FINAL REPORT:

Belongil Creek catchment issues study

September 2019

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1 Introduction

Alluvium Consulting Australia Pty. Ltd. (Alluvium) have been engaged by Byron Shire Council (Council) to develop the Belongil Creek catchment issues study. The Belongil Creek catchment is an integral component of the Byron Bay community. The catchment provides significant social, environmental and economic values to the local community. Many of these values are threatened without changes in management responses.

Belongil Creek is a small intermittently closed and open lagoon (ICOLL) system west of Byron Bay. The morphology of the estuary has evolved due to the wave dominated coastline and associated longshore drift processes which have formed the Belongil sand spit. Under natural littoral and runoff processes the beach berm would form a barrier to create a closed lake system which would have inundated much of the lower catchment. The beach berm is periodically eroded due to combination coastal erosion and increased water levels associated with rainfall.

In the last 50 years there has been significant urban and industrial development within the Belongil Creek catchment. This has resulted in increased runoff and pollution into Belongil Creek. To manage flood risk and water quality issues within the catchment the estuary mouth is mechanically opened when the water level at the Ewingsdale Road bridge gauge reaches 1 m AHD (Australian Height Datum). The mechanical opening of the estuary has allowed agriculture and urban development to expand within the catchment.

Agricultural development, drainage works, urbanisation and mechanical opening of the estuary have drastically changed the ecological condition of the estuary and catchment. Ongoing development, climate change and the associated sea level rise will threaten many of the social, environmental and economic values within the catchment.

This study aims to:

1. Summarise the current condition of the catchment
2. Identify the major management issues within the catchment
3. Outline a framework for the development of a Belongil Creek catchment plan.

The development of this report has involved an extensive review or previous studies, a stakeholder workshop with state agencies, Council staff, local businesses and landholders and discussions with the Coast, Estuary and Catchment Panel.

1.1 Study area

Belongil Creek is situated approximately two kilometres to the west of the township of Byron Bay in northern New South Wales (Figure 1). The Belongil Creek estuary entrance is located on Belongil Beach and drains a catchment area of approximately 34 km². The creek flows from the discontinuous watercourses within the Cumbebin Swamp in a northerly direction for approximately 3 km before entering the South Pacific Ocean. A large portion of the remaining drainage network within the catchment is in the form constructed drains including the Union Drain from the west of the catchment. These drains have significantly increased the tidal influence within the catchment. The Belongil Creek catchment supports a diverse range of land uses and industries including urban and industrial areas, agricultural areas and high value ecological areas including Cumbebin Swamp Nature Reserve and Tyagarah Nature Reserve. Mapping associated with the State Environmental Planning Policy (Coastal Management) highlights significant areas of Coastal Wetlands and remnant pockets of Littoral Rainforest near the estuary entrance.

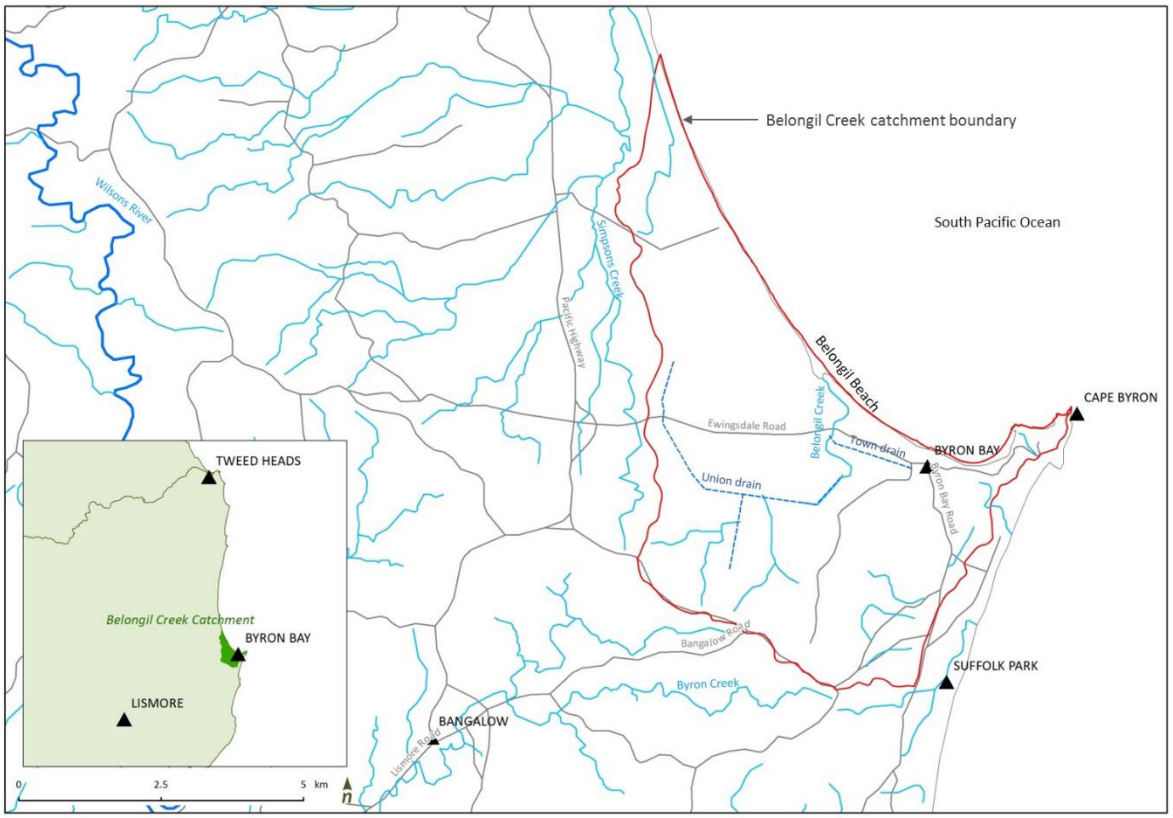


Figure 1 *Belongil Creek catchment study area*

1.2 Existing studies

There have been numerous studies undertaken in the Belongil Creek catchment in the past 20 years. The key studies and a brief overview of the study/outcomes are provided below in Table 1. This study aims to build on these previous studies and outline a framework for the integrated management of the catchment.

Table 1. Some of the key studies in the Belongil Creek catchment

Study	Overview/outcomes
Byron Bay Embayment CMP Scoping Study BMT WBM (in prep 2019)	Outlines the scope for the Coastal Management Program (CMP) for Cape Byron to South Golden beach focusing on the open coast and estuary entrance only. Recommends a separate/standalone CMP for the Belongil Estuary when resources permit..
Byron Shire WSUD policy and strategy BMT WBM (in prep 2019)	Development of financially sustainable Water Sensitive Urban Development (WSUD) policy and strategy to guide staff and key stakeholders in future urban and waterway planning across the Byron Shire.
Belongil Creek entrance opening strategy (Alluvium) (in prep 2019)	Outlines a framework for the future management and artificial opening of the Belongil Creek entrance. No major changes to the current opening regime (i.e. 1m AHD) are proposed.
Capacity assessment of the Belongil Creek Drainage System (2016) (AWC and BMT WBM)	Assessment of sustainable effluent release pathways for current Byron Bay Sewage Treatment Plant (BB STP) and future projected 5ML/day and 8ML/day outflows. Recommended retaining existing release point and developing an additional release point into the Industrial Estate drain.

Belongil Creek floodplain risk management study and plan (BMT WBM, 2015)	Provides an overview of flood risk across the Belongil Creek catchment. Presents management options for existing problems and ensuring new development is compatible with flood hazard and does not create additional flooding problems.
Byron Bay Drainage Strategy (2010) (SMEC)	Outlines recommendations for the improvement of Byron Bay stormwater drainage system. Recommendations included wetlands, pumps, levees and improved drainage networks.
Belongil Creek Entrance Opening Strategy (EOS): Review of Environmental Factors (2005) (IERM)	Aimed to mitigate impacts due to artificial entrance opening of Belongil Creek. Outlines the impacts of estuary opening and provides recommendations to mitigate these. Reviews the environmental impacts associated with the artificial opening of the Belongil Creek entrance. Provides a number of recommendations to protect environmental, social and economic values.
Belongil Estuary Study and Management Plan (2001) (Peter Parker Environmental Consultants)	Outlines an integrated management plan for the estuary. Identifies major values and threatening processes. Poor water quality from urban areas, agricultural runoff and acid runoff identified as a major threat.

1.3 Report structure

This report has the following structure:

- **Section 1** provides an overview of the study, study area and existing studies
- **Section 2** provides an overview of the catchment physiology
- **Section 3** outlines the sub-catchments within the study area and outlines the values and threats within each area
- **Section 4** summaries the major management issues facing the Belongil Creek catchment
- **Section 5** recommends a framework for the Belongil Creek catchment process.

2 Catchment physiology

This section provides an overview of the catchment including geology and soils, historical changes, drainage processes, land uses, coastal areas and ecology. A more comprehensive overview of the catchment can be found in the *Belongil Creek entrance opening strategy – initial findings report* (Alluvium, 2018).

2.1 Overview

The Belongil Creek estuary drains a catchment area of approximately 34 km² which supports a diverse range of land uses and industries including urban and industrial areas, agricultural areas and high value ecological areas including Cumbebin Swamp Nature Reserve and Tyagarah Nature Reserve. The catchment supports a range of vegetation communities of high conservation value, including mangroves, saltmarsh, broad-leaved paperbark swamps and swamp oak forest, with fringing rainforest patches providing habitat for threatened plant species including the white laceflower and stinking Cryptocarya. Mapping associated with the Coastal Management State Environmental Planning Policy (SEPP) highlights significant areas of Coastal Wetlands and remnant pockets of Littoral Rainforest near the estuary entrance. The Byron Bay township and Industrial estate are the two major urban and industrial centres within the catchment. Agricultural areas are primarily used for grazing. An overview of the major features, assets and infrastructure in the Belongil Creek catchment is provided in Figure 2.

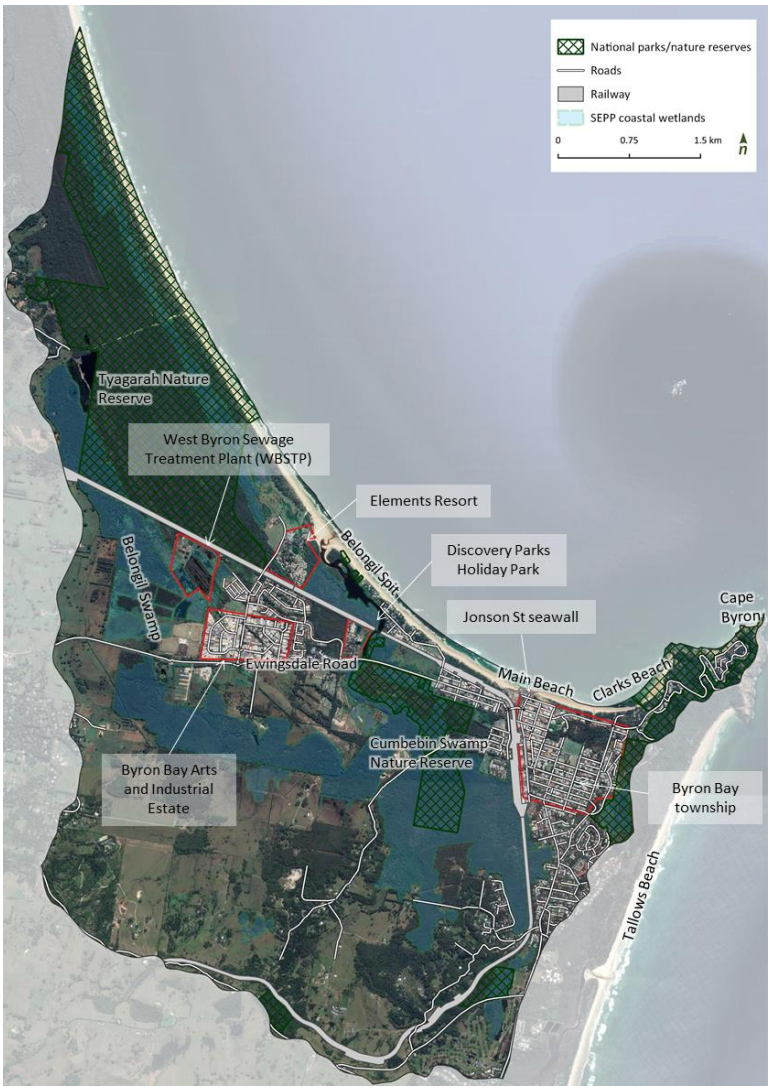


Figure 2 *Major features, assets and infrastructure within the Belongil Creek catchment*

2.2 Landscape setting

The Belongil Creek catchment is bound by steep basaltic hills and slopes falling from the Lismore Plateau in the west and south, beach ridges and back barrier embayment's along the coast to the north and the elevated slopes of Cape Byron in the east. Most of the catchment is flat to undulating, low lying terrain (below 4 m AHD), dominated by estuarine alluvial plains and swamps and wetlands (Willing & Partners Geomarine, 1996). Elevations range from approximately 160 m AHD at the southern catchment boundary near Mcleods Shoot to up to 6 m AHD along the beach ridges and back barrier embayment's in the north and up to 90 m on the eastern hillslopes of Cape Byron.

A significant proportion of the low lying catchment is considered to be a wetland. According to WetlandCare Australia (2005) there is approximately 10 km² of wetlands within the catchment (approximately 33 % of the catchment area) (Figure 3).

Much of the wetland area located on the landward side of the beach ridges is considered a low-lying back barrier estuarine swamp with elevations generally below 2.5 m AHD, grading to alluvial footslope plains (DIPNR, 2004). The major geomorphic features of the swamp area as described by DIPNR (2004) are shown in Figure 3 and described below:

1. Sandy Pleistocene beach ridges, with an elevation of approximately 5-6 m AHD, underlain at 0.75-1.4 m by indurated 'coffee rock'. The younger ridges are broader, more widely spaced and higher; all are approximately parallel to the present coastline and are now largely contained within the Tyagarah Nature Reserve. These ridges are interspersed with depressions of various widths, which drain the northern extents of the catchment south eastwards towards the estuary.
2. Areas of low-lying, Pleistocene sandy plain up to 1 km wide, with an elevation of approximately 1.5-2.5 m AHD, generally underlain by indurated 'coffee rock'. The Arts and Industrial Estate and Byron Bay town centre sit on these features.
3. Slopewash fans from adjacent bedrock hills with an elevation of 2.5 m AHD and greater (particularly well-represented to the south of the main part of the swamp).
4. Areas of low-lying, often peaty plain up to 1 km wide, with an elevation of approximately 2.0-2.6 m AHD, with peat and alluvium up to 2.5 m thick underlain by early Holocene sands and muds (e.g. part West Byron STP and re-use sites).
5. Low elevation terraces, possibly Pleistocene or early Holocene, with an elevation of approximately 1.2 - 2.0 m AHD.
6. A back barrier swamp basin, with an elevation of 0.8 - 1.2 m AHD, located wholly on the southern side of Ewingsdale Road. This basin is intersected by the Union Drain. The unit is now largely colonised by *Melaleuca quinquenervia* (Broad leaved paperbark), and there are signs of channel remnants visible.
7. Channels within the swamps gradually become more defined and join to form the Belongil Creek estuary.

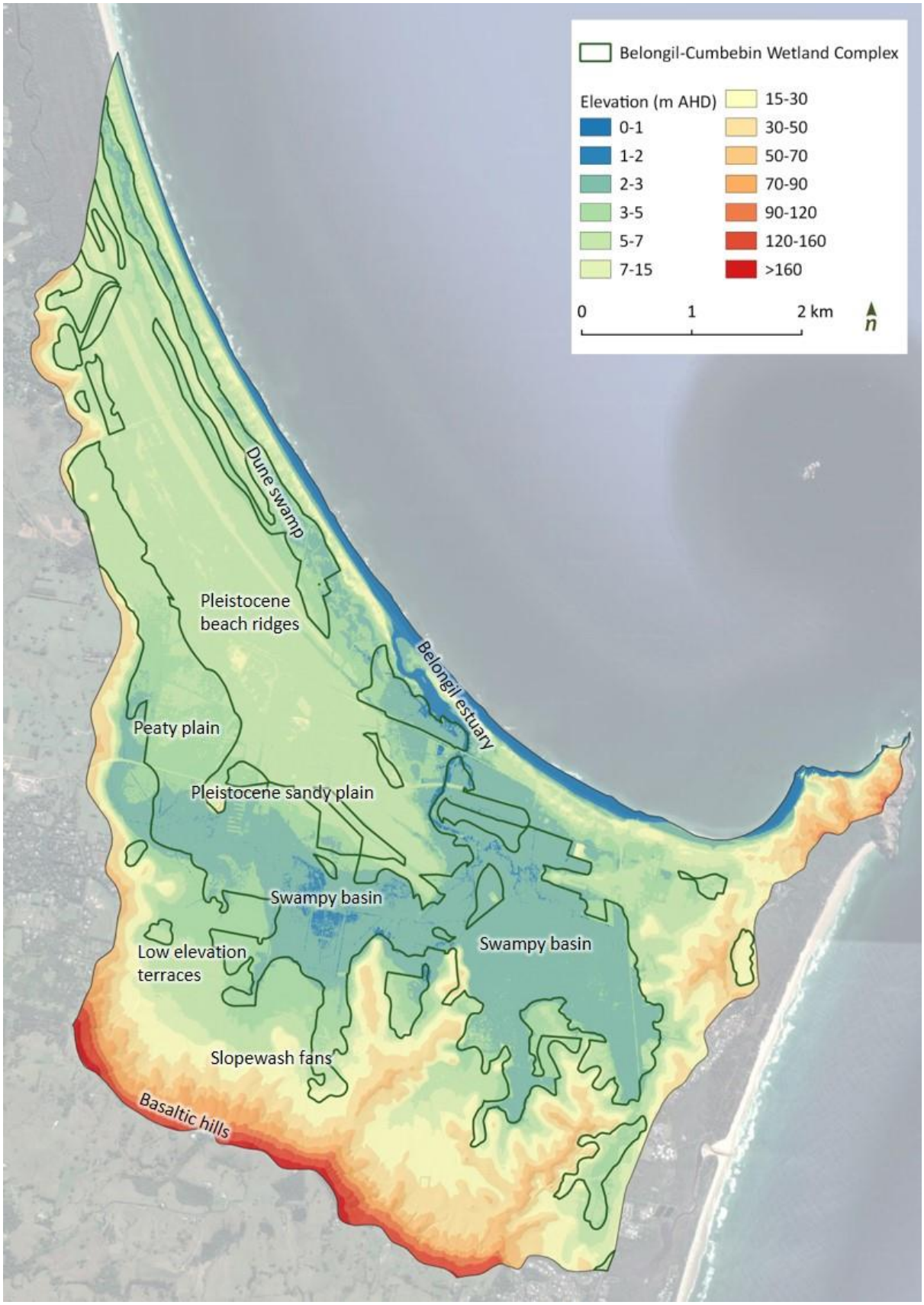


Figure 3 *Surface elevation for the Belongil Creek catchment and major geomorphologic units*

2.3 Geology/soils

The steep hillslopes bounding the south of the catchment are predominately made up of mafic volcanic rocks such as basalt that were erupted through volcanic activity in the Cainozoic period. The lower elevations of these slopes are dominated by Triassic-Jurassic sedimentary rocks including conglomerate and sandstone. The dominant geology of the eastern elevation of the catchment is Carboniferous sedimentary rocks including feldspar-rich sandstone, siltstone, mudstone and conglomerates. Quaternary coastal dune deposits make up the dominant geology of the remainder of the low-lying portions of the catchment (see Figure 4).

As classified under the Australian soil classification, the Pleistocene beach ridges are predominately podosols. Podosols generally contain aluminium and/or iron, are highly sandy and acidic and found in high rainfall areas. The low-lying areas contain soils classified as hydrosols which are seasonally or permanently wet, there is a reasonable amount of diversity of soils types within this group. The footslopes and mid elevations contain kurosols which generally form from highly siliceous parent material and can be highly acidic. The steep basaltic hills have given rise to ferrosols which may suffer from acidification (The Australian Soil Classification).

The soils within the Belongil and Cumbebin swamp areas are complex due to slopewash and alluvial deposition from the surrounding hillslopes. Holocene peats, muds and clays and sandy Pleistocene layers with indurated coffee rock found at shallow depths can be found across the area. The occurrence of Acid Sulfate Soils (ASS) or Potential Acid Sulfate Soils (PASS) have been confirmed in the Holocene clays and peats and Pleistocene sands (DIPNR, 2004). A field study conducted in the upper Belongil Creek catchment (west of the Byron Bay Industrial Estate) by Slavich and Wood (1998) also confirmed the presence of both ASS and PASS. The probability of ASS occurrence within the greater catchment is shown in Figure 4.

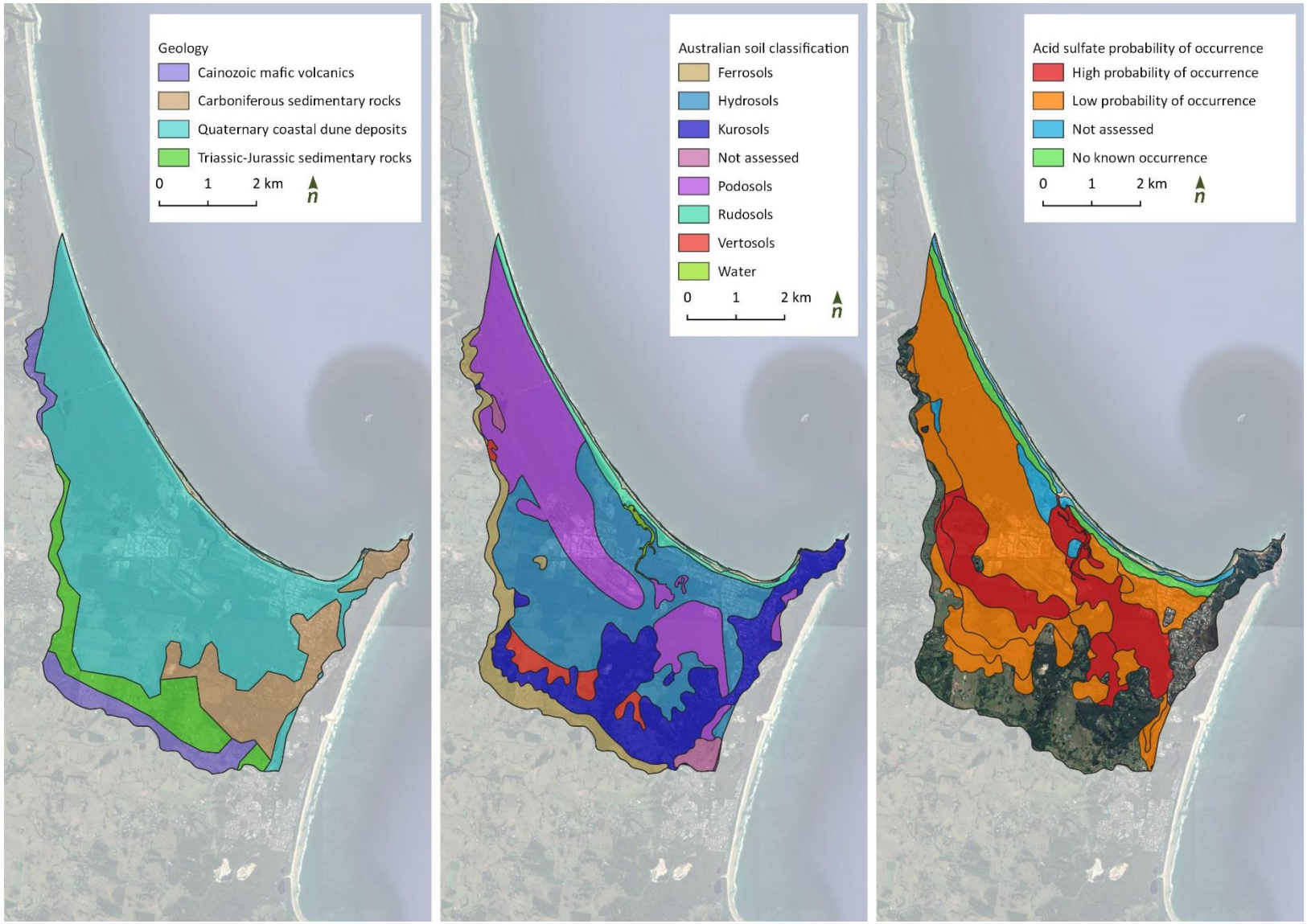


Figure 4 *Geology, soils and acid sulfate soils probability of occurrence within the Belongil Creek catchment*

2.4 Post -European impacts

Prior to European settlement, the north coast of NSW supported one of the largest aboriginal populations in the state (Willings and Partners, 1997). The traditional owners of the Belongil Creek estuary are the Arakwal people who are part of the Bundjalung nation. The Belongil Creek estuary is likely to have been an important resource for its traditional owners providing sources of fish, crabs and shellfish.

European settlement of the catchment began in the 19th century and resulted in the clearing of vegetation and the drainage of wetlands to support agriculture. Some of the major events/changes since settlement are highlighted in Figure 5. The major industry within the catchment between the 1840s and 1880s was timber cutting but other industries such as cropping, dairy farming and fishing grew in importance (Willings and Partners, 1997).

The construction of drains through the swamplands in Ewingsdale opened large areas for pasture. The Drainage Board has actively managed the construction and maintenance of drains in the Belongil Creek catchment since the inception of the *Water Act* in 1912. When the levels in the estuary began to encroach on pasture landholders would dig a channel through the beach berm to drain the wetland. In 1913, the meat processing plant was also constructed which ran until the early 1980s, leading to higher employment and further development within the catchment. The clearing accelerated in the 1960s and 1970s when large areas of the Cumbebin Swamp wetlands were cleared, drained and burnt as a fuel source for the local meatworks. Other major industries during the 1900s included the mining of zircon and rutile up until 1969 as well as whaling station that ran between 1954 and 1962 (Willings and Partners, 1997).

In the last 100 years there has been significant urban and industrial development within the Belongil Creek catchment. Several of these land use developments within the catchment have impacted the Belongil Creek catchment and waterways. These include:

1. land clearing which resulting in fragmentation and loss of connectivity between ecological communities
2. swamp drainage which resulted in loss of floodplain/wetland connectivity and water quality impacts
3. raising of Ewingsdale Road which impacts drainage pathways
4. filling to create railway embankments, blocking original drainage paths
5. sandmining, meat works, whaling station, fish processing and dairy products processing which impacted water quality
6. development of Byron Bay town centre and the Byron Art and Industrial Estate which increased stormwater generation and influenced drainage
7. operation of West Byron Sewerage Treatment Plant and related discharge and reuse within the catchment
8. Byron Bay landfill site which impacted drainage pathways and water quality
9. routing township stormwater into Belongil Creek
10. regular openings of Belongil Creek to the ocean which altered the ICOLL ecological community.

An aerial imagery comparison of the catchment between 1965 and 2018 indicating some of the major changes during that period is provided in Figure 6.

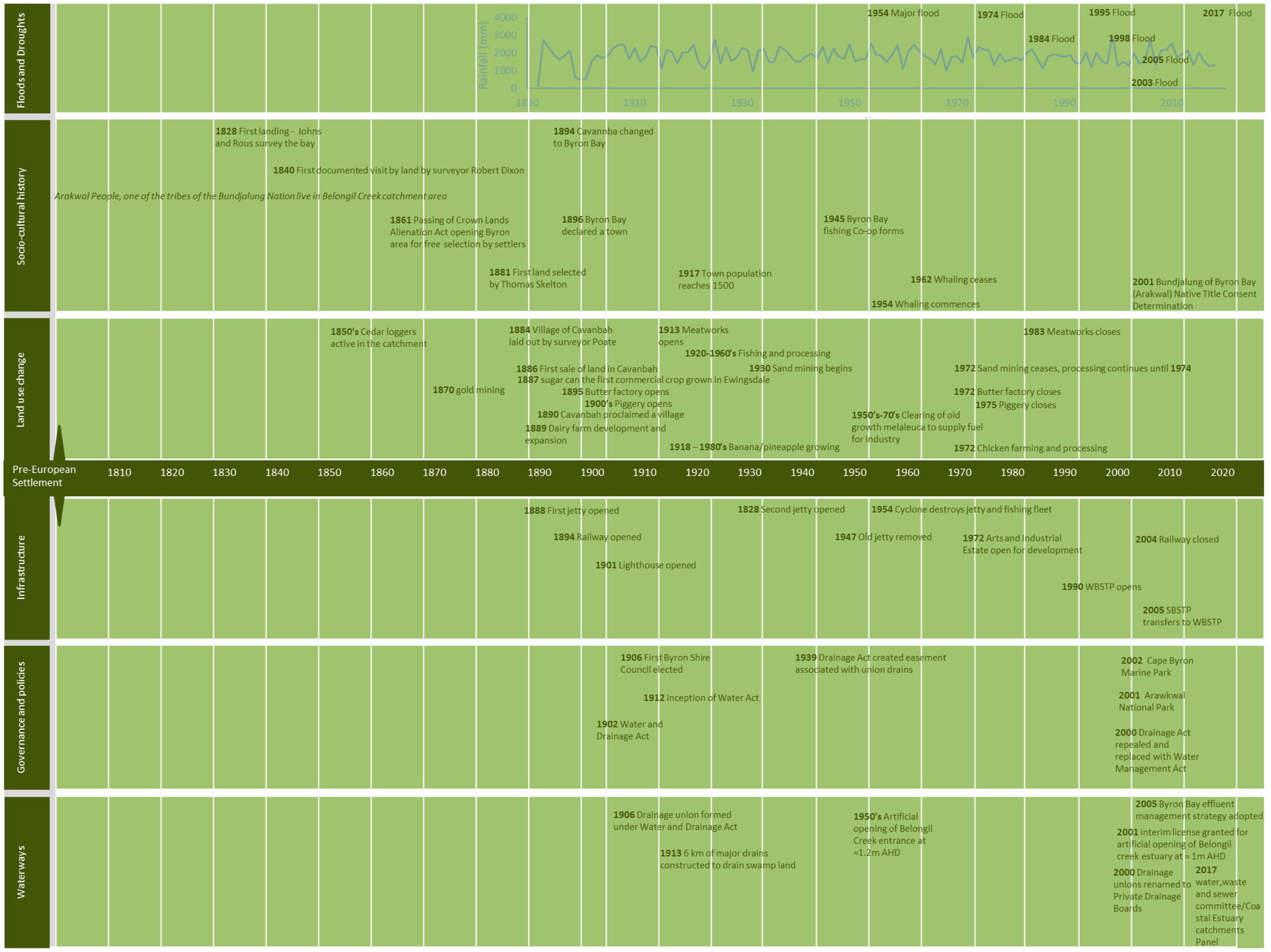


Figure 5. *Timeline of major events/changes in the Belongil Creek catchment*

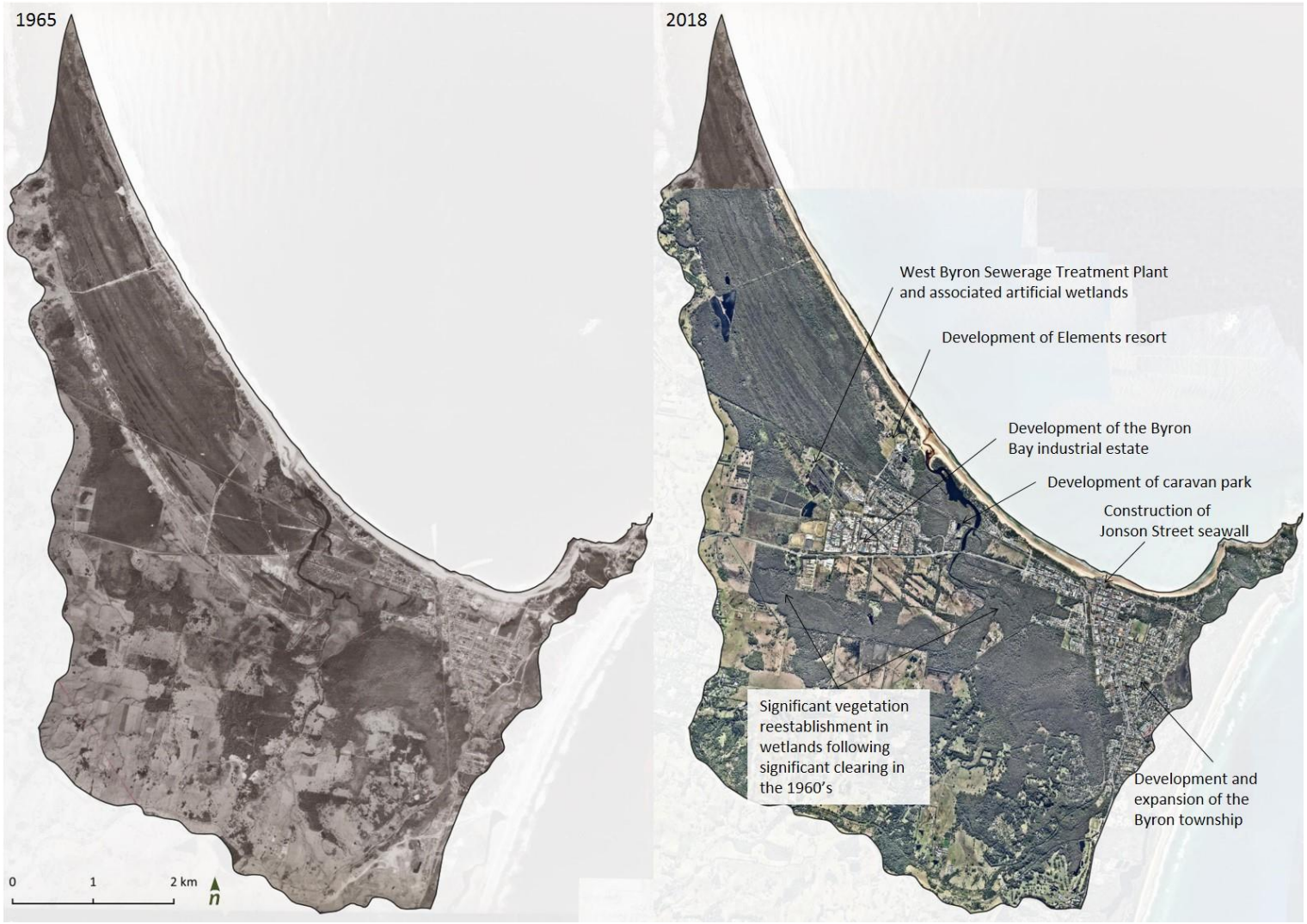


Figure 6 *Aerial imagery comparison of the Belongil Creek catchment between 1965 and 2018*

2.5 Drainage

The Belongil Creek estuary discharges between Belongil Beach and Tyagarah Beach (Figure 7). Upstream from the entrance, the lower estuary turns immediately to the south-east wrapping behind Belongil Spit. The estuary widens through this reach to around 200 m before turning southwards, narrowing to around 50 m and extending further upstream, passing below the railway line and then Ewingsdale Road, some 300 m further upstream. Immediately upstream of Ewingsdale Road, a constructed drain, known as the "Town Drain" or "Butler St Drain" conveys catchment runoff from the northern extents of Cumbebin Swamp and large parts of the CBD of Byron Bay. The locations of the main constructed drains across the lower floodplain are shown in Figure 7.

Upstream of Ewingsdale Road, the estuary again bends eastwards extending a further 660 m before dividing into its two main feeder tributaries which presently drain most of the Belongil Creek catchment. One tributary extends upstream towards the south and east, draining the southern extents of Cumbebin Swamp. The second tributary extends to the south, before connecting to the constructed "Union Drain" which collects runoff from the western parts of the floodplain, including areas within a back-barrier depression west of the Pleistocene barrier ridges. The north-western extent of this depression, to the north of Ewingsdale Road is referred to by some sources as Belongil Swamp.

Belongil Creek catchment's drainage system has been significantly altered over time to enable the expansion of urban and agricultural development across the catchment's extensive low-lying areas. Grazing has occurred in the catchment since before 1891, when papsulum was introduced as a fodder (PPK, 2001). Since then drains have been constructed to aid agricultural land use. The Union Drain was constructed in 1913 by the Belongil Creek Drainage Union. It is estimated that there could be up to 40 km of secondary drains constructed within the catchment including council and private works (WetlandCare Australia, 2005). The use of modern excavators in drain maintenance has also resulted in the deepening and widening of many of the original constructed drains.

A series of secondary constructed drains drain the agricultural lands to the south of the Union Drain which includes inflows from the small tributaries on the northern side of the basaltic plateau. Runoff from the basaltic hills at the south eastern extent of the catchment flow through natural drainage lines to the north where they enter Cumbebin Swamp. Another significant drain is the Industrial Estate Drain which drains the Byron Bay Arts and Industrial Estate before entering the Union Drain approximately 300 m upstream of Belongil Creek.

The drainage works and the artificial opening of the estuary have significantly altered the catchment condition and processes. These impacts include loss of floodplain/wetland connectivity, changes to groundwater levels, reduced flood inundation and variability, increased tidal influence and marine influences on the wetland, increased transport of ASS products and increased oxidation of PASS (IERM, 2005).

The Pleistocene beach ridges that dominate the topography in the north of the catchment direct drainage north west to south east along the swales formed between ridges. Much of this area was mined for zircon and rutile during the 1960s which resulted in a number of the ridges being flattened and dredge water supply drains were constructed through to Belongil Creek. These were later intersected by the construction of the Industrial Estate which reduced drainage rates through these flow paths (PPK, 2001).

In 2006 the effluent from South Byron STP (outside the catchment) was transferred to West Byron STP (inside catchment – see Figure 7). The West Byron STP sits within the Byron Bay Integrated Water Management Reserve (BBIWMR). Currently the STP discharges up to 3ML per day of dry weather flow into the upper Union Drain. In addition, approximately 1 ML/day is used to irrigate a large area (24 ha) of regenerating floodplain forest/wetland. These discharges have resulted in community concern due to the localised increase in the extent of surface water depressions, a reduction in artificial estuary opening events, a reduction in peat fires and acid discharge events (AWC & BMT WBM 2017).

The Byron Bay Drainage Study (SMEC, 2010) identified the major constraints on urban drainage of the Byron Bay CBD. The flat topography, low elevation and extent of impervious areas means drainage is likely to be an ongoing issue for the CBD.

While the catchment boundary is shown to extend northward of Black Rock Road, the conveyance of surface waters from the northern side of the road to the southern side is unclear. Anecdotal evidence suggests part of the constructed drain has been filled by the landowner and there is limited surface water connectivity between land either side of the road.

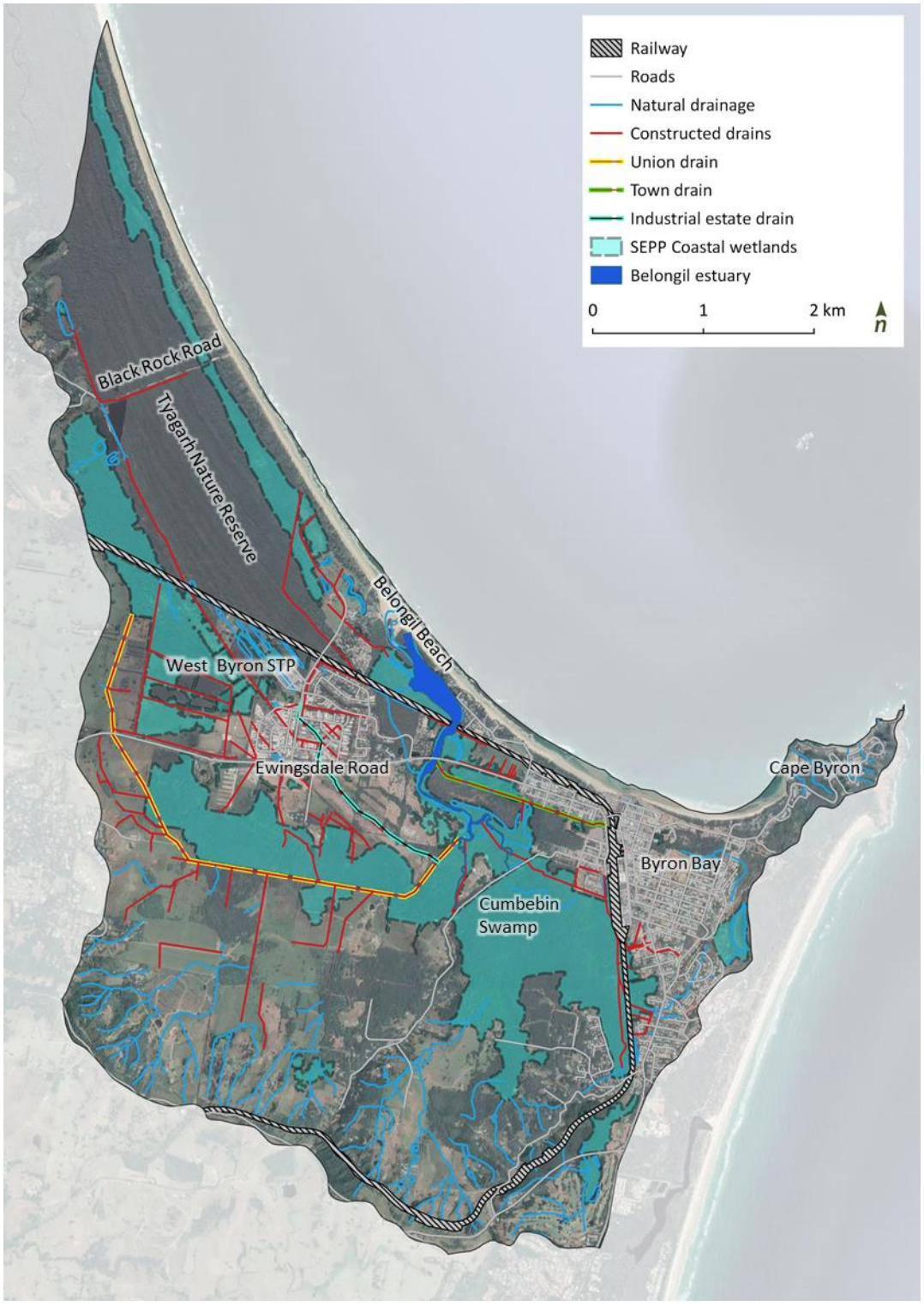


Figure 7 *Constructed and natural drainage network within the Belongil Creek catchment*

2.6 Land use

Historically, much of the low lying land within the catchment would have been permanently or semi-permanently inundated with water forming swamps or wetlands. These areas would have been heavily vegetated by wet heath and swamp plant communities. Water levels are likely to have been similar to Tallows Creek and be up to 2.0 -2.4 m AHD. Water levels of this magnitude would see minor flooding in many developed areas of Byron Bay.

In 1913 the Union Drain was constructed following wetland clearing to allow for agricultural production, residential and industrial uses. It is estimated that approximately 80 % of land within the Belongil Creek catchment has either been cleared, drained or altered in some way (BMT WBM, 2017). These works along with estuary opening have allowed a variety of land uses to develop within the catchment.

NSW land use mapping from 2013 indicates approximately 20 % of the catchment is used for nature conservation including Tyagarah Nature Reserve in the northwest of the catchment and Cumbebin Swamp Nature Reserve. Approximately 21 % of land area including Cape Byron State Conservation area and Arakwal National Park is classified as "Other minimal use area". Grazing of native vegetation or modified pastures is predominately located in the drained low lying lands and alluvial footslopes and plains in the southwestern quarter of the catchment and accounts for approximately 30 % of the catchment. Residential and farm infrastructure accounts for approximately 18 % of the catchment. The remainder of the catchment is made up of smaller enterprises such as plantation forestry, horticulture and services. Under this land use classification only a small area (< 1 %) has been classified as "Marsh/wetland". As outlined in Section 2.1 the area classified as wetland under the Coastal Management SEPP is much larger than this. Much of the land that sits within the SEPP wetland area is classified as "Other minimal use" or "Grazing native vegetation" under the 2013 land use classes outlined below.

The land uses within the catchment are shown in Table 2 and Figure 8.

Table 2. 2013 land use within the Belongil Creek catchment

Land use (Primary class)	Land use (Secondary class - 2013)	Area (ha)	% of catchment area
Conservation and natural environments	1.1.0 Nature conservation	671	19.6
	1.2.0 Managed resource protection	22	<1
	1.3.0 Other minimal use	729	21.3
Production from relatively natural environments	2.1.0 Grazing native vegetation	497	14.5
Production from dryland agriculture and plantations	3.1.0 Plantation forestry	18	<1
	3.2.0 Grazing modified pastures	498	14.5
	3.3.0 Cropping	1	<1
	3.4.0 Perennial horticulture	3	<1
	3.5.0 Seasonal horticulture	1	<1
	3.6.0 Land in transition	20	<1
Intensive uses	5.1.0 Intensive horticulture	0	<1
	5.2.0 Intensive animal husbandry	8	<1
	5.3.0 Manufacturing and industrial	71	2.1
	5.4.0 Residential and farm infrastructure	622	18.1
	5.5.0 Services	136	4.0
	5.7.0 Transport and communication	87	2.5
	5.9.0 Waste treatment and disposal	23	<1
Water	6.2.0 Reservoir/dam	16	<1

6.5.0 Marsh/wetland	1	<1
6.6.0 Estuary/coastal waters	4	<1

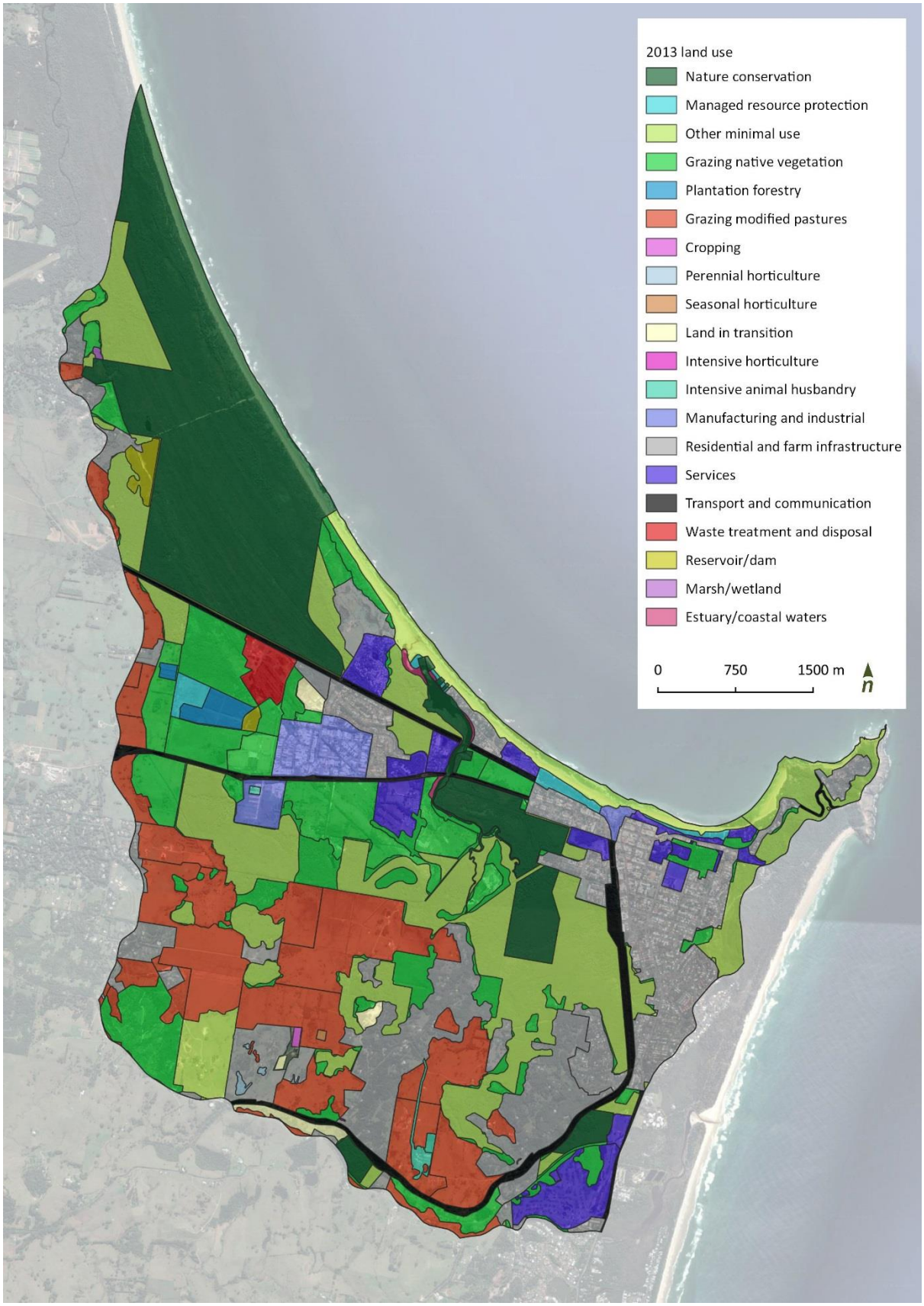


Figure 8 *Land use in Belongil Creek catchment based on the 2013 NSW land use mapping*

2.7 Coastal areas

The entrance of Belongil Creek marks the boundary between Tyagarah Beach to the north and Belongil Spit to the south. Several processes work in unison to influence the dynamic morphology of the entrance and the surrounds which have been studied extensively (e.g. Geomarine, 1997, Parker and Pont 2000, WBM 2000 & 2004, and Baldock at al., 2008). The morphology of the estuary has evolved due to the wave dominated coastline and associated longshore drift processes which have formed the Belongil sand spit. Under natural littoral and runoff processes the beach berm would form a barrier creating a closed lake system. The beach berm is periodically eroded due to a combination of coastal erosion and increased levels associated with rainfall. Construction of protection works at Main Beach, as well as several ad hoc erosion control structures along Belongil Spit have influenced longshore littoral sand supply and erosional processes within the area.

The revised Coastal Management SEPP came into effect on the 3rd of April 2018. The aim of the SEPP is to promote an integrated and co-ordinated approach to land use planning in the coastal zone in a manner consistent with the objectives of the *Coastal Management Act 2016* (CM Act) (New South Wales Government, 2018). According to the Act the coastal zone is comprised of one or more of the following coastal management zones:

1. **Coastal Wetlands and Littoral Rainforests Areas -** defined as areas that display the characteristics of coastal wetlands or littoral rainforests that were previously protected by SEPP 14 and SEPP 26
2. **Coastal Vulnerability Area -** defined as the area subject to coastal hazards such as coastal erosion and tidal inundation
3. **Coastal Environment Area** - defined as the coastal waters of the state, estuaries, coastal lakes and foreshores including beaches, dunes, headlands and rock platforms as well as surrounding land
4. **Coastal Use Area –** defined as land adjacent to coastal waters, estuaries and coastal lakes and lagoons.

The coastal management zones within the Belongil Creek catchment are shown in Figure 9. Significant areas of the catchment are classified as Coastal Wetlands. There is also a small area of Littoral Rainforest near the estuary opening**.** The Coastal Vulnerability Area has not yet been mapped and therefore is not displayed in the figure below. Due to the active coastal erosion of the Belongil Spit it is likely that this area will be classified as a Coastal Vulnerability Area.

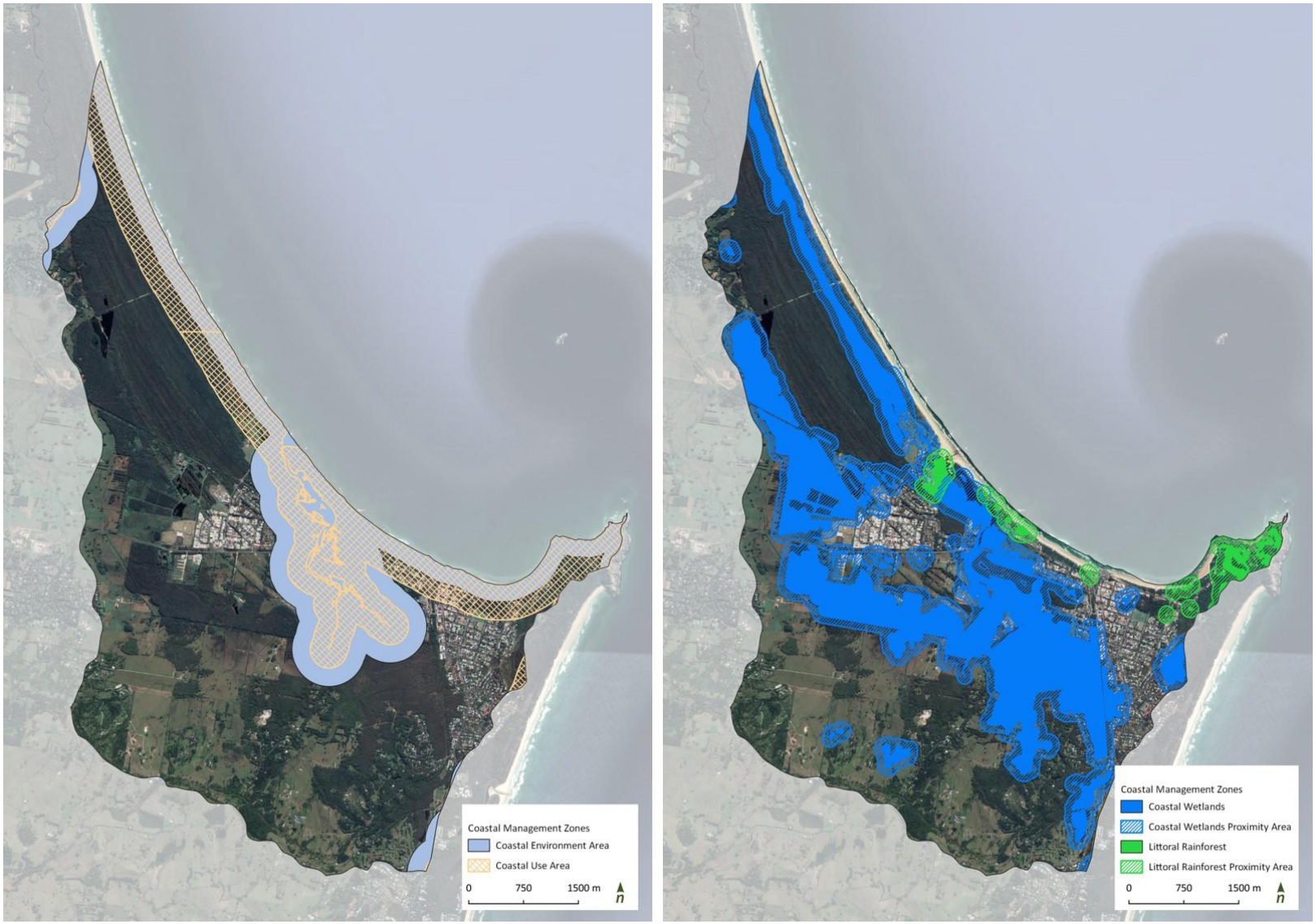


Figure 9 *Coastal management zones within the Belongil Creek catchment*

2.8 Ecology

Despite the extensive changes within the catchment, the Belongil Creek ICOLL and drainage system provides a large expanse of high quality habitat for various terrestrial and aquatic species. A brief overview of both the ecological historical and current condition of aquatic and terrestrial vegetation and fauna communities of Belongil Creek is provided below – a more detailed overview is provided in *Belongil Creek Entrance Opening Strategy – Ecology Assessment* (ESP, 2018).

Vegetation communities

The Belongil Creek catchment supports a diversity of vegetation community types typical of low-lying and seasonally inundated coastal areas on the NSW north coast. Major vegetation communities present (generally following Keith, 2006) consist of:

1. Coastal swamp forest dominated by Broad-leaved paperbark
2. Coastal swamp forest dominated by Swamp oak
3. Littoral rainforest
4. Saltmarsh
5. Mangrove swamp
6. Coastal dune mixed scrub
7. Maritime grasslands on coastal dunes
8. Coastal freshwater lagoons.

The majority of these vegetation community types are protected as Threatened Ecological Community (TEC) types in the *Biodiversity Conservation Act 2016*. Smaller areas of Coastal heath swamp and Wallum sand heath occur in the northern part of the catchment. Vegetation communities in the catchment have been subject to varying degrees of disturbance as a result of clearance, drainage, weed invasion, fragmentation and other factors.

Coastal swamp forest dominated by Broad-leaved paperbark

Much of the low lying (Holocene age) Belongil catchment would have been a mosaic of *Melaleuca quinqenervia* forest, freshwater swamps, *Casuarina glauca* forest on slightly higher or more exposed ground, rainforest patches (often with *Melaleuca*) and saltmarsh. Boundaries would have been dynamic over time with shifts due to climate, fire or changes in the hydrology of the stream or other forces (IERM 2005).

Melaleuca quinqenervia forest is the dominant native vegetation community in low-lying areas with minimal saline influence, forming relatively extensive patches in the catchment and grading into freshwater wetland and heathland communities within Tyagarah Nature Reserve. *Melaleuca quinqenervia* also occurs as individual trees and small patches within grassland in flood-prone areas and localised drainage swales. Swamp mahogany occurs in relatively low numbers within this community with other common secondary species including Pink euodia, Cabbage palm, Rainbow fern and Phragmites.

Artificial drainage of backswamp areas in the Belongil-Cumbebin system since the early 20th century has increased the hydrologic connectivity between the swamp and the estuary, resulting in a net lowering of ground and surface water levels (Talau, 2002 in IERM 2005). Surface drains reduce the time and spatial extent of ponding in the backswamps during the wet season, by increasing the hydraulic potential to transport water to the estuary (IERM 2005). These factors are likely to have led to Swamp sclerophyll forest on the margins being gradually replaced by “drier” community types.

Figure 10. *Example of coastal swamp forest dominated by Broad-leaved paperbark*

Coastal swamp forest dominated by Swamp oak

Swamp oak forest dominated by Casuarina glauca occurs in close association with *Melaleuca quinqenervia* forest and in relatively monospecific stands. It is most common in slightly drier areas and on drain margins. Some larger patches of Swamp oak forest occur west of Ewingsdale Road. *Juncus krausii* and Mangrove fern are common understorey species in this community.

Figure 11. *Example of swamp oak forest bordering the estuary*

Littoral rainforest

Littoral rainforest is present on the northern side of the creek entrance. Parker (2013) mapped an area of 1.8ha of this community type. Common species within this community include Tuckeroo, Beach acronychia and Coast banksia. The Threatened species Stinking cryptocarya occurs within this community.

Erosion of the small area of littoral rainforest at the entrance is evident now due to bank undercutting and this process has been ongoing for some time (IERM 2005). This erosion is shown in Figure 12.

Figure 12. *Littoral rainforest community in the lower estuary, some bank erosion evident*

Saltmarsh

The saltmarsh in the lower reaches of Belongil Creek (downstream of Ewingsdale Rd) is typically fringed on the creek side by mangrove communities (dominated by grey and river mangroves) and casuarina forest (Figure 13). Paperbark swamp occurred on the landward side particularly in the lower reaches. The saltmarsh was in good condition and is dominated by sedges (*Juncus krausii* and *Baumea juncea*) and marine couch (*Sporobolous virginicus*) with occasional small patches of sea purslane (*Sesuvium portulacastrum*) and seablite (*Suaeda australis*) and prickly couch (*Zoysia macrantha*) towards the mouth of the estuary and on the dunes. Common reed (*Phragmites australis*) was present further upstream. Many of the saltmarsh areas (those dominated by marine couch, sedges and mangrove fern) assessed by ESP in September 2018 were inundated by approximately 0.2 m of water when the water level measured 1.0 m at the Ewingsdale Rd Bridge. The saltmarsh was well connected to the main creek channel either directly via continuous mangroves or via a variety of smaller channels. There was no tunnelling for drainage or substantial evidence of human disturbance to these areas of the lower reaches, although all areas have low relief and elevation, so would be easily flooded at times.

Figure 13. *Example of saltmarsh in Belongil Creek estuary, downstream of Ewingsdale Road, with fringing mangroves*

Mangrove forests

The mangrove forests are dominated by *Avicennia marina* (Grey mangrove) with *Aegiceras corniculatum* (River mangrove) and are mid-high open to closed (mangrove) forest (Parker 1996). This was confirmed during a site visit by ESP in September 2018. The Mangrove fern (*Acrostichum speciosum)* also grows in dense patches landward of the mangrove forest fringing the creek and in patches within the saltmarsh. There were several shallow areas with recent recruitment of saplings, particularly at the lower end of the estuary on the accreting eastern bank, which demonstrates possible regeneration and stabilisation of habitats, but also possible encroachment of habitat types such as saltmarsh further upstream. The mangrove forests are likely to have developed in the catchment due to increased marine influence following artificial entrance opening.

The mangrove forest was assessed as in moderate condition, with some signs of stress in the lower estuary where trees had been inundated for extended periods, including yellowing of leaves, black mould on leaves and extended growth of pneumatophores.

The mangrove forests fringing the estuary are primarily intact patches of habitat that are well connected to the main channel, tidal habitats and surrounding vegetation communities further up the shore (i.e. saltmarsh). There is good access to deeper water channels, which provides good quality habitat for a variety of commercial and recreational fish species, particularly as potential nursery habitat.

Figure 14. *Example of dense mangrove forest fringing the main estuary channel*

Coastal dune mixed scrub
Small linear stands of mixed Coastal dune scrub occur along the frontal dune of Belongil Spit as well as north of the creek entrance. Common species include Coast banksia and Coast wattle as well as the introduced Horsetail she-oak and Bitou bush.

Maritime grasslands on coastal dunes
Dune grassland is typically sparse and open on sand seaward of the frontal dune, with Spinifex, Goat's foot convolvulus and Pigface typically grading into Coast wattle thickets further up the dune. Bitou bush has an occasional occurrence.

Coastal freshwater lagoons
More extensive areas of freshwater wetland occur in low lying swales north of Belongil Creek. This community type has also been mapped in the modified wetland system of the West Byron STP.

Fauna habitats
Closely associated with the distribution of vegetation communities, the Belongil Creek catchment provides the following major habitat types:

1. Freshwater, brackish and estuarine aquatic habitats
2. Intertidal sandflats and mangrove communities
3. Saline influenced saltmarsh and rushland communities
4. Swamp sclerophyll forest dominated by Swamp oak
5. Swamp sclerophyll forest dominated by Broad-leaved paperbark, including areas with a Cabbage palm and Pink-flowered doughwood midstorey
6. A 1.8ha patch of littoral rainforest at the creek mouth
7. Freshwater wetlands

8. Periodically inundated grasslands.

Parker (1996) provides a discussion on fauna assemblages in the Belongil estuary, concluding that "the biodiversity of terrestrial fauna within the Belongil-Cumbebin drainage basin is extraordinary". The Belongil system contains a diversity of fauna habitats in relatively close proximity. Drainage in the catchment, changes in land-use and an increase in artificial openings of the creek mouth have favoured some fauna groups whereas the availability of habitat for others has decreased.

The specific habitat resources for key threatened fauna are discussed below.

Amphibians
The Belongil catchment represents relatively good quality habitat for native frogs. Saline influence and past disturbance may limit the suitability of habitats for several species. Areas of Swamp sclerophyll forest provide habitat for a range of tree frog species such as the Dwarf green tree-frog (*Litoria fallax*), Dainty green tree-frog (*Litoria gracilenta*), Green tree-frog (*Litoria caerulea*) and Peron's tree-frog (*Litoria peronii*). Burrowing frogs such as the Scarlet-sided pobblebonk (*Limnodynastes terraereginae*) and Ornate burrowing frog (*L. ornatus*) may also occur.

Habitats in the Cumbebin Swamp, Tyagarah Nature Reserve and wider Belongil catchment provide habitat for acid frogs including the Threatened Wallum sedge-frog (*Litoria olongburensis*) and the Wallum froglet (*Crinia tinnula*).

Frogs that occur in rainforest habitats at higher elevation, such as the barred frogs, are unlikely to occur. Cane toads are relatively common in the area and are likely to occur throughout.

Reptiles
Areas of Swamp sclerophyll forest provide habitat for a range of reptiles and the catchment provides a mosaic of varying habitat types that together provide a diversity of habitat niches for reptiles. Common species include: Green tree snake; Brown tree snake; Carpet python; Red-bellied black snake; Brown snake; Yellow-faced whip snake; Eastern water dragon; Bearded dragon; Lace monitor and several smaller skinks.

Marine turtles are common in coastal waters although nesting events on beaches in the locality are relatively rare.

Birds
Bird diversity in the Belongil catchment over the course of a year is particularly high due to the close proximity of a variety of habitat types including sand and mudflats, ocean beaches, coastal heathlands, swampland, sclerophyll forest, wetland, open pasture and beachfront.

Nectarivorous birds such as honeyeaters and lorikeets move locally in response to changes in the availability of nectar and or pollen. Extensive areas of *Melaleuca quinquenervia* forest provide a good forage resource for these species when in flower.

Many insectivorous birds from higher latitudes spend winter in the locality and visit the catchment seasonally or periodically. These include species such as the Fantail cuckoo, Rainbow bee-eater, Tree martin, Black-faced cuckoo-shrike, Cicada bird, Golden and Rufous whistler, Rose robin, White-throated gerygone, Silvereye, Olive-backed oriole and Spangled drongo.

Birds associated with permanent watercourses and wetland areas such as bitterns, rails and the Bush hen occur in the riparian and swampland margins of Belongil Creek. The catchment does not support a large number of mature trees with large hollows but may provide forage habitat for hollow-nesting birds that occur in areas of Blackbutt forest in the wider locality.

The Threatened Eastern osprey and White-bellied sea-eagle both forage over the Belongil Creek system.

Belongil Creek and the adjacent section of Belongil Beach provide suitable habitat for migratory and resident shorebird species. Although mudflats and sandflats within the Belongil Creek system are not extensive by the

standards of most coastal waterways, they are of significance due to the relative lack of similar habitats in the local area and support a relatively high diversity of bird species over the course of a year.

Pied oystercatchers may nest in the dune system close to the Belongil Creek entrance. Little terns have nested in this area in the past and an area of the dunes south of the Belongil Creek entrance is managed as a bird nesting area to encourage future breeding events.

Mammals

A range of mammal species occur in the coastal strip between Tyagarah in the north and Broken Head to the south. Rare mammals that occur in heathland habitats in the locality, such as the Eastern chestnut mouse and the Long-nosed potoroo, may persist within Tyagarah Nature Reserve.

The Swamp wallaby, Short-beaked echidna, Northern brown bandicoot, Brown antechinus and Melomys are all widespread within the Study area. The Common brushtail and Ringtail possum are also common.

Koalas are regularly recorded within areas of suitable habitat in the catchment. Koalas have little reliance on habitats subject to inundation although Swamp mahogany trees are a preferred feed tree and often occur in association with Broad-leaved paperbark.

A diversity of microchiropteran bat species occur in the locality, although roosting habitat in the form of caves and hollow-bearing trees is relatively rare. The Grey-headed and Black flying-fox forage in various vegetation community types during peak flowering and fruiting times. The Common blossom bat is a relatively common occurrence.

Fish assemblages

The estuary supports a wide range of commercially and recreationally important fisheries species (including oysters, mud crabs, prawns, and fish) and is considered to be an important nursery habitat for juvenile fish (Schnierer 1988; Parker 1998).

The Belongil Creek estuary supports a typical fish community that is dominated by mullet (*Mugilidae*), whiting (*Sillagonidae*), bream (*Sparidae*), flathead (*Platycephalidae*), glassfish (*Ambassidae*) and tailor (*Pomatomidae*), with abundances varying strongly between the summer and winter seasons (Schnierer 1988). Many of the species found in the Belongil Creek estuary are commonly found in the region and neighbouring ICOLL systems such as Tallow Creek (WBM 2001) and are either permanent or temporary residents of the estuary.

A total of 58 species of fish, among which are two members of the pipefish family that are listed species under the *Environment Protection and Biodiversity Act (1999)*, have been recorded from the Belongil Creek estuary. In a survey that included the entrance of the estuary, areas around the Ewingsdale Road bridge and the Union Drain, Schnierer (1988) recorded 52 species of fish occurring in the system. These species include commercially and recreationally important fishery species such as mullet (*Mugilidae*), whiting (*Sillaginidae*), bream and tarwhine (*Sparidae*), luderick (*Kyphosidae*), tailor (*Pomatomidae*) and flathead (*Platycephalide*). A large proportion (88 %) of targeted species were juveniles, highlighting the importance of the estuary as a nursery for fish. Approximately a quarter (23 %) of the fish species caught were marine species and are typically associated more with inshore reefs and were also recorded at nearby reefs such as Julian Rocks (Parker 1998). Only one exotic species, the mosquitofish (*Gambusia* sp.) has been recorded.

Estuarine invertebrates

Schnierer (1988) previously studied the composition of benthic organisms (infauna and epifauna) of Belongil Creek at sites between the entrance and the upstream drainage lines. The invertebrate community was typical of estuarine environments in sub-tropical eastern Australia, and was dominated by mollusc, crustacean, polychaete and insect species. The sites closest to the estuary mouth supported the most diverse assemblages. Total abundance of fauna was greatest in summer.

An assessment of the estuary for commercial and recreationally important fisheries is provided in the subsequent section. Commercially and recreationally important invertebrate species recorded in the Belongil Creek estuary (Schnierer 1988) include:

1. Mud crab (*Scylla serrata*)
2. Blue swimmer crab (*Portunus armatus*),
3. Greentail prawn (*Metapenaeus bennettae*),
4. Sydney rock oyster (*Saccostrea glomerata* (originally listed as C. commercialis))
5. Estuarine yabby (*Trypaea australiensis*).

Fish habitat and fisheries

Fish habitat is defined under the NSW *Fisheries Management Act 1994* as any area occupied, or periodically or occasionally occupied, by fish or marine vegetation (or both), and includes any biotic or abiotic component. This includes the water column, the substrate (such as sand, mud, cobbles or reef) and other features submerged by water which are used by fish to shelter, access food (such as aquatic vegetation and algae), to breed and which provide territorial markers for migration (NSW DPI 2013). Fisheries NSW are responsible for ensuring no net loss of key fish habitats.

Key mapped fish habitat in the study area of the Belongil Creek between the entrance and the Ewingsdale Road bridge includes:

1. open oceanic water, defined as extending from the intertidal zone to the oceans. This includes a range of habitats such as the water column, the continental shelf, beaches, rocky and coral reefs and seamounts. In the study area, this includes the beaches north and south of the creek entrance.
2. coastal lagoons and wetlands, a large open body of saline or brackish water which has a relatively narrow permanent or intermittent connection to the sea. Many coastal lakes and lagoons alternate between being open or closed to the ocean. These are known as Intermittently Closed and Open Lakes and Lagoons (ICOLLs).
3. estuarine wetlands: estuarine fish habitats where fresh water from rivers and streams mixes with the salty ocean water. This brackish water environment supports a variety of fish habitats, including mangroves, sandflats and deep pools. Estuaries provide important feeding, spawning and nursery sites for many aquatic animals. Many invertebrate (crabs and mosquitoes) and vertebrate groups (fish) rely on estuarine water to complete their life cycles and others, such as migratory shore birds, visit estuaries to feed and rest.

The majority of the fish habitat in the Belongil Creek catchment consists of estuarine and coastal wetlands that encompass the creek and drains themselves, and the surrounding low lying areas. The entrance of the creek and the coastal beaches are zoned as oceanic. Only a very small section of coastal lagoon is mapped to the east of the Belongil Creek entrance.

No commercial fisheries (for species such as rock oysters, mud crab, whiting or mullet, etc) exist in the Belongil Creek estuary. Recreational fishing is not allowed in the Belongil Creek estuary as it is zoned as a Special Purpose Zone within the Cape Byron Marine Park.

3 Sub-catchment assessment

3.1 Overview

The Belongil catchment has been delineated into sub-catchments in order to develop a more detailed understanding of the existing condition, processes, values and threats (Figure 15). The sub-catchments were delineated based on several factors including landscape features, land use, wetland features and drainage infrastructure. A summary of each sub-catchment was developed outlining the drainage pathways, preferred drainage strategy features, ecological values, catchment loads, and any key current and/or future threats identified.

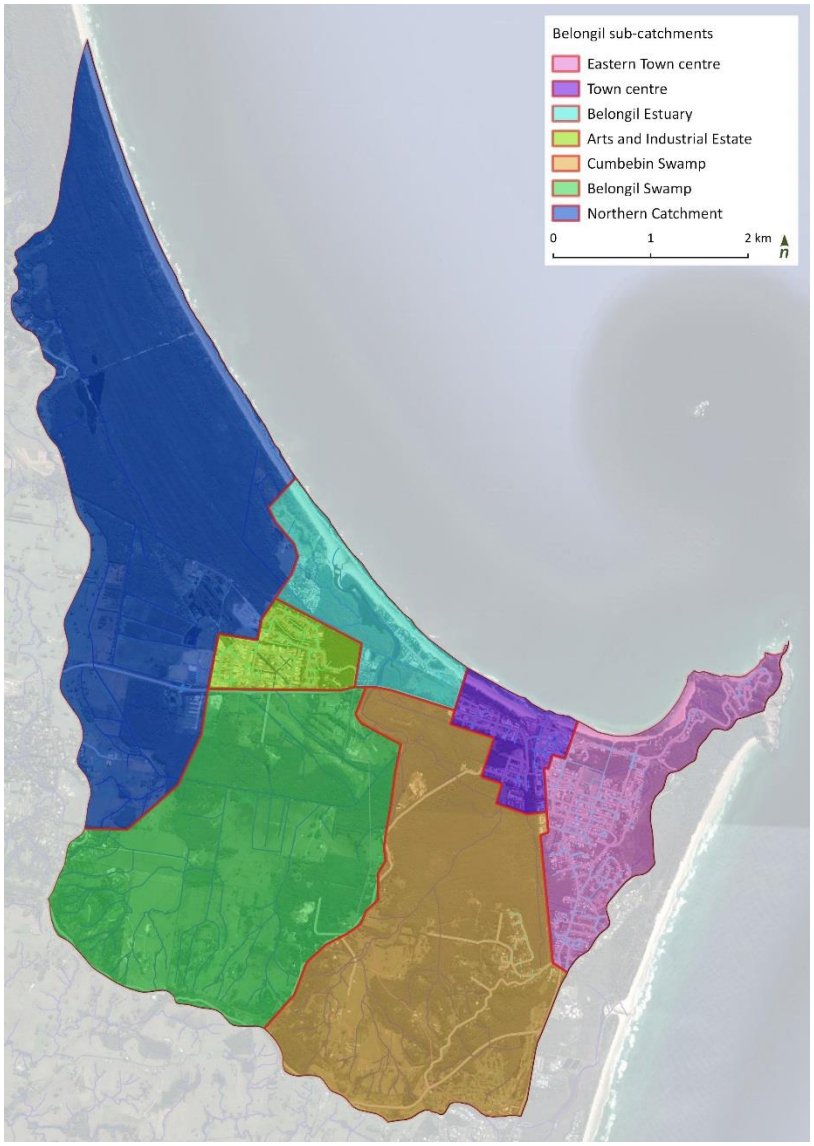


Figure 15. *Sub-catchments delineated within the Belongil catchment*

Catchment loads assessment

In order to identify the potential hot spot areas contributing to water quality issues in the Belongil Creek catchment, the Rapid Catchment Assessment Tool (RCAT) was applied. The RCAT was developed to help identify likely risk areas for generation of four common pollutants (TSS, TN, TP and e.Coli) from the different sub-catchments. An overview of each pollutant is provided in Table 3.

Table 3 An overview of the four pollutants assessed in the RCAT modelling

Pollutant	What is it a measure of?	Catchment source?	Impact on estuary?
Total Suspended Solids (TSS)	TSS measures the amount of particulate matter suspended in the water column and usually associated with fine sediments. These can be both inorganic (sands, silts and clays) and organic (leaf litter, macroalgae, decaying vegetation).	The generation of particulate matter can happen anywhere in a catchment, but often higher levels are correlated with disturbance, such as land clearing and erosion of exposed soils, animal access in streams and also in-stream (bed and banks) erosion.	Higher TSS values (>10mg/L) can reduce light penetration into the water column and therefore limit the solar radiation received by bottom dwelling organisms, especially seagrasses. In addition, other pollutants, such as heavy metals and petroleum hydrocarbons can be adsorbed onto particulates and then become available once they enter estuaries.
Total Nitrogen (TN)	TN is a measure of the amount of nitrogen (a key nutrient for vegetation and other organism growth) available in both dissolved and particulate forms within the water column.	Typically nitrogen can be associated with both diffuse sources such as fertilisers, animal droppings, vegetation, but also point sources such as sewage treatment and overflows and industrial waste streams.	Nitrogen is an essential nutrient in ecosystems, but as for any nutrient, an oversupply can lead to excessive growth of vegetation and/or algae. This can then lead to "boom/bust" cycles where the excessive growth can die off, decay and re-release nitrogen back into the water column. This can then lead to depletion of oxygen in the water column causing fish death, bad odours and increased nutrient release from bottom sediments, further exacerbating the problem.
Total Phosphorus (TP)	As for TN, TP is a measure of both the dissolved and particulate forms of phosphorus in the water column.	Phosphorus sources can also be very similar to nitrogen, but in addition, it is present in many soils and dissolved phosphorus readily binds to particulate matter if present.	Very much like nitrogen, excess phosphorus can lead to excessive growth of vegetation and algae, but in estuarine systems is usually not the limiting nutrient for growth (usually there is an excess, so growth will be more related to the amount of nitrogen present).
E. coli	Escherichia coli is an indicator organism of faecal contamination, but is non-specific so can indicate human	E. coli are a useful organism to indicate the presence of faecal contamination so	Within estuaries, E. coli is always likely to be present, but in well flushed systems, levels

	or animal waste (it is found in the gut of warm blooded mammals). E. coli refers to a wide range of bacteria species, some of which can be harmful if ingested.	sources can be related to sewage, septic tanks, onsite treatment plants, animals, birds and decaying matter.	are typically low. Higher levels usually mean that areas are not suitable for recreational purposes due to the risk of illness from ingestion of waters.

For each sub-catchment the land use was determined within each sub-catchment as well as annual rainfall, and the estimated proportion of rainfall that leads to runoff from each land use category. The model utilises runoff water quality data from different land uses based on previous studies to estimate the contaminants contributed to a waterway based on the proportion of land use types within its catchment. The results are shown in total pollutant load per sub-catchment and per hectare load.

The modelling estimates that substantial pollutant generation occurs within the agricultural areas particularly within Belongil Swamp and that higher density urban and industrial areas also contribute considerable per hectare pollutant loads. The RCAT results for Total Nitrogen (TN) are shown in Figure 16, the full results of the RCAT modelling are provided in Attachment A and discussed further in the sub-catchment summaries below.

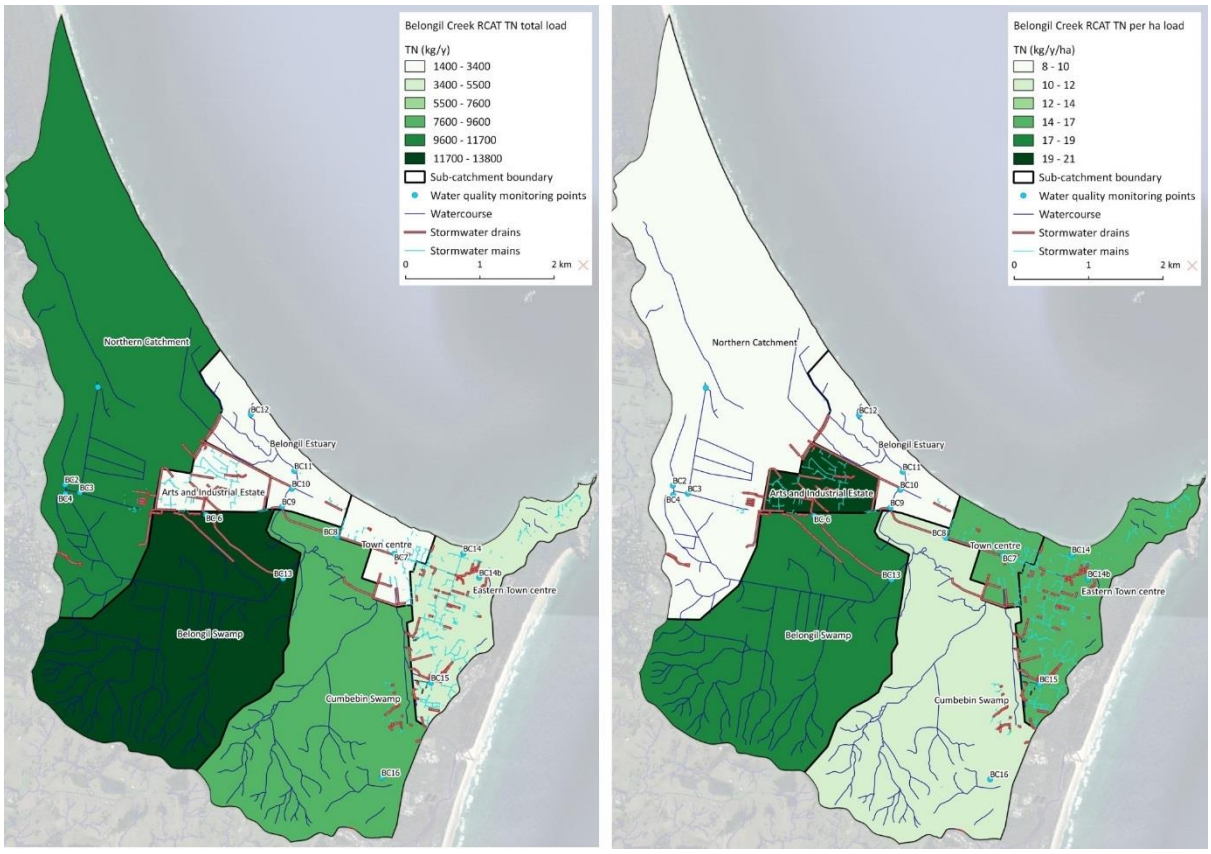


Figure 16. *RCAT modelling results for Total Nitrogen*

3.2 Eastern town centre

The Eastern town centre sub-catchment incorporates the Cape Byron State Conservation Park in the north-east, a Byron Bay residential area in the south and the town centre east of Jonson and Middleton Street. While the land east of railway line would naturally drain west toward the Belongil estuary, the railway embankment, ground levels and limited hydraulic gradient generally don't allow this to occur efficiently. A pipeline diverts some of the runoff near the Byron Bay playing fields towards Clarkes Beach.

Some of the key major issues/threats identified in the sub-catchment include:

1. Very low hydraulic gradient and capacity of existing town drainage system (estimated capacity <1-year ARI)
2. Movement of poor quality stormwater into the Belongil estuary and beach zone/ocean via Town Drain and out of the Clarkes Beach outlet
3. Drainage and drain maintenance issues within coastal wetlands
4. Illegal camping and littering.

A summary of the Eastern town centre sub-catchment features, values and conditions are presented in Figure 17 and major issues and threats are presented in Figure 18.

3.3 Town centre

The Town centre sub-catchment incorporates the town centre east of the railway line and west of Middleton and Jonson Street as well as the residential areas around Shirley Street and Butler Street Reserve west of the railway line. While the sub-catchment is dominated by urban residential and commercial land uses, there are some important areas of residual native vegetation cover including the Butler Street Reserve and the dune area north of the railway line.

Some of the key major issues/threats identified in the sub-catchment include:

1. Very low hydraulic gradient and capacity of existing town drainage system (estimated capacity <1-year ARI)
2. Movement of poor-quality stormwater via drains into estuary
3. Illegal camping and littering.

A summary of the Town centre sub-catchment features, values and conditions are presented in Figure 19 and major issues and threats are presented in Figure 20.

Eastern town centre

Overview/drainage

The Eastern town centre sub-catchment incorporates the Cape Byron State Conservation Park in the north east, a Byron Bay residential area in the south and the town centre east of Jonston and Middleton Street. While the land east of railway line would naturally drain west toward the Belongil estuary, the railway embankment (Photo 3), ground levels and limited hydraulic gradient generally don't allow this to occur efficiently. A pipeline diverts some of the runoff near the Byron Bay playing fields towards Clarkes Beach. Floodwaters from the catchment generally drain northward via the Clarkes Beach outfall (Photo 4). In major flood events water rises east of Middleton Street and flows into the town centre

Ecological values

- Cape Byron State Conservation Park situated in the north east of the sub-catchment
- Arakwal National Park borders the east of the sub-catchment
- Includes a coastal wildlife corridor linking the dunes around Clarkes Beach with the Arakwal National Park. The south eastern portion of the catchment provides a wildlife corridor that borders an SEPP coastal wetland and eventually links into Cumbebin Swamp Nature Reserve
- Flying fox camp adjacent to Middleton Street
- Pockets of preferred koala habitat throughout the sub-catchment
- Areas of North Coast Clay Heathlands
- Limited natural watercourses within the sub-catchment, generally limited to within the national parks. Photo 2 shows a stream in relatively good condition with a structurally diverse suite of native vegetation that drains an area east of Paterson Street toward a small wetland within the Arakwal National park
- Open drains around Cowper Street tend to be overgrown with vegetation (Photo 1)

Water quality

- RCAT model results suggests relatively high TSS loads generated from the sub-catchment. While the total loads were fourth highest in the catchment the relative size compared to the other sub-catchments contributes to it yielding the second highest per ha load
- Similar trends can be seen in relation to TN,TP and E.coli loads
- High proportion of the catchment is urbanised resulting in efficient runoff generation due to the impervious surfaces, but the receiving environment is inefficient
- Pathways to the two ocean release points (Clarkes Beach outfall and Belongil estuary via Town drain) with limited treatment
- Poor sediment control and unregulated dewatering from construction sites also poses a threat to water quality within the sub-catchment
- Potential illegal cross-connections between stormwater and sewer, requires further investigation

Figure 17. *Eastern town centre sub-catchment summary*

Eastern town centre

Sub-catchment issues and threats

Movement of poor quality water out of Clarkes Beach outlet. Silting up of outlet can also affect flows

Coastal erosion hazard

Illegal camping and dumping

Movement of poor quality water into Town drain and ultimately Belongil estuary and beach

Climate change likely to lead to greater intensity, duration and frequency of storm events. Sea level rise increasing risk of flooding and storm surges

Proposed preferred drainage strategy option to increase drainage network and drain to a large wetland/retention basin and double the existing capacity of the Clarkes Beach drain

Insufficient capacity of existing town drainage system (estimated capacity <1 year ARI)

Mosquito/midge management

Risk of transport of acid discharge from the oxidization of ASS if disturbed

Drainage and drain maintenance issues within coastal wetlands

Introduced plants (primarily around the frontal dunes, boundaries and tracks due to dumping, garden escapees and drainage)

Inappropriate fire regimes threatening North coast clay heathlands

Introduced animals (fox, cane toad, wild dog, feral cat)

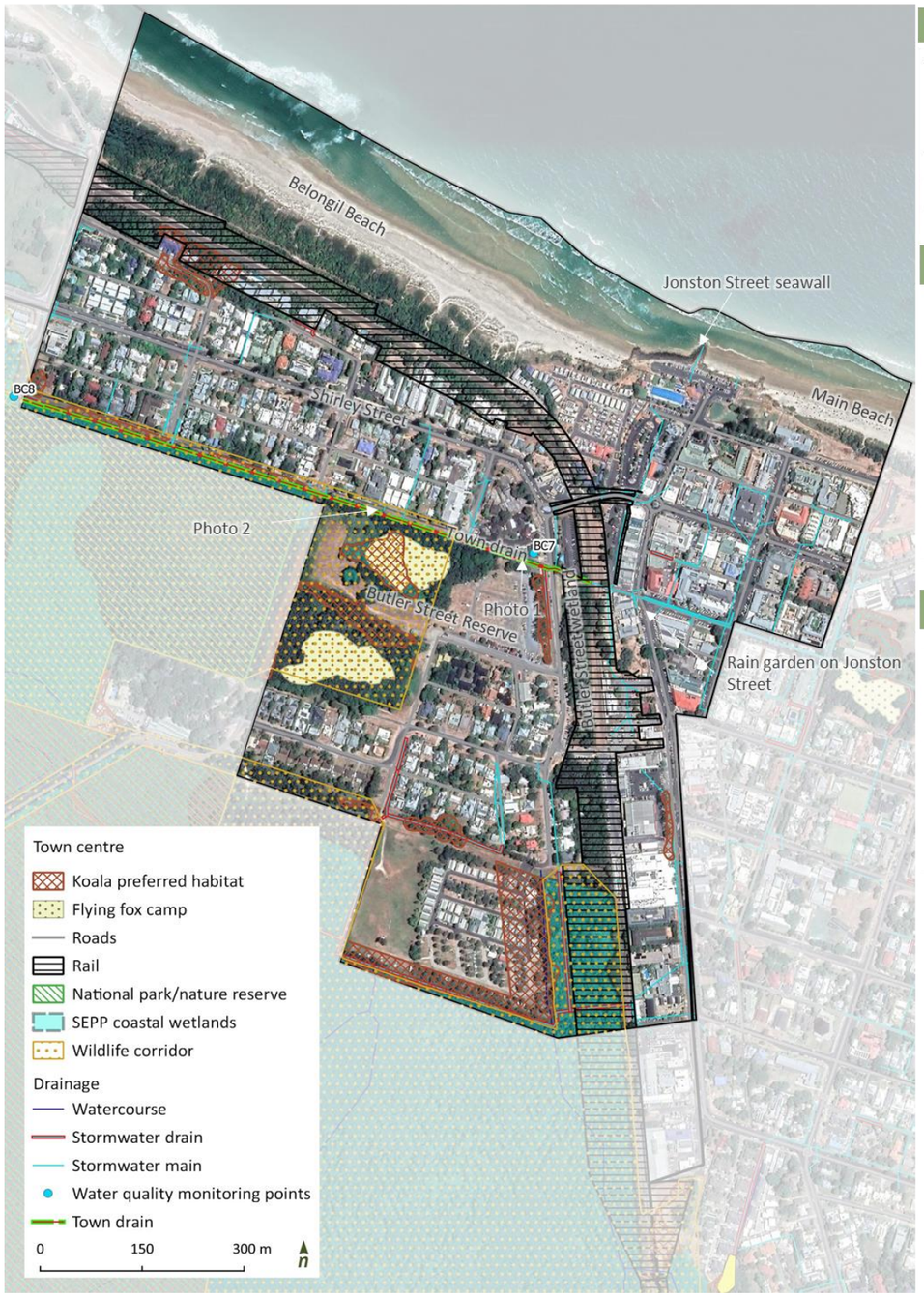
Illegal development - properties renting out illegal structures or overloading capacity of dwellings putting strain on sewer system particularly in peak holiday periods

Illegal stormwater/sewer cross connections

Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

Figure 18. *Eastern town centre sub-catchment issues and threats*

Town centre



Overview/drainage

The Town centre and Shirley Street sub-catchment incorporates the town centre east of the railway line and west of Middleton and Jonston Street as well as the residential areas around Shirley Street and Butler Street Reserve west of the railway line. The stormwater from the town centre drains westward under the railway embankment via the Town drain (Butler Street drain) and a set of culverts south of the woolworths complex. The Shirley Street residential area is drained by the Butler Street drain that conveys the water through to the Belnogil estuary. The capacity of the existing stormwater drainage system including the Town drain is limited by the hydraulic gradient and ultimately controlled by the Belongil estuary water level and entrance conditions. Flood levels are determined by catchment runoff and tailwater conditions.

Ecological values

- Butler Street Reserve sits at the eastern edge of the Cumbebin Swamp Nature Reserve and provides an important coastal wildlife corridor between Belongil estuary, Cumbebin swamp and eventually further west into SEPP coastal wetlands
- Butler Street wetland sits between Butler Street and the rail embankment
- Important dune system between the railway line and Belongil Beach
- Flying Fox camp in the Butler Street Reserve
- Preferred koala habitats areas adjacent to the railway and Butler Street Reserve
- Town drain overgrown with weeds in some locations (Photo 1). The right bank generally has a graded planar morphology with open grassland vegetation up to the road embankment while the left bank is densely vegetated and extends into the Cumbebin swamp (Photo 2)

Water quality

- RCAT model results suggests relatively low total TSS, TN, and TP loads generated from the sub-catchment but due to relatively small catchment size, the per ha loads are estimated second highest in the catchment.
- Urban, commercial and roads are the dominant land uses within the sub-catchment resulting in efficient runoff generation due to the impervious surfaces
- Efficient pathway to Belongil estuary via Town drain with limited treatment
- Poor sediment control and unregulated dewatering from construction sites also poses a threat to water quality within the sub-catchment
- Potential illegal cross-connections between stormwater and sewer, requires further investigation
- Potential poor quality ground water leached from old dump site

Figure 19. *Town centre sub-catchment summary*

Town centre

Sub-catchment issues and threats

Coastal erosion hazard

Movement of poor quality water via drains into estuary

Proposed preferred drainage strategy option to build protective levee within the Byron Street Reserve between Cavvanbah Street and Kendal Street. Four pump stations and underground drainage system required to convey water to pump stations

Threats to Flying fox camp through loss of habitat

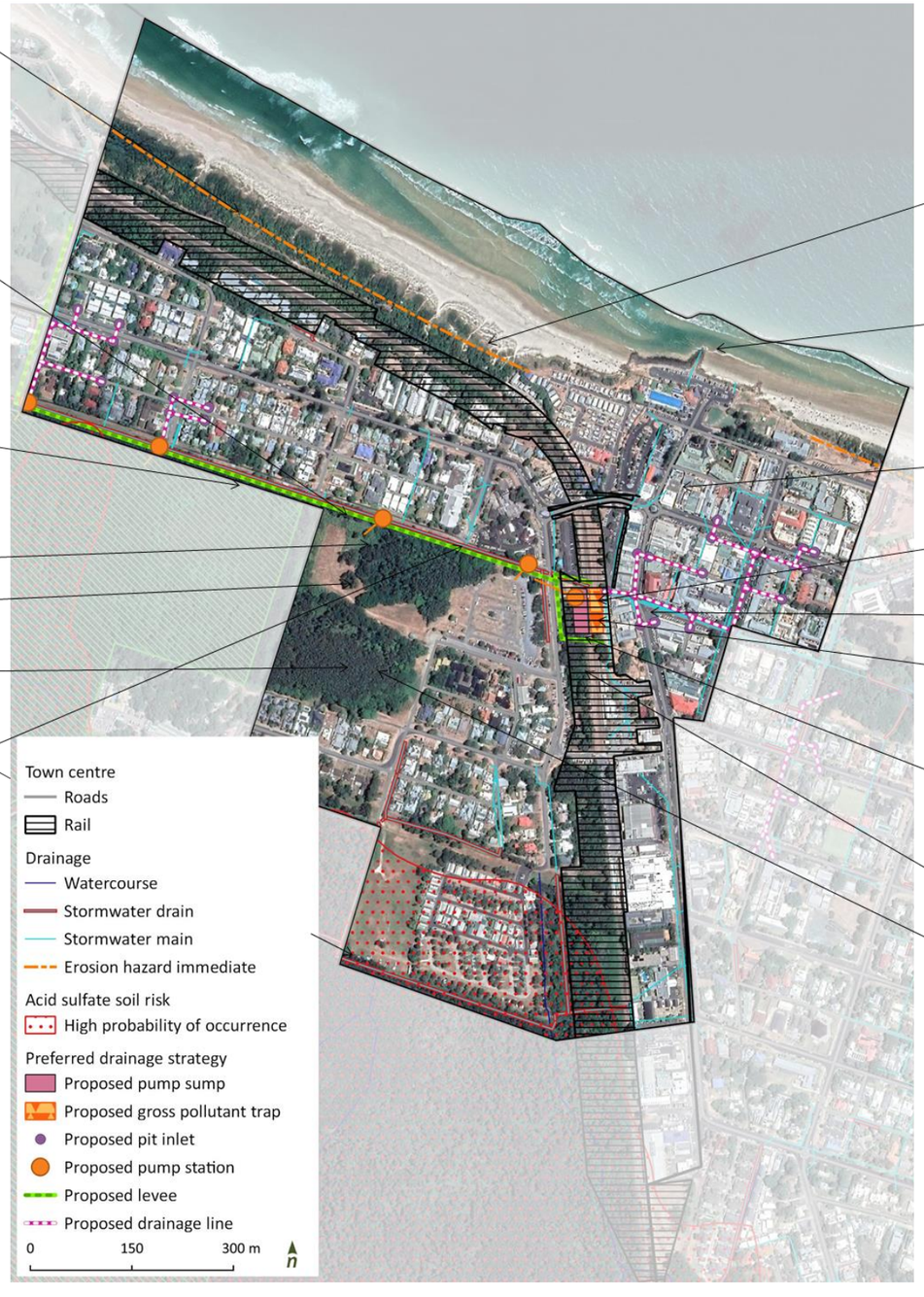
Contaminated leachate from old dump site

Introduced plants (primarily around the frontal dunes, boundaries and tracks due to dumping, garden escapees, grazing and drainage)

Drains constricted by sediment and vegetation build up

Illegal camping and dumping throughout catchment

Illegal development - properties renting out illegal structures or overloading capacity of dwellings putting strain on sewer system particularly in peak holiday periods



Potential overland flows entering sewerage pump stations

Climate change likely to lead to greater intensity, duration and frequency of storm events. Sea level rise increasing risk of flooding and storm surges

Jonson Street sea wall and adhoc erosion control structures influencing shoreline change through downdrift erosion effects

Insufficient hydraulic gradient and capacity of existing town drainage system (estimated capacity <1 year ARI)

Gross Pollutant Trap (GPT) relatively ineffective

Sediment control and dewatering from construction sites

Draft proposal for wetland site

Proposed preferred drainage strategy option to provide collection of the 10 year ARI flowrate in underground drainage system conveyed to a pump station west of the railway line. The pump station would be surrounded by a levee built to 3m AHD to prevent backflow from ocean.

Butler Street bypass to be constructed

Introduced animals (fox, cane toad, wild dog, feral pig and cat)

Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

Figure 20. *Town centre sub-catchment issues and threats*

3.4 Belongil estuary

The Belongil estuary sub-catchment extends from Ewingsdale Road to the estuary entrance at Belongil Beach. It incorporates a residential area extending north of the railway line along the Belongil Spit, the Big 4 Caravan Park between Ewingsdale Road and the railway and Elements Resort in the north west. There are significant areas of Coastal Wetlands and remnant pockets of Littoral Rainforest near the estuary entrance. The sub-catchment includes the major outfall for the greater catchment, the Belongil estuary. The estuary level is a key control of upstream waterway condition and processes and is itself impacted to varying degree by all the other sub-catchments.

Some of the key major issues/threats identified in the sub-catchment include:

1. Movement of poor quality water via drains into estuary from both urban and agricultural areas including acid runoff
2. Erosion of the northern bank of the estuary threatening littoral rainforest
3. Erosion of the northern bank of the estuary adjacent to Elements Resort

A summary of the Belongil estuary sub-catchment features, values and conditions are presented in Figure 21 and major issues and threats are presented in Figure 22.

3.5 Arts and Industrial Estate

The Arts and Industrial Estate sub-catchment supports predominately commercial and industrial land use in the western portion and residential land in the north. There is a significant area of coastal swamp forest east of Sunrise Boulevard which includes primary koala habitat and provides an important coastal wildlife corridor. in the east. Stormwater is generally conveyed via the Industrial Estate Drain that flows in a south easterly direction downstream of Ewingsdale Road, eventually entering the Union Drain before it reaches Belongil Creek.

Some of the key major issues/threats identified in the sub-catchment include:

1. Poor stormwater quality associated with runoff from industrial areas and roads
2. Movement of poor quality water via Industrial Estate Drain into estuary
3. Flash flooding of streets within the Arts and Industrial Estate

A summary of the Arts and Industrial Estate sub-catchment features, values and conditions are presented in Figure 23 and key major issues and threats are presented in Figure 24.

Belongil estuary

Overview/drainage

The Belongil estuary sub-catchment extends from Ewingsdale Road to the estuary entrance at Belongil Beach. It incorporates a residential area extending north of the railway line onto the Belongil spit, the Big 4 caravan park between Ewingsdale Road and the railway and Elements Resort in the north west. Water levels in the estuary are primarily controlled by the estuary entrance condition. When open, the estuary is tidally influenced at levels ranging between ≈ 0.2 and 0.8m AHD (Photo 1). When closed, water levels can rise up to ≈ 1m AHD at which time the entrance is mechanically opened to reduce the risk of flooding.

Ecological values

- Significant ecological values within and surrounding the estuary
- Migratory shorebird habitat and nesting area (Photo 4)
- SEPP coastal wetlands
- Pockets of littoral rainforest
- Preferred koala habitat areas on the southern side of the estuary
- Coastal wildlife corridor extending to Tyagarah Nature Reserve in the north and Cumbebin swamp in the south
- Vegetation condition surrounding the estuary is predominately considered to be in good condition, with areas of salt marsh, mangroves and littoral rainforest.
- Limited riparian buffer exists on the eastern bank between the railway bridge and Childe Street, some erosion of the right bank present around the Chlide/Manfred Street intersection.
- Some bank erosion of the western bank adjacent to the area of littoral rainforest (Photo 2) as well as the northern bank adjacent to Elements Resort (Photo 3)

Water quality

- RCAT model results suggests the sub catchment is the lowest contributor of both total and per ha loads for all modelled constituents. This is a result of the relatively high proportion of the sub-catchment being water, conservation or green space
- Pollutants from surrounding land uses may have a significant impact on the overall water quality of the Belongil estuary and beach given proximity
- Water quality within the estuary heavily influenced by upstream contributions from all other sub-catchments

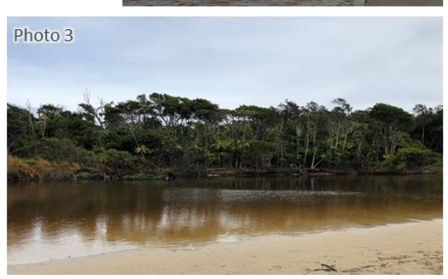


Figure 21. *Belongil estuary sub-catchment summary*

Belongil estuary

Sub-catchment issues and threats

Coastal erosion hazard

Proposed expansion of Elements Resort

Erosion of the northern bank of the estuary adjacent to Elements Resort

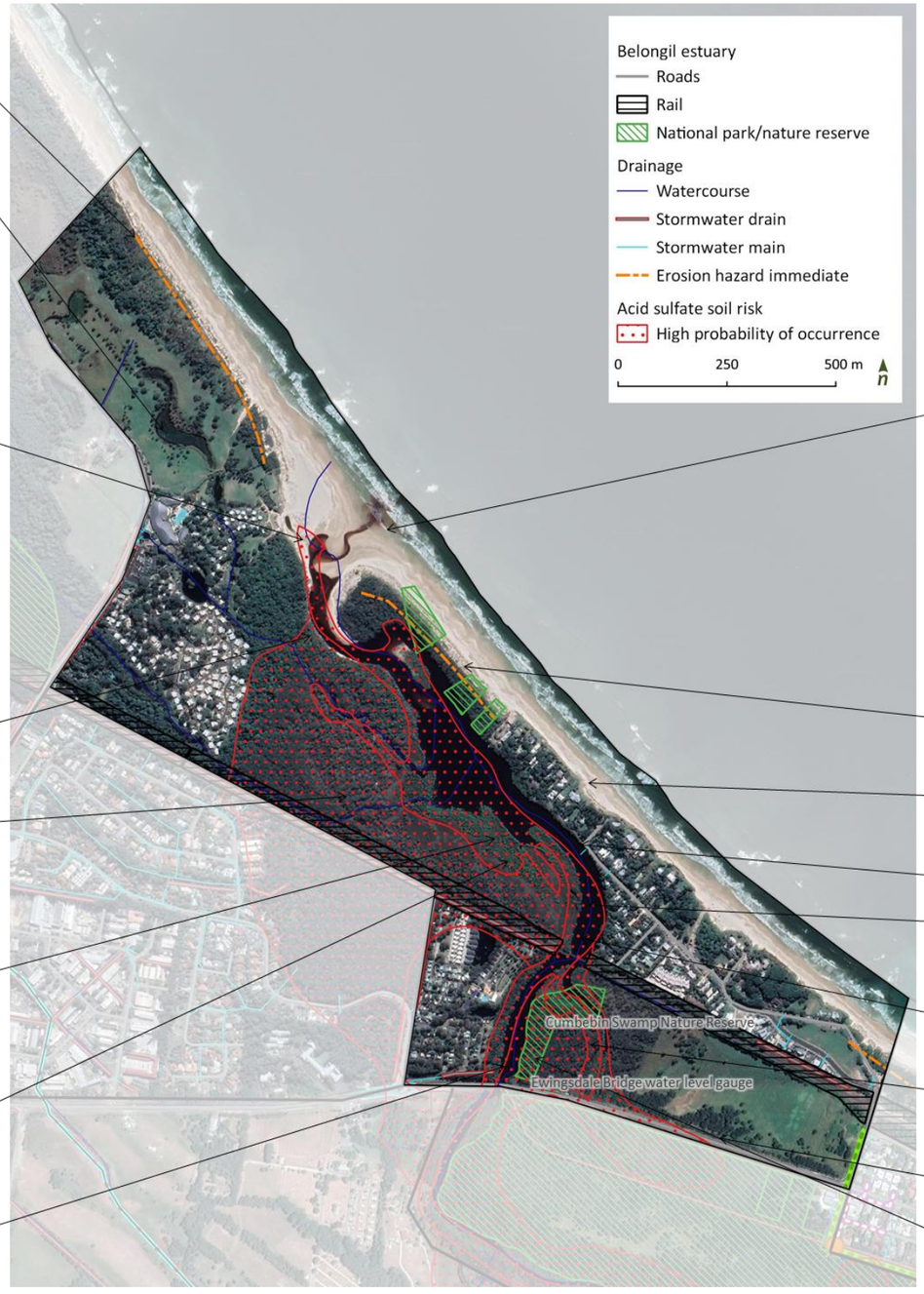
Erosion of the northern bank of the estuary threatening littoral rainforest

Introduced plants (primarily around the frontal dunes, boundaries and tracks due to dumping, garden escapees, grazing and drainage)

Climate change likely to lead to greater intensity, duration and frequency of storm events

Protection of existing native flora and fauna assemblages within and surrounding the estuary

Movement of poor quality water via drains into estuary (blackwater events)



Illegal development - properties renting out illegal structures or overloading capacity of dwellings putting strain on sewer system particularly in peak holiday periods

Illegal camping and dumping throughout the catchment

Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

Sea level rise increasing risk of flooding and storm surges as well as impacting of estuary entrance conditions and processes

Potential breach of spit currently separating the estuary and beach

Adhoc erosion control structures influencing shoreline change through downdrift erosion effects

Bank erosion adjacent to Childe/Manfred Street

Fish kills in estuary and nearshore zone

Water quality in the estuary

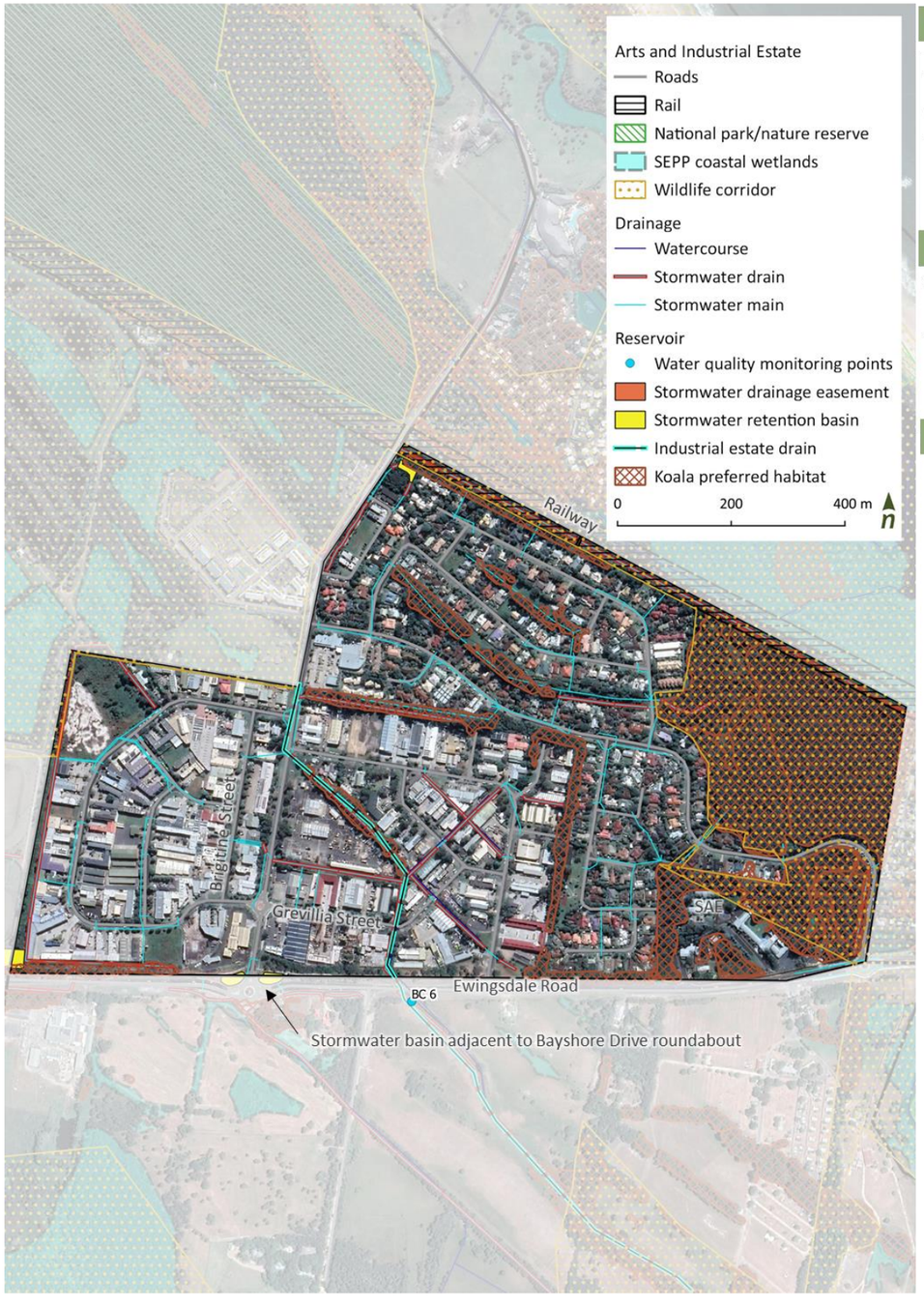
Risk of transport of acid discharge from the oxidization of ASS if disturbed

Formalisation of Ewingsdale Road drainage needs to be considered as a part of the roads duplication project

Introduced animals (fox, cane toad, wild dog, feral cat)

Figure 22. *Belongil estuary sub-catchment issues and threats*

Arts and Industrial Estate



Overview/drainage

Arts and Industrial Estate sub-catchment supports predominately commercial and industrial land use in the western portion and residential land in the north and an area of coastal swamp forest in the east. Stormwater is generally conveyed via the Industrial estate drain that flows in a south easterly direction downstream of Ewingsdale Road, eventually entering the Union drain before it reaches Belongil Creek. During flood events water can back up from Ewingsdale Road and inundate roads and private properties particularly around Grevilla Street and Brigatine Street.

Ecological values

- Coastal swamp forest acts as refuge and Wildlife corridor in the eastern side of the catchment. Includes significant areas of preferred koala habitat
- Predominately constructed drains throughout the catchment

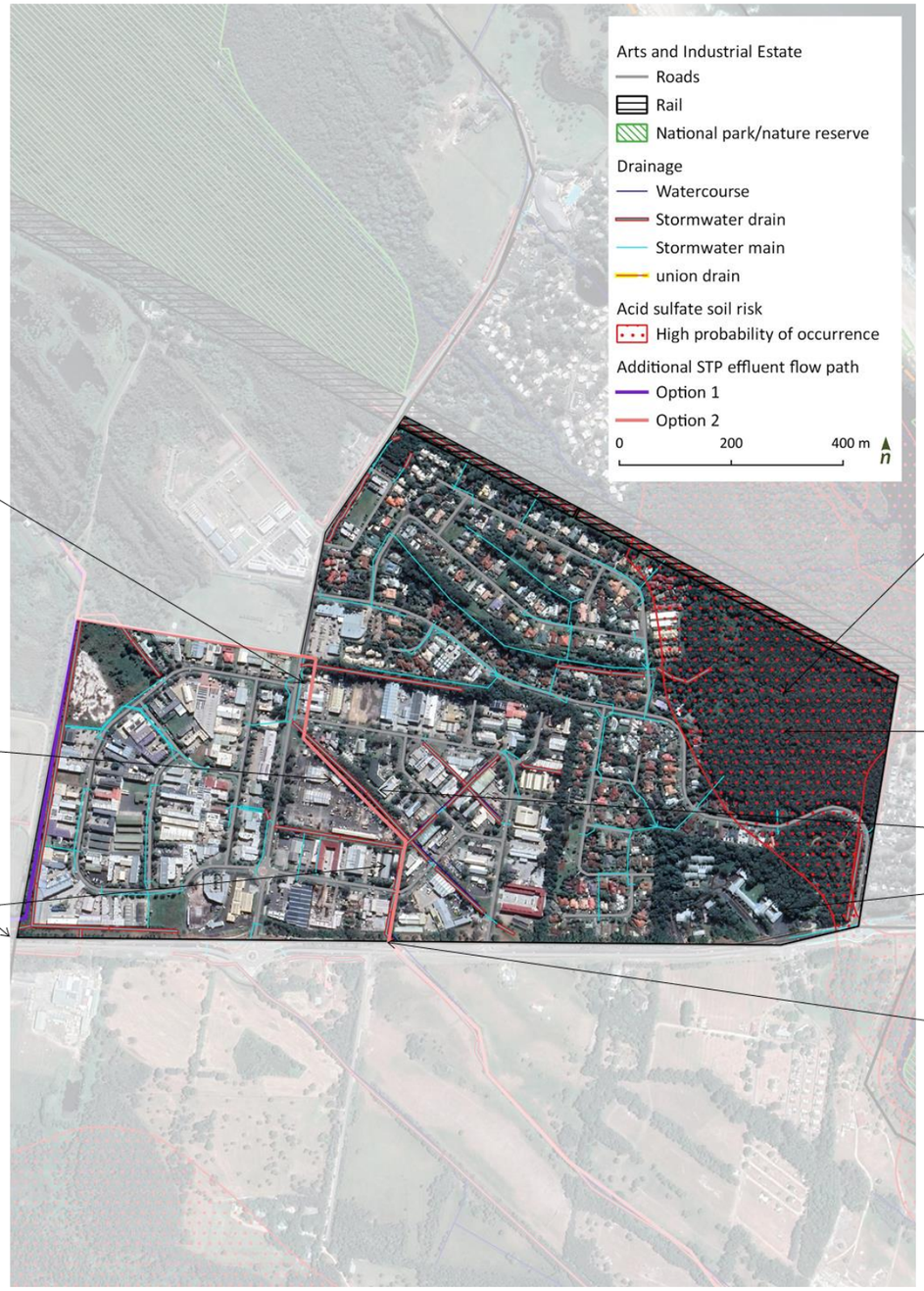
Water quality

- RCAT model results suggests relatively low total loads of all modelled constituents generated from the sub-catchment but due to relatively small catchment size and dominant land use, the per ha loads are estimated to be the highest in the catchment for all constituents except E.coli
- Industrial, urban, commercial and roads are the dominant land uses within the sub-catchment resulting in efficient runoff generation due to the impervious surfaces
- Efficient pathway to Belongil estuary and beach via Industrial estate drain with limited treatment
- Many potential point sources of pollutants within the sub-catchment due to the dominant land uses
- Potential illegal cross-connections between stormwater and sewer

Figure 23. *Arts and Industrial Estate sub-catchment summary*

Arts and Industrial Estate

Sub-catchment issues and threats



Illegal development - properties renting out illegal structures or overloading capacity of dwellings putting strain on sewer system particularly in peak holiday periods

Additional effluent release option 2 – release into the Industrial estate drain with some degree of discharge to continue through existing release point

Illegal dumping

Poor stormwater quality associated with runoff from industrial areas and roads

Formalisation of Ewingsdale Road drainage needs to be considered as a part of the road duplication project

Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

Introduced plants (primarily around the frontal dunes, boundaries and tracks due to dumping, garden escapees, grazing and drainage)

Risk of transport of acid discharge from the oxidization of ASS if disturbed

Increased flood risk associated with climate change and sea level rise

Onsite sewerage treatment at SAE College

Preferred drainage strategy recommends upgrading the existing pipe culverts under Ewingsdale Road in order to pass the 100 year ARI flow

Figure 24. *Arts and Industrial Estate sub-catchment issues and threats*

3.6 Cumbebin Swamp

The northern portion of the Cumbebin Swamp sub-catchment incorporates the Cumbebin Swamp Nature Reserve and surrounding SEPP Coastal Wetlands. South of the coastal wetlands is predominately agricultural land including livestock grazing and rural residential zones extending to the Hayters Hill escarpment. The Byron Bay golf course also sits in the south-eastern corner of the sub-catchment.

Some of the key major issues/threats identified in the sub-catchment include:

1. Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)
2. Agricultural land use such as livestock and horticulture increasing nutrient loads to downstream receiving waters
3. Introduced animals (fox, cane toad, wild dog and feral cat) and Introduced plants (primarily around the boundaries and tracks due to dumping, garden escapees, grazing and drainage)
4. Low lying land susceptible to inundation, likely to worsen with sea level rise

A summary of the Cumbebin Swamp sub-catchment features, values and conditions are presented in Figure 25 and key major issues and threats are presented in Figure 26.

3.7 Belongil Swamp

The Belongil Swamp sub-catchment is predominately agricultural land used for grazing livestock and for rural residential living. Flows drain from the south western escarpment toward the Union Drain that then conveys flows to the east adjacent to a SEPP Coastal Wetland. Land in the north of the sub-catchment between the coastal wetland and Ewingsdale Road is currently predominately used for grazing and also supports a recreational ground and caravan park.

Some of the key major issues/threats identified in the sub-catchment include:

1. Poor drainage of low lying land, particularly between Ewingsdale Road and the Coastal Wetland
2. Potential impacts of proposed West Byron development including disturbing ASS, increased stormwater discharge, increased sewer discharge, construction in flood hazard zone, impacts on flora and fauna
3. Agricultural land use such as livestock and horticulture increasing nutrient loads to downstream receiving waters
4. High risk of transport of acid discharge from the oxidization of ASS
5. Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)
6. Low lying land susceptible to inundation, likely to worsen with sea level rise

A summary of the Belongil Swamp sub-catchment features, values and conditions are presented in Figure 27 and key major issues and threats are presented in Figure 28.

3.8 Northern catchment

The Northern catchment is dominated by the Pleistocene barrier ridges that lie within the Tyagarah Nature Reserve north of the railway line. South of the railway is predominately used for grazing livestock and also supports the West Byron STP and BBIWMR which is situated between the railway and Ewingsdale Road. A network of constructed drains including the main arm of the Union Drain coveys flows in a southerly direction before flowing to the east into the Belongil Swamp sub-catchment.

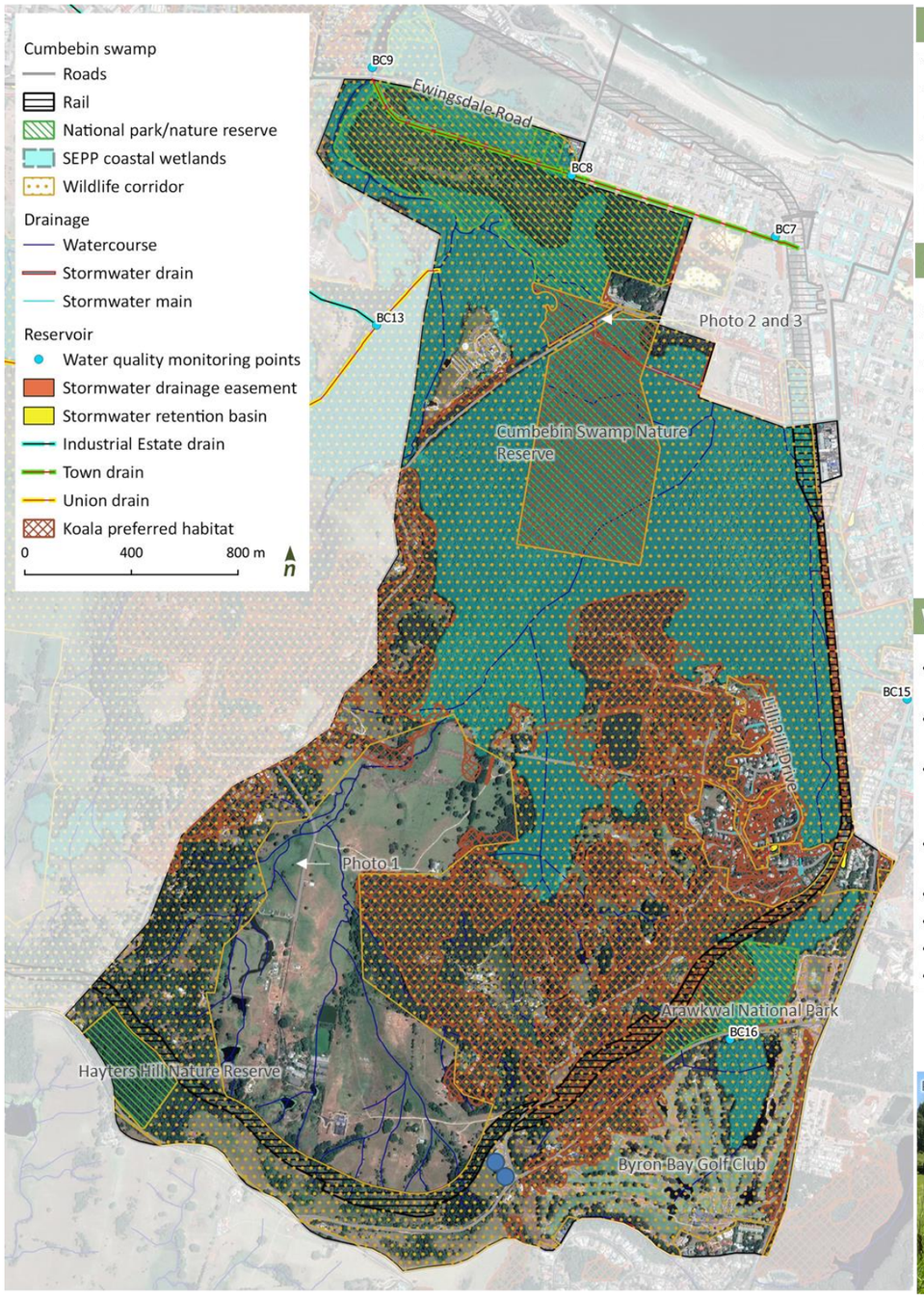
Some of the key major issues/threats identified in the sub-catchment include:

1. Movement of poor quality water via drains into estuary
2. Agricultural land use such as livestock and horticulture increasing nutrient loads to downstream receiving waters
3. Potential increase in water table in land surrounding the BBIWMR resulting in increased frequency, extent and depth of surface water inundation and associated impacts on landholders
4. High risk of transport of acid discharge from the oxidization of ASS
5. Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

   Low lying land susceptible to inundation, likely to worsen with sea level rise.

A summary of the Northern sub-catchment features, values and conditions are presented in Figure 29 and key major issues and threats are presented in Figure 30.

Cumbebin swamp



Overview/drainage

The Cumbebin swamp sub-catchment incorporates the Cumbebin Swamp Nature Reserve and surrounding SEPP coastal wetland in the north and predominately agricultural land extending from the Hayters Hill escarpment in the south to the coastal wetlands. The Byron Bay golf course also sits in the south eastern corner of the sub-catchment. Two main feeder tributaries presently drain into the Belongil Creek estuary upstream of Ewingsdale Road in the north of the sub-catchment. One tributary extends upstream towards the south east, draining the southern extents of Cumbebin Swamp and the southern agricultural area. The second tributary extends to the south, before connecting to the constructed "Union Drain" in the Belongil swamp sub-catchment.

Ecological values

- Cumbebin Swamp Nature Reserve in the north of the catchment
- Hayters Hill Nature Reserve in the south west
- Arakwal National Park adjacent to the golf course in the south east
- Significant portion of the sub-catchment zoned as SEPP 14 coastal wetlands
- Majority of the sub-catchment acts as a significant coastal wildlife corridor
- Significant areas of preferred koala habitat throughout the sub-catchment
- Waterways draining the agricultural land in the south are relatively small streams with relatively poor native riparian vegetation width and longitudinal connectivity (Photo 1)
- Waterways within the swamp are surrounded by significant native coastal swamp vegetation with evidence of introduced ground cover species near the road reserve (Photo 2 and Photo 3)

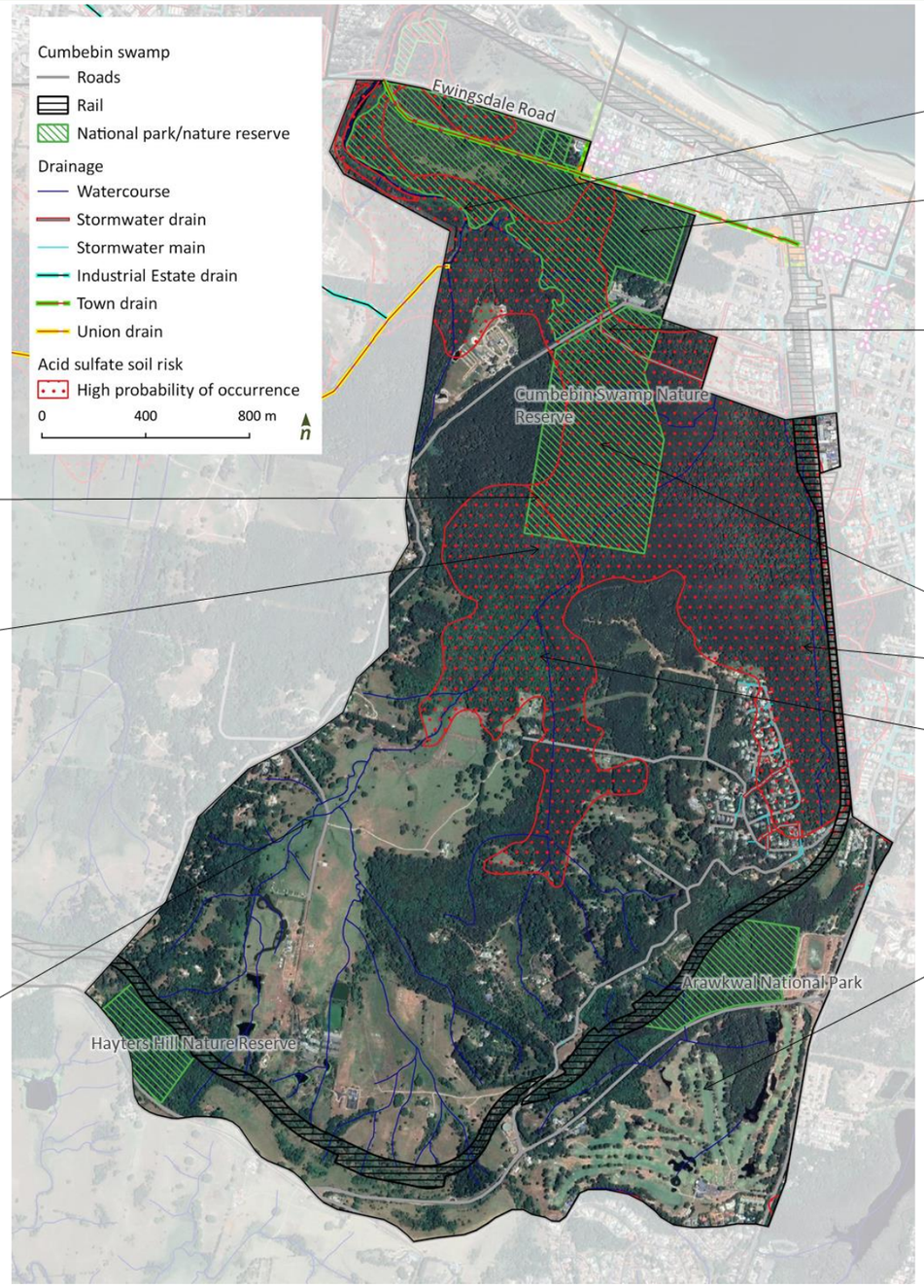
Water quality

- RCAT model results suggests relatively high total TSS, TN, and TP loads generated from the sub-catchment but due to due to the large size the per ha loads are relatively low
- The sub-catchment is estimated to be contributing the second highest total and per ha loads of E.coli. This is likely attributable to the relatively high proportion of rural residential and livestock land use
- Conservation (Cumbebin Swamp Nature Reserve) makes up a significant portion of the land use (≈ 41%), while the relative pollutant concentration of the modelled constituents is lower than that of rural residential or livestock land uses, the size of the area would result in higher loads
- Potential for flushing of acidic water and other associated products (e.g. Monosulfidic Black Ooze, Iron (Fe) etc.) from the oxidization of ASS
- Potential for significant blackwater events associated with the decay of organic material in standing water bodies
- Potential impacts from fertilizers, pesticides and herbicides applied to golf course and other agricultural enterprises
- Potential illegal cross-connections between stormwater and sewer
- Pathway to Belongil estuary via Town drain with limited treatment

Figure 25. *Cumbebin swamp sub-catchment summary*

Cumbebin swamp

Sub-catchment issues and threats



Increased land inundation due to sea level rise

Illegal camping and dumping throughout the catchment

Introduced animals (fox, cane toad, wild dog, feral cat)

Climate change (likely to lead to greater intensity, duration and frequency of fires, more severe droughts and storms and increased regional flooding

Agricultural land use such as livestock and horticulture increasing nutrient loads to downstream receiving waters

Illegal development - properties renting out illegal structures or overloading capacity of dwellings putting strain on sewer system particularly in peak holiday periods

Movement of poor quality water via drains into estuary (blackwater events)

Introduced plants (primarily around the frontal dunes, boundaries and tracks due to dumping, garden escapees, grazing and drainage)

Sand mining tailings (potentially radioactive sand mining tailings was used as fill between the 30's-70's in numerous locations around Byron, these were generally removed from urban areas following investigation in the 80's but anectdotal evidence has suggested some tailings may have been dumped around Skinner Shoot Road near the southern part of Cumbebin Swamp Nature Reserve)

Inappropriate fire regimes (increased frequency of fires)

Maintenance of drainage network within coastal wetlands and around railway

Risk of transport of acid discharge from the oxidization of ASS if disturbed

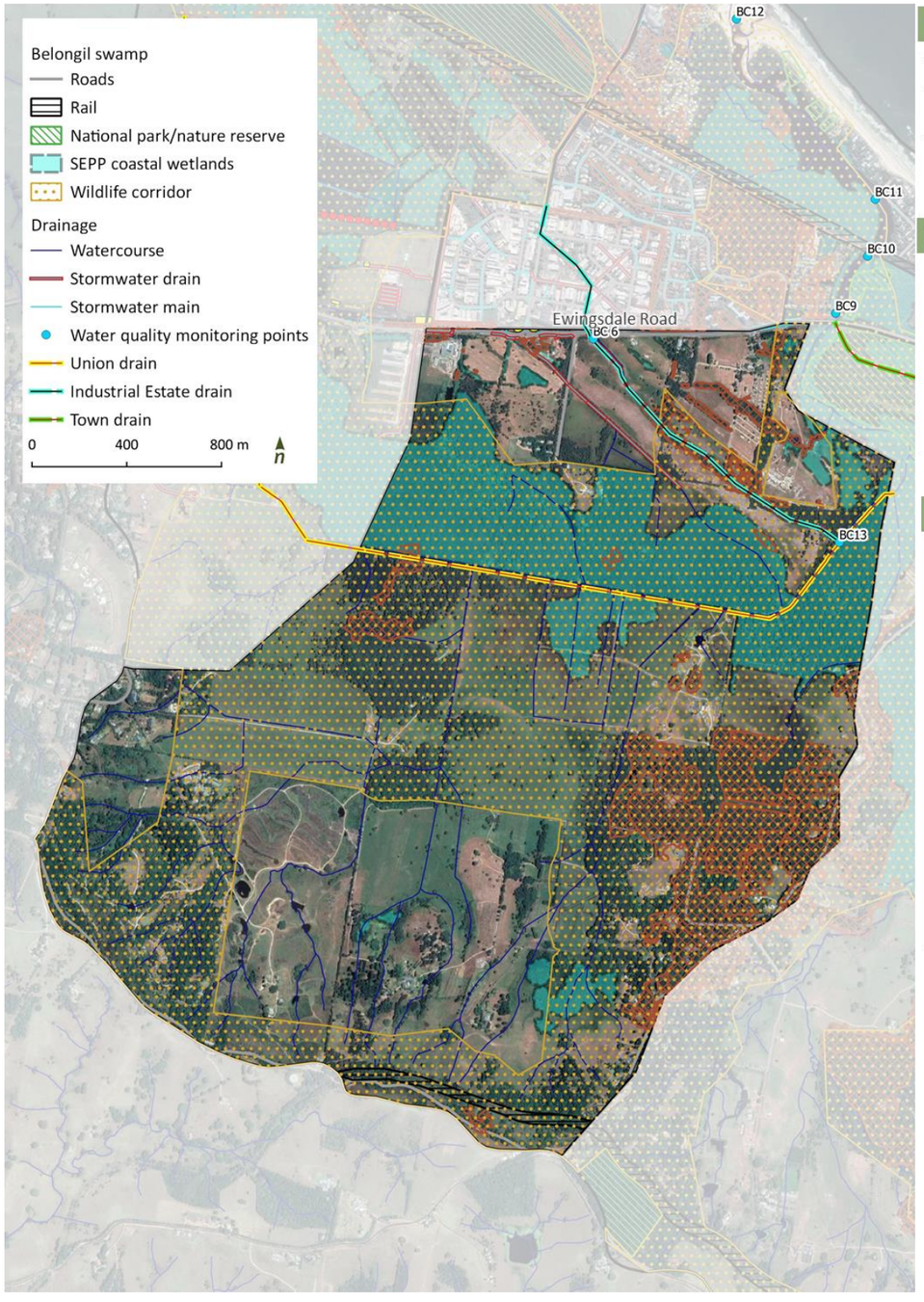
Potential pesticide and fertiliser runoff from golf course requires further investigation

Alterations in bushfire zone mapping potentially leading to land management changes

Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

Figure 26. *Cumbebin swamp sub-catchment issues and threats*

Belongil swamp



Overview/drainage

The Belongil swamp sub-catchment is predominately agricultural land of Ewingsdale, Mcleods Shoot and Skinners Shoot that drain the south western escarpment toward the Union drain that conveys flows to the east along side an SEPP 14 coastal wetland. Agricultural land south of Ewingsdale Road is drained toward the coastal wetland area and the main drain from the Arts and Industrial estate dissects the catchment in the north eastern corner before entering the union drain and ultimately Belongil Creek.

Ecological values

- Significant portion of the lower sub-catchment zoned as SEPP 14 coastal wetlands
- Significant wildlife corridor extending between the swamps and wetlands and ultimately the coast
- Area of primary koala habitat along the lower portion of the Industrial Estate drain and significant areas of tertiary habitat particularly around the SEPP 14 coastal wetlands
- Waterways draining the agricultural land in the south are relatively small streams with relatively poor native riparian vegetation width and longitudinal connectivity
- Minor drain draining the Ewingsdale Road reserve and crossing Melaleuca Drive. The drain is overgrown with vegetation and filled with sediment

Water quality

- RCAT model results suggest that the sub-catchment is the highest contributor to total loads for all modelled constituents but only the highest per ha load for E.coli
- This is likely attributable to the large size of the sub-catchment and relatively high proportion of land used for livestock production and rural residential living. Conservation also makes up a notable portion of land use which has a lower relative pollutant concentration of the modelled constituents than the other dominant land uses
- Potential for flushing of acidic water and other associated products (e.g. MBO's, Fe etc.) from the oxidization of ASS
- Potential for significant blackwater events associated with the decay of organic material in standing water bodies
- Potential impacts from fertilizers, pesticides and herbicides applied to agricultural enterprises
- Proposed West Byron development would significantly increase proportions of urban, commercial and road land use within the sub-catchment which would likely increase the relative loads of each of the constituents and change the dynamics of the Belongil ICOLL
- Potential illegal cross-connections between stormwater and sewer
- Pathway to Belongil estuary via Union drain with limited treatment

Figure 27. *Belongil swamp sub-catchment summary*

Belongil swamp

Sub-catchment issues and threats

Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

Illegal development - properties renting out illegal structures or overloading capacity of dwellings putting strain on sewer system particularly in peak holiday periods

Illegal camping and dumping throughout the catchment

Increased land inundation due to sea level rise

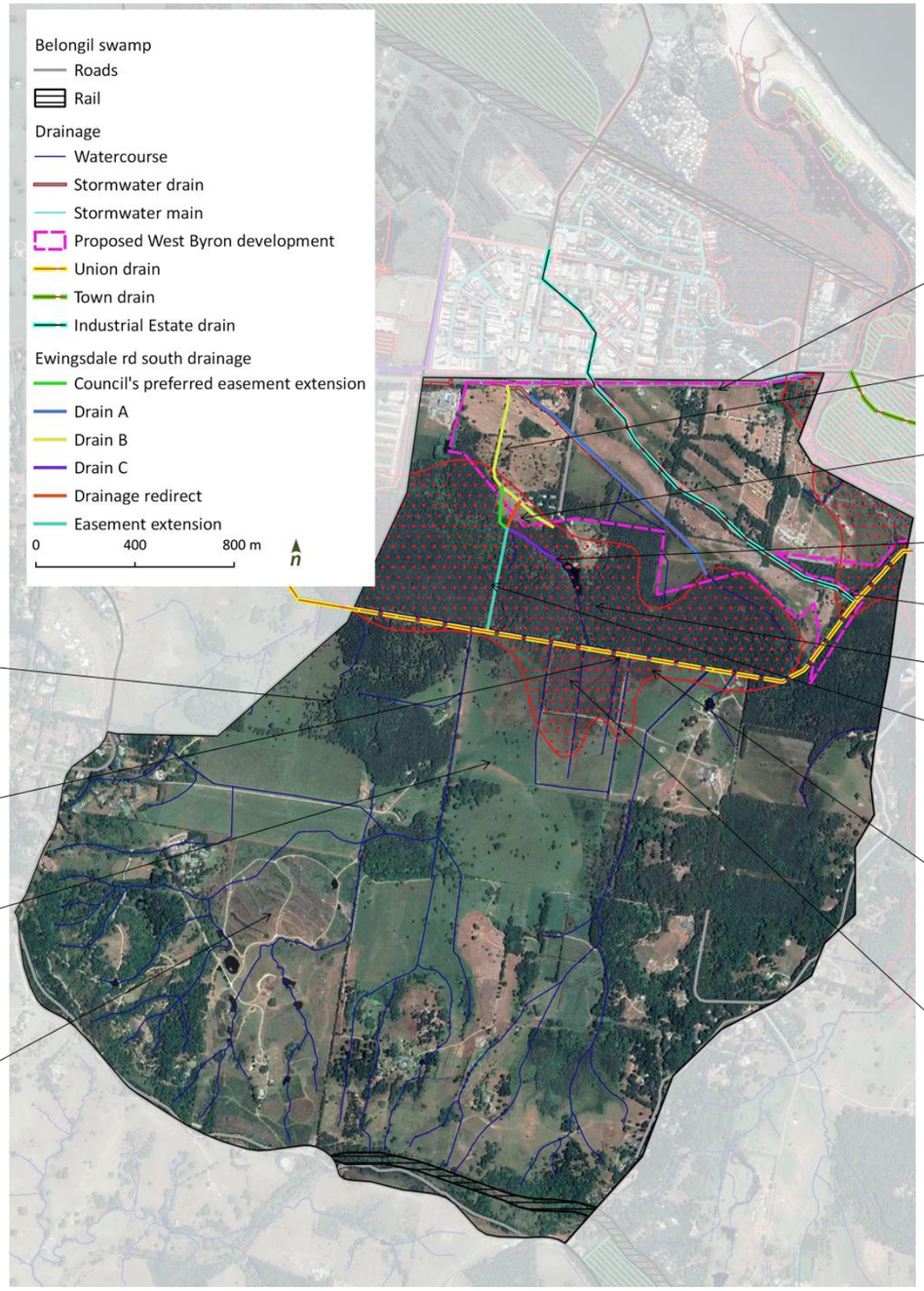
Introduced plants (primarily around boundaries and tracks due to dumping, garden escapees, grazing and drainage)

Introduced animals (fox, cane toad, wild dog, feral cat)

Movement of poor quality water via drains into estuary (blackwater events)

Climate change (likely to lead to greater intensity, duration and frequency of fires, more severe droughts and storms and increased regional flooding

Private wetland construction ongoing by land owner



Formalisation of Ewingsdale Road drainage needs to be considered as a part of the duplication project. Appropriate trunk flowpaths to be identified and legalised withy easements

Impacts of proposed West Byron development including disturbing ASS, increased stormwater discharge, increased sewer discharge, construction in flood hazard zone, impacts on flora and fauna

Existing council drainage easement

Poor drainage of low lying land adjacent to Melaleuca Drive. Drain redirected to allow for land owners waste water treatment system. Redirect very inefficient and long term solution is required

Minor drainage depression linking land west of Melaleuca Drive with the coastal wetland

Last portion of drain from Industrial estate privately owned, may inhibit additional drainage strategy

Drainage and drain maintenance issues within coastal wetlands

Councils suggested easement extension would trigger EIS as construction is in SEPP coastal wetland

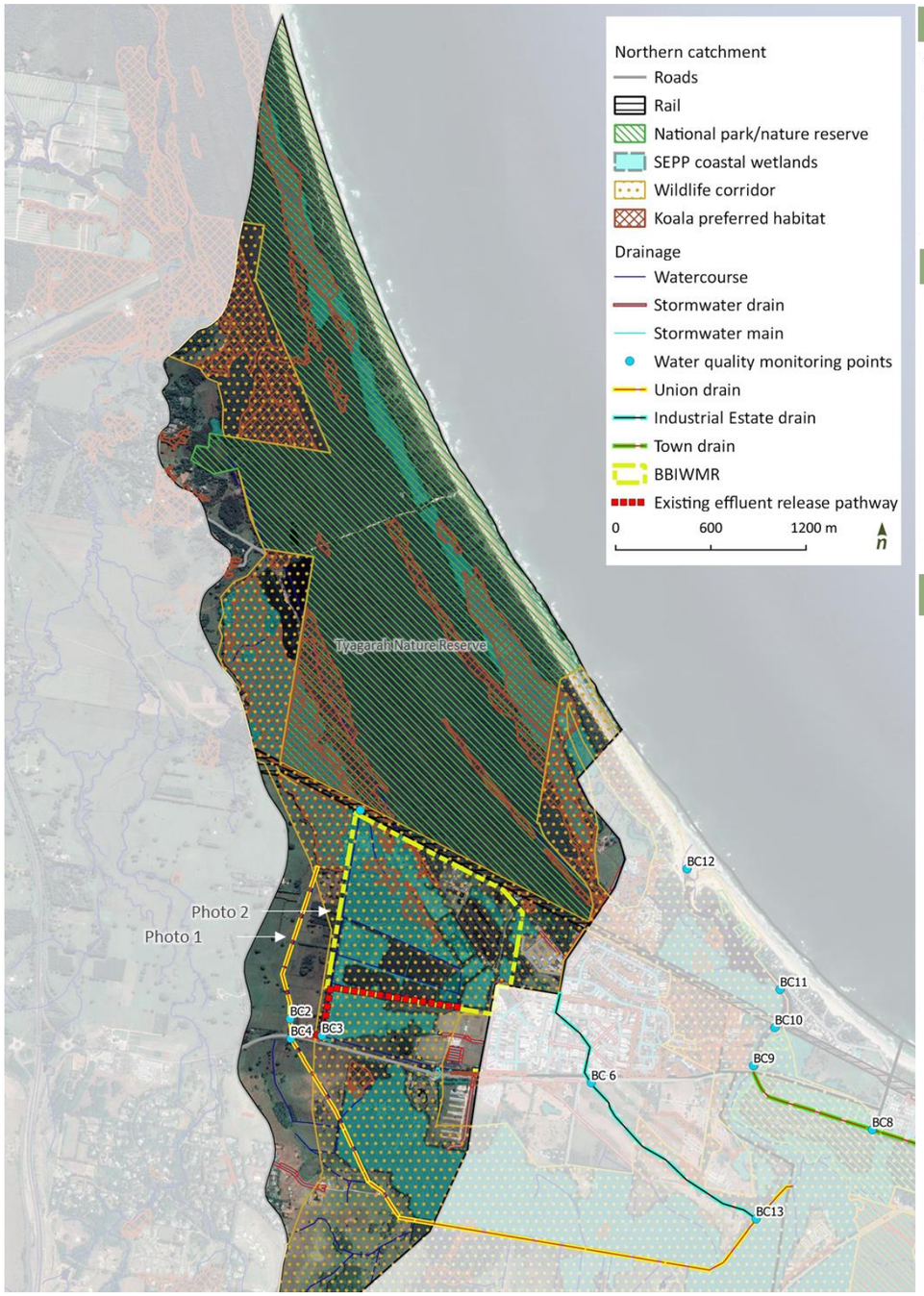
High risk of transport of acid discharge from the oxidization of ASS

Potential rise in groundwater level requires further investigation

Alterations in bushfire zone mapping potentially leading to land management changes

Figure 28. *Belongil swamp sub-catchment issues and threats*

Northern catchment



Overview/drainage

The northern catchment is dominated by the Pleistone barrier ridges that lie within the Tyagarah Nature reserve north of the railway line. A back-barrier depression west of the Pleistocene barrier ridges is drained by the Union drain in a southerly direction, crossing Ewingsdale Road before flowing east into the Belongil swamp sub-catchment. The south eastern extent of this depression is referred to by some sources as Belongil Swamp. The West Byron Sewerage Treatment Plant (WBSTP) and Byron Bay Integrated Water Management Reserve (BBIWMR) is situated between the railway and Ewingsdale Road. Increased inundation and water table issues have been raised by landowners in the sub-catchment.

Ecological values

- Tyagarah Nature Reserve makes up a large portion of the sub-catchment
- Significant areas of preferred Koala habitat within Tyagarah Nature Reserve and throughout the wildlife corridor
- Significant coastal wildlife corridor
- Significant portion of the sub-catchment zoned as SEPP 14 coastal wetlands
- Wetlands in the Byron Bay Integrated Water Management Reserve (BBIWMR) provide high value habitat, particularly for water birds as well as wildlife corridor between the SEPP 14 coastal wetlands and Tyagarah Nature Reserve
- Union drain congested with weed in many locations (Photo 1)
- Heavily vegetated on the western side within the BBIWMR, receiving significant irrigation from the treated effluent (Photo 2)

Water quality

- RCAT model results suggests relatively high total TSS, TN, and TP loads generated from the sub-catchment but due to due to the large size the per ha loads are relatively low
- Livestock production is the second most significant land use after conservation
- Conservation (Tyagarah Nature Reserve) makes up a significant portion of the land use (≈ 59%), while the relative pollutant concentration of the modelled constituents is lower than that of peri urban or livestock land uses, the size of the area would result in higher total loads
- Sub-catchment contains the STP and associated treatment wetlands
- Potential for flushing of acidic water and other associated products (e.g. MBO's, Fe etc.) from the oxidization of ASS
- Potential for significant blackwater events associated with the decay of organic material in standing water bodies
- Potential impacts from fertilizers, pesticides and herbicides applied to golf course and other agricultural enterprises
- Potential illegal cross-connections between stormwater and sewer
- Efficient pathway from the agricultural land south of the railway to Belongil estuary via Union drain with limited treatment. Less efficient pathway for the northern portion of the sub-catchment due the railway emabankment
- Pathway from STP to Union drain via several treatment wetlands

Figure 29. *Northern sub-catchment summary*

Northern catchment

Sub-catchment issues and threats

Increased land inundation due to sea level rise

Land clearing and future development (increased pressure on existing infrastructure, increased importing of water, increased impervious surfaces etc.)

Introduced plants (primarily around the frontal dunes, boundaries and tracks due to dumping, garden escapees, grazing and drainage)

Illegal camping and dumping

Introduced animals (fox, cane toad, wild dog, feral pig and cat)

Potential hydraulic discontinuity of the northern catchment due to railway corridor

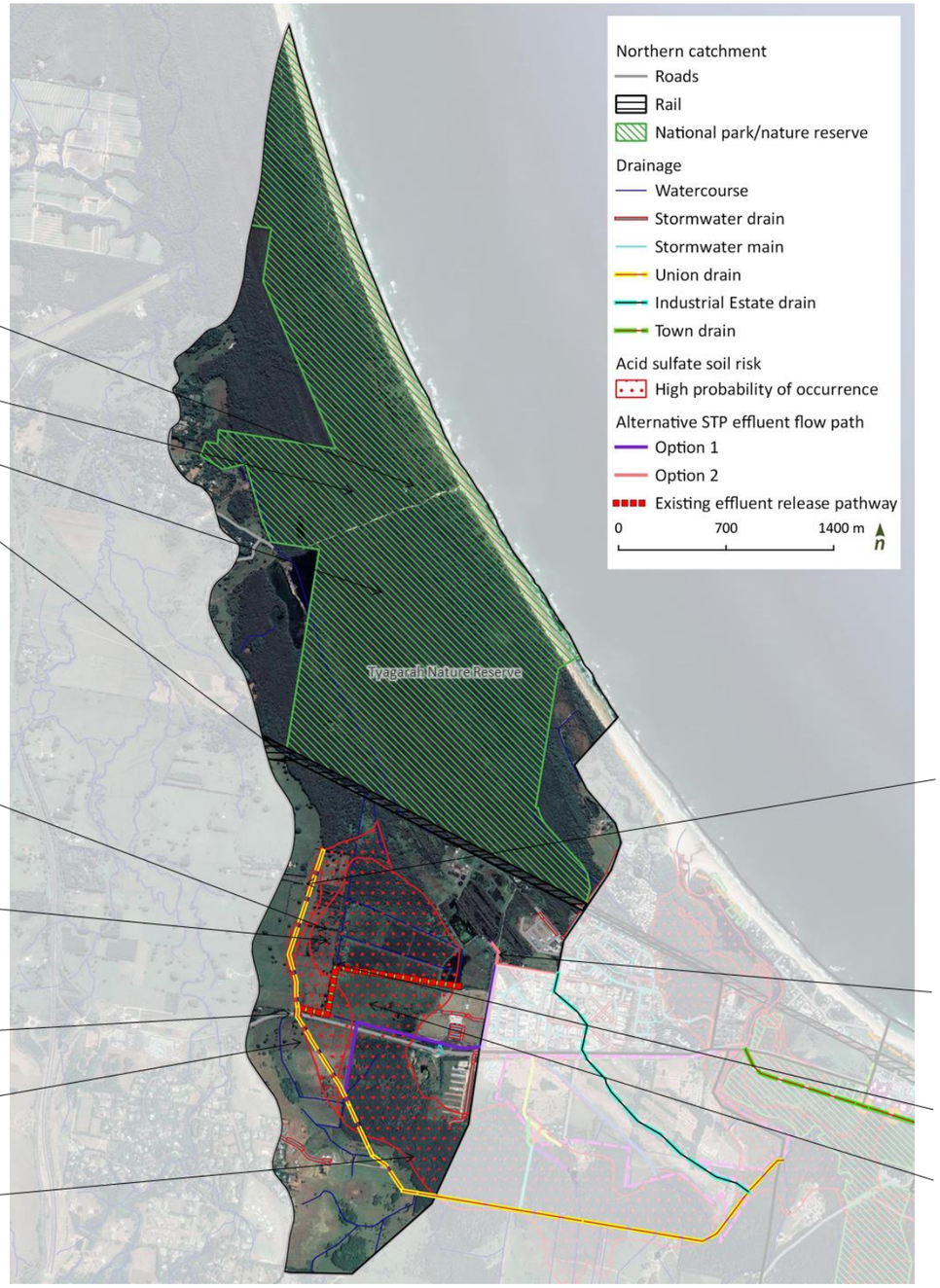
Movement of poor quality water via drains into estuary (blackwater events)

Potential increase in water table in land surrounding the BBIWMR resulting in increased frequency, extent and depth of surface water inundation

Additional effluent release option 1 may result in increased duration of inundation particularly Downstream of Ewingsdale Road

Erosion of the banks of the Union drain

Climate change (likely to lead to greater intensity, duration and frequency of fires, more severe droughts and storms and increased regional flooding



Illegal development - properties renting out illegal structures or overloading capacity of dwellings putting strain on sewer system particularly in peak holiday periods

Formalisation of Ewingsdale Road drainage needs to be considered as a part of the duplication project

Alterations in bushfire zone mapping potentially leading to land management changes

Subsidence of low lying land affecting drainage patterns and vegetation cover, in some areas drying out of peat topsoil has led to large hollow pockets and weakened the root systems of many trees which are then prone to falling during strong winds

Additional effluent release option 2 – release into the Industrial estate drain with discharge to continue through existing release point

Increased weeds and algal blooms associated with increased nutrient loads from effluent release

High risk of transport of acid discharge from the oxidization of ASS

Figure 30. *Northern sub-catchment issues and threats*

4 Management issues

4.1 Overview

The Belongil Creek catchment supports a range of environmental, economic and social values. A higher-level summary of some of these values include:

1. The ecological values of the estuarine, terrestrial and wetland communities that still exist within the catchment including the ecosystem services they provide (i.e. urban cooling, water treatment, flood detention, fish nursery, erosion protection etc.).
2. The significant economic values from the businesses and industries that exist within the Byron Bay township and Arts and Industrial Estate areas
3. The economic benefits provided by the tourism and agricultural industries
4. The cultural values of the catchment to the Arakwal people
5. The social and recreational values provided due to scenic values, bird watching, swimming and canoeing/kayaking.

Management decisions which aim to protect one of the above-mentioned values may have the unintended consequence of impacting on other values. Currently there are several management issues which threaten the environmental, economic and social values within the Belongil Creek catchment. With ongoing population growth, increasing tourism and the threat of climate change and associated sea level rise these management issues are likely to be exacerbated in the future. Some of the major management issues which threaten the catchment values are outlined below.

4.2 Water quality

Water quality in the Belongil Creek has previously been described as moderately impacted (WBM, 2001), indicating that catchment conditions are likely affecting the health of the waterway. The water quality within the downstream ICOLL systems such as the Belongil Creek estuary are naturally highly variable and dependent on many conditions and processes. When the entrance is open, the system is influenced by regular tidal inundation and when the entrance is closed, the ICOLL acts more like a lake. The long-term variability in entrance opening frequency gives rise to large variation in the physio-chemical properties of the waterway. The water quality is therefore heavily influenced by both freshwater and saline inflows as well factors such as catchment runoff, groundwater inflows, wetland drainage and direct rainfall.

Regardless of whether the entrance is open or closed, one of the major drivers of estuary water quality in this system is the inputs from the catchment. Major changes in the catchment over the last 100 years have had significant impacts on the water quality in the estuary. These include:

1. Artificial drainage of land has led to the oxidation of ASS through lowering of the water table and drying out the soil profile (particularly in the organic peat layer). Following a rainfall event, the drains convey surface runoff along with the oxidation products directly into the downstream estuary. There has also been a reduction in the storage and treatment of runoff in wetlands.
2. Significant development of the Byron Bay township and Arts and Industrial Estate leading to poor quality stormwater entering the estuary via the Town and Union Drains. Typically, this water is characterised by high BOD, low dissolved oxygen and high inorganic nitrogen.
3. Agricultural runoff significantly increasing nutrient and sediment loads into the estuary.
4. Discharge of treated STP into Union Drain increasing nutrient loads.

To date the major constructed water quality treatment systems include STP and the associated wetland in the BBIWMR and a private landholder in the upper Belongil Swamp sub-catchment constructing wetland style systems. Some treatment systems have been proposed in the Byron Bay township as part of the Byron Bay Drainage Strategy, but options were limited due to low relief, land availability and drainage capacity.

There is currently no catchment specific water quality or loads targets for the estuary. The development of targets should be based on the ecological outcomes desired in the estuary and the ecosystem services that the waterway is intended to provide. Catchment specific water quality or loads targets would assist in identifying appropriate treatment location and sizes and help in future land use planning. Any targets should be based on a sound management framework that seeks to identify the values of the waterway that are important to protect and enhance, the difference between the current situation and the future conditions necessary to preserve the identified values, and the management actions needed to move from the current to the desired future situation.

4.3 Biodiversity

The biodiversity values of the Belongil Creek catchment have been significantly modified since European settlement. Land clearing, drainage works, urbanisation and changes to estuary management have resulted in loss of significant ecosystems, fragmentation of residual ecosystems and increased marine influences and pollutant loads within the estuary.

Despite the modifications the catchment still maintains a diversity of healthy ecological communities and fauna habitats in close proximity. These areas are likely to provide substantial ecosystem services. However, while there is broad understanding of the existing values, a detailed understanding of the existing ecosystem condition is not available. There is currently insufficient information to gauge the current status or condition of the estuary. The last detailed ecological assessments within the estuary were undertaken over 20 years ago.

An assessment of the existing benthic and fish fauna would help understand the ecological values provided by the estuary. In other estuarine systems across the east coast of Australia, rapid declines over 20 year time frames have been recorded. Benthic and fish fauna are potential sentinel species, are the food of larger fish and shorebirds and tend to respond on more rapid timescales than larger fauna at the top end of the food chain. They can therefore help indicate changes that can hopefully be rectified before they impact on other species. Understanding the ecological condition of the estuary can help inform the development of water quality targets and approaches to mitigate threats.

Many of the coastal wetland communities and terrestrial ecosystems are degraded and/or fragmented. The existing values and services provided by these systems are poorly understood. Furthermore, the outcomes sort from these areas are not clearly defined. This limits the ability to determine appropriate management actions for these areas. There are opportunities to restore, protect and connect these ecosystems which has the potential to significantly improve biodiversity and ecosystem services.

4.4 Climate change

The impacts of climatic change are far reaching. Key indicators of change include rainfall patterns, increased frequency of extreme weather events, increased temperature and sea-level rise. 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 0.4 and 0.9 m increase by 2050 and 2100 respectively. Likely global mean sea-level rise by 2100 has been projected to exceed the 0.9 m benchmark (by 0.08) in the highest emissions scenario. The IPCC also suggest the possibility of greater rises should unfavourable conditions prevail, such as ice sheet collapse (OEH 2018).

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. The predicted inundation levels within the Belongil Creek catchment for the highest modelled emissions pathway (RCP 8.5 i.e. current trajectory) in 2050 and 2100 is illustrated in Figure 31. It is noted that these levels do not take into consideration storm surges and wave overtopping which could be significant.

The predicted inundation extents indicate large areas of the catchment will be subjected to tidal inundation within the next 30 years. This would have significant implications for ecosystems, agricultural and urban areas. Stormwater infrastructure and sewage systems are also likely to be compromised given significantly the

reduced capacity for drainage. An improved understanding of the impacts of sea level rise and tidal inundation will assist in future land use planning within the catchment.

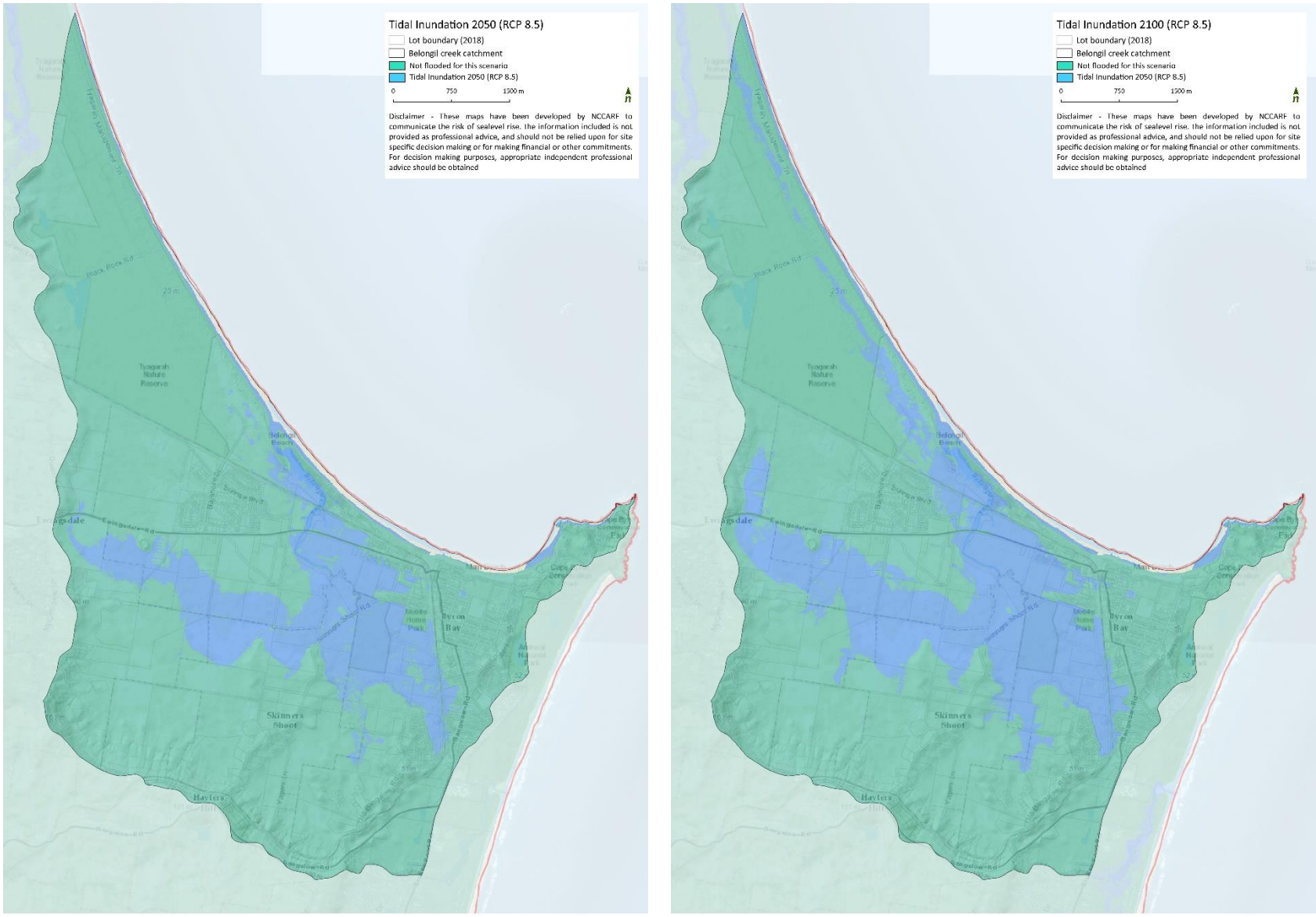


Figure 31. *The estimated extent of tidal inundation under the existing high emissions trajectory in the Belongil Creek catchment in 2050 (left) and 2100 (right)* (NCCARF, 2019)

4.5 Entrance management

The Belongil Creek estuary entrance has been artificially opened for over 100 years. Without this artificial opening the estuary level would have inundated large areas of the catchment (Figure 32). The artificial opening has had significant impacts on the ecology of the ICOLL system. It has, however, allowed the development of many of the economic and social values of the Byron Bay community (i.e. urbanisation, agriculture etc.).

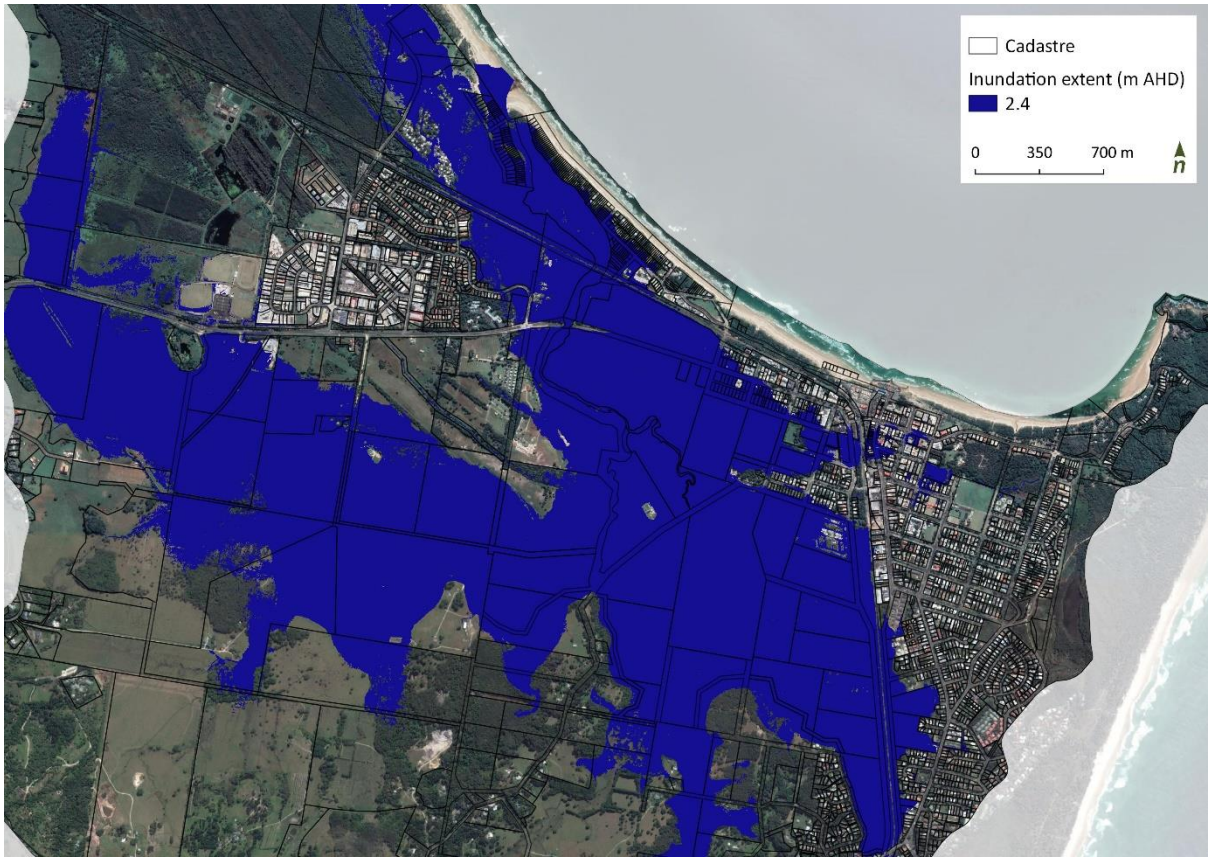


Figure 32. *The inundation extent within the Belongil Creek catchment without artificial entrance opening*

For the last two decades the entrance has been opening at a trigger level of 1 m AHD. As the sea level rises, opening at a 1 m AHD level will become less practical, requiring increasingly frequent intervention. The trigger level for estuary opening will need to be raised as the sea level rises. This will have incremental impacts on ecosystems, agricultural and urban areas as discussed in Section 4.4.

The Belongil Spit and estuary entrance area is a dynamic landscape (Figure 33). Since the 1960s the entrance has migrated over 150 m to the north and the spit has reduced in width from 100 m to 40 m. In the near future there is the potential for the entrance to either migrate further to the north or break through the spit further to the south. This area contains a number of important values including Littoral Rainforest, bird nesting habitat, Elements Resort and residential properties along Belongil Beach. The ongoing artificial opening of the estuary which is critical for many of the existing catchment values will require adaptive management of the entrance zone and opening arrangements.

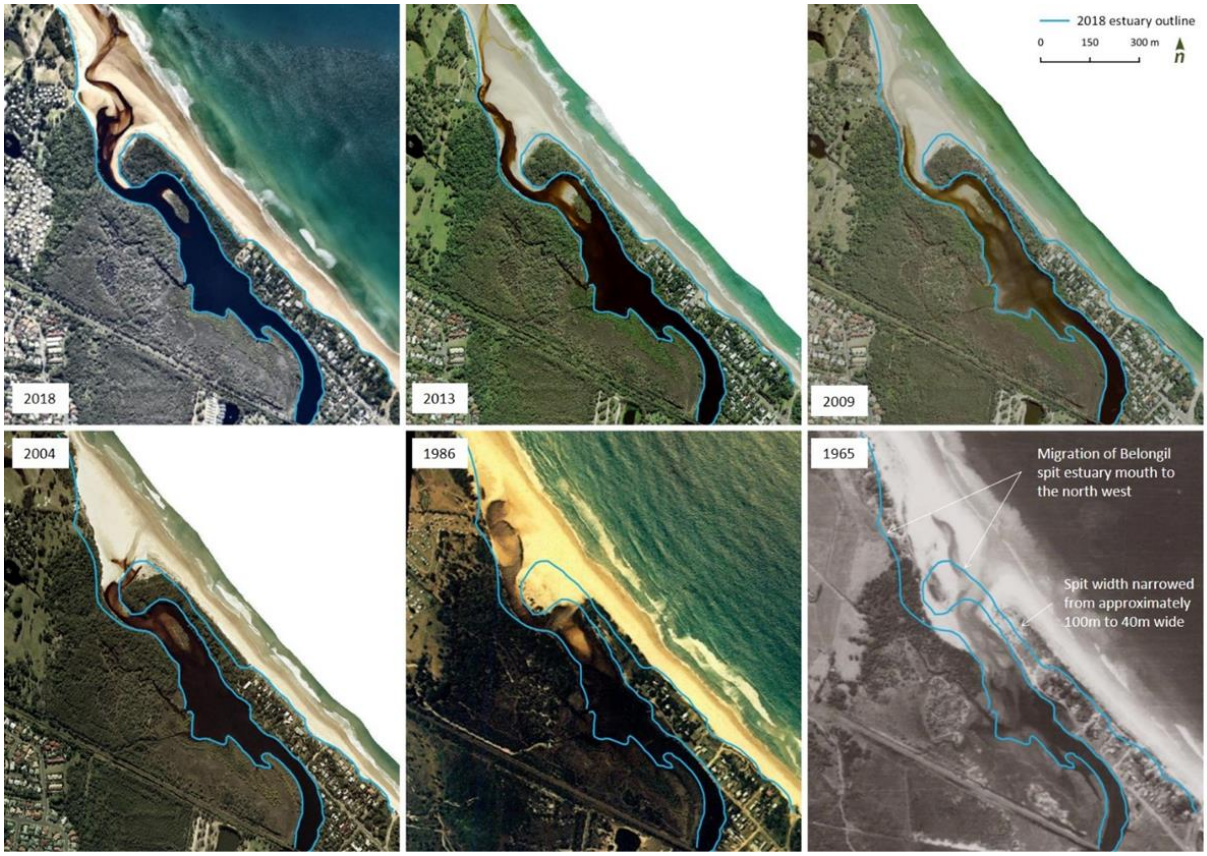


Figure 33. *Historical aerial imagery comparison of the Belongil Spit and estuary entrance*

4.6 Flooding and drainage

Overview

There have been significant studies looking at the flooding and drainage issues within the Belongil Creek catchment. The catchment has been heavily modified to allow for the agricultural and urban development of the catchment. These modifications include:

1. Extensive drain networks to reduce floodplain inundation and improve drainage from agricultural and urban areas
2. A railway corridor which presents a major constraint to stormwater and flood flows with much of the discharge from the part of the CBD east of the railway conveyed by a single undersized culvert.
3. Increased impervious areas with limited local treatment or detention.

The flat topography and limited hydraulic gradient through the catchment presents a number of challenges from a drainage perspective. The low gradient means water levels in the upstream reaches need to be elevated to drive flow through the drains into the estuary. This results in slow drainage rates and prolonged periods of inundation and nuisance flooding of urban and agricultural areas.

Byron Bay Drainage Study

In 2010 SMEC developed the *Byron Bay Drainage Study* which aimed to reduce the extent and frequency of flooding compared to the existing situation. The study found that drainage within the CBD is highly constrained and there is limited opportunity to provide stormwater treatment of urban areas.

The key recommendations from the investigation included:

1. Pump stations and improvements in street drainage required for the Town Drain area

2. A levee along Byron Street adjacent to Town Drain

3. A new wetland and basin near Cowper Street to convey runoff to Clarke Beach.

Flood studies

Several recent flood studies have been developed for the Belongil Creek catchment. These studies have helped two Flood Planning Levels to be derived for use by Council. These Flood Planning Levels are based on a 1 % Annual Exceedance Probability (AEP) catchment flood occurring with either 0.4 m or 0.9 m of sea level rise. The previous modelling has indicated that there is minimal variation in flood extent between the 1 % AEP event and the 10 % AEP event. However, inundation across the floodplain is typically 0.1 m deeper for the 1 % AEP event when compared to the 10 % AEP event. Drainage in most flow events will be impacted by both local catchment rainfall patterns and the tailwater conditions in the primary drains and in the broader Cumbebin Swamp area. The tailwater level will be a major issue during very intense rainfall events.

The initial state of the entrance at the onset of a flood and the way in which the modelled entrance of a closed or constrained entrance evolves as the flood event progresses has been acknowledged for some time (Cooke et al., 2013; Lyons and Williams, 2012; Wainwright et al., 2004, 2011). Modelling the entrance as closed (high barrier) and not evolving over time will result in conservative estimates of catchment flood elevations whereas applying an open entrance will result in a non-conservative estimate. To some extent, the reverse applies for ocean inundation dominated events.

The recent flood investigations have not adequately assessed the impacts of entrance morphology dynamics on flood levels. The SMEC study regarded a "closed" entrance as having the entrance bed elevations set at 0.0 m AHD which is significantly lower than a typical closed entrance with a trigger level of 1 m AHD. The BMT WBM study adopted a uniform depth of -2.0 m AHD which extended well behind Belongil Spit for nearly 1300 m upstream of the entrance. This level of scouring is excessive. It is likely the model configuration has resulted in somewhat non-conservative flood elevations in areas upstream of the estuary which may impact on developments and flood planning levels.

Drainage board

The Belongil Catchment Drainage Board (BCDB) manage an area to the north of Belongil Creek estuary which drains into the Union Drain. The BCDB is not a consent authority but has functions as outlined under Section 202 of the *Water Management Act 2000*. The primary purpose of the BCDB is to maintain the Union Drain's efficiency to reduce the impact on agricultural land. Under the act the BCDB must limit environmental impacts and follow Ecological Sustainable Development (ESD) principles. Given BCDB only manage a small area of the drainage network and do not manage some of upstream contributing catchment and downstream receiving waters, their ability to impact drainage or adhere to ESD principles is limited.

Maintenance issues

The low relief and limited capacity drains within the urban areas of the Belongil Creek catchment require significant maintenance to help reduce conveyance issues. Without maintenance the drains would become choked with instream vegetation and sediments which reduce drainage capacity. Byron Shire Council undertake regular maintenance of many of their urban drains to reduce drainage impacts within the catchment.

Historically many of the drains and stormwater system have drained directly into low lying wetland areas. Many of these areas are now contained within Coastal Wetland areas within the Coastal Management SEPP (Figure 34). After decades of untreated stormwater discharges these areas are likely to be experiencing sedimentation. Ongoing sedimentation will impact the drainage capacity from the upstream catchment and exacerbate nuisance flooding. There are significant regulatory constraints in improving drainage in these areas due to the Coastal Wetland classification under the SEPP and limited existing drainage infrastructure (which would be more easily maintained under the SEPP).

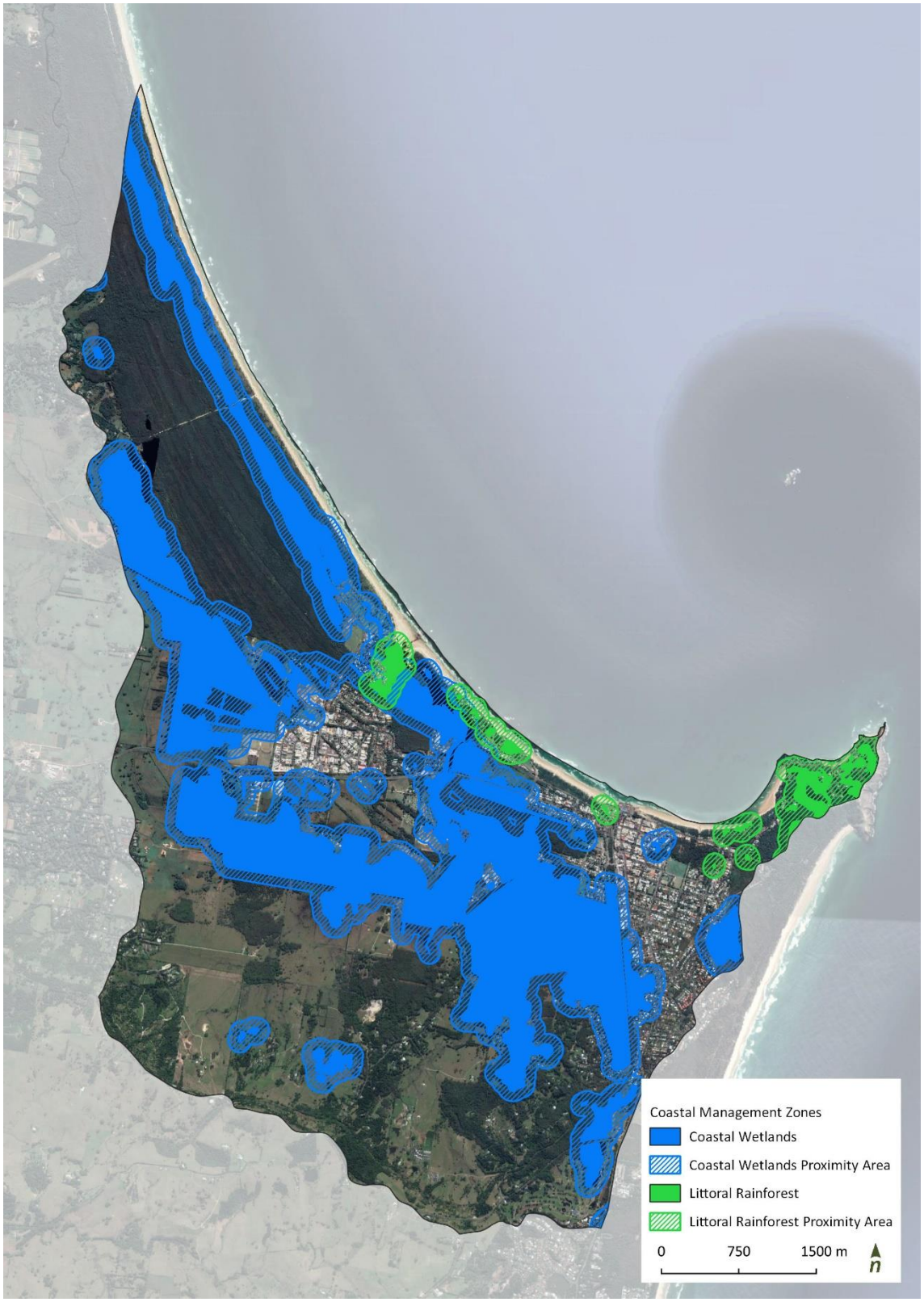


Figure 34. *The Coastal Wetland areas with the Belongil Creek catchment*

4.7 Water supply and sewage

Water supply for potable and non-potable use within the catchment is predominately imported from outside the catchment from Rocky Creek Dam which is managed by Rous Water. The wastewater is treated at West Byron STP which sits within the BBIWMR. Currently the STP discharges up to 3 ML/day of dry weather flow into the upper Union Drain. In addition, approximately 1 ML/day is used to for urban reuse and irrigation of a large area (24 ha) of regenerating floodplain forest/wetland.

The 3 ML/day which is currently discharged to the Union Drain has caused substantial angst amongst landholders due to the perception of increased inundation. However since discharges began in 2006 there has been a reduction in artificial estuary opening events, a reduction in peat fires and acid discharge events (AWC & BMT WBM 2017).

Due to increased development within Byron Bay, effluent inflow rates to West Byron STP are projected to increase over the next 5-10 years. AWC & BMT WBM (2017) undertook an investigation into potential release pathways projected 5 ML/day and 8 ML/day flows. The main recommendation was the development of an additional discharge location through the Industrial Drain while maintaining the current discharge locations.

The 2017-2027 Effluent Reuse Strategy (BSC, 2017) recommended the expansion of the Byron Bay urban reuse scheme and further constructed wetlands within Belongil Creek catchment. These recommendations would significantly reduce the perceived impacts of discharge directly into the drainage network and provide environmental and social outcomes. The expansion of the use of recycled water within the catchment has the potential to provide beneficial outcomes for certain land uses, help restore wetland environments within the catchment and minimise the impact of ASS.

However prior to significant increases in effluent rates and recycled water reuse within the catchment, a detailed understanding of the hydrological impacts on specific land uses is required. These need to include both beneficial and detrimental impacts. This process can help determine the optimal reuse volume and locations and catchment land uses. Without defining the target condition of specific land use areas, it is difficult to determine the optimal effluent management arrangements (i.e. volume of water to be released/reused within the catchment).

4.8 Groundwater

An understanding of the groundwater dynamics in the Belongil Creek catchment is important due to its role in supporting agriculture and groundwater dependent eco-systems (GDEs), regulating acid water discharge from ASS and influencing water quantity and quality as it flows downstream.

Ground water levels within the Belongil Creek catchment would have varied under natural conditions as a result of rainfall variability and beach berm levels. However, the construction of drains and the artificial opening of the estuary have significantly lowered groundwater levels. The lowering of groundwater levels results in oxidisation of soils containing iron sulfides (commonly pyrite) which results in acid production (i.e. Acid Sulfate Soils). When water in drains (from tidal surges or surface flow) or groundwater interacts with these soils it can result in chronic discharge of acidic water entering the waterways. When this process occurs it can result in rapid oxygen depletion and potential fish kills within the estuary.

There is currently limited monitoring of groundwater levels within the Belongil Creek catchment apart from in the BBIWMR. An improved understanding of groundwater levels and rainfall-aquifer dynamics may assist in developing management responses which limit acid runoff entering the estuary. This may involve modifying effluent discharges, adapting estuary opening times and drain management approaches.

4.9 Future land use planning

The current land use within the Belongil Creek catchment has developed in part due to historical drainage works and artificial estuary openings. There are currently extensive pressures on all land use areas within the catchment which is likely to result in land use changes. 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. Infill urban development and intensification will also impact the catchment through reduction in imperviousness and increases in pollutant generation. Understanding these impacts on different land use types will be necessary to understand how investments in land use change (e.g. dryland grazing to wetland grazing, or urbanisation) should be made in the future. While it is known that land use changes will be inevitable, how that change will interact with projected climate change and sea level rise is unknown. A lack of information exists around the following areas:

1. The constraints and vulnerabilities of land use due to the floodplain landscape, coastal processes, projected sea level rise and temperature increases
2. How tidal inundation will impact flow regimes within the catchment and the ability of the existing drainage infrastructure to meet the demands of future climate scenarios
3. How low-lying areas (urban, agricultural, industrial) will be impacted and/or protected from tidal inundation
4. How infill development will impact drainage, water quality and catchment health.
5. Economic impacts, such as productivity losses, under future climate change scenarios

Informed land use planning decisions cannot be made without a clear understanding of these issues.

5 Recommended framework and actions

5.1 Catchment management framework

The future management of the Belongil Creek catchment should be implemented within a catchment management framework. The management framework could be part of a NSW Coastal Management Program (CMP). Coastal management programs (CMPs) set the long-term strategy for the coordinated management of the coast, with a focus on achieving the objects and objectives of the Coastal Management Act 2016 (CM Act).

The framework adopted (i.e. within a CMP or otherwise) should identify key values/assets in the study area, articulate clear objectives for these value/assets, guide assessment of condition and future trajectory and allows for effective restoration prioritisation. The planning framework provides for comparison of different management options and the design, implementation and monitoring of restoration works. A conceptual diagram of a typical catchment management framework is shown in Figure 35. All of these key components are aligned with various stages of the CMP process.

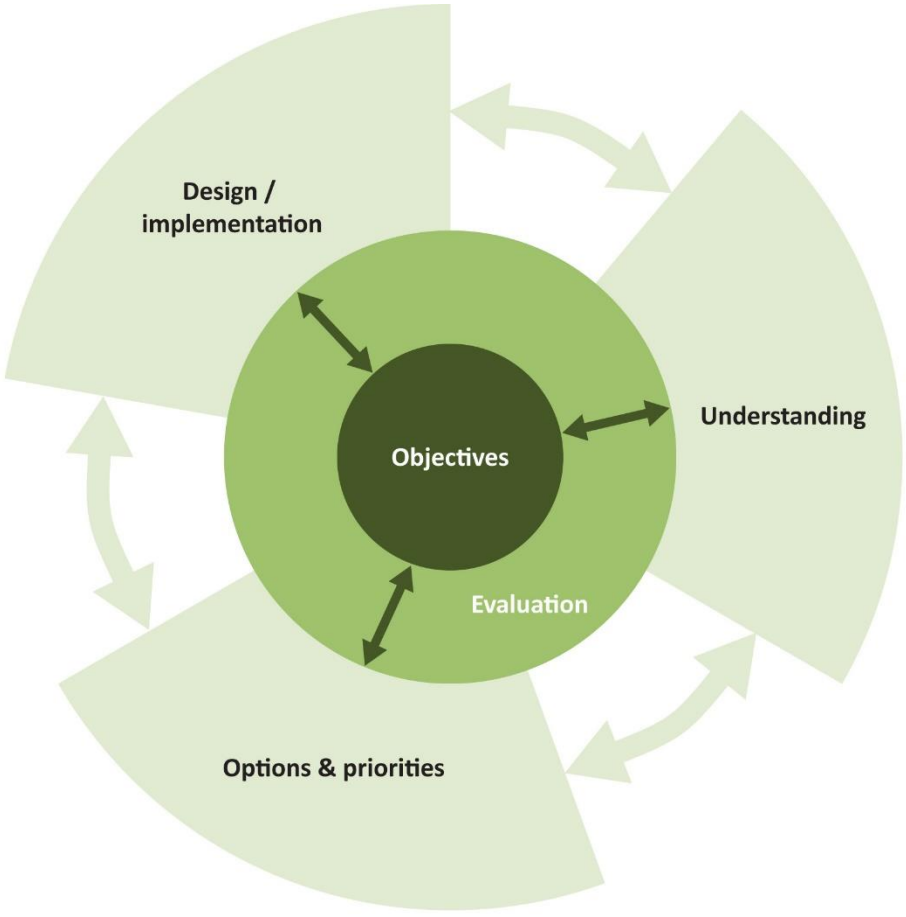


Figure 35 *The key components of a catchment management framework*

It is recommended future management of Belongil Creek focus on identifying the Understanding, Objectives and Options and priority components of the framework outlined in Figure 35. The recommended stages for the management of Belongil Creek are outlined in Figure 36. Each of these stages is discussed below.

Figure 36. *The proposed components required for the management of Belongil Creek*

5.2 Stage 1 -Stakeholder and community engagement plan

The development of a stakeholder and community engagement plan is an essential component of the catchment management. The support of key stakeholders and the community will be essential for effective catchment management. It is recommended that the plan identifies a Working Group which provides guidance to make the final decisions/recommendations relating to the management of the Belongil Creek catchment. The Working Group should include councillors, council staff, Arakwal Corporation, state agencies (i.e. OEH, DPI – Fisheries, DPI – Marine Parks and National Parks and Wildlife) and other key stakeholders (i.e. landholders, Drainage Union, business groups).

Four broad outcomes should be sought from the engagement process through the catchment management process (Figure 37). These outcomes form a hierarchy recognising that a shared understanding of the catchment values and processes, and the constraints which catchment management must operate within is required by all stakeholders. Without this understanding it will be difficult to get broad agreement from all stakeholders on the actions required. Catchment management needs to be informed by evidence-based decision making through a collaborative process. If the decisions are made through active dialogue with stakeholders, there will be responsibility and accountability for their implementation.

The stakeholder and community engagement plan should build on recent Council engagement activities including the Byron Bay Town Centre Masterplan, the Coastal Management Program and Belongil Creek estuary opening strategy.

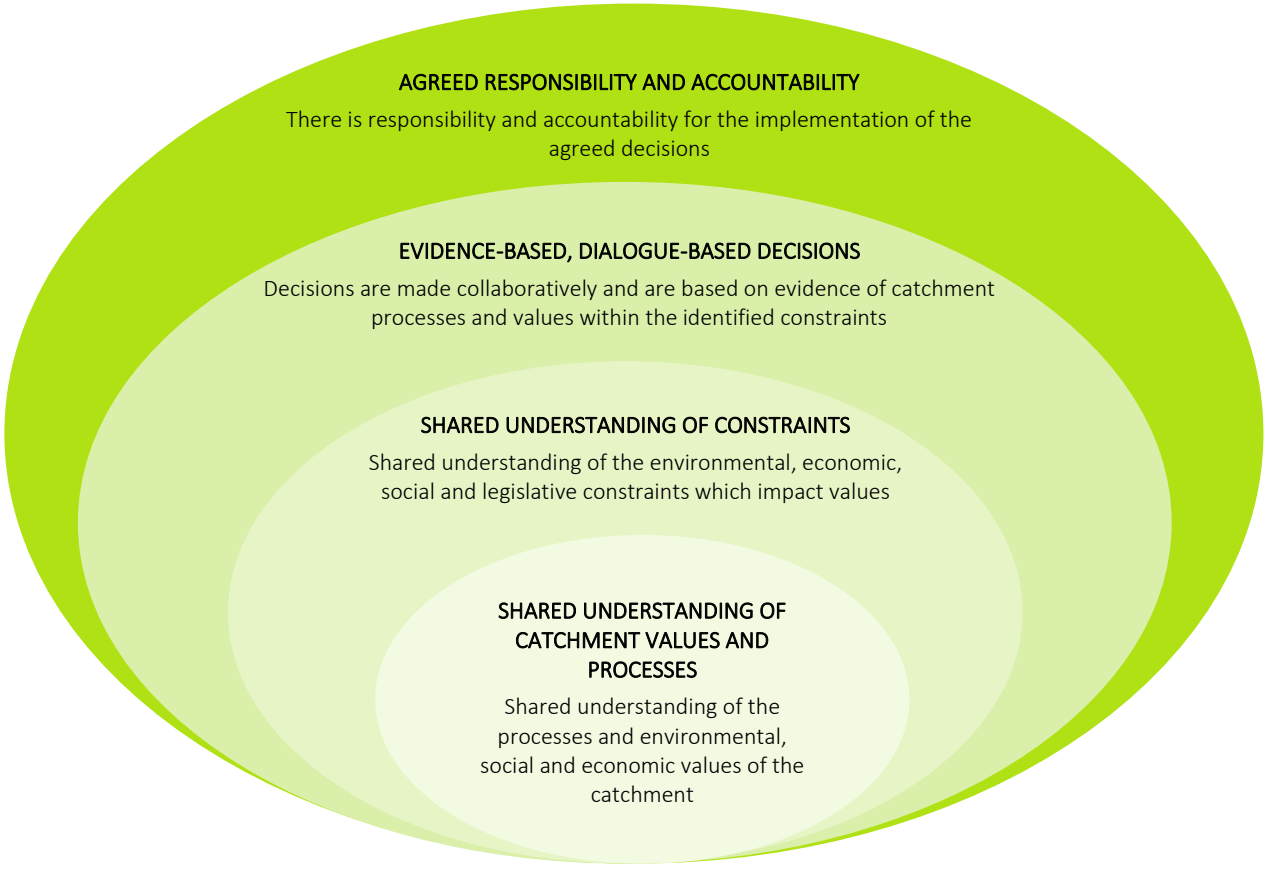


Figure 37. *Four outcomes of successful communication and engagement for the management of the Belongil Creek catchment*

5.3 Stage 2- Identify catchment values

Effective catchment management needs to be developed around the management of values within the catchment. Far too often catchment management processes focus on the management of threats without the broader understanding of what will be the response of the system to those management actions.

The Belongil Creek catchment supports a range of environmental, economic and social values as outlined in Section 4.1. An important part of the stakeholder and community engagement process is to ensure all catchment values are documented. The values should be identified at both the catchment and sub-catchment scale.

The Working Group then needs to identify those values which may be required now and into the future and decide on the outcomes sought for those values. The criteria used to assess these outcomes also needs to be specified. An example using wetland communities as a value is shown in Figure 38.

Identified values need to be either addressed at the sub-catchment or catchment scale. By choosing to address certain values at the sub-catchment scale more targeted assessments of outcomes and responses can be developed.

Figure 38 *Example of value, outcome and criteria*

5.4 Stage 3 - Assessment of existing condition

Existing scenario
In this stage existing information should be examined to determine if each criterion is achieved. The suitability of existing information needs to be assessed as part of this stage. In some cases, knowledge gaps will need to be filled. These knowledge gaps may include:

1. Catchment modelling of surface and groundwater processes to understand hydrologic impacts and loads
2. Hydrodynamic modelling and drainage impacts
3. Ecological monitoring to understand estuarine values (i.e. fish assemblages etc.).

Identify management responses
Where the criterion is not achieved the likely management response required to achieve the criterion should be outlined. Where the criterion is achieved the existing management arrangements need to be outlined. This should be a higher-level assessment as opposed to a detailed action plan.

Document costs and benefits
The cost of management responses need be clearly outlined. This should include the costs to design, implement and maintain the response and should consider secondary costs (i.e. landholder or community impacts). The benefits should also be clearly outlined. Where possible an economic evaluation process should be adopted that incorporates the ecological services provided by each value.

5.5 Stage 4 – Assessment of future condition

Development of future scenarios
A range of likely future scenarios will be required for 10, 25 and 50 year timeframes. These should include the predicted sea level rise and tidal inundation impacts. A tidal inundation study may be required to inform this task. The future scenarios should include population changes, WTP discharge increases and potential land use changes. Each criterion should be assessed under each future scenario.

Identify management responses
Where the criterion is not achieved the likely future management response required to achieve the criteria should be outlined. This should be a higher-level assessment as opposed to a detailed action plan.

Document costs and benefits
The cost of management responses to achieve the criterion under each future scenario needs to be clearly outlined. This should include the costs to design, implement and maintain the response and should consider secondary costs (i.e. land use change, landholder or community impacts). If required the benefits and economic evaluation process undertaken in Stage 3 should be updated.

5.6 Stage 5 – Declare strategic intent for waterway

Evaluation of costs and benefits
Each value needs to be examined in terms of the costs and benefits determined in Stage 3 and Stage 4. The Working Group needs to be heavily involved in this stage to determine:

1. Where the benefits are so high that the costs are warranted
2. Where the costs are so high the benefits are not warranted
3. Where the benefits are so low the costs are not warranted
4. Where trade-offs need to be made between the management of certain values.

The strategic intent for catchment values need to be clearly outlined and have broad agreement amongst the stakeholders. This will involve identifying which outcomes are achievable, and are of sufficient value to the community, under existing and future scenarios. It will also need to identify the outcomes that are not feasible due to budgetary, environmental and social constraints. Where values cannot be maintained under future threats (i.e. sea level rise) these need to be specified.

Outline objectives
Based on the strategic intent identified by the Working Group, objectives for each value needs to be determined. This will be a revision of the outcomes identified in Stage 2. Depending on the costs and benefits analysis the objectives may relate to:

1. Reducing the rate of decline in values
2. Maintaining or protecting the current values
3. Enhancing the values where the outcomes may not be being achieved currently.

For each objective, new criteria may be needed to determine if the desired outcome is achieved and these should be outlined consistent with the outcomes of Stage 2.

5.7 Stage 6 – Determine actions to achieve to objectives

Options assessment
Management options to achieve the new criteria identified in Stage 5 should be developed and assessed. The options assessment will expand on the higher-level management responses identified in Stage 3 and Stage 4. The options will need to consider all environmental, economic, social and legislative constraints. Modelling is likely to be required to assess the impact of options on water quality/catchment loads and flooding and drainage. Where possible the models and outcomes from existing studies should be utilised/modified for this task.

The options should be evaluated based on the degree to which they achieve the criteria, their costs and impacts on the surrounding community and environment. The final selection of management options should be endorsed by the Working Group.

Outline actions and responsibilities
Management actions need to be outlined to assist in the design and implementation of management options. Actions should be identified for the design, implementation and monitoring of each management option. For each action key organisational responsibilities and potential timelines should also be outlined.

5.8 Stage 7 – Business case

Determine costs and benefits of actions

The costs of management actions should be estimated. To determine the benefits of actions a likelihood-consequence-risk framework that draws on available information to understand the potential physical, economic and social risks of a do nothing scenario (base case) should be used. Any reduction in those risks associated with the management actions creates an economic benefit. These benefits can then be compared to the indicative costs associated with proposed action to form a business case. Ultimately the business case uses a cost-benefit analysis framework consistent with international best practice and NSW state guidelines including *Guidelines for using cost-benefit analysis to assess coastal management options* (OEH. 2018).

Identifying and managing funding sources

Given that there are likely to be a wide variety of projects and actions required to achieve the objectives of the catchment plan, it is vital to ensure that the plan is ultimately supported by efficient investment and funding. It is equally important that investment is prioritised to ensure the greatest possible return on investment is achieved with a clear structure to identifying key projects. As it is also highly likely that actions and projects will need to be managed within the constraint of the available funds, the investment process must be managed to ensure the most cost-effective options are identified and prioritised. Investment within a constrained budget must facilitate the improved allocation of investment funds. The principle of cost-effectiveness will ensure that maximum benefits are derived from a given pool of investment.

A list of the possible funding sources is shown in Table 4. This list is not exhaustive and should be expanded upon as part of the Belongil Creek catchment plan. Some key elements of the different funding sources are:

1. Requirement to be repaid. While most finding sources are typically by way of budget allocations or grants, where projects have a capital component and partial/full long-term commercial returns, funding that is repaid over the long-term may be appropriate.
2. Public or private capital investments. There will be opportunities for private sector capital investments in addition to a typically predominantly public capital investment approach.
3. Regulated/government decision or voluntary. Some funding sources require regulation to underpin their use, while some are purely voluntary.
4. Commonly used in catchment management. Some funding sources are common for catchment management, while some are still emerging as options.

The effective management of funding can lead to new funding sources underpinned by greater efficiencies and economies of scale from consolidated funding and greater levels of funding that are currently unavailable for worthy projects. It is worth noting that some funding sources may require alterations to existing governance arrangements to be the most effective. Equally, some funding sources may require the formation of new funding pathways. It should also be noted that a lack of fund management and efficiency can be a major impediment to broadening the suite of potential funding sources to support catchment management initiatives.

One option for the development of the Belongil Creek catchment plan is through the development of a Coastal Management Program (CMP) as part of the NSW Coastal and Estuaries Program which is guided by the Coastal Management Act 2016. A CMP for the Belongil Creek estuary would work with state agencies to set the long-term strategy for the coordinated management of the catchment. A CMP may also help access funding for the additional investigation which will be required to fill the knowledge gaps identified in this report.

Table 4. A broad suite of possible funding sources

Funding source	Repaid to investors (Y/N)?	Public or private capital?	Regulated/ government decision or voluntary?	Commonly used in catchment management (Y/N)?
Government budget				
Budget appropriations	N	Public	Government decision	Y
New investment				
Bonds	Y	Private	Voluntary	N
Philanthropic	N	Private	Voluntary	Y
Fees and charges				
Water quality offsets	N	Private	Regulated	N
Developer charges	N	Private	Regulated	Y
Licence fees	N	Private	Regulated	Y
Load-based charges/taxes	N	Private	Regulated	N
Catchment management levies	N	Private	Government decision	N
Nature-based tourism levy	N	Private	Regulated	Y

5.9 Monitoring and evaluation

The adopted management process needs to clearly outline a framework for the monitoring and evaluation of the recommended actions. The use of a program logic model should be considered as part of this task. The program logic approach would clearly outline the intended outcome in the catchment values as a result of each action. This will help to identify areas where evaluation will be most important, and informing the development of meaningful evaluation questions which can assist in the adaptive management of the catchment into the future.

5.10 Project timing and key issues to be addressed

It is expected that Stage 1 to Stage 7 of the Belongil Creek catchment management process be developed over 12 -24 months to allow time for adequate stakeholder and community engagement and filling of knowledge gaps. The framework presented within this report provides flexibility for stakeholders to help identify the major values and management issues within the catchment. However, it is envisaged the following issues/knowledge gaps will need to be addressed as part of the Belongil Creek catchment plan and/or CMP:

1. Identify trunk drainage routes and management issues. Development of options for the future management of drainage. Survey and investigate preferred drainage paths from Ewingsdale Road.
2. Coastal inundation risk mapping under climate change.
3. Vegetation communities at risk from climate change and sea level rise.
4. Assessment of estuary ecological communities.
5. Identify potential areas for land use change that would improve water quality and habitat values.
6. Identify sewer/stormwater cross-connection.
7. Identify suitable locations for water quality treatment infrastructure.
8. Development of catchment specific water quality and loads targets based on the ecological values, based on these targets identify the capacity of the system for future development and wastewater discharge.

9. Recommend updates to Belongil Creek estuary opening strategy following completion of catchment plan.

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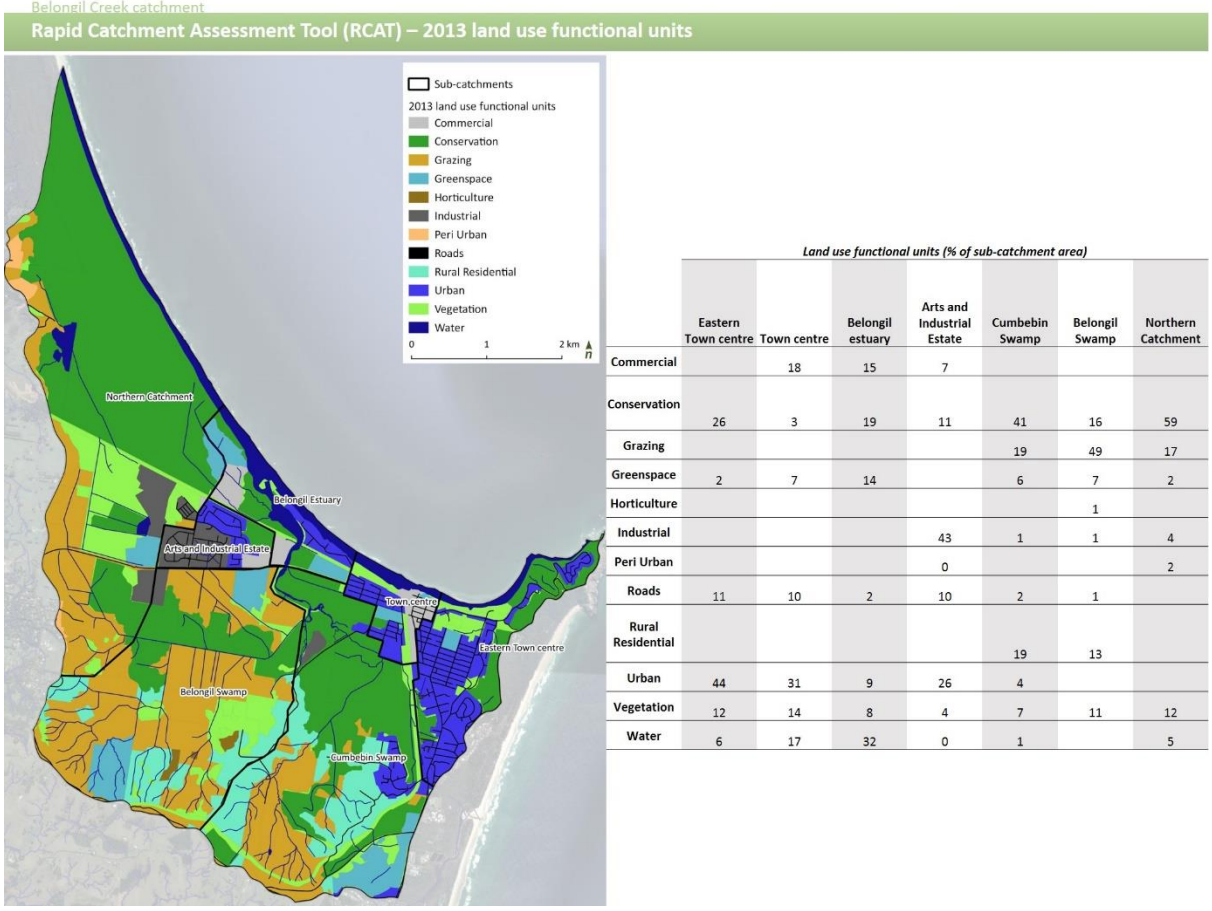
Attachment A - RCAT modelling



Land use functional units (% of sub-catchment area)

	Eastern Town centre	Town centre	Belongil estuary	Arts and Industrial Estate	Cumbebin Swamp	Belongil Swamp	Northern Catchment
Commercial		18	15	7			
Conservation	26	3	19	11	41	16	59
Grazing					19	49	17
Greenspace	2	7	14		6	7	2
Horticulture						1	
Industrial				43	1	1	4
Peri Urban				0			2
Roads	11	10	2	10	2	1	
Rural Residential					19	13	
Urban	44	31	9	26	4		
Vegetation	12	14	8	4	7	11	12
Water	6	17	32	0	1		5

Figure 39.*The land use functional units used to inform the RCAT modelling*

Belongil Creek catchment

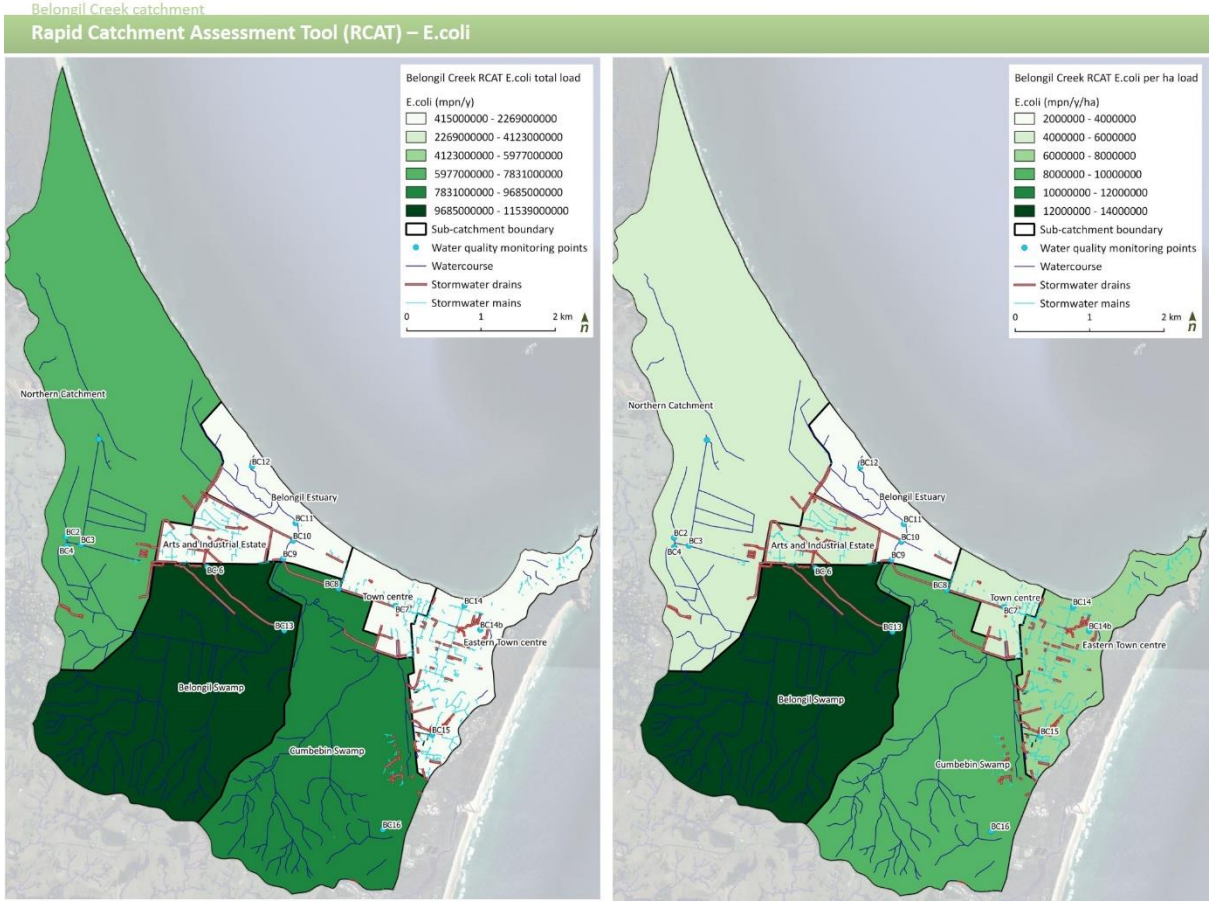


Figure 40. *RCAT modelling results for E.coli, total load (left). Per hectare load (right)*

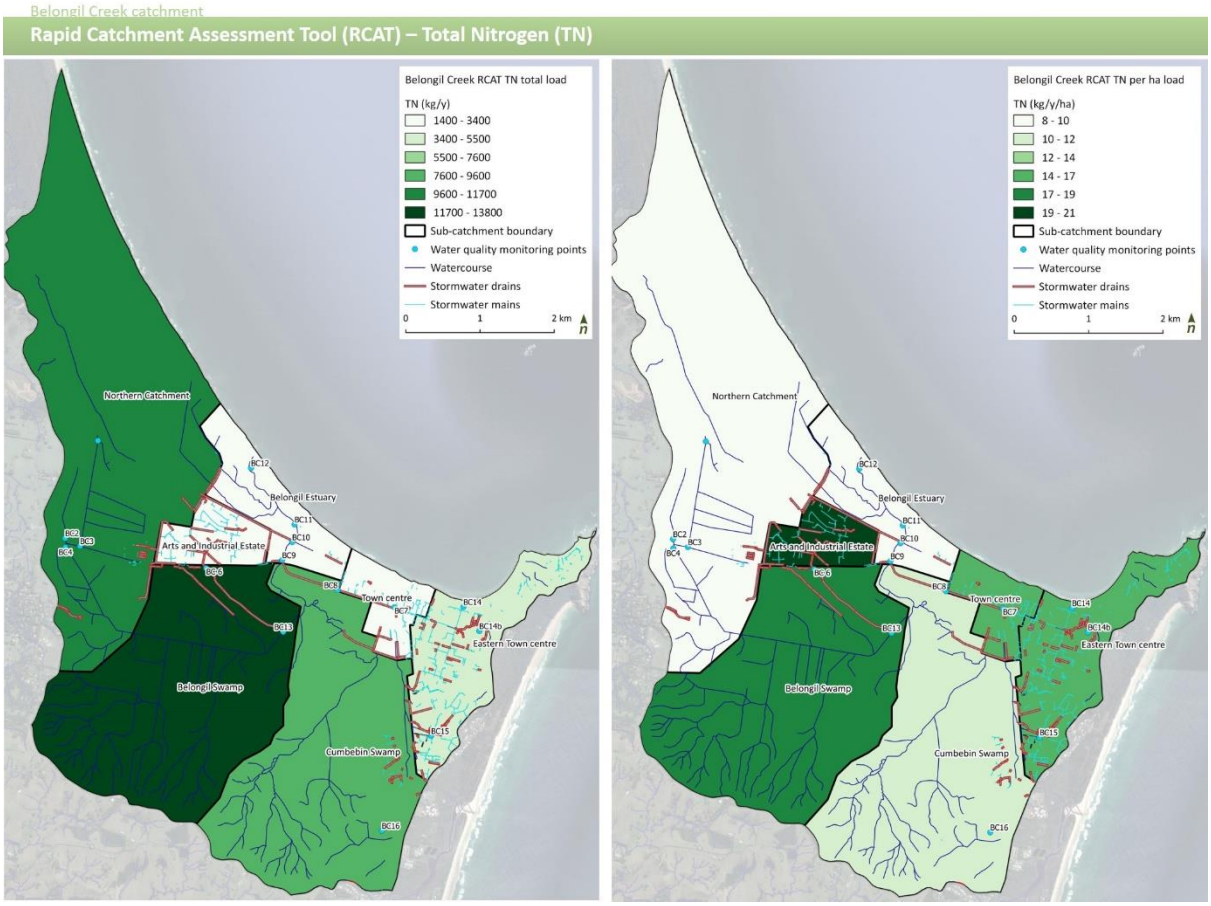


Figure 41. *RCAT modelling results for Total Nitrogen, total load (left). Per hectare load (right)*

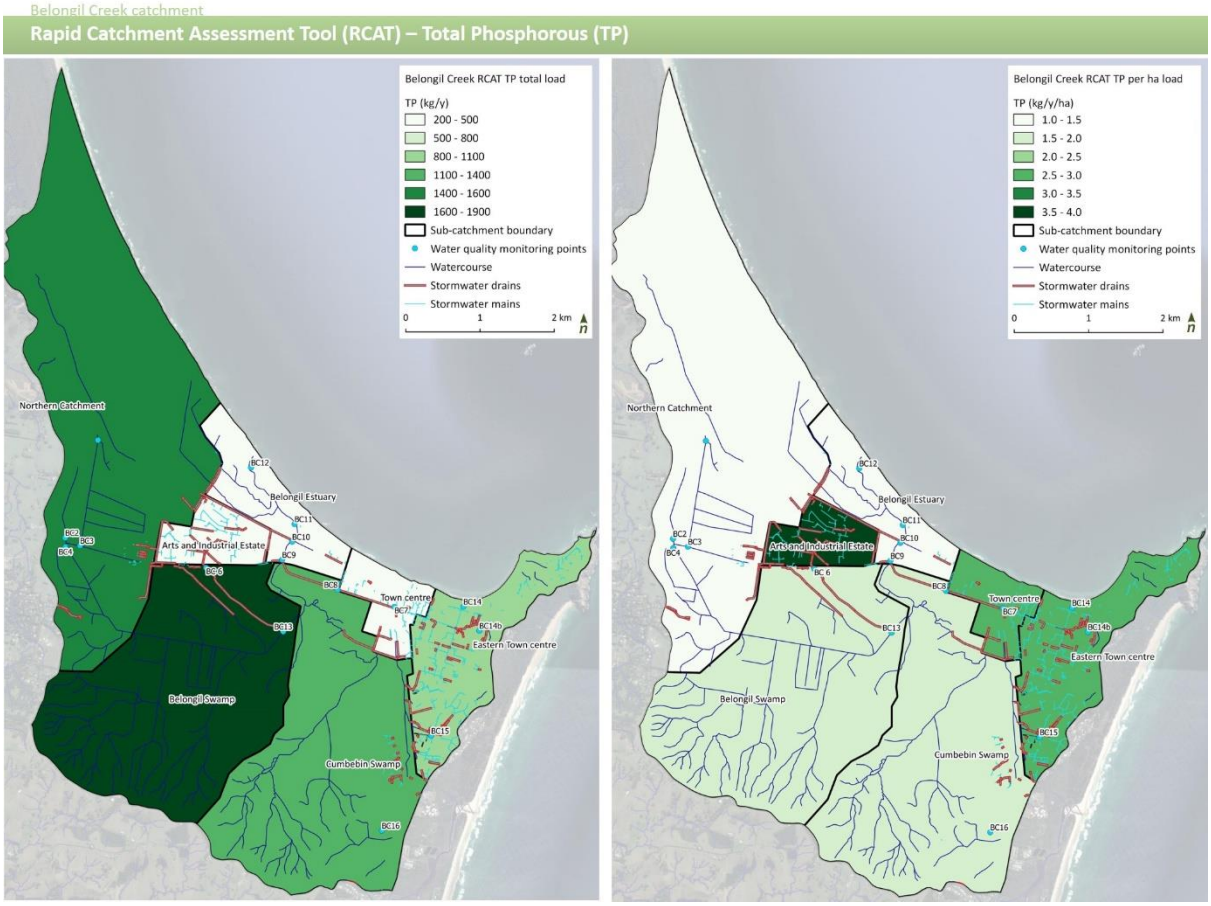


Figure 42. *RCAT modelling results for Total Phosphorous, total load (left). Per hectare load (right)*

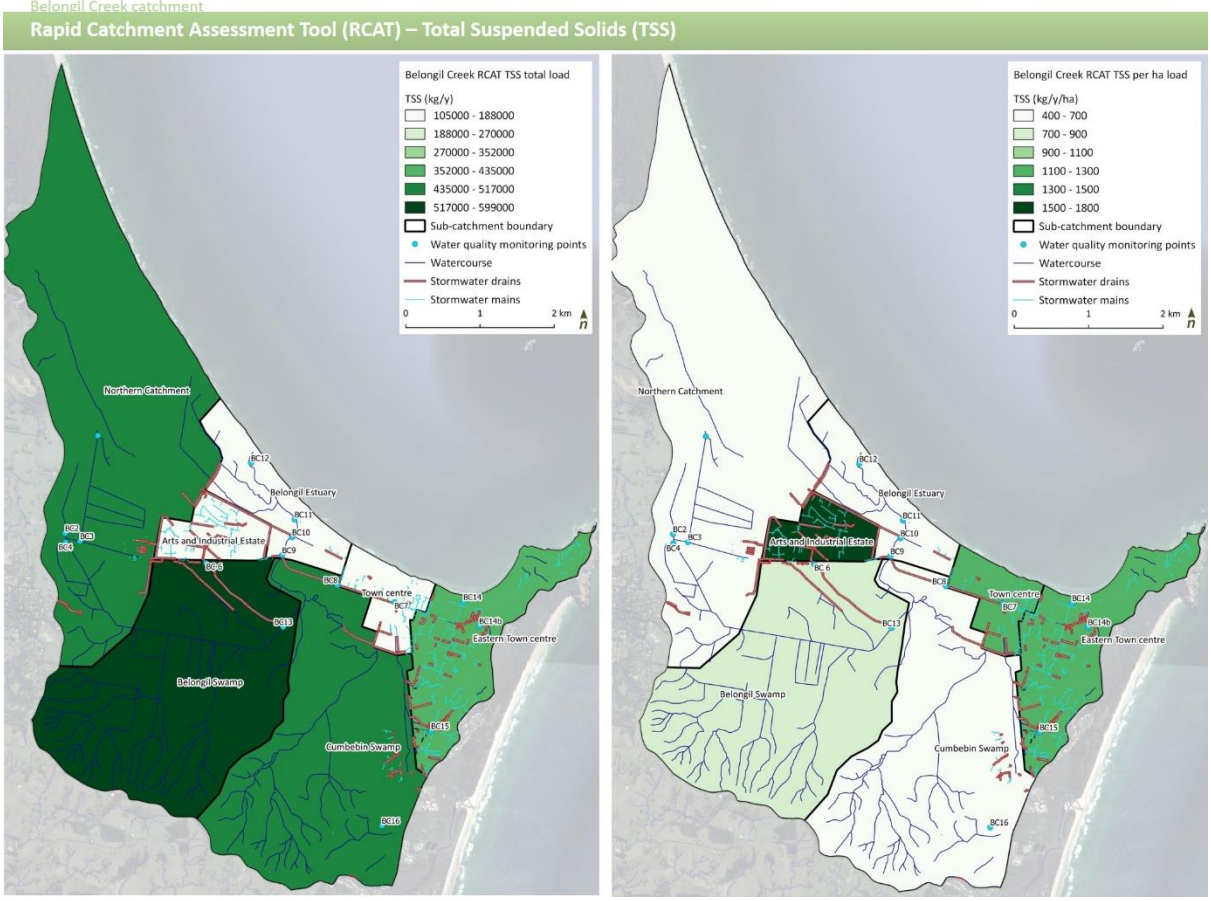


Figure 43 *RCAT modelling results for Total Suspended Sediment, total load (left). Per hectare load (right)*