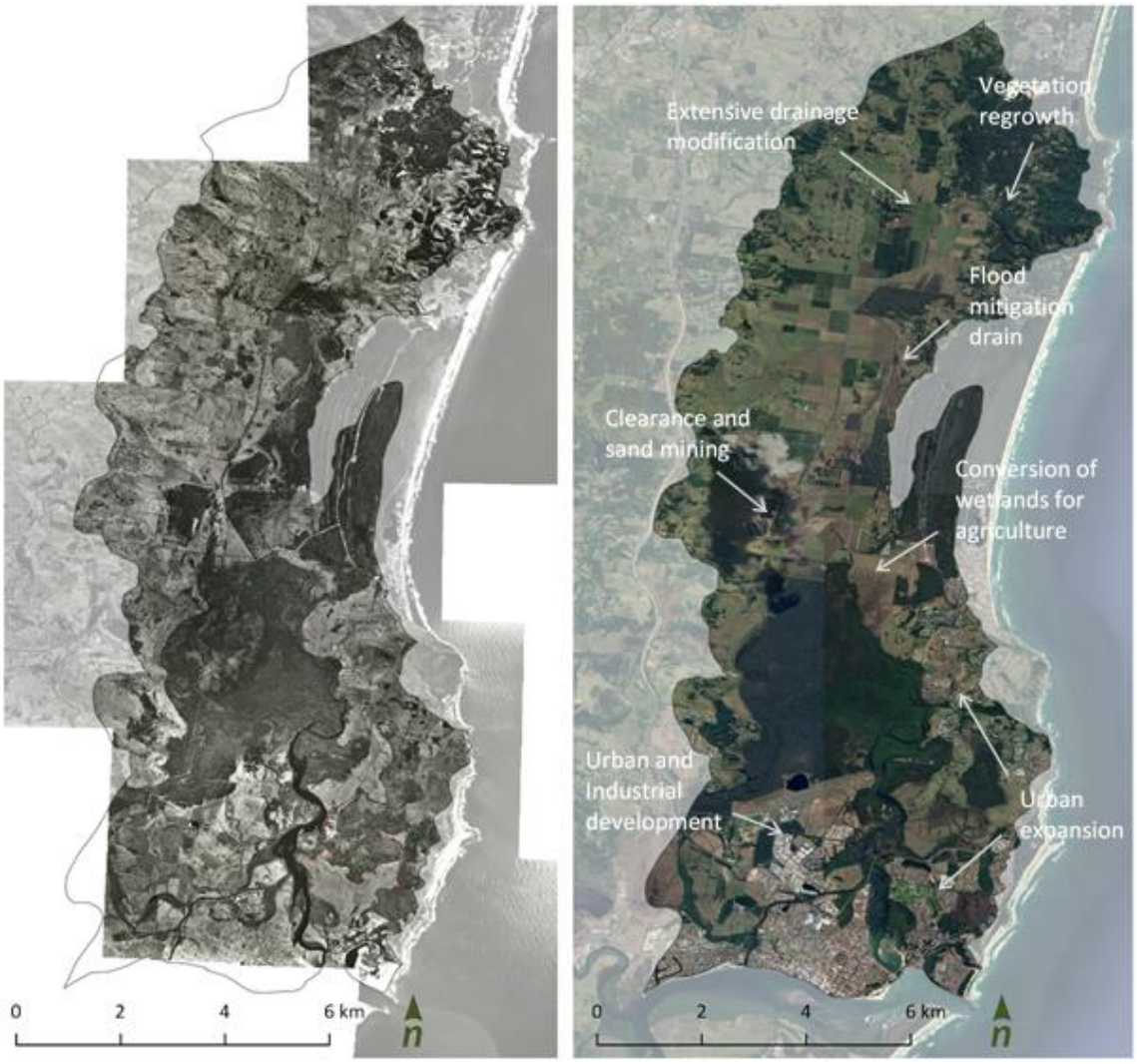


Figure 15. *Historical imagery highlights widespread change to the North Creek catchment between 1967 and 2017*

Figure 16. *Historical imagery reveals the degree of drainage modification within the central section of Newrybar Swamp since 1967. The 1967 imagery shows an array of swampy discontinuous watercourses which have been replaced by linear drains.*

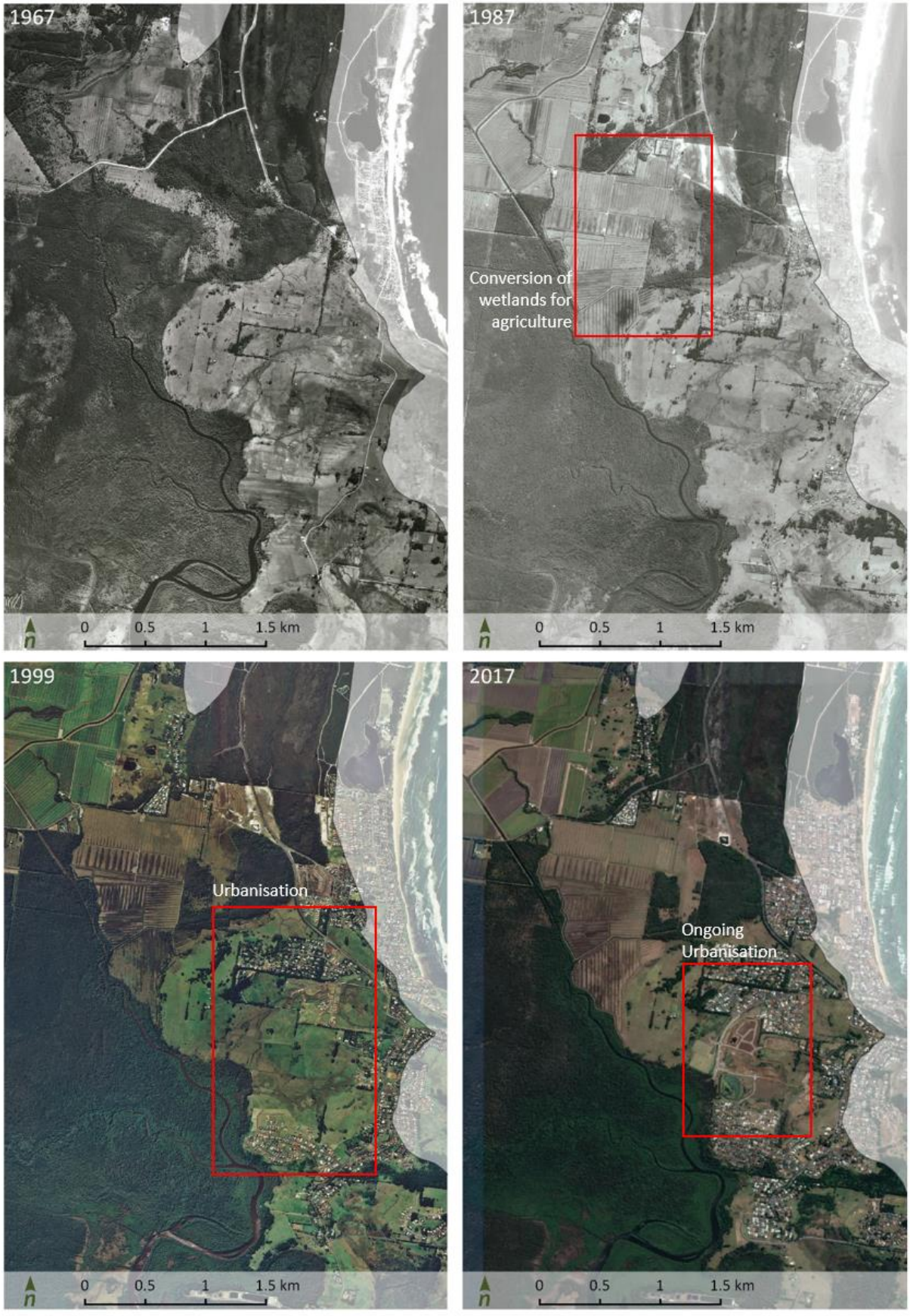


Figure 17. *Historical imagery from 1967, 1979, 1999 and 2017 illustrating land use change near Lennox Head*

3.4 Land use

Key points

- Present day landuse includes rural residential, horticulture and grazing, and increasing macadamia plantations and conservation areas
- Urban growth is increasing incrementally, with around 2 – 5% of the catchment classified as urban release/growth areas

Overview

Land use within the catchment has changed over time following the initial and extensive clearing of vegetation and subsequent drainage works (as discussed previously in Section 3.3).

Today, the slopes of the Alstonville Plateau and surrounding coastal uplands and headlands support rural residential and agricultural (horticulture and grazing) land uses (Figure 18.). The reclaimed floodplains of upper North Creek are primarily agricultural, including sugarcane, grazing and increasing macadamia plantations. Ballina Nature Reserve represents a significant percentage of the catchment (6.1 %). South of the reserve, Ballina airport and light industrial areas fringe the urban development of the Ballina township.

North Creek – linear drain in upper catchment (2018)

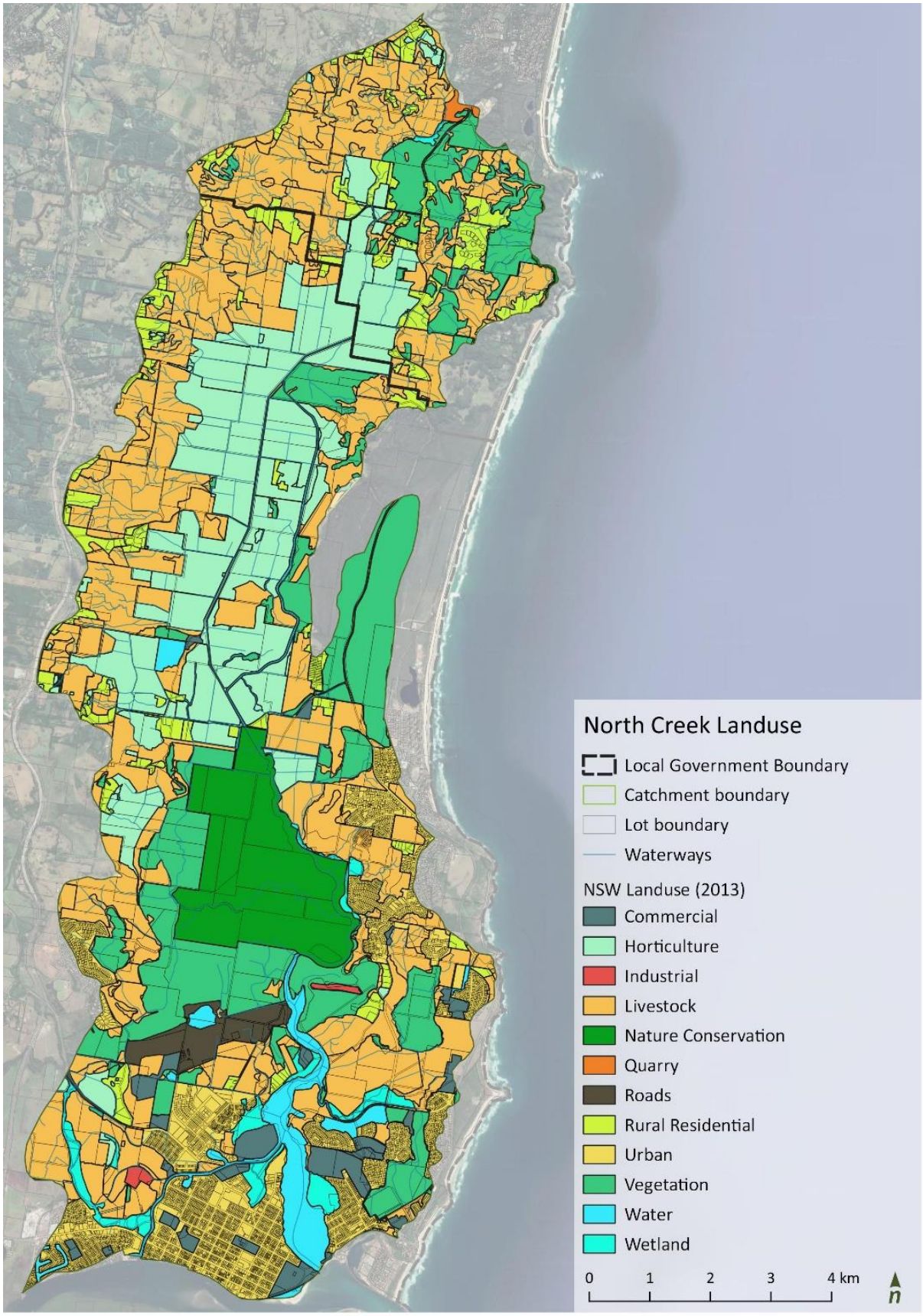


Figure 18. *A summary of simplified land use categories within the North Creek catchment*

Trends in land use change

Land use data from 2007 (NSW DECC 2007) and 2013 (OEH 2017a) which covers the North Creek catchment was used to identify changes in the landscape which may be of significance to the development of the CMP. Descriptions for each land use type vary as both layers employ different classification schemes. While the difference in classification schemes limits a direct comparison, a summary of the general changes between 2007 and 2013 in the landscape is listed below (and the data is provided in Table 6):

- Urban coverage increased from 16.8 % (2007) to 18 % (2013)
- Total grazing area increased from 32.1 % (2007) to 35.8 % (2013)
- Sugar cane reduced from 17 % (2007) to 12.9 % (2013)
- Tree nut (Macadamias) coverage increased from 0.3 % (2007) to 3.8 % (2013) predominately in the upper catchment

Table 6. Land use data for the North Creek catchment from 2007 and 2013. Percentages displayed as the proportion of total catchment area. Different land use classification schemes were employed for 2007 and 2013, meaning that the percentage difference between the standardised categories used in this table may not be reflective of actual land use change (trend only). Land uses that generally increased in percentage are highlighted with orange text (blue for decrease).

2007 Land use			2013 Land use	
Area (Ha)	%		Area (Ha)	%
3596.8	33.0 %	Livestock ↑	3970.8	36.0 %
2161.1	19.8 %	Horticulture ↓	1929.8	17.5 %
2012.0	18.5 %	Vegetation ↓	1763.7	16.0 %
770.3	7.6 %	Urban ↑	1084.4	10.4 %
700.5	6.4 %	Nature Conservation ↓	681.8	6.2 %
491.1	4.5 %	Rural Residential ↑	597.2	5.4 %
330.8	3.1 %	Commercial ↓	331.1	3.0 %
220.8	2.3 %	Water ↓	219	2.2 %
214.2	2.0 %	Roads ↓	190.7	1.7 %
155.4	1.4 %	Industrial ↓	145.2	1.3 %
106.6	1.0 %	Wetland ↓	18.8	0.2 %
51.3	0.5 %	Quarry ↓	13.3	0.1 %

Urban growth

Assuming the growth rate of urban area from 2007 to 2013 as 0.2 % of the catchment per year (as per the above comparison), it is estimated that the current urban coverage sits at 19 % for 2018.

The 185 ha of Urban Release Areas constitute 1.7 % of the catchment and are provided for by Ballina Local Environment Plan (LEP). A further 588 Ha of Strategic Urban Growth Area (SUGA) contributes another 5.3 % of the catchment available for strategic urban development. The land adjoining these areas comprises of another 855 Ha or 7.8 % of the catchment, some of which overlaps with the Urban Release Areas. Most of these potential development areas fall largely within regionally significant farmland areas on fertile volcanic soils that top the Astonville Plateau, Lennox Head and Skennars Head. Therefore, there may be implications for future development for agricultural productivity in the region.

Future trajectory
With the population of the Ballina Shire growing at a rate of approximately 500 people per year, the North Creek catchment has been identified as an area to help accommodate this growth.

Continued urban development along the plateau and catchment hillslopes may have implications for:

- Some hillslope locations of mapped regionally significant farmland (DIPNR 2005)
- Aquifer recharge, the expression of springs along the basin and the native vegetation communities which depend on them
- Baseline nutrient inputs and surface freshwater flows
- Fauna movements.

Urban coverage increased at a rate of 0.2 % of the total catchment area per year between 2007 and 2013. While growth rates are rarely linear, if the growth rate is assumed constant, the Urban Release Areas and the Strategic Urban Growth Areas (which constitute 7 % of the catchment combined) would accommodate this rate of increase until 2050.

An increasing extent of tidal inundation by 2050 and 2100 is likely to have implications for existing and planned urban areas, farmland and assets and infrastructure within these land uses and tenures (Figure 19).

An initial high-level assessment of the projected increased impact of tidal inundation (HAT plus sea level rise extent) based on the CoastAdapt modelling has been considered for this scoping study (Figure 19, Table 7). Increased areas of agricultural land and urban areas are expected to be impacted by tidal inundation (e.g. up to a 50% increase for agricultural areas from 2050 to 2100, and a substantial increase in urban areas impacted). This overlay assessment is indicative only, based on a simple bucket fill model and broadscale elevation data (NCCARF 2018). A more detailed assessment of tidal inundation potential (hazard areas) would be beneficial for the CMP process. Impacts can be mitigated for these areas through targeted planning in the CMP.

Table 7. Indicative areas impacted by projected tidal areas (based on CoastAdapt modelling)

	Total Area inundated 2050 (ha)	Total Area inundated 2100 (ha)	Change (ha)	% change
Coastal Forest (Ballina Nature reserve)	1440	1535	95	7
Agricultural Land (hort)	521	799	279	54
Agricultural Land (livestock)	875	1021	147	17
Urban Area	156	568	412	265

One of the most significant land use changes within the catchment basin has been the transition from sugarcane to macadamia farming. Between 2007 and 2013, the area of sugar cane reduced by approximately 0.7 % (of the total catchment area) per year while macadamias increased by approximately 0.6 %. If these rates of transition are assumed constant, the total area covered by cane farms could be as low as 2 % of the catchment by 2030.

While there are multiple drivers and limitations to the rate and extent of this transition, the tidal inundation extents and projected variations in climate need to be taken into consideration as land use change continues. It is likely that increases in sea level will threaten the viability of agriculture in low-lying areas through changes in drainage, soil condition and groundwater dynamics. Understanding these impacts on different land use types will be necessary to understand how investments in land use change (e.g. macadamias) should be made in the future.

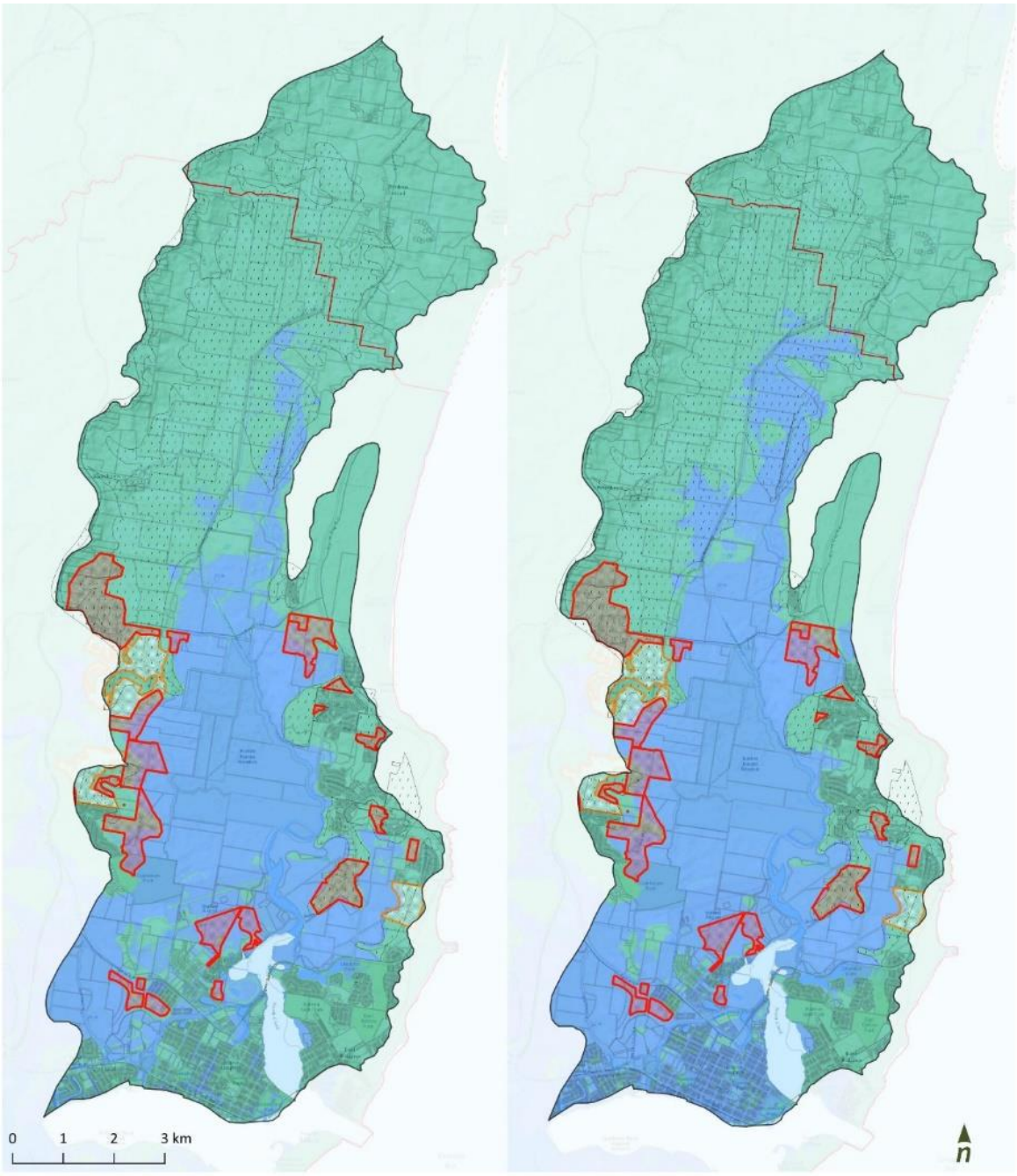


Figure 19. *Projected tidal inundation extents, planned growth areas and regionally significant farmland within the North Creek catchment (NCCARF 2018)*

3.5 Groundwater

Key points

> Groundwater levels are strongly influenced by tidal cycles across the mid and lower catchment

> The complex interaction between groundwater levels, tidal influence, recharge and water quality is a key management challenge for the North Creek catchment

Groundwater dynamics in the North Creek catchment have an important role in:

- Supporting agriculture and groundwater dependent eco-systems (GDEs)
- Regulating acid water discharge from acid sulfate soils (ASS)
- Influencing water quantity and quality as it flows downstream.

Aquifers and recharge
The catchment is host to two aquifers, the unconfined 'Alstonville' within the basalts of the Alstonville Plateau, and the 'Richmond Coastal Sands' within the catchment basin itself. Both are managed and protected by water sharing plans under the Water Act 2000. A radon mass balance study by Southern Cross University concluded that North Creek is groundwater dominated in its upper reaches above Ross Lane. This is linked to the relatively small catchment size, extensive drainage network and permanent spring discharge from the Alstonville Plateau (Atkins et al. 2013).

As noted previously, the catchment experiences a relatively high annual rainfall of ~1800 mm, much of which falls during the summer months (see Figure 10). Along the plateau, rainfall infiltrates through the well-draining soils, into the basalt aquifer beneath, and is expressed as numerous springs at the foot slopes of the escarpment, some of which are permanent.

The high rainfall and relatively small and flat catchment basin contribute to a groundwater level within the coastal sands which is relatively shallow, at around two metres deep. The extensive drainage network which cuts through this shallow aquifer, enables groundwater to flow into the drains (Atkins et al. 2013). Both these factors contribute to a permanent freshwater recharge of the upper reaches of North Creek (before the bifurcation of the Union and Flood Mitigation Drains).

Tidal influence
The penetration of the tidal wedge along the creek also influences groundwater dynamics. The tidal water mixes along the North Creek estuary to just north of Ross Lane, however the overall height of the creek can raise as much as 0.7 m (by tidal influence) a further 6 km north (Atkins et al. 2013).

This fluctuation of the water level across the drain network creates a pumping effect, where the groundwater surrounding the drains is raised and lowered with each tidal cycle. As the tide lowers, groundwater flows back into the drain, drawing with it the chemical characteristics of the surrounding soil water. The drain network therefore receives a chronic discharge of acidic groundwaters sporadically throughout the catchment wherever the acid sulfate soils occur (Atkins et al. 2013). Under flood conditions, this pumping effect is overprinted by the complete saturation of the subsoil, leading to a large pulse of acidic water into the drains and subsequent dilution depending on flood magnitude.

The supporting study for the proposal of McGeary's sand mine (Enviro Solutions 2017) found that groundwater levels upstream of the tidal gates show indications of daily fluctuations in response to the nearby Union and Mitigation Drains. The four-week study, which measured water quality and groundwater levels across six boreholes to asses variation across the proposed site, included the following observations:

- Groundwater levels were typically 1-3 m below ground level and exhibit daily fluctuations in response to the tidal influence within nearby Union and Mitigation Drains.

- Low permeability coffee rock within the coastal dune and beach deposits is largely discontinuous through the soil profile.
- Iron cemented and clay layers within the shallow aquifer (the Richmond Coastal Sands Groundwater Source) act as partial barriers to vertical flow and as such can form perched aquifers.
- Groundwater level response to rainfall is rapid given the porosity of the sandy deposits.
- Groundwater is moderately acidic, with an average pH of 4.2.
- Electrical conductivity (EC) ranges from 56-1,560 µS/cm.
- Concentrations of arsenic, nickel and zinc exceeded one or more national screening levels adopted for the protection of freshwater and marine ecosystems and drinking water.
- Elevated nitrogen levels were found (mostly organic) and metals in groundwater may be related to the addition of fertilisers.

Knowledge gaps

This complex interaction between groundwater levels, tidal influence, recharge and water quality, is not well understood, and will continue to be a key management challenge for the North Creek Catchment, particularly with rising sea levels in the future that will extend the tidal influence further inland.

North Creek – lower estuary

3.6 **Ecology**

Key points

- Threatened ecological communities within the North Creek catchment include Coastal swamp oak forest, Littoral rainforest and coastal vine thickets, and Lowland rainforest
- There are a number of species and ecological communities that are vulnerable to a changing catchment and coastal processes, land use and climate change impacts

Threatened, protected and migratory species

The 'Protected Matters Search Tool' was employed to identify species protected under the Environment Protection and Biodiversity Conservation Act 1999 within the North Creek catchment.

The search identified a total 87 threatened species and 77 migratory species within the catchment and its immediate surrounds (1 km buffer). The list included six critically endangered birds; the regent honeyeater, curlew sandpiper, the great knot, the swift parrot, the northern Siberian bar tailed godwit and the eastern or far eastern curlew, a critically endangered insect (Australian fritillary) and gastropod (Mitchell's rainforest snail) (DEE 2015).

The NSW 'Bionet' database search tool was also employed to identify the potential threatened and protected species within the catchment (OEH 2018e). The query identified a total of 1739 listed animal and plant species within the catchment and a one-kilometre buffer zone. Of these, 364 were listed as protected, 79 vulnerable & protected and 40 as either endangered or critically endangered. Critically endangered species included birds; the red goshawk and the beach stone curlew, and one critically endangered plant; the coastal fountainea. Other endangered fauna and flora included the: giant barred frog, Davidson's plum, hairy quondong, spider orchid, southern swamp orchid, basket fern, flat fork fern and the small-leaved tamarind. The EPBC Protected Matters report is provided in Attachment B.

Widespread clearing, agriculture and flood mitigation works across the North Creek catchment have contributed to the fragmentation of terrestrial and aquatic ecological communities and habitat, however important remnant and restored areas are present, as discussed below.

Terrestrial ecology

Three threatened ecological communities are located within the catchment. These are the Coastal swamp oak forest of NSW, the Littoral rainforest and Coastal vine thickets of Eastern Australia, and Lowland rainforest of Subtropical Australia (DEE 2017). Areas of Coastal swamp oak lie mainly within the Ballina Nature Reserve (BNR) and the latter two threatened communities are distributed predominantly within sections of 'Littoral rainforest' which are highlighted in red in **Figure** 20**.** It is possible that further detailed mapping of areas listed as 'residual native cover' and areas listed as 'Other' in **Figure** 20 may identify previously unknown pockets of these communities, such as the pockets of coastal littoral rainforest identified within the proposed McGeary's sand quarry (Parker 2017).

The largest contiguous zone of protected native vegetation is contained within the BNR, which makes up six percent of the catchment. The reserve hosts the 'Coastal swamp oak forest' threatened ecological community, as well as mangrove forest wetlands and salt marsh complexes, all of which provide refugia for a variety of native flora and fauna and exotic species. Threatened species recorded in the reserve include Osprey (*Pandion haliaetus*), Mangrove Honeyeater (*Lichenostomus fasciogularis*), Black Flying Fox (*Pteropusalecto*), Grey-headed Flying Fox (*Pteropus poliocephalus*) and Little Bent-wing Bat (*Miniopterus australis*) (NPWS 2003).

The extents of both Coastal Wetlands and Littoral Rainforests within the North Creek catchment under the Coastal Management SEPP have been determined by recent state-level vegetation mapping. Within the North Creek catchment approximately 20 km² is classified as Coastal Wetland. This includes large areas of the North Creek estuary, the Ballina Nature Reserve and Birrung Creek area to the east of Byron Bay Road. Three small areas of Littoral Rainforest areas comprising a total of 0.8 km² are located in the east of the catchment near

Birrung Creek, north of Skennars Head Road and along the upper reaches of Midgen Creek near Broken Head reserve.

The hydrology and ecology of the BNR has been significantly altered since European settlement. Increased catchment runoff, sedimentation, ad-hoc drainage works, disturbance of acid sulfate soils and introduced flora and fauna (pigs) have significantly changed and continue to change the wetland system. As a result of these changes, sections of the BNR, which also contains the threatened ecological community – the Coastal swamp oak forest – has experienced dieback. Weed infestations also continue to proliferate within the largely inaccessible reserve.

The decline of koala populations across north east NSW has been attributed to the reduction of suitable habitat and pest species (e.g. wild dogs). Remnant primary and secondary koala habitat has also been noted in sections of the North Creek catchment (BSC 2017a). While North Creek catchment does not contain a significant number of koalas, the populations that do occur have been identified within proximity to the development areas in the Cumbalum and Ballina East precincts. The proximity of these areas increases the risk of further koala population decline through interaction pest species / domesticated animals. The remaining habitat areas within the catchment are small fragmented patches with restricted opportunities for improved connectivity. While extensive 'potential' habitat exists within low lying areas surrounding Ballina Nature Reserve, their long-term potential may be limited by the impacts of projected sea-level rise.

Seagrass, salt marsh and mangrove communities

The historic modification of the waterways has impacted upon the extent and health of the seagrass, salt marsh and mangrove communities of North Creek. These communities provide several key ecological functions for the estuary, including feeding grounds for fish and habitat for a range of native fauna and flora, some of which are threatened (Hydrosphere 2011). A significant proportion of the salt marsh which exists within the catchment is protected within Ballina Nature Reserve. Elsewhere, salt marshes exist along tributaries where protection is available behind fringing mangrove communities (such as Little Fishery Creek) (**Figure** 20**.** These salt marsh communities, in conjunction with the adjacent estuarine sand shoals, provide key feeding, roosting and nesting areas for 19 species of shorebird, seven of which are threatened (Hydrosphere 2016).

The oyster reef at North Creek immediately downstream of the Prospect Bridge is an important ecological asset. An in-press study has shown that the North Creek oyster reef and seven other remnant Sydney Rock Oyster reefs bear distinct assemblages of macroinvertebrates with 30 % higher densities, five times the biomass and almost five times the productivity of adjacent bare sediments (McLeod et al. 2019)

Seagrass meadow distribution will vary within most estuaries depending on habitat stability and water clarity. The most common species within the Richmond River and North Creek system is the fast growing *Zostera Muelleri* subsp. *Capricorni* (ABER 2008). Three species of marine turtle are known to forage in this type of habitat; the Loggerhead turtle (*Caretta caretta*); Leatherback turtle (*Dermochelys coriacea*) and Green Turtle (*Chelonia mydas*) are also potential visitors to North Creek (Hydrosphere 2016). Historical modifications of the North Creek channel have led to variations in the seagrass communities over time, however mapping suggests that seagrass coverage increased between 1942 and 2000 (ABER 2008). Recent assessments of seagrass health within the North Creek estuary have been limited due to boat access restricted to the Creek's main channels (Ryder et al. 2015). Further mapping of all three communities by DPI Fisheries in 2019 will provide enhanced understanding of macrophyte distributions in the near future.

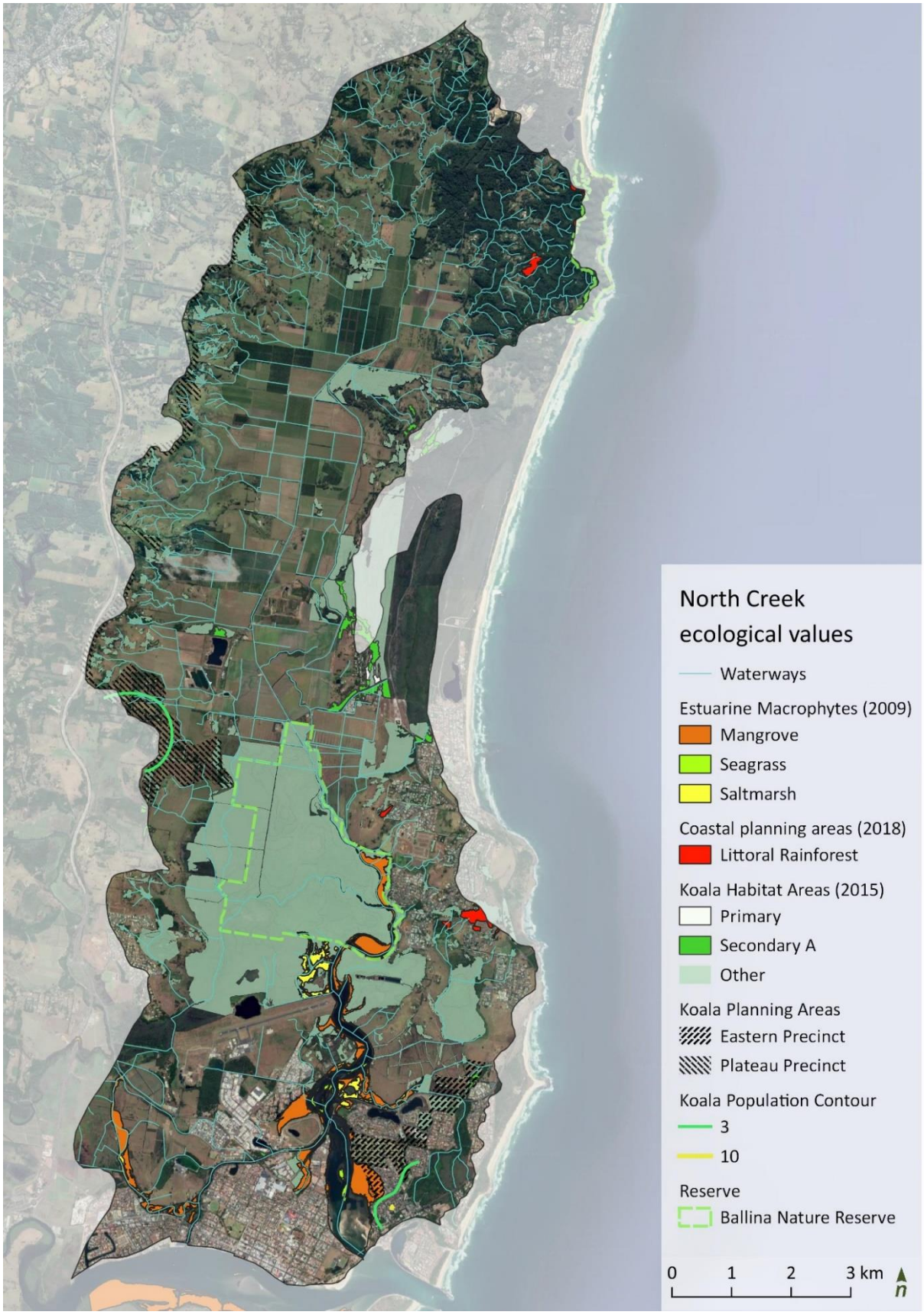


Figure 20. *A collage of ecological values within the North Creek catchment (Creese et al. 2009; BSC 2017; DPE 2018)*

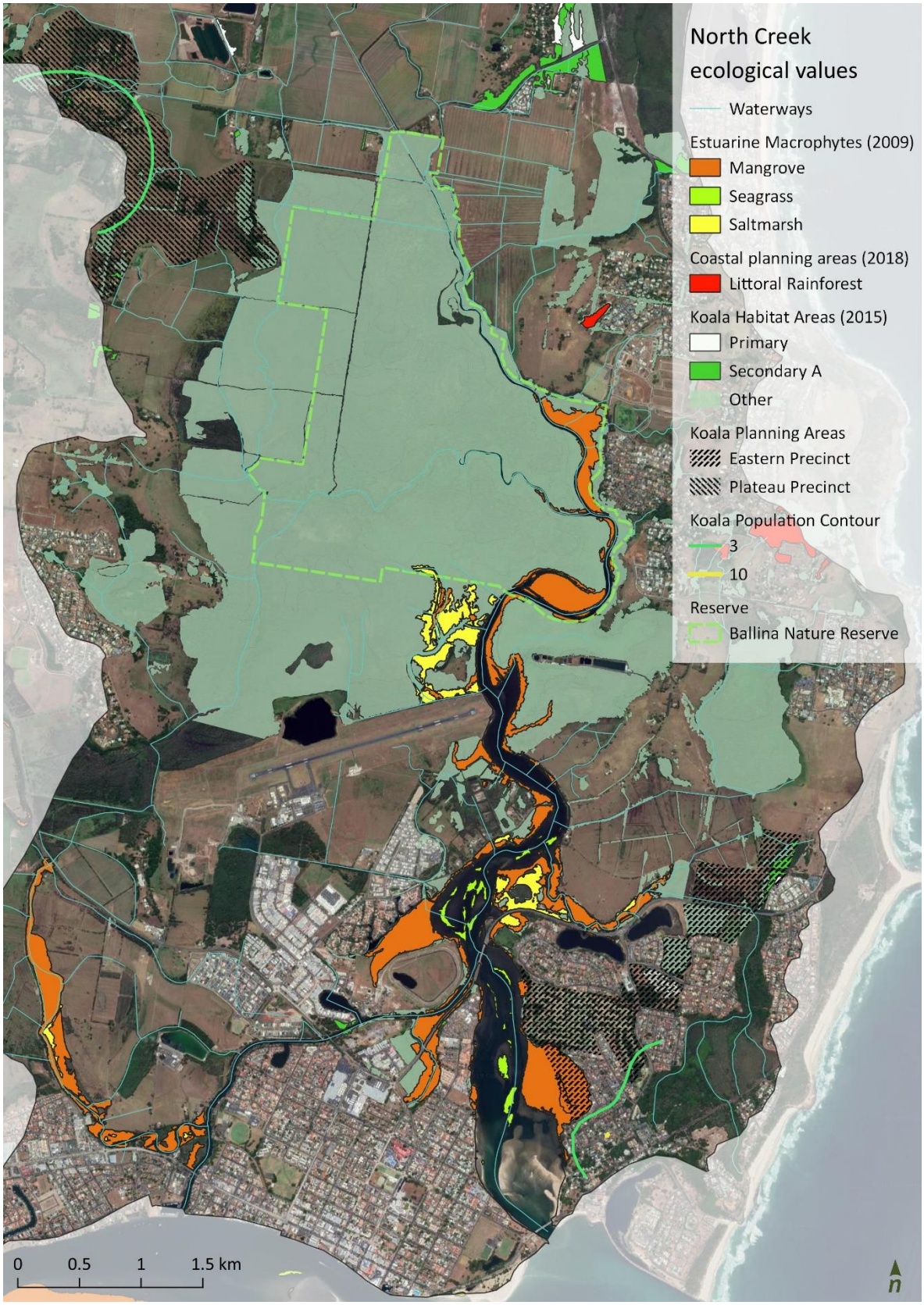


Figure 21. *A closer view of the mapped ecological values in the southern half of the North Creek catchment*

3.7 Catchment runoff and water quality

Key points

- The modified nature of the North Creek catchment and floodplains, including past vegetation clearing, planting of exotic species, and the low gradient drainage network, creates a challenging environment for managing water quality
- Poor water quality through the drainage network has contributed to fish kill events and a decline in the oyster production
- Agricultural runoff is the primary source of diffuse pollutant loads
- There is (modelled) potential for significant pollutant generation from both urban and rural areas during runoff events
- There is a need for, and opportunity to, enhance water quality monitoring across the catchment to better inform future management activities and priorities.

Modified catchment setting

The heavily modified nature of the North Creek catchment creates a physical and hydrological environment which lends itself to poor water quality.

The widespread clearing of floodplain vegetation has removed flood adapted species which would typically withstand periods of inundation. Native species have been replaced by poorly adapted exotic species which are more likely to die (due to inundation), and subsequent plant decomposition and accumulation in the drain network contributes to lower dissolved oxygen levels (Hydrosphere 2011).

The drainage process from the floodplain is slow due to the low gradient of the topography and vegetation, often taking many days following an event (Enviro Solutions 2017).

Blackwater events

Under flood conditions, the extensive drain network facilitates the outflow of these drain waters, which can deliver masses of decomposing and deoxygenating material all at once to produce what is otherwise known as blackwater. In conjunction with antecedent conditions which were particularly dry, blackwater events were a major contributor to the fish kills of 2001 and 2008 within the greater Richmond River system, including North Creek (Wong et al. 2010, 2018). Anecdotal reports by local fishermen indicate an observed reduction in fish numbers within the North Creek estuary in recent times. Reductions in water quality impact fish and other aquatic fauna, causing death, disease, limiting survivorship of juveniles and act as a behavioural barrier.

Persistent poor water quality

Frequent episodes of poor water quality will persist in the lower reaches of North Creek following rainfall. The exact reason for this is unclear, however it is likely to be a combination of several issues. Water flow through the extensive drain network is restricted by the low gradient on the floodplain. This leads to stagnation under drier conditions and an increased opportunity for the accumulation of pollutants from the adjacent agricultural land (ABER 2008; Hydrosphere 2011). Conversely, under wetter conditions, the drain network can also facilitate the export of nutrients and sediment into the main channel.

Chronic discharge of acid water also reduces the pH of these waters, this is in part due to the groundwater dominance of the catchment as described earlier. The pH typically decreases progressively upstream (ABER 2008). The drains which cut though larges sections of acid sulfate soils facilitate the expression of acidic groundwater as it passes through oxidised acid sulfate soils (ABER 2008; Atkins et al. 2013). Groundwater outflow increases the overall tidal peak within the drains as it intercepts the incoming tide. This temporarily raises groundwater levels, thus increasing the amount of disturbed acid sulfate soils that is drained with each tidal cycle (Atkins et al. 2013). Furthermore, acid sulfate soil runoff affects the upper reaches of the North

Creek estuary during smaller runoff events during the wet season when groundwater levels are relatively high (Hydrosphere 2011).

Mono-sulfidic black ooze

The drains within catchment basin have a high supply of organic matter in both particulate and dissolved forms. The combination of stagnant water, acidic groundwater ingress and organic matter creates a favourable environment for low oxygen environments to develop. In combination with iron and sulfur from acid sulfate soils areas that are also likely to enter drains, these factors would appear to provide ideal conditions to promote the formation of "Mono-sulfidic Black Ooze" (MBO). While MBO production has been well documented in the Tuckean swamp, some 25 km southeast Ballina, the conditions described suggest that its occurrence within the North Creek catchment is possible (Hydrosphere 2011).

If MBO is discharged into the lower estuary during small runoff events (i.e. without sufficient flushing), it can cause severe oxygen depletion which is likely to be a significant stressor on oyster health. While the direct linkage between MBO and QX disease has not been established, anecdotal evidence suggests that there is a relationship between MBO release and QX disease outbreak. Observations noted by oyster famers are that outbreaks typically correlate with the outflow of drain waters after rain events – when outflows are not large enough to flush the entire system but just enough to push the stagnant waters into the estuary.

Nutrients and contaminants

Over the past two decades, oyster leases within the lower North Creek estuary have suffered several harvest closures. Extending for up to 9 months of the year, these closures were primarily due to rainfall exceedances, high levels of nutrients and faecal coliforms associated with catchment runoff during the 2001 and 2008 flood events (Hydrosphere 2011). Ryder et al. (2015) suggests that contaminants were likely sourced from agricultural and urban runoff and the STP, which was replaced by the Ballina recycled water treatment plant in 2016. Wastewater that is not re-used is released by the plant back into the North Creek canal on the ebb tide, having a negligible impact on nutrient and algal biomass (NSW Water Solutions 2009). Faecal coliforms are likely to persist in the creek, given the presence of drains open to grazing cattle and that chronic turbidity inhibits the sterilising effect of sunlight as it penetrates the water-column.

The floodplain drainage patterns have the potential to exacerbate deoxygenation of the estuary by acting as a conduit for water with low dissolved oxygen (DO) (Hydrosphere 2011). It has been shown that DO decreases progressively upstream which is driven by low oxygen swamp and drain inputs. Additionally, humic rich and tannin rich waters of the upper catchment, combined with high temperatures and high TN levels which are not necessarily available for plant uptake are expected drivers for summer algal blooms (ABER 2008). This influences the DO concentrations, along with longer flushing times in the mid to lower estuary (ABER 2008).

Snapshot monitoring

Figure 22. and Figure 23. provide a snapshot into the water quality conditions of the North Creek estuary near the Ballina Airport during the month of June and provide an example of the biochemical dynamics described above. The figures show how a large rainfall event during mid-June caused a shift from saline to fresh conditions within the estuary. During this time pH levels lowered and DO levels dropped to levels around 3-4mg/L, which are potentially hazardous to aquatic life (RCC 2017). If this rainfall event occurred during the warmer months, the likely result would be a greater reduction in DO. Note the small rainfall event on the 30th of June was also associated with a spike reduction of DO to within this hazardous range.

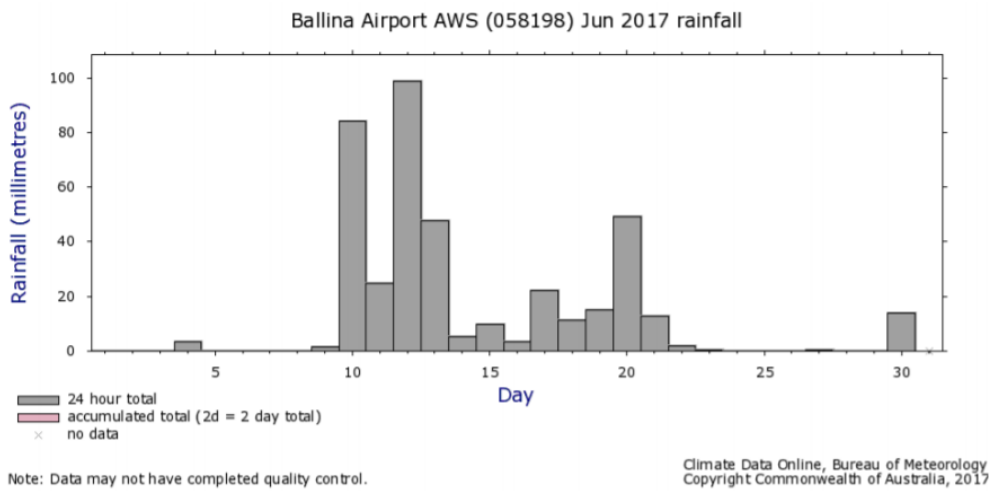


Figure 22. *Rainfall recorded at Ballina Airport over the month of June 2017 (BOM 2018).*

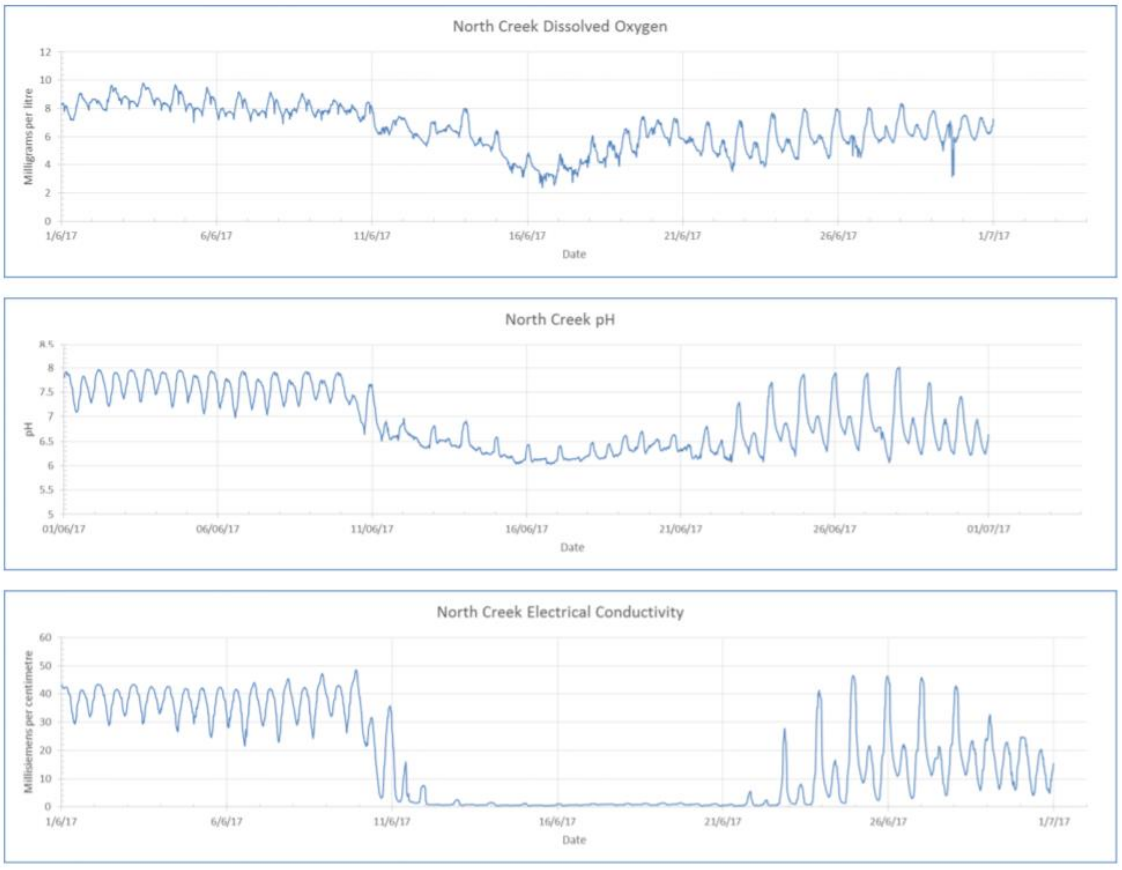


Figure 23. *Rous County Council Data Logger water quality plots for June 2017 (near Ballina airport) (RCC 2017).*

In addition to the Rous County Council water quality data, the Eco-health monitoring program (2014-15) provided the most recent analysis of surface water quality across multiple sample points within North Creek system. Exceedances of ANZECC trigger thresholds were common for all five sample sites in North Creek. The consistently low pH and DO readings likely relate to drainage modification and the presence of acid sulfate soils as previously explained. The monitoring program also observed high levels of suspended solids which remain in suspension for the length of the estuary (Ryder et al. 2015).

Catchment runoff / water quality modelling

There is substantial anecdotal and recorded information that indicates agricultural and urban development, drainage works and disturbance of acid sulfate soils has degraded (and will continue to degrade) water quality within the North Creek estuary. However, to date there has been limited modelling or monitoring that helps determine the catchment drivers of poor water quality (and their spatial and temporal variations). As part of this scoping study, a new Rapid Catchment Assessment (RCAT) model of the North Creek catchment was developed to help identify likely risk areas for generation of four common pollutants.

The model utilises runoff water quality data from different land uses to estimate the contaminants contributed to a waterway based on the proportion of land use types within its catchment. The modelling estimates that substantial pollutant generation (i.e. Total Nitrogen (TN) and *E. coli*) occurs within the agricultural areas upstream of Ross Lane (Figure 24.) and that higher density urban areas also contribute considerable pollutant loads, namely Total Phosphorous (TP) and Total Suspended Solids (TSS). The full results of the RCAT modelling are summarised in the Water Quality Monitoring Plan (Attachment F).

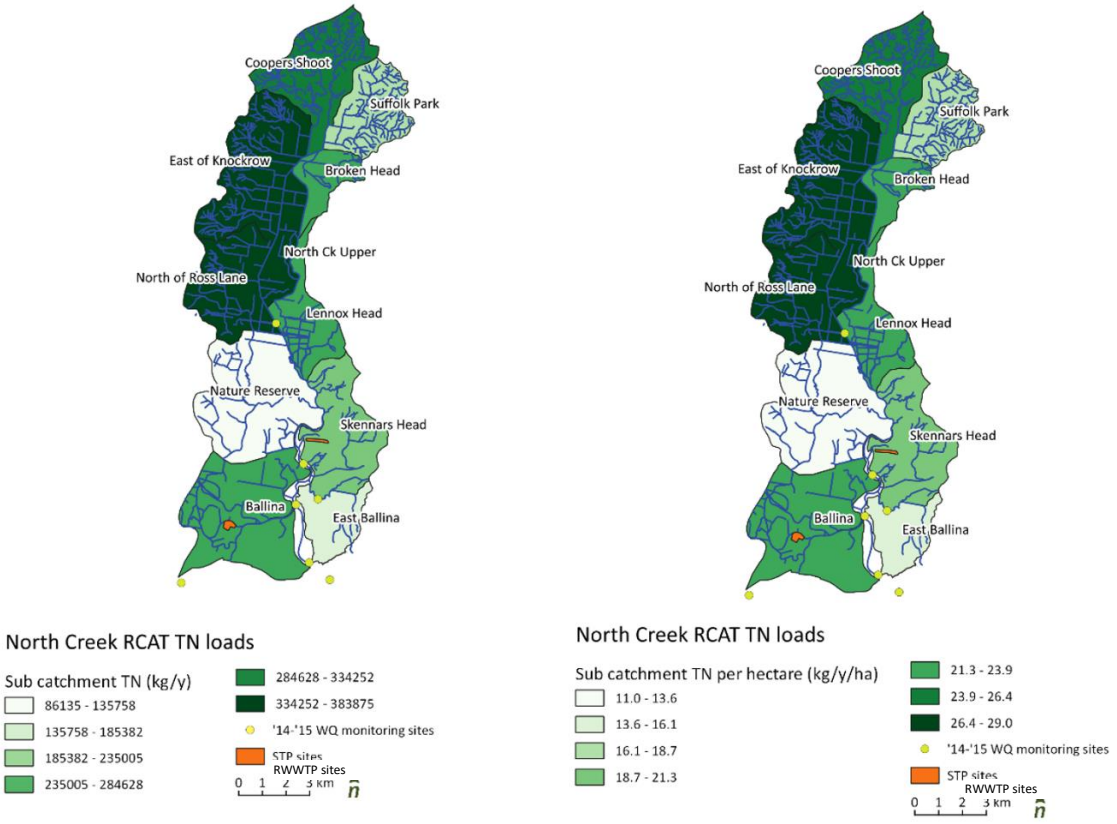


Figure 24. *Estimated TN loads within the North Creek catchment.*

The RCAT modelling highlights the potential for significant pollutant generation during runoff events from both urban and rural areas, though given previous studies have also inferred that groundwater sources are dominant, the relationship between surface runoff and groundwater contributions will need to be better defined in the future.

The extensive drainage work through the catchment has created predominately perennial waterways which interact with groundwater sources rather than just being conduits of surface runoff. This ongoing interaction is different to that which would have occurred under wetland back barrier environmental conditions. The informally planned floodplain drains draw groundwater from surrounding soils and also expose acid sulfate soils (where present) to oxygen, this lowers the pH of groundwater as well as the surface waters into which it flows. Given that the drains have periods of low or no flow but still hold water, these conditions allow for the processing of organic compounds which, in the presence of acidic water, can lead to anoxic or even anaerobic conditions. As noted previously, there is also the possibility of MBO production within the catchment.

Rubbish
The illegal dumping of rubbish is a priority concern for the community. The Ballina Shire recognises pollution (rubbish) as a significant financial, environmental and social problem and incurs significant costs for the investigation, collection and disposal of illegally dumped material.

Household, garden, building and commercial waste introduces chemical and physical pollution into the catchment and its waterways. Green waste can spread exotic weeds and pests, create a fire hazard, while hazardous materials can contaminate waterways, soil and degrade the surrounding environment. Litter and hard rubbish impact on the catchment's scenic amenity, trap and kill local wildlife, some of which are threatened.

Illegal dumping is known to occur along the fringes of Ballina Nature Reserve. As development within catchment progresses and regional population increases the threat posed by illegal dumping is likely to increase.

Summary points
Some specific points noted from the existing literature and data, which relate to water quality challenges in the North Creek catchment include:

- Agricultural land use is a major source of diffuse pollutant loadings (Hydrosphere 2011).
- Extraction of groundwater to a depth of 20 m at the Ballina Shire Council sand quarry south of the Ballina Nature Reserve may impact the hydrological conditions of the reserve as well as exacerbate acid sulfate soil oxidation (NPWS 2003).
- Humic rich and tannin rich waters of the upper catchment combined with high temperatures are expected drivers for summer algal blooms (ABER 2008), and high TN levels which are not necessarily available for plant uptake.
- Floodplain drainage has the potential to exacerbate deoxygenation of the estuary by acting as a conduit for water with low dissolved oxygen (DO) (Hydrosphere 2011).
- Dissolved oxygen also decreases progressively upstream and is driven by low oxygen swamp and drain inputs. DO concentrations are influenced by high dissolved and particulate loads in relation to humic groundwater inputs, leaf litter fall and summertime phytoplankton blooms (ABER 2008).
- Longer flushing times likely enhance hypoxia (oxygen deficiency) in the lower to mid estuary (ABER 2008).
- pH generally decreases progressively upstream. Chronic acid groundwater discharge from the incised drain network is the likely driver (ABER 2008).
- Acid sulfate soil disturbance has resulted in chronic and acute discharges of acid and associated pollutants (ABER 2008).
- Acid sulfate soil runoff affects the upper reaches of North Creek estuary during smaller runoff events in the wet season when groundwater levels are relatively high (Hydrosphere 2011).
- Sections of the drain network coincide with sections of the Tuckean soil-landscape within the North Creek catchment. Some of these drains are suitable environments for the development of monosulfidic lack ooze (MBO), which has the capacity to rapidly deoxygenate water and damage waterway ecology (Hydrosphere 2011).
- Groundwater near McGeary's sand mine is moderately acidic, with an average pH of 4.2 and an EC from 56-1,560 µS/cm (Enviro Solutions 2017).
- Arsenic, nickel and zinc exceeded one or more national screening levels adopted for the protection of freshwater and marine ecosystems in the bores near the mine (Enviro Solutions 2017).

- Elevated nitrogen levels (which are mostly organic) and metals in groundwater may be related to the addition of fertilizers (Enviro Solutions 2017).

Trajectory
Left to persist, the catchment runoff and water quality issues outlined above are likely to contribute to the ecological decline of the system and consequently the social, economic and ecological values. Poor water quality is likely to impact tourism, recreation and biodiversity, particularly in its ability to provide scenic amenity, a clean and safe environment for people and wildlife, its ability to support oyster culture and act as a nursery for the local, pelagic and migratory species. This in turn can impact the opportunity for growth of industries which rely on these benefits, such as development and tourism.

Knowledge gaps
There is limited modelling or monitoring data that help in determining catchment drivers (and their spatial and temporal variations) of pollutant generation. The RCAT modelling undertaken for this study highlights the potential for significant pollutant generation during runoff events from both urban and rural areas, however this is yet to be confirmed with detailed monitoring.

Furthermore, there is a lack of understanding of the interactions with Richmond River estuary. Following rainfall events, pollution generation within North Creek catchment is likely to degrade water quality the North Creek estuary. However, during ambient conditions tidal exchange between the Richmond River and North Creek estuaries may have a significant impact on water quality. The relative role of catchment runoff in North Creek and tidal exchange with the Richmond River estuary on the overall water quality within the North Creek estuary is not fully understood.

A Water Quality Monitoring Program (WQMP) (Attachment F) will be implemented as part of Stage 2 to determine the linkage between catchment processes and poor water quality in the estuary. The WQMP will also monitor oyster health to assess the water quality drivers of impacts on fisheries (such as QX disease in oysters). The WQMP would aim to:

1. Determine the variation in water quality parameters throughout the North Creek catchment to help identify the areas of the catchment where excessive pollutant generation is occurring

2. Determine the relevant impact of ambient conditions (i.e. anoxic conditions developing in pooled water within drains from groundwater ingress) or runoff events on water quality

3. Identify the water quality parameters in the estuary which increase the susceptibility of oysters to QX disease

Monitoring is to be undertaken for a minimum of 18 months but ideally up to three years to help understand seasonal variations. If there are budget constraints less frequent monitoring can be undertaken (i.e. bimonthly) across more sites (i.e. including either representative sub catchments or all sub catchments) as opposed to more frequent monitoring along the main stem of North Creek only. Sampling within the sub catchments can help identify the source of water quality issues. Sampling in North Creek alone would still provide insight however tidal processes are likely to mean identifying the sources of water quality issues will be more difficult.

The WQMP can help identify where excessive pollutant generation is occurring within the catchment. The outcomes can help improve the risk assessment in Stage 2 and identify priority sub-catchments for water quality improvement works (to be developed as part of Stage 3).

Development of Source Catchment model of surface and groundwater pathways using outputs from a hydrodynamic model and WQMP data would ultimately provide the best approach to asses pollutant pathways through the catchment.

3.8 Dredging and sand mining

Key points

- Sand shoals in the lower estuary have been extensively dredged to allow ship navigation
- The feasibility of dredging in lower North Creek is being considered to provide a sand resource, to improve navigability, and to increase tidal flushing and improve water quality in North Creek
- Sand mining may exacerbate acid water discharge into North Creek

Shoals

The development of sand shoals within the lower North Creek estuary is a natural process as evidenced by early parish mapping of the Richmond River mouth and the North Creek estuary (Figure 25). These shoals provide important habitat and food for migratory shorebirds and juvenile fish species. Extensive dredging has been undertaken in the past to allow for ship navigation and the economic development of the region. The most recent dredging activity was undertaken in 1990s (Hydrosphere 2016). The subsequent redevelopment of sand shoals in the estuary has raised interest in the possibility of further dredging, with the completion of a scoping study (Hydrosphere 2016) and feasibility study (Hydrosphere 2018).

Figure 25 *The 1887 Ballina parish map overlying recent aerial imagery indicating extensive shoaling.*

Dredging aim, and risks and benefits

The 2016 scoping study outlines the aims, risks and potential benefits related to dredging in the estuary (Hydrosphere 2016). The primary aim of dredging North Creek is to provide a sand resource, to improve navigability and to increase tidal flushing and hence improve water quality in North Creek (Hydrosphere 2016). The subsequent feasibility study (Hydrosphere 2018) found that areas A, B and D will yield suitable material for development fill, as per Figure 26. The key risks from dredging activities include:

- The targeted sediment volume for dredging is up to twice the annual littoral sediment transport rate along the Ballina coastline, which will influence coastal sediment dynamics.
- Potential risk to key roost areas and foraging grounds for several species of shorebirds which are favoured by a range of stakeholders.
- Limited flexibility in the selection of a dewatering location, which will require agreements to be made with landholders adjacent to the Southern Cross Industrial Estate.
- The presence of acid sulfate soils in the majority of proposed dredging areas, which will require an acid sulfate soil management plan under the NSW ASSMAC Acid Sulfate Soils Assessment Guidelines (1998).

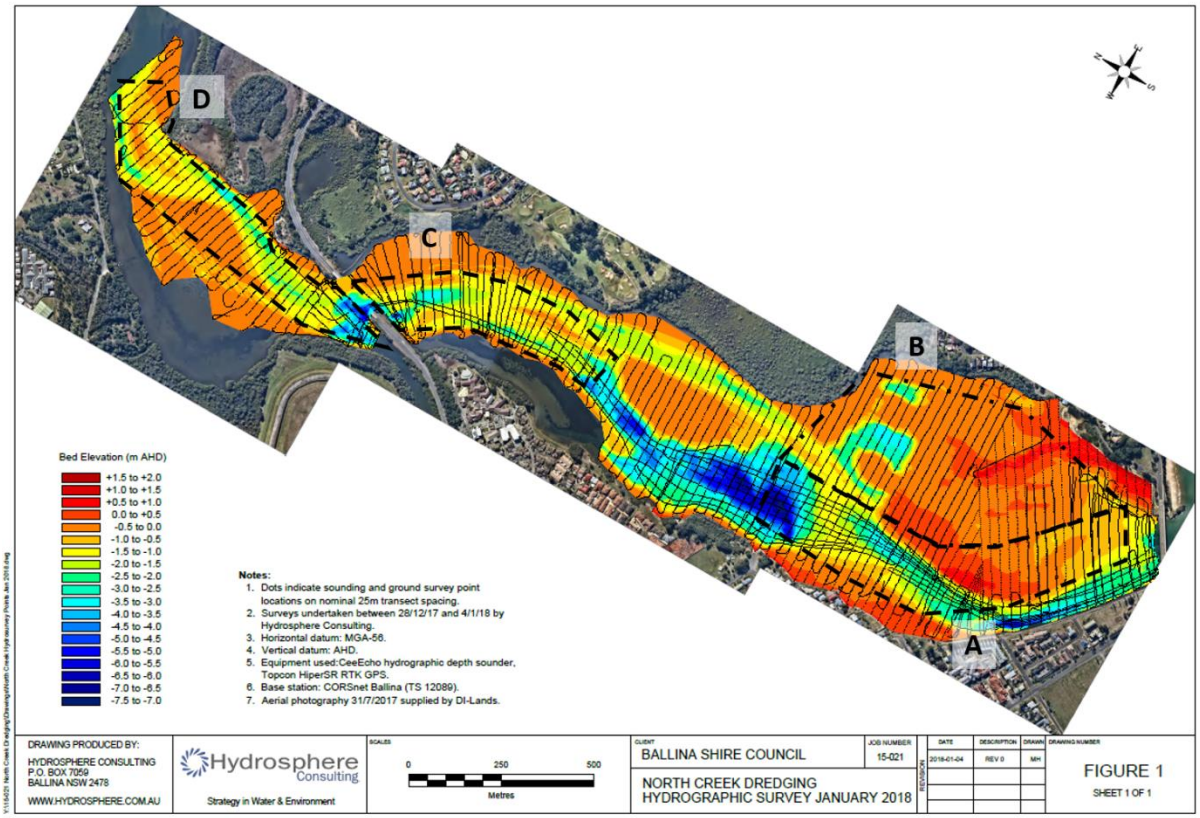


Figure 26. *The bed elevation of lower North Creek was surveyed in relation to the proposed dredging areas A-D as part of the Dredging Sedimentation Investigation Report (Hydrosphere 2018).*

The completed dredging scoping study and feasibility study anticipates water quality improvements from the proposed dredging work. The dredging of the channel is expected to facilitate (Hydrosphere 2016, 2018):

- Increased flushing with low turbidity, low nutrient and low pathogen oceanic water
- Conveyance of flood waters through the system
- Reductions in the residence time of poor-quality water following catchment rainfall events
- Reductions in suspended fine material, which can smother marine flora and fauna.

Modelling has not yet been undertaken to support these anticipated outcomes.

While it is possible for dredging works to achieve environmental outcomes such as those proposed, such a proposal needs to be informed by further investigations, clear goals and an adaptive management approach. The 2016 scoping study recommends the following be undertaken as part of further planning and assessment of the project:

- Liaise with North Creek oyster lease operators to better understand poor water quality events
- Undertake integrated hydrodynamic modelling (tidal prism, residence times) to assess anticipated tidal exchange characteristics
- Evaluate the potential for poor water quality during works and determine appropriate mitigation strategies
- Determine the ecological impact of dewatering.

Assessment of the anticipated increases to the tidal prism as a consequence of the proposed dredging will need to take into account the groundwater dynamics in the catchment. As over two thirds of North Creek is tidal, any increase to the tidal amplitude may increase the volume of acidic groundwater released into North Creek on the ebb tide. Dredging approval would be subject to the completion of an environmental impact assessment.

Shoaling is perceived to be play a causal role in the water quality issues facing the estuary. The Serpentine Sand flats and adjacent areas are also very popular recreational areas. For some members of the community the shoaling diminishes these recreational values (i.e. loss of deep water).

Sand mining

Given the shallow water table and prevalence of acid sulfate soils and potential acid sulfate soils across the catchment basin, current sand mining activities may exacerbate acid water discharge into North Creek. Such discharge would occur through the generation of acid runoff from oxidation of mined sulfide bearing sands (Enviro Solutions 2017). The compliance of dewatering practices is critical to limiting the water quality impacts within the North Creek catchment. As this is a compliance issue, further investigation may go beyond the scope of the CMP process and require actions from the relevant government agency. The proposal for the McGeary's sand mine and future recreation area was withdrawn in 2018 and as a result there is no current proposal for the expansion of sand mining within the catchment.

A rehabilitation plan will be necessary for the historic mine site. An understanding of the remediation approach is necessary to inform the water quality monitoring program. Sample site placement may be influenced by the rehabilitation regime, which could involve activities which may impact downstream water quality. The historic sand mine is also host to vegetation communities that may require protection throughout the rehabilitation process.

The McGeary's sand mine EIS provides valuable information on the hydrology and ecology of the site itself and illustrates the sensitivity of the catchment basin's shallow aquifer to disturbances (Parker 2017). A site visit to the historical sand mine mid 2018 revealed that the quarry lakes are crystal clear and spoil heaps are largely devoid of vegetation, which can be an indicator of the presence of acid sulfate soils.

Continued urban development within the catchment, in conjunction with the minimum fill requirements as provided in the Ballina Development Control Plan mean that there will be an ongoing sand requirement in the region. Cheap and effective sourcing of sandy material within the region to facilitate the projected growth will be required. Given the abundance of sand within the North Creek catchment appropriate consideration will need to be given to the impacts on groundwater, drainage and aquatic and terrestrial ecology for any future extraction proposals, as well as the suitability of the sand for use as fill.

Sand mining within the catchment was identified as a threat during the community stakeholder engagement process for the scoping study.

3.9 Drainage

Key points

> Extensive drainage works have been undertaken over time to mitigate flooding and enable agricultural and urban development

> Changes to the drainage patterns have substantially altered the hydrology, surface and groundwater interactions, which underpins the majority of ongoing management challenges for the catchment

Coastal floodplain context

As outlined previously, North Creek's drainage system has been significantly altered over time to enable the gradual expansion of urban and agricultural development across the catchment's extensive low-lying wetland known as Newrybar swamp. As the catchment topography is dominated by the low relief coastal floodplain, even relatively small structures (levees and constructed drains) and minor alterations to channel and floodplain grades can have a significant impact of drainage, more so than in other landscapes.

The catchment has a history of opportunistic floodplain works, levees, drains and floodgates, installed and modified by landholders to improve property scale operations. However, in several cases these works have had unforeseen adverse impacts for neighbouring properties, the community, the nature reserve and downstream environment. A brief review of the main drainage works is provided below.

Main drainage works

After the introduction of the Union Drain north of Ross Lane in the early 1900's, further drainage works were considered necessary to mitigate flooding in the east. The Richmond River County Council's 1975 investigation into Newrybar Swamp drainage yielded key observations of drainage behaviour prior to the installation of the mitigation drain (Barlow 1975). Namely that:

- The area now known as the Ballina Nature Reserve consisted of mainly mangroves and tea-tree swamp, with much of it either permanently flooded either by runoff or tidal water.
- During flood events, large volumes of overland flow were discharged across Ross Lane into the Ballina Nature Reserve.
- Flood outflow from above Ross Lane via the main drain was considerably influenced by the level of the storage formed in the Ballina Nature Reserve.
- Discharge of floodwaters in Ballina Nature Reserve occurred through Deadman's Creek.
- Calculated water levels of the swamp prior to the mitigation drain estimated no significant change in the natural flooding and drainage of the Ballina Nature Reserve area.

By 1979 the Mitigation Drain was built, which allowed for almost complete cultivation of the Newrybar Swamp (WBM 2015). These works aimed to interfere as little as possible with the existing flood pattern around Ballina Nature Reserve (Barlow 1975). Soon after drain construction, levees and tidal flood gates were also constructed by individual landholders to improve yields. However, these works also had adverse impacts on flood behaviour, and reduced the benefit of the Mitigation Drain (and also impacting on landholder relationships). The net result was that considerably more runoff was directed downstream via the Mitigation Drain and North Creek and correspondingly, considerably less runoff overflowed into the Ballina Nature Reserve wetlands (WBM 2015).

In 1984, The water resources commission of New South Wales examined mitigation options to alleviate flood related issues, however, concluded that levee modification was not possible due to lack of landholder cooperation. Attempts at flood mitigation since have been relatively unsuccessful with levees being broken by

floodwaters or removed by landholders (WBM 2015). Anecdotal evidence suggests that some floodgates have not functioned for at least ten years.

Current flow paths and challenges

At present, uncertainty surrounds the hydrology within the Ballina Nature Reserve. This is largely due to the patchwork of drains dug prior to the declaration of the reserve and the reduced inflows from the north. As noted previously, Deadman's Creek used to flow south east into North Creek along its original drainage path as recently as 1975, however now it is understood to flow to the north. The extent of flow along Deadman's Creek within the western half of Ballina Nature Reserve is shown in Figure 27. It is possible that sediments shed off the Ballina Heights district immediately upstream of Robert's and Deadman's Creeks have gradually accreted within the reserve since the late 1970's. Given the extremely flat nature of the terrain, minor changes in the topography are likely to result in the redirection of flow.

There is anecdotal evidence which suggests that the former main drainage line through the Ballina Nature Reserve wetland to North Creek, Deadman's Creek, is now blocked due to sedimentation. This is reducing flow through the wetland and impacting the drainage of rural properties to the west and north of the Ballina Nature Reserve including the area to the north of Ross Lane.

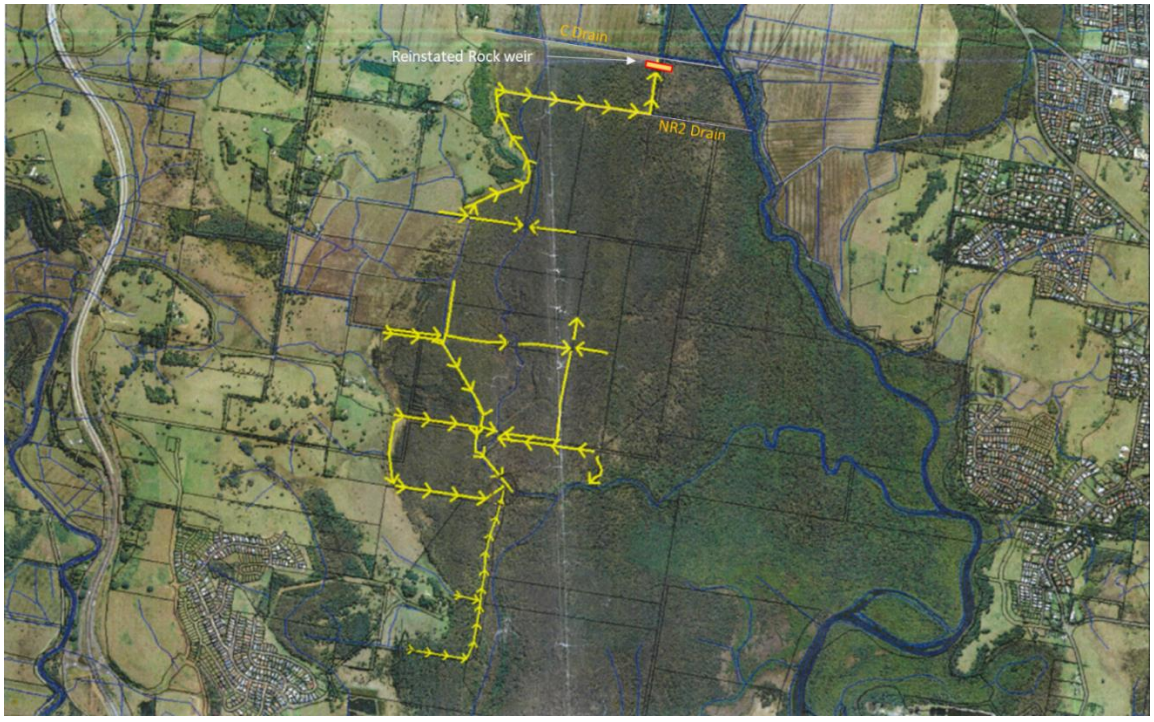


Figure 27. *Anecdotal assessments of flow within the patchwork of drains which have been dug prior to and after the establishment of Ballina Nature Reserve (courtesy of I. Gaskell).*

With further residential development planned within the catchment, stormwater inputs and associated sediment loads are likely to increase. A hydraulic assessment for Precinct B of the Cumbalum Urban Release Area (CURA) by WBM in 2017 addressed potential flood impacts of the development located west of the Ballina Nature Reserve. The report suggested that an extension of the NR1 channel from the reserve would provide adequate drainage for predicted floodwaters despite localised peak flood level impacts on adjoining properties.

The CURA Precinct B hydraulic assessment assumed the removal of a rock weir between the two channels NR2 and C which typically maintained a 0.5 m relative height difference in water levels between the reserve and the adjacent drains. The weir however has been recently rebuilt by persons unknown, possibly to withhold southern floodwaters which flow northwards and inundate sections around Ross Lane for extended periods. Anecdotal reports suggest that the weir holds water back within the reserve and thereby reduces floodwater residence time around Ross Lane.

Continued development in the Ballina Heights region is likely to exacerbate the issues described above. A considered approach will be required in dealing with the associated increase in stormwater and sediment inputs. There are anecdotal reports of a proposal for the routing of storm water from Ballina Heights through part of Roberts Creek and along a channel adjacent to Ballina airport. This option, however, may have other consequences, such as a reduced opportunity for the attenuation of stormwater contaminants.

Predicted changes in sea level and rainfall intensity will influence how water flows through this developing landscape. This added complexity will impact flood risk, which is currently managed through the 2012 Ballina Floodplain Risk Management Plan and its associated development controls. These development controls define minimum flood planning levels, which are based on the future flood level predictions for years 2050 and 2100.

Changing hydrology/drainage patterns

The hydrology and drainage pattern of the catchment continues to change. This is leading to a variety of hydrological issues across the catchment including poor water quality, changes to ecological communities and impacts on landholders. There is no 'silver bullet' for this issue, as each mitigating activity has its own flow on effects. This is demonstrated by the extensive ad-hoc levees across the catchment and ongoing flooding challenges, including those discussed with landholders (see Text Box 1).

Text Box 1 – June 2018 landholder workshop discussion points

On the 25th of June 2018, a landholder workshop was held as part of the scoping study engagement activities, including discussion on the drainage issues facing the catchment. Discussion points included:

- Flows through the Ballina Nature Reserve and Deadman's Creek have changed over time.
- The existing LiDAR dataset through the Ballina Nature Reserve is not detailed enough to model hydrology (as originally raised by Ballina Shire Council).
- The construction and deconstruction of the rock weir between drain lines NR1 and NR2 (of concern to landholders)

Another concern raised was the apparent effect of floodgate infrastructure on floodwater residence time north of Ross Lane, however floodgates can only work where there is no pressure on them opening outwards (due to tidal inundation under downstream flooding or king tide conditions). All floodgates will 'drain' water out at any time where there is no pressure on them opening outwards.

The rock weir in the drain between NR2 and NR1 was of particular focus during the landholder workshop. Participants considered that the weir requires active management by the relevant authority, as its position within the drainage network is perceived to have flood level implications for immediate landholders and the wider landscape. As such, the rock weir may influence the modelling results of stormwater flows relevant to the proposal of the Cumbalum Urban Release Area B. If this is the case, whether the weir is in position or not could have consequences for future stormwater designs. It was also noted that multiple flood gates across the drain network which are either faulty or in disrepair add further complexity to the assumptions upon which flood modelling is based.

Further investigation/validation of flood behaviour observations reported by landholders would assist with future management decisions.

Additional parts of the drainage and management story for North Creek also include:

- The WBM 2015 Newrybar Swamp drainage and flood mitigation study, which provides recommendations for flood and drainage management in the catchment. Recommendations are understood to be in the early stages of implementation. Given that the Ballina Floodplain Risk Management Plan (BFRMP) is due for review, the above mentioned drainage issues within the catchment may be suitably dealt with through a revision which incorporates any further information derived through Stage 2 of the CMP process.

- Changing the hydrology of the Ballina Nature Reserve through reinstating flow through Deadman's Creek may disturb a considerable portion of the reserve, which is classified as coastal wetland and is protected under the Coastal Management Act 2016. Given the recent coastal reform, there are numerous objects and management objectives which can be utilised to support restoration of the hydrologic regime within the Ballina Nature Reserve (if it was deemed necessary). A proposal for the necessary works could be constructed with appropriate legal counsel.

Finding a solution to the drainage issue will require the co-operation between all stakeholders across the catchment. While the current drainage issues regarding Ballina Nature Reserve, and other areas, are of concern, they also need to be considered in relation to the larger scale drainage issues facing the catchment across 50 to 100 year timescales. Projected sea level rise may overprint the flooding issues currently experienced, thus negating any solutions considered in isolation. Developing a shared understanding of the trajectory of the catchment and the tensions between the short- and long-term needs of the catchment community, as part of the CMP, will assist to facilitate progress on the issue.

North Creek (northern rural catchment) – The Union Drain which runs parallel to Newrybar Swamp Road

3.10 **Waterways**

Key points

- The laterally unconfined streams of the foothills and coastal floodplain have been extensively modified since European settlement
- Discontinuous swampy meadows have been converted to a network of linear drains and levees across the mid-catchment zone
- Tidal ingress up the waterways influences over 70% of waterway length
- The overall geomorphic condition of North Creek is relatively stable, linked to the relatively low gradient across the catchment
- Riparian condition is good where native vegetation remains across the Ballina Reserve area, and moderate to poor in upper and lower parts of the catchment where native vegetation and mangroves have been lost.

Northern catchment
In northern parts of the North Creek catchment, confined and partially confined headwaters flow from the Alstonville plateau (to the north-north west), and to the east, laterally unconfined coastal streams drain coastal swampland. Most of these headwater streams remain in a near natural state.

On the lower (foothill) elevations and transitioning to the coastal floodplain, laterally unconfined coastal streams from the east have been substantially modified since European settlement. Prior to settlement, these streams were largely discontinuous swampy meadows, however, now form a network of linear drains (see Figure 28). As noted previously, this extensive network of channels and levees was constructed to maximise agricultural development. Channelization has also facilitated an increase in tidal ingress which now influences 72 % of North Creek's stream length (Ryder et al. 2015). As noted in the groundwater discussion, flood gates have been installed to manage tidal flow and there is a complex groundwater, tides and surface water relationship.

Mid to southern catchment
Through the mid to lower catchment, the estuarine reaches of North Creek maintain a sinuous planform. The mid reaches upstream of the airport have a relatively natural channel form with mangrove forests established along the banks in many locations. There is also significant instream wood which provides instream habitat. The Ballina Nature Reserve wetland system drains into North Creek from the north of catchment. The hydrology of this wetland has been extensively modified due to drainage works and urbanisation of the surrounding catchment. As it stands, the estuary condition falls short of achieving several objectives within the Marine Estate Management Strategy.

The lower section through Ballina has been extensively modified including the use of rock revetment to reduce bank erosion. Expansive intertidal flats in the shallow lower reach provide important habitat for instream biota which support local fish and seabird populations (Ryder et al. 2015).

Figure 28. *The natural and modified waterways of the North Creek catchment.*

Estuary branches
Four main arms of the North Creek estuary extend within the Ballina urban area, Chickiba Creek, North Creek Canal and Little Fishery Creek (Figure 28).

Winding through East Ballina, Chickiba Creek and its fringing wetlands have been modified for development and consequently experience an altered hydrology. This has led to vegetation dieback, fragmentation and poor water quality (BSC 2006).

The North Creek Canal runs through the heart of the Ballina township and connects to the Richmond River creating an island. The canal follows the route of shallow wetlands which previously occurred in this area. The channel was widened and deepened to facilitate the movement of cane barges to the Broadwater Sugar Mill. The tidal inlet is lined with mangrove vegetation however bare stretches remain exposed to risk of erosion by boat-wash (Hydrosphere 2011). Some rock revetment work has been undertaken through this section.

Sandwiched within urban development, Fishery Creek extends from the North Creek Canal to the west beyond the limits of urban development. Its vegetation is largely intact, and its channel stable, despite some fragmentation of its fringing wetland. The Ballina Recycled Waste Water Treatment Plant discharges into the North Creek canal 1300 m from Richmond River and 2.2 km from North Creek.

Waterway condition
Despite extensive modifications, North Creek's overall geomorphic condition is relatively stable, assisted by the relatively low gradient across the catchment, and residual native vegetation in the mid-catchment area. However, overall, much of the riparian vegetation condition is moderate to poor, given the dominance of invasive exotic species in the freshwater reaches and loss of mangroves in the lower estuarine zone (Ryder et al. 2015). Lateral connectivity is fragmented and the opportunity to extend mangrove communities is restricted by urban development and rock armouring of the intertidal edge in the lower catchment.

Protecting waterways in good condition, improving water quality, and dealing with the impacts of increased tidal influence across the catchment, will continue to be key management challenges for the North Creek catchment waterways and floodplains.

The mid reaches of North Creek which retain good riparian vegetation coverage

3.11 **Social context**[1]

Key points

- The Bundjalung people are the traditional custodians of the land
- The North Creek catchment is home to an estimated 34,000 people, concentrated within the urban centers of Ballina, East Ballina, West Ballina and the townships of Lennox Head and Skennars Head
- The population of Ballina Shire is predicted to grow by between 20 and 28 % by 2036, with the main growth centres at Ballina North, Lennox Head and Cumbalum

Population

The North Creek catchment lies in the heart of Ballina Shire Local Government Area. It is home to an estimated population in the order of 34,000 people, most of whom are concentrated within the urban centers of Ballina, East Ballina, West Ballina and the townships of Lennox Head and Skennars Head (ABS 2017).

Census data for Ballina provides an indication of the demographics of the region. At the time of the 2016 census, the median age of people in Ballina was 55 years, and:

- Children aged 0-14 years made up 11.7 % of the population compared to the State average of 18.5 %.
- People aged 65 years and over made up 36.3 % of the population compared to the State average of 16.2 %.

Of occupied private dwellings in Ballina:

- 34.7 % were owned outright (compared to State average of 32.2 %)
- 16.5 % were owned with a mortgage (compared to State average of 32.2 %)
- 40.2 % were rented (compared to State average of 31.8 %).

The main population growth areas are Ballina North, Lennox Head (spanning the eastern catchment boarder) and Cumbalum (spaning the western catchment border). Population numbers in these areas are predicted to grow by 20 – 28 % by 2036. Population growth in other smaller settlements is expected to be in the order of up to 5 % by 2036 (ABS 2017).

Settlements

The residential areas in the North Creek catchment include areas of Ballina, followed by several smaller settlements, several of which span the North Creek catchment boundary. Rural residential properties are also scattered across the catchment. The population numbers for the main residential areas in the North Creek catchment at the time of the 2016 census are shown in Figure 29..

[1] Similar social context information is also re-presented in Attachment A as part of the Community and Stakeholder Engagement Plan (CSEP) to enable the CSEP to be a stand-alone document as well.

Figure 29. *Population count from the 2016 census within the residential centres of the North Creek catchment area*

Employment
At the time of the 2016 census, the top employment industry in Ballina was aged care residential services (6.1 % of workers). Other major industries of employment included supermarket and grocery stores 4.1 %, other social assistance services 3.2 %, accommodation 3.2 % and hospitals 3.2 % (ABS 2017).

Similar employment trends hold for surrounding settlements (e.g. Lennox Head, Cumbalum) with major employment industries including hospitals, cafes and restaurants, aged care services, plus primary education (ABS 2017.

The most common occupations in Ballina and surrounding regions included technicians and trades workers 15.7 %, professionals 15.4 %, labourers 14.8 %, community and personal service workers 14.1 %, and sales workers 12.3 % (ABS 2017).

Tourism is also an important part of the Ballina Shire economy with over 1,500,000 international and domestic visitors in 2017/2018 (Tourism Research Australia, 2019). The majority of these visitors are likely to visit within the summer months and school holidays to enjoy the coastal environment and waterways, including parts of the North Creek catchment, particularly Ballina and Lennox Head.

Diversity
The most common ancestries in Ballina at the time of the 2016 census were English 30.9 %, Australian 29.1 %, Irish 9.5 %, Scottish 8.0 % and German 2.8 % (ABS 2017). In addition:

- The percentage of Aboriginal and/or Torres Strait Islander people in the Ballina region was 4.3 %, compared to a State average of 2.9 %.

- The majority of residents, 78.8 %, were born in Australia, compared to the State average of 65.5 %.

Aboriginal cultural heritage
The Ballina Shire, including North Creek catchment area, has important Aboriginal culture and heritage values. An overview of the Shire's Aboriginal and Culture and Heritage is described in Text Box 1.

Text Box 1 – The Shire's Aboriginal Culture and Heritage

Source: https://www.ballina.nsw.gov.au/cp_themes/default/page.asp?p=DOC-ONO-01-56-87

The Bundjalung people are the traditional custodians of the land, having cared for and lived off the land for thousands of years. The many natural features and landforms that make up the Ballina Shire landscape were understood by the Bundjalung people to be the creation of their Dreamtime ancestors.

Bundjalung people tell of how, before the coming of white man, they lived in harmony with the natural environment. Like other Indigenous culture, the Bundjalung people suggest they belong to the land and the land to them. The land provided a wide variety of foods including fish, crustaceans, mammals, birds, reptiles, vegetables and fruits. Shelters were made of timber, bark, branches and palms. Fire was used to cook food and timber, rock and fibres used to make tools and utensils with which to hunt, gather and prepare food. Individuals were part of a complex kin and tribal grouping that frequently moved across different parts of the land in search of food and in response to seasonal change and for ceremony. Bundjalung peoples' culture and traditions evolved over many thousands of years with the passing down of knowledge from previous generations and adapting to environmental change.

Management of Aboriginal Heritage matters in the shire is overseen by JALI Local Aboriginal Land Council and is supported by the National Parks and Wildlife Act (1974) and the NSW Heritage Act (1977) which provide legal protection for Aboriginal sites and relics in NSW, including sites yet to be recorded.

North Creek and its catchment also have specific significance to the Bundjalung people. Gahan (2018) provides a summary of the Bundjalung custodianship of the North Creek catchment before 1840. Key points from this summary include (Gahan 2018):

- Today it is recorded that the Bundjalung people occupied the Creek's catchment from, at least, 4000 BC – that is for over 6000 years.

- A vast kitchen midden once stretched for hundreds of metres along North Creek. The midden predominately consisted of oyster shell provide an indication of the extensive use of North Creek by the Bundjalung peoples over many centuries. Only a remnant of this midden remains intact.

- The Bundjalung peoples viewed the catchment as an integrated, cyclical system and as a result were careful and systematic in what they took from the environment. This knowledge was recorded and passed on through oral traditions of storytelling and song.

- The natural sand shoals in the lower estuary were utilised for permanent fish traps.

- Long wide nets were also used to capture ground dwelling species such as paddy melons and bandicoots.

- Small bands of extended family groups often came together to have much larger gatherings. Early European settlers in the area witnessed and recorded such meetings at Chickiba Lake, when oysters were in abundance.

Jali Local Aboriginal Land Council have been consulted during the development of this document, and in respect to these discussions culturally sensitive information/sites are not included in this report.

European heritage

Gahan (2018) provides a summary the history of European settlement in the North Creek area. Key points from this study include:

- 1828 - Henry John Rous sailed along the east coast. He has been widely celebrated as the first European to explore the Richmond River.

- 1840s – 1850s - A permanent settlement at Ballina by Europeans dates from the early 1840s. Small groups of cedar cutters and their families are recorded to be the earliest to relocate here – this included on land at Prospect on North Creek, and at Shaw's Bay where the North Creek joined the Richmond River. A small stream near Shaw's Bay provided freshwater for the first European settlers.

  Throughout the 1840s cedar cutters and traders were the primary European inhabitants. The Bundjalung people continued to live within the catchment. Bundjalung men were known to also work for the cedar cutters during this period and provided local knowledge. In the 1850s the Native Police rode into Ballina and executed a dawn raid on Bundjalung families camped on the northern side of North Creek, many people were murdered or wounded.

- 1860s - From the early 1860s a new land legislation known as the Robertson Land Acts spurred a further wave of European migration to the Richmond River. The legislation enabled settlers to select land parcels for farming or improvement provided it was occupied. This encouraged farming families to the district. Land located on the North Creek floodplain was amongst the first areas to be farmed in Ballina.

  Early farming practices in the catchment included mixed-cropping, sugar cane production, cattle grazing and dairying. These activities drastically changed the landscape through the clearing of native vegetation. Farming was popular in the North Creek catchment due to the fertile soils.

- 1870s - In 1870 a vehicular ferry was installed across North Creek, along the North Creek Road, to enable the transport of produce and people to and from the farms established along the North Creek.

- 1880s - The establishment of the mill at Broadwater in 1881 saw much of the floodplain areas south of Ballina cleared and cultivated for sugar cane, marking a change in land use that continues to the present day.

- 1890s – By the 1890s, dairy farming also became a dominant landuse in the region. The processing of timbers was also an important industry in the Ballina area throughout the closing decades of the nineteenth century.

  While modest timber houses for many decades dominated both the rural and urban landscape, a number of larger and 'finer' domestic houses from the turn of the century remain in the Ballina area. A number of domestic buildings now form part of the Norton Street Heritage Trail in Ballina, including the restored Ballina Manor. Other historical buildings and community halls are present in the towns and across the rural landscape.

- 1900s onwards - In 1906, the Newrybar Drainage Trust established – under the NSW Water and Drainage Act – 'to drain off the flood waters, and so rendering the land fit for grazing and agriculture'. Water was drained from the swamp into North Creek. This resulted in a major transition in ecosystems as the wetland communities were lost the drainage works and farming.

  Engineering works within the Richmond River and North Creek increased navigability of the waterways which enabled the North Creek to be an important transport corridor between the farms in the catchment and the Ballina community.

  Further drainage works through the 20th Century led to the widespread loss of wetlands and the expansion of agricultural throughout the catchment.

North Creek floodplain – remnant wetland habitat

3.12 **Economic context**

Key points

- The economy of the Ballina Shire is underpinned by health care, construction and retail trade
- The economy is relatively resilient (diversified)
- Tourism and agriculture, forestry and fishing are also key industries
- Oyster harvesting in the lower estuary is sensitive to environmental factors, including water quality, resulting in annual fluctuations in production and value

Key industries

The North Creek catchment supports diverse economic values. The catchment itself is located within one of the fastest growing parts of regional New South Wales, driven largely by tourism and migration. Residential development within and surrounding the catchment a key driver of increasing economic value (BSC 2017b).

The largest industry sectors for the Ballina Shire in 2018/2019 are shown in Table 8. Health care and social assistance, construction and retail trade are the top three industries underpinning the economy. A large proportion of the land that supports key industry sectors is located within the North Creek catchment, which lends to a relatively higher economic value when compared against the other catchments in the Shire.

Table 8. Key industry sectors (NIEIR 2019)[2] – economic value-add by industry ($m and %) compared to State values (% only).

Industry	Ballina Shire $m	Ballina Shire %	NSW %
Health Care and Social Assistance	202.4	12.9	7.7
Construction	176.1	11.2	8.4
Retail Trade	124.9	8.0	5.1
Rental, Hiring and Real Estate Services	120.6	7.7	4.7
Education and Training	112.4	7.2	5.3
Manufacturing	96.4	6.2	6.3
Professional, Scientific and Technical Services	88.0	5.6	9.7
Public Administration and Safety	80.6	5.2	5.5
Accommodation and Food Services	80.3	5.1	3.2
Financial and Insurance Services	75.0	4.8	14.4
Agriculture, Forestry and Fishing	74.6	4.8	1.4
Administrative and Support Services	54.7	3.5	4.5
Transport, Postal and Warehousing	51.7	3.3	5.8
Electricity, Gas, Water and Waste Services	46.5	3.0	2.4
Mining	44.7	2.9	3.6
Wholesale Trade	43.8	2.8	4.9
Arts and Recreation Services	38.9	2.5	0.9
Other Services	31.9	2.0	2.2
Information Media and Telecommunications	21.9	1.4	4.0
Total Industries	**1,565**	**100.0**	**100.0**

[2] Accessed at <https://economy.id.com.au/ballina/value-add-by-industry> in December 2019.

Based on available economic data for Ballina Shire, the total economic value-added in 2018-2019 was approximately $1.57 billion (value added is a measure of the value generated by business activity by different industry sectors).

The concentration ratio when considering the top four contributing industries in Ballina Shire is 39.9%, compared to 40% for New South Wales. This signals that economic diversity in the Ballina Shire are similarly distributed to that of the state, preliminarily indicating that the shire's economy is expected to be resilient to shocks. However, health care and social assistance, and construction are (by some margin) the two largest contributors to regional value-add and if they were to encounter challenges then the stability of the economy would be tested. Health care is not as prominent at the State level.

Tourism

The topography and proximity of the North Creek catchment acts as gateway to the most widely accessed coastal zone within the Shire, providing access and the scenic amenity that are key to the health of tourism in the Shire.

The value of the tourism industry within the Shire is typically spread across multiple industries, however the total value added by tourism and hospitality in the Ballina Shire in 2018/19 was estimated at $120 million (NIEIR 2019)[3].

While a breakdown of the seasonal fluxes is not available, a significant proportion of the visitors to the Ballina Shire state the main reason for their visit is for holiday or visiting friends and family (NIEIR 2018). Therefore, it is likely that there are peaks in visitor numbers around school holidays and holiday periods such as Christmas and Easter. Tourism is also a very labour-intensive sector, resulting in tourism activity being a major contributor to local employment, particularly for young people that are typically overrepresented in unemployment and underemployment statistical measures.

Agriculture, forestry and fishing

Of the $74.6 million contributed by agriculture, forestry and fishing to the Ballina Shire economy, $4.3 million is attributed to agriculture, forestry and fishing support services and of that $1.3 million is attributed to fishing, hunting and trapping (NIEIR 2019). Anecdotal reports indicate that fishing within North Creek is in decline. The mullet fishery at Misshingham Bridge, located in the Richmond River near North Creek's entrance, was estimated to be worth $500,000 to the local economy in 2004 (DPI 2004).

The upper North Creek catchment is predominately utilised for agricultural activities, namely horticulture (sugar cane, citrus and increasing macadamia) and pastoral use. In 2015/16 macadamia nuts were largest commodity produced in the Shire, contributing 46.3% to Ballina Shire's agricultural output (ABS 2017).

Agriculture within the Ballina LGA is experiencing a relative decline in overall significance to the regional economy. Table 9 provides approximate economic values for the three main agricultural activities within the North Creek catchment. These values were calculated utilising 2013 NSW land use classification and 2015/16 ABS economic data as an indication of the proportion of value generated by the catchment in relation to the 2018 NIEIR analysis of ABS economic data for the Ballina and Byron Shires. This method provides an indicative measure only as it assumes that all the land within the LGA is productive as per its classified use. This means that it does not take into consideration the possibility of land use change since 2013 or the time needed for recently established macadamia farms (of which there are some) to mature and produce a commercial crop.

[3] Accessed via <https://economy.id.com.au/ballina/tourism-value> in December 2019.

Table 9. The approximate economic value of the main agricultural activities from within the North Creek catchment (NIEIR 2018)

Agricultural activity	2015/16 North Creek catchment contribution by land use area	2015/16 Value added by the Ballina Shire
Macadamia nuts	$2,710,000	$34, 800,000
Sugarcane	$1,170,000	$6,460,000
Grazing (cattle and calves)	$560,000	$2,440,000

Oysters

Despite the oyster harvest area in North Creek closing in 2006, leases within the estuary can still be utilised for farming of oysters, which only require transportation to Mobbs Bay in the Richmond River for depuration prior to harvest. Given there are less than five oyster operators within the lower Richmond/North Creek estuaries, DPI NSW cannot release the economic production data for this system due to confidentiality concerns.

Consequently, it is difficult to determine the exact economic value contributed by North Creek in terms of oyster production. What can be described is the overall percentage change in value and production of oysters from the area, which are provided in Table 10 and illustrated in Figure 30. The variability of the data highlights the sensitivity of oyster productivity to multiple environmental and demographic factors of which water quality and adequate training are considered to be the most influential (Schrobback 2015).

Table 10. Comparison data for the productivity of and value of the oysters harvested within Mobbs bay in the Lower Richmond river, opposite to the North Creek mouth entrance (DPI 2019).

Summary	Change from previous year	Change from previous year
Period	Quantity (dozens) % change	Value ($) % change
2007/08 to 2008/09	83% increase	110% increase
2008/09 to 2009/10	76% decrease	70% decrease
2009/10 to 2010/2011	85% decrease	88% decrease
2010/2011 to 2011/12	264% increase	304% increase
2011/2012 to 2012/13	116% increase	123% increase
2012/13 to 2013/14	77% increase	83% increase
2013/14 to 2014/15	48% decrease	41% decrease
2014/15 to 2015/16	67% decrease	64% decrease
2015/16 to 2016/17	46% increase	37% increase
2016/17 to 2017/18	17% decrease	2.7% decrease

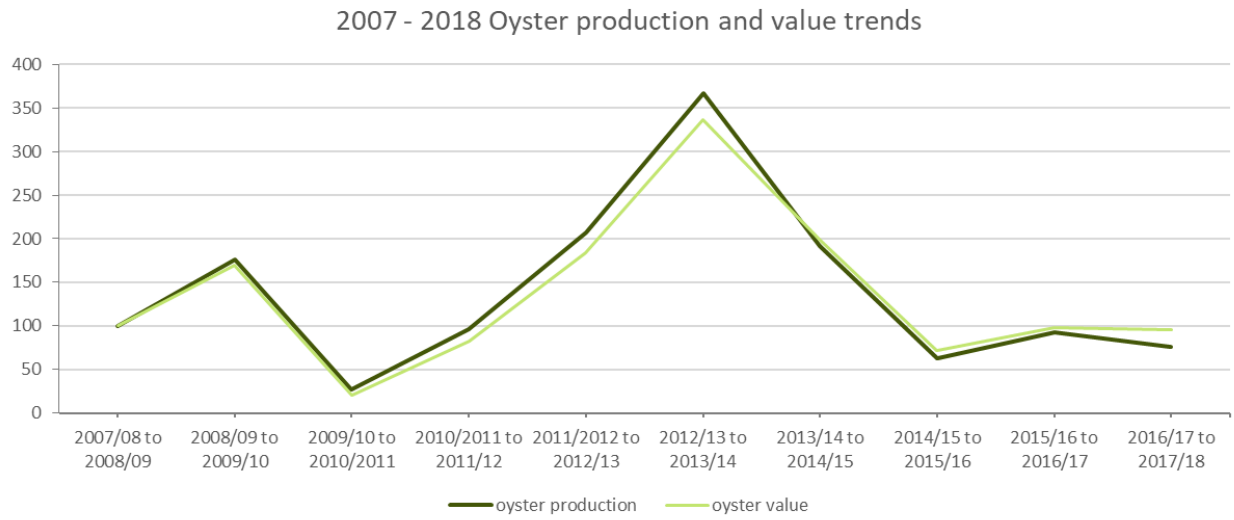


Figure 30. *Oyster production and value trends for the Lower Richmond river and North Creek area. Arbitrary values were assigned to the y axis as only percentage data was provided by DPI NSW.*

North Creek estuary – oyster farming

3.13 Stakeholder and community values

Key points

- A diversity of stakeholders have an interest in the CMP development
- An Agency Reference Group has been established to collaborate during the CMP development
- Key values identified by the community (via survey) included native vegetation, biodiversity, waterbirds, swimming and fishing
- Key threats to values identified by the community (via survey) included rubbish, urbanisation, agriculture, stormwater discharge, loss of riparian vegetation, poor drainage.

Community and Stakeholder Engagement Plan

The Community and Stakeholder Engagement Plan (C&SEP) developed for the North Creek CMP process is provided in the attachments to this document (Attachment A). The C&SEP provides a summary of the key catchment context, engagement objectives, and actions to guide engagement with the community and other stakeholders in the development (and later the implementation) of the CMP.

The C&SEP actions during the scoping phase of the CMP (Phase 1) have included:

- Establishment of an Agency Reference Group, and initial meeting to launch the CMP process
- Identification of stakeholders and key interests
- Phone / email interviews with key stakeholders
- Landholder workshop (25th June 2018)
- Online survey and information stand at two community markets (May - July 2018)
- A focus on gathering community and stakeholder feedback on catchment values and perceived issues/threats.

Agency Reference Group

A key component of the engagement process is the establishment of the Agency Reference Group (ARG) to provide guidance on the study and also latter stages of the CMP. The ARG for the North Creek CMP includes representatives from:

- Ballina Shire Council
- Rous County Council
- DPIE Environment, Energy and Science – Coast and Estuaries
- DPI - Fisheries
- DPIE – Crown Lands
- TfNSW - Maritime
- North Coast Local Land Services NRM
- Jali Local Aboriginal Land Council

The ARG convened early in the scoping study to discuss the desired project outcomes, share knowledge and explore the vision for the North Creek catchment. Discussion included zoning, engagement, water quality and drainage as key elements to include in the CMP process. Minutes from the first ARC meeting are provided in the attachments.

Initial stakeholder interviews

The ARG members provided a list of key stakeholders with interests in the catchment. These stakeholders had a diverse range of interests in the North Creek catchment and included:

- Landholders
- Oz Fish
- Ballina Fisherman's Co-op
- Australian Seabird Rescue
- Steinhardt's Oysters
- Richmond Oysters
- Ballina Environment Society
- Ballina Coast care
- Richmond River Cane Growers Limited
- Australian Macadamia Society
- NSW farmers representation

An attempt to contact each stakeholder by phone and/or email was made early during the development of this scoping study. Key questions were asked including:

- What is your interest/concern in the North Creek catchment?
- Do you know of any data/information which should be included in the scoping study?
- What level of engagement would you like through the CMP process?

An overview of the responses from each stakeholder is provided in the Attachment D.

Community interests

The broader catchment community has been engaged through several avenues during the scoping study.

An information flyer also produced and shared through the BSC website (Figure 31.). The flyer content was designed to inform the community of the recent NSW coastal legislation reform and how they can be involved in shaping the future of management in North Creek through the CMP process.

An information stand was also held at two successive Sunday markets in Ballina in July 2018 where residents could share their knowledge on the history and management of North Creek, values and issues of concern.

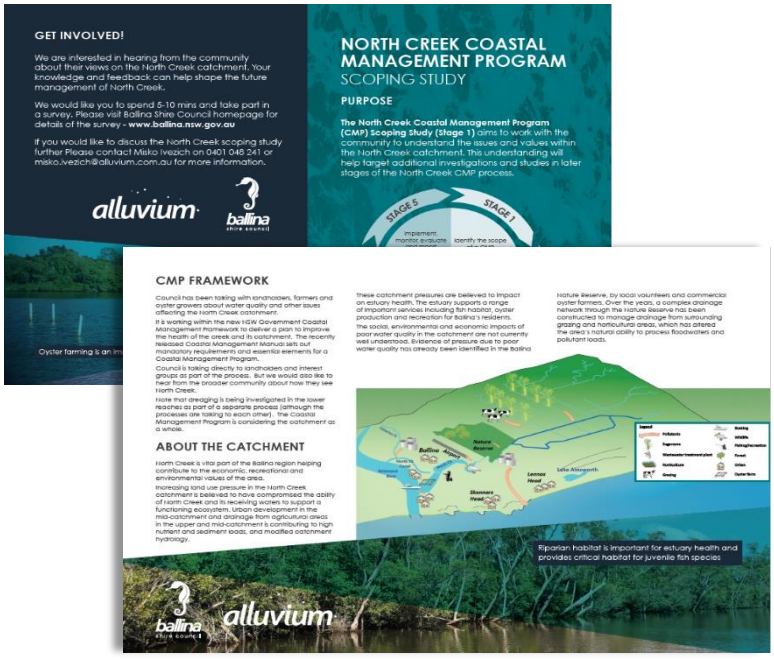


Figure 31. *The information flyer distributed as part of the North Creek scoping study*

An online survey was also made available to the North Creek community via the Ballina Shire Council website and shared through social media platforms. The online survey was designed to draw out the social, economic and environmental values and issues within the catchment, as outlined in the following section.

Online survey

The survey was open to the public over May and July 2018. During this period 150 responses were collected. The survey comprised of 13 questions and took an average of eight minutes to complete. Questions aimed to capture the demographics of the respondents, their values, concerns, interest and observations within the catchment over time. The results from key sections of the survey are provided in Table 6. Additional results are provided in Attachment D.

Table 6. Summary of results from the Ballina community survey

CMP theme	Results	Implication/message
Community demographics		
Age 	• More than half (59 %) of respondents were aged over 50	• Age distribution has implications for the future economic and infrastructure development for the Ballina Shire • The community has a strong desire to be engaged with the process of the North Creek CMP development
Occupation 	• 20 % of people surveyed are retired • The greatest proportion of respondents (10 %) are employed in education and training, and library occupations	
Club membership 	• Most respondents (61 %) did not identify as a local activity group member • 15 % were a part of local fishing groups, 14 % community groups and 9 % environmental groups	
Community engagement 	• Nearly half (45 %) of respondents indicated they will check the website for updates • 30 % would attend future information events • 97 % of respondents left their contact details with the wish to be informed in the development of the CMP	

CMP theme	Results	Implication/message
Catchment values		
Areas of Interest 	• Primary areas of interest are: o Overall Catchment Health (37 %) o Urban areas, boat ramps, swimming areas (20 %) o Ross Lane & the Ballina Nature Reserve (12 %)	• These values and initiatives will help inform future management strategies for the coastal area • Strong focus of water management-based positive changes indicates the important value of the North Creek catchment to the community
Important values 	• 76 % of respondents identified Native vegetation as a 'very important' catchment value • Other key values include Biodiversity, Waterbirds, Swimming and Fishing	
Positive Initiatives 	• 20 % of respondents identified initiatives in waterway regulation, riparian restoration or environmental education • Improvements to pathways were suggested by four percent of respondents	
Desired Positive Changes 	• Five main categories were identified for desired positive changes: o Improved environmental protection (24 %) o Dredging of lower estuary to commence (22 %) o Improvements in water quality (22 %) o Drain maintenance (16 %) o Reduced development (9 %)	

CMP theme	Results	Implication/message
Catchment threats		

Community-identified threats 	• The community considers the following to be the top 6 threats to catchment values:
	  ○ Rubbish
	  ○ Urbanisation
	  ○ Agriculture
	  ○ Stormwater discharge
	  ○ Loss of riparian vegetation
	  ○ Poor drainage
	• Only 15 % listed climate change as a top 5 threat
		• Important to gain community feedback to ascertain where there may be ongoing issues as there is a lack of monitoring
		• The community may also have photographs or other information to inform historical changes/threats to the catchment

Factors contributing to threats 	• A significant proportion identified siltation and reduced tidal flushing as the primary threat factor • Others focus on the upstream factors, such as agricultural runoff, acid drainage and urban pollution	• It is apparent that perceived threats are widespread throughout the catchment

3.14 **Land tenure**

Key points

> North Creek catchment is host to a mosaic of public and private land tenure which is subject to a number of local, regional and state management arrangements

The North Creek catchment is host to a mosaic of public and private land tenure which is subject to a number of local, regional and state management arrangements. These arrangements have changed over time, leading to complexity when attempting to determine responsibilities as land management issues arise. A summary of the existing tenures is noted in Table 11 and Figure 32. Multiple responsible authorities contribute to the complexities in the existing management arrangements within the Ballina Shire.

Table 11. An overview of the tenure categories found within the catchment and their corresponding responsible authorities

Property type	Responsible authority
National Park	National Parks and Wildlife
Road Reserve	Ballina Shire Council
Agricultural drain	Private landholders
Natural waterway	Crown Land Reserve Manager – Department of Industry (DOI) -Crown Lands and Water Department of Primary Industies (DPI) - Fisheries
Crown land reserve	Crown Land Reserve Manager – Department of Industry (DOI) -Crown Lands and Water
Native Forest	Ballina Shire Council
Freehold	Private landholder

North Creek urban area through Ballina

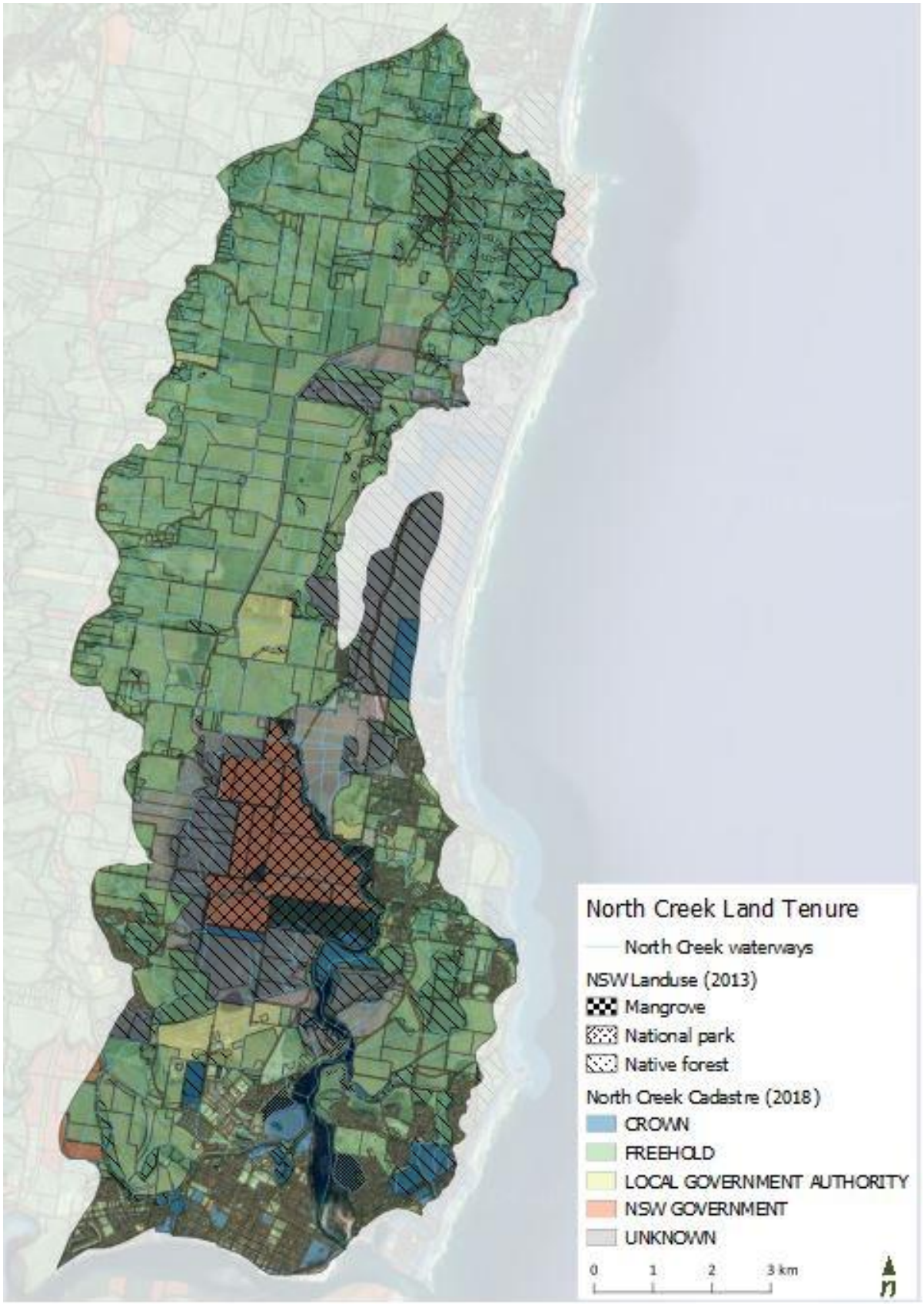


Figure 32. *The varying land tenure of the North Creek catchment*

3.15 Coastal management areas

Key points

- There is some overlap of the coastal management areas with planned urban growth and proximity areas
- Coastal wetlands and littoral rainforests are given the highest priority for management; there is approximately 20 km^2 of coastal wetlands and 0.8 km^2 of littoral rainforests in the North Creek catchment
- It is possible that the boundaries of some coastal management areas will need to be revised as part of the CMP process

SEPP areas

The spatial extent of the coastal zone is comprised of a combination of coastal management areas which are mapped in the recently released Coastal Management State Environmental Planning Policy (SEPP) in accordance with the principles articulated in the CM Act 2016.

The four coastal management areas outlined in the Coastal Management SEPP include Coastal Wetlands and Littoral Rainforest, Coastal Use areas, Coastal Environment areas and Coastal Vulnerability areas. Specific management objectives for each coastal area are provided within with the CM Act 2016. Given that the North Creek catchment spans across the Ballina and the Byron LGA boundary (Figure 33.), the Byron Shire will also need to be engaged throughout the CMP development process.

Considerable overlap exists between the coastal management areas and planned urban growth and proximity areas (see Figure 33.). If multiple coastal management areas apply to a single parcel of land, the CM Act imposes a hierarchy as to which coastal management objectives apply. The hierarchal order for coastal management areas is presented below (highest priority first):

- Coastal Wetlands and Littoral Rainforest Area
- Coastal Vulnerability Area
- Coastal Environment Area
- Coastal Use Area.

The Coastal Management SEPP, which provides development controls for each coastal management area, will not apply to certain applications for development consent until 3 April 2019 (Hawley, 2018). Further explanation of the intended effects of the Coastal Management SEPP is provided in explanatory notes available on the NSW State Government website. The extents of the coastal management areas provided in the Coastal Management SEPP are based on regional mapping which can change as new information becomes available. The mapped areas act as a starting point for councils in the development of their CMPs.

Changes in the extent to any of the coastal areas by a planning proposal will be subject to government and community consultation under the EP&A Act 1979. The CMP may cover areas outside of the mapped coastal zone if the management of external areas significantly impacts issues within the coastal zone. This is of relevance to North Creek, especially in terms of land use within Newrybar Swamp and its impact on estuarine health. The extent of each coastal management area within the North Creek catchment is discussed in the following section.

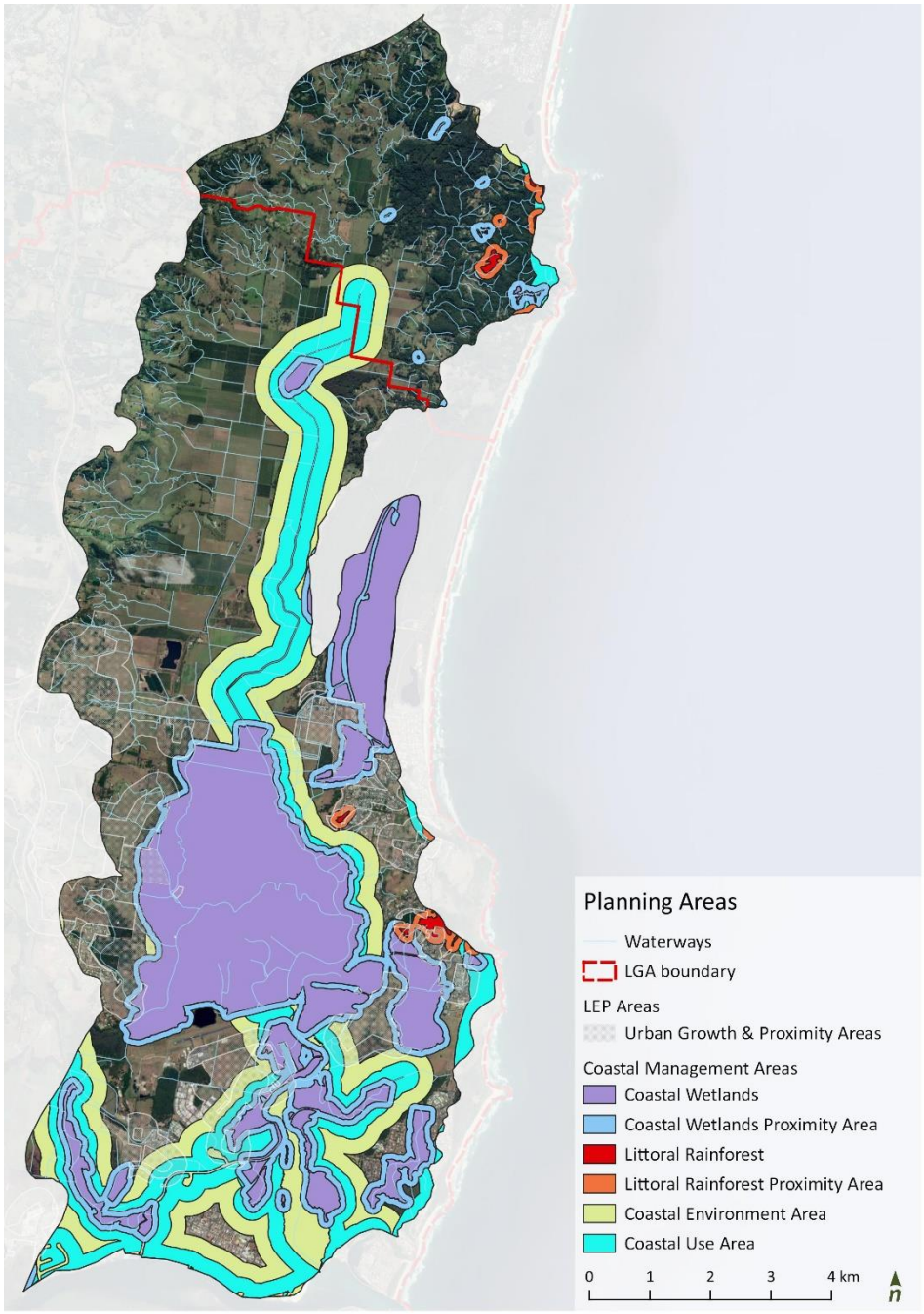


Figure 33. *An overview of the coastal management areas in relation to designated growth areas under the Ballina LEP.*

Coastal Wetlands and Coastal Littoral Rainforests

The extents of both Coastal Wetlands and Littoral Rainforests within the North Creek catchment are shown in Figure 34.. These extents are based on recently improved state-level vegetation mapping.

Within the North Creek catchment approximately 20 km² is classified as Coastal Wetland. This includes large areas of the North Creek estuary, the Ballina Nature Reserve and Birrung Creek area to the east of Byron Bay Road. Three small areas of Littoral Rainforest areas comprising a total of 0.8 km² are located in the east of the catchment near Birrung Creek, north of Skennars Head Road and along the upper reaches of Midgen Creek near Broken Head reserve.

The NSW coastal management objectives for Coastal Wetlands and Littoral Rainforests areas are provided in Table 12.

Table 12. Management objectives for Coastal Wetlands and Littoral Rainforests as described in Section 6(2) of the CM Act

Objective	Description
a	To protect coastal wetlands and littoral rainforests in their natural state, including biological diversity and ecosystem integrity
b	To promote the rehabilitation and restoration of degraded wetlands and littoral rainforests
c	To improve the resilience of coastal wetlands and littoral rainforests to the impacts of climate change, including opportunities for migration
d	To support the social and cultural values of coastal wetlands and littoral rainforests
e	To promote the objectives of State policies and programs for wetlands or littoral rainforests

Current management arrangements for critically endangered Littoral Rainforest areas are provided for by the Saving our Species program which supports the Biodiversity Conservation Act 2016. Littoral Rainforest areas within the catchment span two priority management regions: Newrybar to Cape Byron (Byron LGA) and West of Boulder Beach in Ballina (Ballina LGA). The management objectives for Littoral Rainforests within the Byron and Ballina LGAs is provided in Table 13.

Table 13. Management objectives from the Saving our Species program for Littoral Rainforests across both the Byron and Ballina LGAs

No.	Objective
a	Exclude fire from part/all of the site
b	Minimise impacts of recreational activities
c	Reduce and maintain weed densities at low levels
d	Reduce impacts of tidal/wave activity or storm surges on species habitat
e	Track species abundance/condition over time

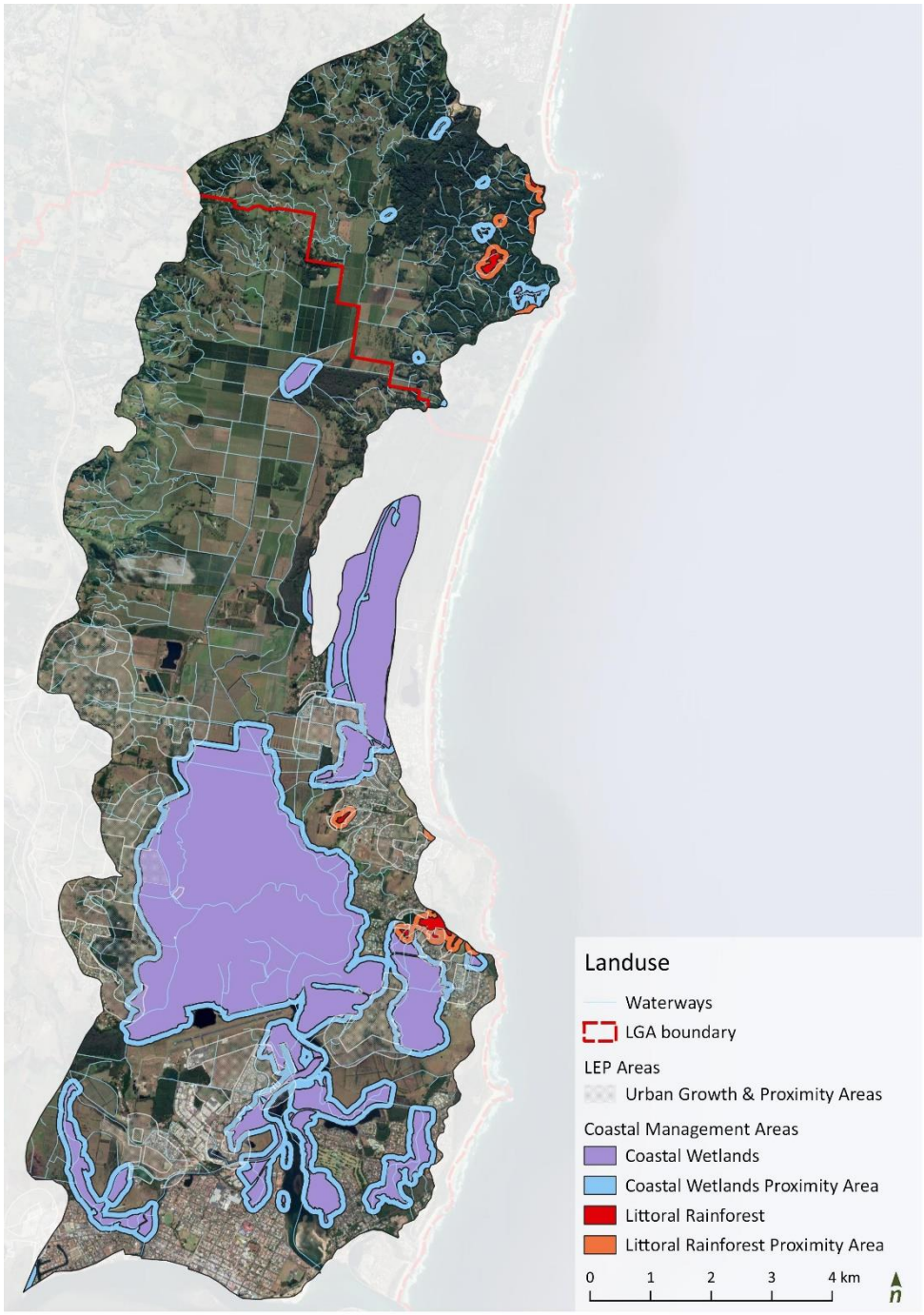


Figure 34. *The extents of Coastal Wetlands and Littoral Rainforests.*

Coastal Use areas

The extent of both Coastal Use and Coastal Environment areas within the North Creek catchment are shown in Figure 35. Coastal Use areas include areas adjacent to coastal waters, estuaries, coastal lakes and lagoons where the impacts of development on the benefits of these areas need to be considered.

The extent of Coastal Use areas is based on set distances from coastal water bodies and are dependent on factors such as topography, local scenic amenity and the local development approach (OEH 2018b). Coastal use areas within the catchment currently extend approximately 250 m inland from water bodies. Approximately 22 km^2 of the North Creek catchment is classified as a Coastal Use area. Management objectives for Coastal Use areas are provided in Table 14.

Table 14. Management objectives for Coastal Use Areas (as described in Section 9(2) of the CM Act 2016)

Objective		Description
a		To protect and enhance the scenic, social and cultural values of the coast by ensuring that
	i	The type, bulk, scale and size of development is appropriate for the location and natural scenic quality of the coast
	ii	Adverse impacts of development on cultural and built environment heritage are avoided or mitigated
	iii	Urban design, including water sensitive urban design, is supported and incorporated into development activities
	iv	Adequate public open space is provided, including for recreational activities and associated infrastructure, and
	v	The use of the surf zone is considered
b		To accommodate both urbanised and natural stretches of coastline.

Development controls for land mapped as Coastal Use areas are contained within Division 4 of the Coastal SEPP. Considerations for development within this area support the management objectives, and specifically address the preservation and management of safe public access, physical and visual amenity, Aboriginal cultural heritage, practices, and places, and cultural and built environment heritage. Adverse impacts on these values must be managed accordingly.

Coastal Environment areas

A similar perimeter-based approach is applied to the delineation of Coastal Environment areas. These areas include land and waterbodies which have been identified as ecologically sensitive to impacts from coastal development activity. Perimeter controls vary from 100 m for estuaries/submerged lands and 500 m for coastal lakes and lagoons. As it stands, Coastal Environment areas cover approximately 40 km^2 of the North Creek catchment.

Development controls provide for the consent authority to consider the extent to which the development will meet management objectives and impact upon natural hazards and local cultural, ecological and amenity values. Currently mapped Coastal Use and Coastal Environment areas do not extend along the Union Drain to the same extent as they do along the Flood Mitigation Drain. The CMP may need to consider the modification of the extent of these areas.

Management objectives for Coastal Environment areas are noted in Table 15.

Table 15. Management objectives for Coastal Environment areas (as described in Section 8(2) of the CM Act 2016)

Objective	Description
a	To protect and enhance the coastal environmental values and natural processes of coastal waters, estuaries, coastal lakes and coastal lagoons, and enhance natural character, scenic value, biological diversity and ecosystem integrity
b	To reduce threats to and improve the resilience of coastal waters, estuaries, coastal lakes and coastal lagoons, including in response to climate change
c	To maintain and improve water quality and estuary health
d	To support the social and cultural values of coastal waters, estuaries, coastal lakes and coastal lagoons
e	To maintain the presence of beaches, dunes and the natural features of foreshores, taking into account the beach system operating at the relevant place
f	To maintain and, where practicable, improve public access, amenity and use of beaches, foreshores, headlands and rock platforms.

Development controls for land mapped as Coastal Environment areas are contained within Division 3 of the Coastal SEPP. Considerations for development within this area support the management objectives, and specifically address the preservation and management of the integrity and resilience of the biophysical, hydrological, and ecological environment; coastal environmental values and natural coastal processes; water

quality of the marine estate; marine vegetation, native vegetation and fauna, undeveloped headlands and rock platforms; existing public open space and access; Aboriginal cultural heritage, practices and places; and the use of the surf zone. Adverse impacts on these values must be managed accordingly.

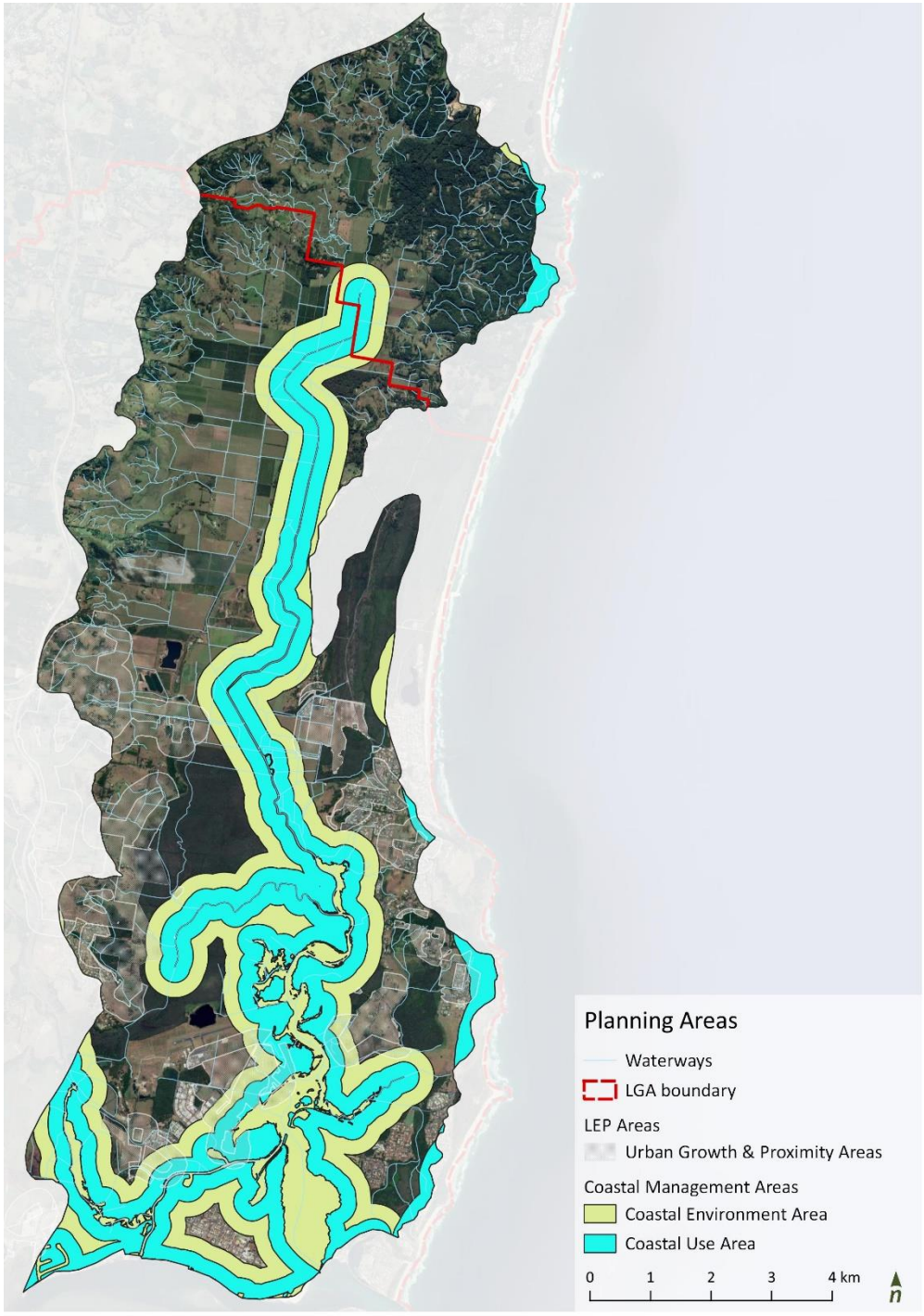


Figure 35. *The current extents of Coastal Use and Coastal Environment areas.*

Coastal Vulnerability areas

No mapped Coastal Vulnerability areas are currently available through the Coastal Management SEPP mapping. Mapped coastal hazards as defined in the LEP and DCP by previous coastal hazard studies may be used to guide the mapping of coastal vulnerability areas for all coastal hazards. Considerations for mapping include the sensitivity, adaptive capacity and tolerance of the community to coastal hazards. Hazards which are likely to impact areas of North Creek include storm surge and tidal inundation. The issues raised by these

hazards and specifically where they are likely to occur will require further clarification in order to determine the extent of Coastal Vulnerability areas within the North Creek catchment.

The 2015 Ballina Floodplain Risk Management Plan accounts for the vulnerability associated with flooding and tidal inundation which is predicted to increase with climate change. The flood extents produced as part of the supporting study are based on state sea level rise benchmarks which are no longer prescribed. This does not mean that the management plan's flood extents are no longer applicable but rather that state government now recommends that local government authorities adopt regionally relevant sea level rise planning levels in planning documents henceforth. This approach provides flexibility for BSC to reconsider local conditions when determining future hazards.

Impacts of projected land use changes

With the growing urbanisation of the catchment, land has been designated to accommodate population growth. An assessment has been conducted to determine the area of land currently designated to coastal environment area and coastal use area that may be impacted by these changes (see Figure 36 for current spatial extents). Based on the land presently designated to urban release area, approximately 15 hectares of this overlaps with coastal land of most of which falls under the classification of coastal use area. An additional 262 hectares of strategic urban growth area intersects with coastal land.

Modification of the spatial extents

Coastal Use and Environment areas as well as Coastal Wetland areas are likely to be the main management areas applicable to the issues that will be the focus of the new CMP. The management of many of the issues facing North Creek will require a catchment wide response. Given the extent of the issues and the potential solutions, it is possible that the boundary of Coastal Use and Coastal Environment areas will need to be revised. Revising these areas so they encompass the broader contributing catchment will help to manage the issues at hand and balance the social, economic and ecological needs of the catchment.

Any proposed amendments to the mapping of these coastal management areas must be identified in the final CMP, including the supporting evidence. The CMP must also identify the information about these amendments which can be used to support the preparation of planning proposals which inform the gateway determination process under section 3.34 of the EP&A Act (CMM 2018).

3.16 Existing management plans review

Key points

- There are five key existing management plans for the North Creek catchment; the Richmond River Estuary CZMP, Ballina Nature Reserve Management Plan, Ballina Floodplain Risk Management Plan, Ballina Local Environmental Plan, and Ballina Development Control Plan
- The majority of recommendations and actions from existing plans are in early stages of implementation
- Limited funding opportunities and administrative challenges have been a barrier to coastal management, as well as challenges with effecting desirable change on privately owned land

The key existing management plans relevant to the North Creek catchment include:

- The Richmond River Estuary CZMP (2012)
- Ballina Nature Reserve Management Plan (BNRMP) (2003)
- Ballina Floodplain Risk Management Plan (BFRMP) (2013)
- Ballina Local Environmental Plan
- Ballina Development Control Plan (2012)

This section provides a review of the intent and objectives of these plans, as well as implementation and outcomes to date (where sufficient information is available to provide comment), and any barriers and learnings noted. Only very limited information / monitoring has been available to inform an audit of these plans, as the majority of actions are in early stages of implementation.

Table 16 provides a summary of the existing management plans and their objectives.

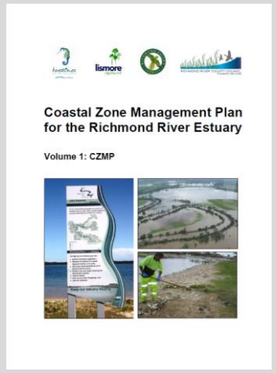
Existing plans

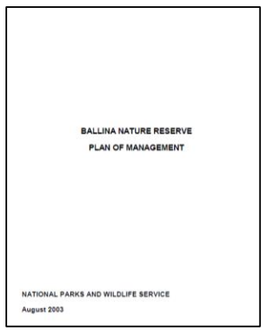
The Richmond River CZMP, BNRMP and BFRMP are generally in accord with the issues / challenges, objectives and management actions. Implementation of the range of recommendations and management actions across the plans is in early days, with limited information / monitoring data available on progress to date. Each of the existing plans has a broader - or more targeted - scope than the North Creek catchment itself. However, these plans align well to provide a platform for the next step of a focused CMP on the North Creek catchment.

The complex governance arrangements, limited funding opportunities and the inability to effect desirable change on privately owned land have been significant barrier to coastal management within the North Creek catchment (and surrounds).The North Creek CMP provides an opportunity to simplify governance arrangements and clearly specify the roles and responsibilities of Council and other agencies, and undertake the integrated technical studies required to address the complex surface, groundwater and tidal dynamics across the catchment. The outcomes of these studies, which will shape the final CMP, as well as the extent of its respective coastal management areas, have the potential to improve integrated land management outcomes across the mosaic of public and private land tenure across the catchment. With adequate funding the North Creek CMP can overcome many of the barriers which have inhibited coastal management arrangements to date.

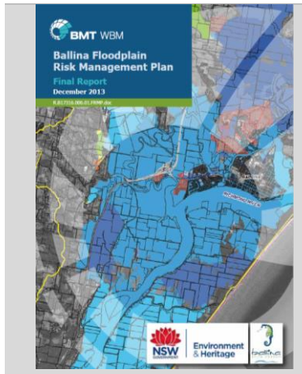
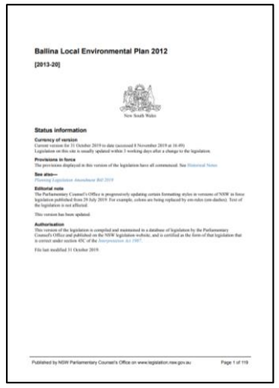
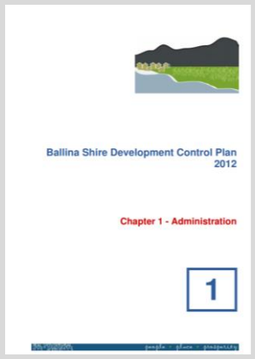
Table 16. Summary of the existing management plans for the Ballina Shire and North Creek catchment

Plan name and date	Summary of the plan	Plan objectives	Key recommendations	Plan progress and other observations

Richmond River Estuary CZMP (2012)
 	
 
 	
	The Coastal Zone Management Plan for the Richmond River Estuary (CZMP) is the current 10-year strategic plan (beginning in 2012) based on the Richmond River Estuary Processes Study (2006) which details the actions needed to achieve the management objectives of the Richmond River estuary, including North Creek (Zone 1).
	
	• 10-year strategic plan based on the Richmond River Estuary Processes Study (2006)
	• Details the actions needed to achieve management objectives for the Richmond River estuary
	• Overall success is defined as continuous improvement towards objectives and application of measures which address the root causes of problems facing the estuary
		1. To encourage economically viable and environmentally sustainable land use practices in the catchment
		2. To ensure strategic planning instruments and programs are consistent with and where applicable, directly address the aims of the CZMP
		3. To ensure efficient and effective management of the estuary through appropriate governance, funding and monitoring
		4. To increase knowledge of the impact of existing practices on estuary values and facilitate continuous improvement
		5. To reduce pollutant loads to the estuary
		6. To protect and enhance the riparian zone
		7. To minimise the frequency and severity of environmental events such as fish kills
		8. To optimise flood mitigation works and flow control structures to improve estuarine water quality
		9. To minimise constraints to estuary adaptation to climate change
		10. To protect and enhance the biodiversity values of the estuary
		11. To provide the increased use of the estuary whilst minimising environmental impact and conflict between users
		12. To protect the cultural heritage values of the estuary
		13. To protect and enhance visual amenity/aesthetic appeal of the estuary
		14. To enhance sustainable commercial return from industries relying on the estuary and the floodplain
		15. To minimise risk to the health and safety of users of the estuary
			Floodplain infrastructure management and farm management were identified in the CZMP as the greatest management challenges. Riparian zone management, bank erosion, floodplain vegetation management, community education, waterway usage, wastewater management and urban runoff are also of concern. Cultural heritage and fishery management were identified as key values of the estuary.
			
			A total of 13 management strategies were developed in response to these issues. The prioritisation of management strategies listed in Table 13 was supported by an options assessment and cost/benefit prioritisation process detailed in volume 2 of the CZMP. Each strategy lists its objectives and is broken down into actions with key details on tasks, desired outcome, lead organisation, supporting resources, priority, cost, timing and KPIs.
			
			Fundamental management strategies include administrative and governance; climate change adaptation; and monitoring, evaluation and review.
			
			High priority management strategies include floodplain infrastructure management and farm management.
			
			Medium and low priority management strategies include the management of the riparian zone, vegetation, education, waterway usage, wastewater, urban runoff, cultural heritage and fisheries.
				• A mid-term review of the plan the following:
				  ○ 5 strategies or actions were 'on target'
				  ○ 13 strategies or actions were 'partially complete'
				  ○ The remaining 9 strategies or actions were still in the early stages of implementation
				
				• Governance and administrative arrangements were the main barriers to implementation
				• Recognises that not all actions may be carried out over its 10-year time frame
				• Broad scope does not provide a direct focus on the issues facing North Creek.
				
				The ABER review of the plan's supporting study (the Estuary Processes study) found that key elements of the system's understanding were missing, particularly an understanding of the biogeochemical interplay with trophic systems which underpin ecological health and water quality. ABER noted that Southern Cross University is a world leader in MBO research and holds knowledge and data of MBO distribution and processes within the Richmond, and by association, the North Creek catchment. Collaboration with the university in the development of the CMP would leverage this knowledge base in the filling of the knowledge gaps identified as part of this scoping study.

Ballina Nature Reserve Management Plan (2003)  	• Provides the scheme operations in accordance with the *National Parks and Wildlife Act 1974* • The desired outcome is an effective hydrological regime, minimal soil disturbance and improved water quality • Fire, introduced species and drainage are listed as the three key threats to reserve values, drainage being the most significant.	1. Preserve the Reserve as part of a regional network of wetland Parks and Reserves 2. Conserve the diversity of habitat types within the Reserve, with particular emphasis on the protection of the wetland habitat 3. Seek to maintain a hydrological regime in the Reserve that maintains Reserve ecosystems 4. Enhance the viability of habitat by encouraging vegetation corridors off the Reserve where possible 5. Conserve the Reserve's diverse native flora and fauna, including vulnerable and endangered species and regionally significant species 6. Protect the native flora and fauna habitats in the Reserve from processes, uses and pest species threatening its integrity 7. Reduce the distribution and/or spread of introduced species in the Reserve 8. Encourage Reserve neighbours in conserving adjoining natural areas	High priority actions include: • A hydrological assessment of the reserve to examine the feasibility of restoring hydrological regimes to a greater part of the Reserve • An examination of the environmental effects of the drains in the reserve • A whole of catchment study if any changes to the current hydrological regime are proposed that may adversely impact the Reserve • For some drains, maintenance works will only be licensed if they constitute an existing interest pursuant to Section 39 of the *NPW Act* and will not be detrimental to the Reserve ecosystems • NPWS will seek the cooperation of relevant government agencies and Ballina Shire Council to monitor quality of water runoff from surrounding residential, industrial, extractive and agricultural land uses	The plan also provides guidance on actions which address issues relating to native flora and fauna, introduced species, fire management, cultural heritage, recreation and education. A flora and fauna study of the Reserve was given high priority to understand the current species diversity. Such a study would assist in determining if vulnerable, endangered and regionally significant species exist and are not further threatened. It is understood these prioritised actions have not been fulfilled, this is partly due to the NSW NPWS being unable to commission a stand-alone study of the hydrology of the Ballina Nature Reserve (to date); and the governance arrangements associated with the maintenance of any legally recognised drains in the Ballina Nature Reserve requires environmental assessment and subsequent mitigation requirements.

Ballina Floodplain Risk Management Plan (2013)	The primary objective of the Ballina Floodplain Risk Management Plan (BFRMP) is to facilitate the mitigation of flood risk within the Ballina LGA) (WBM 2012).
	
	The plan incorporates flood modelling results from a study area which extends as far north as Ross lane within the North Creek catchment. These levels were noted as particularly sensitive to ocean storm surge. The plan also incorporates 2010 sea level rise planning horizons as published by the Department of Planning under the now superseded 2009 Sea level Rise Policy Statement.
			Flood mitigation measures recommended include:
			• Property modification
			  ○ Update development controls
			  ○ Develop voluntary house raising scheme
			  ○ Develop agricultural levee guidance
			• Response modification:
			  ○ Finalise selection of evacuation centres
			  ○ Develop community engagement strategy
			  ○ Update evacuation planning
			  ○ Develop flood intelligence cards
			  ○ Extend gauge network
				• Development controls have been updated as a result of the BFRMP study
				• It is understood that the remaining recommended actions are still in the early stages in implementation
				
				• Flood levels were noted as being particularly sensitive to ocean storm surge
				• The plan incorporates 2010 sea level rise planning horizons

Plan name and date	Summary of the plan	Plan objectives	Key recommendations	Plan progress and other observations
			○ Assess alternative evacuation order methods ○ Investigate flood warning and prediction system options ○ Raise low points on evacuation routes • Flood modification: ○ Implement Gallans Road cycleway floodway ○ Implement structural measures assessed separately from the BFRMS ○ Consider removal or lowering of Deadman's Creek Road	The plan is due for review in 2019 under its implementation schedule. The review will need to take into consideration the legislative reform that has occurred since, especially regarding climate change and associated sea level rise. The updated regional climate modelling projections for NSW (NARCliM) will also need to be considered.
Ballina Local Environmental Plan (2012) 	The Ballina Local Environmental Plan (updated 2012) provides the zoning and development controls which guide the way land can be used. The general aims of the plan are to foster appropriate management, development and conservation of natural and man-made resources, to promote the social and economic welfare of the community and to provide an improved environment.	Separate objectives exist for each of the 17 Land Use Zones specified in the LEP. In an overall sense, however, the aims of the LEP are to: 1. Provide for a sustainable Ballina that recognises and supports community, environmental and economic values through the establishment and maintenance of the following: - a built environment that contributes to health and wellbeing, - a diverse and prosperous economy, - a healthy natural environment, - diverse and balanced land uses, - healthy, resilient and adaptable communities, - responsible and efficient use of resources, 2. Provide for development that is consistent with Council's established strategic planning framework for Ballina 3. Achieve the objectives of the land use zones set out in the LEP 4. Promote the orderly and efficient use of land having regard to the social and environmental characteristics of the land, 5. Provide for the development of public services and infrastructure.	Specific land zone objectives as defined in the plan.	
Ballina Development Control Plan (2012) 	The Ballina Development Control Plan (DCP) is a council policy document that contains the detailed controls applicable to development in the Ballina Shire. Each chapter of the plan provides detailed controls applicable to different aspects of the Council's development control framework.	1. Ensure that applicable considerations are taken into account in the siting and design of development 2. Ensure that development is undertaken in a manner that is compatible with the physical and environmental characteristics of land 3. Ensure that development is undertaken with regard for applicable public health standards 4. Minimise potential for land use conflict 5. Protect the amenity of urban area though the preservation of significant tress and vegetation 6. Provide assessment criteria that will be applied when Council approval is required to remove or otherwise impact on vegetation 7. Conserve trees of ecological, heritage, aesthetic and cultural significance to Ballina Shire 8. Provide holistic approach to managing development on the floodplain 9. Minimise the impact of flooding on individual owners and occupiers of land and public assets 10. Encourage the development and use of land in a manner compatible with the likely flood hazard 11. Maintain the function of flood mitigation measures 12. Minimise the extent to which emergency vehicles and public infrastructure need to be relied upon in terms of evacuation or other flood responses 13. Consider the future projected impacts of sea level rise on the floodplain	Detailed controls as applicable.	Chapter 2 of the plan is most relevant to the North Creek CMP as it covers general and environmental considerations, vegetation management and floodplain management

Coastal emergency response arrangements

The Ballina Shire Council has prepared two documents that are relevant to the response arrangements in relation to coastal emergencies that may arise; the Ballina Shire Local Disaster Plan (DISPLAN) and the Ballina Shire Local Emergency Management Plan August 2016 (BSC 2012; BSLEMC 2016). A Local Emergency Risk Management Study was undertaken by the committee to identify the hazards that have the potential to pose a risk to the Ballina Shire (BSLEMC 2016).

The plans have identified the coastal hazards that may be relevant to the Ballina Shire: cyclone / East Coast low, coastal erosion, flood / storm surge, severe storm, tidal inundation and tsunami (BSC 2012; BSLEMC 2016). The key agency that is responsible for emergency services is the NSW State Emergency Service (SES). Table 17 summarises the responsible agency and the mitigation or prevention strategies that are in place to manage coastal hazards.

Table 17. Summary of the coastal hazards identified in the Local Emergency Risk Management study (adapted from BSC 2012 & BSLEMC 2016)

Coastal hazard	Responsible agency	Mitigation / prevention strategies (BSC 2012)
East Coast low / cyclone	NSW SES, BSC (Local Flood Plan)	• Preparation, ongoing monitoring • Community education • Audible warning system • Road closures and evacuation plan/s • Annual multi-agency exercise • Review existing plans to endure currency
Tidal inundation / storm surge	NSW SES, BSC (Local Flood Plan)	
Storm	NSW SES, BSC (Local Flood Plan)	
Tsunami	NSW SES, NSW State Tsunami Sub-Plan	• Develop tsunami warning plan • Develop education workshop for community and emergency services personnel • Develop a recovery and rehabilitation plan
Coastal erosion	NSW SES	• Ballina Coastline Interim Measures and Actions plan (pending completion of Coastline Management Study and Coastline Management Plan)

The plans also identify that evacuation routes out of the affected areas may become restricted. As a result, specific areas of the catchment where residents may be able to seek shelter are identified. For example, in the event of inundation due to storm surge, flooding or a cyclone, higher ground in East Ballina and the main town area could be used as refuge (BSC 2012).

Updates on coastal hazard areas and risk determined during the CMP process will provide inputs for future updates of coastal emergency response planning.

3.17 **Synthesis**

Key points

In the past century the North Creek catchment has undergone rapid changes. The vast swampy floodplain and wetlands into which the small coastal catchment creeks flowed have been extensively drained to allow for agricultural and urban development. Now, over half the catchment area is used for agriculture including grazing and sugarcane cultivation and just over 10 % of the catchment urbanised for residential development. With Cumbalum Urban Release Areas A and B due to come online in the short to medium term, development pressures on the catchment are likely to increase.

These changes have already and will continue to fundamentally change the nature of the catchments' hydrology and environment, impacting sensitive terrestrial and estuarine ecosystems, as well as the fisheries and aquaculture industries in the lower estuary. Drainage works have often intercepted acid sulfate soils and increased the connectivity for surface runoff entering the estuary (Enviro Solutions 2017, ABER 2008). These changes have had adverse impacts for waterway and ecosystem health, as well as the oyster industry in the lower catchment (Hydrosphere 2011, Ryder et al., 2015). While the channelization and flood levee works have been beneficial for agricultural development, drainage issues remain a concern for parts of the community, and are a broader challenge for catchment management. Table 18 summarises the key points noted from the information that has been presented across Section 3 of this scoping study.

Table 18. Summary of the background information presented in Section 3 of this report to inform the CMP process

Section	Key points
Geology and soil landscapes	• Much of the catchment is of very low elevation representing formerly freshwater and estuarine wetland locations in a back-barrier environment. • Over 50 % of the North Creek catchment has been identified as at risk from acid sulfate soils (potential or known)
Climate	• The climate of the North Creek catchment is regulated by its proximity to the sea • A relatively short record of temperature and rainfall is available for the Ballina Shire • The catchment has experienced a number of significant flooding events in recent history • Sea level rise is likely to have an increasing impact across the catchment
Historic changes to the catchment	• The Bundjalung people are the traditional owners of the land • Extensive drainage works have modified catchment hydrology, surface water, groundwater and tidal interactions
Landuse	• Present day landuse includes rural residential, horticulture and grazing, and increasing macadamia plantations and conservation areas • Urban growth is increasing incrementally, with around 2 – 5% of the catchment classified as urban release/growth areas
Groundwater	• Groundwater levels are strongly influenced by tidal cycles across the mid and lower catchment • The complex interaction between groundwater levels, tidal influence, recharge and water quality is a key management challenge for the North Creek catchment
Ecology	• Threatened ecological communities within the North Creek catchment include Coastal swamp oak forest, Littoral rainforest and coastal vine thickets, and Lowland rainforest • There are a number of species and ecological communities that are vulnerable to a changing catchment and coastal processes, land use and climate change impacts
Water quality	• The modified nature of the North Creek catchment and floodplains, including past vegetation clearing, planting of exotic species, and the low gradient drainage network, creates a challenging environment for managing water quality • Poor water quality through the drainage network has contributed to fish kill events and a decline in the oyster production • Agricultural runoff is the primary source of diffuse pollutant loads • There is (modelled) potential for significant pollutant generation from both urban and rural areas during runoff events • There is a need for, and opportunity to, enhance water quality monitoring across the catchment to better inform future management activities and priorities.

Section	Key points
Dredging and sand mining	• Sand shoals in the lower estuary have been extensively dredged to allow ship navigation • The feasibility of dredging in lower North Creek is being considered to provide a sand resource, to improve navigability, and to increase tidal flushing and improve water quality in North Creek • Sand mining may exacerbate acid water discharge into North Creek
Drainage	• Extensive drainage works have been undertaken over time to mitigate flooding and enable agricultural and urban development • Changes to the drainage patterns have substantially altered the hydrology, surface and groundwater interactions, which underpins the majority of ongoing management challenges for the catchment
Waterways	• The laterally unconfined streams of the foothills and coastal floodplain have been extensively modified since European settlement • Discontinuous swampy meadows have been converted to a network of linear drains and levees across the mid-catchment zone • Tidal ingress up the waterways influences over 70% of waterway length • The overall geomorphic condition of North Creek is relatively stable, linked to the relatively low gradient across the catchment • Riparian condition is good where native vegetation remains across the Ballina Reserve area, and moderate to poor in upper and lower parts of the catchment where native vegetation and mangroves have been lost.
Social context	• The Bundjalung people are the traditional custodians of the land • The North Creek catchment is home to an estimated 34,000 people, concentrated within the urban centers of Ballina, East Ballina, West Ballina and the townships of Lennox Head and Skennars Head • The population of Ballina Shire is predicted to grow by between 20 and 28 % by 2036, with the main growth centres at Ballina North, Lennox Head and Cumbalum
Economic context	• The economy of the Ballina Shire is underpinned by health care, construction and retail trade • The economy is relatively resilient (diversified) • Tourism and agriculture, forestry and fishing are also key industries • Oyster harvesting in the lower estuary is sensitive to environmental factors, including water quality, resulting in annual fluctuations in production and value
Stakeholder and community values	• A diversity of stakeholders have an interest in the CMP development • An Agency Reference Group has been established to collaborate during the CMP development • Key values identified by the community (via survey) included native vegetation, biodiversity, waterbirds, swimming and fishing

Section	Key points
	• Key threats to values identified by the community (via survey) included rubbish, urbanisation, agriculture, stormwater discharge, loss of riparian vegetation, poor drainage.
Land use / tenure	• North Creek catchment is host to a mosaic of public and private land tenure which is subject to a number of local, regional and state management arrangements
Coastal management areas	• There is some overlap of the coastal management areas with planned urban growth and proximity areas • Coastal wetlands and littoral rainforests are given the highest priority for management; there is approximately 20 km^2 of coastal wetlands and 0.8 km^2 of littoral rainforests in the North Creek catchment • It is possible that the boundaries of some coastal management areas will need to be revised as part of the CMP process
Existing management plans	• There are five key existing management plans for the North Creek catchment; the Richmond River Estuary CZMP, Ballina Nature Reserve Management Plan, Ballina Floodplain Risk Management Plan, Ballina Local Environmental Plan, and Ballina Development Control Plan • The majority of recommendations and actions from existing plans are in early stages of implementation • Limited funding opportunities and administrative challenges have been a barrier to coastal management, as well as challenges with effecting desirable change on privately owned land

Barriers

There are a range of barriers / challenges for developing and implementing management actions to address priority issues (e.g. drainage, water quality) for the North Creek catchment. These barriers have been identified in some of the previous relevant reports (e.g. the CZMP 2012) as well as being raised in stakeholder discussions for this scoping study, and include:

- Limitations in funding opportunities - funding/resources limited by Council's budget
- Limitations in system understanding – e.g. complex surface water, groundwater and tidal dynamics
- Challenges with administrative / governance arrangements
- Challenges with effecting desirable change on privately owned lands, which is, in practice, one of the most significant elements of the governance discussion
- Timeframes to implement actions are often long and require sustained effort to engage stakeholders on desired outcomes
- The time lag between land use planning and execution of development. Significant barriers to achieving best practice outcomes are common (accounting for changing topography, existing/emerging issues, sea level rise).
- The complexity of implications of sea level rise on ecology, existing development, agriculture at a localised scale.

Opportunities

The recent coastal reforms provide an opportunity to overcome barriers through the funding of integrated Coastal Management Programs. The key opportunities for the North Creek catchment CMP include:

- The CMP process enables a holistic consideration of the issues facing the catchment and improved system understanding.
- The concurrent community engagement process will enable ongoing interaction with stakeholders on issues, thus bringing science and existing information to the collective discussion.
- Engagement with agencies across issues on a catchment basis.
- The CMP process will provide a platform and business case for future funding investment as part of the new Coastal Management Framework.
- Ability to incorporate and deliver existing goals and actions in other strategic documents that are aligned with the CMP.
- Funding available through NSW Coasts and Estuaries fund (50:50) and other sources, can assist with rolling out priority studies and actions as part of the CMP process.

There is currently strong community support and interest in the CMP development. The community survey undertaken as part of this scoping study identified that the North Creek catchment provides significant social, economic and environmental values to the community. This includes scenic and amenity values and recreational opportunities. The promotion of the protection and enhancement of these values has the potential to help enhance community support for the management of North Creek. Community support can act as an enabler for catchment management initiatives through providing political pressure and motivation for collaborative partnerships.

Key issues / challenges
Key management issues for the North Creek catchment have been identified through the synthesis of previous work and research (Section 3), and the stakeholder and community engagement process (Section 3.14).

The key management issues for the North Creek CMP identified from the overall strategic context to the CMP in Section 3 include:

- Catchment runoff
  This includes - agricultural diffuse runoff, diffuse urban stormwater and acid sulfate soils runoff. For the purposes of the scoping study, these stressors are combined and referred to collectively as catchment runoff.

- Altered hydrology
  This includes – changing patterns of surface and groundwater interactions, and altered drainage patters across the catchment.

- Climate change
  This focuses on the implications of climate change on sea level rise and increasing tidal inundation across the catchment.

- Sand mining and dredging
  This includes sand mining activities in the catchment, and dredging in the lower estuary reaches.

- Governance / administration
  This refers to the challenges / perceived challenges associated with governance and administrative arrangements for coastal management in the region.

This review and key issues inform the first-pass risk assessment (in Section 5) which is used to prioritise management issues and priority studies/assessments for the later stages of the CMP process.

4 CMP vision and objectives

Developing a future vision and objectives for the North Creek catchment is a strategic focus of the North Creek catchment Community and Stakeholder Engagement Plan (C&SEP) (see Attachment A). This will be an ongoing participatory process that will be shaped over the course of the CMP development and informed by stakeholder interests as well as outcomes from the technical investigations.

A preliminary vision and objectives have been identified following the initial consultation with stakeholders during the scoping study process. This vision will be built on and further refined during Stage 2 and 3. The preliminary vision for the North Creek catchment that is intended to guide the implementation of the Coastal Management Program (i.e. what the CMP is trying to achieve) is:

"A healthy estuary, resilient ecosystems, and a sustainable, productive catchment."

The vision for the CMP process to achieve this is:

"Through evidence based, and dialogue-based collaboration with the catchment's key agency stakeholders and wider community, the CMP process will develop a shared understanding of the coastal and catchment processes of the North Creek catchment and the social, economic and environmental constraints upon those accountable for the implementation of its CMP."

A list of the key stakeholders involved in the process is outlined in Attachment A.

Preliminary objectives linked to the vision statement are provided in Table 19. These are preliminary and will be further developed as the CMP process progresses, with the intent of developing measurable objectives once the outcome of technical investigations is known and the detail of the CMP objectives can be further refined. During Stage 2 and 3 there will be a significantly improved understanding of the environmental, social and economic conditions, values and constraints within the catchment. Consequently, clear and measurable objectives will be able to be identified.

Table 19. Preliminary objectives for the North Creek catchment

Value	Objective
Estuary health	Enhance the condition of the estuary by improving water quality entering from the catchment and protecting and enhancing fringing ecosystems
Wetland	Maximise the ecological health and resilience of coastal wetlands within the catchment
Sustainable industries	Promote economically viable industries which limit the impacts on ecosystems and are resilient to changes associated with climate change
Liveable communities	Create communities which integrate with, and limit the impacts on, the natural environment

North Creek estuarine reach – visioning for a healthy estuary

5 Scope of the CMP

This section includes assessments completed for this scoping study to assist in defining the forward scope of the CMP. This includes:

- A first-pass risk assessment for the key issues (identified in Section 3)
- Prioritisation of issues, studies and recommendations for the CMP forward work program over subsequent Stages of the CMP development.

5.1 First-pass risk assessment

Approach

The first pass risk assessment for the Ballina Shire utilises a similar approach as the threat and risk assessment framework for the NSW Marine Estate (MEMA 2015). The risk assessment has been conducted for three planning horizons, present-day, 2050 and 2100, to consider the emerging risks. The trajectory for future planning horizons assumes no management action is taken beyond current practices (includes only business as usual activities).

For each issues, the likelihood and consequence of a negative impact on key values was assessed using the criteria in Table 20 and Table 21. The likelihood and consequence were then used to assign the level of risk according to the risk matrix in Table 22. The risk to key environmental, social and economic values in the North Creek catchment is provided in Table 23, Table 24 and **Table 25** respectively. The risk assessment is informed by the strategic context to the CMP set out in Section 3, as well as stakeholder engagement discussions during the scoping study development.

Outcomes were cross-checked with the threat and risk assessment (TARA) conducted by NSW Marine Estate using their online tool. Given the broad spatial extent considered by TARA, adjustments were made to reflect the background review specific to the North Creek catchment. Discretion was used to alter the prioritisation of issues based on their final ranking where an issue ranked above another, but management of the lower ranking issue was considered more complex.

Table 20. The likelihood scale adopted for the risk assessment (MEMA 2015)

LIKELIHOOD LEVEL	Description
Rare	This threat is extremely unlikely to be realised at a level that would impact on the benefit within a 20-year period.
Unlikely	This threat is not expected to be realised at a level that would impact on the benefit in a 10-year period, but could be expected in a 20-year period.
Possible	This threat is not expected to be realised at a level that would impact on the benefit every year, but could be expected in a 10-year period.
Likely	This threat is not expected to be continuous, but could be expected to be realised at a level that would impact on the benefit every year.
Almost certain	This threat is expected to be realised at a level that would impact on the benefit frequently throughout a year or more-or-less continuously.

Table 21. The consequence scale adopted for the risk assessment (MEMA 2015)

CONSEQUENCE LEVEL	Description
Insignificant	Realisation of this threat would not have a discernible impact on the benefit at a state-wide scale.
Minor	Realisation of this threat would have only a small or very temporary impact on the benefit at a state-wide scale.
Moderate	Realisation of this threat would significantly reduce the benefit over the medium term (5-10 years) at a state-wide scale, or have major consequences for a sensitive benefit at a regional level.
Major	Realisation of this threat would substantially reduce the benefit for an extended period (10-20 years), but not totally or permanently, at a state-wide scale, or would have catastrophic consequences for a sensitive benefit at a regional level.
Catastrophic	Realisation of this threat would effectively terminate delivery of the benefit either permanently or for a very extended period (>20 years) at a state-wide scale.

Table 22. The matrix used to determine the level of risk as a function of consequence and likelihood of a threat being realised (MEMA 2015).

LIKELIHOOD	LEVEL OF RISK				
ALMOST CERTAIN	MINIMAL	LOW	MODERATE	HIGH	HIGH
LIKELY	MINIMAL	LOW	MODERATE	HIGH	HIGH
POSSIBLE	MINIMAL	MINIMAL	LOW	MODERATE	HIGH
UNLIKELY	MINIMAL	MINIMAL	MINIMAL	LOW	MODERATE
RARE	MINIMAL	MINIMAL	MINIMAL	MINIMAL	LOW
CONSEQUENCE LEVEL	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC

Environmental values

Table 23 provides the first-pass risk assessment based on consideration of two key environmental values within the North Creek catchment, estuary water quality and biodiversity. Water quality and biodiversity are also interlinked, so the results should also be viewed in terms of the combined / overall risk.

Catchment runoff, altered hydrology and climate change are understood to be the main present and/or emerging risks to key environmental values for the North Creek catchment.

The high risk of catchment runoff and altered hydrology impacting on environmental values is linked to associated poor water quality and changing flow patterns, and increasing tidal inundation is expected to be key emerging risk in the future (as discussed in Section 3).

Table 23. Risk assessment for the environmental values of the North Creek catchment for the present-day, 2050 and 2100 planning horizons

Environmental values							
Issue / threat	**Estuary water quality**			**Biodiversity**			**Overall risk**
	Present	**2050**	**2100**	**Present**	**2050**	**2100**	
Catchment runoff	Mod	High	High	Mod	High	High	High
Altered hydrology	Mod	High	High	Mod	High	High	High
Climate change	Min	Low	High	Low	High	High	Mod
Sand mining and dredging	Low	Low	Mod	Min	Min	Low	Low - Mod
Governance / administration	Mod	Mod	Mod	Low	Low	Mod	Mod

Social values

A first-pass risk assessment for the key social values within the North Creek catchment, scenic amenity and recreation, is summarised in Table 24.

Catchment runoff, altered hydrology, sand mining and dredging, are understood to be the main present and emerging risks to social amenity and recreation values for the North Creek catchment.

The overall risk of catchment runoff to the social values of the North Creek catchment is high. This is linked to the impact of runoff on water quality, which would affect both the scenic amenity and recreation value of the waterways. The impact is greater on recreation as poor water quality could have ill health effects. The risk is also high for altered hydrology as the drainage works could affect flows to the waterways, impacting water quality (e.g. flushing effects) and levels (e.g. boating access). Recreation values are anticipated to be most impacted as the mid to lower reaches of North Creek are highly valued by residents.

The present risk of climate change to scenic amenity and recreation is minimal, however, it may escalate to a high risk by 2100. Climate change may affect scenic amenity by raising water levels and impacting existing vegetation communities. The recreation value may be diminished by climate change in a similar manner; sea level rise may impact access to waterways. Shoaling in the lower estuary currently provides habitat for shorebirds and fish species. The mining of these shoals for sand would result in a loss of habitat which was

viewed as contributing to the scenic amenity. It may also affect the fish population where fishing is highly valued. The overall risk of sand mining to the social values is moderate to high.

The present risk of governance to scenic amenity and recreation is low but this may increase to moderate by 2100 as the remaining threats to the catchment go unmanaged and the issues escalate.

Table 24. Risk assessment for the social values of the Ballina Shire for the present-day, 2050 and 2100 planning horizons

Social values							
Issue / threat	**Scenic amenity**			**Recreation**			**Overall risk**
	Present	**2050**	**2100**	**Present**	**2050**	**2100**	
Catchment runoff	Mod	High	High	High	High	High	High
Altered hydrology	Mod	High	High	High	High	High	High
Climate change	Min	Low	High	Min	Mod	High	Mod
Sand mining and dredging	Mod	Mod	Mod	High	High	High	Mod - High
Governance / administration	Min	Low	High	Low	Mod	High	Mod

Economic values

Table 25 outlines the first-pass risk assessment for the key economic values of tourism, agricultural production and aquaculture.

Catchment runoff, altered hydrology and climate change are understood to be the main present and emerging risks to the economic values of the North Creek catchment. Further economic assessment is also presented in Section 6.2.

It is anticipated that (with no intervention) catchment runoff risk of impact on agricultural production and oyster farming will increase in the future. Tourism is impacted by catchment runoff as it affects the scenic amenity and recreational capacity of the waterways.

Table 25. Risk assessment for the economic values of the Ballina Shire for the present-day, 2050 and 2100 planning horizons

Economic values										
Issue / threat	**Tourism**			**Agricultural production**			**Aquaculture**			**Overall risk**
	Present	**2050**	**2100**	**Present**	**2050**	**2100**	**Present**	**2050**	**2100**	
Catchment runoff	Mod	High	High	Min	Low	Mod	Mod	High	High	High
Altered hydrology	Low	Mod	High	Low	Mod	High	Low	Low	Mod	High
Climate change	Min	Min	High	Min	Mod	High	Min	Low	High	Mod - High
Sand mining and dredging	Low	Mod	Mod	Min	Min	Min	Min	Low	Mod	Mod
Governance / administration	Min	Min	Low	Min	Min	Low	Min	Min	Low	Low - Mod

Final ranking of issues

Based on an appreciation of the risk rankings across environmental, social and economic values, an overall priority ranking of management issues is shown in Figure 36. The purpose of this ranking is to provide an appreciation of which management issues have the greatest current and future potential impacts on the diversity of values in the North Creek catchment. This enables an appreciation of how management effort and actions should be prioritised for the CMP, including studies required in Stage 2 of the CMP development, and evaluation / prioritisation of management options in Stage 3 of the CMP development.

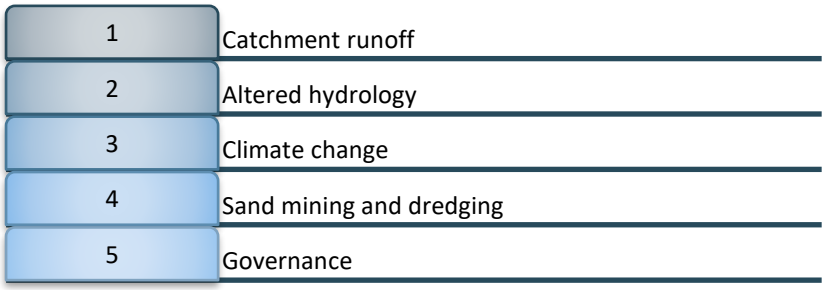


Figure 36. *Final ranking of key management issues for the North Creek catchment*

5.2 Priority issues and recommendations

The scoping study process across Section 3 to 5 of this document has provided an appreciation for:

- The technical studies and plans completed to date, and the state of current knowledge on coastal values and management challenges for the North Creek catchment (Section 3)
- The key management issues for the North Creek CMP, and priority issues as informed by a first-pass risk assessment (Section 3 and Section 5)
- Recommendations/strategies in existing plans (including the CZMP) to be carried forward into the CMP (for evaluation of options in Stage 3) (Section 3)
- Gaps/opportunities for additional improvement of the knowledge base for the CMP development (Section 3 and Section 5)

A summary of the key existing management sources relevant to the priority issues, and recommended gaps to fill as part of the Stage 2 CMP process (or beyond) is provided in Table 26.

Additional studies are also recommended that could be included in Stage 2 of the CMP development, or alternatively as part of the CMP actions (Table 26 and Table 27).

Recommended studies and indicative budgets are nominated for inclusion into the forward works program in Section 7.

Table 26. Summary of key issues, including gaps to fill for CMP Stage 2 (or Stage 3/action in the CMP)

ID	Management issue/Threat	Description	Level of risk	Assessment of Knowledge Gaps		Recommendation for further studies	Responsible Agency and costing	CMP stage	Priority for Stage 2 inclusion
				Knowledge Gap	Importance				
1	Altered hydrology	The hydrology and drainage pattern of the catchment continues to change. This is leading to a variety of hydrological issues across the catchment including poor water quality, changes to ecological communities and impacts on landholders. The issues is likely to be exacerbated by sea level rise.	High	Given the low relief of the catchment, high resolution digital elevation data are required in order to model catchment hydrology at the level of precision required.	*Very important* – modelling of the catchment cannot occur without this information. A number of recommended studies depend on this information.	a) Collection of high-resolution topographic data to 0.1 m vertical resolution of entire catchment b) Bathymetric survey of all key drains and estuary channel c) Development of hydrodynamic model of the catchment to assess flow dynamics and drainage pathways and impacts on existing land uses. Coupled catchment-coastal model including tidal and storm tide inundation.	BSC, Rous County Council $250 - $350,000	Stage 2	High
		The drainage works within the catchment impacts on landholders, catchment and estuary ecosystems. There is limited integration between catchment drainage and estuary health.	High	The condition of drains is not well understood. This includes the impacts on adjacent land uses and ecosystems.	*Important* – Understanding the existing drainage regime will be critical to determining the viability of certain land uses within the catchment	d) Mapping of drain condition and capacity based on the outcomes of studies 1 (a), 1 (b) and 1 (c) e) Assessment of the impacts of drains on adjacent land uses and ecosystems f) Economic analysis of the cost and benefits of existing drainage works g) Review of governance arrangements for drains management	BSC, Rous County Council $60,000	Stage 2 OR Stage 3 or action out of CMP	Moderate
2	Catchment Runoff	Agricultural and urban development, drainage works and disturbance of acid sulfate soils has degraded water quality within the North Creek estuary	High	The catchment drivers (and their spatial and temporal variations) of pollutant generation.	*Very important* – understanding the drivers of water quality is critical to enable management	a) Implement North Creek Water Quality Monitoring Program (WQMP) which will include ambient and event based monitoring for over 18 months across different areas of the catchment b) Development of Source Catchment model of surface and groundwater pathways using outputs from study 1 (c) and WQMP to assess pollutant pathways through the catchment	BSC, Rous County Council $150,000	Stage 2	High
3	Climate change	Projected sea level rise will have significant impacts on environmental, social and economic impacts within the catchment	High	The tidal amplitude and influence within the catchment for the present and future time frames (20, 50 and 100 years)	*Very important* – This information is required to help the economy, ecosystems and communities adjust to the impacts of climate change (inform adaptation options)	a) Use the hydrodynamic model developed in study 1 (c) to assess tidal inundation for a range of likely climate change scenarios including: • Impacts on aquifer systems and discharge of acid water • Assessments of key ecosystems that will be impacted • Assessment of key land uses that will be impacted by sea level rises and changes to climate • Assessment of socio-economic impacts of sea level rise and changes to climate Actions should feed into the Climate Action Strategy, and then results of the actual studies into the Local Growth Management Strategy (Agricultural Lands section).	BSC $100,000	Stage 2 / feed into Climate Action Strategy	Moderate
4	Sand accumulation in estuary	Sand mining of shoals is currently being considered to improve water quality and provide a sand resource.	Moderate	The impact of dredging on water quality and tidal inundation is unknown	*Important* – prior to assessing dredging proposals the full impacts of the works on the catchment and estuary needs to be understood	a) Use the hydrodynamic model developed in study 1 (c) to assess impacts of dredging to assess impacts on tidal exchange b) The degree of sediment ingress into North Creek and therefore the rate to potential depletion of sand resource in the lower Richmond River c) Use the catchment model developed in study 2 (b) to assess a range of dredging/catchment scenarios including: • Sand resource value and economics • Assess impacts on estuarine habitat, shorebirds, cultural heritage • Implementation impacts (i.e. dewatering, noise and vibration, traffic planning, detailed works planning etc.) • Economic analysis of the cost and benefits of proposed dredging works d) Community engagement on the ecological values of shoals in lower estuary environments	BSC $250,000	Stage 2 OR Stage 3 or action out of CMP	Moderate

Table 27. Additional knowledge gaps and recommended studies for North Creek catchment (CMP Stage 2 or beyond)

ID	Management issue/Threat	Description	Level of risk	Assessment of Knowledge Gaps		Recommendation for further studies	Responsible Agency and costing	CMP stage
				Knowledge Gap	Importance			
5	Land use planning	Land use planning decision are currently made with considerable uncertainty surrounding future conditions (i.e. seal level rise, drainage)	High	The long term sustainability and economic viability of certain land uses.	*Very important* – Will assist in helping the communities and economies of the catchment be viable into the future	a) Based on the outputs of the climate change and catchment runoff assessments economic analysis should be undertaken to determine the viability of each industry in different areas of the catchment b) Based on the outcomes of 5 (a) determine land use zones and identify management objectives for each zone Actions should feed into the Climate Action Strategy, and then results of the actual studies into the Local Growth Management Strategy (Agricultural Lands section).	BSC $30,000	Stage 2 OR Stage 3 or action out of CMP - Feed into Climate Action Strategy
6	Ecosystems (vegetation)	Vegetation communities are highly fragmented within the catchment.	Moderate	There has been some mapping within the Ballina Nature Reserve and of littoral rainforest and coastal wetlands Naturally occurring vegetation across the catchment is not fully known.	*Moderate* - Would be very useful in planning riparian and other revegetation projects and would assist with long term planning for Ballina Nature Reserve.	a) Mapping of existing vegetation communities across the catchment b) Mapping of pre-European vegetation communities if possible c) Priority zones for linkages and reinstatement of natural vegetation d) Based on the climate change studies determine the likely changes to vegetation community Note that these studies feed into a Biodiversity Strategy.	BSC $50,000	Stage 2 OR Stage 3 or action out of CMP - Biodiversity Strategy
7	Ecosystems (Saltmarsh, seagrass, mangrove)	Saltmarsh, seagrass and mangrove communities are very important to the estuary ecology and provide significant ecosystem services.	High	Existing communities are mapped, but there are knowledge gaps around potential for reinstatement and migration under climate change scenarios. The potential for reinstatement and the impacts of climate change are not well understood.	*Important* – these areas support fish populations and provide significant ecosystems services	a) Based on the climate change studies determine the likely changes to saltmarsh, seagrass and mangrove communities b) Map potential reinstatement locations c) Identify potential opportunities for migration with sea level rise e) Develop a draft saltmarsh, seagrass and mangrove migration policy	BSC $25,000	Stage 2 OR Stage 3 or action out of CMP
8	Ecosystems (fish and wild oyster populations)	The estuary is a very important habitat for fish and wild oysters.	High	Regular monitoring not undertaken, species and populations information is largely anecdotal. Scientific basis for recovery can't be established without monitoring.	*Important* – anecdotal information is concerning but no supporting monitoring data.	a) Baseline and regular monitoring required to characterise existing population and changes over time. b) Monitor of cultured oyster health during WQMP implementation to identify parameters (and potentially land-uses) which impact on morbidity and mortality oy oysters	BSC, DAF $40,000	Stage 2 OR Stage 3 or action out of CMP
9	Ecosystems (Shorebirds)	The estuary and catchment provide important habitat for shorebirds. Current information and monitoring of lower estuary exists and will be monitored through dredging investigation and activities.	Moderate	Upper estuary and catchment usage unknown.	*Moderate* – not essential but would be simple to expand dredging related monitoring	a) Expand monitoring relating with dredging to include upper estuary.	BSC $20,000	Stage 2 OR Stage 3 or action out of CMP
10	Ballina Nature Reserve (BNR)	The Ballina Nature Reserve is a large area of the catchment that is classified as a coastal wetland. Drainage through the area has been extensively modified.	High	There is little understanding of the ecological values and drainage pathways within the Ballina Nature Reserve.	*Important* - Consideration of management and conservation values cannot be updated without this work.	a) Determine the current drainage characteristics of the Ballina Nature Reserve based on the outputs from study 1 (c) b) Assess the ecological condition of the ecosystem c) Based on the climate change studies determine the likely changes to ecosystems within the Ballina Nature Reserve d) Update actions list within the Ballina Nature Reserve Plan of Management e) Seek legal counsel on pathways by which coastal wetlands can be disturbed for improved hydrological and ecological outcomes	BSC, Rous County Council, NPWS $50,000	Stage 2 OR Stage 3 or action out of CMP

6 Preliminary business case and forward program

6.1 Preliminary economic analysis

Overview
The purpose of this section is to introduce the best-practice approach for completing the full economic business case (to be delivered over Stages 2 and 3), and to identify key infrastructure and service types that will be the focus of the analysis. The full economic business case will estimate the existing and future risks throughout North Creek, indicate the net benefits of each adaptation option (or package of options) and will ultimately influence final plan development (in Stage 4). The economic business case builds-on to the biophysical investigation (undertaken for this CMP and as part of previous regional studies), supplying decision-makers with additional information to inform the best way forward. The process presented is consistent with State investment frameworks.

This preliminary assessment includes:

- Data to inform the economic assessment
- Defining the economic 'base case'
- Determining the preferred adaptation approach
- Financing mechanisms
- A case study on tidal inundation implications based on high level scoping study information.

Data to inform the economic assessment
To understand how the economy might be affected by a changing climate the full economic business case for the CMP will include an economic assessment of each priority issue. The precision of the analysis relies on the availability and quality of suitable data, and how it is used.

A summary of the main data types that are likely to be required for the full economic business case are listed in Table 28. The economic assessment will use data from several sources, including primary studies, grey literature and previous assignments completed. Expert judgement is used where information gaps are encountered. Given the quality of the input data, the economic analysis will include significant sensitivity analysis to underpin informed decision-making.

Table 28. Data to inform the economic assessment

Priority issues	Potential impacts	Biophysical data (typically) required	Economic data (typically) required
Catchment runoff	Poor downstream water quality	Change in water quality parameters (e.g. TSS, TN, TP)	Pollution abatement costs
Altered hydrology	Reduced water availability	Loss of productivity (e.g. yield reduction)	Gross margins for impacted agricultural outputs
	Poor downstream water quality	Change in water quality parameters (e.g. TSS, TN, TP)	Pollution abatement costs
	Risks to fauna	Any available risk assessments	Benefit-transfer (e.g. avoided management cost)
Climate change (resulting in sea level rise, erosion)	Flood inundation of various land uses and infrastructure (incl. land loss)	Stage-damage assessment (built-assets)	Stage-damage curves from previous flood assessments
		Loss of productivity (e.g. yield reduction)	Gross margins for impacted agricultural outputs
		Area of natural asset by type	Value of ecosystem services (using a benefits-transfer approach)

Priority issues	Potential impacts	Biophysical data (typically) required	Economic data (typically) required
		Loss of biodiversity (i.e. change in extent and condition of key biodiversity assets)	Values from primary studies
		Damage to tourism assets	Reduction in revenues to tourism operators
	Poor downstream water quality	Change in water quality parameters (e.g. TSS, TN, TP)	Pollution abatement costs
	Loss of land and infrastructure	Erosion assessment (land use areas)	Value of production / infrastructure / ecosystem services
Sand mining	Poor downstream water quality	Change in water quality parameters (e.g. TSS, TN, TP)	Pollution abatement costs
	Flood inundation of various land uses and infrastructure (incl. land loss)	Area of natural asset by type	Value of ecosystem services (using a benefits-transfer approach)
		Loss of biodiversity (i.e. change in extent and condition of key biodiversity assets)	Values from primary studies
		Damage to tourism assets	Reduction in revenues to tourism operators

The focus of the detailed economic assessment will be determined by the biophysical risk assessments (assets at risk), the economic base case (the economic risk of doing nothing differently) and the available adaptation options.

Defining the economic 'base case'

Defining the economic base case is a fundamental step in developing the full business case. For this analysis it enables an assessment of risk, estimates potential economic damage and loss from coastal inundation and erosion in the absence of intervention. It will provide foundational data that will be used to undertake the cost-benefit analysis of the possible management and adaptation options. The base case can be thought of as a register of all relevant land uses and other components that might be affected under different flood conditions and over multiple planning horizons.

Figure 37 depicts how information derived from the base case analysis is used to determine the benefit of adaptation. Simply, the figure highlights that the economic value of an asset may decline over time due to coastal hazard impacts where this is no adaptation. However, with adaptation the economic outcomes are improved and that improvement is quantified as the benefit. This approach to analysis is leading practice and will provide an informed basis for the development of the CMP.

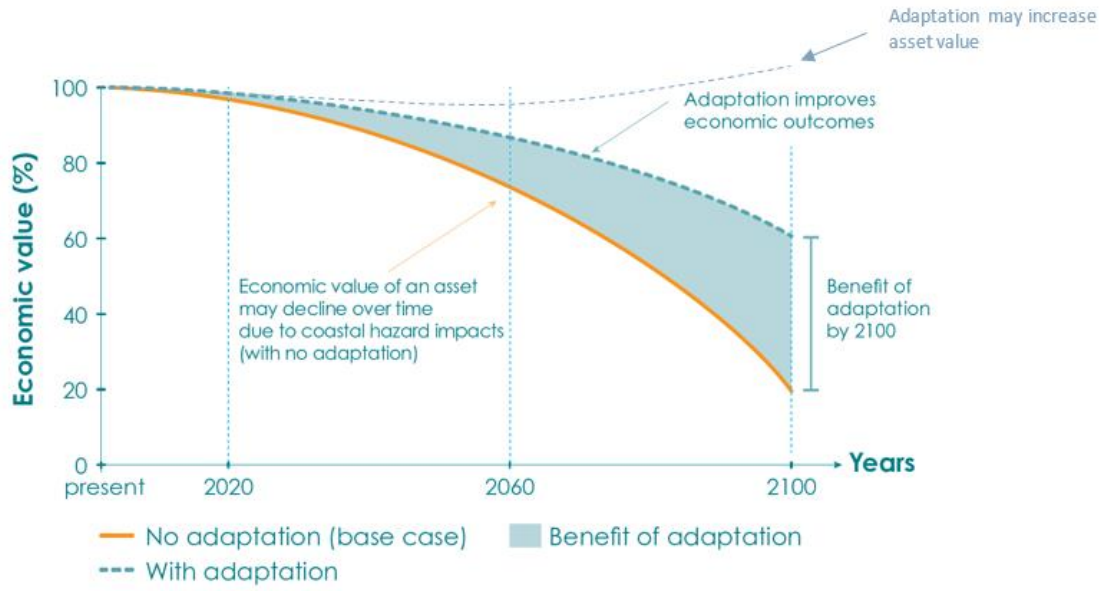


Figure 37. *Conceptual model of how base case information is used to determine the benefit of adaptation/management*

The base case is presented in terms of 'damages' (e.g. asset damage to buildings or infrastructure) and 'losses' (e.g. losses of economic value to key industries, such tourism because of loss of infrastructure). The damages and losses are assessed as the total sum of exposed assets (for a certain likelihood of AEP in a given year).

The timing of coastal risk events is not known and therefore the average annual damage (AAD) is estimated at each time period. AAD is the probability-weighted estimate of damage and loss. It can be understood using the standard risk equation:

$$Risk = 'expected\ damage' = \sum_{i=1}^{\infty} damage\ (of\ hazard\ event\ i)\ \times likelihood\ (of\ hazard\ event\ i)$$

where damage is a function of exposure and sensitivity of assets, and the likelihood of damage or loss occurring is based on the modelled annual exceedance probability. The AAD is the best-practice approach to estimate potential economic impacts of flood hazards (and for CBA of natural disasters) in a given year.

Overview of key asset classes and valuation

Table 29 has been included to provide an overview of key asset classes at risk, including an initial estimation of replacement costs in the event that the coastal hazard damages the asset. These costings can be used as a starting point for future analysis. At a later stage of the CMP they should be revised with Council to ensure they are appropriate for the North Creek catchment at that time.

Table 29. Discussion of key asset classes (including indicative damage/loss estimate)

Type	Component	Units	Low estimate	High estimate	Reference/Comment
Pipes	Pipe (sewerage)	$/linear m	164	201	Coastal hazards (e.g. inundation and erosion) threaten the stability and performance of the pipe network. Data measuring the metres of pipe affected by coastal hazards at each township in North Creek will be determined during Stage 2 of the analysis. The damage can then be approximated in dollars using the replacement costs taken from Rawlinsons (2018).[4] If the Shire has site specific data this will be preferred to Rawlinsons.
	Pipe (stormwater)	$/linear m	213	260	
Road infrastructure	Roads	$/lane km	$150,000		Similar to the pipe network, roads are threatened by coastal hazards. The costs of the road per kilometre will vary depending on the type of road – i.e. whether a road is a major road or minor road. Gargett (2017) estimates the current value of a paved undivided road at $150,000 per km.[5] The cost of traffic signals and culverts has been taken from Rawlinsons (2018).
	Traffic signals	$ per set	110,000	137,000	
	Culvert	$/linear m	1,565	1,915	
Residential / Commercial buildings	Flood damage (slab on ground)	$/m^2	Variable		See discussion under *Economic costs of flood risk* (below) on the stage-damage relationship of different asset types.
	Flood damage (raised)				
	Flood damage (industrial)				
	Flood damage (other commercial)				
	Erosion damage	$/m^2	1,324	2,866	Erosion threatens the integrity of a structure. It differs from flooding because erosion will likely compromise the stability of the foundations and therefore put the entire structure at risk. At this stage of the process it is likely that an asset will be assumed irreparably damaged if it is within the erosion zone (in a given time period) – determined Stage 2. Construction costs can be estimated using the online tool provided by BMT Quantity Surveyors (https://www.bmtqs.com.au/construction-cost-table). At this stage of the CMP process adjustments have not been made to convert replacement cost estimates from Brisbane (as the closest major city) to North Creek.
	Airport	$/structure	n/a	n/a	Further research required (to be completed at a later stage, if necessary)

[4] Rawlinsons (2018) Australian Construction Handbook is viewed as a leading authority on the various aspects of Australian construction costs.
[5] Gargett (2017). Growth in the Australian Road System. Department of Infrastructure and Regional Development: Information Sheet. Australia Government. Accessed at <https://www.bitre.gov.au/publications/2017/files/is_092.pdf> on 22/11/2019.

Type	Component	Units	Low estimate	High estimate	Reference/Comment
Other infrastructure	Carpark	$/structure	n/a	n/a	Further research required (to be completed at a later stage, if necessary)
	Jetty	$/structure	n/a	n/a	Further research required (to be completed at a later stage, if necessary)
Agriculture / Aquaculture	Macadamia trees/nuts	Gross margin[6] ($/ha)	-2,189	5,995	The production of Macadamia nuts is a significant agricultural industry throughout the Ballina Shire and more broadly North Coast NSW. In 2015/16 macadamia nuts were the largest commodity produced in the Shire, contributing 46.3% to the Shire's agricultural value and 39.8% of the value of macadamia nut production in New South Wales (ABS 2017). Coastal hazards threaten the productivity of agricultural land. A study completed for North Coast NSW provides an indication of the estimated gross margin per hectare for macadamia trees (Quinlan 2004).[7] The study should be treated with extreme caution given that is was published 15 years ago; however, it provides insight into the differences of gross margins given the age of a macadamia tree. The gross margins vary between -$2,189 and $5,995 (2018$) for a 3 year old tree and a 15 year old tree, respectively. This is critical for this assessment because of the substantial time lag between the establishment of a new tree crop and profitable production. For example, if productive mature macadamia trees are damaged during a coastal hazard event, and they need to be replaced, there will be at least 5 years before the production turns an annual profit.
	Sugar cane	Gross margin ($/ha)	1,360	2,769	Sugarcane is another important crop in Ballina Shire. Similar to the discussion of macadamia trees above, coastal hazards (e.g. inundation) threaten the production of sugar cane. Sugar cane is susceptible to saline (e.g. marine) water which affects the yield. Initial estimated gross margins have been obtained from a tool produced by Sunshine Sugar for NSW farmers (http://sunshinesugar.com.au/new-to-the-industry/information-for-new-growers/19-new-grower-information.html). The low estimate is based on the plant cane value and the high estimate is from the ratoon cane. Both values have been converted to 2018$.
	Oysters	Gross margin ($/m)	TBC	TBC	Despite the oyster harvest area in North Creek closing in 2006, leases within the estuary can still be utilised for farming of oysters, which only require transportation to Mobbs Bay in the Richmond River for depuration prior to harvest. Given there are less than five oyster operators within the lower Richmond/North Creek estuaries, DPI NSW cannot release the economic production data for this system due to confidentiality considerations. Consequently, it is not possible at this time to determine the economic value of oyster production and the gross margins secured. The gross margin for oysters will need to be confirmed in the following stages of the CMP.

[6] The gross margin equals the revenue minus the variable (non-fixed) costs of production.

[7] Quinlan, K. (2004). Macadamia costs and returns for northern NSW. NSW Department of Primary Industries. Accessed at <https://www.agmrc.org/media/cms/macadamiacostsandreturnsfornorthern_7BB3544DE59D5.pdf> on 18/11/2019.

Type	Component	Units	Low estimate	High estimate	Reference/Comment
Natural / environmental assets	Coastal forests and wetlands	$/ha/yr	543	3,692	Natural assets provide a range of 'services' that contribute to human wellbeing through both their extent and condition. Some of the key services include tourism (recreation and visual aesthetic), attenuation of wave energy and erosion protection, carbon storage and sequestration, and maintaining nursery. The initial unit estimations have been determined using a benefit transfer process, which is where the benefits identified in a primary study in a given location are then adjusted for a different location. The values provided here represent the benefit from the Whitsundays (with no adjustment), which will be adjusted (where necessary) for the North Creek catchment at a later stage of the CMP process.
	Mangroves	$/ha/yr	3,591	9,563	
	Beach	$/ha/yr	3,000,000	5,400,000	It should be noted that beach assets generate three values. Firstly, use values associated with visitation. Secondly existence values (they are valued by the community purely because they exist). Thirdly, as they provide a degree of coastal protection to assets inland of the beach (beach absorbs energy from storm events). These values are highly variable depending on the specific beach asset.
Tourism	Average spend per night	$/night	69	221	Tourism Research Australia publishes data relating to tourism at the local government level. The adjacent data is based on a four-year average from 2014 to 2017 (TRA 2019). Disaggregated tourism data specifically for North Creek does not appear to be publicly available. Anecdotally, if the region is temporarily affected by a hazard (e.g. a significant storm) then we would likely see tourists that have already travelled to North Creek partake in a non-coastal activity (e.g. shopping). In many cases this would result in a substitution of expenditure in the region – not lost expenditure. However, a potentially profound issue is the risk that tourists who are considering travelling to the region perceive that the region has been damaged by the coastal hazards and choose not to visit North Creek altogether. This would result in a loss to the region's economy. From a desktop analysis, it is difficult to appreciate the extent of the tourism market in North Creek and the visitors' preferences. At later stages of the CMP, it will be valuable if Council could help contextualise the North Creek tourism sector and ground-truth estimations.

Economic costs of flood risk to building assets

The economic cost of flood risk to building assets (the consequence component of a risk assessment) varies with the depth of flooding and building type. Depending on the flood event, the costs may include:

- Direct internal damage (e.g. wall linings, floorings, wiring, curtains etc.)
- Direct external damage (e.g. window frames, external wall materials)
- Direct structural damage (e.g. footings for elevated houses)
- Indirect damage (e.g. chattels).

Using vulnerability curves developed by Geosciences Australia and insurance data from the 2011 floods in South East Queensland, it is possible to estimate stage-damage curves for different flood heights for different build asset types.[8] The stage-damage relationship for residential and commercial buildings is shown in Figure 38.[9] The relationships indicate that slab-on-ground and raised construction builds (both including residential assets) are significantly affected at 100mm height and then trends at a flatter incline after that. A key driver of this is the susceptibility of internal wiring within the house that will most likely be destroyed during a flood. Alternatively, the stage-damage profile for industrial (e.g. a warehouse) and other commercial buildings exhibit a steadily increasing relationship reflecting the different purpose, needs and construction of the asset.

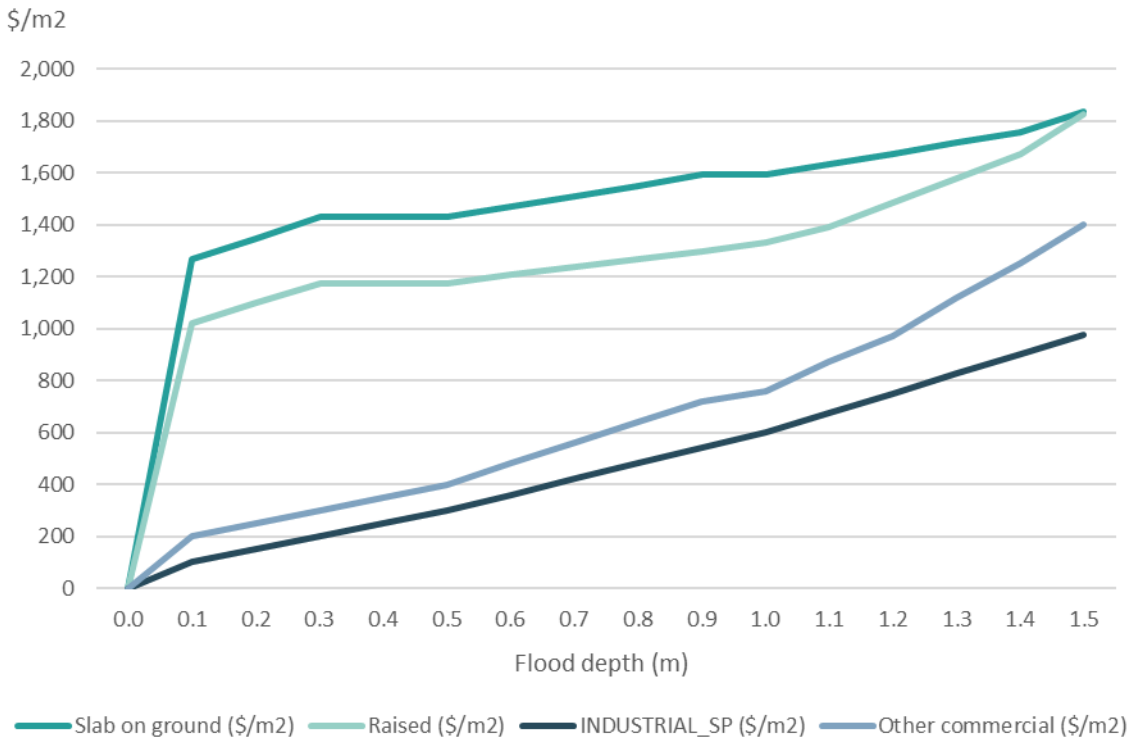


Figure 38. *Estimated direct stage-damage curves for buildings ($/m²)*

Source: NCEconomics modelling based on Geoscience Australia (2017) Vulnerability of Australian Houses to Riverine Inundation. Analytical and empirical vulnerability curves, BMT-WBM (2017) Brisbane River Strategic Floodplain Management Plan. Technical Evidence Report.

[8] At this stage of the CMP process the data presented captures the stage-damage relationship in South East Queensland. In the following stages of the CMP process it may be appropriate to adjust the relationship reflecting conditions in North Creek.

[9] The stage-damage curves are based on the modelled estimates used for the Brisbane River Strategic Floodplain Management Plan (BMT-WBM (2017) Brisbane River Strategic Floodplain Management Plan. Technical Evidence Report).

Determining the preferred management options through economic analysis
A full cost benefit analysis (CBA) will be completed in Stages 2 and 3 of the CMP process to indicate the viability of management options, ranking them based on their economic efficiency.

CBA is a comprehensive approach that identifies and values as many relevant benefit streams (e.g. flood protection, recreation) and costs (e.g. construction costs, land foregone) as possible. Both market and non-market values (e.g. public amenity) are considered. Importantly, per NSW government (2017), CBA is required to be undertaken for any new or altered capital, recurrent or regulatory action for any policy, program, project, proposal or initiative. Therefore, the CBA output is a vital input if Council seeks State co-investment in any of the coastal management measures.

For this CBA, the benefits will be the estimated reductions in base case damage and loss that can be attributed to the performance of the management options (refer to Figure 37). The costs are the estimates of the lifecycle costs of each option. There are two key decision rules in CBA that guide whether an option is economically viable. The first is the benefit cost ratio (BCR), which is expressed as the benefits (in dollars) divided by the costs. This suggests that an option is appropriate if the BCR is greater than one – the higher the ratio the better the option. The other rule is a net present value (NPV) assessment, which is calculated by subtracting the benefits from the costs (in present day dollars). If the NPV is greater than zero then the option is viable.

Benefits are closely linked to the values and characteristics of the community, land use, assets in the exposure zones, catchments and receiving environment. Several different types of economic valuation methodologies will be used to undertake the CBA. This will likely include a mix of market valuation (e.g. gross margins for products), non-market valuation approaches (e.g. revealed preference – travel cost method) and benefit-transfer. The approach to developing a CBA must be participatory to ensure that key benefits and costs are scoped for inclusion in the analysis. Council and community are best placed to uncover intangible benefits and costs that are unique to North Creek.

The quality of data for coastal analysis can vary. Therefore, sensitivity analysis must be undertaken to provide confidence in modelled outcomes. Sensitivity analysis highlights how results are likely to change under alternative assumptions/inputs or within certain tolerances. Best-practice approach to sensitivity analysis requires the use of monte-carlo simulations, which calculates a range of possible results for any specified variable. This process enables the analyst to locate which input is driving the outcome of the model and then determining if further work is required to improve confidence in that input/s.

The results from the CBA can be used to rank each adaptation option based on its economic efficiency. This information can then be provided to decision-makers as a key input to prioritise the best outcome for North Creek.

Case study for tidal inundation

A preliminary loss assessment has been undertaken as part of the CMP scoping study.[10] The purpose of the assessment is to gain an appreciation for the potential magnitude of impact of the projected increase in tidal inundation for the North Creek catchment (in the absence of intervention).

In Section 3.4, indicative areas that may be impacted by increasing tidal area were considered, based on the CoastAdapt high level HAT plus sea level rise projections. As a case-study, an initial valuation of horticultural land potentially impacted by tidal inundation for 2050 and 2100 planning horizons has been considered.

Table 30. Indicative areas impacted by projected tidal areas (based on CoastAdapt modelling)

	Total Area inundated 2050 (ha)	Total Area inundated 2100 (ha)	Change (ha)	% change
Agricultural Land (hort)	521	799	279	54

Agricultural values that were derived from the gross margins (revenues less operational costs) of dominant regional crops – sugarcane and macadamia.[11] That is, the economic value of the permanent losses of agriculture is estimated as the capitalised value of annual gross margins foregone. A 50:50 mix of sugarcane and macadamia crop (gross margins have been capitalised) has been assumed for the purposes of the high-level assessment. Unit rates for the crops are noted in Table 29.

The estimated loss to agricultural (horticulture) land due to tidal inundation in 2050 is estimated to be in the order of $14 million, potentially increasing to $22 million by 2100.

Natural assets in the catchment

An indicative estimate of natural asset values across the catchment, based on current mapped areas and unit rates from Table 29 include:

- Total mangrove/saltmarsh areas are valued at **$720,000** to **$1,870,000** per year
- Coastal forests (Ballina Nature Reserve) are valued at **$365,900 to $2,488,400** per year
- Sea grass ecosystems in the North Creek estuary are values at **$15,300** to **$27,800 to** per year

These values are indicative estimates only, and should be considered in conjunction with broader economic values of the catchment described in Section 3 as the basis for investment in the CMP process.

Financing mechanisms

The total approximate cost for the proposed studies is in the order of $600,000 to $700,000 (refer Table 26 and Table 27). The Ballina Shire Council is envisaged to incur the primary administrative burden as the driver of the CMP process. More detailed estimate for the total cost of the CMP can be determined by the BSC through the allocation of labour against each action listed in the forward program (Table 31).

Funding has been made available to support local government in the management of coastal issues (such as for hazard mapping). This funding is accessible through the Coastal and Estuary grants program. Five streams of funding exist, one for planning and studies and four for implementing works identified in certified coastal zone or estuary management plans. The planning stream will fund:

- Development of CMPs (including individual stages) or the transition of a CZMP to a CMP, consistent with the in the NSW Coastal Management Manual

[10] This is a preliminary estimate only. The values presented here should not be relied upon for decision making. Instead, they are included to guide discussion, and preliminarily indicate the possible magnitude and extent of loss to agricultural land due to a changing climate. A full economic analysis should be undertaken in Stages 2 and 3.

[11] Gross margin is calculated by subtracting the variable cost from the revenue.

- Studies to understand coastal processes and map coastal hazards/coastal vulnerability area
- Studies to understand threats to the objectives of coastal management areas within the NSW coastal zone
- Investigations and designs for infrastructure works recommended in a certified CZMP or CMP
- Cost-benefit analyses and distributional analysis of who pays.

Each of the recommended actions listed in this scoping study fall within the funding requirements for the planning stream.

The preliminary economic assessment for the CMP scoping study has indicated that there is a strong case for investing in the CMP priority studies and CMP development for North Creek. This is based on consideration of the potential implications of tidal inundation impacts on agriculture alone being in the order of up to $14 million by 2050, and the ecosystem services values of natural assets in the catchment being in the order of up to $1 million per annum.

6.2 CMP Stages 2 to 5 forward work program

Ballina Shire Council is the primary (lead) agency responsible for the development of the North Creek CMP. Fast tracking is not considered for the North Creek CMP due to the degree of risk and uncertainty identified. The management issues are complex and interrelated and will require completion of the recommendations through Stages 2 and 3 in order to inform an effective CMP.

Established partnerships exist with Rous County Council and other key stakeholders for the delivery of the recommended studies for Stage 2 of the CMP and beyond (refer Table 26, Table 27). The spatial scope of the CMP is confirmed as the full North Creek catchment and estuary.

The proposed forward program for the CMP development is outlined in Table 31.

Table 31. The forward program for the remaining stages of the CMP process for the North Creek catchment

Milestones and Actions			Estimated cost ($)	Estimated completion date
STAGE 1 – Determine the scope of the CMP				
Draft completion				Jun-19
Review and feedback				Nov-19
Final report and grant acquisition				Dec-19
STAGE 2 – Determine risk, vulnerabilities and opportunities			**$540,000 (upper total)**	
Confirm Stage 2 scope and objectives (project team meeting) and update project plan			5,000	Mar 20
Refine understanding and fill high priority knowledge gaps – Stage 2 studies			$400,000 - $500,000	Sep-20
1. Altered hydrology	a)	Collection of high-resolution topographic data to 0.1 m vertical resolution of entire catchment	$250,000 - $350,000	
	b)	Bathymetric survey of all key drains and estuary channel		
	c)	Development of hydrodynamic model of the catchment to assess flow dynamics and drainage pathways and impacts on existing land uses. Coupled catchment-coastal model including tidal and storm tide inundation.		
2. Catchment runoff	a)	Implement North Creek Water Quality Monitoring Program (WQMP) which will include ambient and event based monitoring for over 18 months across different areas of the catchment	$150,000	
	b)	Development of Source Catchment model of surface and groundwater pathways using outputs from study 1 (c) and WQMP to assess pollutant pathways through the catchment		
Update understanding of threats to coastal values and management opportunities			5,000	Oct 20
Update of risk assessment			10,000	Oct 20
Identify timing and priorities for responses/actions, thresholds and lead times			5,000	Nov 20

Milestones and Actions	Estimated cost ($)	Estimated completion date
Preparation for planning proposal to amend coastal management areas	5,000	Nov 20
Stage 2 communication and engagement as per Community and Stakeholder Engagement Plan	10,000	Nov - Dec-20
STAGE 3 – Identify and evaluate options	**$112,500**	
Confirm Stage 3 scope and objectives (project team meeting) and update project plan	5,000	Jan 21
Identify and collate management options across all priority issues	20,000	Feb 21
ARG meeting and confirm and refine all management options	10,000	Feb 21
Evaluate and prioritise management options across all priority issues – efficacy, economic cost-benefit, plan for implementation	60,000	Mar 21
Identify pathway and timing of actions	7,500	Mar-21
Stage 3 communication and engagement as per Community and Stakeholder Engagement Plan	10,000	Feb – Mar 21
STAGE 4 – Prepare, exhibit, certify and adopt CMP	**$52,500**	
Confirm Stage 4 scope and objectives (project team meeting) and update project plan	5,000	Apr 21
Preparation of draft CMP	30,000	Jun-21
ARG meeting to discuss draft CMP	7,500	Jun 21
Exhibition of the draft CMP and the Planning Proposal		Jun-21
Review and adoption of the draft CMP		Sep-21
Submission of the draft CMP to the Minister for certification		Sep-21
Publishing of the Certified CMP in the Gazette		Dec-21
Stage 4 communication and engagement as per Community and Stakeholder Engagement Plan	10,000	
TOTAL Phases 2 - 4		**$600,000 - 705,000**
STAGE 5 – Implement, monitor, evaluate and report		
Implement actions in the published CMP		
Implement an effective monitoring, evaluation and reporting (MER) program		
Monitor indicators, trigger points and thresholds		
Amend, review and update the CMP		
Report to stakeholders and the community on progress and outcomes through the IP&R framework		

6.3 Links to existing programs

Several programs exist which are likely to benefit the North Creek CMP through the provision of information and support for the delivery of the recommended actions. These are summarized below.

Marine Estate Management Strategy

Key actions that the Marine Estate Management Strategy will deliver in Stage 1 (2018 -2020) can be found at the NSW Marine estate website. The Marine Estate Management Authority will also deliver pilot program in the Richmond River catchment. This pilot project involves on ground works to address priority threats and risks to the social cultural and economic values of environmental assets in the Richmond River estuary, including North Creek. Many agencies including DPI Fisheries, North Coast Local Land services and EES will be involved. The actions relevant to the development of a coastal management program for North Creek involve:

- A floodplain assessment involving capturing information about existing drainage infrastructure assets, landscape values and constraints in data acquisition phases in order to populate a multicriteria analysis to inform objective and holistic management decision making for agencies involved in floodplain management; and
- Bank management, marine vegetation and foreshore structure strategies.

The Marine Estate Management strategy also lists two actions targeted at LGA's which involve the implementation of a targeted marine litter campaign and the development of a Marine Litter Working Group.

Richmond River Governance Framework

The NSW government in collaboration with local councils in the Richmond River catchment is developing a revised governance framework that will establish the responsibility for delivering improved river health outcomes in the Richmond River catchment. The outcomes of this co-developed framework may inform or even fulfill the requirements of the recommended governance review for Stage 2 of the North Creek CMP.

NSW Adaptation Research Hub

The NSW Adaptation Research Hub is in the process of producing research material which can further enhance the understanding of the local scale impacts of climate change. Multiple projects are directly relatable to the inundation hazard facing the North Creek catchment and will inform the approach for studies in Stage 2.

IP&R Framework

The Integrated Planning and Reporting framework is established under Chapter 13 of the Local Government Act 1993. It allows for NSW councils to understand how the multiple plans interact within the larger governance framework to ensure holistic and sustainable planning. The CM Act 2016 requires that CMPs to be given effect within the IP & R framework (Figure 39. This means that the CMP and its identified activities should align with the broader community strategic plan, consider community priorities and ensure that its activities are feasible, financially viable and able to be resourced.

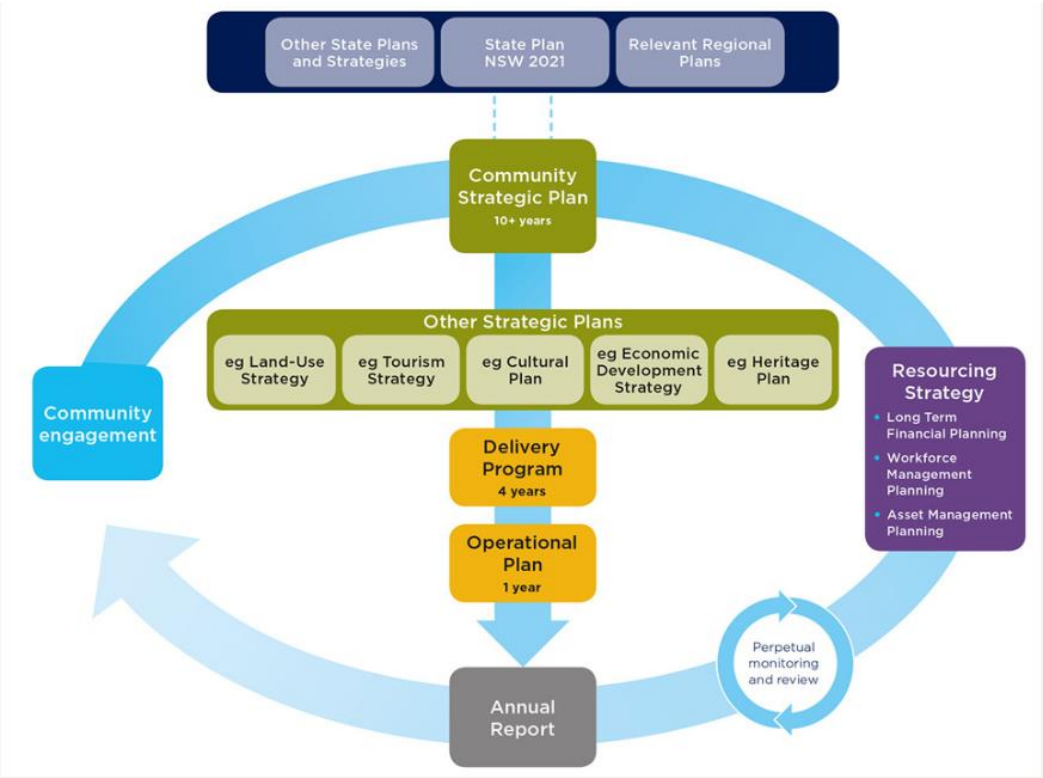


Figure 39. *An overview of the integrated planning and reporting framework (OLG 2018)*

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Attachment A
Community and Stakeholder Engagement Plan

Attachment B
EPBC report

Attachment C
First ARG meeting minutes

Attachment D
Stakeholder survey responses

Online survey

The survey was open to the public over May and July 2018. During this period 150 responses were collected. The survey comprised of 13 questions and took an average of eight minutes to complete. Questions aimed to capture the demographics of the respondents, their values, concerns, interest and observations within the catchment over time.

The results from key sections of the survey are provided in Figure 40 to Figure 46. Key findings from the survey include:

- The majority (59%) of the respondents were greater than 50 years old
- The survey reached a wide distribution of occupations. The most prominent categories were Retired (20%), Education, Training and Library Occupations (10%) and Management, Health Care and NRM each comprising seven percent.
- Other occupation groups included Farming Fishing and Forestry (six percent), Business and Financial (five percent), Arts, Design <entertainment Sports and Media (five percent) and Construction and Extraction (five percent).
- Most respondents (61%) did not identify as a member of any type of local activity group. 15% were part of local fishing groups, 14% community groups and 9% environmental groups.
- The areas of interest within the catchment varied. The most popular area of interest was overall catchment health (37%), 30% of respondents were interested in their primary areas of activity or residence such as urban areas, boat ramps, swimming areas and approximately 12% were interested in the areas around Ross Lane and the Ballina Nature Reserve.
- The following catchment values were ranked by the corresponding proportion of respondents as 'very important' : Native vegetation (76%), Biodiversity (70%), Waterbirds (69%), Scenic values (57%), Swimming (55%), Other (54%), Fishing (53%), Walking/Cycling (49%), Oysters/Aquaculture (42%) and Agriculture (20%).
- The top six threats facing the catchment as identified by respondents are pollution (rubbish) (62%), urbanisation (56%), agriculture (54%), stormwater discharge (52%), Loss of riparian vegetation (52%) and Poor drainage (46%).
- Only 15% of respondents listed climate change as a top 5 threat to North Creek.
- Most respondents provided reasons as to why the top threats are a risk to the North Creek catchment. Their responses revealed that most are concerned about the relationships between residential and agricultural development, increased runoff, reduced water quality and biodiversity. Two broad areas of focus were evident within the respondents. A significant proportion identified siltation and reduced tidal flushing as the primary factor while many others focus on the upstream factors, such as agricultural runoff, acid drainage and urban pollution.
- Respondents expressed a general lack of positive improvement to conditions over time. 34% considered the siltation in the lower end of the estuary to be a negative change and 30% identified water quality decline. Riparian decline was also noted by 12% and other changes constituted 12%. Some 'other' changes noticed included improved sewage management and urban development.
- When asked to identify positive initiatives within the catchment, 68% of respondents couldn't or chose not to. A combined total of 20% of respondents identified initiatives in either waterway regulation, riparian restoration or environmental education. Four percent also recognised initiatives relating to improvements in pathways for walkers and cyclists.
- Desired positive changes within the catchment were grouped into five main categories. Approximately a quarter of the respondents requested improved environmental protection, 22% desired the dredging of the lower estuary to commence and another 22% desired improvements in

water quality. 16% stressed the need for drain maintenance and nine percent expressed a desire for reduced development.

- 45% of respondents indicated that they will check the website to keep updated, 30% would be interested in attending future information sessions/workshops and 20% would like to remain informed by email.
- Most (97%) respondents left their contact details with the wish to be informed in the development of the Coastal Management Program.

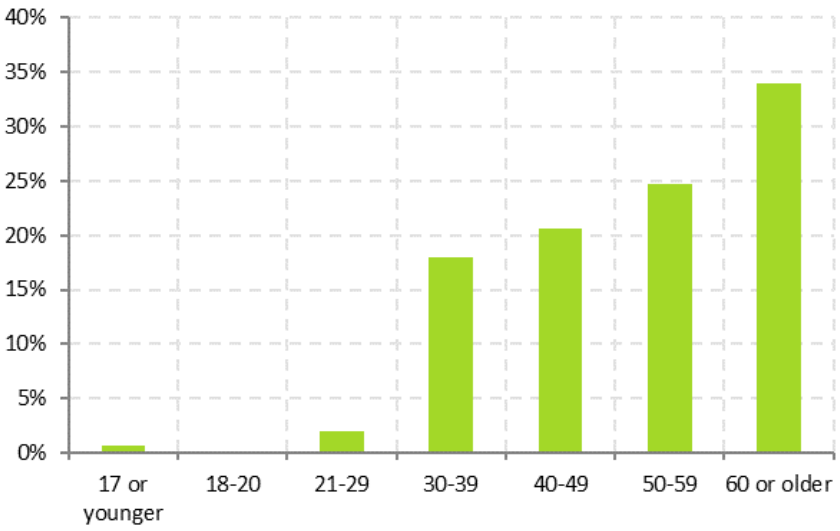

Figure 40. *Distribution of respondents by age group*

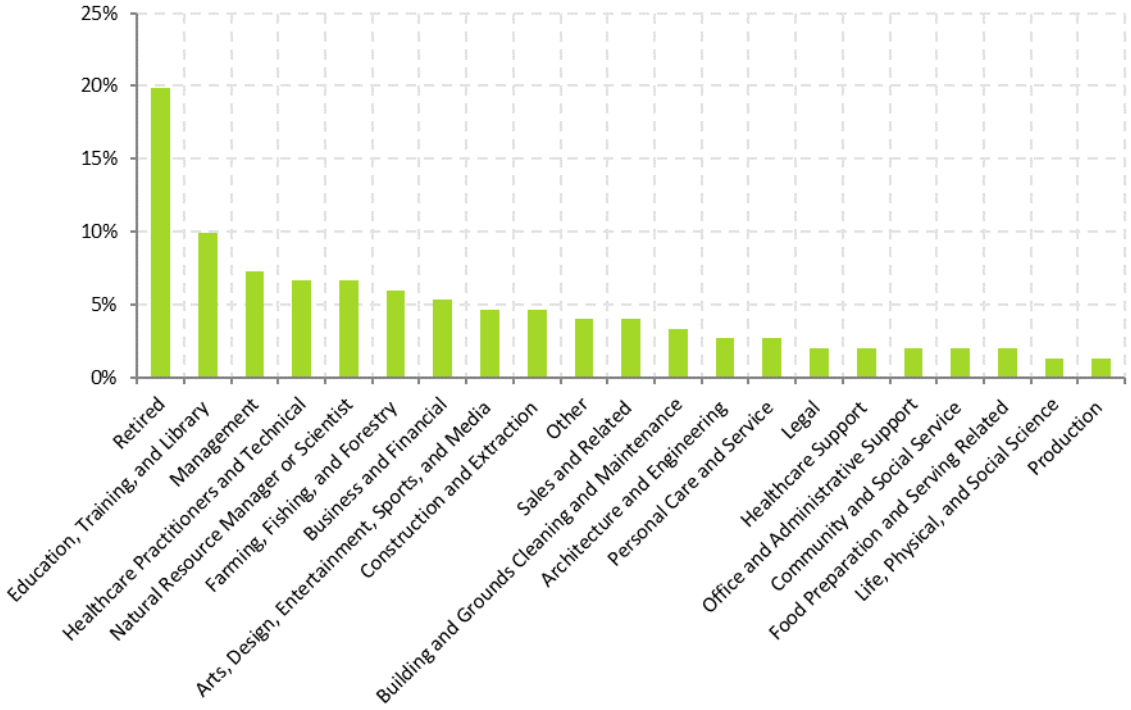

Figure 41. *Distribution of occupation across 150 respondents*

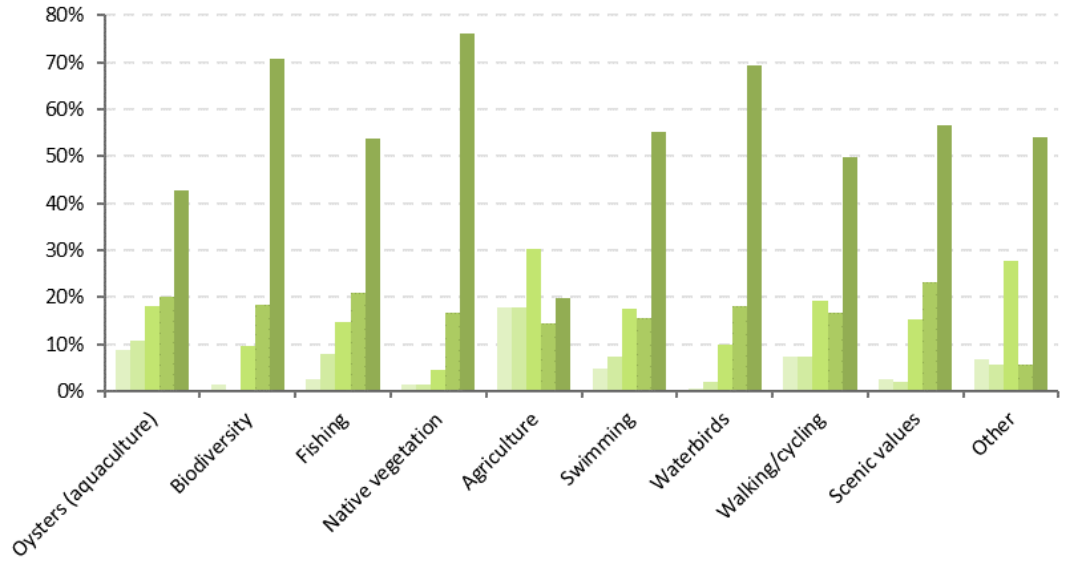

Figure 42. ***C****ommunity value importance levels, ranging from 'not at all important' (light green' to 'very important' (dark green)*

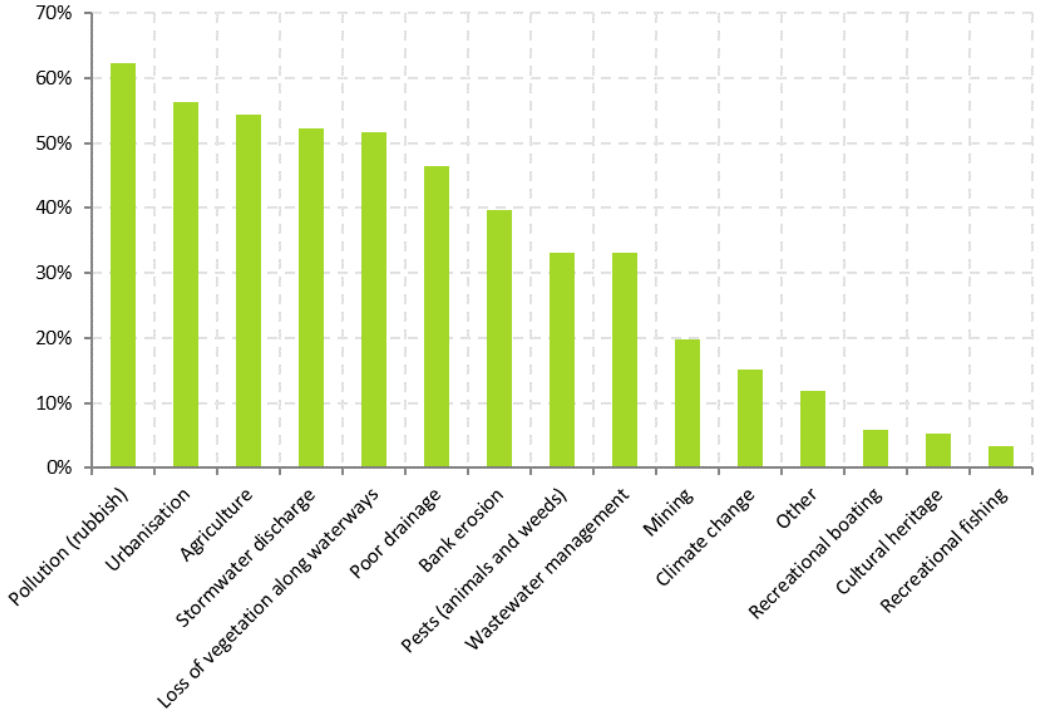

Figure 43. *Top threats considered by the community to be facing North Creek*

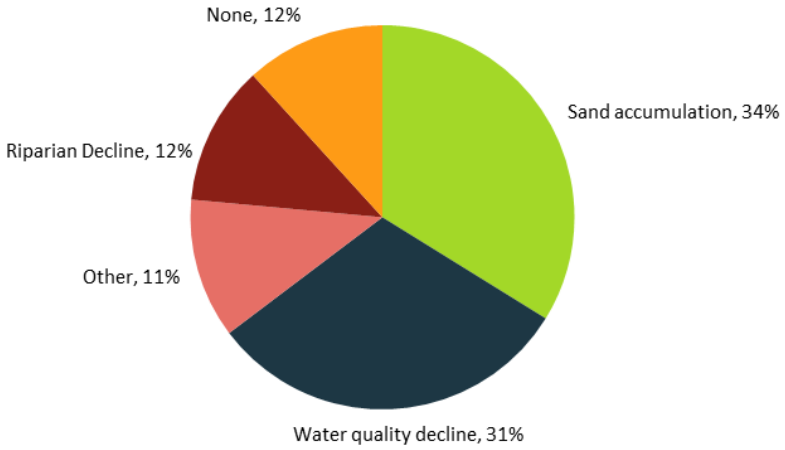

Figure 44. *The changes (positive or negative) witnessed in the catchment over time*

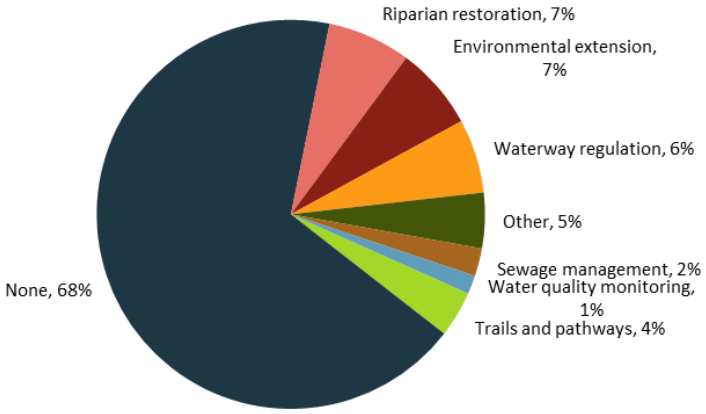

Figure 45. *Positive initiatives witnessed in the catchment in recent years*

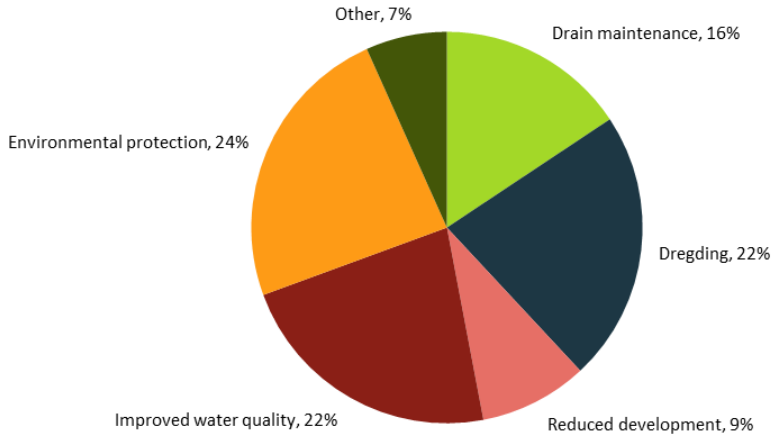

Figure 46. *The types of changes desired within the catchment*

Attachment E
Relevant policies

NSW Marine Estate Strategy 2018 - 2028

This overarching strategy coordinates the policy directions for managing the Marine Estate as a single continuous system over the next 10 years. It integrates all relevant NSW government agencies with local government, industry, stakeholders and communities.

The threat and risk assessment (TARA) of the NSW Marine Estate was conducted by the Marine Estate Management Authority and forms the basis for the strategy and is itself based on the perceptions of local communities, including Ballina. The North Creek CMP is required to consider the risk assessment which has identified the key threats facing the northern NSW coast. Stormwater pollution was found to be the highest priority threat – which is particularly relevant to the North Creek system given the increasing urban footprint.

The TARA was key in the development of eight management objectives which are listed in the strategy. A monitoring program will inform on strategy progress after five years and will also help to fill key knowledge gaps. Table 32 identifies the management actions in the strategy which relate to the North Creek CMP. Management action 1.5 for example requires the adoption of the risk-based framework for considering waterway health outcomes in strategic land-use planning decisions to improve the management of water pollution. This framework will assist in the development of management responses specific to the waterway issues faced by the North Creek catchment.

Table 32. Marine strategy objectives and actions relevant to the North Creek CMP

Objective	Actions relevant to North Creek CMP
1. Improving water quality and reducing litter for the benefit of marine habitats, wildlife and community	1.1 Improve water quality in agricultural and urban catchments using a pilot-based implementation of the Risk-based Framework. 1.2 Improve management of diffuse source- water pollution by: - Clarifying NSW Gov and local gov roles and responsibilities - Using mechanisms within existing policy. - Improving minimum standards and ensuring compliance 1.4 Implement a targeted marine litter campaign and establish a Marine Litter Working Group. 1.5 Develop monitoring, reporting and performance indicators for water quality actions, and incorporate them, and key knowledge gaps, into the monitoring program.
2. To protect coastal and marine habitats and associated species and enhance the health of the Marine Estate by improving the design, quality and ongoing management of foreshore development, use and waterway infrastructure.	2.1 Assess and manage cumulative and legacy impacts for estuary entrance modification and dredging by: - strategically dredging trained entrances to minimise the impact of interruptions to sand movement caused by entrance infrastructure and redeploying sand at erosion and sediment deprived locations - developing and incorporating practical design features that maximise marine habitat and recreational values into existing training walls during maintenance and upgrade works 2.6 Assess and manage cumulative and legacy impacts on foreshore development and land-use change in the coastal zone by: - reviewing and updating existing coastal design guidelines to promote best-practice designs in coastal urban environments. - implementing policy changes to enable adequate assessment of and response to the impact of existing infrastructure that modifies freshwater flows or drains wetlands when rezoning or when land-use change is considered to remediate the legacy impacts of older infrastructure.

3. Understand, adapt and increase resilience, to help mitigate the impacts of climate change on the NSW Marine Estate.	3.1 Enhance mapping of estuarine communities (such as saltmarsh and mangroves) to identify those communities most at threat from sea level rise under expected climate change scenarios and use this information to model areas of land suitable for retreat and those that should be prioritised for protection. 3.3 Build the knowledge and capacity of coastal and marine managers and the community to increase resilience to climate change in the Marine Estate through strategic adaptation planning and management. 3.5 Research and monitor the effects of climate change on the Marine Estate to fill knowledge gaps and inform future management actions, focusing on marine biodiversity and coastal communities.
4. Work with Aboriginal communities in the management of Sea Country to reduce threats and risks to Aboriginal cultural heritage	4.1 Work with Aboriginal communities to evaluate current arrangements for Aboriginal involvement in Sea Country management and decision-making and establish and implement a framework to ensure the involvement of Aboriginal people is effective and appropriate.
5. To understand and mitigate threats to threatened and protected species in NSW	5.6 Understand and reduce impacts of habitat modification on marine wildlife through mapping of key habitat areas, embedding rehabilitation and conservations actions in planning processes, and collaborating with land owners and the community to protect species and habitats.
6. To ensure that fishing and aquaculture is managed in a way that is consistent with ecologically sustainable health, heritage and social benefits of fishing and seafood consumption.	6.6 Apply best-practice guidelines for seagrass protection in the NSW Oyster Industry Sustainable Aquaculture Strategy.
7. To balance protection of coastal and marine habitats and species with ongoing access and safe and sustainable boating.	7.5 Improve awareness of threats to threatened and protected species, and compliance with regulations, through data sharing, education, social research and compliance planning to reduce impacts of boating.
8. Improve the social, cultural and economic benefits that the NSW community derives from the Marine Estate by responding to priority threats	8.1 Increase stakeholder and community awareness of Marine Estate values, management arrangements and promote safe and ecologically sustainable use of the Marine Estate by: - building on existing school and community education programs to encourage environmental stewardship, enhance self-compliance and promote physical and mental health benefits associated with nature - developing and promoting best practice guidance / codes of practice to reduce resource use conflicts - developing online information resources and expansion of digital technologies
9. To improve governance arrangements across the Marine	9.1 Improved co-ordination and integration across all levels of government (including cross-border and the land–sea interface) by developing a governance framework piloted at a catchment scale.

	Estate to support coordinated, transparent, inclusive and effective decision-making	9.2 Increased stakeholder and community participation by building capacity and awareness of coastal and marine management, piloted at a catchment scale and locally via marine park management planning pilots.

North Coast Regional Plan 2036

The NSW government's North Coast Regional Plan 2036 provides the overarching framework of vision, goals and actions designed towards a prosperous future. Investments will focus on further upgrades to the Pacific Motorway, hospitals, education and tourism. The plan sets regional planning priorities and guidance for regional and local planning decisions (Figure 47).

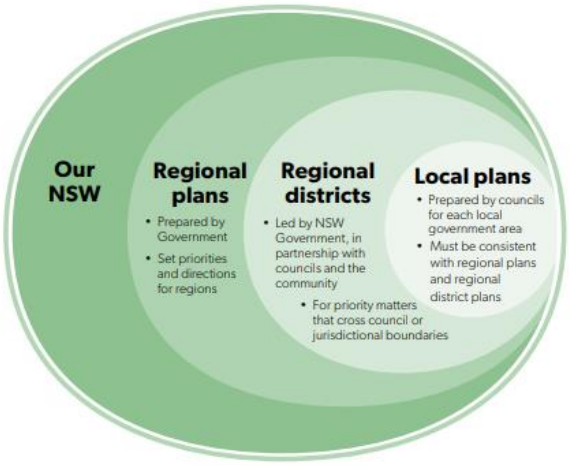

Figure 47. *The NSW state planning hierarchy (NCRP 2016)*

Four regionally based goals are set by the plan, they focus on enhancing the environment, economy, communities and lifestyle options. Three planning principles are also outlined as guides for growth on the North Coast, they aim to achieve a balance between urban expansion and the protection of coastal and environmental assets:

1. Direct growth in identified urban areas
2. Manage the sensitive coastal strip
3. Provide great places to live and work in a unique environment

A series of directives are expanded upon within each of the regional goals. Directives relevant to the North Creek CMP are included in Table 33.

Table 33. North Coast Regional Plan 2036 directives relevant to the North Creek CMP

Directive	Actions	Responsibility	Partners
1. Deliver environmentally sustainable growth	1.2	BSC	DPIE
2. Enhance biodiversity, coastal and aquatic habitats and water catchments	2.1 & 2.2	BSC	DPIE, EES
3. Manage natural hazards and climate change	3.1, 3.2 & 3.3	BSC	DPIE, EES

11. Protect and enhance productive agricultural lands	11.1,11.3 11.4 & 11.5	BSC	DPIE, DISRD
12. Grow agribusiness across the region	12.4	BSC	DPIE
13. Sustainably manage natural resources	13.1, 13.2	BSC	DPIE, DISRD
16. Collaborate and partner with Aboriginal communities	16.1,16.2	BSC	DPIE, AANSW, LALC
18. Respect and protect the North Coast's Aboriginal Heritage	18.1	BSC	DPIE, AANSW, EES, LALC

Local Land Services North Coast – Local Strategic Plan 2016-2021

Local Land Services is an integrated organisation charged with the responsibility of ensuring service delivery in the areas of agricultural advisory services, biosecurity, emergency management and natural resource management. The Local Land Services 10-year State Strategic Plan sets the long-term agenda for Local Land Services at state and local levels. Nested beneath the state plan are 11 regional plans, one of which is the North Coast Strategy for 2016. Under each of the broad state-wide goals, regional expected outcomes are listed. Some of the outcomes relevant (either directly or indirectly) to issues facing North Creek catchment are listed in Table 34 (NCLSP 2016).

Table 34. A summary of the expected strategic outcomes for the North Coast listed under the four state-wide goals

Goal 1: Resilient, self-reliant and prepared local communities	**Goal 2: Bio secure, profitable, productive and sustainable primary industries**	**Goal 3: Healthy, diverse and connected natural environments**	**Goal 4: Board members who are collaborative, innovative and commercially focussed**
Local ownership for social, economic and environmental issues	Adopt innovative policies and practices	Land use aligned with land capability	Participatory decision making
Work with government and industry to develop innovative climate change adaptation approaches	Maintain or improve natural resource base through exercise of NRM practices	Natural environment continues to provide amenity value	Legislative and regulatory responsibilities are met
Make and take responsibility For decisions about NRM, Biosecurity and agricultural productivity.	Adopting policies and practices that deal with adapting to climatic change	Natural resources are managed in a culturally appropriate manner	High level of stakeholder confidence

Ballina Shire Council – Climate Action Strategy 2012 -2020

The Climate Action Strategy complied by BSC identifies both climate mitigation and adaptation strategies at a very broad level. Development of the strategy involved community input, which provided an understanding of the community's expectations regarding the Shire's climate change response. Key strategies relevant to the North Creek CMP include:

Flood and coastal management

- Establish management strategies for identified flood and coastline hazards.
- Incorporate State Government climate change policy into floodplain and coastline management planning.
- Integrate floodplain and coastal management policy into local planning frameworks.

Biodiversity and environmental management

- Strengthen the resilience of the Shire's natural environments to the impacts of climate change.
- Integrate biodiversity management into corporate and land use planning policy.

Regional governance arrangements
The North Coast Delivery, Co-ordination and Monitoring Committee is commissioned with the responsibility to overlook and coordinate the application of the 2036 Regional Plan. The committee is a platform that supports closer working relationships between the NSW Government and North Coast councils. Steering committees from each regional centre, including Ballina, will report to them.

Governance of the Marine Estate is overseen by the Marine Estate Management Authority, which was established in 2012. The Authority developed the Marine Estate Management Strategy 2018-2028 and advises the Minister for Primary Industries and the Minister for the Environment. The strategy co-ordinates all aspects of Marine Estate management under one framework, including local councils.

As the coastal zone is also part of the Marine Estate, the Coastal Management Act 2016 also supports the aims of the *Marine Estate Management Act 2014*. In recognition of the need for expert advice on coastal issues, the NSW government has appointed the NSW Coastal Council, an independent and expert panel, which advises the Minister on coastal issues. The council can perform performance audits on the local council's implementation of its coastal management program.

Local governance arrangements
Reform of the Local Government Act 1993 enabled the Rous County Council to merge with and adopt the responsibilities of smaller county councils in the Northern Rivers region. The Rous County Council is the Flood Mitigation Authority responsible mitigation in the rural environment (not urban areas), this includes the upper and mid reaches of North Creek. The County's natural resource management function relates only to the environmental consequence resulting from the operation of flood mitigation infrastructure on the broader environment. The County is not responsible for other complex management issues relating to estuary ecological health, wetland health and water quality. These responsibilities are shared by Ballina Shire Council and other agencies resulting in a complex governance arrangement.

Attachment F
Water Quality Monitoring Program