Byron Shire ICOLL Water Pollution Source Tracking and Control Programs for Belongil Creek, Tallow Creek and Ti-Tree Lake

Stage 2 Study

Final Report

August 2023

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This technical report is one part of delivery of Stage 2 of the Coastal Management Program (CMP) for the Southern Coastline of Byron Shire and final outcomes of the overall program will be produced in fully accessible format. If you have trouble accessing any information provided in this document, or for more information or alternatives (read alternate text of figures, etc.), please speak with BSC Coast and Estuary staff on (02) 6626 7000.

Acknowledgement of Country:

In preparation of this document, Council acknowledges the Bundjalung of Byron Bay – Arakwal people as the Traditional Custodians of the land in Byron Shire, and form part of the wider Aboriginal nation known as the Bundjalung.

Byron Shire Council and the Traditional Custodians acknowledge the Tweed Byron Local Aboriginal Land Council and the Jali Local Aboriginal Land Council under the *Aboriginal Land Rights Act 1983*.

Council also acknowledges all Aboriginal and Torres Strait Islander people who now reside within the Shire and their continuing connection to Country and culture.

Acknowledgement of financial assistance:

Byron Shire Council has prepared this document with financial assistance from the NSW Government through its Coastal Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning and Environment.

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23-002 WATER QUALITY SOURCE TRACKING AND POLLUTION CONTROL PROGRAMS BELONGIL CREEK, TALLOW CREEK AND TI-TREE LAKE ICOLLS

REV	DESCRIPTION	AUTHORS	REVIEW	APPROVAL	DATE
0	Draft for client review	K. Pratt, J. Fullerton	M. Howland	M. Howland	10 July 2023
1	Final Report	K. Pratt	M. Howland	M. Howland	22 August 2023

EXECUTIVE SUMMARY

This document is part of delivery of Stage 2 of the Coastal Management Program (CMP) for the Southern Coastline of Byron Shire. A CMP is a plan of action for Council and other public authorities to identify coastal management issues and the actions required to address these issues.

This report documents the Byron Shire ICOLL Water Pollution Source Tracking and Control Programs for Belongil Creek, Tallow Creek and Ti-Tree Lake. Results are presented separately for each ICOLL in the following sections:

- Section 4 - Belongil Creek ICOLL
- Section 5 - Tallow Creek ICOLL
- Section 6 - Ti-Tree Lake ICOLL

The programs identify and prioritise water quality pollutant sources for each ICOLL and provide potential management options to address water quality threats. Management options recommended for further consideration will be assessed in detail as part of Stage 3 of the CMP. Recommendations for future water quality monitoring are also provided.

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1. INTRODUCTION

Byron Shire Council (BSC) is currently preparing Coastal Management Programs (CMPs) for its coastal zone in accordance with the NSW Coastal Management Framework. Council has adopted two Stage 1 Scoping Studies including the Scoping Study for the Southern Byron Shire Coastline and Belongil estuary.

This project is part of delivery of Stage 2 CMP projects to fill data gaps and identify opportunities. It aligns with one of the key objectives identified in the Scoping Study for the Southern Byron Shire Coastline (Rhelm, 2021): *"To improve the quality of estuarine (Belongil Creek, Tallow Creek and Ti Tree Lakes) and South Byron coastal waters"* and will further identify risks and opportunities associated with several of the key threats identified:

- *"Water pollution from urban stormwater and treated effluent discharge.*
- *Water pollution from agricultural diffuse source runoff.*
- *Pollution of water, beach sand and other habitat areas from litter, solid waste, marine debris and microplastics."*

Belongil Creek, Tallow Creek and Ti-Tree Lake are classified as ICOLLs (Intermittently Closed and Open Coastal Lakes or Lagoons), which predominantly stay in a 'closed' state and open intermittently depending on rainfall and/or coastal conditions. ICOLLs are complex environments and water quality is affected by a number of interrelated factors including catchment derived inputs, internal water quality processes including sediment/water interactions, the balance between fresh and saltwater inputs, entrance condition (open vs closed), and marine sources of pollutants including litter and debris. Whilst there is some degree of understanding of water quality issues in each catchment, BSC has identified a need to prepare a source identification study to gain a better understanding of water quality pollutant sources, locations and impacts, and to assist in the development and implementation of a source control program (BSC, 2022a). While identifying potential future sources of water quality pollution are outside the scope of the current study, it is acknowledged that future climate scenarios may impact on ICOLL water quality through increased risk from climate extremes including drought, increased temperatures, bushfire, rainfall intensity, flood and tidal/coastal inundation. Coastal hazard mapping and assessment for future climate scenarios is currently underway as part of the CMP and any additional water quality sources and impacts identified as part of that process will be considered in future stages of the CMP.

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Potential management options are recommended for further consideration at Stage 3 of CMP development. Going forward, Council will be preparing three distinct CMPs, one for each of the open coast, Belongil Creek and Tallow Creek.

1.1. Study Area

The study area is defined by the hydrological catchment boundaries of Belongil Creek, Tallow Creek and Ti-Tree Lake ICOLLs. The spatial extent of the study area is illustrated on Figure 1.

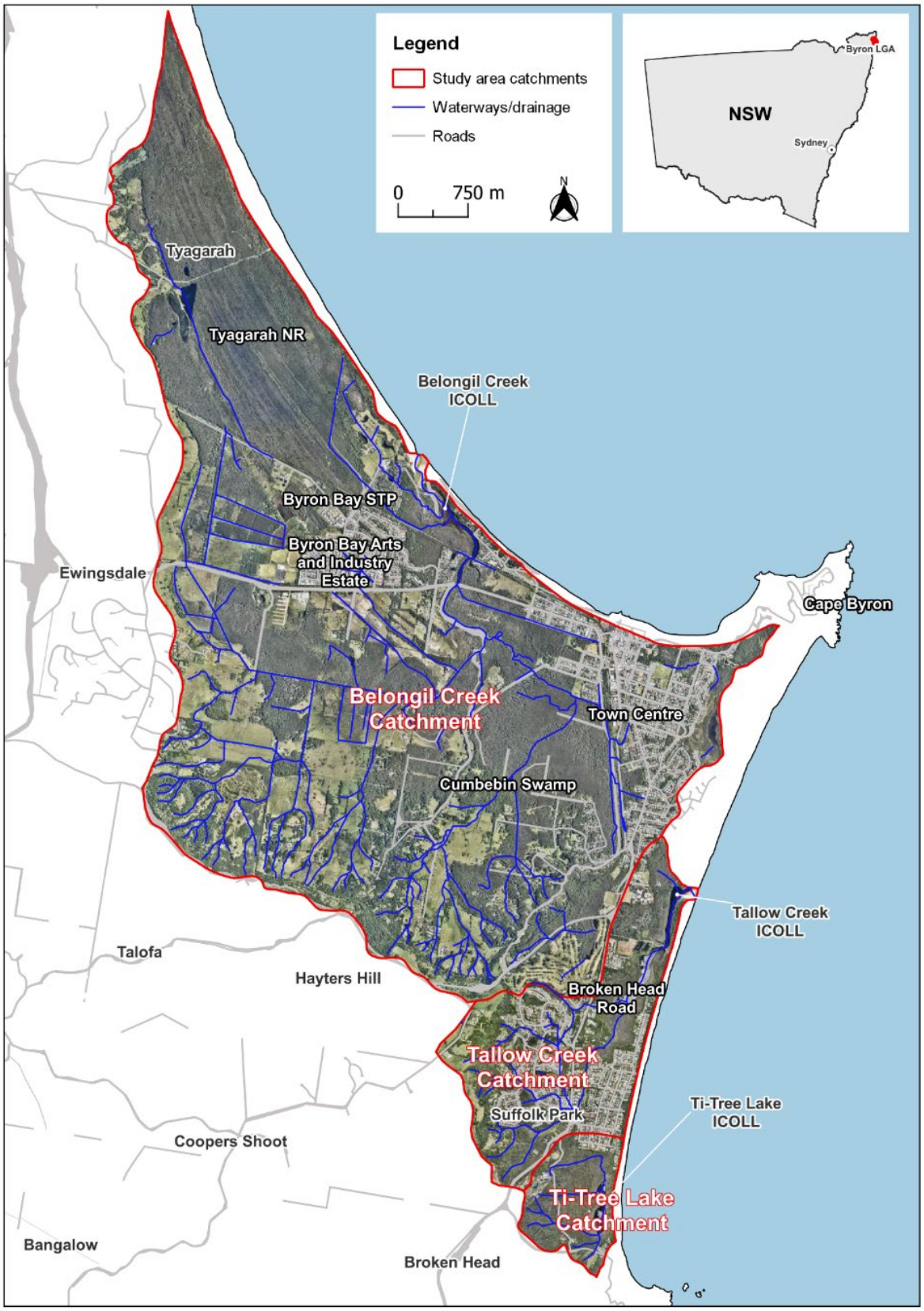

Figure 1: Study area map

Note: Dual naming Cape Byron / Walgun. Source: Mapping data provided by BSC (2023a), DPE (2023) and Nearmap (2022).

2. METHODOLOGY

The Byron Shire ICOLL Water Pollution Source Tracking and Pollution Control Programs were developed through desktop study, stakeholder consultation and inspection of key sites in the catchments. Review and integration of existing information, and datasets was a critical component in the identification of water quality pollution sources. Data sources included background reports and studies, mapping data (e.g. catchment characteristics, land use and infrastructure), and water quality data provided by BSC for catchment monitoring and ICOLL entrance management (refer Appendix 1 for a full list of data sources used). Stakeholder engagement was also vital in confirming the understanding of key issues and in verifying information as observed and experienced by those that live and work in close proximity to the ICOLLs. Key tasks and project stages are shown below in Figure 2 .

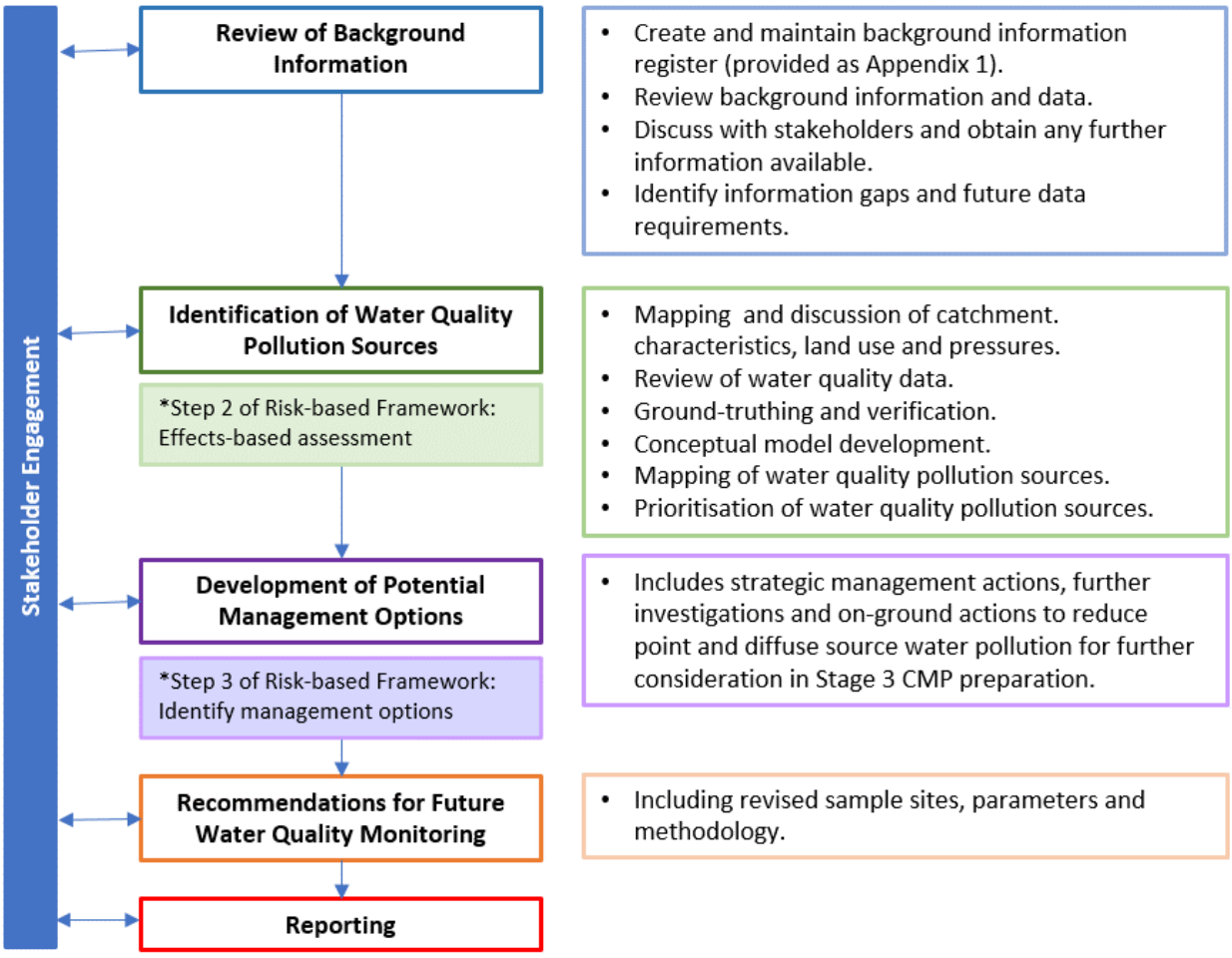

Figure 2: Project methodology key tasks

*Comparable steps in the NSW Risk-based Framework (see below for more information)

2.1. NSW Risk-based Framework

The *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* is a protocol that decision-makers, such as councils and environmental regulators, can use to help manage the impact of land-use activities on the health of waterways in New South Wales (Dela-Cruz *et al*., 2017). The Risk-based Framework was developed in direct response to increasing urban development and a

lack of integrated management of urban development, waterway health, and the community's expectations of the state's waterways.

The current Stage 2 study aligns with Steps 2 and 3 of the Risk-based Framework (noted in Figure 2 above). While the scope of the current study did not include implementation of the Risk-based Framework, there are many elements that are similar between the two approaches including:

- Step 2: Effects-based assessment. This step aims to assess how land use activities will affect water quality. This aligns with a primary aim of this study to identify sources of water quality pollution. A conceptual model has been developed for each ICOLL as part of this study to provide a broad overview of pressures, stressors and state of waterways, which is consistent with the approach for a moderate risk/complexity catchment defined in the Risk-based Framework.
- Step 3: Comparing against waterway objectives – the Risk-based Framework identifies the key purpose of this step as identification of management options. The current study does not include development of a quantitative model and scenario testing, which is discussed as a desirable methodology in this step of the Risk-based Framework. However, due to the high level of existing information available, including previous modelling undertaken in the Belongil Creek catchment, management options were identified to address issues based on the review of background information, discussions with stakeholders and evaluation of pollution sources.
- The current study also includes providing high level assessment and prioritisation of management options ready for input into Stage 3 of the CMP. This is similar to Step 4 of the Risk-based Framework (Strategic Impact Assessment).

3. STAKEHOLDER ENGAGEMENT

Previous stakeholder engagement was undertaken as part of the Stage 1 Scoping Study for the Southern Byron Shire Coastline and Belongil Estuary (Rhelm, 2021) including a community survey, stakeholder workshops and On-Country walkovers with Arakwal and Jali LALC cultural representatives. The community engagement clearly identified litter and poor water quality in the estuaries as a high priority threats with specific concerns regarding stormwater and sewerage management. Key sectors of the community are invested in improving water quality in the ICOLLs (Plate 1).

Stakeholder engagement specifically for this study was undertaken to gather information and understand key issues, locations and available data. A Stakeholder Engagement Plan (Appendix 2) was developed at the outset of the project which documents consultation and liaison activities for the project. Stakeholder meetings were held with Council staff, state government agencies, and relevant local organisations/community groups listed in Table 1. Feedback from stakeholders was used to identify and confirm potential pollution sources and management options.

Plate 1: Community and stakeholder involvement in caring for Byron ICOLLs

Source: RHS photo provided by Byron Coastal and ICOLL Centre (2023)

Table 1: Stakeholders engaged as part of the study.

Stakeholder Group	Division/ Group Name
Byron Shire Council	Coast, Estuary and Biodiversity Services
	Assets and Major Projects
	Environmental Health
	Resource Recovery
	Open Spaces and Facilities
	Drainage / Stormwater / Floodplain Management
	Water and Sewerage
Byron Council Advisory Committee	Coast and ICOLL Advisory Committee

Stakeholder Group	Division/ Group Name
State Government Agencies	Department of Planning and Environment (DPE) – Biodiversity Conservation Division (BCD)
	National Parks and Wildlife Service (NPWS)
	Department of Primary Industries (DPI) - Cape Byron Marine Park
Non-government Organisations / Groups	Water Places Byron Coastal and ICOLL Centre Positive Change for Marine Life (PCFML) Tangaroa Blue

4. BELONGIL CREEK ICOLL

4.1. Background

Belongil Creek is a small ICOLL located approximately two kilometres to the west of the Byron Bay town centre. Tidal areas of the creek below mean high water mark (MHWM) are zoned Special Purpose within the Cape Byron Marine Park. Significant areas of Coastal Wetlands and remnant pockets of Littoral Rainforest are mapped within the catchment and protected under the *Coastal Management Act 2016*. Belongil Creek is a culturally significant place for First Nations people and is included within the Native Title Area of the Bundjalung People of Byron Bay.

The Belongil Creek entrance is located on Belongil Beach and drains a catchment area of approximately 32 km². The Belongil Creek catchment has been significantly altered since European settlement in the 19th century through:

- Extensive vegetation clearing.
- Floodplain drainage works undertaken to drain floodplain wetlands and enable the expansion of agricultural, urban and light industrial development across low-lying areas.
- The entrance of Belongil Creek has been artificially managed for over 100 years to manage flood risk and water quality issues.

It is estimated that approximately 80% of land within the Belongil Creek catchment has either been cleared, drained or altered in some way, which has significantly altered the catchment condition and natural processes (Alluvium, 2019). These historical modifications and the ongoing use of land have significant impacts on water quality, which has been reported as generally poor throughout catchment waterways except for the lower estuary sites where regular flushing with marine water improves water quality conditions (Alluvium, 2019 and 2021; AWC 2020a; BMT and AWC, 2017; BSC, 2008).

Plate 2: Belongil Creek Entrance, April 2023

4.2. Identification of Water Quality Pollution Sources

4.2.1. Catchment characteristics, land use and pressures

Catchment characteristics such as waterways, geology, soil types (including potential and actual acid sulfate soils), topography/slope, and artificial drainage of land influence pollutant sources and how pollutants will behave in the environment and impact water quality in downstream ICOLLs. Human uses of land and waterways also impact water quality in downstream receiving environments. In the Belongil Creek catchment the dominant land use pressures are agricultural and industrial activities, urban residential, tourism and commercial land uses and the sewerage and stormwater systems that service them. The Belongil Creek catchment also receives the additional pressure of sewage pumped from the Tallow Creek and Ti Tree Lake catchments for treatment at the BBSTP. Mapping of catchment characteristics, land uses and human-induced pressures was undertaken for each ICOLL catchment and is discussed below.

Catchment elevation, waterways and drainage

Catchment characteristics for Belongil Creek are mapped in Figure 3. Catchment elevation ranges from approximately 135 mAHD in the upper catchment to 1 mAHD on the floodplain. Both natural and artificial drainage is shown including major drainage systems connecting catchment areas to Belongil Creek:

- The Union Drain is the major drain on the western side of the catchment connecting floodplain areas to Belongil Creek. It was constructed in 1913 by the Belongil Creek Drainage Union (Alluvium, 2019). 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).
- Butler Street Drain is the major surface water drain on the eastern side of the catchment connecting the Byron Bay town centre stormwater network to Belongil Creek near Ewingsdale Bridge in the mid-estuary. This drain runs through Cumbebin Swamp Nature Reserve.
- The Industrial Estate Drain is the major surface water drain through the Byron Bay Arts and Industry Estate connecting into the Union Drain and upper Belongil Creek.

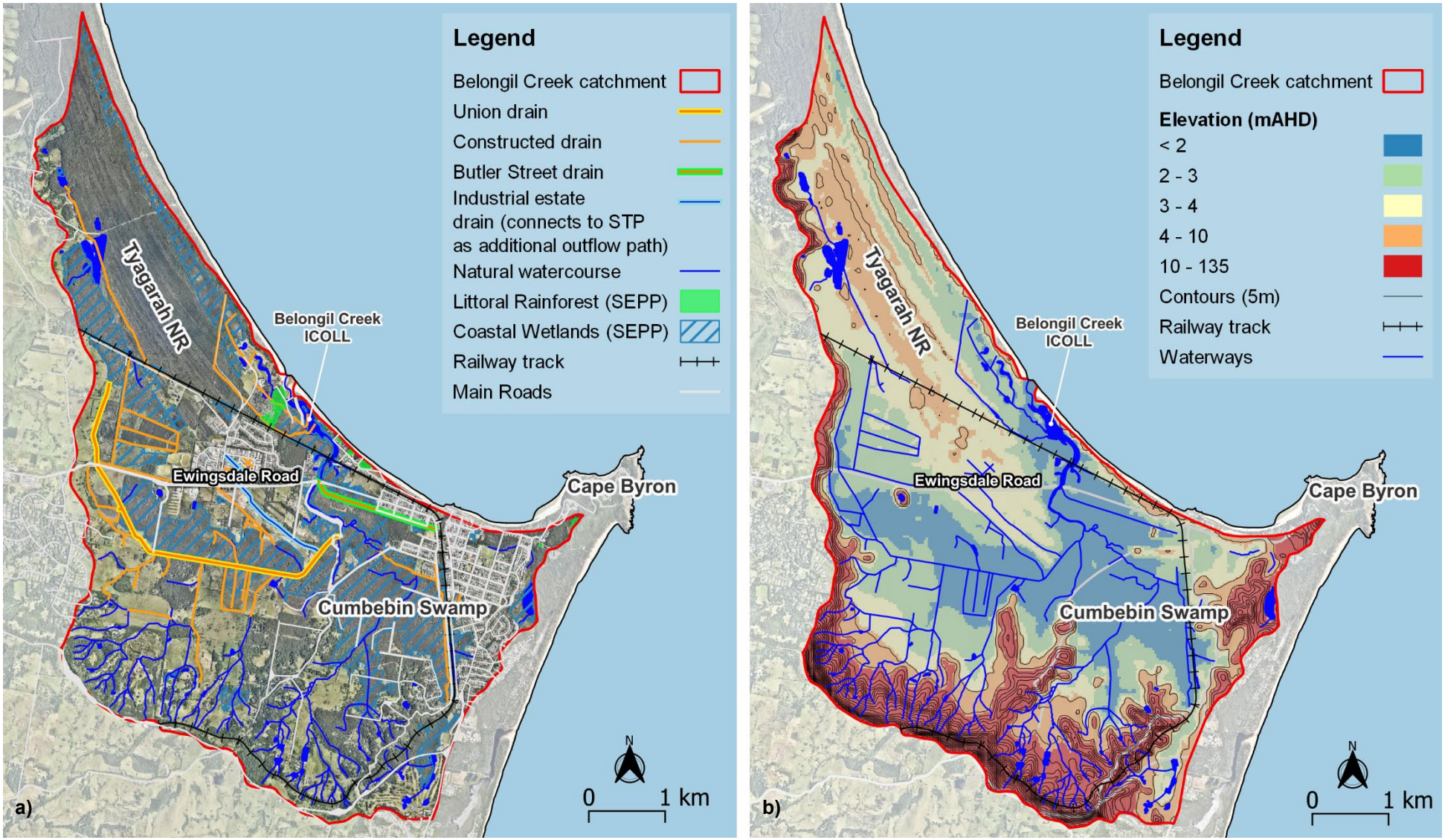

Figure 3: a) Belongil Creek natural waterways, wetlands and artificial drainage b) Belongil Creek elevation and waterways (natural and constructed)

Note: Dual naming Cape Byron / Walgun. Source: Mapping data provided by BSC (2023a), DPE (2023), Geoscience Australia (2023) and Nearmap (2022).

Acid Sulfate Soils

Potential Acid Sulfate Soils (PASS) are naturally occurring sediments and soils containing iron sulfides on the floodplain/ tidal flats. When PASS is exposed to air through excavation or lowering of the water table (e.g. through construction of drains) a chemical oxidation reaction can occur converting soils to actual Acid Sulfate Soil (ASS) and producing sulfuric acid. During subsequent rainfall events acid runoff can be transported to nearby waterways. Acid runoff can also mobilise toxic metals and other contaminants (e.g. iron, aluminium, arsenic etc.) from soil and transport them to waterways. The Belongil catchment ASS risk map (Figure 4) shows that a large proportion of the Belongil Creek Catchment is either Class 2 or Class 3 ASS. This indicates the likely presence of potential ASS occurring just below the natural land surface (Class 2) and >1m below the natural land surface (Class 3) over extensive areas of the floodplain. Class 1 ASS is mapped within the Belongil Creek estuary itself indicating ASS is likely to be found on and below the natural ground surface (typically in sediments within parts of the creek). Water quality decline associated with ASS impacts has been repeatedly documented in previous studies of Belongil Creek (Parker and Pont, 2001; Belongil Acid Sulfate Soils Working Group, 2003; Alluvium, 2021) and has also been noted in the water quality review completed for 2016-2022 as part of this study (refer Section 4.2.2).

ASS impacts pose an ongoing threat to water quality particularly during high risk periods including:

- Dry times when the water table is low enough to expose PASS to air and cause oxidation of previously waterlogged ASS. Artificial drains exacerbate the issue by exposing PASS layers beneath the ground surface, by facilitating the lowering of the water table and acting as a conduit for rapid transportation of acid runoff and pollutants to Belongil Creek during subsequent rainfall events.
- During excavation and/or disturbance of soil (e.g. during earthworks, drain maintenance etc.). Effective management involving testing and treatment of ASS is necessary to manage risk and prevent adverse water quality impacts.

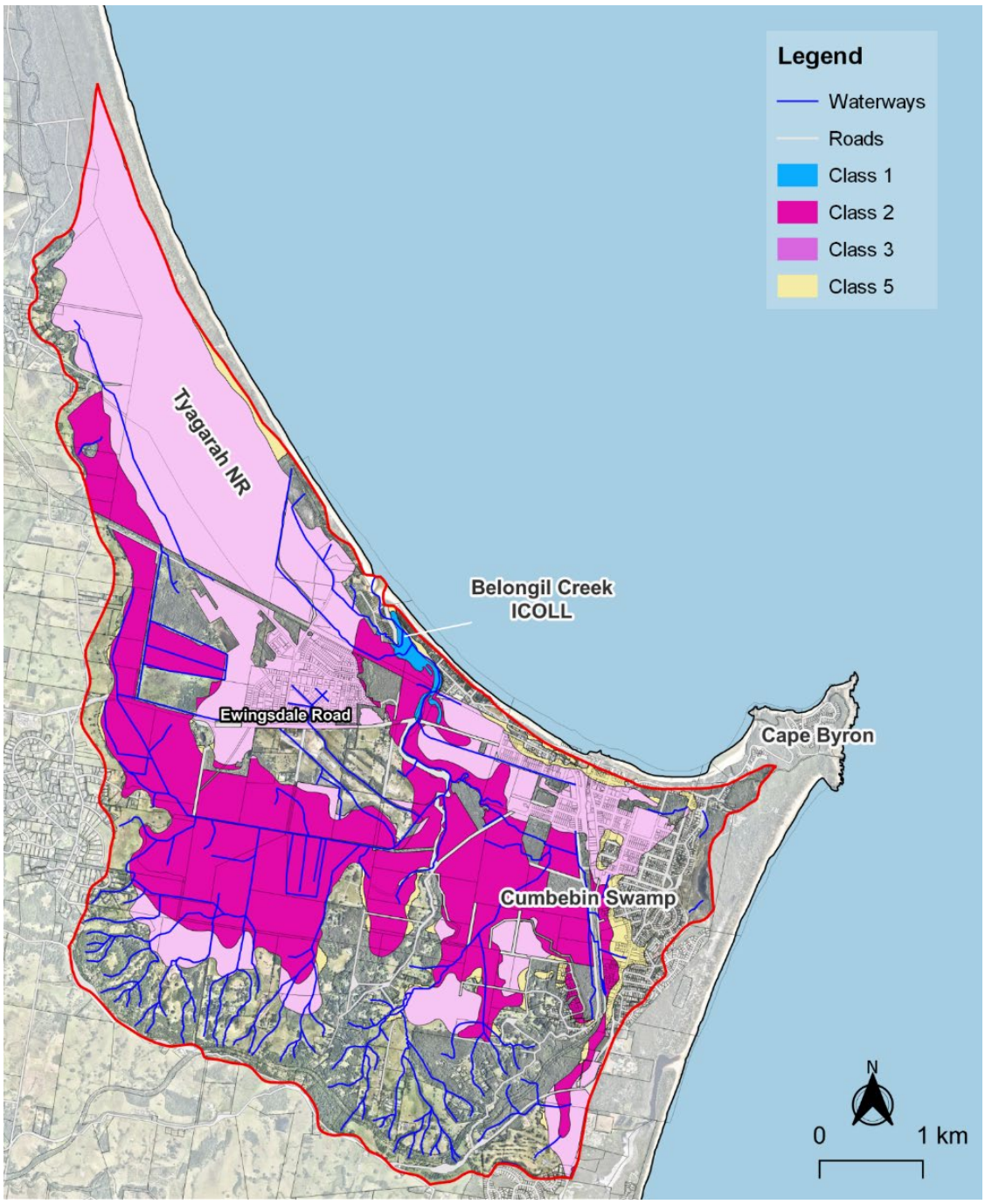

Figure 4: Belongil Creek Catchment acid sulfate soil risk

Note: Dual naming Cape Byron / Walgun. Source: Mapping data provided by BSC (2023a), DPE (2023) and Nearmap (2022).

Land use and land tenure

The Belongil Creek catchment has a mix of land uses as shown on Figure 5. The land use mapping is the latest statewide land use dataset available from the NSW Government based on 2017 mapping (DPE, 2020). The mapping dataset gives a good overall picture of land use, however some variation may exist between mapped land use extents and current land use in 2023.

The dominant land classification within the study area is 'Vegetated areas', comprising approximately 38% of the catchment. Vegetated areas occur mostly within National Parks estate include Tyagarah Nature Reserve, Cumbebin Swamp Nature Reserve and parts of Arakwal National Park in addition to vegetated

areas on private land, Council-managed land and Crown land. This land use category includes both remnant, regrowth, native and exotic vegetation.

Grazing land is the next most common land use, comprising 27% of the catchment, the majority of which is located on the floodplain and extending to the upper south and west parts of the catchment. Diffuse source runoff from agricultural land was identified as a priority threat to the NSW marine estate by the Marine Estate Management Strategy Threat and Risk Assessment (MEMS TARA, WBM, 2017) and a major cause of poor water quality in estuaries through the contribution of significant sediment, chemical and nutrient loads to the estuary, primarily during runoff (rain) events. Unrestricted stock access to waterways can create issues of bank instability and erosion through trampling, damage to riparian vegetation, weed encroachment and direct input of nutrients and pathogenic contaminants to waterways. MWA (2019) reported that farm runoff into the Union Drain includes nutrients from fertilisers and manures, sediment from erosion and farm chemicals. Cattle graze to the waterline on drains and creeks stripping riparian vegetation and destabilising banks (MWA, 2019). Grazing also decreases native vegetation recruitment while farm management promotes pasture species through slashing and seeding which are intolerant to flooding and can die-off in periods of extended inundation, resulting in blackwater generation and low dissolved oxygen concentrations. As discussed above, artificial drains exacerbate ASS issues and impacts on water quality. Poor quality agricultural land runoff has flow-on effects to estuarine ecosystems and productivity in the immediate vicinity and downstream in the estuary. Much of the current agricultural use of the floodplain relies on the continued use of the existing system of constructed drains to remove water from low-lying areas and facilitate agricultural activities.

Services and Infrastructure land uses comprise 12.7% of catchment including the Byron Bay Arts and Industry Estate, the Byron Bay Sewage Treatment Plant (BBSTP), railway line and commercial parts of the Byron Bay town centre. Urban residential areas (11.5% of the catchment) are located in the Byron Bay town centre, Belongil Beach, Sunrise residential estate and the 'Harvest' (part of West Byron) subdivision currently under construction. It also includes caravan parks, resort/holiday accommodation and the Byron Bay Golf Course. Tourism is a major industry in Byron Bay, with an average of 15,000 visitors to the LGA each day recorded in the year to June 2019, representing a 44% increase in the local resident population at that time (BSC, 2020). From 2020 - 2030, visitor numbers to the Byron Shire are forecast to grow by between 50% and 75% (BSC, 2020). Urban, industrial and tourism development has affected estuarine processes through changes to hydrologic characteristics and vegetation as well as the discharge of pollutants through stormwater runoff and point source pollution such as treated sewage discharges. Impacts from urban, tourist and commercial development are anticipated to increase with increasing population and tourism pressures in Byron Bay.

Rural residential land use makes up 10% of the catchment area in the mid floodplain and upper catchment areas, comprising large lifestyle lots and some hobby farms. Horticulture and animal production comprise only a small proportion (0.6% and 0.2%) of the catchment area respectively.

Land tenure within the study area is illustrated on Figure 5. Most of the study area is freehold land under private ownership (77.43%). Approximately 20% of land is managed as National Park/Reserve. Crown land is divided into Council - managed (0.54%) and Crown land not managed by Council (2.44%). Native Title (non-exclusive) exists across parts of the Belongil catchment including much of Tyagarah Nature Reserve, parts of the lower Union Drain and the lower section of Belongil Creek.

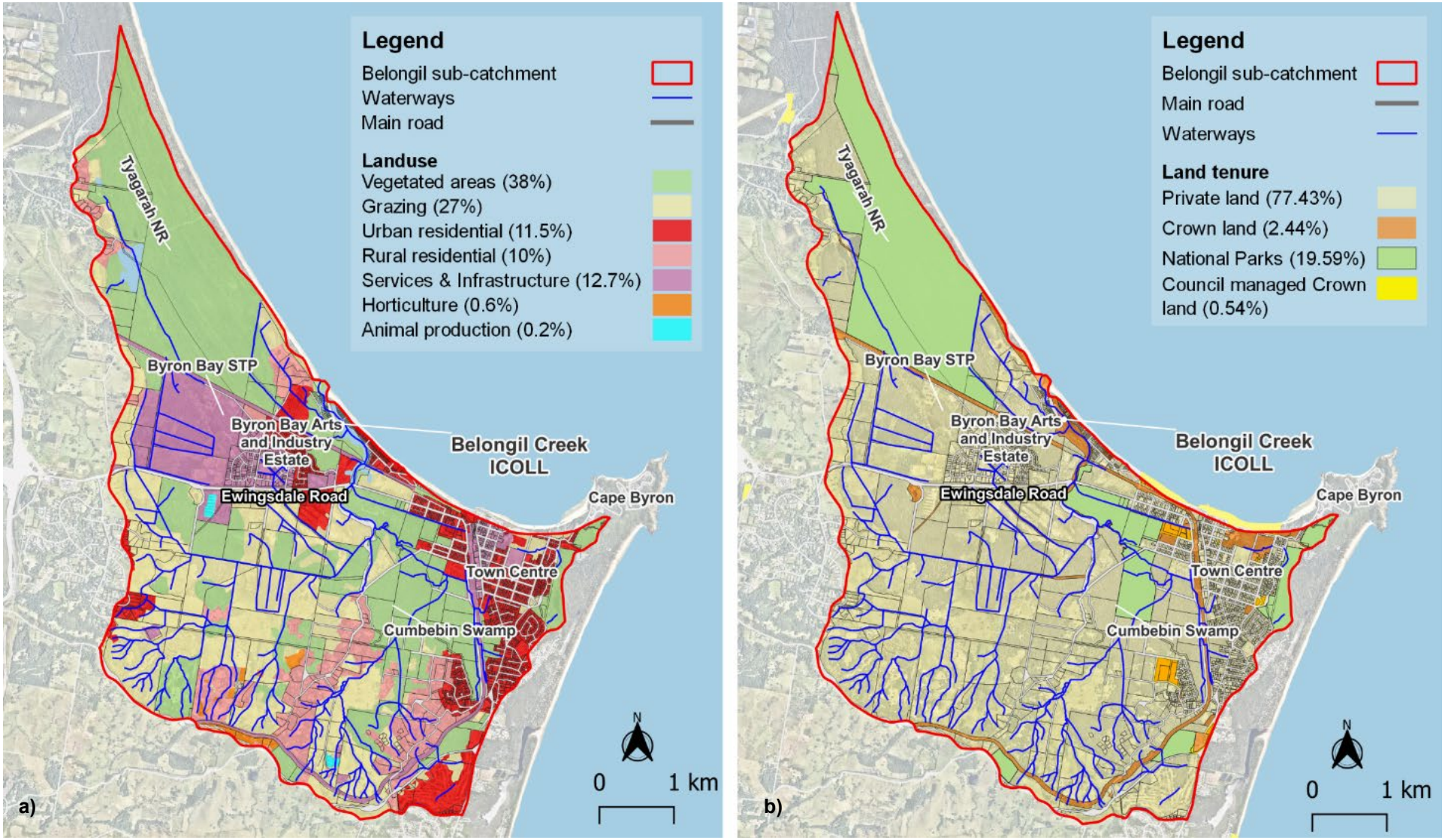

Figure 5: a) Belongil Creek catchment landuse b) Belongil Creek catchment land tenure

Note: Dual naming Cape Byron / Walgun. Source: Mapping data provided by BSC (2023a), DPE (2020, 2023) and Nearmap (2022).

Sewer infrastructure

Belongil Creek catchment sewer infrastructure is shown on Figure 6 (a). Figure 7 provides a simplified overview of the Byron Bay wastewater treatment process and infrastructure including the Byron Bay Sewerage Treatment Plant (BBSTP) and the Byron Bay Integrated Water Management Reserve (BBIWMR).

All urban and industrial areas of Byron Bay are serviced by a reticulated sewerage system, a series of pipelines and pumps that convey wastewater from households and businesses to the BBSTP for treatment. In 2006 the South Byron STP in the Tallow Creek catchment was decommissioned and all wastewater from the Suffolk Park and Broken Head urban areas is now transferred to the BBSTP. On average the BBSTP currently discharges approximately 3.85ML/day of tertiary treated effluent to constructed wetlands (BBIWMR) and the 24 ha Melaleuca forest (AWC and BMT, 2017). This aligns with monitoring data for the past five years (P. Orams, pers. comm., 18 July 2023). The constructed wetlands further 'polish' the treated effluent to a very high standard prior to release to the drainage network on the upper floodplain of Belongil Creek (Figure 7) at approximately 2.5 ML/day in dry weather as seen in monitoring data for station EPA4 (P. Orams, pers. comm., 18 July 2023). In addition, some treated effluent (currently approx. 0.5 ML/day) is supplied back to town as recycled water for outdoor irrigation and municipal uses (Figure 7). A reduction in the incidence and severity of ASS impacts and peat fires in the upper Belongil Creek catchment has been reported since the regeneration and irrigation of the 24 ha wetland area (Melaleuca forest) within the BBIWMR using tertiary treated effluent (AWC, 2020a), this being an explicit objective of the BBIWMR. This is a result of maintenance of higher groundwater levels that increase soil moisture and prevent exposure of ASS.

The quality of BBSTP treated effluent discharge is typically of a higher standard than the receiving environment within the Upper Union Drain (AWC, 2019 also refer Section 4.2.2) however, due to the relatively constant discharge of effluent relative to other flows into the catchment (e.g. runoff), the BBSTP represents a constant low concentration, but high total load source of pollutants (primarily nutrients) to Belongil Creek and this is projected to increase in the future with increased development in the catchment (Mayjor *et al.*, 2023; AWC and BMT, 2017). Modelling of projected future increases to BBSTP discharge to 5ML/day (at 2025) or 8ML/day (at 2050) resulted in increased flows and increased inundation of floodplain areas, decreases in salinity and increases in total nutrient concentrations (total nitrogen (TN) and total phosphorus (TP) in the estuary (AWC and BMT, 2017). Long-term median changes in modelled nutrient levels in Belongil Creek were considered to be relatively minor (TN increase of 2.7% and TP increase of 2%), however short-term peaks in nutrient concentrations are expected (up to 92% increase in TP for the 8ML/day scenario) during certain conditions such as during extended entrance closure and/or dry weather periods (AWC and BMT, 2017). Given that nutrient concentrations are already elevated above levels considered suitable for healthy aquatic ecosystem function at most water quality sampling sites (refer Section 4.2.2), increased BBSTP discharges will place more pressure on the ecosystem values of Belongil Creek estuary in the future. This includes increased potential for algal blooms and depletion of dissolved oxygen and growth of aquatic weeds. AWC and BMT (2017) recommended an additional effluent release pathway from the BBSTP into the Industrial Estate Drain to reduce the impacts associated with increased inundation of the floodplain. This option, however, will not mitigate the predicted increases in nutrient concentrations in the estuary. At the time of this report the additional flow path has been constructed but is not yet operational (Figure 7). Additionally, the current flows to the BBSTP have triggered initiation of planning an upgrade to the STP. Considerations are likely to include expansion of treatment/reuse wetland to buffer impacts on the catchment (P. Orams, pers. comm., 18 July 2023).

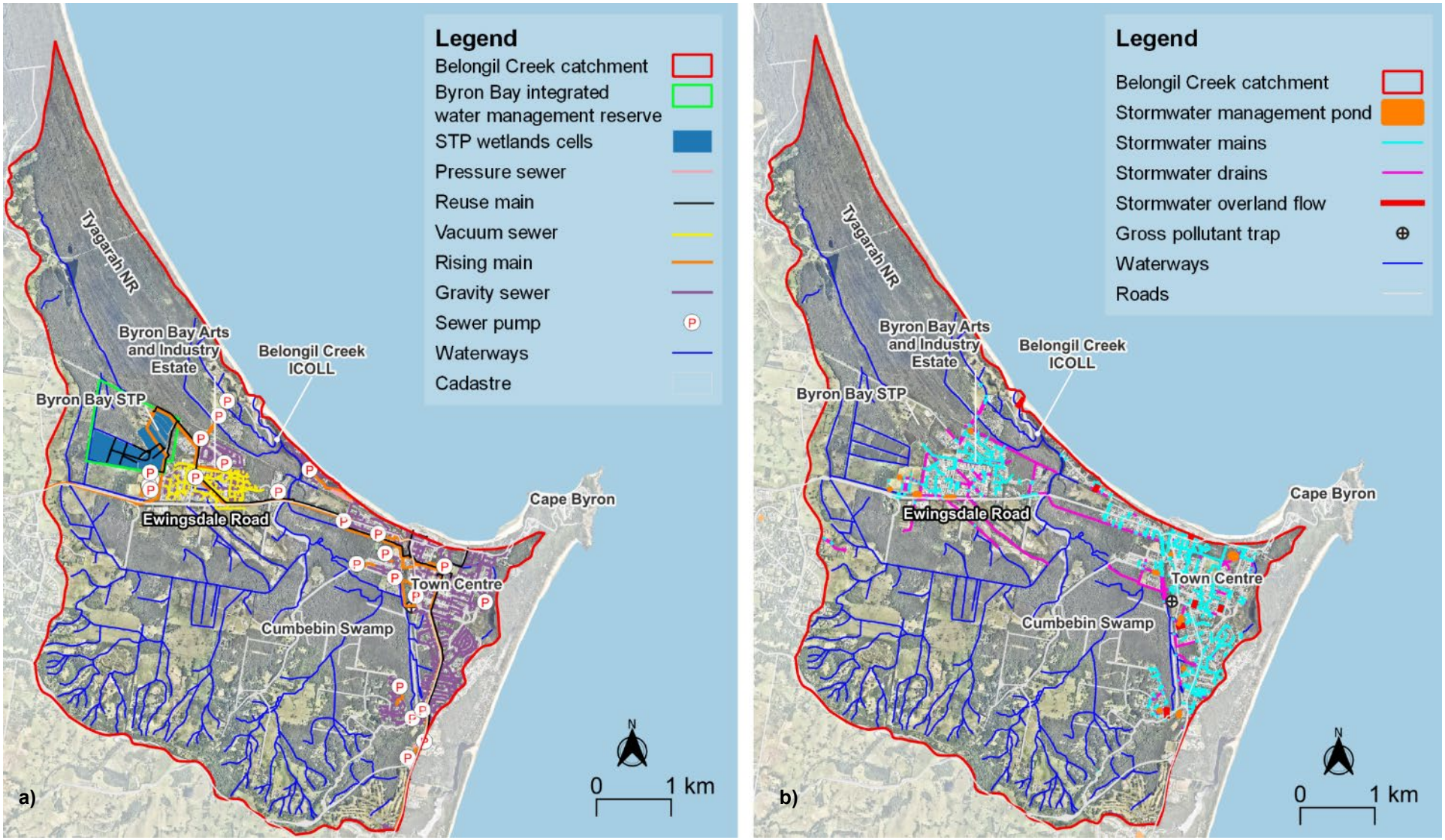

Figure 6: a) Belongil Creek catchment sewer infrastructure b) Belongil Creek catchment stormwater infrastructure

Note: Dual naming Cape Byron / Walgun; GPT near the Butler Street drain has recently been removed. Source: Mapping data provided by BSC (2023a), DPE (2023) and Nearmap (2022).

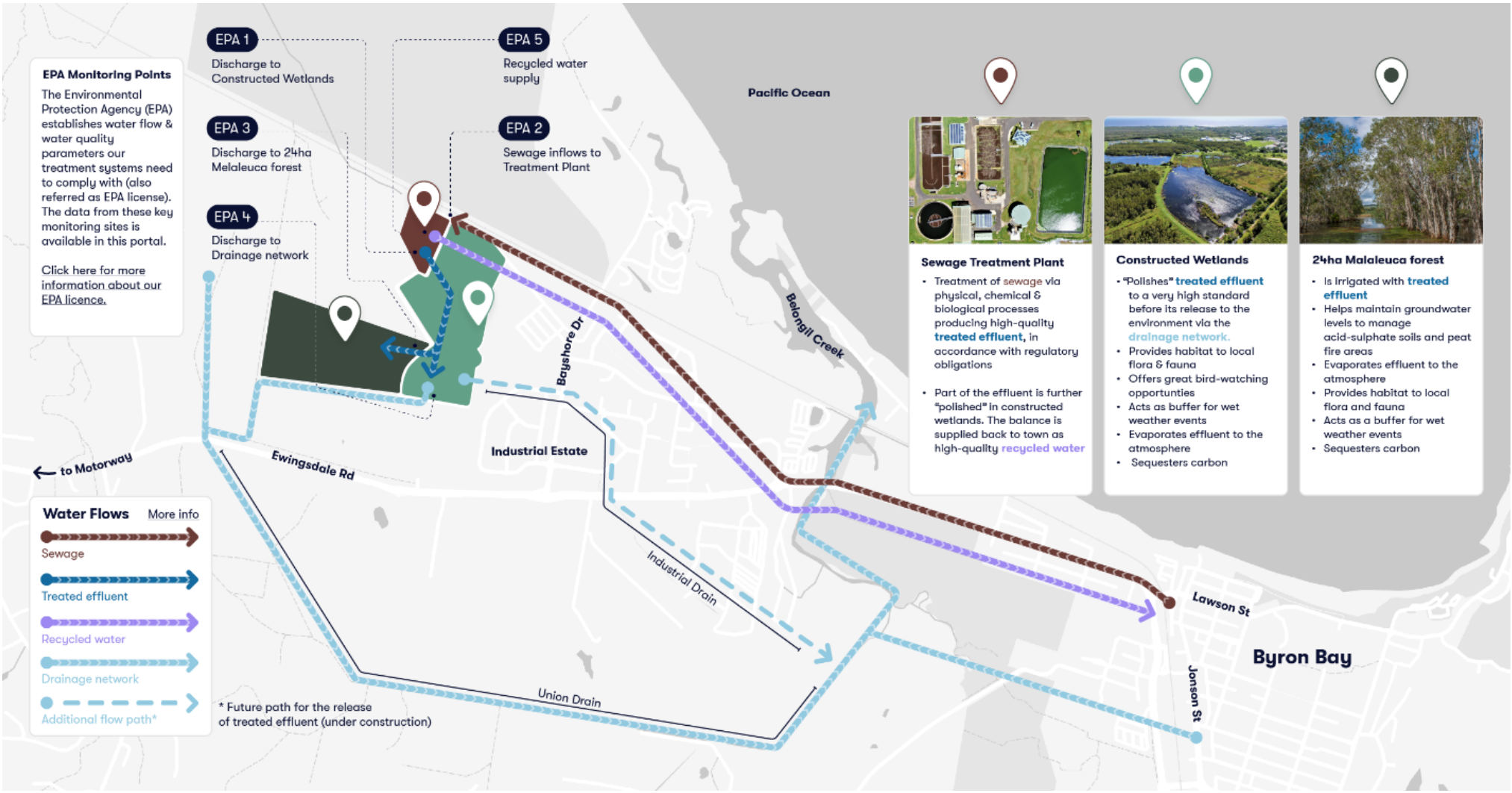

Figure 7: Byron Bay wastewater treatment process simplified infographic

Source: BSC (2023b)

BSC sewer overflow incident reporting

A review of BSC sewer overflow incident reporting from the last six years (2016-2022) was undertaken as part of this project. BSC provided the following information for review:

1. List of sewer overflow reports from the BSC customer request management (CRM) database from April 2016 – April 2022. BSC noted that the list of customer reported overflows may not provide a complete record of all overflows but is the typical way that BSC is notified about smaller overflow events.
2. Reports sent to the NSW Environmental Protection Authority (NSW EPA) by BSC documenting all reportable overflow incidents for Byron Bay. These reports are a requirement of BSC's NSW EPA Licence (EPL 3404) where some environmental impact has occurred (i.e. discharge of effluent to the environment). BSC noted that there may be some of the reported overflow incidents included in the CRM report if the public reported something prior to Council actioning the overflow incident.
3. *Memo - Impact on Sewer Infrastructure of Flood Event Commencing 30 March 2022* (BSC, 2022b), which describes the impact of major flooding events on sewer infrastructure in the Byron Shire. Overall the BBSTP had no major issues during the event, however there was one incident noted in the memo relevant to Byron Bay, with relevance to the Tallow Creek catchment (refer Section 5.2.1, Sewer infrastructure).

Figure 8 shows the number and type of customer reported sewer overflow events from April 2016 – April 2022 in the Belongil Creek catchment. There was a total of 52 customer reported incidents over this six year period. The highest number of reported incidents by customers occurred in 2020 (total of 31) which was substantially more than in any other year and is likely due to the higher than average rainfall experienced in 2020 leading to overloading of the sewer system (Figure 8). The majority (27) were caused by sewer blockages/ chokes, six were caused by tree root blockages, eight were related to vacuum pod failures, four were related to sewer pump station failures, three were due to sewer pipe breaks and the remainder were due to other equipment failure (1) or not reported (3). Illegal development in Byron Bay (renting out illegal structures) or overloading the capacity of dwellings has been previously identified as putting strain on the sewer system, particularly in peak holiday periods (Alluvium, 2019). Council staff responded to all incidents and completed inspections, repair and clean up actions as required. Some incidents were associated with overflows from private properties and property owners were responsible for corrective actions.

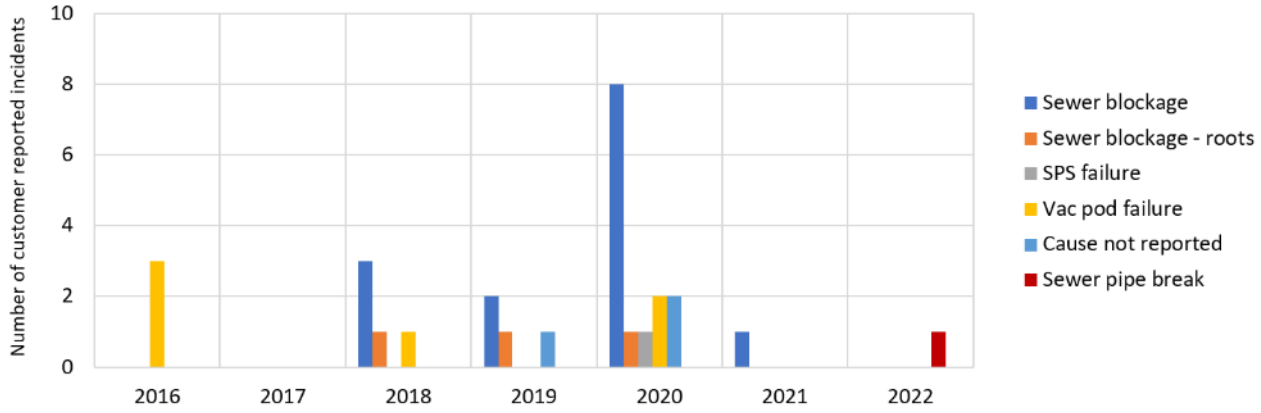

Figure 8: Number of customer-reported sewer overflow incidents in the Belongil Creek catchment April 2016 – April 2022.

Appendix 3 summarises details of the reports sent to the NSW EPA documenting all reportable NSW EPA incidents for Byron Bay for the Belongil Creek catchment 2016 – 2022. Council staff and / or contractors responded to all incidents and completed inspections, repair and clean up actions as required. There were four incidents from 2019 - 2022 where the estimated volume of effluent discharged to the environment was significant (1,000 – 200,000 L). In all cases Council took action to clean up and disinfect the sites as soon as possible after being notified of the incident. Typically a vacuum pump out truck was used to remove effluent discharged to the environment. Follow up actions were also carried out as a priority including repair, investigation into the cause of the incident and actions to prevent or mitigate against the recurrence of such an event.

Sewer overflow incidents represent a short-term but potentially high impact point source of pollutants to stormwater drains and downstream receiving environments including the Belongil Creek ICOLL. Review of BSC water quality monitoring data (Section 4.2.2) identified strong evidence of poor water quality runoff from urban and industrial areas (i.e. nutrients, turbidity and elevated levels of bacteria). It is currently unknown whether sewer overflow incidents are contributing to poor stormwater quality. Microbial source tracking, which uses DNA analysis to identify sources of faecal contamination (i.e. human vs. dog vs. other animal sources) could be undertaken to provide further information and assist in directing management action.

Management action should be prioritised to address sewage infrastructure impacts on Belongil Creek ICOLL, a highly sensitive downstream receiving environment. Council is currently preparing an Integrated Water Cycle Management Strategy (IWCM) and the issue of sewage system performance and overflow frequency is being addressed through that process. Issues related to trade wastewater discharge, illegal stormwater to sewer connections and wet and dry weather overflows identified as part of this study have been raised and will be addressed through that process.

Stakeholders have also raised concerns regarding the potential presence and impact of Endocrine Disrupting Compounds (EDCs) in BBSTP effluent discharged to the environment. EDCs are natural or synthetic chemicals that interact with the endocrine system altering its normal functioning (e.g. natural hormones, synthetic steroidal hormones and synthetic chemicals including some pesticides, dioxins, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), phenols and several heavy metals) (Williams *et al.*, 2007). EDCs can be released from a range of point sources including STPs, pulp and paper mills, intensive animal operations (e.g. feedlots, piggeries etc.) and industrial sites, as well as diffuse sources, such as agricultural runoff from land treated with pesticides and landfill leachate. The presence and potential impact of EDCs within the Belongil Creek ICOLL has not been investigated to date.

On-site sewage management

Approximately 20% of properties within the Belongil Catchment are unsewered and manage wastewater using on-site wastewater management systems. This includes approximately 150 septic systems, two of which are large in size but generally well-managed at the Steiner school (PR57230) and SAE (PR 38912) (pers. comm M. Bingham, 2023). The SAE system is located within the sewered areas of Byron Bay on Ewingsdale Road and could be connected to the sewage network in future with minimal additional cost. Poorly designed or located on-site wastewater management systems, or those that are not functioning adequately (e.g. through lack of maintenance, ground conditions, age etc.) can contaminate groundwater and downstream waterways. However, due to the low density of on-site wastewater management systems in the catchment (approx. 1/20ha) and implementation of BSC's On-site Wastewater Management Strategy

and associated approvals, the Belongil catchment has been characterised as a low on-site wastewater management system risk to public and environmental health (pers. comm M. Bingham, 2023).

Stormwater infrastructure

Belongil Creek catchment stormwater infrastructure is shown on Figure 6 (b). All urban and industrial areas of Byron Bay are serviced by an urban stormwater system, a series of drains, pipes, pits and other infrastructure that convey stormwater from households and businesses to the receiving environments, Belongil Creek ICOLL and the ocean. Belongil Creek ICOLL receives stormwater inputs directly from roads and urban areas and also from major stormwater drains including Butler Street Drain which drains the majority of the Byron Bay town centre and the Industrial Estate Drain, draining the Byron Arts and Industry Estate. Typically, this water is characterised by high biological oxygen demand (BOD), low dissolved oxygen and high inorganic nitrogen (Alluvium, 2019). Poor quality stormwater is attributed to the following:

- Urban runoff – fertiliser, pesticides, herbicides, organic matter (e.g. grass clippings and vegetation), pet waste and other chemicals (e.g. detergents, paint etc.).
- Road runoff – hydrocarbons, oil and grease etc.
- Intermittent sewer overflows - the majority of sewer overflow events discussed above discharge directly into the stormwater system and may contribute to poor water quality recorded at these locations.
- Litter –recent work by BSC has provided more information on the scale of the litter problem in the Byron Shire which is discussed below.
- Commercial food waste – stakeholders have reported food waste from businesses being present in stormwater drains in the Byron Bay town centre.

The CMP Scoping Study (Rhelm, 2021) identified that there is currently limited primary stormwater treatment infrastructure within the Belongil Creek catchment with future options limited due to low relief, land availability and drainage capacity (Rhelm, 2021). Currently, there are no actively maintained gross pollutant traps (GPTs) throughout the Shire (BSC, 2023c). Stormwater maintenance is currently undertaken primarily on a reactive basis due to limited resourcing. Funding increases to the stormwater maintenance budget are required to implement more proactive maintenance schedules (K. Weallans, pers. comm., 20 July 2023).. Many of the urban stormwater systems drain directly into low lying wetland areas, many of which are now contained within Coastal Wetland areas within the *SEPP (Resilience and Hazards) 2021* (refer Coastal Wetland mapping Figure 3). There are significant regulatory constraints in improving drainage in these areas due to the Coastal Wetland classification under the SEPP including removal of vegetation and ongoing sedimentation in these areas is likely to impact drainage capacity into the future.

It is understood that a GPT near the Butler Street drain was removed as part of the Byron CBD bypass works, due to inadequate drainage. However, Council has applied for a grant to design the Byron Bay Drainage Strategy update and if successful, that would include a constructed wetland located at Butler Street drain (Rhelm, 2021). It is noted that Native Title exists over some of this area and will need to be considered in project planning phases. BSC is also currently conducting a litter basket trial installed within stormwater pits to capture litter and debris before it reaches Belongil Creek. Details of the current trial are provided below (refer section on Litter and marine debris).

The *Byron Shire Council Water Sensitive Urban Design (WSUD) Policy and Strategy* (BMT WBM, 2021) includes strategic actions to guide WSUD in the Shire, although no on-ground actions were identified. Relevant planning actions to the control of water quality pollution sources are:

- Strategy A - *"Improve Council's planning, processes and capacity to integrate WSUD into Council works and address catchment based priorities"*
    - Action A6 – Catchment Planning - Identify conditions and sensitivity of major catchments to water cycle issues and develop priority actions as part of a holistic catchment planning process. Separate one for each catchment. Belongil by June 2021, Tallows by June 2022.
- Strategy C – *"Increase Council's ability to leverage funding to implement, operate and maintain WSUD infrastructure now and into the future"*
    - Action C1 - O&M Program / Plan for WSUD - Develop a Stormwater Operation and Maintenance Program and Plan for all urban drainage assets. The plan should clearly show costs associated with WSUD specific assets. The plan would identify the minimum recommended operation and maintenance requirements for each WSUD device or WSUD type. Details such as tasks, frequency of works, record keeping, expected costs should be included.
    - Action C3 – Increasing Funding for WSUD- Increase Council's ability to leverage funding for WSUD systems maintenance.

Litter and marine debris

The state-wide *Marine Debris Threat and Risk Assessment* (MDTARA) defined marine debris as anthropologically manufactured or processed materials that have been deliberately or accidentally disposed of in, abandoned in, or transported to estuarine, coastal and marine environments (State of NSW and DPE, 2023). Debris has wide-ranging negative impacts on the environment and on socio-economic values such as the entanglement of fauna in debris, the ingestion of debris, or the changing of habitats, reduction in recreation or a decrease in our appreciation of nature (State of NSW and DPE, 2023).

The CMP Scoping Study (Rhelm, 2021) identified '*Pollution of water, beach sand and other habitat areas from litter, solid waste, marine debris and microplastics*' as a high risk threat in the first-pass risk assessment for the study area. This is consistent with results of the community survey which identified litter and marine debris as the biggest threat (equally with a lack of compliance) to the Byron Shire coastal zone (Rhelm, 2021).

Results from local litter surveys undertaken monthly in hot spots throughout the Shire in 2020/ 2021 reveal that Byron Bay is by far the most littered suburb, followed by Brunswick Heads and Suffolk Park (Figure 9, BSC, 2023c). Cigarette butts (smoking) were the most frequently littered item in Byron Bay, followed by beverage and takeaway containers and other items. The increased litter volumes detected within Byron Bay was attributed to the significantly higher volume of visitors to Byron Bay as opposed to other parts of the Shire (BSC, 2023c).

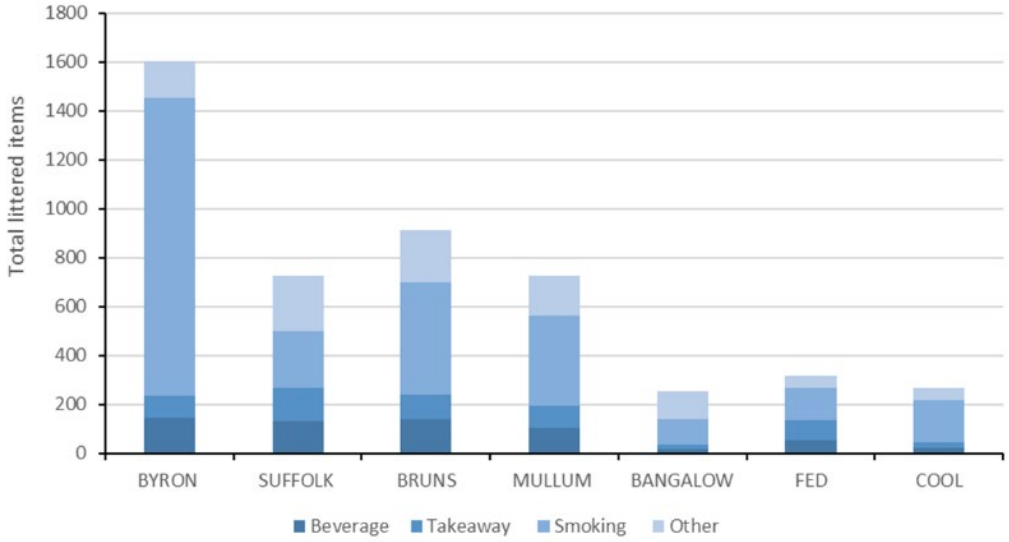

Figure 9: Total number of littered items per suburb from monthly local litter check surveys undertaken throughout the Shire in 2020/2021.

Source: (BSC, 2023a)

Baseline data from the Key Littered Items Study (KLIS) and Australian Litter Measure (AUS LM) surveys conducted in late 2022 and early 2023 by BSC identified a considerable amount of litter both on land and within Belongil Creek estuary itself. A total of 118 kg and 518 items were collected in the baseline KLIS surveys (from 4 x 20 m transects in Belongil Creek mangroves), including 217 pieces of plastic and 106 glass items (BSC, 2023c). Plastic items were the most prominent type of litter in all environments, and 'retail' land types have the largest amount of litter in the Shire, which suggests retail areas may be a primary source of litter (Figure 10). Additionally, whilst undertaking AUS LM surveys, visual inspections of nearby drains were undertaken, with litter commonly identified in and surrounding the drains in most locations (BSC, 2023c). This is consistent with site inspections (particularly Butler Street Drain) carried out as part of this study in April 2023 (refer Section 4.2.3).

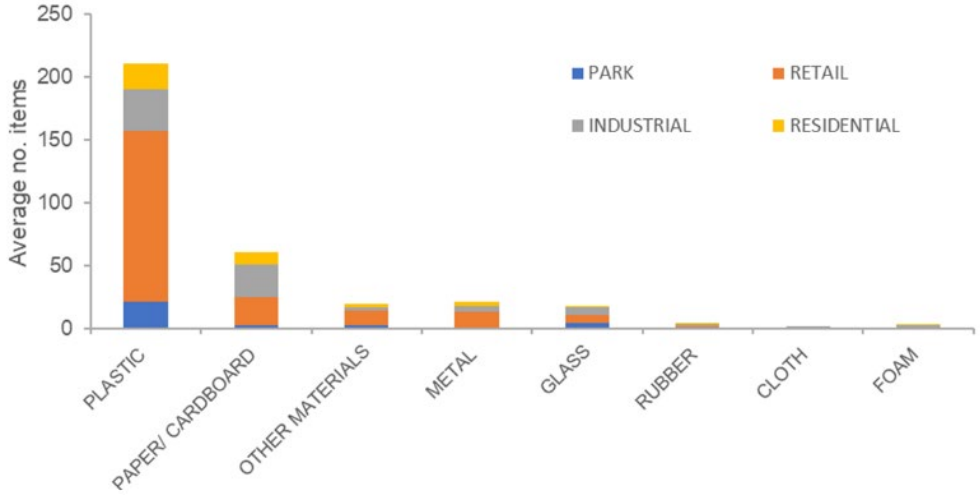

Figure 10: Average no. of littered items and material compositions identified at various land type sites during baseline AUS LM (land-based) data surveys undertaken in Byron Bay in August 2022.

Source: (BSC, 2023c)

The NSW EPA is responsible for leading programs to deliver litter reduction, with powers and responsibilities to reduce litter and enforce the laws shared across NSW state and local governments, businesses and

individuals. There are state-wide strategies and programs in place to reduce litter and its impact on waterways and the marine estate including:

- NSW Waste and Sustainable Materials Strategy 2041
- The NSW Plastic Action Plan
- NSW Litter Prevention Strategy
- Marine Estate Management Strategy

The Marine Estate Management Strategy 2018-2028 (MEMS, NSW Marine Estate Management Authority, 2018) sets a management objective *'To improve water quality and reduce marine litter for the benefit of marine habitats, wildlife and the community'.*

BSC is currently implementing the 'Source to Sea' project which involves deploying and maintaining litter baskets within stormwater pits to capture and remove litter at the source before it reaches downstream environments and to further understand the benefit of potential devices (BSC, 2023c). A total of 24 stormwater inlet pits were selected for litter basket deployment in May 2023 consisting of 20 within the Byron Bay Town Centre and four within the Byron Bay Industrial Estate. Servicing is to be carried out bi-monthly for the trial duration of one year, concluding in May 2024. Monitoring of litter will be repeated through time to assess the effectiveness of the trial at reducing litter impacts on the estuary.

Dip sites and contaminated land

A search of the *Protection of the Environment Operations Act 1997* (POEO Act) Public Register (NSW EPA, 2023) and DPI cattle dip site locator (DPI, 2023) identified five sites within the catchment with potential to contaminate downstream waterways. These are shown in Figure 11.

The BBSTP is subject to environment protection licence (EPL 3404) under the POEO Act for the discharge of treated wastewater. The EPL specifies discharge conditions and details monitoring and reporting requirements for the treatment plant.

The decommissioned Butler Street Reserve landfill site is a notified contaminated land site subject to active POEO Act licencing and management regulated by the NSW EPA. The Butler Street Reserve was an unlicensed landfill up until the mid-1970s. Investigations to date indicate that PFAS (per-and-poly fluoroalkyl substances) in the groundwater is not a human health risk. However the level of PFAS detected in soils underlying the reserve is comparatively high and further investigations are ongoing by BSC in partnership with the NSW EPA (BSC, 2023d).

Information is available from DPI (2023) on the status of the three recorded dip sites in the catchment including a list of chemicals used historically at the dips (Figure 11). The impact from historical dip sites on Belongil Creek is unknown. There is also the potential for further unknown contaminated land sites within the catchment associated with small private landfills, and animal industries etc. that do not appear on government registers.

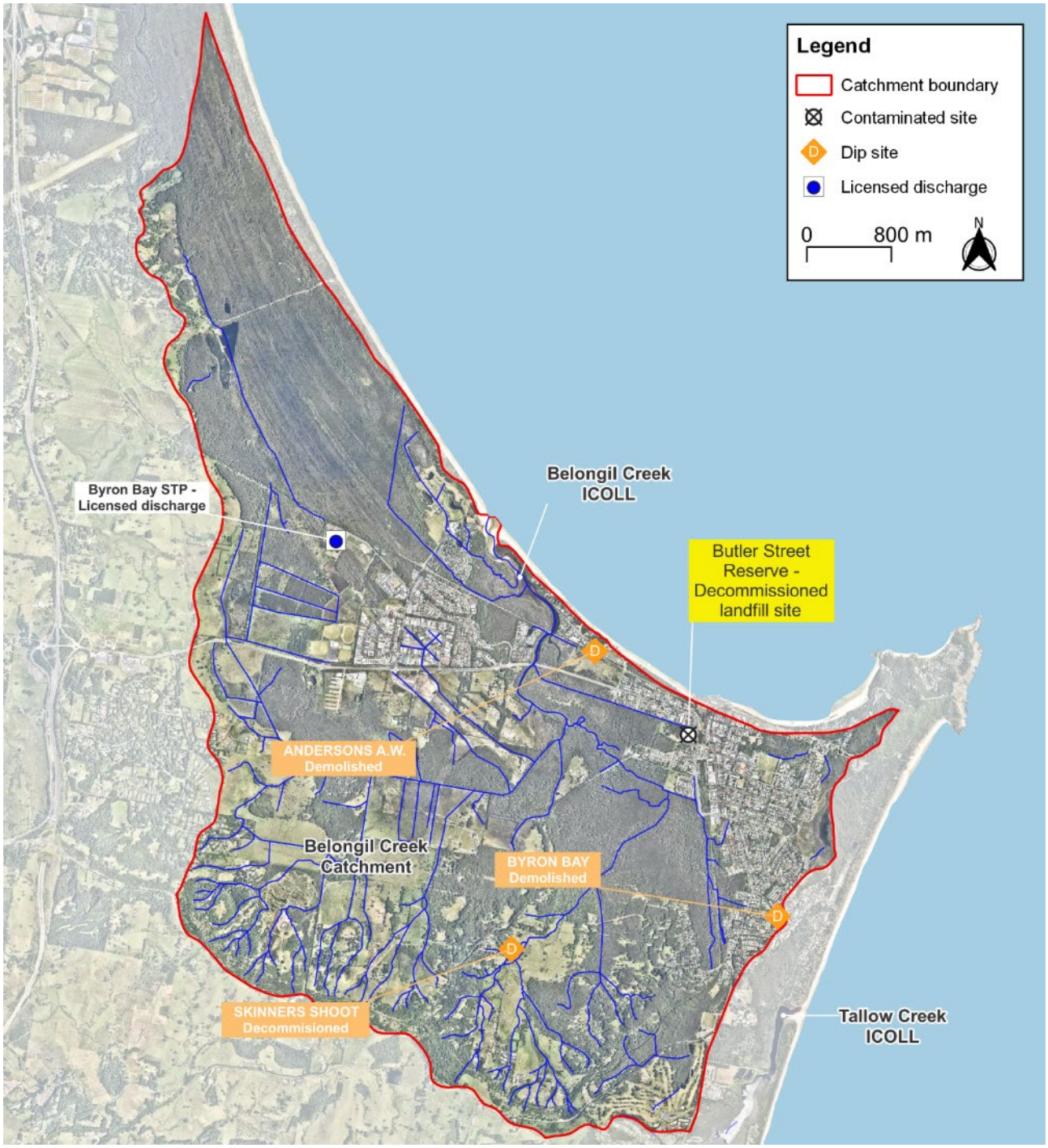

Figure 11: Search results of the POEO Act Public Register and DPI cattle dip site locator.

Source: BSC (2023a) NSW EPA (2023a, b), DPE (2023), Nearmap (2022) and DPI (2023).
Dip site status terms (DPI, 2023):
Demolished – is where the dip site has been partially or wholly dismantled or demolished prior to the introduction of the decommissioning policy. In many cases there is no physical signs of the dip ever being there.
Decommissioned – means all the standing structures, shed, fencing and roof have been dismantled. The bath itself, if present, is emptied of all chemical fluid and may have contaminated timbers from the roof and draining pen put into it and then is capped with concrete lids. The bath may have already been demolished prior to decommissioning in which case it is usually smashed and buried. An information plaque is attached to one of the concrete lids to indicate its Departmental file number, dip name and direction of the dipping. Clean soil may be spread around the bath to run flush with the bath edge and then grassed. The draining pen concrete floor is usually left intact so as not to disturb the possibly contaminated soil.

DPE Estuary Health Risk Dataset

The NSW DPE has developed an estuary health risk dataset for each estuarine catchment in NSW (Dela-Cruz, *et al.*, 2019) to support development of CMPs under the NSW Risk-based Framework. The intent of the dataset is to help identify strategic priorities for managing nutrient and sediment runoff throughout a catchment so that estuary health is protected, maintained and/or improved. The dataset provides an overview of broadscale risk to estuarine health from modelled catchment export of nutrients and sediment based on mapped land use categories on a sub-catchment scale. When used as part of CMP studies, the dataset can be used to help map where further studies and/or management actions in a catchment would contribute to achieving some of the management objectives relating to nutrient and sediment load reduction. Risks from other pressures such as ASS, blackwater events, bank erosion, pesticides, point source pollution and other catchment contaminants are not considered in the risk assessment. The current estuary health risk results for TN, TP and total suspended solids (TSS) loads are mapped in Figure 12. Rapid Catchment Assessment Tool (RCAT) modelling of the Belongil catchment was also undertaken at a local level recently (Alluvium, 2019). This is shown in Figure 13.

While the two assessments are different in terms of sub catchment delineation and results, some common key areas are highlighted:

- The Arts and Industry Estate – high rates of TN, TP and TSS contribution.
- Town Centre – moderate rates of TN, TP and TSS contribution.
- Belongil Swamp – moderate – high rate of TN contribution.

The water quality data review, ground-truthing and verification tasks completed as part of this study provides more detailed local information that is generally consistent with the overall results produced by the modelling.

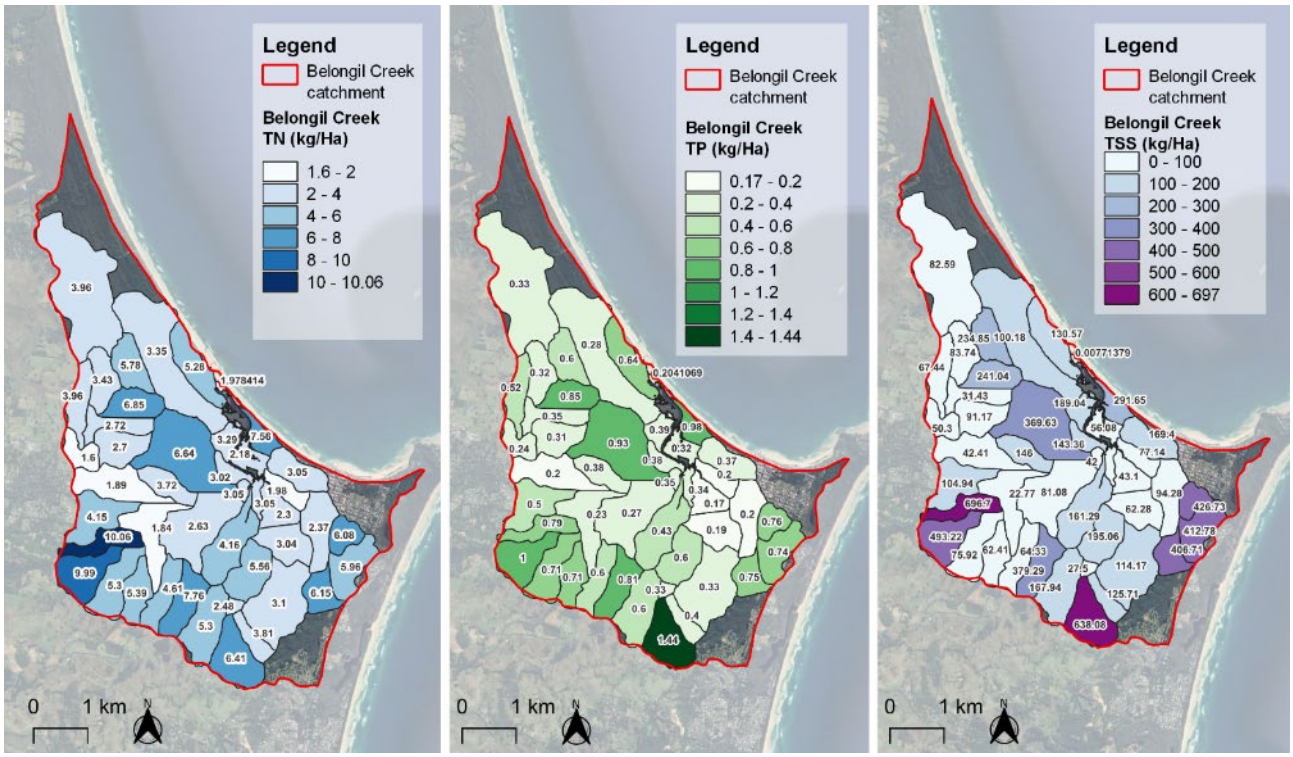

Figure 12: Belongil Creek Estuary Health Risk Dataset results for TN, TP and TSS (kg/ha/yr)

Source: DPE (2023), Google satellite.

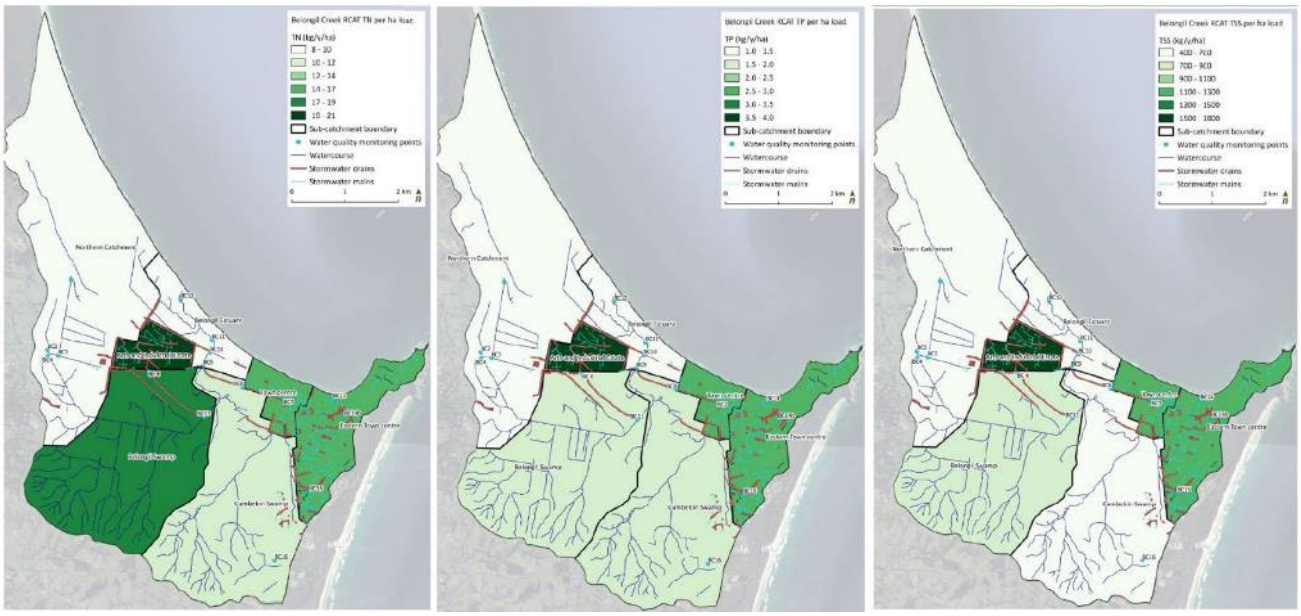

Figure 13: Belongil Creek RCAT modelling results for TN, TP and TSS (kg/ha/yr)

Source: Alluvium (2019)

4.2.2. Review of water quality monitoring data

BSC undertakes water quality monitoring of the Belongil Creek catchment waterways as part of two primary programs:

1. Byron Bay Surface Water Quality Monitoring Program – incorporating environmental monitoring sites and sites required by the NSW EPA as part of the BBSTP Licence conditions. Between 2016 and 2022 the program included surface water sampling at 18 sites on a monthly basis and in response to rainfall events. Four of the sites (BC05, BC08, BC10 and BC14b) were discontinued at different stages throughout the sample period.
2. Entrance Opening Strategy (EOS) monitoring – water quality and level loggers and event based sampling in accordance with the Belongil Creek Entrance Opening Strategy (EOS) Rev 1 (Alluvium, 2021) and requirements of licences and permits in currency (a Crown Land licence and a Marine Parks permit is required for entrance management works in accordance with the EOS).

The locations of sample sites are shown on Figure 14 including routine sample sites and water quality logger sites. Site details are provided in Table 2 below.

Table 2: Byron Bay Surface Water Quality Monitoring Program sampling sites

Zone	Site ID	Location	Sample type	Status
Upper catchment (BBSTP discharge)	BC23 (EPA4)	Discharge to Belongil Ck Wetland	Monthly and event	Current
Upper Floodplain (Agriculture and BBSTP)	BC02	Bottom Moran's Hill Drain (approx. 100m upstream from junction with BBSTP wetlands discharge)	Monthly and event	Current

Zone	Site ID	Location	Sample type	Status
	BC03	Junction of BBSTP Wetlands & Cavanbah Centre	Monthly and event	Current
	BC04	Upper Union Drain, South of Ewingsdale Culvert	Monthly, event and permanent logger site (north of culvert).	Current (surface water sampling) Logger discontinued March 2022
	BC05	Union Drain, end of Melaleuca Drive	Monthly and event	Discontinued November 2020
Mid Floodplain (Industrial Estate)	BC06	Top end of Belongil Fields (Industrial) drain	Monthly and event	Current
	BC13	Bottom end of Belongil Fields drain (Union Drain outlet)	Monthly and event	Current
Mid Floodplain (Urban)	BC07	Butler Street drain – downstream of Butler Str. Culvert	Monthly and event	Current
	BC08	Butler Street drain, Southern end Kendall Street	Monthly	Discontinued August 2018
Upper Estuary	BC09	Ewingsdale Rd, northern side of bridge	Monthly, event and permanent logger site (EOS program).	Current
Mid Estuary	BC10	Belongil Creek railway bridge (Drain runs down southern side of rail line/ outlet at rail bridge)	Monthly	Discontinued August 2018
Lower Estuary	BC11	Manfred Street drain outlet, Belongil Creek	Monthly and event	Current
Estuary Entrance	BC12	Belongil Creek Outlet, east of Elements Resort	Monthly and event	Current
Upper town catchment (Urban Stormwater)	BC15	Bangalow Road, north of 80 Bangalow Rd	Monthly and event	Current
	BC17	Old Bangalow Road	Monthly and event	Current
Upper town catchment (Golf course)	BC16	Golf Course outlet, Bangalow Road	Monthly and event	Current
	BC14	Clarks Beach stormwater outlet (beach side)	Monthly and event	Current

Zone	Site ID	Location	Sample type	Status
Coastal draining (Urban Stormwater)	BC14b	Massinger Street – on Sunny Hills side – opposite Kipling Street	Monthly and event	Discontinued December 2022
Monitoring Parameters assessed:	Salinity, pH, turbidity, total suspended solids (TSS), total nitrogen (TN), oxidised nitrogen (NO_x), ammonia (NH_3), total phosphorus (TP), ortho-phosphate (Ortho-P/PO_4),chlorophyll a, *E. coli,* enterococci, dissolved oxygen (DO, loggers only). Refer to Glossary and Abbreviations at the end of this report for further descriptions of parameters.			

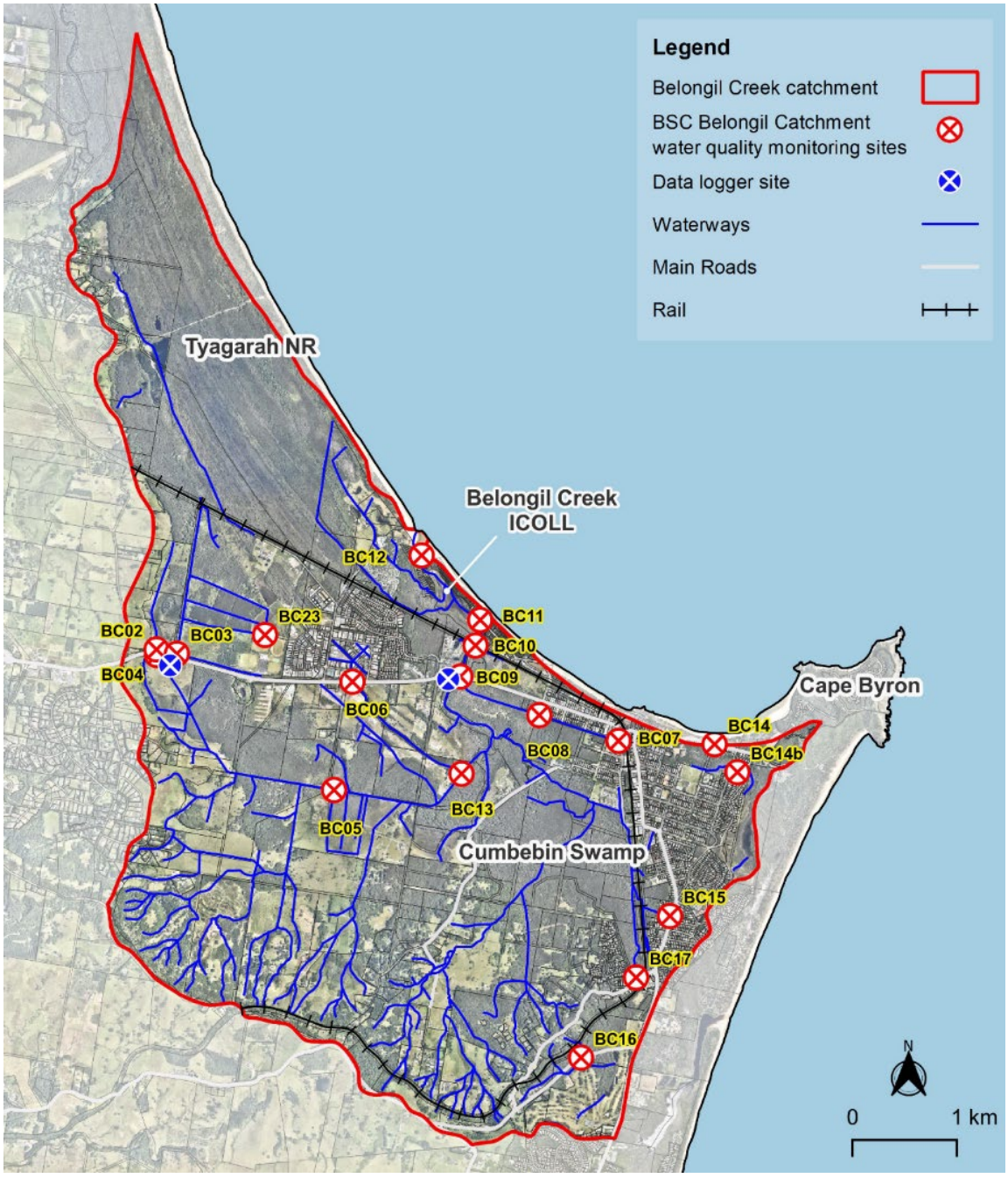

Figure 14: Belongil Catchment water quality sampling sites

Source: BSC (2023a), DPE (2023) and Nearmap (2022).

Byron Bay Surface Water Quality Monitoring Program

A review of water quality data collected over the last six years of BSC's Byron Bay Surface Water Quality Monitoring Program was undertaken (monthly monitoring from 2016-2022). Box and whisker plots for all data available for this period are shown in Figure 18, Figure 20 and Figure 19. Sampling sites have been grouped by geographical location and pollutant source category. See Figure 17 for an explanation of box plots.

There are no locally-derived water quality objectives for the Byron Shire ICOLLs. In the absence of local guidelines, the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) are considered to be the most relevant published guidelines to use in the assessment of water quality. The guidelines are essentially "trigger values", the numeric criteria that, if exceeded, indicate potential for harmful environmental effects to occur. The default trigger values are conservative and precautionary. If they are not exceeded, a very low risk of environmental damage can be assumed. If they are exceeded, further investigation is "triggered" for the pollutant concerned. Guidelines are compared against the median value (middle line in the box and whisker plot) to assess whether water quality conditions are potentially impacting aquatic ecosystem health. Note that NSW DPE are in the process of developing revised water quality guidelines for different estuary types and the findings below could be revisited once revised guidelines are available.

Water quality guideline values (ANZG, 2018) are shown in Table 3 below and as dashed lines for estuarine and freshwater systems as applicable in Figure 18, Figure 20 and Figure 19.

Table 3: Water quality guidelines for protection of ecosystem health and primary contact recreation

	Lowland River (freshwater)		Estuary	
	Upper guideline	Lower guideline	Upper guideline	Lower guideline
DO (%sat)	110	85	110	80
pH	8.5	6.5	8.5	7
Turbidity (NTU)	50	-	10	-
TN (mg/L)	0.5	-	0.3	-
NH_3	0.02	-	0.015	-
NO_x (mg/L)	0.04	-	0.015	-
TP (mg/L)	0.05	-	0.03	-
PO_4 (mg/L)	0.02	-	0.005	-
Chlorophyll *a* (ug/L)	5	-	4	-
Enterococci (cfu/ 100ml)	35	-	35	-

Source: (ANZG, 2018)

Key findings were:

- Belongil Creek estuary sites recorded salinity ranges from freshwater through to marine water indicative of an ICOLL with variable entrance opening regime. As expected, the typical salinity levels were highest at the entrance and decreased with distance upstream. A freshwater to saline salinity range (0-30 ppt) was observed at BC08 (mid Butler St. Drain) indicating periodic tidal ingress at this site. This tidal influence was not observed at BC07 in the upper Butler St. Drain over this time period. Site BC05 (Melaleuca Drive) in the mid-floodplain also showed elevated salinity range (0-30 ppt)

which was higher than the downstream site BC13, and therefore does not seem to be explained by tidal ingress. Further investigation of water quality at this site is warranted to determine the higher salinity. This is near an area of Melaleuca die off and is a specific concern to the Belongil Creek Drainage Board. The remaining sites recorded salinity values generally within the freshwater range (0-0.5 ppt).

- The majority (67%) of sites recorded low pH (i.e. acidic water) with median values during 2016-2022 being outside of the guideline ranges recommended for aquatic ecosystem health. The lowest pH values were recorded at sites in the upper floodplain, dominated by agricultural landuse and modified by artificial drainage works. Site BC02 (Moran's Hill Drain) upstream of the BBSTP discharge confluence recorded the lowest pH (with a median value of pH 5.6 and a range of pH 3 – 7.3). pH gradually increased with distance downstream to the estuary. Several of the sites in the mid floodplain influenced by urban and industrial drainage and landuse also recorded median values below the recommended guidelines, with the exception of BC05 (Melaleuca Drive), which may have been buffered with higher pH tidal influence. The mid, lower and entrance estuary sites were within guideline values, likely as a result of the increased buffering capacity of marine water, which is able to neutralise acidic catchment inputs to the estuary. Site BC23 (STP discharge) also consistently recorded values within the guideline range of pH 6.5 – 8.5, which is in line with the STP licence conditions for wastewater discharge.
- While not included in the 2016-2022 dataset, of note are recent results published on the BSC Water Quality Public Data Portal (BSC, 2023e), showing a decrease in pH at site BC13 from near neutral pH levels (pH 6.1 – 6.5) to acidic conditions (pH 3.6 – 4.3) from February 2023 – May 2023 (Figure 15). These results were significantly more acidic than all previous values recorded at this site from 2016-2022 (range of pH 5.6 – 7). BSC's Environmental Health Officer investigated the Harvest construction site (West Byron Subdivision) which is located immediately upstream of BC13 in May 2023 and identified site pH values of pH 3.1 (newly constructed swale), and pH 4.1 within an existing swale on site (pers. comm M. Bingham, 2023). These results highlight the impact of soil excavation activities within ASS areas on downstream water quality. ASS mitigation measures were undertaken at the site following BSC discussions with construction site managers. BSC will continue to monitor the site throughout the construction phase.

Figure 15: Site BC13 pH results for July 2022- May 2023

Source: BSC (2023e)

- Median turbidity values at all sites assessed over the time period were within the ranges recommended for aquatic ecosystem health (<50 NTU freshwater and <10 NTU estuarine water). Maximum values and outliers identify sites that are susceptible to periodic elevations in both turbidity and TSS indicating poor water clarity at times, likely due to sediment runoff during rainfall events or potentially algal bloom conditions. The highest median turbidity levels occurred within Butler Street Drain (BC07, 26 NTU), followed by the Byron Bay Golf Course outlet (BC16, 18 NTU) and Moran's Hill site in the upper Union Drain, upstream of the confluence with the STP treated effluent outflow (BC02, 16 NTU). A maximum turbidity value of 3,730 NTU was recorded at site BC06 (Industrial Estate Drain) which coincided with a maximum TSS value of 4,200mg/L. Of note is the effect of tannin-stained waters such as occur in Belongil estuary that contain colour and can absorb more light causing turbidity to appear higher than it is. Tannin-staining / colour does not affect TSS values.
- Nitrogen levels are regularly elevated throughout the Belongil Creek catchment sites. All sites exceeded guideline values for TN, with the highest median values detected at BC02 (Moran's Hill Drain, 1.5mg/L TN), and BC07 (Butlers Street Drain, 1.4 mg/L TN), indicating significant sources of TN from the upper floodplain agricultural areas and Byron Bay town centre.
- Oxidised nitrogen (NO_x - bioavailable forms of N) were noticeably higher at site BC15 (Bangalow Road, urban area) than any other site and warrants further investigation of potential sources at this location (e.g. potential sewer leaks/overflows, excessive fertiliser use etc.). Figure 16 shows all NO_x results at BC15 from May 2016 to March 2023 showing consistently elevated levels and three spikes of NO_x occurring in June and December 2019 and again in September 2021. Review of BSC sewer overflow records as part of this project (refer Section 4.2.1, Sewer infrastructure) identified customer reported sewer overflow incidents occurring at properties adjacent to this location in January 2019 (due to pump station 3001 failure from the build-up of oils and grease) and again on 10th February 2020 (due to sewer choke). The consistently high NO_x results indicate an ongoing issue at this site that warrants further investigation. Sites BC07 and BC14 and BC14b also showed elevated median levels of NO_x and occasional spikes over the monitoring period assessed, which may indicate similar issues at these sites and also warrants further investigation. One sewer overflow incident reported to the NSW EPA on 27/1/2021 was described as impacting the Butler Street Drain on the corner of Dryden Street and Shirley Lane with an estimated discharge of effluent to the environment of 10,000L (Appendix 3).

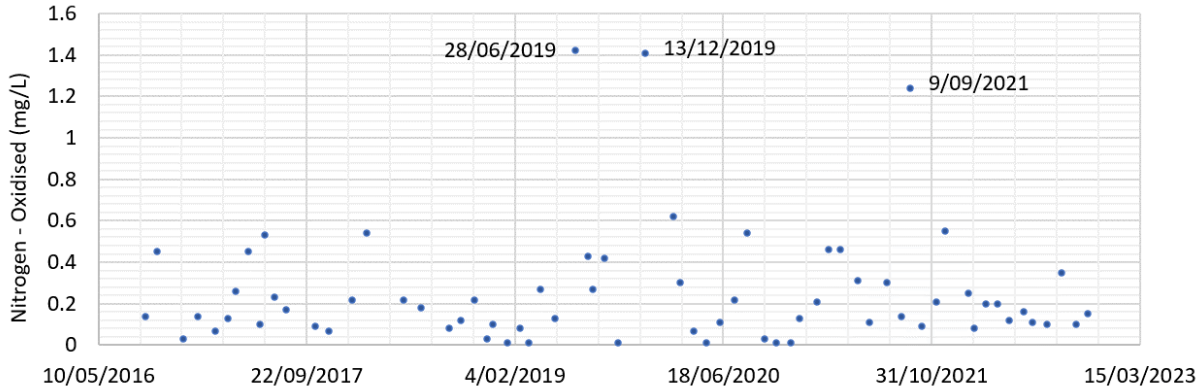

Figure 16: Monthly oxidised nitrogen results at Site BC15 from May 2016 to March 2023

- Ammonia (NH_3 another bioavailable form of N typically dominant in low dissolved oxygen conditions) was noticeably higher at sites BC07 and BC08 (Butler Street Drain, urban area) and is likely to indicate a pollutant source from urban areas and/or the Butler Street historical landfill site.
- Phosphorus levels were also elevated throughout the catchment. The majority of sites (89%) exceeded guideline values for TP, with the highest median values detected at BC08, BC07 (both in Butlers Street Drain) and BC06 (Industrial Estate Drain). Ortho-phosphate (bioavailable form of P) was also elevated at most sites and exceeded guideline values at all estuary sites. The highest levels were again recorded at BC08 (Butlers Street Drain) and BC06 (Industrial Estate Drain).
- Faecal indicator bacteria (*E. coli* and enterococci) was elevated throughout the catchment and particularly at sites draining urban residential and commercial areas. The Butler Street Drain sites (BC07 and BC08) which drains the Byron Bay town centre experienced the highest levels of faecal contamination and was also an area of concern in terms of elevated nutrient concentrations. Site BC15 (Bangalow Road, urban area) also recorded very high levels of *E. coli* and enterococci relative to other sites. These locations also coincide with sewer overflow incidents as discussed for oxidised nitrogen results above and warrants further investigation. To provide further information on the sources of faecal matter, microbial source tracking could be used to identify sources contamination (i.e. human vs. other animal sources) and assist in confirming the nature of issues and direct management action.
- Previous review of BSC water quality data from 2002 – 2008 also reported strong evidence of poor quality runoff entering Belongil Creek from the Byron Bay town centre (i.e. a major contributor of nutrients, turbidity and elevated levels of bacteria) (BSC, 2008).

The water quality monitoring program results indicate a number of ongoing pollutant sources to Belongil Creek ICOLL requiring management action to reduce pollutant export to the estuary.

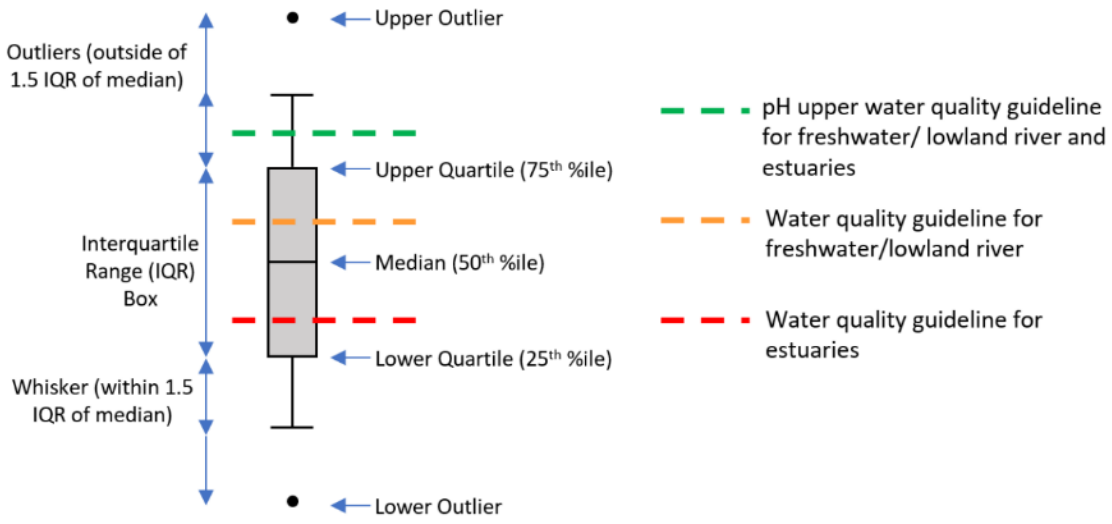

Figure 17: Explanation of box plots and water quality guidelines

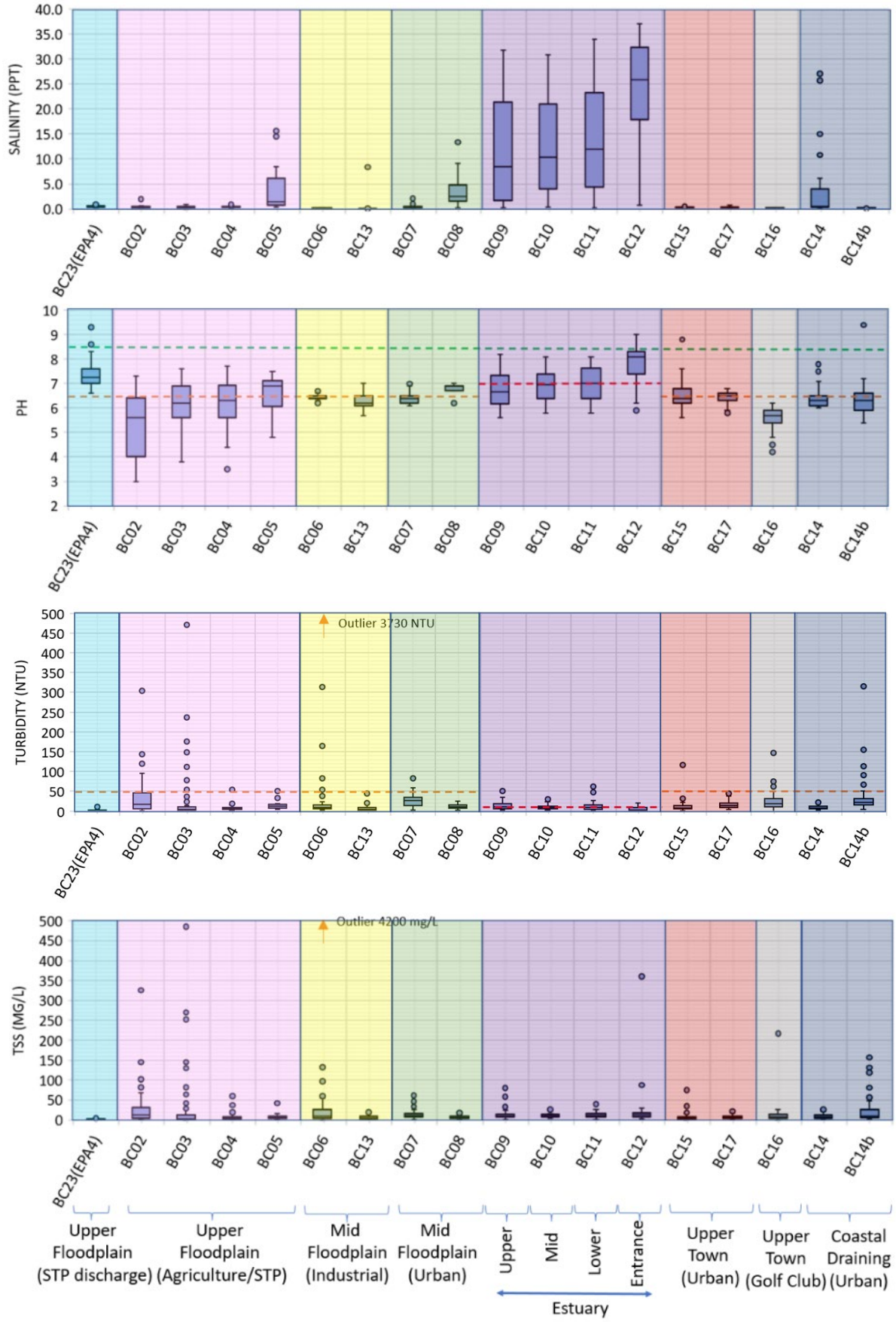

Figure 18: Belongil Creek water quality data 2016-2022 (salinity, pH, turbidity and TSS).

Note: dashed lines on charts show water quality guideline values for freshwater/ lowland river (orange) and estuaries (red). Upper guideline for pH 8.5 is the same for freshwater/ lowland river and estuaries and is shown as green dashed line.

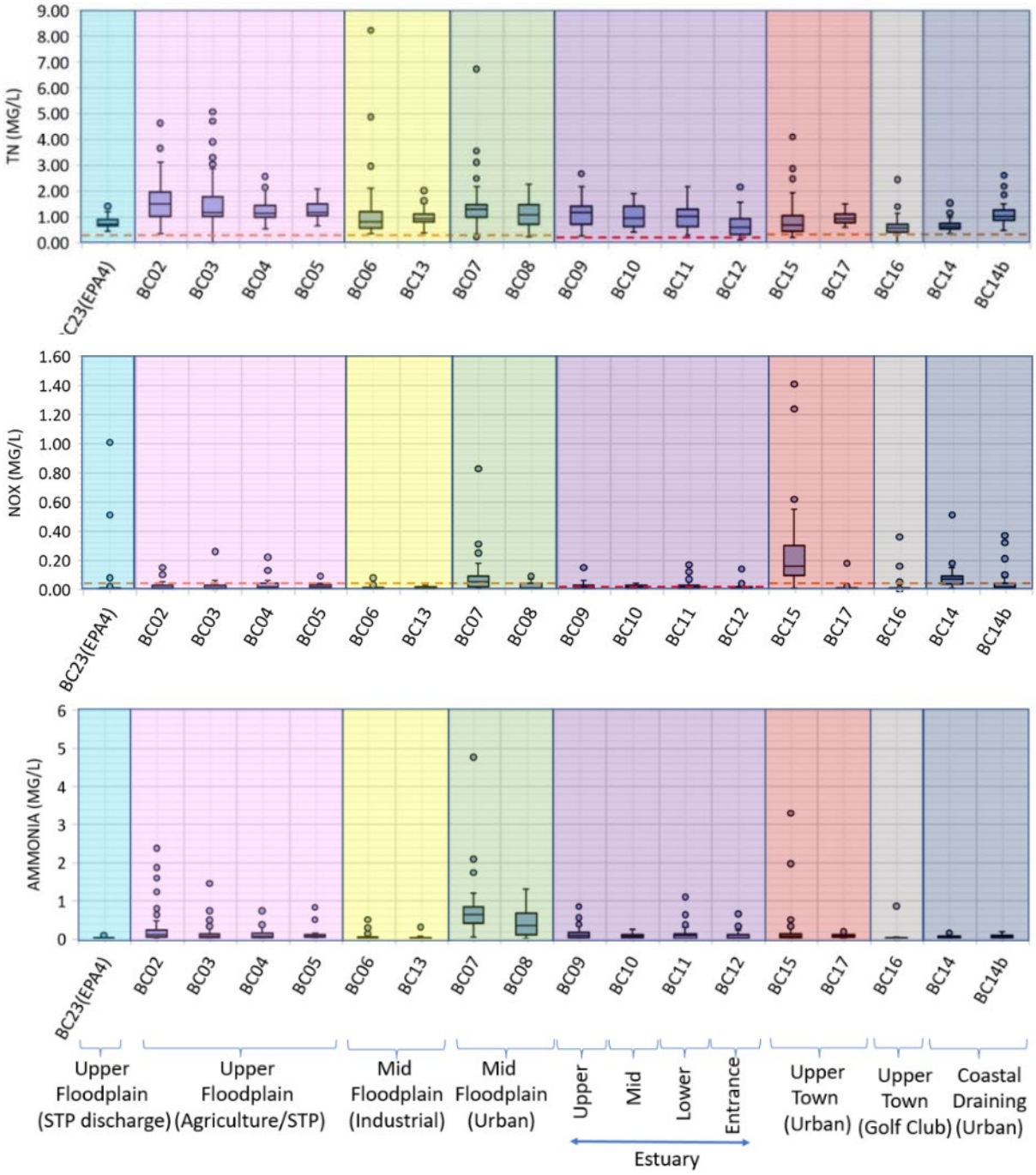

Figure 19: Belongil Creek water quality data 2016-2022 (TN, NO_x and NH_3). Water quality guideline values shown as dashed lines.

Note: dashed lines on charts show water quality guideline values for freshwater/ lowland river (orange) and estuaries (red). Upper guideline for pH 8.5 is the same for freshwater/ lowland river and estuaries and is shown as green dashed line.

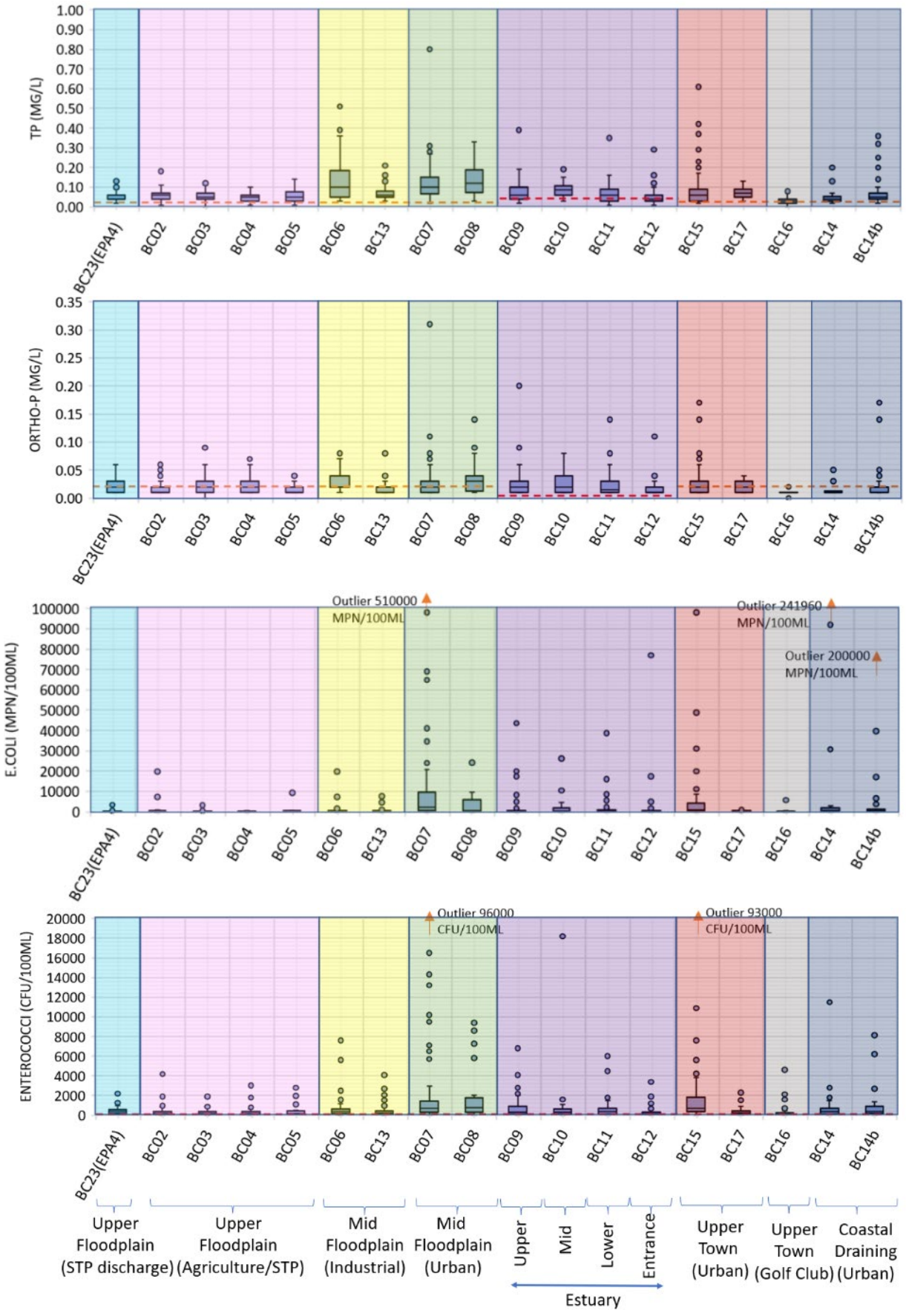

Figure 20: Belongil Creek water quality data 2016-2022 (enterococci, *E. coli*, TP and Ortho-P).

Note: dashed lines on charts show water quality guideline values for freshwater/ lowland river (orange) and estuaries (red). Upper guideline for pH 8.5 is the same for freshwater/ lowland river and estuaries and is shown as green dashed line.

ICOLL entrance opening strategy monitoring

BSC manages and monitors artificial entrance opening events in accordance with the approved *Belongil Creek Entrance Opening Strategy* Rev 1 (Alluvium, 2021). A series of Belongil estuary entrance management reports from 2016 – 2022 document the health of the Belongil estuary as part of the license conditions surrounding the artificial openings of the creek mouth. The reports include a series of annual reports, and technical memorandums reporting on individual entrance opening events. Monitoring results have allowed for documentation of the water quality conditions prior to, during and following artificial entrance opening events and well as results from an in-situ logger at Ewingsdale Bridge. An overview of water quality conditions in Belongil Creek and processes associated with entrance opening is summarised from AWC (2016-2022) and Alluvium (2019, 2021) as follows:

- The water quality within the Belongil Creek estuary is naturally highly variable. 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.
- An entrance opening event, independent of rainfall, will generally result in a reduction in pH, a reduction in dissolved oxygen and an increase in dissolved iron in the estuary.
- Following an opening event establishment of tidal conditions in the estuary increases pH, dissolved oxygen and salinity. There is significant variability with this due to varying tides (therefore ability for tidal exchange) and continued rainfall following opening resulting in continual flushing of estuarine waters.
- Poor quality water (low pH, low dissolved oxygen, high nutrient concentrations, high inorganic nitrogen, and high iron and aluminium) is advected from the drains and swamps upstream following entrance opening.
- If the entrance channel remains open, persistent tidal conditions in the system can result in localised groundwater drawdown which may lead to acidic discharge from the organic peat layers into the drains.
- The entrance opening event monitoring data has repeatedly shown that dissolved oxygen, electrical conductivity and pH values decrease in the short term following artificial opening, however with good rainfall the water quality does not reach critical levels and fish kills are largely avoided.
- Overall, water quality in the Belongil Creek estuary is highly variable which is a function of the degraded catchment conditions and the dynamic nature of the catchment hydrology.
- Major changes in the catchment in the last 100 years have significantly impacted water quality. These changes included disturbance of ASS, BBSTP discharges and agricultural and urban runoff.
- Entrance opening events can result in a short-term changes in water quality and have resulted in adverse events in the past such as fish kills. However, catchment pollution inputs and hydrological modifications have negatively impacted water quality over much longer time scales and create conditions to precipitate poor events when the entrance opens (Alluvium, 2021).

4.2.3. Ground-truthing and verification

Site visits were conducted at key sites in the Belongil Creek catchment in April 2023 to ground truth the preliminary mapping at key locations and gain additional understanding of likely pollutant sources. A field water quality meter was used to undertake spot measurements whilst in the field to better understand the sites. Appendix 5 includes field data recorded during site inspections.

The majority of constructed surface water drains visited in April 2023 were in poor condition. Poor water quality was recorded at many sites including low dissolved oxygen values and high turbidity. Many drains including the Upper Union Drain, Industrial Estate drains and Butler Street Drain were observed to be showing signs of nutrient enrichment (e.g. excess algae and aquatic plant growth, Plate 3, Plate 4, Plate 5, Plate 6). The aquatic weed *Salvinia molesta*, was also observed at several sites within the Upper Union Drain (Plate 3), within BBSTP wetlands and some urban stormwater drains. Salvinia is a fast growing and highly adaptable weed that can spread rapidly when conditions are favourable. Still or slow moving, warm fresh water with high nutrient concentrations are ideal conditions for growth. Salvinia can form thick mats which prevent light and oxygen from entering a waterway/ waterbody and can shade out other aquatic plants and degrade habitat for aquatic organisms. Decomposing Salvinia can reduce water quality by consuming large amounts of dissolved oxygen. Council's preferred management strategy to control Salvinia is biological control using the Salvinia weevil (*Cyrtobagous salviniae*).

Pont and Parker (2001) discussed the two major issues associated with deep, steep-sided, square or rectangular drains which are common on the Belongil floodplain such as the upper Union Drain and drains within the Byron Arts and Industry Estate:

1. Deep drains carry more water at a higher velocity which can result in increased flooding at catchment outlets and increased bank erosion.
2. Deep drains may cause a draw-down effect on groundwater resulting in greater exposure of ASS.

Plate 3: a) Culvert south of Ewingsdale Road within the Upper Union Drain (Moran's Hill) b) Footbridge over Union Drain downstream/ south of culvert.

Oil-like sheens were observed on water in the Industrial Estate Drain at Banksia Drive (Plate 4 a) though it was not identified whether these were algal-based or from hydrocarbons. Build-up of litter (mostly plastics) was observed in the upper Butler Street Drain upstream of the bypass culvert Plate 5 b).

Plate 4: a) Industrial Estate Drain at Banksia Drive b) Confluence along Industrial Estate Drain.

Plate 5: a) Butler Street Drain downstream of bypass culvert b) Butler Street Drain upstream of bypass.

Plate 6: a) Water quality sample site BC15 downstream of Bangalow Road b) Water quality sample site BC17 downstream of Old Bangalow Road.

Access to the mid catchment rural areas was limited due to private ownership and lack of public roads. Observations were recorded from vantage points along public roads (Plate 7).

Plate 7: a) Mid catchment grazing land, Skinners Shoot b) View of rural landuse and vegetated areas in the mid catchment from St. Helena Road.

The Belongil Creek estuary sites inspected all showed improved water quality conditions with higher dissolved oxygen levels and lower turbidity compared to the sites further upstream. The creek entrance was open to ocean at the time of the site inspection and the creek was flowing strongly downstream.

Plate 8: a) Belongil Creek at Ewingsdale Bridge b) Confluence of Butler Street Drain with Belongil Creek at Ewingsdale Bridge, note orange iron-staining at base of flood level marker.

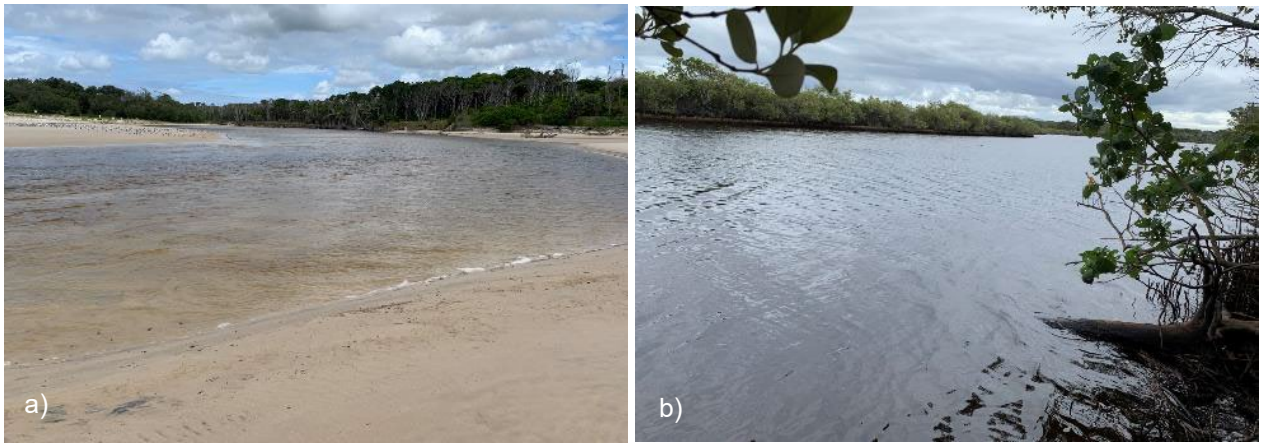

Plate 9: a) Belongil Creek mouth on Belongil Beach b) Lower estuary at Manfred Street

4.2.4. Conceptual model

Based on the information gathered during this study a conceptual model has been developed for Belongil Creek ICOLL to provide a broad overview of pressures, stressors and state of waterways (Figure 21).

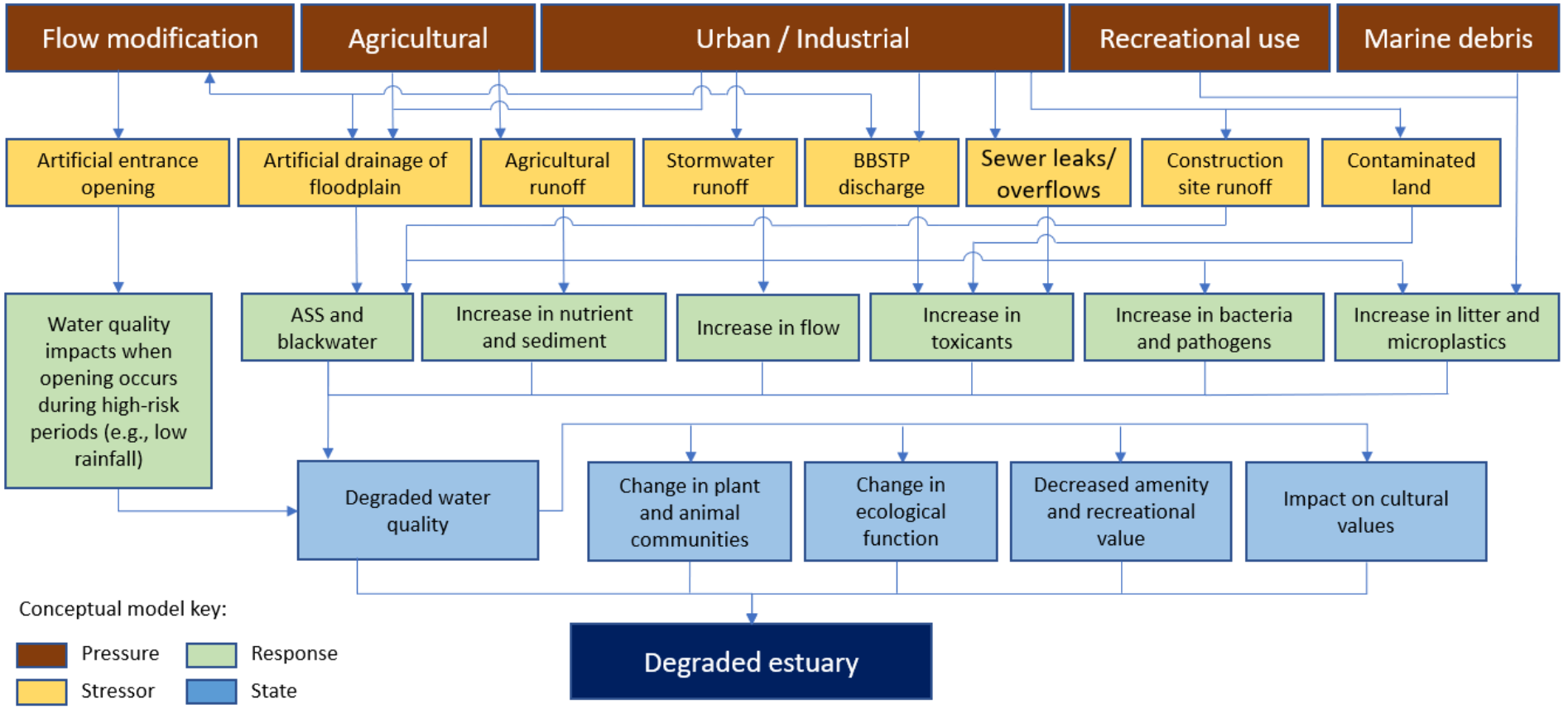

Figure 21: Belongil Creek pollutant sources conceptual model

4.2.5. Mapping of water quality pollution sources

Preliminary mapping of water quality pollutant sources was prepared using the information gathered as part of review of existing studies, modelling (e.g. DPE Estuary Health Risk Dataset and RCAT) and existing datasets and information gathered as part of stakeholder engagement. Local knowledge, observations and understanding gathered from stakeholders provided real world verification and confirmation of our understanding of the systems and pollutant sources. Site inspections carried out in April 2023 (refer Section 4.2.3) assisted in the verification and characterisation of pollutant sources.

Figure 22 maps key pollutant sources identified for the Belongil Creek ICOLL. This includes a combination of point sources (e.g. BBSTP and stormwater discharge points etc.) and diffuse pollution sources (e.g. areas of agricultural land and urban development with no defined point of discharge). Identified sources that were difficult to define spatially on a map were documented and described in the legend text (e.g. marine inputs of litter and intermittent sewer overflow events etc.)

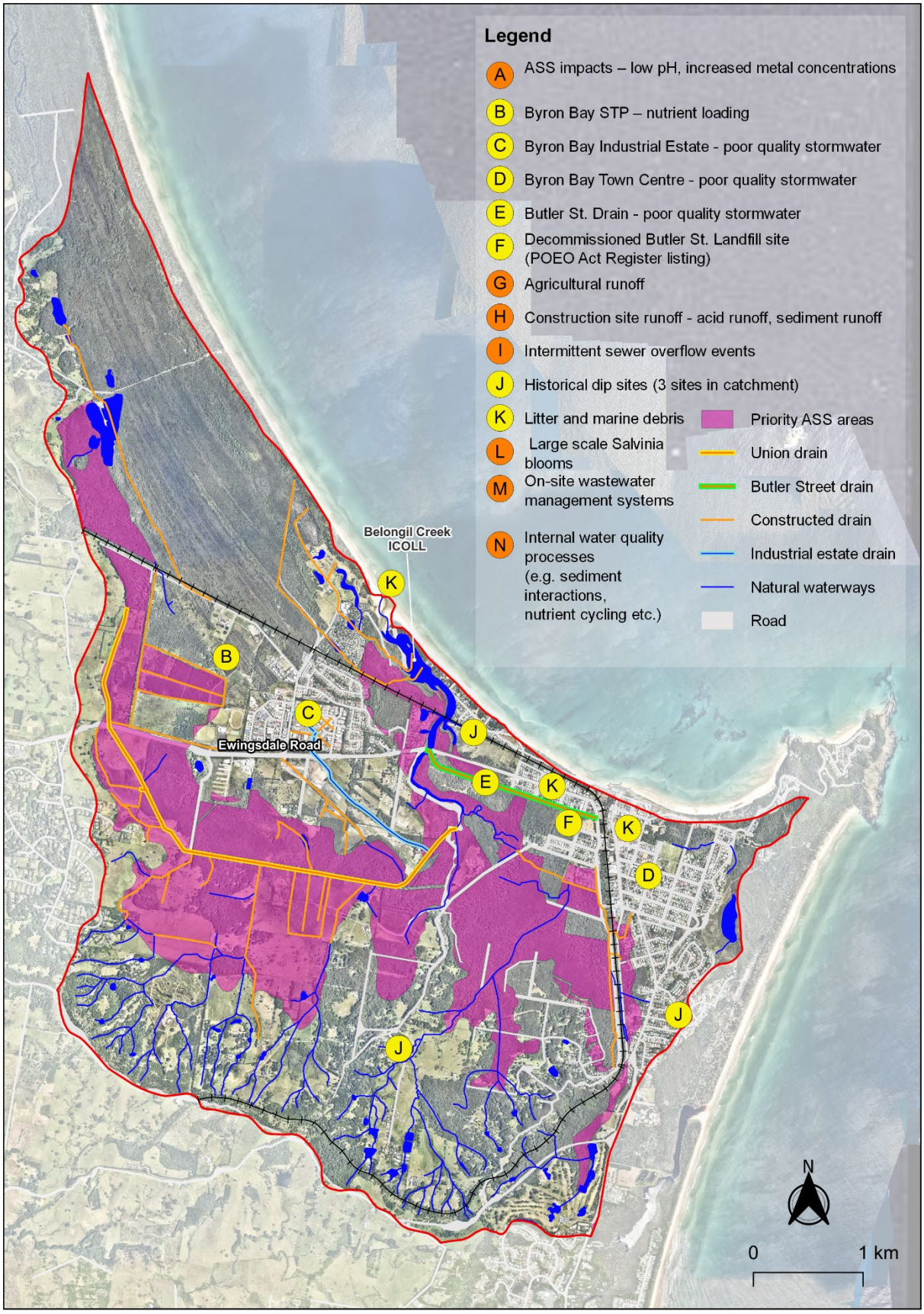

Figure 22: Belongil Creek pollutant sources

Note: Diffuse sources shown as orange A, G, H,I, L, M and N in legend only, they are not specific to any one location and have not been mapped.
Source: BSC (2023a), NSW EPA (2023), DPI (2023), DPE (2023), and Nearmap (2022).

4.3. Prioritisation of water quality pollution sources

Prioritisation of the identified pollutant sources will assist in directing management and resources into areas that will have the greatest impact on improving water quality in the Belongil Creek ICOLL. Multiple lines of evidence were considered in the prioritisation of water quality pollution sources, categorised as follows:

1. The NSW Estuary Health Risk Dataset (Section 4.2.1) - considered as one of the broad components of prioritisation, noting that the model generates sub-catchment 'risk' based on nutrient and sediment loadings from diffuse pollution sources with no consideration of other pollutants or point sources.
2. RCAT Modelling completed by Alluvium (2019) for Belongil Creek Catchment (Section 4.2.1).
3. Water quality data collected within ICOLLs and the catchments as part of the Byron Bay Surface Water Quality Monitoring Program and analysis presented in Section 4.2.2.
4. Information gathered as part of desktop review from previous studies.
5. Stakeholder feedback.
6. Field observations noted during site inspections (Section 4.2.3).

For each pollutant source, each category was scored as High (3), Medium (2) or Low (1) according to water quality source pollutant priority. Where there were no data available for a category (e.g. ASS not considered in NSW Estuary Health Risk Dataset) no score was assigned for that category. The total score was averaged for each pollutant source considering only the categories where data were available. Ranking of key pollutant sources affecting water quality by priority for management is provided in Table 4 below. The prioritisation matrix and detailed scoring is provided in Appendix 6.

Table 4: Priority ranking of water quality pollutant sources in the Belongil Creek catchment using multiple lines of evidence.

ID	Water Quality Pollutant Source	Average Score	Rank
E	Butler Street Drain - poor quality stormwater	3.00	1
B	Byron Bay STP - increased nutrient loading	2.67	2
D	Byron Bay Town Centre - poor quality stormwater	2.50	3
I	Intermittent sewer overflow events	2.33	4
K	Litter and marine debris	2.33	4
A	ASS impacts - low pH, increased metal concentrations	2.25	6
C	Byron Bay Industrial Estate - poor quality stormwater	2.17	7
G	Agricultural runoff	2.17	7
L	Large-scale Salvinia blooms	2.00	9
N	Internal water quality processes (e.g. sediment interactions, nutrient cycling etc.)	2.00	9
F	Decommissioned Butler St. Landfill site (POEO Act Register listing)	1.33	11

ID	Water Quality Pollutant Source	Average Score	Rank
H	Construction site runoff - ASS impacts, sediment runoff etc.	1.33	11
J	Historical dip sites (3 sites in catchment)	1.00	13
M	On-site wastewater management systems	1.00	13

4.4. Potential Management Options

Potential management options to address the identified water quality pollution sources are documented in Table 5 below. Potential management options include strategic management actions, further investigations and on-ground works to reduce point and diffuse source water pollution for further consideration in Stage 3 CMP preparation or via other operational and strategic planning processes where relevant.

A high-level assessment of options is given in Table 5 to provide sufficient information to progress potential options to Stage 3 of the CMP (Options Assessment). This assessment is based on the current understanding of management options to address the pollutant sources identified by this study. A description of each management option is provided along with details of any management action currently underway or planned to address pollution sources. A qualitative assessment of feasibility, acceptability to stakeholders and a preliminary assessment of approval requirements is provided along with a coarse cost estimation (estimated low-high range). The likely responsibilities for actions and potential partnerships for implementing actions have also been identified. Finally, a recommendation is made as to whether the option has merit and should be considered further. Options recommended for further consideration will be assessed in detail as part of Stage 3 of the CMP. Note that Stage 3 of the CMP may incorporate additional options to address pollution sources and is not limited to those listed in Table 5.

The option assessment methodology and detailed scoring is provided in Appendix 7.

Table 5: Belongil Creek ICOLL potential pollution control options for consideration in Stage 3 of CMP

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
E	1	Butler Street Drain - poor quality stormwater	• 'Source to Sea' project • Illegal Dumping and Litter Education and Enforcement Plan (IDLEEP) for 2024 – 2029. • Byron Bay Drainage Strategy (under development) • Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021) • BSC Water Quality Monitoring Program	Continue and/or expand 'Source to Sea' project if the trial is successful and considered sustainable.	3	2	3	1	9	BSC	Yes - dependent on outcomes of trial due to finish May 2024.
				Update and implement IDLEEP for 2024-2029.	3	2	3	1	9	BSC	Yes
				Investigate feasibility of a constructed wetland located at Butler Street Drain as part of Byron Bay Drainage Strategy update.	2	2	1	-1	4	BSC	Yes
				Review and upgrade/improvement of urban stormwater infrastructure as part of Byron Bay Drainage Strategy. Includes transitioning existing concrete drainage to WSUD when road upgrades/ development occurs (e.g. rain gardens, biofiltration etc.)	2	2	1	0	5	BSC	Yes - acknowledging the Byron Bay Drainage Strategy is the appropriate mechanism for consideration of this option. Any related action should be referenced in the CMP.

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				Implement strategies A and C of BSC WSUD Policy.	2	2	3	1	8	BSC	Yes
				Enhanced monitoring and maintenance of sewage infrastructure – as for ID I below.	Refer ID: I						
				Urban stormwater quality improvement community education campaign targeted for residents, businesses industry and visitors.	3	2	3	1	9	BSC	Yes
B	2	Byron Bay STP – nutrient loading	• NSW EPA Licence 3404 monitoring and management, BBIWMR • Additional STP discharge location • 2017-2027 Effluent Reuse Strategy (BSC, 2017a) - expansion of reuse scheme	Options to minimise BBSTP discharge of pollutants (primarily nutrients) to Belongil Creek including: • increasing reuse of wastewater (e.g. Effluent Reuse Strategy 2017-2027). • Explore options for improved effluent treatment at BBSTP, to enhance nutrient removal. • Offsets through riparian / wetland restoration (e.g. on Crown land, or freehold land through agreements, or	3	2	-1	1	5	BSC – BBSTP actions should be considered through the current IWCM process currently underway.	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				purchase of land for offsets). • Consider holistic approach and integrate with floodplain restoration initiatives discussed at IDG and IDA.							
				Investigate the potential presence and impact of EDCs on Belongil Creek ICOLL	2	2	3	1	8	BSC	Yes
D	3	Byron Bay Town Centre - poor quality stormwater	• 'Source to Sea' project • IDLEEP for 2024 – 2029. • Byron Bay Drainage Strategy (under development). • Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021). • BSC Water Quality Monitoring Program	Continuation of Source to Sea project – as for ID E above.	Refer ID: E						
				Update and implement IDLEEP for 2024-2029 – as for ID E above.	Refer ID: E						
				Investigate feasibility of a constructed wetland located at Butler Street Drain as part of Byron Bay Drainage Strategy update – as for ID E above.	Refer ID: E						
				Review and upgrade/improvement of urban stormwater infrastructure throughout catchment as part of Byron Bay Drainage Strategy. Includes transitioning	Refer ID: E						

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				existing concrete drainage to WSUD when road upgrades/development occurs (e.g. rain gardens, biofiltration etc.) – as for ID E above.							
				Implement strategies A and C of BSC WSUD Policy – as for ID E above.	Refer ID: E						
				Enhanced monitoring and maintenance of sewage infrastructure – as for ID I below.	Refer ID: I						
I	4	Intermittent sewer overflow events	• NSW EPA Licence 3404 monitoring, maintenance, reporting and management. • BSC Water Quality Monitoring Program.	Enhanced monitoring and maintenance of sewage infrastructure to minimise sewage system failures related to trade waste discharges, illegal stormwater to sewer connections, wet weather inflow and infiltration and sewage system performance. Particular attention to be given to locations in the vicinity of the sites highlighted as part of this review (e.g. SPS3001 catchment, Butler Street Drain etc).	3	2	1	1	7	BSC - This should be undertaken through the current IWCM process currently underway.	Yes – acknowledging the IWCM is the appropriate mechanism for consideration of this option. Any related action considered as part of the IWCM should be referenced in the CMP.
				Conduct a targeted microbial source tracking	2	2	3	1	8	BSC	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				study to identify sources of faecal contamination (i.e. human vs. other animal sources) and assist in directing management action.							
K	4	Litter and marine debris	• 'Source to Sea' project • IDLEEP for 2024 – 2029. • Clean up campaigns by various organisation and volunteer groups (e.g. KLIS, AUS LM, Tangaroa Blue clean ups etc.) • MEM Strategy Actions	Continuation of Source to Sea project – as for ID E above.	Refer ID: E						
				Update and implement IDLEEP for 2024-2029 – as for ID E above.	Refer ID: E						
				Continue regular litter clean up campaigns.	3	2	3	1	9	BSC and other organisations / volunteer groups	Yes
				Continue litter surveys to monitor progress through time.	3	2	3	1	9	BSC and other organisations / volunteer groups	Yes
				Continue to develop and implement litter and illegal dumping education campaigns in collaboration with North East Waste and the NSW EPA. With specific focus on visitors and tourism sector.	2	2	3	1	8	BSC, North East Waste and the NSW EPA	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
A	6	ASS runoff	• BSC monitoring and management of construction activities / DA condition enforcement. • BSC Water Quality Monitoring Program	Enhanced monitoring and management of construction activities involving excavation of soil within ASS risk areas, particularly large-scale developments with high risk of harm to downstream sensitive environments (e.g. Harvest/ West Byron subdivision).	3	2	1	1	7	BSC	Yes
				Investigate suitability for Blue Carbon projects on the floodplain (i.e. reintroduce tidal flows to an area of land through removal of drain/levee or other type of flow restriction). Requires identification of suitable sites in collaboration with landholders / land managers. Online tools including BlueCAM can be used to calculate carbon credits. Locations in the vicinity of the Upper Union Drain are key areas to target.	0	2	2	1	5	BSC / landholders / Belongil Catchment Drainage Board	Yes – acknowledging low feasibility score reflecting need for further investigations into viability and ecological impact on freshwater wetland areas.
				Modify drain morphology (e.g. drain shallowing and widening or use of rock weirs etc.) to maintain	3	1	1	1	6	BSC / landholders / Belongil Catchment	Yes – acknowledging low CA score reflecting

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				higher groundwater levels and reduce the prevalence of ASS runoff. Requires identification of suitable sites in collaboration with landholders / land managers. Locations in the vicinity of the Upper Union Drain are key areas to target.						Drainage Board	additional investigation required to clarify technical viability, likely high cost and potential low acceptability for some stakeholders.
				Long-term land use transition strategies for low-lying areas with high ASS risk.	3	1	1	1	5	BSC	Yes
				Buy-back and wetland restoration schemes of agricultural lands with high ASS risk.	2	1	0	1	4	BSC / landholders / Belongil Catchment Drainage Board	Yes
				Collaborate with Belongil Catchment Drainage Board to address ASS issues.	3	2	3	1	9	BSC / Belongil Catchment Drainage Board	Yes
C	7	Byron Bay Industrial Estate - poor quality stormwater	• Council Environmental Health Group inspections and enforcement of non-compliant practices (limited	Increased resourcing of Environmental Health Group for inspections of premises / businesses and where necessary issue of enforcement orders for non-compliance.	3	2	1	1	7	BSC	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
			resources has prevented recent programs). • 'Source to Sea' project. • Byron Bay Drainage Strategy. • BSC Water Quality Monitoring Program.	Continuation of Source to Sea project – as for ID E above.	Refer ID: E						
				Update and implement IDLEEP for 2024-2029 – as for ID E above.	Refer ID: E						
				Stormwater treatment improvements within the Byron Bay Arts and Industry Estate.	2	2	0	1	5	BSC	Yes
G	8	Agricultural runoff – sediment, nutrients and other contaminants (e.g. pesticide and herbicides)	• BSC Water Quality Monitoring Program.	Enhanced monitoring and management of construction activities involving excavation of soil within ASS risk area – as for ID A above.	Refer ID:A						
				Long-term land use transition strategies for agricultural land on the floodplain.	3	1	1	1	5	BSC	Yes
				Buy-back and wetland restoration scheme for floodplain agricultural lands. Examples could include: - Offset scheme for current and future WWTP nutrient	2	1	-1	0	2	BSC	Yes, acknowledging low CA score reflecting additional investigation required to clarify technical

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				export to the catchment. - WWTP levy (rate payers and visitors) to fund buy back of agricultural lands. - Wetland restoration as blue carbon project to sequester carbon and nutrients to offset the increasing impacts from WWTP.							viability, likely high cost and potential low acceptability for some stakeholders
				Targeted education program working with agricultural industries on reduced fertiliser / pesticide / herbicide use.	2	2	3	1	8	BSC	Yes
				Working with Belongil Catchment Union Board to improve point and diffuse source pollutants.	3	2	3	1	9	BSC	Yes
				Rehabilitate riparian zones and degraded areas including revegetation, assisted bush regeneration, and cattle exclusion from waterways where applicable. Key areas are: Upper Union Drain, Moran's Hill and mid-floodplain drains and	3	2	0	1	6	BSC	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				waterways. Investigate incentive schemes/ partnerships with landholders for rehabilitation projects as part of the CMP (e.g. Grants/ River Reach programs etc.)							
				Conduct a microbial source tracking study to identify sources of faecal contamination (i.e. human vs. cattle vs. other animal sources) and assist in directing management action – as for ID I above.	Refer ID: I						
H	9	Construction site runoff - ASS impacts, sediment runoff	• Council oversight and enforcement of DA conditions. • Water quality monitoring program	Enhanced monitoring and management of construction activities involving excavation of soil within ASS risk area – as for A above. Particularly areas involving large-scale developments (e.g. Harvest/West Byron) with potential for significant water quality impacts on downstream receiving environments – as for ID A above.	Refer ID: A						
				Targeted erosion and sediment control education	2	2	3	1	8	BSC	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				program run over a two-year period which aims to educate and regulate the industry.							
F	9	Decommissioned Butler St. Landfill site (POEO Act Register listing)	Ongoing NSW EPA and BSC monitoring and management including PFAS investigations.	Continue investigations in line with NSW EPA directions. Report results and progress.	2	2	3	1	8	BSC and NSW EPA	Yes - acknowledging the EPL is the appropriate mechanism for this option. Any related action(s) should be referenced in the CMP.
J	11	Historical dip sites (3 sites in catchment)	No active management	Pesticide water quality sampling and analysis within estuary to detect whether chemicals listed as used in dips are present in estuary water.	2	2	3	1	8	BSC	Yes

*CA Score -coarse assessment score

5. TALLOW CREEK ICOLL

5.1. Background

Tallow Creek is a small ICOLL located approximately three kilometres to the southeast of the Byron Bay town centre. The lower catchment is dominated by natural vegetation and high value ecological areas within the Arakwal National Park. Significant areas of Coastal Wetlands and Littoral Rainforest are mapped within the catchment and protected under the *Coastal Management Act 2016*. Tidal areas of the creek below MHWM are zoned Special Purpose within the Cape Byron Marine Park. Tallow Creek is a special place to the Bundjalung People of Byron Bay (the Arakwal) comprising many special places and historically being a rich source of wild food and resources (NPWS, 2007) and is included within the Native Title Area of the Bundjalung People of Byron Bay.

The Tallow Creek entrance is located on Tallow Beach and drains a catchment area of approximately 5.35 km². The Tallow Creek catchment has been significantly altered since European settlement in the 19th century through:

- Extensive sandmining around the lower creek.
- Extensive vegetation clearing in the mid and upper catchment.
- Urban development and stormwater drainage works. The Tallow Creek upper catchment consists primarily of urban land use within the residential housing estates of Suffolk Park.
- Legacy informal drainage works (for example, evidence of historic placement of pipes in the wetlands to the west of Beachside Dr to improve drainage and allow community access) (N. Graham, pers. comm., 2 August 2023).
- The entrance of Tallow Creek has been artificially managed over a number of years to manage flood risk to properties adjacent to the estuary. Some artificial opening events have been associated with poor water quality episodes and fish kills in the past.

Water quality in the upper catchment is routinely poor, with elevated levels of algae, faecal indicator bacteria (i.e. enterococci*, E. coli*), nutrients, turbidity and low dissolved oxygen (AWC, 2020).

Plate 10: Tallow Creek Entrance, April 2023

5.2. Identification of Water Quality Pollution Sources

5.2.1. Catchment characteristics, land use and pressures

Catchment elevation and drainage

Catchment characteristics for Tallow Creek are mapped in Figure 23. Catchment elevation ranges from approximately 135 mAHD in the upper catchment to 1 mAHD on the floodplain. Natural waterways and floodplain areas of the Tallow Creek system have been modified through development and other human activities including:

- Stormwater drains, swales, pipes and culverts to convey stormwater away from roads and dwellings / businesses to downstream waterways.
- Morphologic changes to the Tallow Creek waterway, including:
    - a straightened and widened section of the previously narrow sinuous creek (as seen on 1958 air photo) to the north of the current Tallow Creek footbridge as a result of sand mining.
    - a realigned and filled section of the upper estuary running parallel to Broken Head Road constructed as part of the Suffolk Park estate subdivision.
- Baywood Chase Lake, a large artificial lake constructed for stormwater detention as part of the Baywood Chase subdivision (refer to stormwater infrastructure section below for more details).

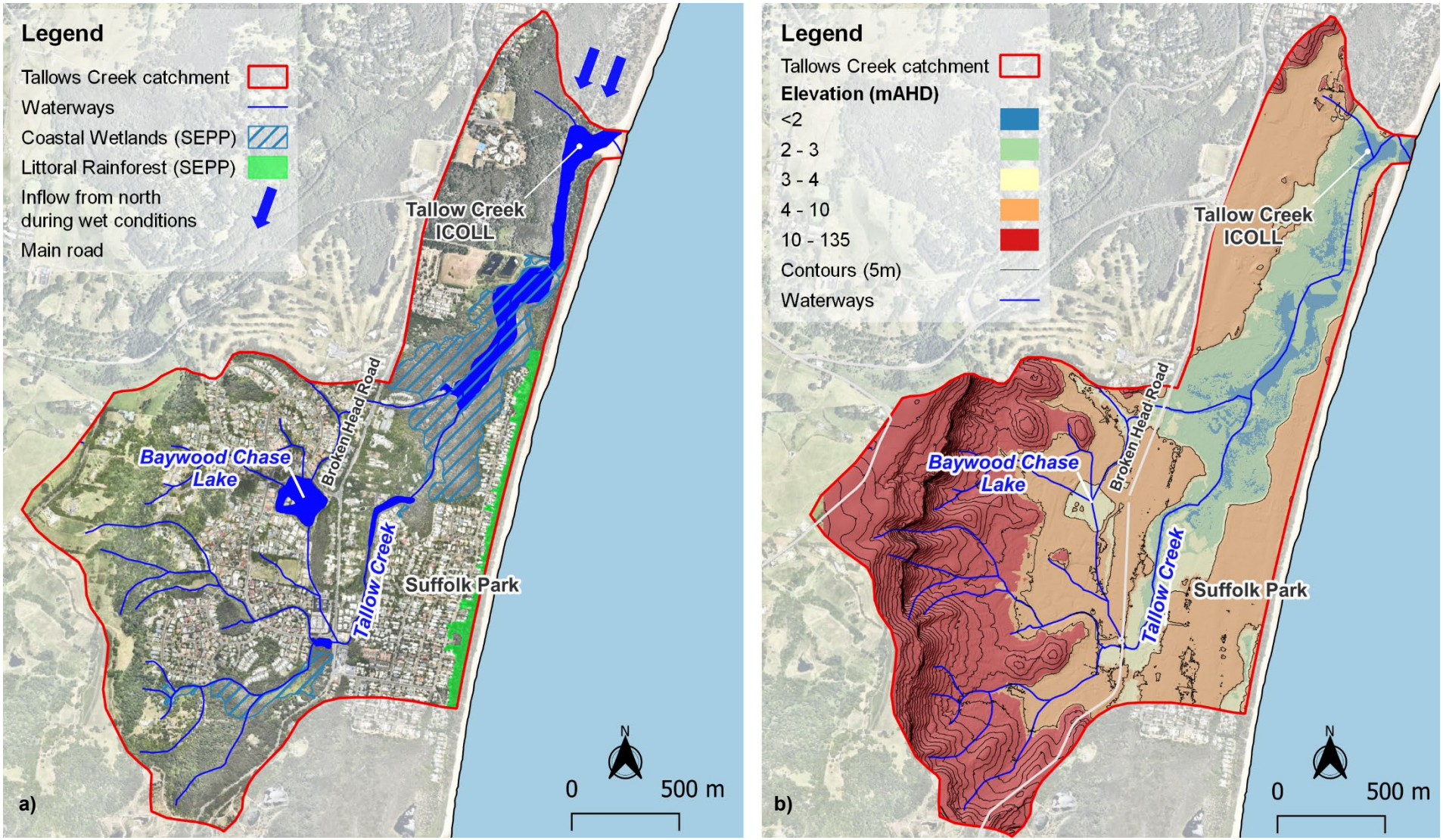

Figure 23: a) Tallow Creek drainage, b) Elevation and natural waterways

Source: Mapping data provided by BSC (2023a), DPE (2023), Geoscience Australia (2023) and Nearmap (2022).

Acid Sulfate Soils

The *Byron Local Environmental Plan 2014* ASS risk maps show that the majority of the eastern side of the Tallow Creek Catchment is either Class 2 or Class 3 ASS (Figure 24). This indicates the likely presence of potential ASS occurring just below the natural land surface (Class 2) and >1m below the natural land surface (Class 3). Exposure of these soils to air through excavation or lowering of the water table can produce sulfuric acid which may impact nearby waterways including Tallow Creek. Generally, pH values have been reported within guidelines for healthy aquatic ecosystem function in Tallow Creek (AWC, 2020; WBM, 2015), however low pH values (below guidelines) have been detected periodically at water quality sampling sites in the upper estuary and this has been associated with estuary opening events. This could indicate increased drainage of ASS during lower water levels when the entrance is open. It has also been suggested that lower pH could be due to mobilisation of Monosulfidic Black Ooze (MBO) from bottom sediments during opening events (Waddy, 2019).

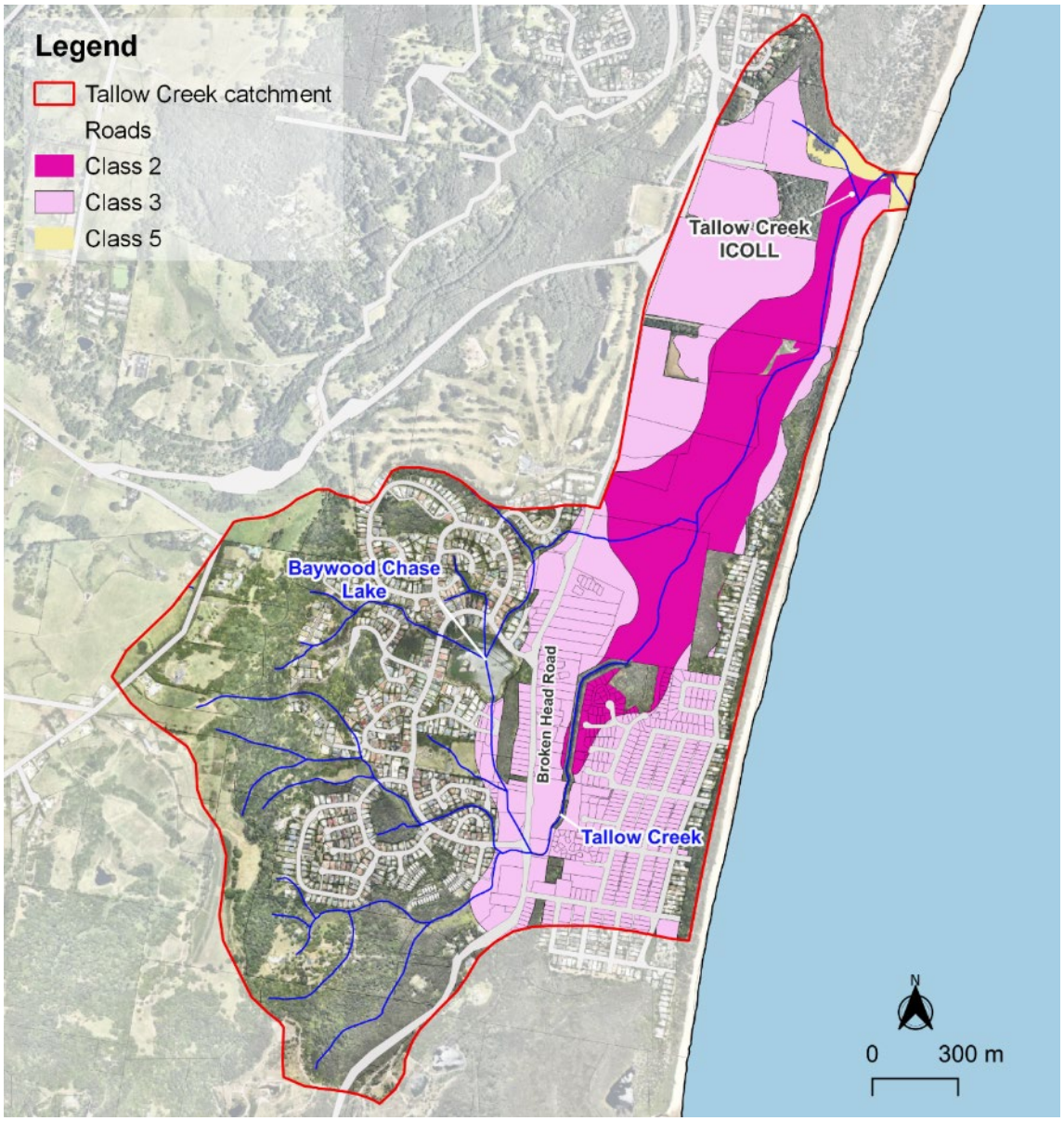

Figure 24: Tallow Creek acid sulphate soil risk.

Source: Mapping data provided BSC (2023a), DPE (2023) and Nearmap (2022).

Sediment / water interactions

Waters within Tallow Creek are potentially impacted by the biogeochemical interactions between surface waters and bottom sediments within the lagoon.

A student study Waddy (2019) identified that the riparian zone and backswamp areas of the lagoon contain ASS, which may accumulate organic matter and soluble oxidised acidic products during prolonged dry periods. Sediments within Tallow Creek lagoon were found to generally contain low concentrations of acid volatile sulfides and comparatively larger concentrations of chromium reducible sulfur species. Monosulfides and sediments with high oxygen demand dominated by chemical processes were identified in the sediments in the southern portion of the lagoon suggesting that these sediments would more readily react, consume oxygen and acidify the water column if resuspended and potentially increase turbidity and the possibility of remobilisation of pollutants (e.g. metals) and nutrients.

In addition, under some conditions, the lagoon experiences stratification which impacts the health of aquatic species and can also promote nutrient cycling and eutrophication in the ICOLL (AWC, 2019; Pugh, 2021; Waddy, 2019).

Sediment characteristics have implications for entrance management of Tallow Creek. Council is undertaking a review of entrance management arrangements as a separate project and no recommendations as to entrance opening or management are made herein.

Land use and land tenure

The Tallow Creek catchment has a mix of land uses as shown on Figure 25, the dominant land use classification within the study area is urban residential, comprising approximately 35.5% of the catchment which includes much of the localities of Baywood Chase, Byron Hills and Suffolk Park. Construction of 17-lot community title subdivision is currently underway on Bottlebrush Crescent, Suffolk Park. The next most dominant land use as indicated by the land use mapping data (DPE, 2020) is grazing land and accounts for 25.4% of the catchment, occurring mostly around the fringe areas of the Baywood Chase subdivision. This area is previously cleared farm land, although regrowth of vegetation is now evident for much of this area and active grazing likely to only occur on part of this area on the western slope of the catchment. Vegetated areas comprise 19.1% including lower catchment areas within Arakwal National Park in addition to vegetated areas on private and Council and Crown land. 6.9% of the catchment is covered by water whilst Services and infrastructure comprise 5.5% of the catchment including the decommissioned South Byron STP site and Byron Bay High School. Rural residential land use makes up 4.8% of the catchment area in close proximity to Baywood Chase and Suffolk Park urban areas. Roads account for 2.5% whilst Horticulture accounts for 0.2% of the catchment area.

Land tenure within the study area is illustrated on Figure 25. Most of the study area is freehold land under private ownership (87.9%). Approximately 10.5% of land is managed as National Park/Reserve. Crown land is divided into Council - managed (1.26%) and Crown land not managed by Council (0.34%).

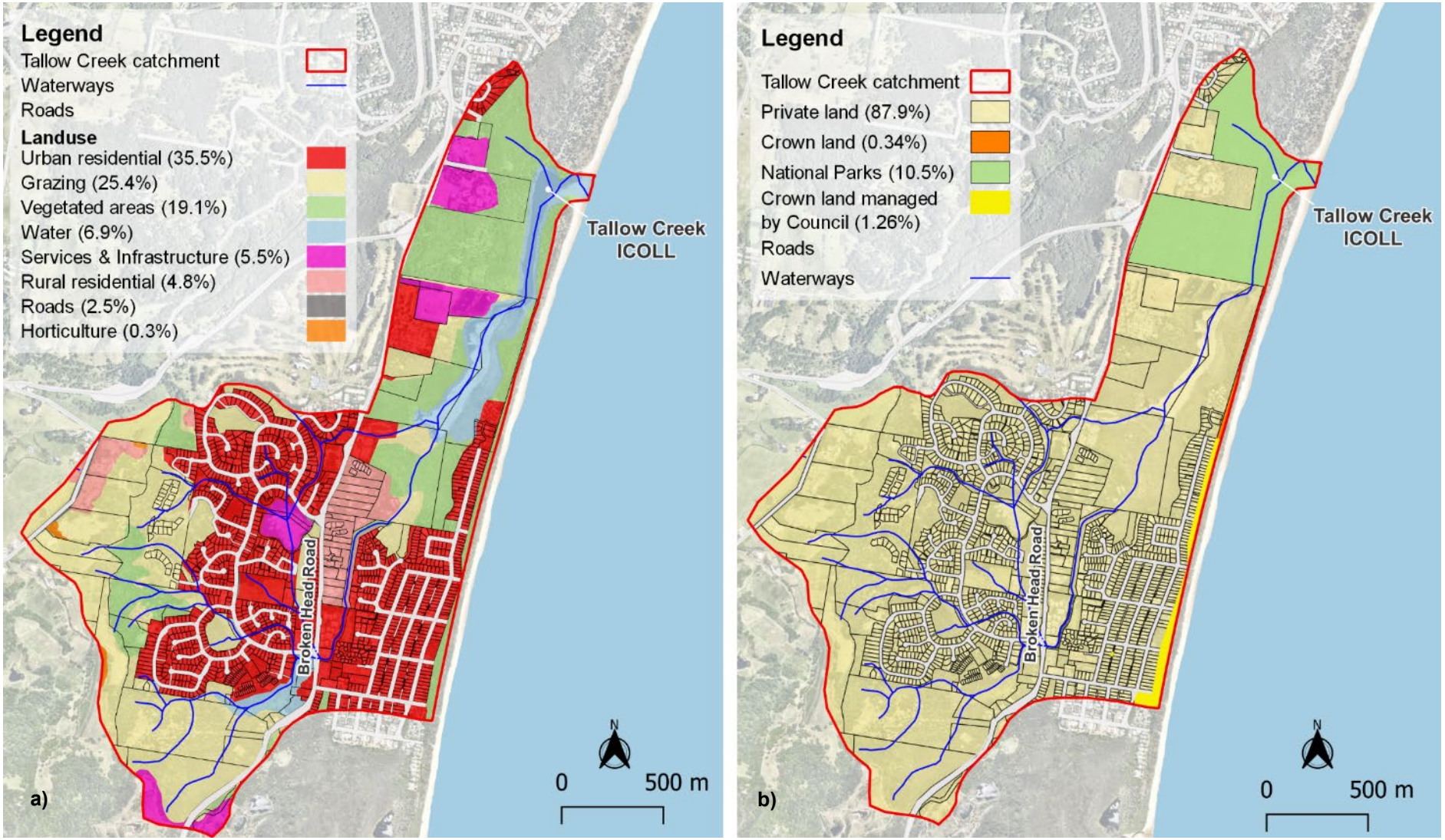

Figure 25: a) Tallow Creek catchment landuse and b) Tallow Creek land tenure

Source: Mapping data provided BSC (2023a), DPE (2020, 2023) and Nearmap (2022).

Sewer infrastructure

Tallow Creek catchment sewer infrastructure is shown on Figure 26. All urban and commercial areas of Suffolk Park are serviced by a reticulated sewerage system, a series of pipelines and pumps that convey wastewater from households and businesses to the BBSTP for treatment. From the early 1970's to 2005 (approx. 32 years), Tallow Creek received direct input of secondary treated wastewater from the South Byron STP (Smith *et al*., 2016). The South Byron STP was decommissioned in 2005 and all wastewater flows are now diverted to the BBSTP in the Belongil Creek Catchment.

While there have been no STP discharges to Tallow Creek since 2005, a study of nitrogen stable isotopes in 2016 (Smith *et al.,* 2016) determined there was evidence of residual wastewater nitrogen remaining within the system, although levels had substantially reduced since South Byron STP decommissioning. This was attributed to a slow recovery rate and therefore lower resilience of ICOLLs to anthropogenic N inputs.

The NSW DPE raised concerns over the potential for connectivity (overtopping or via groundwater) between the former South Byron STP effluent treatment ponds (un-remediated) and the adjacent Tallow Creek. A separate investigation looking into the potential connectivity of the treatment ponds with the creek is ongoing with preliminary results indicating that the ponds are not likely to pose a risk to Tallow Creek if they are left in an undisturbed state and recreational use (i.e. swimming etc.) is restricted (Cavvanba, 2023). Further testing of sites in Tallow Creek was recommended by Cavvanba (2023) to confirm that groundwater is not having an influence on nutrient and heavy metal concentrations in Tallow Creek.

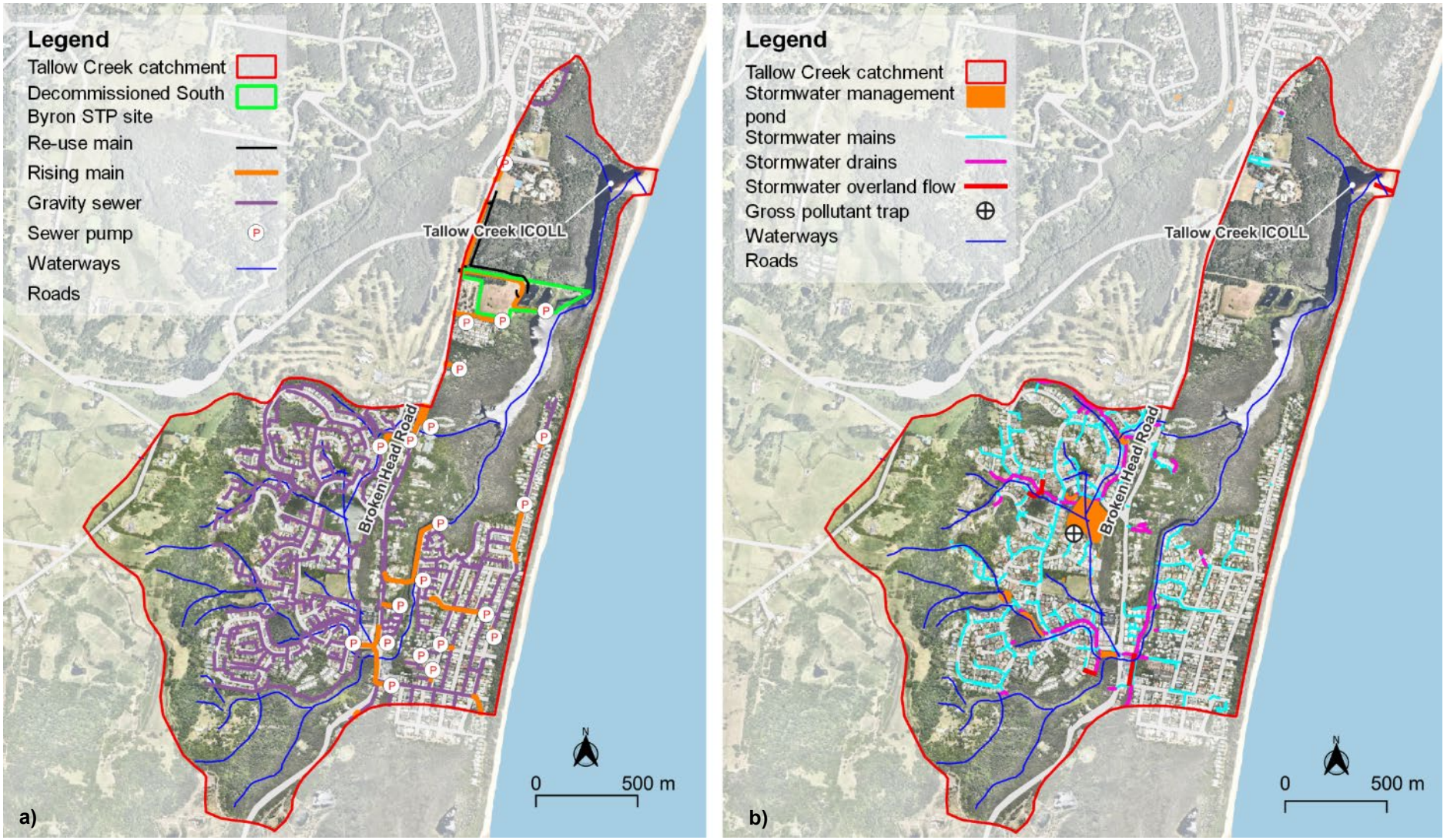

Figure 26: a) Tallow Creek sewer and b) Tallow Creek stormwater infrastructure

Source: Mapping data provided BSC (2023a), DPE (2023) and Nearmap (2022).

BSC sewer overflow incident reporting

A review of BSC sewer overflow incident reporting from the last six years (2016-2022) was undertaken for the Tallow Creek catchment as part of this project.

Figure 27 shows the number and type of customer reported sewer overflow events from April 2016 – April 2022 in the Tallow Creek catchment. There was a total of 12 customer reported incidents over this six-year period. The majority (7) were caused by sewer blockages/ chokes, two were caused by tree root blockages, two were due to sewer pipe breaks and the remainder were due to other equipment failure (1). The highest number of reported incidents by customers occurred in 2020 (total of 9) which was substantially more than in any other year and is likely due to the higher than average rainfall experienced in 2020 leading to overloading of the sewer system. Council staff responded to all incidents and completed inspections, repair and clean up actions as required. Some incidents occurred within private properties and property owners were responsible for corrective actions. There were no incidents during 2016-2022 in the Tallow Creek catchment that met the criteria requiring Council to report the incident to the NSW EPA (i.e. no environmental damage occurred as a result of discharge to the environment).

BSC also provided information on the impact of major flooding events (in March / April 2022) on sewer infrastructure in the Byron Shire. There was one major incident noted, with relevance to the Tallow Creek catchment, a pump station overflow due to flooding and subsequent equipment failure. Pump station SPS3016 on Beachcomber Drive, Byron Bay was 'heavily impacted' by the flooding event (BSC, 2022b). The event resulted in discharge of raw sewage to the hind dune area immediately behind Tallow Beach within Arakwal National Park. NPWS reported that this incident heavily impacted the Arakwal National Park due to the flow of sewage through the National Park bushland and into Tallow Creek, as well as pooling and settling of sewage along the flow path after the cessation of flow (Norman Graham, pers. comm., 2 August 2023).

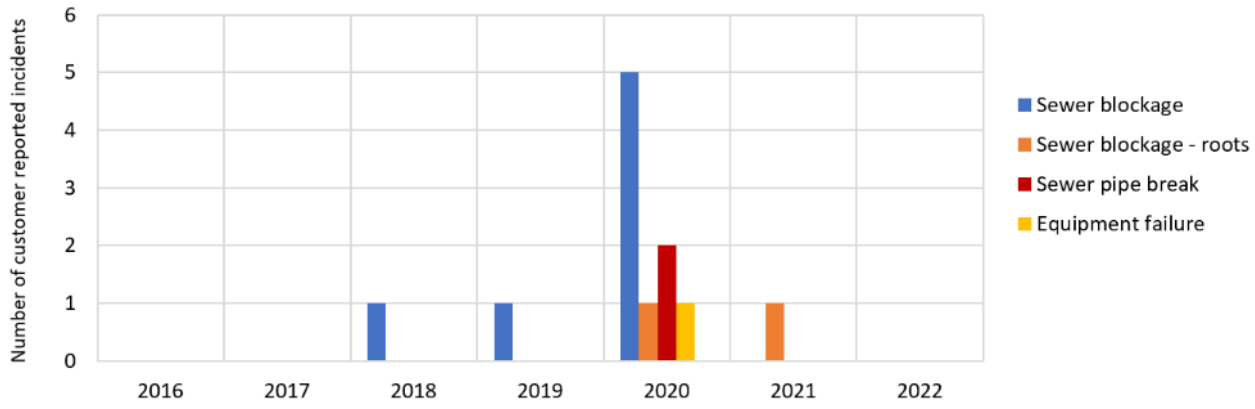

Figure 27: Number of customer-reported sewer overflow incidents in the Tallow Creek catchment April 2016 – April 2022

Sewer overflow incidents represent a short-term but potentially high impact point source of pollutants to stormwater drains and downstream Tallow Creek. Review of BSC water quality monitoring data (Section 5.2.2 identified evidence of poor water quality runoff from urban areas (i.e. nutrients, turbidity and elevated levels of bacteria). Intermittent sewer overflow incidents are likely to be a contributing factor to poor stormwater quality at times in the Tallow Creek catchment. Management action should be prioritised to address sewage infrastructure impacts on the Tallow Creek ICOLL, a highly sensitive downstream receiving

environment. Council is currently preparing an Integrated Water Cycle Management Strategy and the issue of sewage system performance and overflow frequency is being addressed through that process. Issues related to wet and dry weather overflows identified as part of this study have been raised through that process.

On-site Sewage Management

A small number of properties within the Tallow Creek catchment are unsewered and manage wastewater using on-site wastewater management system. This includes approximately 40 septic systems (pers. comm M. Bingham, 2023). Due to the low density of on-site wastewater management systems in the catchment and implementation of BSC's On-site Wastewater Management Strategy and associated approvals, the Tallow Creek catchment has been characterised as a low on-site wastewater management system risk to public and environmental health.

Stormwater infrastructure

Tallow Creek catchment stormwater infrastructure is shown on Figure 26. Catchment areas are serviced by an urban stormwater system, a series of drains, swales, pipes, pits and other infrastructure that convey stormwater from households and businesses to the receiving environment, Tallow Creek and directly to the ocean via infiltration through the dunes in some places. Tallow Creek receives stormwater inputs directly from roads and urban areas and also from major stormwater detention devices including Baywood Chase Lake, a large artificial lake constructed during the Baywood Chase development in the 1990's. Poor stormwater quality is attributed to the following:

- Baywood Chase Lake - a significant source of poor quality water to Tallow Creek (discussed further below).
- Urban runoff from households, gardens and open space areas. Pollutants typically exported from urban areas include fertiliser runoff (bioavailable nutrients), pesticides, herbicides, pet droppings, litter, grass clippings and other organic matter that can decompose in stormwater systems and consume oxygen from the water.
- Stormwater drains and retention basins in the upper catchment that are a source of Salvinia to downstream areas.
- Road runoff – hydrocarbons, oil and grease etc.
- Residents of Suffolk Park are also concerned about the quality and residence time of stormwater that sits in the dune swale east of Alcorn Street, although this area drains through dunes directly to the ocean rather than to Tallow Creek.
- Intermittent sewer overflows - The majority of sewer overflow events discussed above recorded at these locations.

Baywood Chase Lake

Baywood Chase Lake is a significant source of poor quality water to Tallow Creek. Poor water quality in the lake has been documented regularly over a number of years including blooms of blue-green algae (cyanobacteria), elevated levels of pathogens and faecal indicator bacteria (i.e. enterococci, *E. coli*), elevated nutrients and low dissolved oxygen (McKnight, 2015; AWC, 2018; AWC, 2020b).

The artificial lake was constructed in 1990 as an 'end of pipe' stormwater retention device as part of the Baywood Chase development. It receives stormwater inputs from surrounding urban areas with little upstream treatment prior to reaching the lake. The lake covers an area of approximately 3 ha, has a flat central basin approximately 4m deep, steeply sloping batters and three small islands constructed on the western side which are roosting sites for a large number of Ibis and other birds. There is also a small inlet sediment basin on the northwest side of the lake, which was constructed to capture and treat first-flush flows from the north (AWC, 2018). Other stormwater treatment devices include two small bioretention systems and a GPT (although not actively maintained) and on the southern side of the lake (AWC, 2018).

The lake is thought to be poorly mixed, and previous work identified two distinct zones: a mixed zone to the north with flows entering from stormwater drains to the west and northwest; and a 'dead zone' to the south with little mixing (Figure 28). Although it is noted that the extent and presence of the two zones is likely to change depending on seasonal conditions and inflows to the lake (AWC, 2020b). Results of water quality sampling in December 2019, during drought conditions, indicated highly stratified conditions that were homogenous across the lake. Surface waters were supersaturated in dissolved oxygen with a pH of 10 (driven by an algae bloom) whilst bottom waters were anoxic with pH of 6.5. Nutrient concentrations (particularly phosphorus) were also considerably higher in bottom waters, with sediments the likely source (AWC, 2020b). An investigation into the issues and options for improving management and rehabilitation of the lake was undertaken by AWC in 2018. Addition of recycled water to the lake to improve flushing and water quality was the primary recommended action of the draft management plan (AWC, 2018). This option is no longer considered feasible, however the management plan includes a number of other recommendations considered in Section 5.4.

Figure 28: Hydrodynamics of Baywood Chase Lake showing mixed and dead zones and bathymetry.

Source: AWC (2020b)

Litter and marine debris

Results from local litter surveys undertaken monthly in hot spots throughout the Shire in 2020/ 2021 reveal Suffolk Park is the third most littered suburb in the Byron Shire after Byron Bay and Brunswick Heads (Figure 9, Section 4.2.1). Litter carried in stormwater or from marine/ocean water ingress as well as illegal dumping, and rubbish left behind after bush parties within the Tallow Creek estuary were all raised as key sources of litter to the ICOLL by stakeholders.

BSC is currently implementing the 'Source to Sea' project in the Byron Bay town centre and Industrial Estate (refer Section 4.2.1 "Litter and Marine Debris" in the Belongil Catchment) which involves deploying and maintaining litter baskets within stormwater pits to capture and remove litter at the source before it reaches downstream environments (BSC, 2023c). If successful, there may be opportunities for expansion of the trial in the Tallow Creek catchment.

Dip sites and contaminated land

A search of the POEO Act Public Register (NSW EPA, 2023a), DPI cattle dip site locator (DPI, 2023) and the NSW EPA List of Notified Contaminated Land Sites (NSW EPA, 2023b) identified three sites within the catchment (Figure 29). The EPL for the decommissioned South Byron STP site is no longer active (surrendered) but the site is currently subject to investigations to determine the risk of decommissioned STP ponds to water quality in Tallow Creek (refer Sewer infrastructure discussion above for details). The Suffolk Park Service Station appears on the NSW EPA list of notified contaminated land sites, but the NSW EPA has investigated contamination at the site and decided that regulation under the *Contaminated Land Management Act 1997* is not required (NSW EPA, 2023b). The Suffolk Park dip site has been remediated and does not pose an ongoing risk to Tallow Creek (DPI, 2023). Further information on contaminated land and historical dip sites including a list of chemicals used historically at the dips is provided in Figure 29 and in Appendix 4.

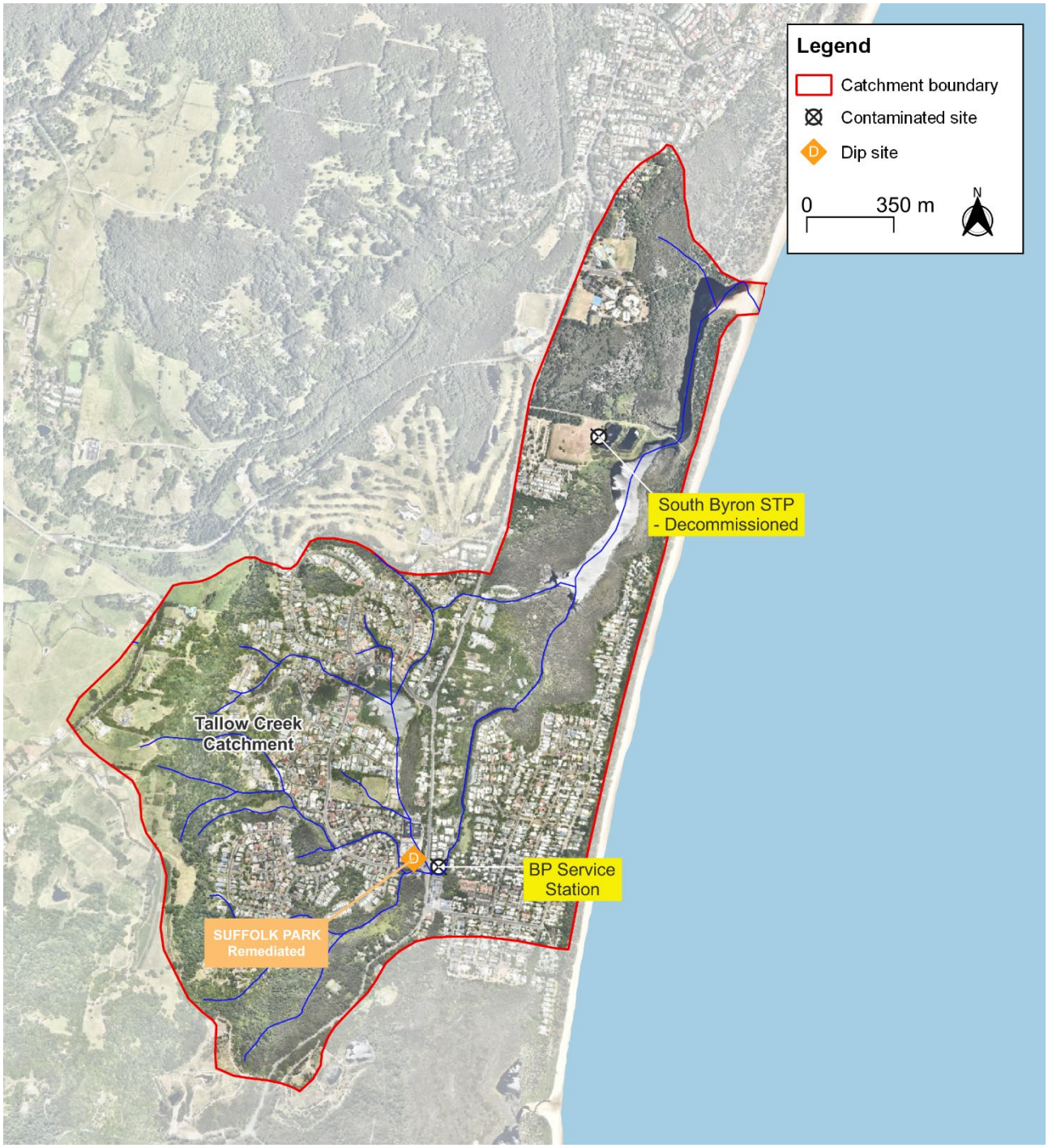

Figure 29: Search results of the POEO Act Public Register and DPI cattle dip site locator.

Source: Mapping data provided BSC (2023a), NSW EPA (2023a,b), DPI (2023) and Nearmap (2022)

DPE Estuary Health Risk Dataset

The Department of Planning and Environment (DPE) has developed an estuary health risk dataset for each estuarine catchment in NSW (Dela-Cruz, *et al.*, 2019) to support development of CMPs under the NSW Risk-based Framework. The intent of the dataset is to help identify strategic priorities for managing nutrient and sediment runoff throughout a catchment so that estuary health is protected, maintained and/or improved. The dataset provides an overview of broadscale risk from modelled catchment export of nutrients and sediment based on mapped land use categories on a sub-catchment scale. It does not provide high resolution at a local level. When used as part of CMP Studies, the dataset can be used to help map where

further studies and/or management actions in a catchment would contribute to achieving some of the management objectives relating to nutrient and sediment load reduction. Risks from other pressures such as ASS, blackwater events, bank erosion, pesticides, point source pollution and other catchment contaminants are not considered in the risk assessment. The current estuary health risk results are mapped in Figure 30, noting that the DPE catchment for Tallow Creek differs to the catchment defined for this study.

Key areas are highlighted:

- Urban development in the mid catchment, particularly in the vicinity of the Suffolk Park Shopping Centre, Suffolk Park Petrol Station and surrounding urban residential/tourist accommodation areas (high export of TN, TP and TSS relative to other areas of the catchment).
- Tourist accommodation, decommissioned South Byron STP site and vegetated areas adjacent to Tallow Creek ICOLL mid-estuary reaches including the Ingenia Holiday Park (moderate export of TN, TP and TSS relative to other areas of the catchment).
- Urban residential areas in the Baywood Chase estate, particularly to the north of Baywood Chase Lake (moderate export of TP and TSS and low to moderate export of TN relative to other areas of the catchment).
- Byron Bay High School and surrounding land in the north of the catchment, close to the entrance.

The water quality data review, ground-truthing and verification tasks completed as part of this study provide more detailed local information that is generally consistent with the overall results produced by the modelling.

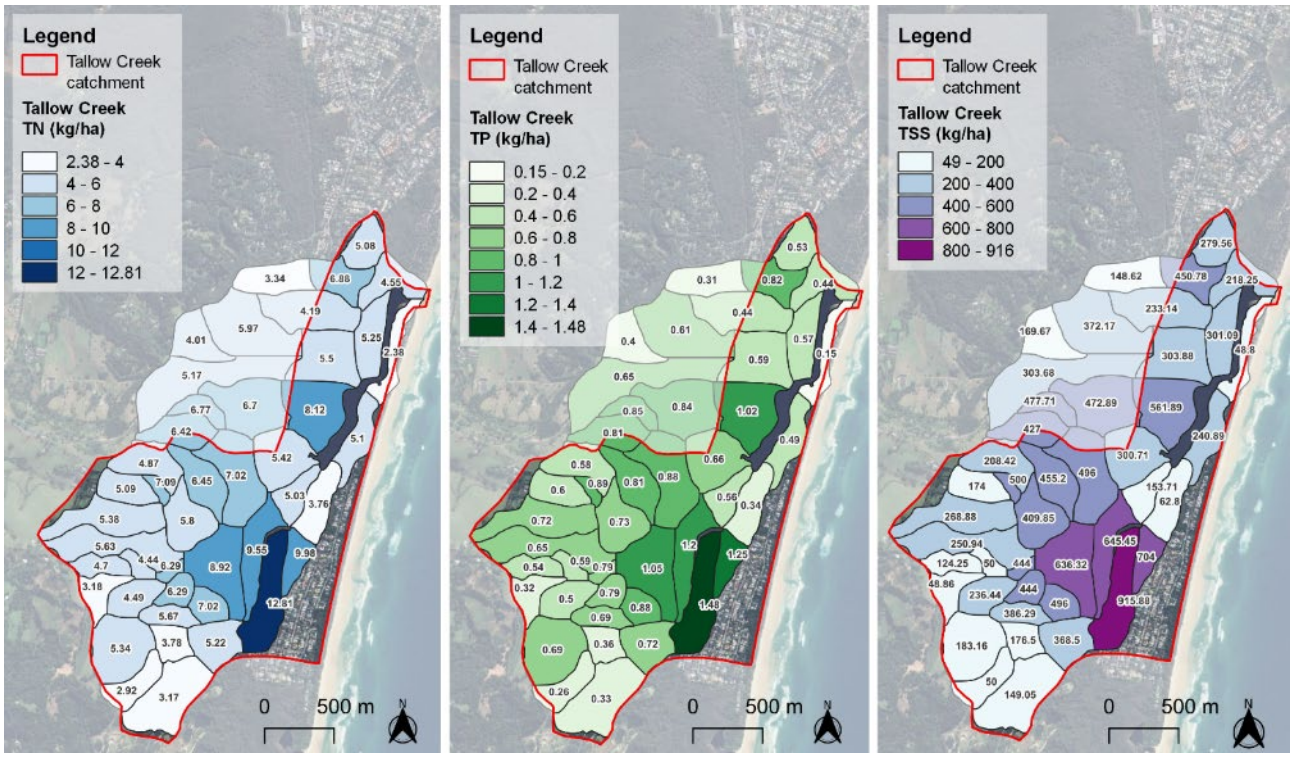

Figure 30: Tallow Creek Estuary Health Risk Dataset results for TN, TP and TSS (kg/ha/yr)

Source: Mapping data provided by DPE (2023)

5.2.2. Review of water quality monitoring data

BSC undertakes or has recently undertaken water quality monitoring of the Tallow Creek catchment waterways as part of two primary programs:

1. Byron Bay Surface Water Quality Monitoring Program – between 2016 and 2022 the program included surface water sampling at 3 sites on a monthly basis and in response to rainfall events.
2. Entrance Opening Strategy (EOS) monitoring - water quality and level loggers and event based sampling in accordance with the Environmental Management Plan and Opening Strategy for Tallow Creek (BMT WBM, 2015) and requirements of licences and permits in currency (a NPWS licence and a Marine Parks permit is required for entrance management works in accordance with the EOS).

The locations of sample sites are shown on Figure 14 including routine sample sites and water quality logger sites. Site details are provided in Table 6.

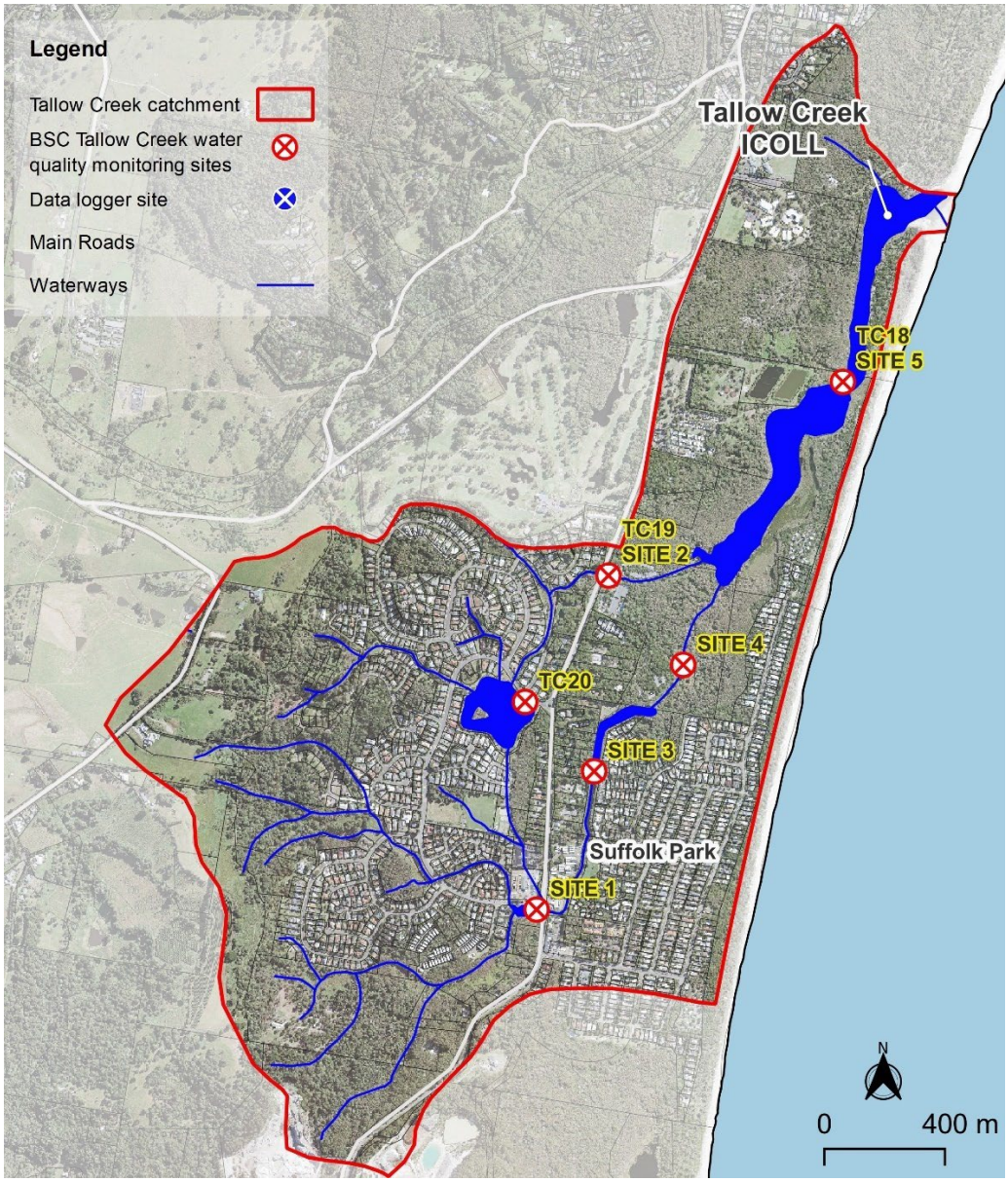

Figure 31: Tallow Creek catchment water quality monitoring sites

Source: Mapping data provided BSC **(2023a), DPE (2023) and N**earmap (2023).

Table 6: Sampling sites in Byron Bay Surface Water Quality Monitoring Program and Tallow Creek Entrance Opening Strategy

Zone	Site ID	Location	Sample type	Status
Upper catchment (urban)	TC20	Baywood Chase Lake Outlet (Teak Circuit, Beech Drive)	Monthly	Current
Upper Creek	TC19 and (EOS) Site 2	Crystalbrook resort (formerly Byron at Byron, eastern side of culvert under Broken Head Rd.)	Monthly	TC19 Current EOS Site 2 discontinued Oct 2022
Upper Creek	(EOS) Site 1	Entry point from Byron Hills drainage system – Broken Head Rd near service station	Monthly	Discontinued Oct 2022
Upper Estuary	(EOS) Site 3	End of Marattia Place	Monthly	Discontinued Oct 2022
Mid Estuary	(EOS) Site 4	Behind 34-38 Alcorn Street	Monthly	Current
Mid Estuary	TC18 and (EOS) Site 5	Tallow Creek at the footbridge	Monthly and permanent logger site	TC18 current Logger decommissioned early 2023
Parameters assessed	pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), *E. coli,* enterococci, chlorophyll *a*, cyanobacteria, turbidity, total suspended solids (TSS), total nitrogen (TN), oxidised nitrogen (NO_x), ammonia (NH_3), total phosphorus (TP), ortho-phosphate (Ortho-P/ PO_4), biological oxygen demand (BOD). Refer to Glossary and Abbreviations at the end of this report for further descriptions of parameters.			

Byron Bay Surface Water Quality Monitoring Program and Tallow Creek Entrance Opening Strategy

A review of water quality data collected over the last six years of BSC's Byron Bay Surface Water Quality Monitoring Program (monthly monitoring from 2016-2022) and Tallow Creek Entrance Opening Strategy was undertaken. Box and whisker plots for all data available for this period are shown in Figure 33 and Figure 34. Note that not all parameters were assessed at all sites (shown by absence of box plot) and only surface water samples were included in the box plots to provide a consistent comparison between sites.

Water quality guideline values (ANZG, 2018) are shown as dashed lines for estuarine and freshwater systems as applicable. Guidelines are compared against the median value (middle line in the box) to assess whether water quality conditions are likely to be negatively impacting aquatic ecosystem health. Refer Section 4.2.2 for water quality guidelines used and explanation of box and whisker charts.

Key findings were:

- Both TC20 and TC19 recorded median pH values from 2016-2022 within the guideline ranges recommended for aquatic ecosystem health. TC18 and Site 1 recorded a median values slightly less than the minimum guideline value indicating acidic conditions at these locations at times. Site 3 in the upper estuary and Site 4 in the mid estuary recorded median pH values of 6.05 and 6.18 respectively which was below the lower pH guidelines recommended for estuary health (pH 7.0). While below the guideline values, these pH levels are not considered to be critical for aquatic life and may reflect the influence of naturally occurring humic-rich groundwater from surrounding coastal wetland areas.
- Surface water temperatures ranged from 12ºC to 33ºC across all sites with a median of approx. 19.5ºC across all sites, except for TC18 in the mid estuary, with a slightly higher median value of 21ºC. Higher temperatures at this site may reflect warming from solar radiation at this open water site with little shading.
- Tallow Creek mid estuary site TC18 recorded conductivity ranges from freshwater through to marine water indicative of an ICOLL with variable entrance opening regime. Sites 3 and 4 recorded conductivity ranges from freshwater through to brackish water, typical of mid and upper estuarine reaches with influence from both freshwater runoff and tidal ingress. A freshwater to slightly brackish conductivity range was observed at site TC19 indicating only a very minor tidal influence at this site. Conductivity values at the Baywood Chase Lake Outlet (TC20) and at Site 1 in upper Tallow Creek were within the freshwater range at all times (0-0.5 ppt).
- Surface dissolved oxygen median levels were below the recommended guidelines values for all sites assessed. The lowest median values were detected within upper creek and upper estuary sites TC19 (49% saturation) and Site 3 (46% saturation) indicating poor aquatic ecosystem health at these locations. These locations are impacted by urban runoff and typically have low or no flow. BOD levels were noticeably elevated at TC19 than at other sites, indicating oxygen consumption by bacteria and other microorganisms is a dominant factor at this location. Site 4 in the mid estuary and Site 1 in upper Tallow Creek showed improved DO levels which may be associated with improved flow conditions at these sites (Site 1 is downstream of a constructed cascade which acts to aerate water). Site TC18 recorded the highest DO conditions with a median of 78% saturation, only just below the guideline for aquatic ecosystem health. Increased flows and tidal movement at this site are likely to contribute to better DO conditions. While dissolved oxygen data were not available for Baywood Chase Lake for this period, previous study has indicated the lake is prone to stratification and development of anoxic (close to zero DO) conditions in benthic waters (refer Section 5.2.1 Stormwater infrastructure).
- Faecal indicator bacteria levels (*E. coli* and enterococci) were elevated at all sites with the highest values experiences at TC20 (Baywood Chase Outlet) and generally decreasing with distance downstream to the estuary. Baywood Chase Lake has been previously documented as a source of faecal pollution and previous study have attributed this largely to the abundant bird population roosting on island on the lake. Sewer overflow incidents have also been documented within the Tallow Creek catchment and microbial source tracking could be implemented to identify the sources of faecal contamination (i.e. human vs. bird vs dog vs. other animal sources) and would assist in confirming the nature of issues and direct management action.

- Chlorophyll *a* was elevated at TC19 (median value 52 µg/L and maximum outlier value of 1,740 µg/L) which was a substantial increase compared to other site and indicates this site is subject to eutrophication and algal blooms. All other sites recorded chlorophyll *a* values either close to or below recommended guidelines for aquatic ecosystems. While chlorophyll *a* data were not available for Baywood Chase Lake for this period, previous study has indicated the lake is prone to algal blooms and high chlorophyll *a* values (refer Section 5.2.1 Stormwater infrastructure). TC19 is located downstream from the Baywood Chase Outlet and likely to be heavily influenced by poor water quality discharging from the lake.
- Cyanobacteria levels were also exceptionally high at TC19 indicating the site is subject to blooms of cyanobacteria (blue green algae), which are also known to occur at Baywood Chase Lake.
- Median turbidity values at all sites assessed over the time period were within the ranges recommended for aquatic ecosystem health (<50 NTU freshwater and <10 NTU estuarine water). Turbidity generally increased with distance upstream and was highest at Baywood Chase Lake outlet (TC20 median value 26 NTU). Turbidity values at TC18 in the estuary were much lower (median value 3.1 NTU) indicating good water clarity. TSS values followed a similar trend with highest values recorded at Baywood Chase Lake (TC20) and decreasing with distance downstream to the estuary.
- Nitrogen levels were regularly elevated throughout the Tallow Creek catchment sites. All sites exceeded guideline values for TN, with the highest median values detected at TC20, 1.51 mg/L TN (Baywood Chase Lake), followed closely by TC19, 1.21 mg/L TN (Crystalbrook Resort downstream of Baywood Chase Lake) indicating nutrient sources from these locations. TN values were lower at the remaining sites in upper Tallow Creek, and upper and mid estuary, but still well in excess of recommended guidelines. The median TN value at TC18, 0.78 mg/L TN (mid estuary) was almost half the median concentration recorded at TC20 (Baywood Chase Lake Outlet), but still more than doubled the TN guideline of 0.3 mg/L for healthy aquatic ecosystem function.
- Oxidised nitrogen (NO_x - bioavailable forms of N) were noticeably higher at site TC19 than at the other sites (including T20 Baywood Chase Lake outlet) and warrants further investigation of potential pollution sources at this location (e.g. potential sewer leaks/overflows, excess fertiliser use etc.). Figure 32 shows all NO_x results at TC19 from September 2017 to November 2022 showing consistently elevated levels and occasional spikes of NO_x occurring in November 2019 and again in February 2022. The consistently high NO_x results indicate an ongoing issue at this site. This is consistent with field observations in April 2023, when this location was choked with Salvinia covering the entire water surface indicating nutrient enrichment /eutrophication (Plate 12).

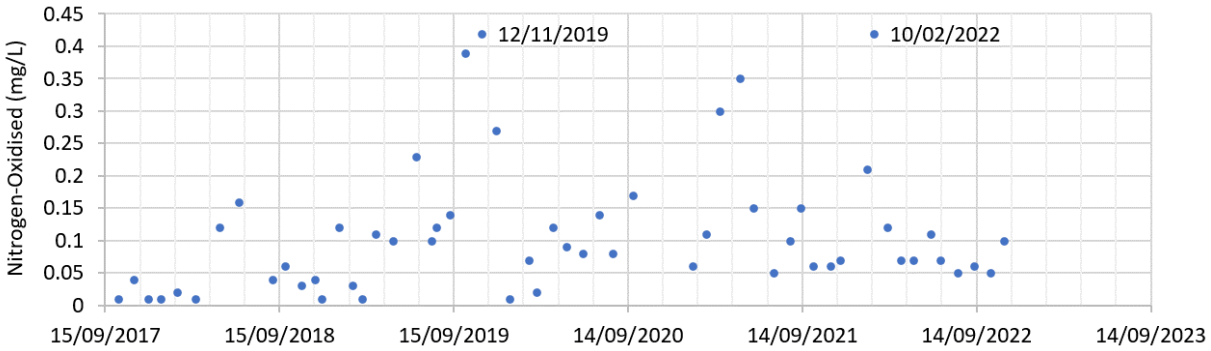

Figure 32: Oxidised nitrogen at Site TC19 from September 2017 to November 2022

- Ammonia (NH_3 another bioavailable form of N typically dominant in low dissolved oxygen conditions) was also noticeably higher at site TC19 and is likely to indicate a pollutant source requiring further investigation.
- Phosphorus levels were also elevated throughout the catchment. All sites exceeded guideline values for TP, with the highest median values detected at TC19 and TC20 with median values of 0.16 mg/L and 0.14 mg/L respectively, being approximately three times the guideline value for TP.
- Ortho-phosphate (bio-available forms of phosphorus) recorded a reverse trend compared to TP, with the highest values detected at TC18 in the estuary (median value 0.03 mg/L) which is in excess of recommended guidelines for aquatic ecosystem health. It is possible that lower ortho-phosphate values were recorded at the upper catchment sites is due to the uptake of this bioavailable form of phosphorus by aquatic plants / weeds (e.g. *Salvina*), algae and cyanobacteria which have been detected in abundance at the upper catchment sites.

The water quality monitoring program results indicate a number of ongoing pollutant sources to Tallow Creek ICOLL requiring management action to reduce pollutant export to the estuary.

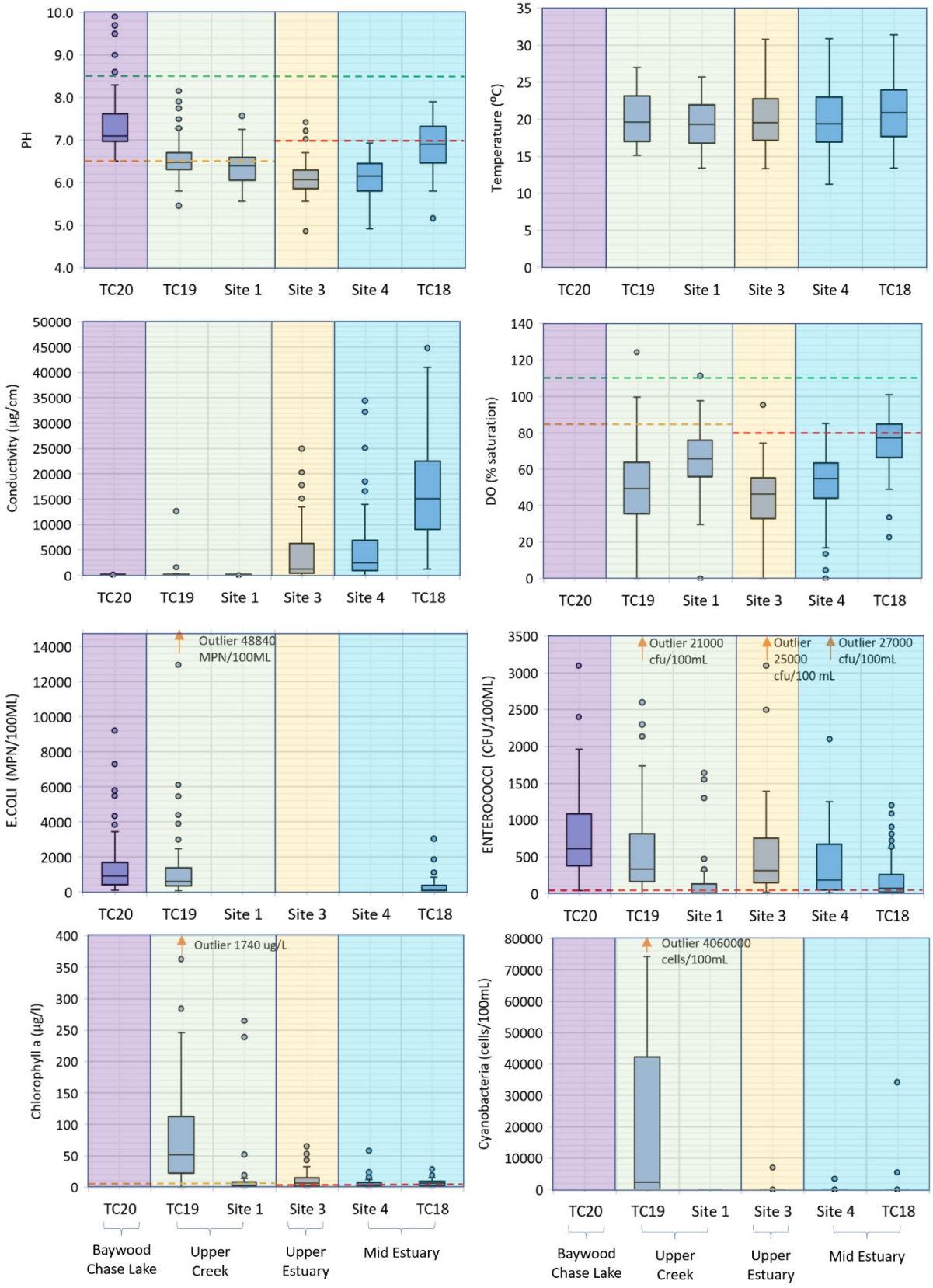

Figure 33: Tallow Creek water quality data 2016-2022 (pH, temperature, conductivity, DO, *E. coli,* enterococci, chlorophyll *a* and cyanobacteria).

Note: dashed lines on charts show water quality guideline values for freshwater/ lowland river (orange) and estuaries (red). Upper guideline values where applicable are shown as green dashed line.

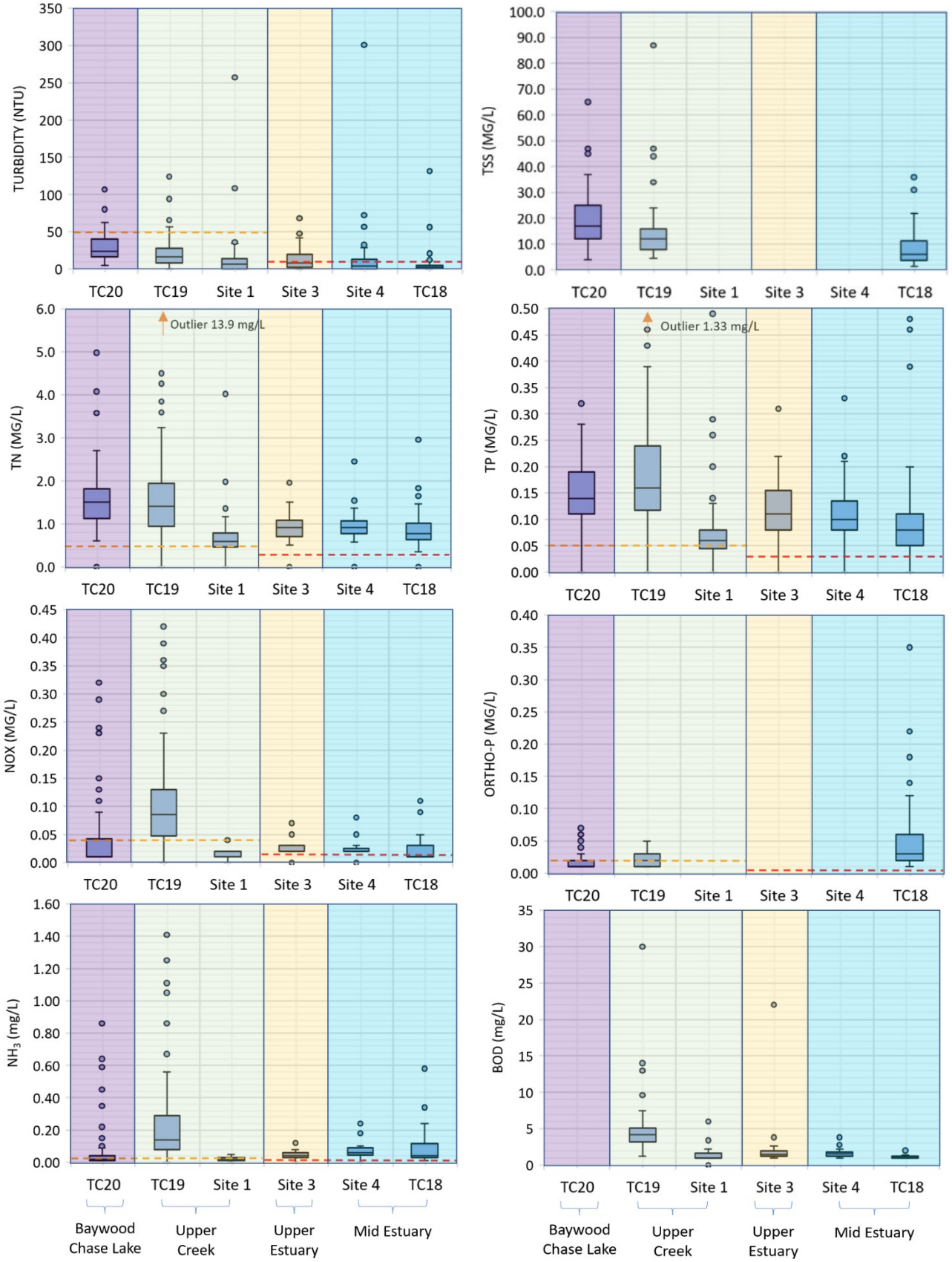

Figure 34: Tallow Creek water quality data 2016-2022 (turbidity, TSS, TN, TP, NO_x, Ortho-P, NH_3, and BOD).

Note: dashed lines on charts show water quality guideline values for freshwater/ lowland river (orange) and estuaries (red).

ICOLL entrance opening strategy monitoring

BSC manages and monitors artificial entrance opening events in accordance with the approved *Environmental Management Plan and Opening Strategy for Tallow Creek* (BMT WBM, 2015). Monitoring results have allowed for documentation of the water quality conditions prior to, during and following artificial entrance opening events. Some opening events have been associated with poor water quality episodes and occasionally, fish kills. Pugh (2021) discusses that from August 2017 until November 2020 there were 19 natural openings of Tallow Creek, none of which caused fish kills. Two artificial opening events (one unsanctioned event initiated by community members and one initiated by BSC) occurred in the period, and both caused major fish kills (Pugh, 2021).

While entrance opening events are not the focus of this study, the water quality monitoring undertaken associated with events provides insights into the water quality conditions and processes in Tallow Creek that precipitate adverse environmental effects. AWC (2021) provides a complete review and summary of all the monitoring completed for entrance opening activities. Key relevant points related to water quality processes were summarised as:

- Water quality declines during the ICOLL closed condition.
- Vertical stratification is common in the system with poor quality anoxic waters settling to the bottom of the channel.
- Fish kills can occur after long periods of high water and creek opening with no rainfall.
- A key source of pollution (nutrients, toxic blue green algae and enterococci) is the Baywood Chase Lake.
- Vegetation is dynamic with species assemblages in the low elevation zones routinely dying off and coming back after high water periods.
- There is stakeholder conflict between retention of the existing ecological and hydrological regime to limit environmental impacts, whereas many are concerned only with flood protection of private and public property and infrastructure.

AWC (2019) recommended refinement of the entrance opening management plan conditions (water level, rain, tide, swell etc.) to reduce the risk of fish kills. At the time of preparation of this report, the entrance opening strategy was under review. Monitoring has also confirmed the need for water quality improvement in the catchment, particularly Baywood Chase Lake to reduce the impact on the downstream sensitive receiving environment of Tallow Creek ICOLL (AWC, 2019).

5.2.3. Ground-truthing and verification

Site visits were conducted at key sites in the Tallow Creek catchment in April 2023 to ground truth the preliminary mapping at key locations and gain additional understanding of likely pollutant sources. A field water quality meter was used to undertake spot measurements whilst in the field to better understand the sites Appendix 5 includes field data recorded during site inspections.

The majority of constructed surface water drains and stormwater infrastructure visited in the upper Tallow Creek catchment in April 2023 were in poor condition. Poor water quality was recorded at many sites including low dissolved oxygen values and high turbidity. Several sites were observed to be showing signs of

nutrient enrichment (e.g. excess algae and aquatic plant growth). Baywood Chase Lake, in particular was showing signs of eutrophication including very high dissolved oxygen conditions (106.5 % saturation), high pH (9.85), high turbidity (76.6 NTU), and a green tinge to the water (Figure 12) indicating an algal bloom. A foul odour was also noted around the lake and while no testing for algal species was undertaken, it is possible the bloom was cyanobacteria as has been identified previously on several occasions.

Plate 11: a) Baywood Chase Lake looking south to islands b) Immediately downstream of lake outlet c) Lake outlet in 2018 during previous study (AWC, 2018)

Salvinia molesta an aquatic weed was also observed at several sites within urban stormwater drains and, in some cases, covered the entire water surface (Plate 12a). The stormwater pond opposite the Suffolk Park Service Station also contained Salvinia, but to a lesser extent, and was dispersed between water lilies and other aquatic macrophytes (Plate 12b). Council manages Salvinia in this stormwater pond as an upper catchment source to the catchment and estuary using Salvinia weevil (*Cyrtobagous salviniae*) which has kept growth under control in recent months. It is understood that resort management also manages an ongoing Salvinia infestation in the channel and within the wetlands at the Crystalbrook Resort. In 2021, during a long dry period and a long period of creek entrance closure with elevated water levels, the Salvinia infestation became rampant across Tallow Creek estuary as well as several other locations within the Shire. Management at that time was hampered by a lack of weevil availability which is the recommended management method for Council-managed sections of the Tallow Creek catchment.

Plate 12: a) Water quality sampling site TC19 at Crystalbrook Resort downstream of Broken Head Rd. culvert, choked with Salvinia b) Shallow pond opposite Suffolk Park Service Station upstream of Broken Head Rd. culvert.

The majority of urban areas observed during site inspection in Suffolk Park were characterised by curb and gutter stormwater infrastructure (Plate 13a) draining to open stormwater drains and/or vegetated swales and drainage basins. A large, vegetated swale was inspected along Beech Drive which was in generally good condition (Plate 13b).

Plate 13: a) Typical curb and gutter roadside Beech Drive, Suffolk Park b) Stormwater swale bordering a parcel of urban bushland, Beech Drive.

The site of the former South Byron Bay STP was visited (Plate 14). The former STP has been remediated and there are plans to remediate the ponds (though bank reprofiling, revegetation and fencing) in the future. No water quality sampling was undertaken at the ponds due to restricted access to the waterbody. The ponds appeared to be in good condition with well vegetated riparian zones, clear open water and emergent macrophytes along the edges. There were no signs of algal bloom conditions or Salvinia infestations observed during site inspection. Abundant wildlife was noted in and around the ponds.

Plate 14: a) Remediated land at site of former STP / landfill site b) Decommissioned South Byron STP sewage ponds adjacent to mid estuary reaches of Tallow Creek.

The lower catchment area bordering Tallow Creek estuary was dominated by natural vegetation. Water quality conditions observed in these reaches were vastly improved compared to the upstream areas. Water was typically tannin-stained, clear (low turbidity and improved dissolved oxygen levels at 60-90% saturation). There was little evidence of litter or Salvinia / algal blooms within the estuarine sites at the time of the site visit (Plate 15, Plate 16). The creek entrance was closed at the time of the site inspection with very little downstream flow evident (Plate 17).

Plate 15: a) Open water pool in upper estuary b) Melaleuca forest bordering the upper estuary west of Midgen Environment Park (Alcorn St).

Plate 16: a) Mid Tallow Creek estuary b) BoM water level logger at Tallow Creek footbridge c) Marine Park Special Purpose Zone signage.

Plate 17: a) Tallow Creek mouth on Tallow Beach b) Lower Tallow Creek near entrance

5.2.4. Conceptual model

Based on the information gathered during this study a conceptual model has been developed for Tallow Creek ICOLL to provide a broad overview of pressures, stressors and state of the estuary (Figure 35).

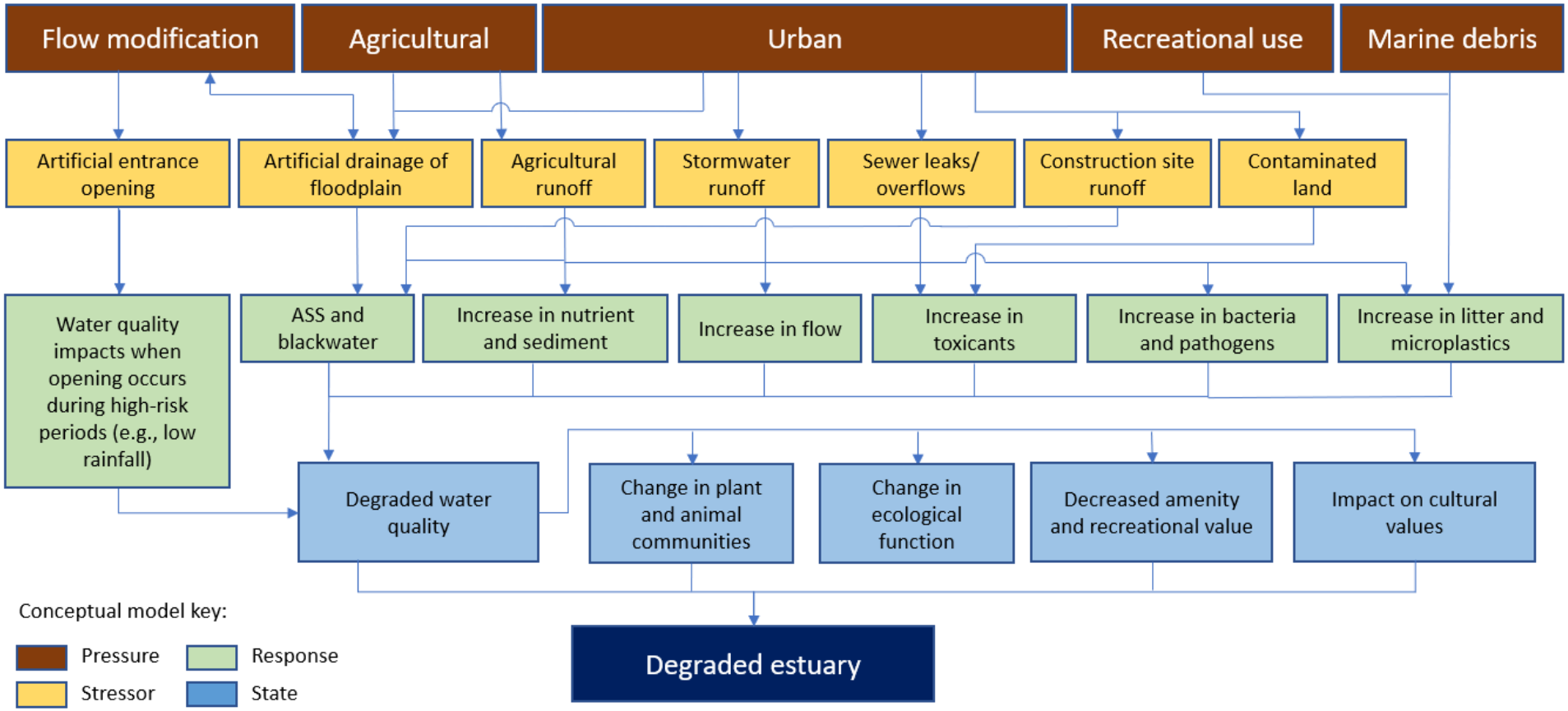

Figure 35: Tallow Creek pollutant sources conceptual model

5.2.5. Mapping of water quality pollution sources

Preliminary mapping of water quality pollutant sources was prepared using the information gathered as part of review of existing studies, modelling (e.g. DPE Estuary Health Risk Dataset and RCAT) and existing datasets and information gathered as part of stakeholder engagement. Local knowledge, observations and understanding gathered from stakeholders provided real world verification and confirmation of our understanding of the systems and pollutant sources. Site inspections carried out in April 2023 (refer Section 5.2.3 assisted in the verification and characterisation of pollutant sources.

Figure 36 maps key pollutant sources identified for the Tallow Creek ICOLL. This includes a combination of point source pollution (e.g. Baywood Chase Lake) and diffuse pollution sources (e.g. areas of urban development with no defined point of discharge). Identified sources that were difficult to define spatially on a map were documented and described in the legend text (e.g. intermittent sewer overflow events etc.)

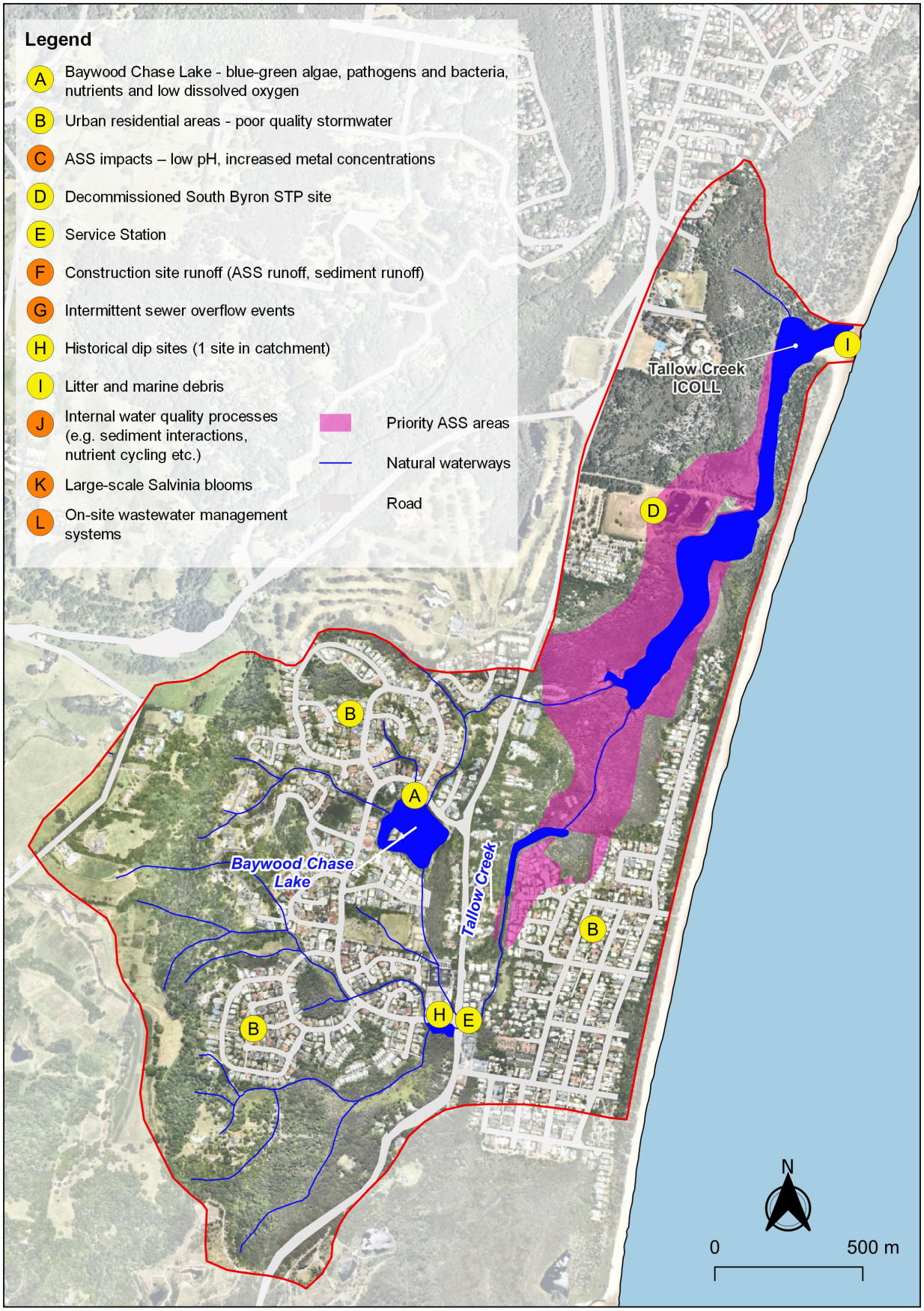

Figure 36: Tallow Creek pollutant sources

Note: Diffuse sources shown as orange A, G, H, I, L, M and N in legend only, they are not specific to any one location and have not been mapped.
Source: Mapping data provided BSC (2023a), NSW EPA (2023a,b), DPE (2023) and Nearmap (2022).

5.3. Prioritisation of Water Quality Pollution Sources

Prioritisation of the identified pollutant sources will assist in directing management and resources into areas that will have the greatest impact on improving water quality in the ICOLLs. Multiple lines of evidence were considered in the prioritisation of water quality pollution sources, categorised as follows:

1. The NSW Estuary Health Risk Dataset (Section 5.2.1) - considered as one of the broad components of prioritisation, noting that the model generates sub-catchment 'risk' based on nutrient and sediment loadings from diffuse pollution sources with no consideration of other pollutants or point sources.
2. Water quality data collected within ICOLLs and the catchments as part of the Byron Bay Surface Water Quality Monitoring Program and analysis presented in Section 5.2.2.
3. Information gathered as part of desktop review from previous studies.
4. Stakeholder feedback.
5. Field observations noted during site inspections (Section 5.2.3).

For each pollutant source, each category was scored as High (3), Medium (2) or Low (1) according to water quality source pollutant priority. Where there was no data available for a category (e.g. ASS not considered in NSW Estuary Health Risk Dataset) no score was assigned for that category. The total score was averaged for each pollutant source considering only the categories where data were available. Ranking of key pollutant sources affecting water quality by priority for management is provided in Table 7 below. The prioritisation matrix and detailed scoring is provided in Appendix 6.

Table 7: Priority ranking of water quality pollutant sources using multiple lines of evidence.

ID	Water Quality Pollutant Source	Score	Rank
A	Baywood Chase Lake - blue-green algae, pathogens and bacteria, nutrients and low dissolved oxygen	3.00	1
B	Urban residential areas - poor quality stormwater	2.50	2
I	Litter and marine debris	2.33	3
G	Intermittent sewer overflow events	2.00	4
J	Internal water quality processes (e.g. sediment interactions, nutrient cycling etc.)	2.00	4
K	Large-scale Salvinia blooms	2.00	4
C	ASS impacts – low pH, increased metal concentrations	1.33	7
D	Decommissioned South Byron STP site	1.33	7
F	Construction site runoff (ASS impacts, sediment runoff)	1.25	9
E	BP Service Station	1.00	10
H	Historical dip sites (1 site in catchment)	1.00	10
L	On-site wastewater management systems	1.00	11

5.4. Potential Management Options

Potential management options to address the identified water quality pollution sources are documented in Table 8 below. Potential management options include strategic management actions, further investigations and on-ground works to reduce point and diffuse source water pollution for further consideration in Stage 3 CMP preparation or via other operational and strategic planning processes where relevant.

A high-level assessment of options is given in Table 8 to provide sufficient information to progress potential options to Stage 3 of the CMP (Options Assessment). This assessment is based on the current understanding of management options to address the pollutant sources identified by this study. A description of each management option is provided along with details of any management action currently underway or planned to address pollution sources. A qualitative assessment of feasibility, acceptability to stakeholders and a preliminary assessment of approval requirements is provided along with a coarse cost estimation (estimated low-high range). The likely responsibilities for actions and potential partnerships for implementing actions have also been identified. Finally, a recommendation is made as to whether the option has merit and should be considered further. Options recommended for further consideration will be assessed in detail as part of Stage 3 of the CMP. Note that Stage 3 of the CMP may incorporate additional options to address pollution sources and is not limited to those listed in Table 8.

The option assessment methodology and detailed scoring is provided in Appendix 7.

Table 8: Tallow Creek ICOLL potential pollution control options for consideration in Stage 3 of CMP

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
A	1	Baywood Chase Lake - blue-green algae, pathogens and bacteria, nutrients and low dissolved oxygen	• Draft Baywood Chase Management Plan (AWC, 2018) • Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021) • BSC Water Quality Monitoring Program • Byron ICOLL Research Centre initiatives including citizen science monitoring.	Solar powered artificial aeration (Rank: 2 AWC, 2018)	3	1	3	0	7	BSC	Yes
				Rehabilitate sediment basin adjacent to lake (Rank: 2, AWC, 2018)	2	2	2	1	7	BSC	Yes
				Weed removal and native plantings including shade trees and habitat restoration (Rank 3, AWC, 2018)	2	2	3	1	8	BSC	Yes
				Create and install vegetated swales (Rank 4, AWC, 2018)	2	2	2	0	6	BSC	Yes
				Recirculation to treatment wetland and swale (Rank 4, AWC, 2018)	2	2	0	1	5	BSC	Yes
				Bird management - island re-shaping / removal (Rank 5, AWC, 2018)	-1	0	2	1	2	BSC	Yes – noting low feasibility score reflecting need for further investigation of viability and likely negative impact on native bird habitat.

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				Bioremediation tablets (Rank 5, AWC, 2018)	0	0	2	1	3	BSC	Not recommended
				Baffle inlets (Rank 6, AWC, 2018)	0	1	3	1	5	BSC	Yes
				Install benches and plant with macrophytes (Rank 7, AWC, 2018)	2	2	0	1	5	BSC	Yes
				Lower outlets (Rank 8, AWC, 2018)	0	0	2	-1	1	BSC	Not recommended
				Sediment treatment/ capping	1	0	3	1	5	BSC	Yes – noting further investigation required.
				Removal of contaminated sediments	1	0	0	0	1	BSC	Not recommended
				Partial infilling or complete removal of lake and replacement with high efficiency treatment system and additional public open space.	3	2	0	0	5	BSC	Yes
				Review and upgrade/improvement of urban stormwater infrastructure throughout catchment e. Includes transitioning existing concrete drainage to WSUD when road	2	2	1	0	5	BSC	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				upgrades/ developed occurs (e.g. rain gardens, biofiltration etc.)							
				Design and implement a monitoring program for pre and post any remediation works at Baywood Chase Lake to assess effectiveness of actions.	2	2	2	1	7	BSC	Yes
B	2	Urban residential areas - poor quality stormwater	• 'Source to Sea' project • IDLEEP for 2024 – 2029. • Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021). • BSC Water Quality Monitoring Program • Byron ICOLL Research Centre initiatives including citizen science monitoring	Potential expansion of Source to Sea project in Tallow Creek Catchment (if trial in Byron Bay is successful)	3	2	3	1	9	BSC	Yes - dependent on outcomes of trial due to finish May 2024.
				Update and implement IDLEEP for 2024-2029.	3	2	3	1	9	BSC	Yes
				Review and upgrade/improvement of urban stormwater infrastructure throughout catchment e. Includes transitioning existing concrete drainage to WSUD when road upgrades/ development occurs (e.g. rain gardens, biofiltration etc.) - as for ID A above.	Refer ID: A						

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				Implement strategies A and C of BSC WSUD Policy.	2	2	3	1	8	BSC	Yes
				Enhanced monitoring and maintenance of sewage infrastructure – as for ID G below.	Refer ID: G						
				Urban stormwater quality improvement community education campaign.	3	2	3	1	9	BSC	Yes
I	3	Litter and marine debris	• 'Source to Sea' project • IDLEEP for 2024 – 2029. • Clean up campaigns by various organisation and volunteer groups (e.g. KLIS, AUS LM, Tangaroa Blue clean ups etc.) MEM Strategy Actions	Potential expansion of Source to Sea project in Tallow Creek Catchment – as for ID B above.	Refer ID: B						
				Update and implement IDLEEP for 2024-2029 – as for ID B above.	Refer ID: B						
				Continue litter clean up campaigns – as for ID B above.	Refer ID: B						
				Continue surveys to monitor progress through time – as for ID B above.	Refer ID: B						
				Continue to develop and implement litter and illegal dumping education campaigns in collaboration with North	2	2	3	1	8	BSC North East Waste and the NSW EPA	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
				East Waste and the NSW EPA. With specific focus on visitors and tourism sector.							
G	4	Intermittent sewer overflow events	NSW EPA Licence 3404 monitoring, maintenance, reporting and management.	Enhanced monitoring and maintenance of sewage infrastructure within the ICOLL catchments (considered to be high value receiving environments) to minimise sewage system failures related to trade waste discharges, illegal stormwater to sewer connections, wet weather inflow and infiltration and sewage system performance.	3	2	1	1	7	BSC - This should be undertaken through the current IWCM process currently underway.	Yes – acknowledging the IWCM is the appropriate mechanism for consideration of this option. Any related action considered as part of the IWCM should be referenced in the CMP.
				Microbial source tracking to identify sources of faecal contamination (i.e. human vs. other animal sources) and assist in directing management action.	1	2	3	1	7	BSC	Yes
J	4	Internal water quality processes with the ICOLL (e.g. sediment interactions,	None	No actions recommended	-	-	-	-	-	-	-

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
		nutrient cycling etc.)									
K	4	Large-scale Salvinia blooms	Salvinia monitoring and management in accordance with Salvinia control manual/ DPI and Rous County Council (RCC) recommendations	Continue Salvinia monitoring and management in accordance with Salvinia control manual/ DPI and Rous County Council recommendations (i.e. Biological control using Salvinia Weevil)	3	2	3	1	9	BSC/ DPI/ RCC	Yes
D	7	Decommissioned South Byron STP site	• Ongoing investigations to assess impact on Tallow Creek	Further testing of sites in Tallow Creek was recommended by Cavvanba (2023) to confirm that groundwater is not having an influence on nutrient and heavy metal concentrations in Tallow Creek.	1	2	3	1	7	BSC	Yes
C	7	ASS runoff	• BSC monitoring and management of construction activities / DA condition enforcement. • BSC Water Quality Monitoring Program	Continue monitoring and management of construction activities involving excavation of soil within ASS risk areas.	3	2	3	1	9	BSC	Yes
F	9	Construction site runoff (ASS	• Council oversight/enforcement	Enhanced monitoring and management of construction sites,	3	2	1	1	7	BSC	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
		impacts, sediment runoff)	of construction phase and DA conditions. • BSC Water quality monitoring program	particularly large-scale developments with potential for significant water quality impacts on downstream receiving environments.							
E	10	Service Station (POEO Act Register listing)	• No active management – NSW EPA has determined regulation under the CM Act is not required.	No further actions recommended	-	-	-	-	-	-	-
H	10	Historical dip sites (POEO Act Register listing, 1 site in catchment)	• No active management	No further actions recommended	-	-	-	-	-	-	-

*CA Score -coarse assessment score

6. TI-TREE LAKE ICOLL

6.1. Background

Ti-Tree Lake is a small ICOLL located approximately six kilometres to the southeast of the Byron Bay town centre. The majority of the catchment is dominated by natural vegetation and high value ecological areas, including the Ti-Tree Lake Aboriginal Area. The majority of the lake itself as well as the ICOLL entrance is privately owned by Jali Local Aboriginal Land Council and is a culturally significant area. Areas of Coastal Wetlands and Littoral Rainforest are mapped within the catchment and protected under the *Coastal Management Act 2016*.

The Ti-Tree Lake entrance is located on Broken Head Beach and drains a small catchment area of approximately 1.2 km². Much of the Ti-Tree Lake catchment is in a natural vegetated state however some areas of the catchment have been developed for various uses which have been reported as known pollutant sources to Ti-Tree Lake. This includes:

- Broken Head Quarry - located in the upper catchment and while the quarry is no longer operational, and has undergone restoration in recent years, a large, constructed sediment pond remains at the site which ultimately drains to Ti-Tree Lake.
- Urban development, sewer infrastructure and stormwater drainage works on the southern extremity of the Suffolk Park residential estate and northern portion of Broken Head residential area. A small number of stormwater drains from Suffolk Park exit into the northern part of the Ti-Tree Lake catchment.
- Recreational use of the lake has been raised as having potential to impact water quality, litter and cultural sensitivities.

Any on-ground works within Jali LALC's land would need to be in accordance with directives from Jali Local Aboriginal Land Council.

Plate 18: Ti-Tree Lake entrance on Broken Head Beach, April 2023

6.2. Identification of Water Quality Pollution Sources

6.2.1. Catchment characteristics, landuse and pressures

Catchment characteristics, waterways and elevation

Catchment characteristics for Ti-Tree Lake are mapped in Figure 37. Catchment elevation ranges from approximately 60 mAHD in the upper catchment to 1 mAHD on the floodplain. Waterways are shown including major drainage systems connecting catchment areas to Ti-Tree Lake.

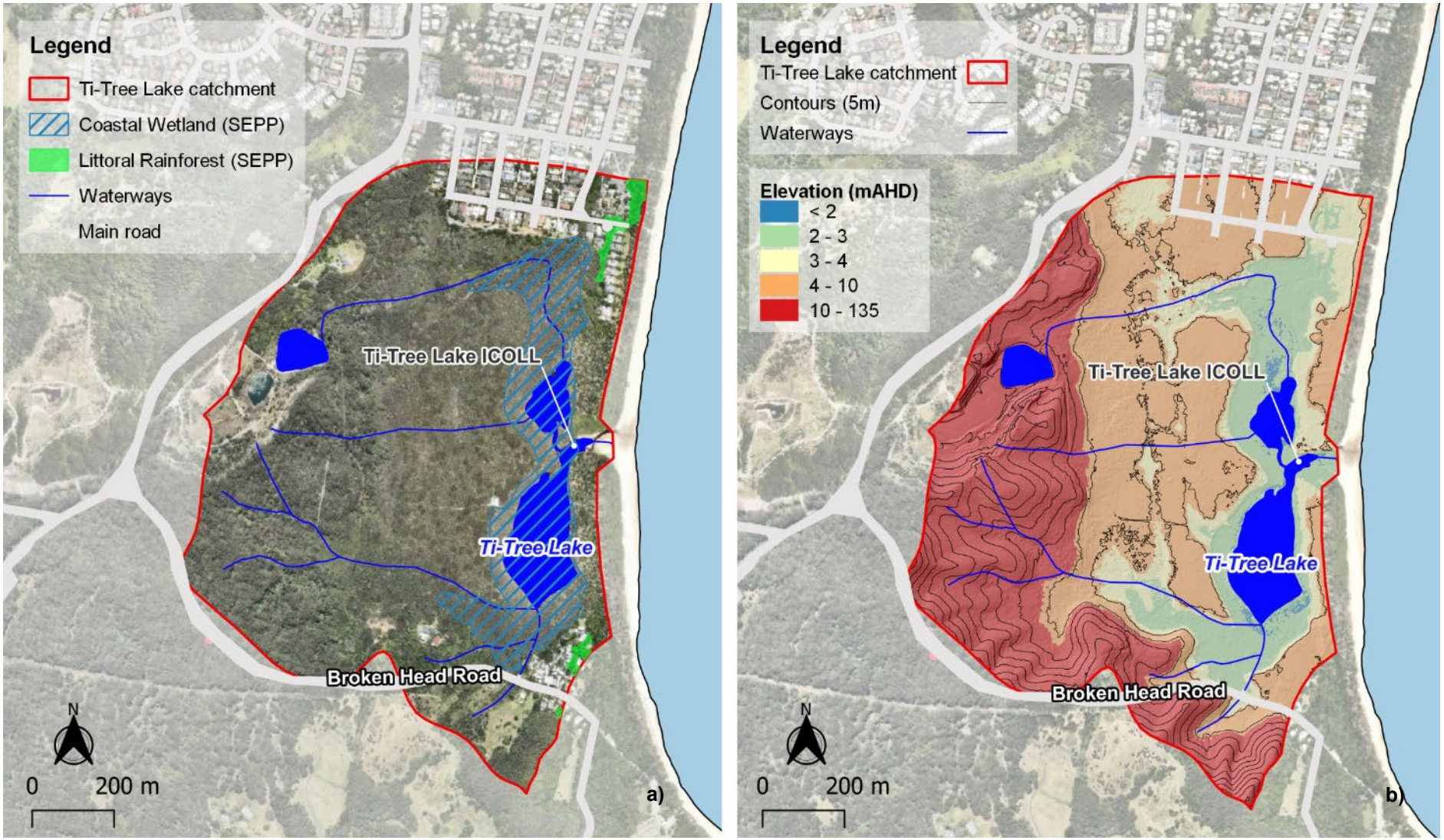

Figure 37: a) Ti-Tree Lake drainage b) Ti-Tree Lake elevation and natural waterways

Source: Mapping data provided by BSC (2023a), DPE (2023), Geoscience Australia (2023), and Nearmap (2022).

Acid Sulfate Soils

The Byron Local Environmental Plan 2014 ASS risk map show small areas of the Ti-Tree Lake Catchment is either Class 2 or Class 3 ASS. This indicates the likely presence of potential ASS occurring within 0-1m below the land surface over a relatively small area of the catchment to the south and north of the lake and including the lake bed itself. Exposure of these soils to air through excavation or lowering of the water table can produce sulfuric acid which may impact nearby waterways.

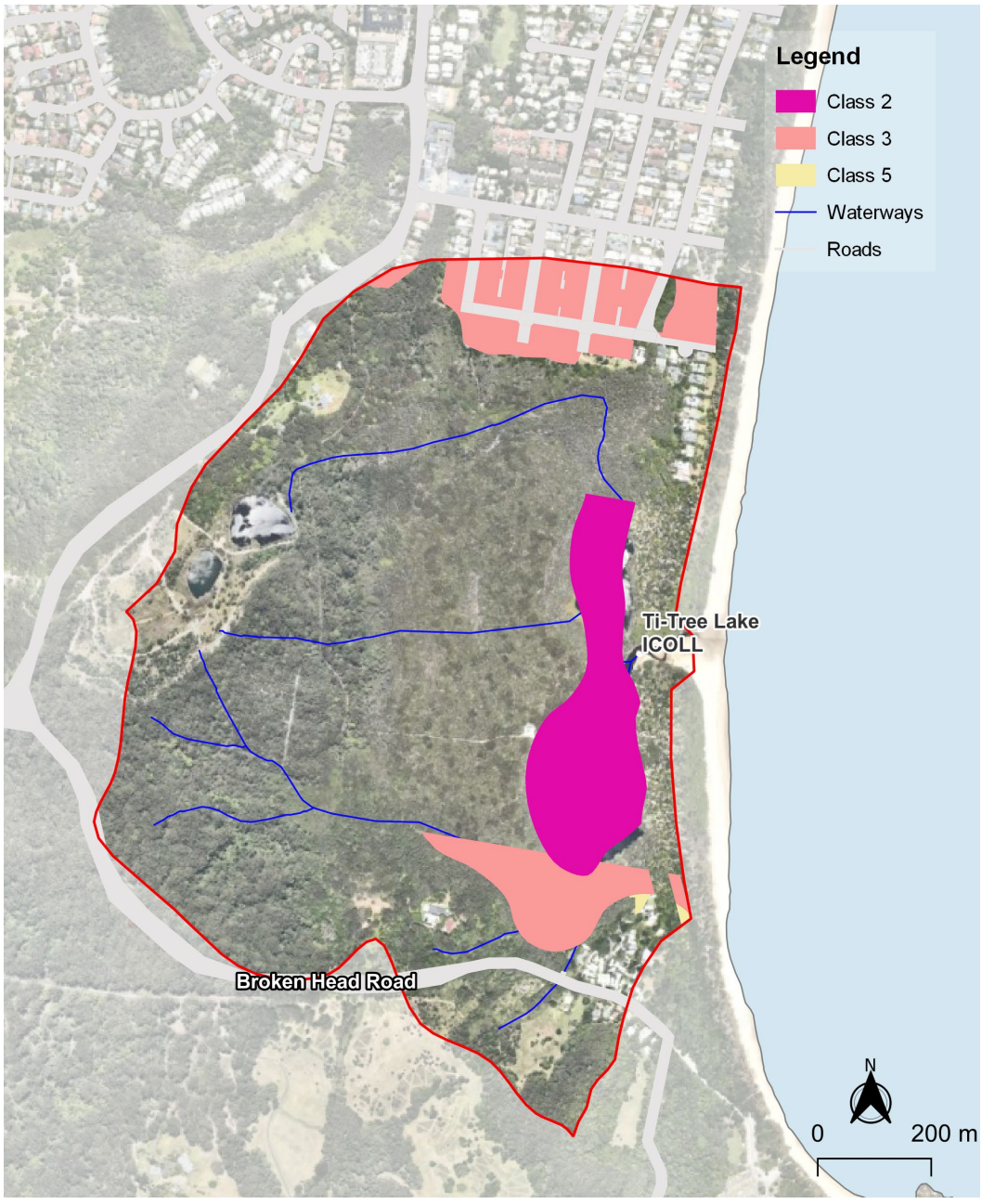

Figure 38: Acid sulfate soil risk map

Source: Mapping data provided by BSC (2023a), DPE (2023) and Nearmap (2022).

Land use and land tenure

The Ti-Tree Lake catchment has a mix of land uses as shown on Figure 39. The dominant land use classification within the study area is 'Vegetated Areas', comprising approximately 77% of the catchment.

Urban residential areas comprise 10.3 % of the catchment mostly areas on the southern extent of the Suffolk Park locality and Broken Head Road. Grazing land is the next most common mapped land use, comprising 7.5% of the catchment, the majority of which is located to the south of this catchment on previously cleared farm land, although regrowth of vegetation is now evident for much of these parcels. The proportion of this and which is actually used for grazing is unknown. Services and infrastructure comprise 5.4 % of the catchment and is made up of the former Broken Head quarry site.

Land tenure within the study area is illustrated on Figure 39. Most of the study area is freehold land under private ownership (85%). Approximately 11% of land is managed as National Park/Reserve. Crown land is divided into Council – managed (1.9%) and Crown land not managed by Council (2.1%). The majority of the catchment is zoned for Environmental Conservation (C2) or Environmental Management (C3), with some small parcels already developed and zoned for Tourism (SP3), and some areas zoned for Primary Production (RU1) and Rural Landscape (RU2). There is a possibly of some future development in the catchment, however this is likely to be minor given existing zoning and planning controls and presents a low risk to the health of the Ti-Tree Lake ICOLL.

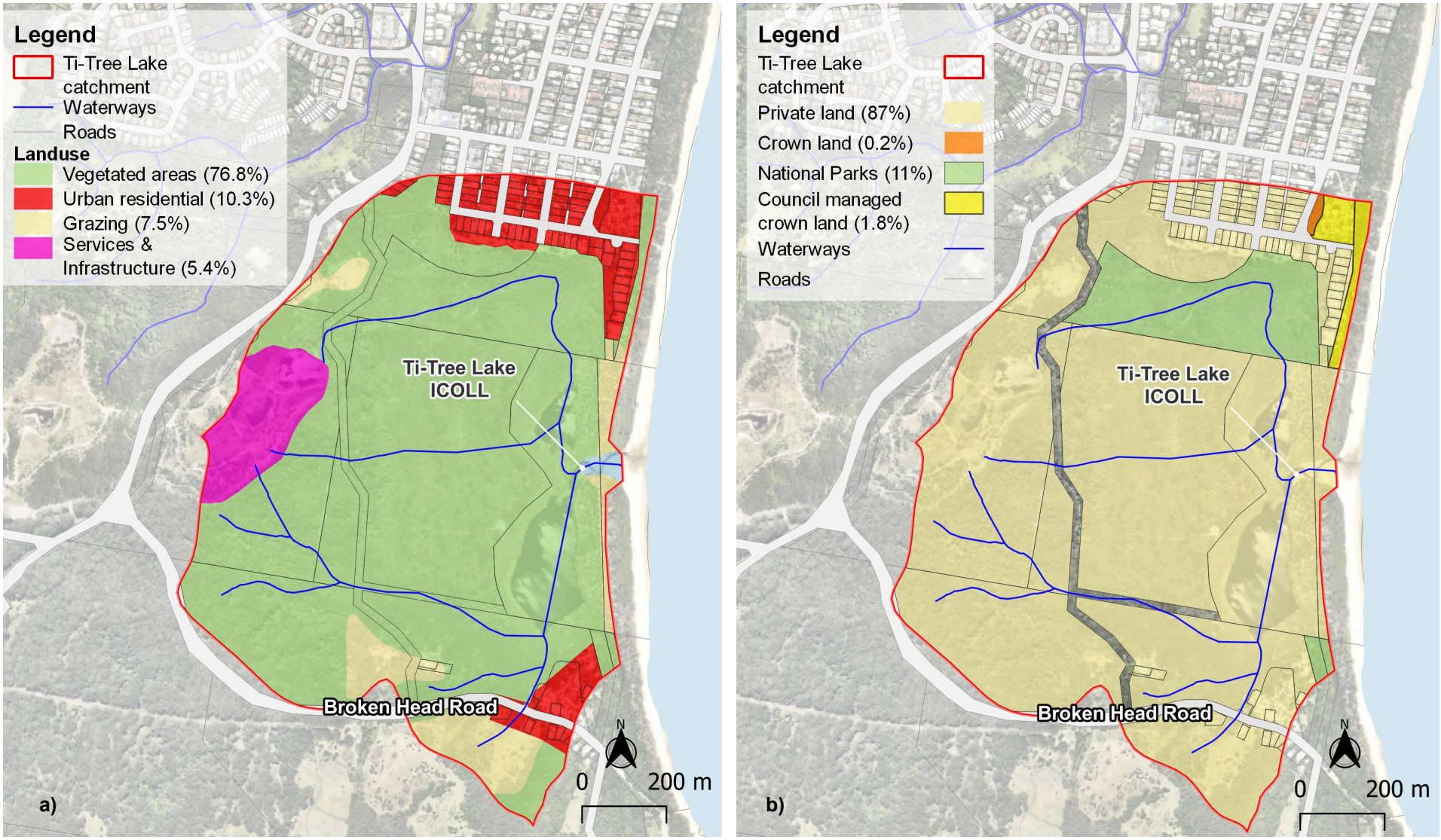

Figure 39: a)Ti-Tree Lake catchment landuse and b) Ti-Tree Lake land tenure

Source: Mapping data provided BSC (2023a), DPE (2020,2023) and Nearmap (2022).

Sewer infrastructure

Ti-Tree Lake catchment sewer infrastructure is shown on Figure 40a. The urban areas of Suffolk Park and Broken Head are serviced by a reticulated sewerage system, a series of pipelines and pumps that convey wastewater from households and businesses to the BBSTP for treatment. A sewer rising main extends from Broken Head in the south through the Ti-Tree Lake catchment to Suffolk Park urban areas. There are three sewer pump stations in the catchment, one in Broken Head and two in Suffolk Park. Breaks in the Broken Head to Suffolk Park sewage main have been reported in the past (Baker and Pont, 1998; Colman, 1999), however, there were no recently reported incidents of sewer overflows within the Ti-Tree Lake catchment (2016 – 2022).

On-site sewage management

There are a small number of rural properties on large lots that are not connected to the sewer systems and are serviced by on-site wastewater management systems. Due to the low density of on-site wastewater management systems in the Ti-Tree Lake catchment and implementation of BSC's On-site Wastewater Management Strategy and associated approvals, the Ti-Tree Lake catchment has been characterised as a low on-site wastewater management system risk to public and environmental health.

Stormwater infrastructure

Ti-Tree Lake catchment stormwater infrastructure is shown on Figure 40b. The southern portion of the Suffolk Park urban area in the north of the catchment is serviced by an urban stormwater system, a series of drains, swales, pipes, pits and other infrastructure that convey stormwater from households and businesses to the receiving environment, Ti-Tree Lake and the ocean. A small number of stormwater drains from Suffolk Park exit into the northern part of the Ti-Tree Lake catchment which is densely vegetated with natural coastal wetlands and would provide natural filtering and improvement of stormwater prior to reaching the lake. Urban areas of Broken Head in the south, do not have any formalised stormwater infrastructure, and stormwater from the small urban area is discharged either east to the ocean, or north to natural wetland areas prior to reaching the lake.

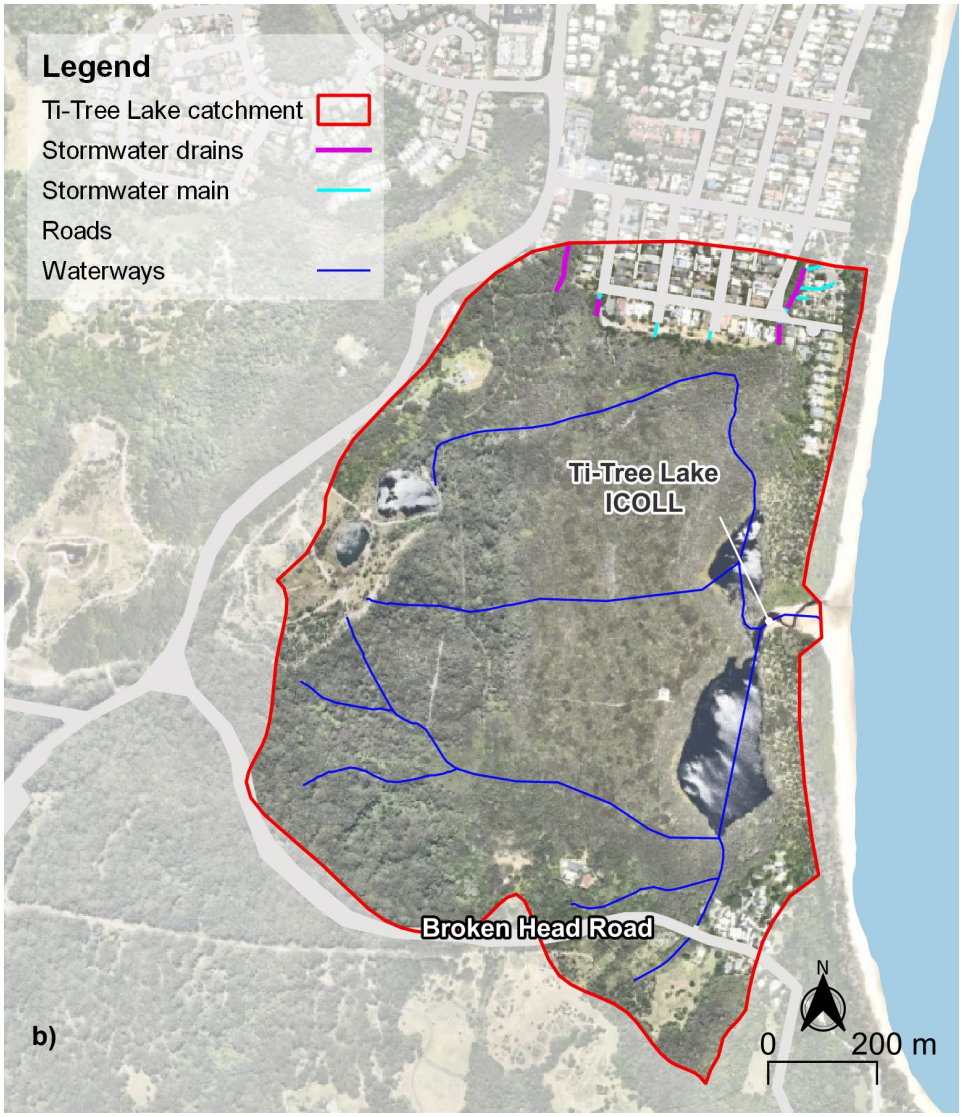

Figure 40: a) Ti-Tree Lake sewer and b) Ti-Tree Lake stormwater infrastructure

Source: Mapping data provided by BSC (2023a), DPE (2023) and Nearmap (2022).

Dip sites and contaminated land

A search of the POEO Act Public Register (NSW EPA, 2023) and DPI cattle dip site locator (DPI, 2023) identified one site within the catchment – the Broken Head Quarry site (Figure 41). The Broken Head Quarry is a land-based extractive activity licenced under the POEO Act (EPL 4860). The quarry has now ceased operations within the Ti-Tree Lake catchment on the eastern side of Broken Head Road and this area is being rehabilitated and revegetated. Two sediment basins remain within the quarry site as shown in Figure 41 which drain eastward to Ti-Tree Lake. The site's EPL requires rainfall events up to 82.5 mm (up to five-day event duration) to be held on site. If discharge occurs it must achieve water quality requirements of <50mg/L TSS and pH of 6.5-8.5 (Morris, 2019). Some non-compliances with water quality limits were recorded for the site in recent years (ENV Solutions, 2020).

Figure 41: Search results of the POEO Act Public Register and DPI cattle dip site locator.

Source: Mapping data provided by EPA (2023a), and Nearmap (2022).

6.2.2. Ground-truthing and verification

Access to much of the Ti-Tree Lake catchment was restricted to those areas accessible from public roads, along tracks within the Ti-Tree Aboriginal Area (National Parks Estate) and the entrance of Ti-Tree Lake on Broken Head Beach. Ti-Tree Lake is a culturally sensitive area and was not visited in accordance with the wishes of traditional owners. Site visits were conducted of public areas in April 2023 to ground truth the preliminary mapping and gain additional understanding of likely pollutant sources. A field water quality meter was used to undertake spot measurements whilst in the field to better understand the sites. Appendix 5 includes field data recorded during site inspections.

The small area of urban residential development at Suffolk Park bordering the northern upper catchment boundary for Ti-Tree Lake were characterised by curb and gutter stormwater infrastructure (Plate 19a). Sheet metal, wood and other building waste was observed dumped along the track within the Ti-Tree Lake Aboriginal Area. Other waste including chairs, mattress, bottles and plastic was also observed along the track.

Urban areas of Broken Head in the south, did not have formalised stormwater infrastructure with roadside swales conveying stormwater to nearby bushland (Plate 19a). A building construction site was observed along Broken Head Road with recent soil excavation of the hillside evident (Plate 19b).

Plate 19: a) Typical curb and gutter roadside MacGregor Street, Suffolk Park b) Building construction along Broken Head Road (business signage has been obscured).

Plate 20: a) Walking track from Suffolk Park through Ti-Tree Lake Aboriginal Area b) Roofing, wood and other waste dumped along the track in the Ti-Tree Lake Aboriginal Area close to Macgregor Street in Suffolk Park.

Water quality was assessed in-situ within a small tannin-stained waterway draining from Suffolk Park to Ti-Tree Lake (Plate 21a). The water was clear (turbidity 2.4 NTU), acidic (pH 4.07), with low dissolved oxygen (7.4 % saturation) likely to reflect the high level of organic matter present and lack of flow. Water at the ICOLL entrance on Broken Head Beach was also tannin-stained and clear (Plate 21b).

Plate 21:a) Small tannin-stained waterway draining to Ti-Tree Lake b) Ti-Tree lake entrance on Broken Head Beach

6.2.3. Conceptual model

Based on the information gathered during this study a conceptual model has been developed for Ti-Tree Lake ICOLL to provide a broad overview of pressures, stressors and state of the estuary (Figure 35).

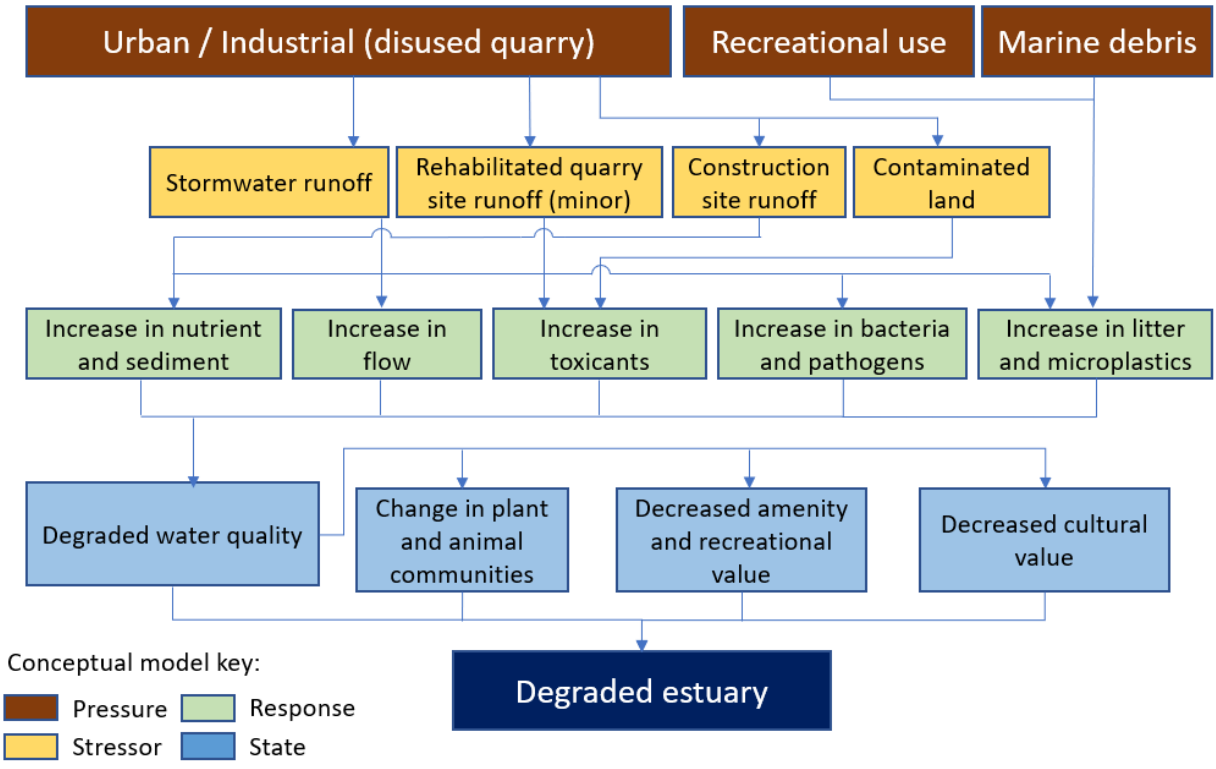

Figure 42: Ti-Tree Lake pollutant sources conceptual model

6.2.4. Mapping of water quality pollution sources

Figure 43 maps key pollutant sources identified for the Ti-Tree Lake ICOLL. This includes a combination of point sources (e.g. Disused Broken Head Quarry) and diffuse pollution sources (e.g. areas of urban development with no defined point of discharge). Identified sources that were difficult to define spatially on a map were documented and described in the legend text (e.g. intermittent sewer overflow events etc.).

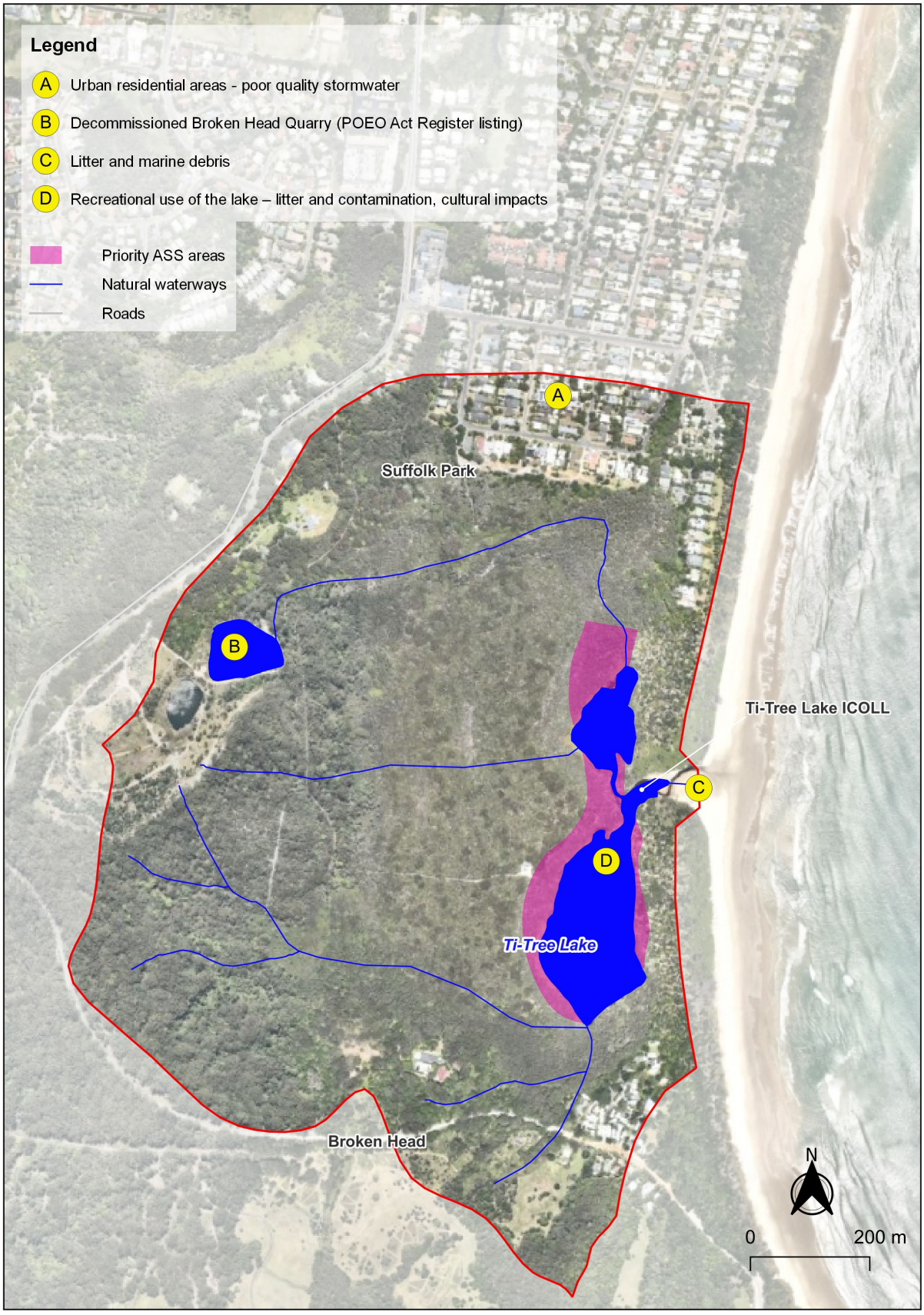

Figure 43: Ti-Tree Lake ICOLL pollutant sources

Source: Mapping data provided BSC (2023a), NSW EPA (2023a), DPE (2023) and Nearmap (2022).

6.3. Prioritisation of Water Quality Pollution Sources

Prioritisation of the identified pollutant sources will assist in directing management and resources into areas that will have the greatest impact on improving water quality in the ICOLLs. Multiple lines of evidence were considered in the prioritisation of water quality pollution sources, categorised as follows:

1. Information gathered as part of desktop review from previous studies.
2. Stakeholder feedback.
3. Field observations noted during site inspections (Section 6.2.2).

For each pollutant source, each category was scored as High (3), Medium (2) or Low (1) according to water quality source pollutant priority. Where there was no data available for a category no score was assigned for that category. The total score was averaged for each pollutant source considering only the categories where data were available. Ranking of key pollutant sources affecting water quality is provided in Table 9 below. The prioritisation matrix and detailed scoring is provided in Appendix 6.

Table 9: Priority ranking of water quality pollutant sources using multiple lines of evidence.

ID	Water Quality Pollutant Source	Score	Rank
D	Recreational use of the lake – pollution, disturbance to lake sediments, cultural impacts.	1.67	1
B	Decommissioned Broken Head Quarry site (POEO Act Register listing)	1.50	2
C	Litter and marine debris	1.33	3
A	Urban residential areas - poor quality stormwater	1.00	4

6.4. Potential Management Options

Potential management options to address the identified water quality pollution sources are documented in Table 10 below. Potential management options include strategic management actions, further investigations and on-ground works to reduce point and diffuse source water pollution for further consideration in Stage 3 CMP preparation or via other operational and strategic planning processes where relevant.

A high-level assessment of options is given in Table 10 to provide sufficient information to progress potential options to Stage 3 of the CMP (Options Assessment). This assessment is based on the current understanding of management options to address the pollutant sources identified by this study. A description of each management option is provided along with details of any management action currently underway or planned to address pollution sources. A qualitative assessment of feasibility, acceptability to stakeholders and a preliminary assessment of approval requirements is provided along with a coarse cost estimation (estimated low-high range). The likely responsibilities for actions and potential partnerships for implementing actions have also been identified. Finally, a recommendation is made as to whether the option has merit and should be considered further. Options recommended for further consideration will be assessed in detail as part of Stage 3 of the CMP. Note that Stage 3 of the CMP may incorporate additional options to address pollution sources and is not limited to those listed in Table 10. The option assessment methodology and detailed scoring is provided in Appendix 7.

Table 10: Ti-Tree Lake ICOLL potential pollution control options for consideration in Stage 3 of CMP

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
D	1	Recreational use of the lake – pollution, cultural impacts.	• Ti Tree Lake Preliminary Draft Management Plan (NPWS, 2015)	• Education regarding ecological and cultural values (e.g. signage, media campaigns etc.)	0	2	3	1	6	Jali/ NPWS/ BSC	Yes
B	2	Decommissioned Broken Head Quarry (POEO Act Register listing)	• Environmental Protection License 4860 monitoring, maintenance, reporting and management.	• Continue monitoring of sediment basin outlet, maintenance, reporting and management in line with EPL 4860.	2	2	3	1	8	NSW EPA / Ledonne Constructions	Yes
				• Event-based water quality monitoring downstream of the sediment basin outlet and in Ti-Tree Lake to assist in determining any ongoing impact from the quarry site.	2	2	3	1	8	Jali/ NPWS/ BSC	Yes
C	3	Litter and marine debris	• Illegal Dumping and Litter Education and Enforcement Plan (IDLEEP) for 2024 – 2029. • Clean up campaigns by various organisation and volunteer groups (e.g. KLIS, AUS	• Update and implement IDLEEP for 2024-2029.	2	2	3	1	8	BSC	Yes
				• Continue litter clean up campaigns.	3	2	3	1	9	BSC and other organisations and volunteer groups	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility	Acceptability	Cost	Approvals	CA* score	Responsibility	Further consideration in Stage 3
			LM, Tangaroa Blue clean ups etc.) • MEM Strategy Actions								
A	4	Urban residential areas - poor quality stormwater	• Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021).	• Review and upgrade/improvement of urban stormwater infrastructure throughout catchment. Includes transitioning existing concrete drainage to WSUD when road upgrades/ development occurs (e.g. rain gardens, biofiltration etc.)	2	2	3	1	8	BSC	Yes

7. RECOMMENDATIONS FOR FUTURE WATER QUALITY MONITORING

BSC has monitored water quality at a number of sites within Belongil Creek and Tallow Creek catchments since 1994. The original purpose of the monitoring program was to monitor impacts of STP discharges as part of consent conditions for STP development (BSC, 2008). The data has also been used for catchment planning and decision-making purposes (BSC, 2017b). The program aims to assess any significant changes throughout the catchment and provide baseline data to determine the impact of management actions that are under consideration in the catchment. The objectives of the water quality monitoring program include (BSC, 2017):

- Determine any significant changes in water quality in comparison to past assessments.
- Assess performance of mitigation measures and management strategies.
- Assess water quality impacts from BBSTP discharge.
- Maintaining a consistent data set for Council's long-term assessment for long term management, protection and restoration.
- Investigate leachate impacts from decommissioned tip site on Butler Street.
- Improve stormwater runoff by knowledge based educational programs.

In mid-2023 the water quality monitoring program ceased due to budget reallocation.

A review of water quality data collected over the last six years of BSC's Byron Bay Surface Water Quality Monitoring Program (monthly monitoring from 2016-2022) was undertaken as part of this project (refer Section 4.2.2 (Belongil Creek Catchment sites) and Section 5.2.2 (Tallow Creek Catchment sites). Based on the outcomes of this assessment it is recommended that a formal review and redesign of the program is undertaken to best meet the current needs of Council within budget limitations. The program could be implemented and part-funded as part of the CMP to inform management actions and track progress through implementation phases of the CMP. Recommendations for consideration as part of future water quality monitoring are as follows:

1. Key existing sites for monitoring pollution sources identified as part of this study:
    a. Butler Street Drain - sites BC07 and BC09.
    b. BBSTP discharge – sites BC23, BC02, BC03, BC04.
    c. Byron Bay Town Centre – sites BC15, BC07.
    d. Byron Bay Arts and Industry Estate - BC06 and BC13.
    e. Agricultural runoff – sites BC02, BC03, BC04 and BC13.
    f. Baywood Chase Lake – sites TC20 and TC19.
    g. Suffolk Park urban residential areas – sites TC20 and TC19, EOS Site 1 and Site 3.
2. Additional locations and parameters to fill data gaps:

a. Additional water quality monitoring locations within Belongil floodplain to better assess ASS impacts and runoff from floodplain land uses. Potentially re-establish site BC05 along the mid-Union Drain or find an alternative location nearby.

b. Additional water quality monitoring locations and parameters within the Industrial Estate areas (Belongil catchment) to better assess water quality closer to potential sources (e.g. corner Bayshore Dr and Banksia Dr).

c. Include oil and grease in the analysis suite for samples. Oil slicks/sheens were observed at some of the sites during site inspections and a number of sewer overflow problems were reported by BSC to be caused by the build-up of oil and grease in the sewerage system. It is therefore considered appropriate to include these parameters in the sampling program to be able to understand the extent of these pollutants reaching waterways in the catchment.

d. Event-based water quality monitoring downstream of the discontinued Broken Head Quarry sediment basin outlet and in Ti-Tree Lake to assist in determining any ongoing impact from the quarry site (acknowledging this would need to be undertaken in collaboration with Jali LALC and NPWS).

e. Dissolved oxygen is a key parameter and should always be recorded in-situ with other field parameters. Dissolved oxygen was not available in the monthly data provided by BSC for 2016-2022 in the Belongil Creek Catchment.

3. Potential rationalisation of sites and parameters:

a. Enterococci could be maintained as the only faecal indicator bacteria and remove *E. coli* from the parameter suite. Enterococci is known to have better survival rates under a range of fresh and saltwater conditions and is the sole preferred indicator recommended by the *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008).

b. Sites BC14 and BC14b are located within stormwater drains discharging to Clarks Beach (not Belongil Creek) therefore an ICOLL specific monitoring program would not include these sites.

c. Sites BC10 and BC11 in the estuary are close together and recorded similar water quality results. BC10 was discontinued in 2018 and this decision is supported by the current review.

4. Additional short-term studies to provide further information about pollution sources and assist in directing management actions:

a. Further investigation of the consistently high NO_x results identified at site BC15, BC07, BC14 and BC14b in the Belongil Creek catchment and TC19 in the Tallow Creek catchment. The elevated NO_x results at these locations indicate an ongoing issue (e.g. potential sewer leaks/overflows, excessive fertiliser use etc.), however the source(s) of NO_x are currently unknown. The microbial source tracking study discussed below should also include these sites as a priority for sampling.

b. Further investigation of elevated salinity at Site BC05 (Melaleuca Drive) which was measured at up to 16 ppt. This was higher than any measurements at the downstream site BC13, and therefore does not seem to be explained by tidal ingress. This is also near an area of Melaleuca die off and is a specific concern to the Belongil Creek Drainage Board.

c. A targeted microbial source tracking study to identify the sources of faecal contamination (i.e. human vs. other animal sources). Elevated levels of faecal indicator bacteria (i.e. enterococci and *E. coli*) have been detected within Belongil and Tallow Creek ICOLLs and connected drainage systems. It is important to note that the faecal indicator bacteria used in monitoring are common to all warm-blooded animals and it is not possible to differentiate between the animal sources of faecal matter (e.g. from cattle, dogs, birds and other wildlife etc.). To conclusively attribute bacteria to any one source, microbial source tracking (e.g. DNA analysis) can be used. This will provide further information required to target management action. For example, if bacteria are primarily associated with dog faeces at certain sites, further controls can be tailored to managing this source (e.g. more education, signage and provision of dog waste bags and bins etc.). If sources are of human origin, this may point to issues with sewerage infrastructure or potentially illegal camping/ parties etc. If sources are linked to birds or other native wildlife, it is likely to pose a lower level of risk to human health and management actions may be unnecessary or limited. This could be completed as a targeted short-term study to determine the origin of faecal indicator bacteria which has been detected at high levels at several sites.

d. Investigate the potential presence and impact of EDCs within the Belongil Creek ICOLL to address concerns raised by stakeholders. There are a number of methods available for screening of water or sediment samples for endocrine disrupting chemicals that could be utilised to provide initial data for the ICOLL.

e. Pesticide assessment of water/sediment within the ICOLLs. There is a moderate risk of contamination due to past and present pesticide use in the catchments including:

    - Cattle dips – there are three historical dip sites located in the Belongil Creek catchment and one in the Tallow Creek catchment. A small number have been demolished but not remediated.
    - Roadside and drain weed maintenance.
    - Agricultural use (pasture management, drain maintenance, pest and weed control).
    - Urban residential and commercial use (pest and weed management).

There has been some assessment of pesticide residue in fish from Tallow Creek system. The study did detect pesticide residues in fish tissues but levels were assessed to be below the level considered unsafe for human consumption (Reichelt-Brushett and Bucher, 2021). Further assessment could implement passive sampling technology to assess pesticide residue at low levels.

5. Investigate partnership with the Byron ICOLL Research Centre to undertaken citizen science monitoring programs and provide additional data for the ICOLLs and catchments while also providing opportunities for community education and awareness building about water quality pollution sources.
6. Reporting and data management:
    a. Data should be regularly added to a central database and error checked to ensure accuracy and consistency.
    b. Consider an annual report card assessing the health of the system for publication on BSC website and providing opportunities for community education and awareness building about water quality pollution sources.

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REFERENCES

.id (2018) *Byron Shire Council Tourism scale and impact analysis.* Report prepared for Byron Shire Council.

Alluvium (2019) *Belongil Creek Catchment Issues Study.* Prepared on behalf of Byron Shire Council.

Alluvium (2021) *Belongil Creek Entrance Opening Strategy and EMP REV1* (amended Dec 2021 - Adopted 27 2 20 - Reso 21-547).

ANZG (2018) A*ustralian and New Zealand Guidelines for Fresh and Marine Water Quality.*

AWC (2016 - 2022) *Belongil Estuary Entrance Monitoring Reports and Opening Event Monitoring Reports.*

AWC (2018) *Baywood Chase Lake Management Plan*. Prepared on behalf of Byron Shire Council.

AWC (2019) *Technical Memorandum: Summary of technical works undertaken by AWC within the Belongil Estuary catchment and technical position on catchment hydrology and water quality.*

AWC (2020a) *Updated Assessment of the Byron Bay STP Treated Effluent Flows on the Belongil Catchment Water Quality and Hydrological Data Analysis from 2016 to 2020.*

AWC (2020b) *Technical Memo Baywood Chase Lake – Water Quality Assessment.*

AWC (2021) *Tallow Creek Entrance Management Reporting Review of monitoring program and data collected from Stage 1 (April 2016) to Stage 9 (October 2020).*

AWC and BMT (2017) *Capacity assessment of the Belongil Creek Drainage System: Development of a preferred STP effluent flow path.*

Baker and Pont (1998) *A pilot study of water quality in Taylors Lake Broken Head*.

Belongil Acid Sulfate Soils Working Group (2003) *Belongil Swamp Acid Sulphate Soils Remediation Concept Plan.*

BMT WBM (2015) *Environmental Management Plan and Opening Strategy for Tallow Creek.*

BMT WBM (2017) *NSW Marine Estate Threat and Risk Assessment Report*. Prepared for the NSW Marine Estate Management Authority.

BMT WBM (2021) *Byron Shire Council WSUD Policy and Strategy.* Prepared on behalf of Byron Shire Council.

BSC (2017a) *2017-2027 Effluent Reuse Strategy.*

BSC (2017b) *Belongil Catchment Surface Water Quality Monitoring Program_Rev1.*

BSC (2020) *Draft Byron Shire Sustainable Visitation Strategy 2020 – 2030.*

BSC (2022a) *Consultant Brief for CMP Stage 2 Study – ICOLL Water Quality Source Tracking and Source Control Program*. Prepared by Byron Shire Council.

BSC (2023a) Mapping data provided by BSC including: Byron ICOLL Catchment Boundaries, Stormwater and Sewer Infrastructure, Acid Sulfate Soils LEP mapping, Water Quality Monitoring Program Sampling Sites.

BSC (2022b). *Memo: Impact on Sewer Infrastructure of Flood Event Commencing 30 March 2022.*

BSC (2023b) *Byron effluent reuse infographic.*

BSC (2023c). *Source to Sea – a Business Case on Reducing the Amount of Litter Entering Our Waterways*. Unpublished Draft Report.

BSC (2023d) *Contamination at Butler Street Reserve.* Available at: https://www.byron.nsw.gov.au/Services/Water-and-sewer/Water-and-sewer-projects/Contamination-at-Butler-Street-Reserve . Accessed April 2023.

BSC (2023e) *BSC Water Quality Public Data Portal*. Available at: http://www.byrondata.sgautomation.com.au/surface-water Accessed May 2023.

Cavvanba (2023) *Pond environmental assessment - Former South Byron Sewage Treatment Plant.* Prepared for Byron Shire Council.

Colman (1999) *Taylors Lake A Snapshot [water quality report]*

Dela-Cruz, J., Pik, A. and Wearne, P. (2017) *Risk-based framework for considering waterway health outcomes in strategic land-use planning decisions.* Office of Environment and Heritage and Environment Protection Authority, Sydney.

DPE (2020) *NSW Landuse 2017 v1.2*. https://datasets.seed.nsw.gov.au/dataset/nsw-landuse-2017-v1p2-f0ed. Accessed Jan 2023.

DPE (2022) *Acid Sulfate Soils Risk Mapping (revision date 24/11/2022).* https://datasets.seed.nsw.gov.au/dataset/acid-sulfate-soils-risk0196c Accessed March 2023.

DPI (2023) DPI cattle dip site locator https://www.dpi.nsw.gov.au/animals-and-livestock/beef-cattle/health-and-disease/parasitic-and-protozoal-diseases/ticks/cattle-dip-site-locator. Accessed March 2023.

DPE (2020) *NSW Landuse 2017 v1.2.* https://datasets.seed.nsw.gov.au/dataset/nsw-landuse-2017-v1p2-f0ed. Accessed Jan 2023.

DPE (2023) – SEED mapping data including: hydroline (waterways and drainage), cadastre, roads, NSW Estuary Health Risk Dataset. Available at: https://datasets.seed.nsw.gov.au/dataset, Accessed January 2023.

ENV Solutions (2020) *EPL 4860 Water Quality Statement of Compliance* - Updated 18/08/2020. Broken Head Quarry.

Geoscience Australia (2023) *ELVIS Spatial data* Available at: https://elevation.fsdf.org.au/ Accessed January 2023.

Mayjor, M., Reichelt-Brushett, A., Malcolm, H., Page, A. (2023) *Water quality fluctuations in small intermittently closed and open lakes and lagoons (ICOLLs) after natural and artificial openings.* Estuarine, Coastal and Shelf Science Vol 281, 5 February 2023, 108208.

McKnight, K. (2012) *Cyanobacterial blooms of a coastal dune lake in northern NSW and the effect of climate on cyanobacterial concentrations.*

Morris, D. (2019) *Broken Head Quarry Pollution Incident Response Management Plan - April 2019.*

Nearmap (2022) Nearmap aerial imagery (date taken 16-11-2022).

NHMRC (2008). *Guidelines for Managing Risks in Recreational Water.*

NSW EPA (2023a) POEO Act Public Register https://apps.epa.nsw.gov.au/prpoeoapp/ . Accessed March 2023.

NSW EPA (2023b). *List of Notified Contaminated Land Sites.* Available at: https://www.epa.nsw.gov.au/your-environment/contaminated-land/notified-and-regulated-contaminated-land/list-of-notified-sites Accessed March 2023.

NSW Government (2023a) *Six Maps*. Available at: https://maps.six.nsw.gov.au/ Accessed January 2023.

NSW Government (2023b). NSW Water Quality and River Flow Objectives – Brunswick River. Available at: https://www.environment.nsw.gov.au/ieo/brunswick/report-02.htm

NSW Marine Estate Management Authority (2018) *Marine Estate Management Strategy 2018-2028.* Available at: https://www.marine.nsw.gov.au/__data/assets/pdf_file/0005/1352831/Marine-Estate-Management-Strategy-2018-2028.pdf - accessed April 2023.

Parker, P. and Pont, D. (2001) *Belongil Estuary Study and Management Plan, November 2001*.

Pugh, D. (2021) *What's the problem with Tallow Creek? An opinion piece.*

Reichelt-Brushett, A. and Bucher, D. (2021) Investigation of contaminants in edible fish from Tallow Creek, Byron Bay, NSW, Australia. Unpublished report, Southern Cross University.

Rhelm (2021) *Coastal Management Program Scoping Study (Stage 1) for the Southern Byron Shire Coastline and Belongil Estuary*.

Smith, P., Oakes, J. M. and Eyre, B. D. (2016) *Recovery of nitrogen stable isotope signatures in the food web of an intermittently open estuary following removal of wastewater loads*. Estuarine, Coastal and Shelf Science 182 (2016) 170-178.

State of NSW and DPE (2023) *Marine Debris Threat and Risk Assessment Summary Report.* Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Coasts/Research/marine-debris-threat-and-risk-assessment-summary-report-230110.pdf - accessed June 2023.

Waddy, S. (2019) *Biogeochemical Characteristics of a Northern NSW ICOLL*. Unpublished Third Year Undergraduate Report. School of Environment, Science and Engineering, Southern Cross University, Lismore.

Wetland Care Australia (2005) *Restoration Strategy Belongil-Cumbebin Wetland Complex – final report.*

Wood and Associates (2019) *Interim Drainage Management Plan. Prepared for the Belongil Catchment Drainage Board.*

Williams, M., Woods, M., Kumar, A., Ying, G.G., Shareef, A., Karkkainen, M. and Kookana, R. (2007) *Endocrine Disrupting Chemicals in the Australian Riverine Environment: a pilot study on estrogenic compounds.* CSIRO & Land and Water Australia.

GLOSSARY AND ABBREVIATIONS

ASS	Acid Sulfate Soils - the common name given to soils containing iron sulfides. When the iron sulfides are exposed to air and produce sulfuric acid, they are known as actual ASS. The soil itself can neutralise some of the sulfuric acid. The remaining acid moves through the soil, acidifying soil water, groundwater and, eventually, surface waters.
BBSTP	Byron Bay Sewage Treatment Plant
BOD	Biological oxygen demand - represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature.
BSC	Byron Shire Council
Catchment	A catchment is an area with a natural boundary (for example ridges, hills or mountains) where all surface water drains to a common waterway/water body.
Chlorophyll *a*	Chlorophyll *a* is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll *a* concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. Chlorophyll *a* is probably a better 'instantaneous' indicator of trophic status than nutrient concentrations because nutrient concentrations are affected by a number of processes and may not reflect trophic status directly. Persistent high chlorophyll *a* levels indicate poor water quality and average low levels generally suggest good conditions. It should be noted that natural peaks in chlorophyll *a* concentrations do occur and include: higher levels after rainfall, particularly if the rain has flushed nutrients into the water; and higher levels are also common during the summer months when water temperatures and light levels are also higher. Chlorophyll *a* statistics therefore need to be evaluated with reference to nutrient trends, rainfall and other seasonal factors.
CMP	Coastal Management Program
CRM database	Customer Request Management database – BSC record of customer enquiries and reports.
DPE BCD	Department of Planning and Environment (DPE) – Biodiversity Conservation Division (BCD)
DPI	Department of Primary Industries
DO	Dissolved oxygen (DO) levels refer to the amount of oxygen contained in water and define the living conditions for oxygen-requiring (aerobic) aquatic organisms. Any deviations from 100% saturation are largely due to biological or chemical processes in the water body which consume or produce oxygen. Oxygen consuming processes include aerobic respiration by phytoplankton, the oxidation of pyrite found in acid sulfate soils, and the biological breakdown of organic matter. Oxygen producing processes include photosynthesis by phytoplankton, seagrass and benthic algae. Most aquatic organisms require oxygen in specific concentration ranges and DO concentration changes above or below these ranges can have adverse physiological effects. In extreme prolonged low DO events (e.g.DO <3mg/L or <~30% saturation), major kills of aquatic life can occur. Other effects of low DO include increased toxicity of many toxicants (e.g. lead, zinc, ammonia etc.), immune suppression in fish, and changes to nutrient cycling between sediment and water which can lead to algal blooms.

E. coli	*Escherichia coli* - bacteria that normally live in the intestines of healthy people and animals.
Enterococci	*Enterococcus* is a large genus of lactic acid bacteria of the phylum Bacillota. Under the new NHMRC (National Health and Medical Research Council) 2008 guidelines, enterococci are the single, preferred faecal indicator, as advocated by the World Health Organisation (WHO 2003) for recreational water quality. Enterococci are a group of bacteria commonly found in the stomach of warm-blooded animals and humans. Although enterococci are not directly harmful to humans, high levels can indicate the possible presence of harmful microorganisms such as bacteria, viruses and protozoa. High levels of these bacteria may indicate a potential health risk for swimmers.
EPA	Environmental Protection Agency
EPL	Environmental Protection Licence
ICOLL	Intermittently Closed and Open Lake and Lagoon
MEMS TARA	Marine Estate Management Strategy Threat and Risk Assessment
MHWM	Mean High Water Mark
NH_3	Ammonia - ammonia is the form of nitrogen taken up most readily by phytoplankton because nitrate must first be reduced to ammonia before it is assimilated into amino acids in organisms. When sediments are anoxic, nitrification is inhibited and ammonia levels in the water column may be elevated. The most common sources of ammonia entering surface waters and groundwaters are domestic sewage, industrial effluents and agricultural runoff (due to ammonia being a common constituent of fertilisers). When ammonia is present in water at high enough levels it can cause direct toxic effects on aquatic life.
NO_X	Oxidised nitrogen - is the sum of nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N). A bioavailable form of nitrogen most readily taken up by organism that live in water.
NPWS	National Parks and Wildlife Service
pH	pH is a measure of how acid or alkaline a water body is on a log scale from 0 (extremely acidic) through 7 (neutral) to 14 (extremely alkaline). The pH of marine waters is close to 8.2, whereas most natural freshwaters have pH values in the range from 6.5 to 8.0. Sources of acid water in coastal systems include humic-rich groundwater (pH~ 4.5) and acid sulfate soil runoff (pH ~ 2 – 4). Most aquatic organisms and some bacterial processes require that pH be in a specified range. If pH changes above or below the preferred range of an organism (including microbes), physiological processes may be adversely affected. This is especially true for most organisms if the ambient pH drops to below ~7 or rises to above 9. Physical damage to the gills, skin and eyes can also occur when pH is sub-optimal for fish and skin damage increases susceptibility to fungal infections such as red spot disease.
PO_4	Ortho - phosphate – dissolved form of phosphorus that is readily taken up by organisms that live in water.
PASS	Potential Acid Sulfate Soil
PCFML	Positive Change for Marine Life

Salinity	Salinity is a measure of dissolved salts in water. The salinity distribution within coastal waterways reflects the relative proportion of fresh water supplied by rivers, and marine water supplied by exchange with the ocean. Salinity of estuaries usually decreases away from the ocean, although low flow periods combined with evaporation sometimes causes the salinity to rise in the upper sections of an estuary. Salinity is a dynamic indicator of the nature of the exchange system. Due to the density variation associated with salinity, it affects mixing and circulation patterns in an estuary and is important in some chemical processes (e.g. dissolved oxygen levels and nutrient cycling). Salinity is also an important ecological parameter in its own right with most aquatic organisms functioning optimally within a narrow range of salinity.
Temperature	Water temperature regulates ecosystem functioning both directly through physiological effects on organisms, and indirectly, as a consequence of habitat loss. Many ecosystem processes are affected by temperature including photosynthesis, aerobic respiration, nutrient cycling, and the growth, reproduction, metabolism and the mobility of organisms. Water is more likely to become anoxic or hypoxic under warmer conditions because of increased bacterial respiration and a decreased ability of water to hold dissolved oxygen. The major seasonal cause of water temperature change is due to the change in the amount of sunlight reaching the earth in addition to climate factors, currents and local hydrodynamics. Temperature in surface waters varies during the day and tends to be highest in the late afternoon as the sun sets, and coolest in the early hours of the morning.
TN	Total nitrogen - represents the sum of all forms of nitrogen present in water. is the sum of nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammonia-nitrogen (NH_3-N) and organically bonded nitrogen. Nitrogen is commonly regarded as the limiting nutrient for primary production in estuarine ecosystems. Over enrichment with nitrogen in estuarine ecosystems can lead to excessive algae and plant growth, eutrophication and subsequent deterioration of water quality conditions affecting the balance of key ecosystem requirements such as DO, pH and water clarity.
TP	Total phosphorus represents the sum of dissolved inorganic, dissolved organic and particulate nutrients. While phosphorus is generally not regarded as limiting primary production in estuaries, it does limit production in freshwater and can control the occurrence of nitrogen-fixing organisms such as cyanobacteria which are commonly associated with toxic blooms.
TSS	Total suspended solids - the dry-weight of suspended particles, that are not dissolved, in a sample of water that can be trapped by a filter that is analysed using a filtration apparatus known as sintered glass crucible. TSS is a measure of the combined concentration of particulate matter (comprising inorganic sediments, organic matter and phytoplankton) in the water column. The relative contribution of these constituents varies widely according to position along the estuary, state of tide and state of flow. TSS is a major driver of water clarity, impacting on the light climate of the water column and sediments.
Turbidity	Turbidity is the measure of the cloudiness of water due to suspended matter such as sediment particles and algae. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Tannin-rich waters contain colour which can absorb more light and turbidity can appear higher than it is.

APPENDIX 1 BACKGROUND INFORMATION REGISTER

Table 1: Byron ICOLL WQ and Source Tracking and Control Program existing data and information register

ID	Information	Notes
	Key data sources for the Belongil Creek catchment	
1.	Alluvium (2019) Belongil Creek Catchment Issues Study.	RCAT Modelling of TSS, TN, TP, E.coli export from sub-catchments. Detailed assessment and mapping of each sub-catchment. <u>Key actions of the program include:</u> - development of a catchment management plan or CMP (CMP now in progress). - stakeholder and community engagement plan and working group (CMP SS prepared Strategy); - identification of catchment values (CMP SS). - assessment of existing and future condition (how do you assess future condition - modelling?). - development of strategic intent for waterways. - development of actions to achieve objectives. - preparation of a business case. - recommended monitoring and evaluation. <u>Knowledge gaps to be addressed by CMP:</u> 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.
2.	Alluvium (2019) Belongil Creek Entrance Opening Strategy and EMP	Outdated. Replaced by REV1, see below. Review Rev1 only

ID	Information	Notes
3.	Alluvium (2021) Belongil Creek Entrance Opening Strategy and EMP REV1 (amended Dec 2021 - Adopted 27 2 20 - Reso 21-547)	Current EOS adopted by Council 27 Feb 2020. Entrance opening triggers/ monitoring requirements and associated EMP. Adopted EOS: Watch level 1.0mAHD, immediate breach level 1.1mAHD. Previously it was mechanically opened at 1.2mAHD. Included study to understand processes – Section 2 System Understanding. Pollution sources identified: - poor quality stormwater from town and industrial estate via Union and Town Drains (High BOD, high inorganic nitrogen), - Agricultural runoff main source of nutrients - ASS contributes acid runoff - STP wastewater discharges Following entrance opening poor water quality advected from drains and swamps upstream (low pH, low DO, high nutrients and dissolved Fe and Al). Entrance opening carried out >100 years by BSC Lists catchment management objectives from stakeholders to be considered by CMP (separated from those relevant for the EOS).
4.	AWC (2018) Belongil Water Cycle Study.	Summary of literature and knowledge gaps and outline for preparation of an integrated water cycle strategy for Belongil Ck.
5.	AWC (2019) Technical Memorandum: Summary of technical works undertaken by AWC within the Belongil Estuary catchment and technical position on catchment hydrology and water quality.	Provides an overview of a series of reports undertaken by AWC from 1999-2016 regarding the impact of the BBIWMR on catchment hydrology and water quality. Concludes there has been an overall hydrological impact (increase in water table level within upper union drain at some locations). Drainage system only works effectively when Belongil Ck mouth is open. Less rainfall required to trigger opening events due to increased water table. WQ monitoring since 2007. Concludes no discernible water quality impact on drainage/estuary system from release of effluent from BBIWMR. Positive water quality impacts include reduced ASS impacts due to higher water table. WQ poor during entrance opening events (low DO and pH) but short lived.

ID	Information	Notes
6.	AWC (2020a) Updated Assessment of the Byron Bay STP Treated Effluent Flows on the Belongil Catchment Water Quality and Hydrological Data Analysis from 2016 to 2020.	The report concludes that the dynamic nature of the catchment's hydrology and that rainfall (or lack thereof), the open/closed condition of the ICOLL's mouth and the prevailing catchment-wide hydrological conditions are the main controllers the water levels in the drainage system and shallow aquifer. WQ discharged from BBSTP generally higher quality than catchment waters with mean value for DO, pH and Turbidity within ANZECC values. Butler St drain is an area of obvious concern in terms of nutrient and bacteria concentrations. Moran's Drain appears to be an area susceptible to ASS oxidation and a source of TSS and NH4 to downstream environments
7.	AWC (2021) Byron Bay STP Licence and Consent Condition Review	Looks at all obligations related to the BBIWMR site, and identifies gaps/risks to be addressed. Audit of the status of the various consent conditions associated with the operation of the Byron Bay Integrated Water Management Reserve. Key issues and risks identified are: Key issues and risks were also identified with the main requirements that require attention including the following: • Update of the Effluent Management Strategy • Communication and internal understanding of compliance with respect to capacity, loads and monitoring of threatened species, Acid Sulphate Soils, Groundwater and Drainage • The Operational Environmental Management Plan requires an update and links to consent conditions • Steps should be taken to develop and Environmental Management System that can be updated and audited as required Discusses wastewater management schemes
8.	AWC (2022) -BBIWMR Operational Environmental Management Plan - Draft 24Oct22	Arises from a key gap from the licence and conditions review (above). It is a working document and is currently being implemented on the ground with the support from AWC.
9.	AWC (various dates from 2016) Belongil Estuary Entrance Monitoring Reports and Opening Event Monitoring Reports	Stage reports were undertaken every 6 months up until Stage 11 when Stage reports became annual. Stage 12 report due by end of year.

ID	Information	Notes
10.	AWC and BMT (2017) Capacity assessment of the Belongil Creek Drainage System: Development of a preferred STP effluent flow path.	[Note: report contains relevant information on stable isotope assessment of effluent impacts downstream of recycled water reuse area]. Assessment of effluent release pathways for current 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 (now operational). The report aims to collate historical information regarding the effluent release from the BBIWMR, artificial Belongil Estuary opening events, Union Drain water levels, local hydrogeology and stable isotope analysis, with the information used to investigate the fate of effluent discharged with the BBIWMR Key objectives are: • Define and determine the sustainable capacity for current and future BB STP release flows in the Belongil Creek • Determine the impact/s of the current flows (at 3ML/day) compared to the aspirational flows (of 1ML/day) on the drainage system and farmland upstream of Ewingsdale Road • Assess whether throughput from the BB STP Constructed Wetlands and 24 ha Melaleuca Wetland (BBIWMR) is also charging those drains. Identify alternative flow path/s for BB STP treated effluent discharge
11.	Belongil Acid Sulfate Soils Working Group (2003) Belongil Swamp Acid Sulphate Soils Remediation Concept Plan.	Specific data relating to acid sulfate soils and acid runoff in the Belongil catchment. Includes an Implementation Plan with priorities, actions required, estimated costings and contingencies, outlines the regulatory context and approvals required. The main ASS remediation strategy recommended was the use of Water Control Structures (WCSs) set at strategic points in the Belongil drainage network to control water levels and manage exposure of ASS. WCSs range from simple drop-boards through to remotely operated, telemetered, hinged weir gates or sluice gates. Other high priority options included re-use/regeneration projects using STP effluent, acquire land to develop new Council regeneration sites, and refine planning and development control.
12.	Belongil Creek logger data	Refer excel files. Two files provided as there was a change over of logger in 2020.
13.	BSC (2005) Draft Belongil Creek Entrance Opening Strategy.	Outdated. Replaced by Alluvium (2021) Belongil Creek Entrance Opening Strategy and EMP REV1
14.	BSC (2017) BSC Belongil Catchment Surface Water Quality Monitoring Program_Rev1	Document outlining the BSC Belongil Catchment Surface Water Quality Monitoring Program including objectives, methods and sites. The purpose of the monitoring program is to gather data for catchment planning and decision making purposes. This program aims to assess any significant changes throughout the catchment and provide baseline data to determine the impact of management actions that are under consideration in the catchment. Sample locations and results shown on online portal - see line 64 "Byron Bay Surface Water Quality Monitoring Program"
15.	BSC (2023) Byron effluent reuse infographic	A simple graphic the summarises Byron's effluent reuse system

ID	Information	Notes
16.	DLWC (1999) Acid Sulfate soils management priority areas in the Byron-Brunswick Floodplain.	Belongil Swamp was identified as one of 28 ASS 'hot spots' in NSW. Priority areas are areas where land management decisions in relation to ASS have contributed to. and can lead to further, severe soil acidification, poor water quality, reduction in agricultural productivity and capability, loss of estuarine habitat, and/or degraded vegetation and wildlife. In most priority areas, wetlands have undergone extensive engineered drainage and flood mitigation schemes. Priority areas have strategic importance with respect to the management of estuarine and floodplain areas and ambient water quality, and require urgent changes to land management to improve environmental quality.
17.	Grennan (2001) Environmental Audit of the Belongil Swamp Acid Sulfate Soil Hotspot Integrated Project.	Identified potential acid sulfate soils (PASS) at 8 sites. The depths of the PASS layers range from 70 -150 cm, which constitutes concern regarding any land disturbances that may expose the layers to the atmosphere. As a result, priority areas for future management have been identified. Water quality analyses and ground truthing of the drainage network were carried out a to assist in the identification of possible acid sulfate soil deposits.
18.	Integrated Ecosystem Research & Management (2005) Belongil Creek Entrance Opening Strategy - Review of Environmental Factors. Report prepared for Byron Shire Council. 12 October 2005.	The report identified the main factors influencing water quality in Belongil as: - ASS drainage: Acidification of drain water appears to be periodically severe (pH < 3.0) along the middle to upper reaches of the Union drain. - Tidal exchange: Increased tidal influence in Belongil creek results in higher salinity throughout the system, greater flushing of nutrients and other constituents and greater water clarity. - Organic matter degradation: Seasonally low dissolved oxygen concentrations in the Belongil creek and drainage network may be influenced by a combination of high temperatures and organic matter loading during the summer wet season. -Phytoplankton: Phytoplankton biomass in the Belongil is periodically high in the drainage network (> 100µg.L-1 chlorophyll-a) most likely reflecting relatively high nutrient loadings, internal nutrient recycling and poor hydraulic flushing during low flow conditions. - Treated sewage effluent: Effluent from the West Byron STW enters the drainage network upstream of Ewingsdale Rd via constructed wetland cells. - Urban runoff: Water quality in the Town drain is commonly extremely poor in respect to BOD, dissolved oxygen and dissolved inorganic nitrogen. - Agricultural runoff: Estimated as the primary source of nutrient loading to the Belongil creek (WBM, 2001), and likely to contribute to both ASS runoff and organic matter loading.

ID	Information	Notes
19.	McGregor Coxall (2016) Byron Bay Town Centre Masterplan. Prepared for Byron Shire Council.	The purpose of the Byron Bay Town Centre Masterplan (BBTCM) is to present a vision and strategy to guide the future form of Byron's Town Centre, and to set out realistic actions and projects to achieve that vision. Water quality improvement actions include: -Primary stormwater corridor along the Byron Street alignment (Butler St. Drain, supporting drainage to Belongil Creek through retention, detention and stream systems. - Establish a stormwater detention zone through wetland treatments within the Sandhills Scrubland Walk. -Utilise entire town centre as part of stormwater treatment and water quality improvement. Identify suitable sites to capture and detain runoff to enable infiltration into the sandy soils of the town centre. This can occur through a variety of ways including raingardens, infiltration beds, stormwater basins, green roofs, porous pavement etc. Transition existing concrete drainage to rain gardens and soft stormwater treatment. -Creek rehabilitation through rubbish and weed removal. -investigate opportunities to develop a series of wetlands for stormwater management and water quality improvement.
20.	Parker, P. and Pont, D. (2001) Belongil Estuary Study and Management Plan, November 2001.	The plan was developed in accordance with the NSW Government's Estuary Management Manual (NSW Government, 1992) and was formally adopted by Council in November 2001. The plan recommended the following high priority actions to manage sources of water quality pollution: - Stormwater management requires the reduction of loads of contaminants at their source. Process such as education, management and enforcement of regulations are essential. -Complete the Butler Street wetland system in accordance with best practice and community expectations. - Evaluate other sites for potential pollutant controls and stormwater treatment systems including wetland systems, e.g., the industrial drain. -Adoption and funding of recommendations in the Stormwater Management Plan; -Encourage and implement source controls in new developments; -Develop an integrated surface water quality program and install a permanent data logger; -Continue to maintain the Butler Street GPT. -Enforce litter and pet droppings regulations. -Conduct further investigation into upper catchment remediation works (e.g., trial drop-boards) in conjunction with an estuary opening strategy.
21.	PKK (2000) Byron Shire Council - Urban Stormwater Management Plans.	Over 22 years old. Identifies issues for Belongil and Tallow/Ti-tree lake combined.

ID	Information	Notes
22.	Slavich and Wood (1998) Acid Sulfate Soil (ASS) Field Survey Upper Belongil Catchment Byron Bay.	This document reports the results of a one day soil sampling exercise which aimed to identify the presence of acid sulfate soils in the upper Belongil catchment, particularly areas close to the Union Drain and near the west Byron sewage treatment plant. Actual acid sulfate soils and potentially acid sulfate soils were confirmed in the upper Belongil Catchment. Remodelling the Union Drain to make it shallower in over deepened sections was recommended for further investigation.
23.	SMEC (2010) Byron Bay Drainage Strategy.	This report presents the findings of flood investigations for improvement of Byron Bay stormwater drainage system following the Belongil Creek Flood Study prepared by SMEC and adopted by Byron Shire Council in November 2009. Four areas dealt with: Cowper and Marvel street sub-catchments; Town Centre; Shirley Street sub catchment; Western Industrial Area. The drainage strategy includes the use of pumps, levees, upgrades to the underground drainage, and a wetland/basin for improvements to water quality and flooding. Very high level study and now outdated. BSC is currently commencing with a $500K project for the planning and design of a new Byron Bay drainage strategy in 2023.
24.	Water Sensitive Cities Institute (2021) Implementing Urban Water Metabolism Approach to Guide Byron Shire Recycled Water Planning	This report uses a water balance approach to assess current/future scenarios for effluent reuse in Byron and Mullum systems. Heavily focused on water quantity but helps in understanding effluent reuse in the context of other water flows i.e. stormwater.
25.	Wetland Care Australia (2005) Wetland Care Australia - Belongil Wetland Restoration Strategy.	Water quality management actions recommended included: -Education of the general public to reduce gross pollutant concentrations. -Reduction of peak discharges and stormwater volumes wherever possible, beginning in the upper catchments - this would include infiltration to groundwater, installation of rainwater tanks on individual lots, and other innovative concepts. -Installation of effective commercial litter traps appropriate to low-gradient environments. -Wetlands to treat dissolved and colloidal stormwater pollutants; -Maintenance of, or increasing hydraulic conveyance capacity of, drain network by considering widening of drains, maintenance of through-flow capacity through wetlands, modelling of culvert capacity under Ewingsdale Road and the railway track, and considering enlargement of culverts if necessary. -Considering drain widening and shallowing to allow mowing of a drier drain floor to replace the need for maintenance excavation of sediments. -Development of a long-term maintenance program.
26.	Willings and Partners (1996) Draft Belongil Creek Data Compilation Study.	The report documents and reviews the relevant data available for Belongil Creek at Byron Bay and was prepared for the Belongil Creek Estuarine Management Committee under the NSW Government's Estuary Management Program. The report will form a basis for the preparation of an Estuary Processes Study, leading to the final preparation, adoption and implementation of an Estuary Management Plan for Belongil Creek.

ID	Information	Notes
27.	Willings and Partners (1997) Belongil Creek Estuary Processes Study.	The Belongil Creek Estuary Processes Study was carried out in accordance with the NSW Government's Estuary Management Policy and under the direction and supervision of the Belongil Estuarine Management Committee. It follows the Belongil Creek Data Compilation Study prepared for the Committee in June 1996. The Estuary Processes Study represents the next stage of the management process in which significant estuarine processes are identified and described.
28.	Wood and Associates (2019) Interim Drainage Management Plan. Prepared for the Belongil Catchment Drainage Board.	Plan prepared in line with the requirements of the Water Management Act S202 for the Functions of Private Drainage Boards: “To prepare, review and implement a management program for its drainage district To maintain in a state of efficiency the drainage works under its charge, and renew such drainage works if necessary……” Discusses drainage management issues and proposes management action to address key issues.
29.	Wood and Associates and SCU (2018) Scoping Management Issues to be included in the preparation of a Drainage Management Plan: a report for the Belongil Drainage Union Inc.	Prepared for the Draining Board as preliminary work to inform the Interim Drainage Management Plan. Discusses ASS issues, management and mitigation measures.

ID	Information	Notes
	Key data sources for the Tallow Creek catchment	
30.	Alluvium (2019) Tallow Creek fish kill ICAM investigation, Final Draft Report for Byron Shire Council. November 2019.	An independent, third-party investigation into the causes of a fish kill that occurred at Tallow Creek on 15 June 2019 that was associated with a mechanical opening of the sand berm entrance of Tallow Creek to the ocean. This investigation adopted the Incident Cause Analysis Method (ICAM) for investigating causes and making recommendations. Causes identified: • The most likely physical-chemical primary cause of the fish kill incident was the influx of water with low dissolved oxygen from shallow areas to deeper areas as the water level in the lagoon area of Tallow Creek dropped. • Dry antecedent conditions prior to the incident exacerbated the potential for a fish kill incident • Forecast rainfall events did not occur following entrance management actions (berm scrape and opening) • Poor land use development decisions in the past have created complex social and environmental challenges at Tallow Creek, with competing interests and risks to a range of different stakeholders/values. • There is ongoing pressure from residents in residential and commercial areas of Suffolk Park and surrounds. This puts pressure on BSC to perform management actions under the agreed EMPOS. • The approved EMPOS implies that action (entrance opening) must be undertaken once the 2.2m AHD trigger level is reached. The report provides several recommendations including revision of the EOS, licences and permits, form a steering committee and prepare an MOU with BSC, NPWS, DPI and Arakwal, seek legal advice about entrance opening responsibilities and flood risk.
31.	AWC (2018) Baywood Chase Lake Management Plan.	Reviews issues and provides various options for management, multi-criteria assessment. Recommends recycled water is added to lake on ongoing basis to improve flows and water quality. Other priority options are remediate sediment basin and bird management. A number of other options were also proposed by the plan. NOTE: NPWS/ Arakwal strongly oppose recycled water option.
32.	AWC (2018) Draft Baywood Chase Lake Recycled Water Feasibility Report	Note: the use of recycled water from West Byron STP in the Tallow Creek catchment is not palatable to stakeholders and should not be considered as a management option.
33.	AWC (2019) Technical Memo – Tallow Creek Opening Fish Kill Event June 2019	The Tallow Creek mouth was artificially opened on Friday 14th June resulting in a significant fish kill event. Reports on environmental monitoring undertaken for the event in accordance with the approved Environmental Management Plan and Opening Strategy for Tallow Creek (BMT WBM, 2015)
34.	AWC (2020) Technical Memo Baywood Chase Lake – Water Quality Assessment	Provides summary of water quality in the lake. Water quality within Baywood Chase Lake is known to be a significant issue within the Tallow Creek catchment as evidenced by frequent algal blooms and surface water quality sampling undertaken by Byron Shire Council at the lake outlet.(sampling during dry periods resulted in very high BGA and E.Coli levels. Bottom waters anoxic). The lake is poorly mixed, high urban stormwater inputs. Recommends addition of recycled water has the potential to improve the health of the lake.

ID	Information	Notes
35.	AWC (2021) Tallow Creek Entrance Management Reporting – Review of Monitoring Program and Data Collected from Stage 1 (April 2016) to Stage 9 (October 2020).	The results of the water quality monitoring of Tallow Creek shows that vertical stratification occurs with anoxic water settling to the base of the channel. Poor water quality is prevalent throughout the catchment likely the combined result of high water levels within the creek and an urbanised catchment. The water level data show that there have been several periods where water level exceeded 1.8m for several months. an unsanctioned opening event initiated by community members) and the second in June 2019 (caused by an artificial opening by BSC). There is stakeholder conflict in regards to the long term management of Tallow Creek , with the key issues being the retention of the natural ecological and hydrological regime to limit environmental impacts versus a more active management regime to ensure flood protection of private and public property and infrastructure.
36.	AWC (various dates) Tallow Estuary Entrance Monitoring Reports and Opening Event Monitoring Reports.	Stage reports were undertaken every 6 months up until Stage 11 when Stage reports became annual. Stage 12 report due by end of year. Reports discuss water quality conditions leading up to and during entrance opening events.
37.	BMT WBM (2015) Environmental Management Plan and Opening Strategy for Tallow Creek, October 2015.	Superseded by more recent positions/licence/permit conditions. Mechanical opening is no longer permitted (only scraping under certain conditions). Relevant Table 5-3 parameter is "Physical (on mechanical opening or skimming)" though a permanent logger is currently in place also. No health parameters currently monitored though some available via Council's surface water portal. Water quality monitoring is undertaken monthly at 5 sites and over several days in association with a berm scraping event. This monitoring is undertaken in association with the NPWS licence to undertake entrance works and is separate to the Byron Bay Surface Water Quality Monitoring Program which is associated with operation of the West Byron STP and the recycled water scheme
38.	BMT WBM (2015) Review of Environmental Factors: Tallow Creek Entrance Opening – Vol. 1 &2, October 2015.	Review of Environmental Factors (REF) for the opening of the Tallow Creek entrance to manage flood levels and/or water quality within the Tallow Creek catchment, in accordance with the Management Plan provided within Council's Tallow Creek Floodplain Risk Management Study and Plan. Volume 1 contains the REF text, while Volume 2 contains supporting materials to the REF, such as predating correspondence and reports.
39.	BSC (2016-2022) Tallow Creek logger data Aug 2016 to Nov 2022	Refer excel file. A multi-parameter water quality logger has been deployed in Tallow Creek since August 2016. From August 2016 to March 2020 (Stages 1-8), the logger was deployed at a fixed level in the water column with water quality parameters logged at hourly intervals. Following a recommendation initially proposed in the Stage 7 Report (AWC, 2019), a new automated sampling unit was installed on the Tallow Creek pedestrian bridge (Site 5 in the lower creek, refer) in April 2020. The unit was able to sample surface and bottom waters using two pumps which sampled bottom and surface waters every 30 minutes. Subsequent vandalism to this system required several rounds of replacement/ amendment to the system including periods where only one logger was available. Since the Feb 2022 floods, there has only been a surface logger in place.
40.	BSC (2016-2022) Tallow EOS 5 site WQ sampling_Aug 2016 to Oct 2022	Water quality data - refer excel file

ID	Information	Notes
41.	BSC (2022) Email RE_ PFAS testing for former treatment ponds at Tallow Creek	GHD conducted an investigation to assess the potential presence of per- and poly-fluoroalkyl substances (PFAS) at the former South Byron Sewerage Treatment Plant (STP). Although there were minor detects of PFAS in the water in the Tertiary ponds and in one soil sample, a comparison with the adopted assessment criteria indicates the concentrations in these areas are below relevant guidelines for the proposed land use and do not pose a significant risk to human or ecological health.
42.	Cavvanba (2012) Detailed Site Investigation South Byron Sewage Treatment Plant	Results for water and sediment quality in the un-remediated tertiary treatment ponds at the former South Byron STP. Details investigations undertaken at STP site (land and water-based). Water quality in ponds: guideline exceedances in heavy metals (Cd, Cu, Pb, Ni, Zn, and Hg), Faecal coliforms, viruses and helminths. Sediment Quality in ponds: guideline exceedances in heavy metals (Cu and Hg), TPHs, Faecal coliforms. Land-based remediation now complete in 2022. Remediation of ponds under investigation.
43.	Cavvanba (2023). Pond environmental assessment - Former South Byron Sewage Treatment Plant. Prepared for Byron Shire Council	Pond sediments contain elevated levels of some heavy metals but are reported to be locked-up, as long as sediments are left undisturbed and represent a low risk of environmental harm to Tallow Creek in this state. Some elevated Ammonia and Cu and Zn in one groundwater sample, adjacent to night soil disposal area. The concentrations of these analytes are not considered to be significant or trigger any requirements for further groundwater monitoring associated with the use of the ponds. Elevated E.Coli detected in surface water of the ponds, and recreational use of ponds not recommended. Remediation of pond sediments is not recommended as disturbance of sediments is likely to spread contamination. Therefore it is recommended that the ponds are left undisturbed. Further water quality monitoring of groundwater and Tallow Creek upstream and downstream of the ponds is recommended to assess nutrient and heavy metals to confirm that groundwater is not having an influence on this water source.
44.	Downe N (2005) A Physicochemical Assessment of Tallows Creek and Lagoon, Northern NSW with recommendations for rehabilitation - SCU student report.	A 3rd year student research project to assess sediment and water quality in Tallow Creek and Lagoon. Short-term investigation from March - May 2005. The major source of contaminants is from treated effluent discharged from the South Byron Sewage Treatment Plant and runoff from associated urban areas. Heavy rainfall causing flushing of drains delivered deoxygenated water, sediment and nutrient loads to the creek and lagoon. Excessive nutrient levels, in particular nitrogen and phosphorous in Tallow Creek and Lagoon are the dominating factors causing management issues. The elevated levels of these nutrients in waterways with long residence times can typically lead to eutrophication and outbreaks of aquatic weeds. Management's primary concern is to reduce the input of these nutrients to the system by a reduction of runoff born nutrients and the proposed decommissioning of the South Byron sewage treatment plant .
45.	McDonald (2013) A baseline study of the aquatic ecological health of the Tallow Creek ICOLL, northern New South Wales. Unpublished Third Year Undergraduate Report. School of Environmental Science and Management, Southern Cross University, Lismore.	Water samples were collected from various locations in the catchment and one form the lagoon. Water quality parameters were varied and often resulted in non compliance with ANZECC (2000) guideline values. The Stream Quality Rating (SQR) across the study area was generally poor with the lagoon scoring fair. Suggests management strategies to improve the quality of catchment inputs and slowing flow rates with Water Sensitive Urban Design principles (WSUD), and enhance vegetated buffer zones through bush regeneration projects.

ID	Information	Notes
46.	NPWS (2007) Arakwal National Park Plan of Management. NSW Department of Environment and Conservation. February 2007.	The traditional owners consider the degradation of Tallow Creek as a major management issue for Country. They are concerned at the changes brought about by sand mining, the sewage treatment plant and urban development in the catchment and they wish the creek to be returned to a useable state. In particular, they wish for current and future generations to be able to swim and fish in the creek in order to maintain associated cultural values for all people. Issues identified relating to Tallow Creek water quality were: South Byron STP (now decommissioned), stormwater and erosion control, maintaining and monitoring water quality in swamps, rehabilitation of wetlands and Tallow Creek; control of pest animals; exclusion of dogs and cats, control of illegal and inappropriate use (e.g. dog walking, camping and dumping). Actions include: Investigate the preparation of a restoration plan for Tallow Creek with other relevant agencies such as Byron Shire Council and the Marine Parks Authority to address: tidal flushing, constructed wetland opportunities, urban stormwater management and community awareness to improve water quality and enhance natural and cultural values associated with the creek.
47.	Previous feedback from Suffolk Park residents to BSC staff	"Residents of Suffolk Park are also concerned about the quality and residence time of stormwater that sits in the dune swale adjacent east of Alcorn Street". No document associated with this note.
48.	Pugh D (2021) Opinion Piece - What's the problem with Tallow Creek?	Dailan Pugh is a member of Council's Coast and ICOLL Advisory Committee. Discussion of Tallow Creek issues including: • Conflict between flooding of residential land and environmental values of the ICOLL. • Residents request artificial opening of Tallow Ck to alleviate flooding, which has resulted in fish kills many times in the past. • "The immediate cause of fish kills when the estuary is opened without sufficient rainfall inflows, is a combination of the decanting of oxygenated surface waters in the estuary, combined with the drainage of toxic waters from the upstream reservoirs into the estuary. This emphasises the urgent need to implement management plans to improve the water quality of the reservoirs and better manage runoff from urban areas." • Key sources poor water quality: Baywood Chase Lake and section of Tallow creek restructured to allow increased development of SP (in vicinity of WQ sites 3&4) – low DO and ASS. • 9 natural openings between 2017-2020 with no fish kills and 2 artificial openings both resulting in fish kills. • Water quality data, processes and causes of fish kills. • Call for holistic Tallow Creek Catchment Management Plan.
49.	Reichelt-Brushett, A. and Bucher, D. (2021) Investigation of contaminants in edible fish from Tallow Creek, Byron Bay, NSW, Australia. Unpublished report, Southern Cross University.	Collaboration between Marine Parks/Arakwal/SCU to understand pesticide levels within fish in Tallow Creek. A variety of fish were sourced (form the creek post the June 2019 fish kill) for analysis of pesticides to gain knowledge about the health of fish within the creek for Arakwal consumption (cultural fishing practices). Several detections of pesticide residue in fish collected from Tallow Creek, however levels were below the guidelines for human health and therefore deemed safe for consumption.

ID	Information	Notes
50.	Smith, P., Oakes, J. M., and Eyre, B. D. (2016) Recovery of nitrogen stable isotope signatures in the food web of an intermittently open estuary following removal of wastewater loads. Estuarine, Coastal and Shelf Science 182 (2016) 170-178.	Nitrogen stable isotope values were used to assess the removal of wastewater nitrogen from the food web within Tallow Creek, following the cessation of wastewater inputs in 2005. Current (2013) d15N values of sediment organic carbon, plants, and animals within Tallow Creek were compared to values obtained before wastewater inputs ceased, and to values within a nearby near-pristine ICOLL (Jerusalem Creek). Most biota had significantly depleted d15N values compared to conspecifics collected before wastewater inputs ceased (mean reduction of 6.0‰; 38% of impacted enrichment), indicating substantial loss of wastewater N since inputs ceased. However, d15N values remained enriched compared to the near-pristine ICOLL for some components (mean enrichment of 3.3‰ or 38%), suggesting that some wastewater N remains. This was attributed to a slow recovery rate and therefore lower resilience of ICOLLs to anthropogenic N inputs.
51.	Summary phone call with Nikki Bourke 22 Nov 2022	[RE status of remediation project for former south Byron STP tertiary treatment ponds]. Land-based remediation done and signed off by EPA in 2022. Remediation of Treatment Ponds under investigation: South Byron STP former treatment pond investigation – report due Dec 2022 Cavvanba Consulting and AWC.
52.	Waddy, S. (2019) Aquatic and sedimentary chemistry within a subtropical ICOLL. Unpublished Third Year Undergraduate Report. School of Environment, Science and Engineering, Southern Cross University, Lismore.	Stratification was observed in several areas of the ICOLL, and many benthic areas had very low concentrations of dissolved oxygen. Additionally lack of flushing and stratified conditions may promote cycling of nutrients leading to eutrophication of the ICOLL. During opening events the oxygen-rich epilimnion may be lost first leaving the oxygen depleted bottom layers and the net deoxygenation of eh water column. Sediments were found to contain low concentrations of acid volatile sulfides, and comparatively larger concentrations of chromium reducible sulfur species. Potential exists for mixing /disturbance of sediments and resuspension of reactive sulfur species and water quality degradation.
53.	Waddy, S. (2019) Tallow Creek Biogeochemical Study - Summary of Key Findings. Southern Cross University.	Summary of above report
	Key data sources for the Ti Tree Lake catchment (also known as Taylor's Lake)	
54.	NPWS (2000) Draft Conservation and Management Plan for Ti Tree Lake Aboriginal Place	Superseded by 2015 plan
55.	NPWS (2015) Ti Tree (Taylors) Lake Aboriginal Place Preliminary Draft Plan of Management	The Ti Tree Lake Aboriginal Area (10.5 hectares) was reserved under the NPW Act in 2010 and is managed by the NPWS. The Plan identifies values, management goals and actions to protect values. Activities identified that could harm the Aboriginal Place include: swimming in the lake, access to the lake, pollutants entering the lake from sewerage, stormwater and rubbish from houses and runoff from the quarry are of particular concern. Superseded by the 2020 plan below.

ID	Information	Notes
56.	Baker and Pont (1998) A pilot study of water quality in Taylors Lake Broken Head	This document was commissioned by the Surfrider Foundation, and was initiated following community concerns over possible sewage contamination of Taylors Lake. A subsequent eight sample survey of water quality in late 1997 indicated potential public health problems and nutrient enrichment in Taylors Lake. A very high count (36,800 colonies per 100 mL) of faecal coliforms was found in a sample from the organic matter in the floor of the southern lake, while a count of 1,400 colonies per 100 mL was found in the water column at the northern end. Anecdotal evidence from local residents also suggested numerous breaks in the Broken Head-Suffolk Park sewage main, and one such incident was observed during the study. A layer of anomalous fine yellow-grey clay in the northern lake indicates sediment pollution.
57.	BSC 1992 Taylors Lake Water Quality Assessment	A short-term study associated with development proposal in the Taylors Lake catchment. Generally water quality was within acceptable levels. Turbidity levels were affected by the upstream quarry operations with the north lake turbidity levels being significantly higher than the south lake.
58.	Colman (1999) Taylors Lake_A Snapshot [water quality report]	Report on the water quality and impacts on Taylors Lake in December '99 for comparison with previous reports and to inform a planned Catchment Management Plan for BSC. The report identified sources of poor water quality: Batson Quarry (large quantities of clay), urban stormwater and sewer from Broken Head and Suffolk Park areas (broken sewer pipe under Taylors Rd. noted previously).
59.	NPWS (2020) Ti Tree Lake Aboriginal Area Plan of Management. State of NSW and Department of Planning, Industry and Environment. Adopted 3 April 2020.	Ti Tree Lake Aboriginal Area is a NPWS managed part of the Ti Tree Lakes catchment. It receives runoff from the southern end of Suffolk Park as well as the quarry. BSC manages the bushland to the NW of the aboriginal area, and Jali LALC owns and manages the lakes themselves.
	GIS layers (Shapefiles)	
60.	2017 land use functional units	Source: DPE 2020 The latest NSW LU available is 2017 V2. Used for broad assessments. Note that accuracy can be limited at small scale and classifications are based on visible land condition and vegetation type. (e.g. open grassland can be categorised as grazing land without having cattle on it).
61.	Sub catchments	Source: RCAT - SubCatchments.shp Only Belongil Catchment. Includes TSS/TN/TP loadings and E.Coli numbers from RCAT model
62.	Tallow Creek catchment	J1386_Study_Area_V03.shp Rhelm This is the whole Southern Byron Shire Coastline and Belongil Estuary CMP Study area (not Tallow Ck catchment)
63.	CMP Study Area	J1386_Study_Area_V03.shp Rhelm This is the whole Southern Byron Shire Coastline and Belongil Estuary CMP Study area (no Tallow Ck catchment)
64.	Water Quality Sampling Sites	ICOLL_WQ_sampling_sites

ID	Information	Notes
65.	EPA licenced discharge points and monitoring locations (EPA sampling sites)	BSC_EPA_sampling_sites
66.	Urban release/strategic growth	
67.	Study Area Boundary (shown in brief)	We have proposed study area based on DPE Estuary Drainage Catchments for the 3 ICOLLs
68.		
	Other relevant data sources to be considered in this project not specific to study area include, but are not limited to:	
69.	'Source to Sea' – a Business Case on Reducing the Amount of Litter Entering Our Waterways (BSC, 2023).	Discusses the scale of the litter problem in the Byron Shire, community litter complaints and concerns, litter monitoring programs implemented and ongoing, litter prevention project implemented and proposed future solutions to address litter issues. A one-year litter basket trial for the Byron Bay Town Centre is proposed involving the deployment and bi-monthly servicing of 24 litter baskets within stormwater inlet pits.
70.	BMT WBM (2017) New South Wales Marine Estate Threat and Risk Assessment Report. Final Report, August 2017. Prepared by BMT WBM for the NSW Marine Estate Management Authority.	Marine Estate Threat and Risk Assessment for NSW marine waters.

ID	Information	Notes
71.	BMT WBM (2021) Byron Shire Council WSUD Policy and Strategy	Council adopted the Byron Shire Council WSUD Policy and Strategy in March 2020. Council committed to the development of guidance materials and to then initiate an update of the Development Control Plan (DCP 2014). A report on the guidance materials and DCP updates is expected to go to Council 23 March 2023. High Level Policy and Strategy Actions to guide WSUD. No on-ground actions identified. Relevant Strategies/ actions are: Strategy A - "Improve Council's planning, processes and capacity to integrate WSUD into council works and address catchment based priorities" Action A6 – Catchment Planning - Identify conditions and sensitivity of major catchments to water cycle issues and develop priority actions as part of a holistic catchment planning process. Separate one for each catchment. Belongil by June 2021, Tallows by June 2022. Strategy C – "Increase Council's ability to leverage funding to implement, operate and maintain WSUD infrastructure now and into the future" Action C1 - O&M Program / Plan for WSUD - Develop a Stormwater Operation and Maintenance Program and Plan for all urban drainage assets. The plan should clearly show costs associated with WSUD specific assets. The plan would identify the minimum recommended operation and maintenance requirements for each WSUD device or WSUD type. Details such as tasks, frequency of works, record keeping, expected costs should be included. Action C3 – Increasing Funding for WSUD- Increase Council's ability to leverage funding for WSUD systems maintenance.
72.	BSC (2008) Water Quality Report for Receiving Waters within the Byron Shire.	This paper reports on long term water quality trends and monitoring results for 2002-2008 within Byron Shire Councils receiving waters (Brunswick River, Belongil, Tallow and Byron Creeks).
73.	BSC (2017) Byron Bay Surface Water Quality Monitoring Program. October 2017.	Description of the BSC water quality monitoring program including sites, frequency and parameters.
74.	BSC (2019) C00195-2019 Byron Shire Council self-report, sewage overflow Byron Bay EPA Licence # 3404	On Friday 4th January 2019, sewage pump station 3001 (SPS3001) on Bangalow Road failed resulting in raw sewage discharge to the environment. There were two customer reports of sewage overflow at 80 Bangalow Road and 11 Blackbutt place on 4th January. Estimated volume of sewage discharged over 6 hour period is 200 kL
75.	BSC (2020) Byron Shire Council self-report, sewage overflow Byron Bay EPA Licence# 3404. Letter to NSW EPA	Provided by BSC March 23 On Friday 17th April 2020 at 6:45am a Council slasher broke a valve on rising main that crosses Belongil Ck (valve was 20-30m away from Creek). Repairs completed within 45 mins of break. Sewer water, no paper or solids were evident. Estimated volume of sewage discharged over 45 minute period 1000 litres. Pump stations were shut down to minimise damage. Immediate area was hosed down with potable water. Reflective guide posts were placed next to the valve on the rising main to prevent further incidents.

ID	Information	Notes
76.	BSC (2021) C01291-2021 Byron Shire Council self-report, overflows within catchment EPA Licence # 3404	At 6:30pm Wednesday 27th January 2021 a customer reported that the private sewer at the corner of Dryden Street and Shirley Lane, Byron Bay was backing up. It was found that there was a blockage within one of the Council gravity sewer mains near the property. Staff attended the site 7:30am Thursday 28th January and it was found that sewage overflow had taken place near this blocked main. It was identified that overflowing sewage was entering nearby stormwater drainage (Butler street drain) which does exit to the nearby Belongil waterway. Raw sewage discharged. Estimated volume of sewage discharged over 10 hour period is 10 kL.
77.	BSC (2022) EPA Licence # 3404 - Byron Shire Council self-report, sewer rising main break EPA Ref: 15204	At approximately 9:30am Monday 15th August 2022, a major sewer rising main burst at the inlet works at the Byron Bay Sewage Treatment Plant (STP). Council staff were onsite when this burst occurred and were able to immediately isolate the pump stations which connect to this rising main (via SCADA). The duration of this mains break was less than 10 minutes. All raw sewage from the burst rising main was collected and treated at the Byron Bay STP. At the time of writing this report, no untreated sewage has been discharged into the surrounding environment. At the time of writing this report, no notifiable overflows have occurred. Council has self-reported this sewer break to the EPA as a precaution given the severity of the sewer main break.
78.	BSC (2022) EPA Licence # 3404 - Byron Shire Council self-report, rising main break resulting in sewage overflow near Milton Street, Byron Bay. EPA Ref: 16178	Byron Shire Council (Council) received notification at 11am Wednesday 5th October about bubbling water appearing on surface at a stormwater drain near Milton Street, Byron Bay. Council staff were onsite within 30 minutes and it was not clear what the cause of this bubbling water was. After isolating a number of mains in the area, it was identified to be the rising main from sewer pump station (Council reference 'SPS3001'). Once identified, Council staff isolated the pump station at approximately 2:30pm brought in vacuum trucks to help with wastewater disposal whilst the pump station was offline. Contractors and staff worked on the main and were able to have the main repaired and pump station back online at approximately 7:30pm. A small pinhole break was located on the rising main which appears to be caused from external damage to the main. At the time of writing this report, it is not clear what caused this break. The estimated volume of untreated sewage discharged over the 3.5 hour period was 50 kL. During the time of the break, it was dry weather and untreated sewage was mainly localised around the stormwater culvert shown in Appendix A.
79.	BSC: Byron Bay Surface Water Quality Monitoring Program: See "Collated monthly catchment WQ data Belongil and Tallow Aug 2016 to Dec 2022.xlxs"	Monthly monitoring in both Tallow (up to Oct 2022) and Belongil catchment. Results are also available online at: http://www.byrondata.sgautomation.com.au/surface-water. Some cross over of sites in Tallow Cr with EOS 5 site sampling.

ID	Information	Notes
80.	Derraik, J. (2002) The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin, 44(9), 842-852. Available at: https://doi.org/10.1016/S0025-326X(02)00220-5.	The deleterious effects of plastic debris on the marine environment were reviewed by bringing together most of the literature published so far on the topic.
81.	Dey, D (2022) Emaill "Sources of water pollution raised at C&ICOLL meeting".	Potential pollutants to be looked into: Tallow Creek source of pollutants: 1. Baywood Lake 2. Bennetts straightened section (dug through acid sulphate soils?) Belongil Creek sources: 1. Butler Street old tip 2. Sunnybrand site 3. STP (e.g. endocrine disruptors) 4. acid sulphate soils
82.	Draft new numerical criteria for NSW estuaries	New numerical criteria for estuaries will be released in 23/24 and are provided by estuary type, Tallow Creek being a "lagoon" (https://www.environment.nsw.gov.au/topics/water/estuaries/estuaries-of-nsw/tallow-creek) and Belongil Creek being a "creek" (https://www.environment.nsw.gov.au/topics/water/estuaries/estuaries-of-nsw/belongil-creek).
83.	Email from Nikki Bourke BSC 27/3/23.	Discusses review of Tallow Entrance Opening Strategy and potential for impact on former STP ponds. Request survey/heights etc. Unknown whether pipe outlet from the eastern pond to the creek still in place/ in use. BSC to check this.
84.	Email regarding ID no.53 report (Cavvanba, 2023)	Provided March 28th 2023. Addresses BSC comments on report Recommend “sampling Tallow Creek for heavy metals and nutrients to confirm that groundwater is not having an influence on this water source. This could be conducted at three sampling points (up-gradient, central, down-gradient) of the former STP ponds and nearby groundwater monitoring wells.” “although the STP infrastructure and night soils have been removed, the impacts in groundwater and likely to still be present which is represented by elevated concentrations of elevated ammonia. Ammonia contamination in groundwater is persistent in the subsurface environment”

ID	Information	Notes
85.	Former South Byron STP Treatment Ponds Options Assessment Design Report (AWC and Cavvanba Consulting, 2023)	Provided March 28th 2023. Report provides a summary of the site analysis, opportunities and constraints plans and preferred design option and costings. Key drivers from the project brief and stakeholder consultation have informed the design direction and options selection. The two options considered were: 1. Naturalisation of Ponds 2. Fill Pond and Reclaim 3. The preferred option selected was Option 1 - Naturalisation of Ponds. The report is to help illustrate the design development process to stakeholders and used as a tool to move into detailed design.
86.	Fw: Balloon-data.msg	[Email from Zoe White containing recent data from Tangaroa Blue and KLIS study]. KLIS data provided as spreadsheet with charts. So far: 1 x sample event along 4 x Belongil Estuary transects in Sep-Oct 22. 5 people collected 11 bags of rubbish in 4 hrs weighing 118kg. Plastic litter made up the majority of items collected, followed by glass, wood and metal. Further surveys are planned every 3 months until Jun 2024. Tangaroa Blue Beach Clean Data provided as spreadsheet with charts: Total of 142 events in Byron Shire from 2012 – 2022, 3175kg litter removed. 10 events at Belongil Beach, 4 events at Tallow Beach, 4 events at Suffolk Park Beach, 1 event at Broken Head Beach. Data provided for balloons, rubber ball toys, straps and bands only. AusMap - Australian Microplastic Assessment Project Byron assessed as “Low” (28 microplastics/m2), 84% foam. Only 1 sample at Main Beach by Durroughby EEC in 2019. No further assessments.
87.	Hadwen, W. L., Arthington, A. H., (2006) Ecology, Threats and Management Options for Small Estuaries and ICOLLs, Sustainable Tourism CRC.	The study investigated critical aspects of ICOLL ecology and asked: how do these systems respond to increasing coastal pressures in general and in particular, those directly or indirectly related to tourism and recreation in their catchments? Includes a case study of sewage nitrogen isotope signatures in biota of Tallow Creek.
88.	Hadwen, W. L., Arthington, A. H., (2007) Food webs of two intermittently open estuaries receiving 15N-enriched sewage effluent. Estuarine, Coastal and Shelf Science 71 (2007) 347-358.	The study has looked at the contribution of wastewater to an entire food web within Tallow Creek ICOLL. This study showed that wastewater N discharged into the ICOLL was assimilated and distributed throughout the entire food web. Furthermore, the d15N signatures of biota at each trophic level were considerably more enriched in d15N than values reported for open systems receiving wastewater (e.g., rivers, permanently open estuaries, exposed rocky shores).

ID	Information	Notes
89.	Hadwen, W. L., Arthington, A. H., (2007) Gut content- and stable isotope-derived diets of four commercially and recreationally important fish species in two intermittently open estuaries. Marine and Freshwater Research, 2007, 58, 363–375.	Despite remaining closed for variable periods, intermittently open estuaries provide habitat for estuarine and marine fish species of commercial and recreational value. To better understand how these systems trophically support their fish assemblages, the diets of four valued fish species, namely Acanthopagrus australis, Platycephalus fuscus, Sillago ciliata and Mugil cephalus, were examined in two intermittently open estuaries (Belongil and Tallow Creek).
90.	Illegal Dumping and Litter Education and Enforcement Plan	BSC seeking funding from NSW EPA to assist with developing an updated and more strategic Illegal Dumping and Litter Education and Enforcement Plan (IDLEEP) for 2024 – 2029. ZW email 8/5/2023
91.	Ivar do Sul, J. A., & Costa, M. F. (2014). The present and future of microplastic pollution in the marine environment. Environ Pollut, 185, 352-364. Available at: https://www.ncbi.nlm.nih.gov/pubmed/24275078. doi:10.1016/j.envpol.2013.10.036.	This study critically analysed at least 101 peer reviewed papers investigating microplastic pollution. Microplastics are commonly studied in relation to (1) plankton samples, (2) sandy and muddy sediments, (3) vertebrate and invertebrate ingestion, and (4) chemical pollutant interactions. All of the marine organism groups are at an eminent risk of interacting with microplastics according to the available literature.
92.	Laist, D. W. (1997) Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In Marine Debris (pp. 99-139). Springer, New York, NY.	Reviewed all available information on marine debris and entanglement interactions and includes a list of species and entanglement incidents recorded in literature. Conclusions included that entanglement incidents were much more frequent and widespread than previously thought.
93.	Ledonne Constructions (2020) Environmental Incident Report - Sewer Main and Recycled Water Main Break	Provided by BSC March 23 On 5th August 2021 at 10am a Positrak operator hit and broke the 1 inch air bleed pipework attached to mains causing recycled water and sewer leaks. Council was notified immediately and when pumps were switched off, the 1 inch pipework was repaired & backfilled. Two Vacuum Trucks were organised to clean and expose site pipework and to control pump station sewer levels. Incident located adjacent to Council Depot on Bayshore Drive, Byron Bay. No sewerage escaped beyond the construction corridor before Vacuum truck arrived. Some recycled water would have entered nearby water way during initial burst of main until pumps were switched off.
94.	Ledonne Constructions (2021) Environmental Incident Report - Sewer Main Break	On 15th October 2021 whilst installing new Recycled Water Main for Byron Shire Council, Excavator struck a 125 OD Sewer Rising Main causing a small puncture in main. OD125 SRM located in the Byron STP at Wallum Place Byron. Incident was reported immediately at 10:30am, and Council was called to switch off pumps however a small flow of sewer water continued to flow into trench due to head pressure of main. A vacuum truck arrived to site at 11:30am to clean out trench, and expose main for repair. Main was repaired by 2:30pm with pumps switch back on around 3pm. No sewerage overflowed the trench however it is more than likely some sewer water drained through the sand base of trench. Estimated Escaped Material in first hour before sucker truck arrived = (48.3*60) – (750) = 2150 L

ID	Information	Notes
95.	Mayjor, M., Reichelt-Brushett, A., Malcolm, H., Page, A. (2023) Water quality fluctuations in small intermittently closed and open lakes and lagoons (ICOLLs) after natural and artificial openings. Estuarine, Coastal and Shelf Science Vol 281, 5 February 2023, 108208.	Just made available early Jan 2023 Study assessed data from: Belongil Creek, Tallow Creek, Woolgoolga Lake and Hearnes Lake. Belongil - Urban development and grazing predominant, highly modified drainage system through the floodplain containing acid sulfate soils (ASS), and long term and current effluent discharge from West Byron Sewage Treatment Plant. Tallows - Urban development, golf course, ASS present,1909–1972 night-cart operations and from 1972 to 2005 effluent discharge from South Byron Sewage Treatment Plant. Dissolved oxygen (DO) depletion was a major driver of fish kills in ICOLLs. Natural openings of ICOLLs did not cause fish kills. Low DO is driven by physical, chemical and biological factors. Sources and drivers of oxygen demand include: wastewater loading, decomposition of veg (e.g. exotic grasses after inundation, dieback veg), Fe chemistry, ASS runoff, groundwater discharge.
96.	MEMA (2018) NSW Marine Estate Management Strategy 2018 – 2028. NSW Government, Marine Estate Management Authority.	It sets the overarching framework for the NSW Government to coordinate the management of the marine estate over the next decade. The Strategy delivers outcomes through the following initiatives: Improving water quality and reducing litter Delivering healthy coastal habitats with sustainable use and development Planning for climate change Protecting the Aboriginal cultural values of the marine estate Reducing impacts on threatened and protected species Ensuring sustainable fishing and aquaculture Enabling safe and sustainable boating Enhancing social, cultural and economic benefits Delivering effective governance
97.	MEMA (2021) Marine Estate Management Strategy – Implementation Plan - 2021-2022.	Outlines how the MEMS (2018) will be delivered in 2021-2022.
98.	Memo: Impact on Sewer Infrastructure of Flood Event Commencing 30 March 2022	Overall, BB STP had no major issues throughout event. One pump station was ‘heavily impacted’ north of Tallow Creek (SPS3016 Byron Bay STP Beachcomber Drive, Byron Bay).
99.	Nanthini devi et al. (2022) Impacts of microplastics on marine organisms: Present perspectives and the way forward. Egyptian Journal of Aquatic Research 48(1)	The review provides details on the microplastics occurrences and their size, types besides impacts of microplastics from phytoplankton to marine mammals.

ID	Information	Notes
100.	National Health and Medical Research Council (2008) Guidelines for Managing Risks in Recreational Waters.	These guidelines aim to protect Australians from threats posed by the recreational use of coastal, estuarine and fresh water environments.
101.	Northern Rivers CMA (2013) Northern Rivers Catchment Action Plan 2013 – 2023. Northern Rivers Catchment Management Authority, April 2013.	The Northern Rivers Catchment Action Plan 2013–2023 (CAP2) is an all-of government and all-of-community plan to guide the sustainable management of natural resources in the Northern Rivers Region for the next decade. These natural resources include soils, biodiversity, rivers, estuaries, wetlands, and coastal and marine environments.
102.	NSW Government (2010) State of Catchments 2010 - Estuaries and Coastal Lakes - Northern Rivers Region.	Belongil Creek scored 'Fair' on the condition index and 'Moderate' on the pressure index. Tallow Creek scored 'Poor' on the condition index and 'Moderate' on the pressure index.
103.	NSW Water Quality and River Flow Objectives - Brunswick River.	The Belongil and Tallow Creek ICOLLs are considered part of the "Brunswick River" catchment in the current WQO's. However, DPE has reviewed and updated WQO's. See below.
104.	Rhelm (2021) Coastal Management Program Scoping Study (Stage 1) for the Southern Byron Shire Coastline and Belongil Estuary.	Note that a summary of the status of management actions recommended in past key management plans is provided in Section 5.3 and Appendix F of the Scoping Study
105.	Sewer Overflow Reports from CRM	Sewer Overflow Reports from CRM (customer request management) system from April 2016 – April 2022. Mainly minor overflows that did not result in any substantial discharge to the environment.
106.	Sheavly, S.B. (2005) Marine Debris - an Overview of a Critical Issue for OurOceans, Sixth meeting of the UN Open- ended Informal Consultative Process on the Oceans and Law of the Sea. The Ocean Conservancy, June 6e10 2005, p. 7.	Discusses the issue of marine debris, sources, impacts and mitigation measures
107.	Smith, S. D. A., Banister, K., Fraser, N., & Edgar, R. J. (2018) Tracing the source of marine debris on the beaches of northern New South Wales, Australia: The Bottles on Beaches program. Mar Pollut Bull, 126, 304-307. Available at: https://www.ncbi.nlm.nih.gov/pubmed/29421101. doi:10.1016/j.marpolbul.2017.11.022.	Identified the source of marine plastic pollution accumulating on 30 km of beach along a 200-km section of the north coast of New South Wales. Just over half (51%) of plastic bottles collected were of domestic origin with the remainder dominated by bottles from China (24%) and south-east Asian countries (21%). As most of the foreign bottles lacked marine growth, and are unavailable for purchase in the region, passing ships are hypothesised as the primary source. Included Byron Bay Beach as a study site.
108.	Survey of Former South Byron STP Treatment Ponds	Provided March 28th 2023 Bathymetric survey of ponds and topographic survey of surrounding areas.

ID	Information	Notes
109.	UNEP, 2005. Marine Litter: An Analytical Overview, Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation, p. 47.	It is estimated that about 6.4 million tons of marine litter are disposed in the oceans and seas each year. According to other estimates and calculations, some 8 million items of marine litter are dumped in oceans and seas every day, approximately 5 million of which (solid waste) are thrown overboard or lost from ships. Furthermore, it has been estimated that over 13,000 pieces of plastic litter are floating on every square kilometre of ocean today. This study, proposes a series of global and regional activities aimed at controlling, reducing and abating the problem.
110.	Vegter, A. C., Barletta, M., Beck, C., Borrero, J., Burton, H., Campbell, M. L., . . . Hamann, M. (2014). Global research priorities to mitigate plastic pollution impacts on marine wildlife. Endangered Species Research, 25(3), 225-247. doi:10.3354/esr00623.	This paper highlights a growing concern related to threats posed to marine wildlife from microplastics and fragmented debris, the need for data at scales relevant to management, and the urgent need to develop interdisciplinary research and management partnerships to limit the release of plastics into the environment and curb the future impacts of plastic pollution.
111.	Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: a review. Environmental pollution, 178, 483-492.	This review focuses on marine invertebrates and their susceptibility to the physical impacts of microplastic uptake. Some of the main points discussed are (1) an evaluation of the factors contributing to the bioavailability of microplastics including size and density; (2) an assessment of the relative susceptibility of different feeding guilds; (3) an overview of the factors most likely to influence the physical impacts of microplastics such as accumulation and translocation; and (4) the trophic transfer of microplastics. These findings are important in guiding future marine litter research and management strategies.

APPENDIX 2 STAKEHOLDER ENGAGEMENT PLAN

Byron ICOLL Water Quality Source Tracking and Control Program Engagement Plan

Table 1: Key engagement activities (refer Appendix 1 for Contact List and Appendix 2 for Contact Register)

Stakeholder Group	Division/ Name	Activities	Timing	Items / key areas for discussion
Byron Shire Council Staff	Coast, Estuary and Biodiversity Services	Inception Meeting (online)	Week 1, 13th December 2022.	• Project start-up • CMP (Coastal Management Program) status • Project proposal / methodology / timing etc. • Data request / available data
		Progress report via email	Fortnightly – Tuesdays staring 17th Jan 2023.	• Project management / progress / data request / project updates
		Progress meetings (online)	Fortnightly – Wednesdays starting 18th Jan 2023.	
		Ongoing liaison and collaboration	Throughout project	
		Review project deliverables	Draft Report due Week 24, 23rd May 2023.	• Client review/feedback to be received within 2 weeks. All feedback to be consolidated by BSC into single set of comments on the Draft report.
		Meeting to discuss Draft Report and feedback (online)	Week 25, 31st May 2023	• Scheduled for halfway through review period.
	Assets and Major Projects	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting.

Stakeholder Group	Division/ Name	Activities	Timing	Items / key areas for discussion
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Remediation of Butler St. landfill and potential for contamination e.g. from PFAS etc. • Remediation of former South Byron STP treatment ponds adjacent to Tallow Creek. • Sand Hills Retention and Wetland Remediation Project. • Capacity for operating and/or maintaining assets and infrastructure relating to water quality. • Any other major projects in the Belongil and Tallow Creek catchments with the potential to impact on water quality.
	Environmental Health	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Catchment pollution sources / key issues e.g. swimming locations, DA conditions relevant to water quality, large developments (e.g. West Byron), OSSMs. • Capacity for operating and/or maintaining assets and infrastructure relating to water quality (e.g.WSUD assets). • Key locations / specific sites of concern - e.g. Baywood Chase Lake • Relevant data that could be useful for project • Any current management actions ongoing or proposed. • Areas for improvement / innovation / monitoring / on-ground actions.
	Resource Recovery	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting

Stakeholder Group	Division/ Name	Activities	Timing	Items / key areas for discussion
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Catchment pollution sources / key issues – e.g., litter sources, waste management processes and activities. • Capacity for operating and/or maintaining assets and infrastructure relating to water quality. • Key locations / specific sites of concern. • Relevant data that could be useful for project • Any current management actions ongoing or proposed (e.g. Stormwater Litter Project in collaboration with Drainage Team, Results of the Mullumbimby Stormwater Litter Study that may be relevant to ICOLLS) • NSW Key Littered Items Study (KLIS). • Australian Microplastic Assessment Project (AusMap). • Areas for improvement / innovation / monitoring / on-ground actions.
	Open Spaces and Facilities	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Catchment pollution sources / key issues – e.g., open space management, fertiliser use / nutrient and sediment sources / pesticide and herbicide use. • Capacity for operating and/or maintaining assets and infrastructure relating to water quality. • Key locations / specific sites of concern. • Relevant data that could be useful for project • Any current management actions ongoing or proposed. • Areas for improvement / innovation / monitoring / on-ground actions.

Stakeholder Group	Division/ Name	Activities	Timing	Items / key areas for discussion
	Drainage / Stormwater / Floodplain Management	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Catchment pollution sources / key issues – e.g., stormwater network issues, drainage, maintenance, GPTs (gross pollutant traps) and other litter control devices, nutrient and sediment sources, acid sulfate soils, water quality issues, pesticide, and herbicide use. • Capacity for operating and/or maintaining assets and infrastructure relating to water quality (e.g. WSUD assets). • Key locations / specific sites of concern (e.g. Baywood Chase Lake) • Relevant data that could be useful for project • Any current management actions ongoing or proposed (e.g. Byron Bay Drainage Strategy). • Areas for improvement / innovation / monitoring / on-ground actions.
	Water and Sewerage	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting

Stakeholder Group	Division/ Name	Activities	Timing	Items / key areas for discussion
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Catchment pollution sources / key issues – e.g., wastewater treatment processes and activities, pump stations and overflows/ leaks, recycled water reuse, reducing stormwater in the sewer, sewer CCTV program, industrial sites etc. • Capacity for operating and/or maintaining assets and infrastructure relating to water quality. • Key locations / specific sites of concern - e.g. Belongil Wastewater Treatment Plant, tertiary treatment wetlands. • Relevant data that could be useful for project. • Any current management actions ongoing or proposed. • Areas for improvement / innovation / monitoring / on-ground actions.
Byron Council Advisory Committee	Coast and ICOLL Advisory Committee	Project introduction email and questionnaire sent via Council	Sent after Committee Meeting on 14th February 2023.	• Provide an introduction to the project, acknowledging that some members have previously made comment on catchment water quality concerns and locations, and requesting any further input and data.
		Presentation on project methodology and findings (online).	Coast and ICOLL Advisory Committee Meeting 15th August 2023.	•
Government Agencies	DPE - BCD	Inception Meeting (online)	Week 1, 13/12/2022	• Project start-up • CMP status • Project proposal / methodology / timing etc. • Data request / available data
		Ongoing liaison and collaboration	Throughout project	• As needed to discuss data, information and matters arising. • Relevant data that could be useful for project
		Review project deliverables	Draft Report due Week 24, 23rd May 2023	• Client review/feedback to be received within 2 weeks. All feedback to be consolidated by BSC into single set of comments on the Draft report.

Stakeholder Group	Division/ Name	Activities	Timing	Items / key areas for discussion
		Meeting to discuss Draft Report and feedback (online)	Week 25, 31st May 2023	• Scheduled for halfway through review period.
	NPWS (National Parks and Wildlife Service)	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Catchment pollution sources / key issues e.g. within National Parks Estate or otherwise, drainage, water quality etc. • Key locations / specific sites of concern - e.g. Arakwal National Park, Cumbebin Swamp Nature Reserve, Tyagarah Nature Reserve, Baywood Chase Lake. • Relevant data that could be useful for project • Any current management actions ongoing or proposed. • Areas for improvement / innovation / monitoring / on-ground actions.
	DPI (Department of Primary Industries) - Fisheries Cape Byron Marine Park	Project introduction email / phone call	Week 8, 30th Jan 2023	• Introduce project, provide background. • Request meeting and preferred times/ format. • Schedule meeting
		Phone and/or online meeting	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Catchment pollution sources / key issues e.g. within or impacting on Cape Byron Marine Park. • Discuss contact with DPI-Fisheries Coastal Systems (North Coast) staff (e.g. information, data sources etc.) • Key locations / specific sites of concern. • Relevant data that could be useful for project • Any current management actions ongoing or proposed. • Areas for improvement / innovation / monitoring / on-ground actions.

Stakeholder Group	Division/ Name	Activities	Timing	Items / key areas for discussion
Non-government Organisations / Groups	Water Places Positive Change for Marine Life (PCFML) Tangaroa Blue	Phone call and/or email	Weeks 8–11 (30th Jan – 16th Feb 2023) initial contact, follow up as required.	• Request/follow up regarding relevant data for project – e.g., location and volume of litter/plastics/ marine debris etc. Some information already provided. • Discuss citizen science programs/ collection of data etc.

APPENDIX 1 CONTACT LIST

Table 2: Contact List (note meeting groups coded by colour)

Stakeholder Group	Sub Group	Division	Name	Role	Email	Desk phone	Mobile	Notes (best contact method, days of work etc.)
Byron Shire Council	Sustainable Environment and Economy	Coastal, Biodiversity and Sustainability Services	Orla Seccull	Coastal & Estuaries Officer	oseccull@byron.nsw.gov.au	02 6626 7118	0408 207 481	Work days: Mon-Wed
			Chloe Dowsett	Coast & Biodiversity Coordinator	cdowsett@byron.nsw.gov.au	6626 7128	0427 210 516	Mon-Fri
		Environmental Health	Tim Connors	Team Leader Environmental Health	tconnors@byron.nsw.gov.au	02 6626 7189	0439 331 834	Mon-Fri
			Michael Bingham	Environmental Health Officer	mbingham@byron.nsw.gov.au	02 6626 7057	0407 454 699	Mon, Tue, Thurs, Fri
			Emma Holt	Environmental Health Officer	eholt@byron.nsw.gov.au	02 6626 7063	0400 479 167	Mon-Fri. On leave until 5th Feb.
		WSUD	Renan Solatan	Development Engineer (SEE - Building & Construction Services)	rsolatan@byron.nsw.gov.au	02 6626 7256	0418 447 013	Mon-Fri
	Infrastructure Services	Drainage / Stormwater (Maintenance and Works)	Kirk Weallans	Operations Coordinator (RE stormwater and drainage maintenance)	kweallans@byron.nsw.gov.au	+61 2 6626 7164	0427 696 384	Mon-Fri

Stakeholder Group	Sub Group	Division	Name	Role	Email	Desk phone	Mobile	Notes (best contact method, days of work etc.)
		Floodplain Management	Scott Moffett	Flooding and Drainage Engineer (RE (Strategic flood planning +drainage and works)	smoffett@byron.nsw.gov.au	02 6626 7227	0439 489 622	Mon-Fri
		Open Spaces and Facilities	Andy Erskine	Open Space Technical Officer	aerskine@byron.nsw.gov.au	02 6626 7240	+61 417 201 891	Andy is in charge of bush regen and has a handle on pesticide and herbicide use.
		Resource Recovery	Zoe White	Resource Recovery Education and Compliance Officer	zwhite@byron.nsw.gov.au	+61 2 6626 7236	+61 448 118 560	Mon-Fri
		Water and Sewer	Jason Stanley	Operations Engineer (RE reducing stormwater in the sewer/sewer CCTV, STP WQ)	jstanley@byron.nsw.gov.au	+61 2 6685 9349	+61 2 6685 9349	
			Pablo Orams	Integrated Water Management Officer (RE recycled water reuse)	porams@byron.nsw.gov.au	+61 2 6685 9314	+61 474 914 208	Mon-Fri

Stakeholder Group	Sub Group	Division	Name	Role	Email	Desk phone	Mobile	Notes (best contact method, days of work etc.)
			Anjila Finan	Data Analytics Officer (RE governance of the WQ monitoring system and responsibilities)	afinan@byron.nsw.gov.au	+61 2 6685 9318	+61 408 632 659	Mon, Tues, Thurs, Fri
			Katrina Curran (AWC)	(Australian Wetlands Consulting) currently seconded to Council to assist in operations at the West Byron STP wetlands	katrina@awconsult.com.au		0430 173 032	Katrina Curran (AWC)
		Assets and Major Projects	Phill Warner	Manager, Assets and Major Projects (RE status of former Butler Street landfill remediation and PFAS investigation)	pwarner@byron.nsw.gov.au	+61 2 6626 7165	+61 407 262 586	Mon-Tues are best

Stakeholder Group	Sub Group	Division	Name	Role	Email	Desk phone	Mobile	Notes (best contact method, days of work etc.)
			Nikki Bourke	Project Officer (RE former South Byron STP pond remediation)	nbourke@byron.nsw.gov.au	+61 2 6626 7086	+61 408 148 879	Mon & Thurs
Government Agencies	DPE - BCD	Water, Floodplains and Coast (North East)	Zoë Immisch	Senior Coast and Estuaries Officer	zoe.immisch@environment.nsw.gov.au	02 6670 8662		
	DPE	Science, Economics and Insights Division	Angus Ferguson	Senior Research Scientist – Estuaries and Catchments Science	angus.Ferguson@environment.nsw.gov.au		0402 689 817	
	NPWS	Byron Bay	Fiona Peek	Team Leader	fiona.peek@environment.nsw.gov.au	02 6670 8600	0437 664 620	Murwillumbah Office
			Jenny Atkins	Ranger in charge		02 6639 8300		
	DPI Fisheries	Cape Byron Marine Park	Andrew Page	Manager	andrew.page@dpi.nsw.gov.au marine.environment@dpi.nsw.gov.au	02 6620 9333	0439 485 266	https://www.dpi.nsw.gov.au/fishing/marine-protected-areas/marine-parks/cape-byron-marine-park
	DPI Fisheries	Coastal Systems (North Coast)	Jonathan Yantsch	Senior Fisheries Manager	jonathan.yantsch@dpi.nsw.gov.au	02 6626 1375	0447 537 168	
Non-government	Water Places		Cate Coorey		catemcoorey@gmail.com			Email initially. Cate is a Byron Shire Councillor and is involved with ICOLL Research Centre.

Stakeholder Group	Sub Group	Division	Name	Role	Email	Desk phone	Mobile	Notes (best contact method, days of work etc.)
Organisations / Groups	Positive Change for Marine Life (PCFML)	Byron Bay Office	Lauren Morgan		l.morgan@pcfml.org.au		0449 142 548	Global organisation with an office in Byron Bay. Web: https://pcfml.org.au/contact PO BOX 238, BYRON BAY, NSW 2481
	Tangaroa Blue		Jodi		jodi@tangaroablue.org			Australia-wide not-for-profit organisation dedicated to the removal and prevention of marine debris. Data provided for Main Beach and Belongil Beach.

APPENDIX 3 BSC SEWER OVERFLOWS REPORTED TO THE NSW EPA 2016 - 2022

Date	Reported by	Location	Suburb	Type	Cause	Estimated volume of effluent discharged (L)
4/01/2019	BSC	SPS3001 on Bangalow Road	Byron Town Centre	Sewage overflow	Pump station failure due to build up of oil and grease.	200,000
17/04/2020	BSC	Rising main that crosses Belongil Ck.	Belongil Creek	Sewage overflow	Sewer pipe damage by heavy machinery	1,000
27/01/2021	BSC	Corner of Dryden St and Shirley Ln.	Byron Town Centre	Sewage overflow	Sewer blockage	10,000
5/08/2021	Ledonne Constructions	Adjacent to Council Depot on Bayshore Dr.	Byron Arts and Industry Estate	Sewer main and recycled water main break	Sewer pipe damage by heavy machinery	not reported
15/10/2021	Ledonne Constructions	Byron STP at Wallum Place	Byron Arts and Industry Estate	Sewer main break	Sewer pipe damage by heavy machinery	not reported
15/08/2022	BSC	Inlet works at the Byron Bay STP	Byron Arts and Industry Estate	Sewer rising main break	Sewer pipe break	0
5/10/2022	BSC	Stormwater drain near Milton Street, Byron Bay	Byron Town Centre	Sewer rising main break	Sewer pipe break	50,000

APPENDIX 4 POEO ACT REGISTER LISTINGS, DIP SITES AND CONTAMINATED LAND

Name	Catchment	Activity	Status	Listing	Chemicals used / of concern
Byron STP	Belongil Creek	Sewage treatment works	Issued EPL 3404	POEO Public Register	n/a
Butler Street Reserve	Belongil Creek	Landfill site (decommissioned)	Under Assessment[1]	NSW EPA list of notified contaminated sites	PFAS
Byron Bay - Beachcomber & Cooper Street	Belongil Creek	Cattle dip	Demolished[2]	DPI Cattle dip site locator	Arsenic, DDT, Dioxathion, Dioxathion Ethion, Ethion, Ethion Chlordimeform, Amitraz
Andersons A.W.	Belongil Creek	Cattle dip	Demolished	DPI Cattle dip site locator	Benzene Hexachloride, DDT
Skinners Shoot	Belongil Creek	Cattle dip	Decommissioned[3]	DPI Cattle dip site locator	Arsenic, DDT, Dioxathion, Dioxathion Ethion, Ethion, Ethion Chlordimeform, Amitraz
South Byron STP	Tallows Creek	Sewage treatment works (Decommissioned)	EPL surrendered	No longer listed	n/a
BP Suffolk Park	Tallows Creek	Petrol station	Regulation under CLM not required[4]	NSW EPA list of notified contaminated sites	n/a
Suffolk Park Dip Site	Tallows Creek	Cattle dip	Remediated[5]	DPI Cattle dip site locator	Arsenic, DDT, Dioxathion
Broken Head Quarry	Ti-Tree Lake	Land-based extractive activity (Expired)	Issued EPL 4860	POEO Public Register	n/a

[1]Under assessment - The contamination is being assessed by the NSW EPA to determine whether regulation is required. The NSW EPA may require further information to complete the assessment. For example, the completion of management actions regulated under the planning process or Protection of the Environment Operations Act 1997.

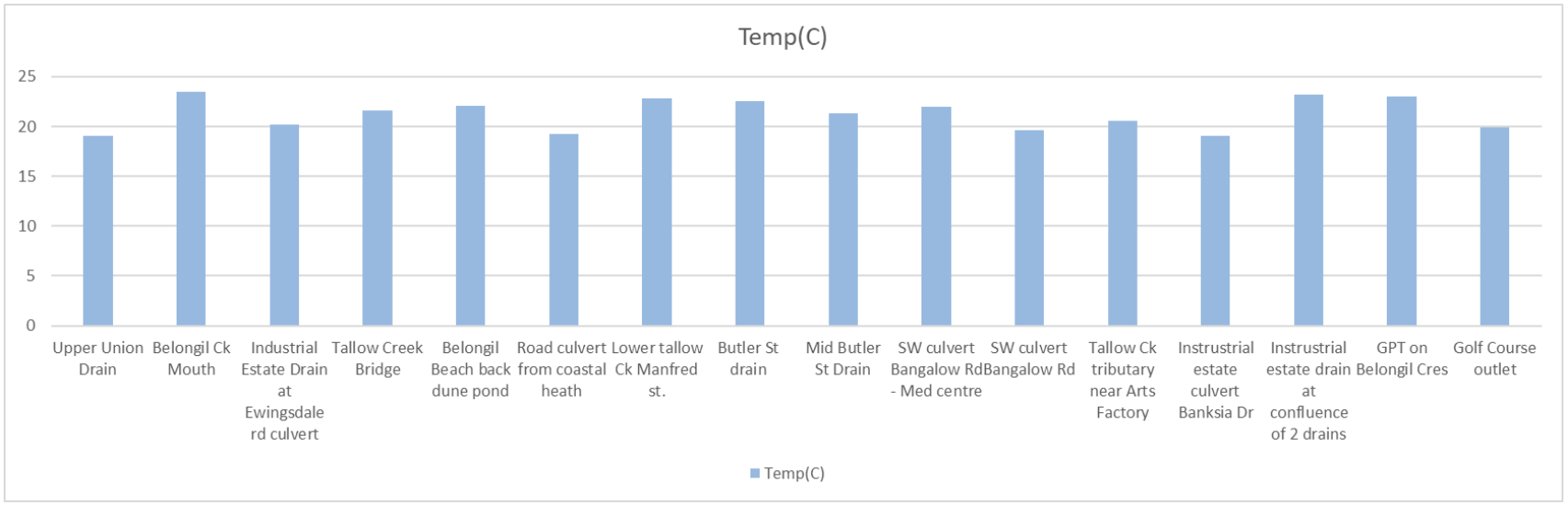
[2]Demolished - is where the dip site has been partially or wholly dismantled or demolished prior to the introduction of the decommissioning policy. In many cases there is no physical signs of the dip ever being there.
[3]Decommissioned – means all the standing structures, shed, fencing and roof have been dismantled. The bath itself, if present, is emptied of all chemical fluid and may have contaminated timbers from the roof and draining pen put into it and then is capped with concrete lids. The bath may have already been demolished prior to decommissioning in which case it is usually smashed and buried. An information plaque is attached to one of the concrete lids to indicate its Departmental file number, dip name and direction of the dipping. Clean soil may be spread around the bath to run flush with the bath edge and then grassed. The draining pen concrete floor is usually left intact so as not to disturb the possibly contaminated soil.
[4]Regulation under CLM Act not required - the NSW EPA has completed an assessment of the contamination and decided that regulation under the Contaminated Land Management Act 1997 is not required.
[5]Remediated - is where the dip site has been demolished, extensive soil testing completed and any contaminated soil with Arsenic or DDT levels above human/environmental health thresholds is removed or securely buried. Please note that this status applies generally to where sites have been remediated by NSW DPI. Any other remediation initiated externally to us will not necessarily be registered and therefore must be checked for through Council.

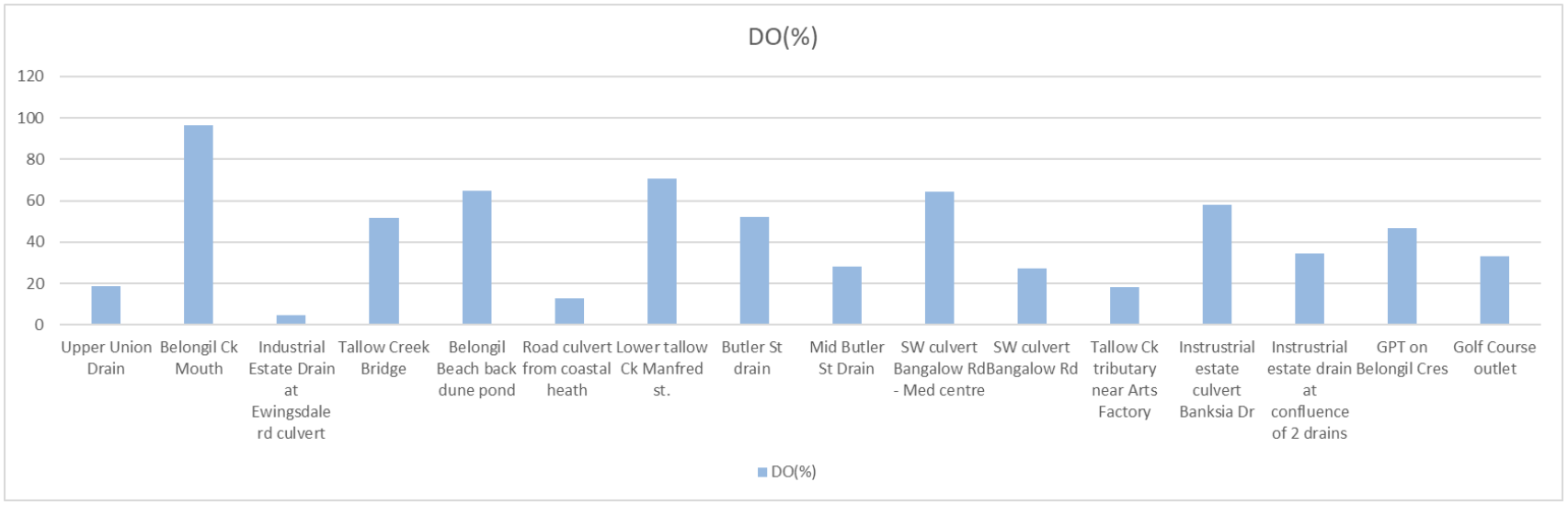
APPENDIX 5 SITE INSPECTION DATA APRIL 2023

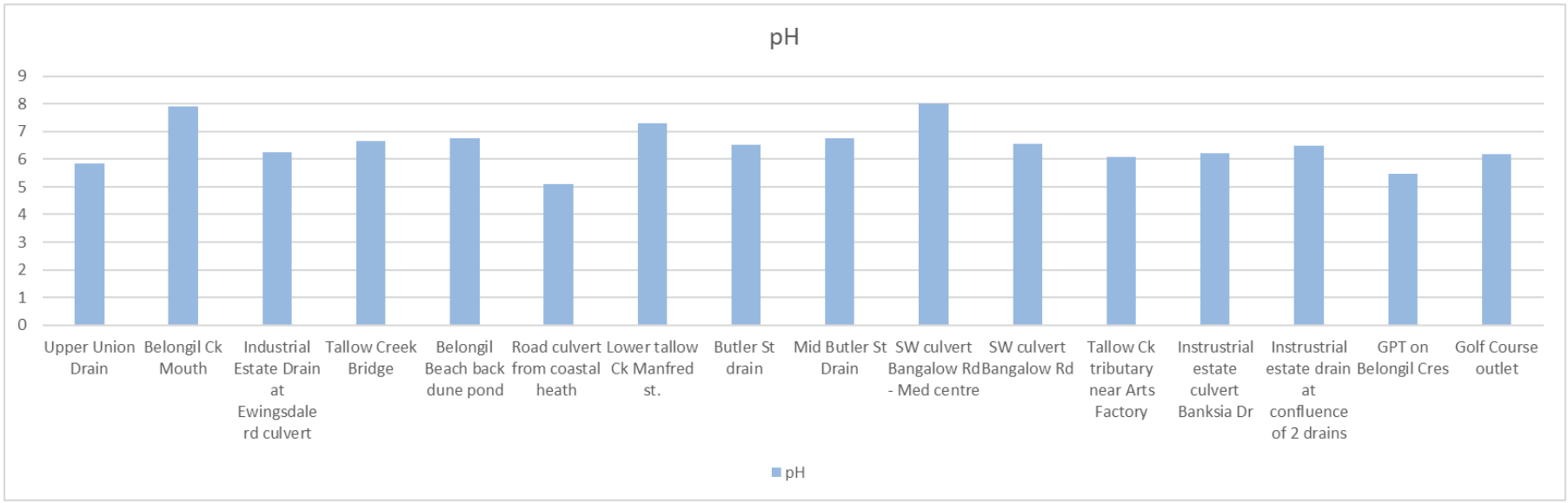
Date	Time	Catchment	Description	BSC WQ Site ID	Site ID	Temp (C)	DO (%)	DO (mg/L)	COND (uS/cm)	SAL (ppt)	TDS (mg/L)	pH	ORP(mV)	Turbidity (NTU)	Photo	Notes
20/04/2023	14:16:14	Belongil Creek	Butler St drain	BC07	10	22.5	52.2	4.51	663	0.3	452.8	6.52	24.9	868	4663-70	Stagnant, scum on surfance brown floc - iron?, choked with vegetation on ds side of culvert. Lots of litter at US end, plastic bottles, cans, wood, organic matter etc
20/04/2023	15:49:34	Belongil Creek	SW culvert Bangalow Rd - Med centre	BC15	12	22	64.3	5.62	423.2	0.2	291.9	8	23.8	311	4700-02	Near medical centre, no flow, surfabce scum/sheen, choked with vegetation
20/04/2023	12:46:43	Belongil Creek	GPT on Belongil Cres	n/a	17c	23	46.9	4.02	219.5	0.1	148.3	5.47	114.8	69.2	4638	Urban residential area, sw drain, litter plastic/plant pot, organic matter
20/04/2023	12:58:28	Belongil Creek	Industrial Estate Drain at Ewingsdale rd culvert	BC06	3	20.2	4.6	0.41	146	0.1	104.6	6.25	-6.4	66.4	4641	Tanin stained, lots of organic matter in water, freshly slashed?, litter, weed mats floating
20/04/2023	10:39:48	Belongil Creek	Upper Union Drain	BC04	1	19.1	18.6	1.72	433.2	0.2	317.1	5.85	52	41.9	4601-02	Lots of salvinia and some litter, no flow/stagnant
20/04/2023	14:57:02	Belongil Creek	Belongil Ck tributary near Arts Factory	n/a	15	20.6	18.2	1.63	1117	0.6	793	6.07	54.6	23.9	4694	Slight DS flow, tannin stained, phragmites dominant
20/04/2023	11:24:22	Belongil Creek	Instrustrial estate culvert Banksia Dr	n/a	17	19.1	58.2	5.38	176.3	0.1	129.1	6.22	4.3	17.8	4616-17	No Flow, tannin stained, water weeds and litter, dead plant material on banks - cleaned out recently?
20/04/2023	11:36:23	Belongil Creek	Instrustrial estate drain at confluence of 2 drains	n/a	17b	23.2	34.5	2.94	536	0.3	360.6	6.49	-66.3	12	4612 and 4622	Stagnant, scurface scum, oil sheen, lots of algae/weed and litter
20/04/2023	16:09:24	Belongil Creek	SW culvert Bangalow Rd	BC17	13	19.6	27.4	2.51	382.1	0.2	276.7	6.55	26.8	9.9	4704 and 4706	White foan on surface DS flow
20/04/2023	13:55:31	Belongil Creek	Mid Butler St Drain	BC08	10b	21.3	28.2	2.42	9337	5.7	6536	6.77	-0.8	7.1	4658-59	flowing DS, plastic chair, water quite clear
20/04/2023	16:22:08	Belongil Creek	Golf Course outlet	BC16	20	19.9	33.1	3.01	452	0.2	325.6	6.2	91.4	6.5		tannin stained clear water
20/04/2023	13:15:52	Belongil Creek	Belongil Creek Bridge	BC09	5	21.6	51.9	4.09	29012	19.3	20178	6.67	41	6.2	4643-50	DS flow tannin stained
20/04/2023	12:26:36	Belongil Creek	Road culvert from coastal heath	n/a	6b	19.2	12.9	1.19	145.8	0.1	106.6	5.11	90.2	4.2		US of Byron Bay Bungalows, clear water, tannin stained
20/04/2023	13:35:25	Belongil Creek	Lower Belongil Ck Manfred st.	BC11	9	22.8	70.5	5.21	39483	26.4	26801	7.29	35	2.8	4652-54	Tannin stained, DS flow clean, rubbish bun overflowing in adjacent car park.
20/04/2023	12:14:31	Belongil Creek	Belongil Beach back dune pond	n/a	6	22.1	64.6	5.63	355.6	0.2	244.5	6.76	65.1	1.6	4624	Elements estate, clean clear tannin stained water , lillies, lots of little fish
20/04/2023	12:00:33	Belongil Creek	Belongil Ck Mouth	BC12	2	23.5	96.6	6.97	42691	28.4	28554	7.9	11.3	1.5	4627-33	Entrance open, fast flowing water out to sea, clear, tannin stained. Dune erosion surounding entrance
20/04/2023	10:00:00	Belongil Creek	Viewpoint along St Helena Rd.	n/a	8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4581-99	View down to Belongil Creek catchment, various points
20/04/2023	10:45:00	Belongil Creek	Cavanba Sports Centre	n/a	4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4606-09	SW drains had litter grates on them, some litter present, grass clippings in drains
20/04/2023	14:25	Belongil Creek	Butler St. Landfill site	n/a	11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4681-83	Lots of litter and debris dumped, no water
20/04/2023	14:35:00	Belongil Creek	Skinners Shoot	n/a	16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4685-87	Photos only - rural residental

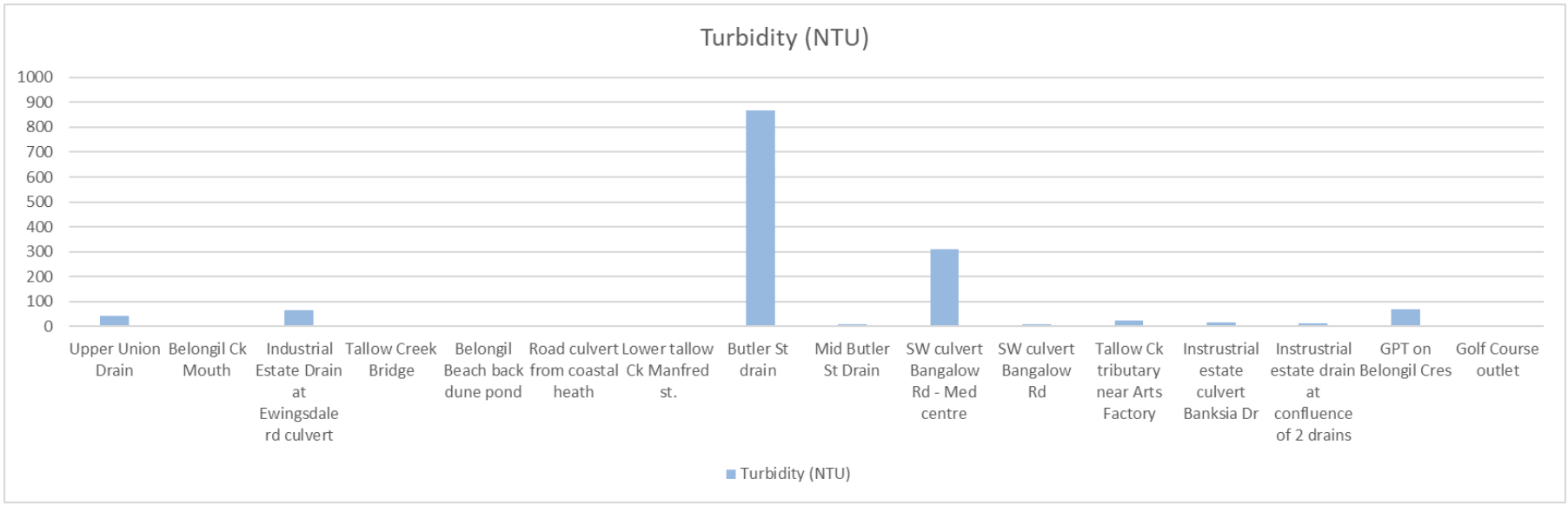
19/04/2023	17:03:01	Tallow Creek	Crystal Brook culvert	TC19	24	22.2	60.8	5.29	174.3	0.1	119.6	7.8	98.5	127	4543-45	Water covered in Salvinia, oily sheen on surface
19/04/2023	16:50:26	Tallow Creek	Baywood Chase Lake	TC20	25	22.7	106.4	9.17	166.5	0.1	113.1	9.87	35.5	76.6	4538-41	Water is green and indicative of algal bloom (could be BGA), bad odour, dead fish reported by landholder. Water quality was poor with temp 27.2 oC, turbidity 76.6 NTU, pH 9.85 and DO 106.5 % sat – this is likely due to oxygen being produced by photosynthesising algae during sunny day, I would expect this would crash to low levels during the night and early morning as algae respire. High pH also indication of an algal bloom.
19/04/2023	16:20:02	Tallow Creek	Tallow Ck. Near footbridge from Midgen Park	n/a	29	22.4	52.8	4.57	1155	0.6	790	6.08	114.7	18.6	4535-37	Pond close to straightened section of Tallow Ck, Salvinia and duckweed on edges but pond mostly clear. Tanin - stained.
19/04/2023	15:46:12	Tallow Creek	SW pond opposite Shell Service Station	n/a	28	20.9	59.3	5.29	171.8	0.1	121.1	6.23	133.7	8.1	4521-29	Slight flow downstream, brown water, lots of salvinia, lillies and other aquatic macrophytes. Rock/constructed weir at dowstream end of pond just upstream of road crossing. Shell service station just downstream. Some litter observed but not a lot. Big pile of prawn heads next to bus stop - next to council bin
19/04/2023	17:55:07	Tallow Creek	Tallow Ck footbridge	TC18	21	22.7	86.8	7.01	18182	11.3	12357	7.48	38.3	2.9	4557-63	Water clean and clear, lots of excersiging people using track
19/04/2023	17:39:31	Tallow Creek	Tallow Ck mouth	n/a	23	21.7	57.6	4.73	18676	11.9	12968	7.76	99	1.8	4565-70	Clean tanin stained, shorebirds. Group of young adults setting up for (low key) beach party. Some litter
19/04/2023	15:15:00	Tallow Creek	Residential area	n/a	30	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		Residential area - gated and no access to Tallow Ck
19/04/2023	15:55:00	Tallow Creek	Retention basin on Bottlebrush Cres.	n/a	27	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		No entry - construction site
19/04/2023	15:59:00	Tallow Creek	SW swale on Beech Dr.	n/a	27b	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4531	Downstream of 27 retention basin. No visible flow or water. Completely vegetated.
19/04/2023	17:39:31	Tallow Creek	STP ponds	n/a	22	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4546-52	No access to water. Lots of birdlife, ponds looked clear
20/04/2023	16:45	Tallow Creek	Patterson St.	n/a	18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4691	Overflows to Tallow Ck in high flow- pump station
21/04/2023	16:49	Tallow Creek	Patterson St.	n/a	19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4696-98	Overflows to Tallow Ck in high flow - channel dug by NPWS
19/04/2023	14:51:21	Ti-Tree Lake	Small creek on NPWS track	n/a	31	20.4	7.4	0.67	194.2	0.1	138.5	4.07	-14.2	2.1	4516-17	Tanin-stained creek, clear, no flow, high organic matter, very low DO
19/04/2023	14:30	Ti-Tree Lake	Ti-Tree Lake mouth on beach	n/a	33	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4507-08	Outlet viewed from the beach only. Did not go to lake itself due to cutural sensitivites, no wq samples taken. Signs of people
19/04/2023	14:40	Ti-Tree Lake	NPWS track	n/a	32	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4513-15	Sheet metal and other debris dumped on track

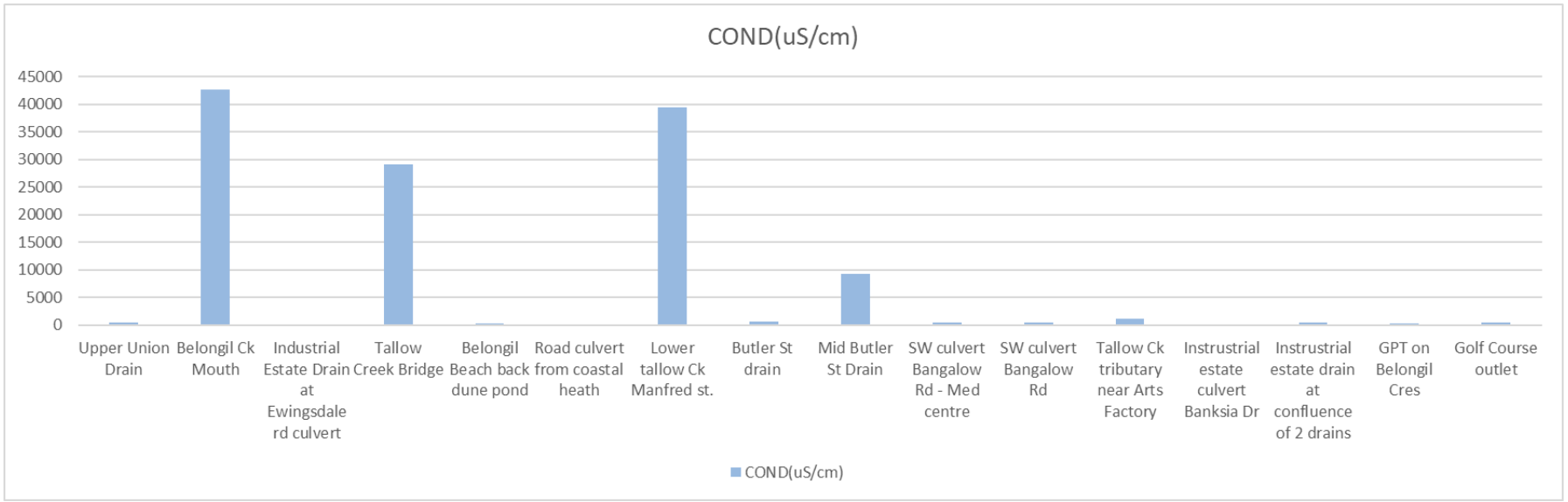
Belongil Creek Catchment Site Inspection April 2023 – Water Quality Data



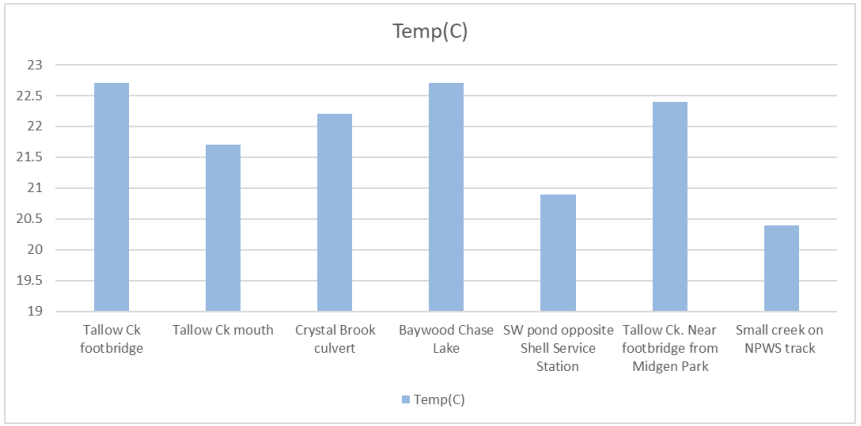


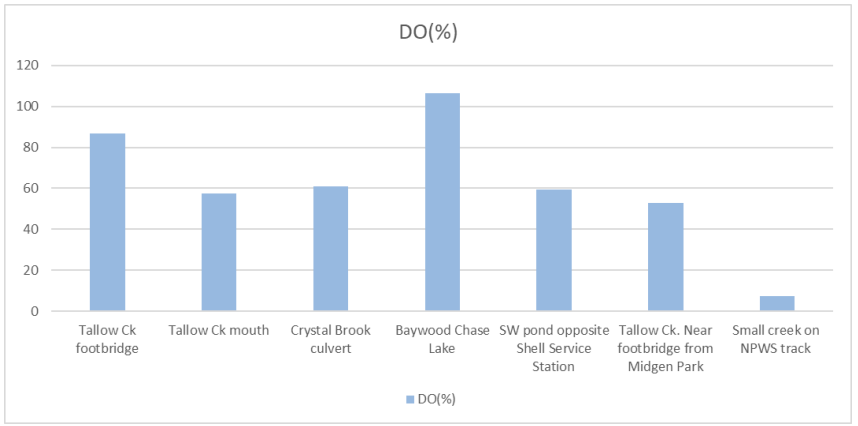

pH
9
8
7
6
5
4
3
2
1
0
Upper Union Drain
Belongil Ck Mouth
Industrial Estate Drain at Ewingsdale rd culvert
Tallow Creek Bridge
Belongil Beach back dune pond
Road culvert from coastal heath
Lower tallow Ck Manfred st.
Butler St drain
Mid Butler St Drain
SW culvert Bangalow Rd - Med centre
SW culvert Bangalow Rd
Tallow Ck tributary near Arts Factory
Instrustrial estate culvert Banksia Dr
Instrustrial estate drain at confluence of 2 drains
GPT on Belongil Cres
Golf Course outlet
pH

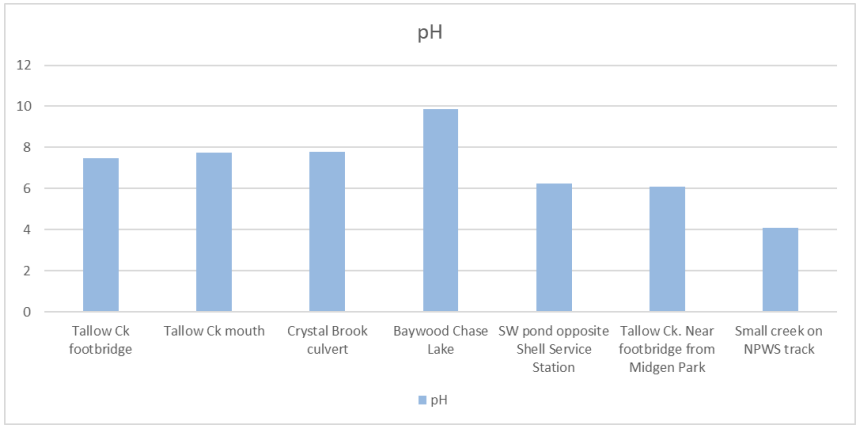

Turbidity (NTU)
1000
900
800
700
600
500
400
300
200
100
0
Upper Union Drain
Belongil Ck Mouth
Industrial Estate Drain at Ewingsdale rd culvert
Tallow Creek Bridge
Belongil Beach back dune pond
Road culvert from coastal heath
Lower tallow Ck Manfred st.
Butler St drain
Mid Butler St Drain
SW culvert Bangalow Rd - Med centre
SW culvert Bangalow Rd
Tallow Ck tributary near Arts Factory
Instrustrial estate culvert Banksia Dr
Instrustrial estate drain at confluence of 2 drains
GPT on Belongil Cres
Golf Course outlet
Turbidity (NTU)

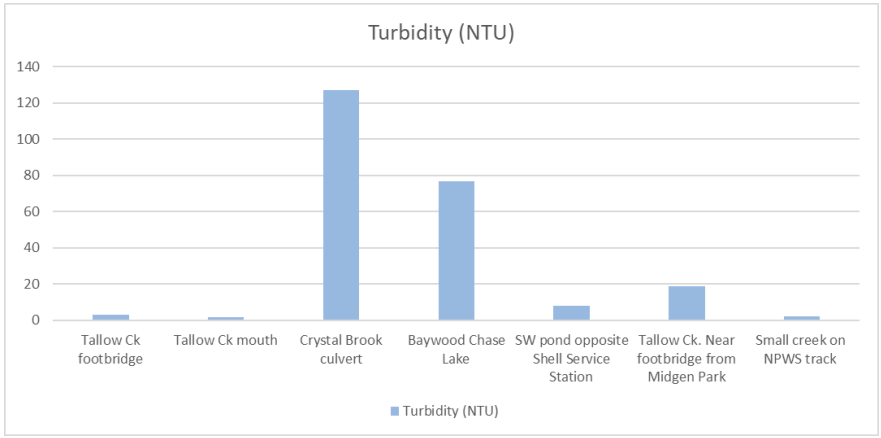

COND(uS/cm)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Upper Union Drain
Belongil Ck Mouth
Industrial Estate Drain at Ewingsdale rd culvert
Tallow Creek Bridge
Belongil Beach back dune pond
Road culvert from coastal heath
Lower tallow Ck Manfred st.
Butler St drain
Mid Butler St Drain
SW culvert Bangalow Rd - Med centre
SW culvert Bangalow Rd
Tallow Ck tributary near Arts Factory
Instrustrial estate culvert Banksia Dr
Instrustrial estate drain at confluence of 2 drains
GPT on Belongil Cres
Golf Course outlet
COND(uS/cm)

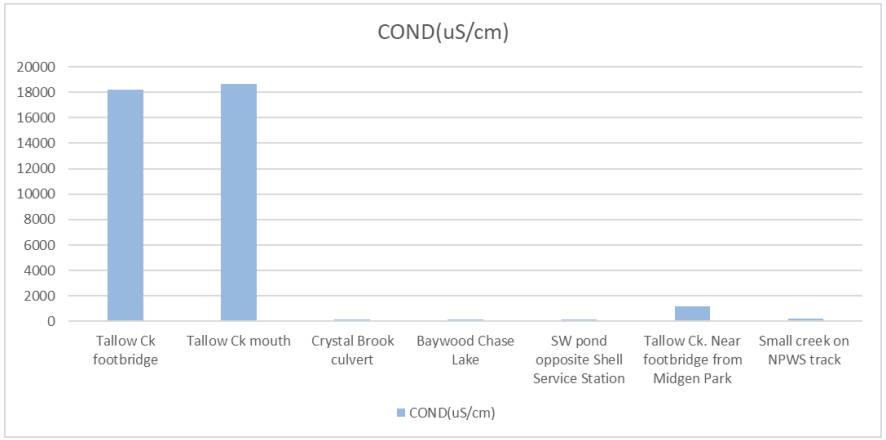
Tallow Creek and Ti-Tree Lake Catchment Site Inspection April 2023 – Water Quality Data










COND(uS/cm)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Tallow Ck footbridge
Tallow Ck mouth
Crystal Brook culvert
Baywood Chase Lake
SW pond opposite Shell Service Station
Tallow Ck. Near footbridge from Midgen Park
Small creek on NPWS track
COND(uS/cm)

APPENDIX 6 WATER QUALITY POLLUTANT SOURCE PRIORITISATION MATRIX

The qualitative assessment of water quality pollutant sources was undertaken using multiple lines of evidence potential options involved scoring against nine different criteria:

1. Effectiveness - being the ability of the option to reduce the risk for which the option has been designed or targeted, or alternatively, the provision of important data or knowledge about the target risk by the option.
2. Technical viability - to highlight where certain options may or may not be technically feasible or would require significant engineering (or other) investigations and construction / implementation capabilities.
3. Ecological sustainability – to identify options with potential for negative or positive environmental impacts in either the short or long term.
4. Stakeholder acceptability – based upon general feedback from stakeholders received and/or documented previously.
5. Meeting Coastal Management Objectives - promoting and achieving the objects of the CM Act and meeting the coastal management objectives.
6. Capital costs to implement the option initially.
7. Ongoing costs per annum.
8. Cost-benefit distribution (private vs public benefit).
9. Legal / Approval Risk - to highlight the legislative and approval requirements (or impediments) to implementing an option within the current legal framework.

The scoring system for the above criteria is outlined in Table 12. Each of the criteria were given equal weighting. The total score for each option was therefore based on a direct addition of scores against each criteria. High scores were generally assigned to options with a high chance of success, low technical difficulty, relatively low cost, and a high level of anticipated stakeholder support.

Table 11: Potential management options coarse assessment scoring system

Score:		-1	0	1
Feasibility	Effectiveness (in addressing direct risks)	Option is unlikely to be effective / substantially reduce targeted risks	Option will not necessarily reduce targeted risk(s) but will provide important knowledge / data about the risk OR Option will bring a minor reduction in the targeted risk(s)	Option will be very effective in eliminating/ reducing/ remediating its target risk(s)

Score:		-1	0	1
	Technical Viability	Is unlikely to be technically viable without substantial engineering (or other) design investigation and capabilities for implementation	Is likely to be technically viable at the site, but would require further investigations to clarify	Is technically viable at the site / location
	Ecological sustainability	Option is likely to have a negative impact on environmental values either directly or indirectly or impacts are unknown	Not expected to have any influence on environmental values	Expected to have a net positive impact on environmental values
Acceptability	Community/ Stakeholder Acceptability	Unlikely to be acceptable to community and politically unpalatable; Extensive community education, endorsement by Minister(s) and Council required	Would be palatable to some, not others (~50/50 response); Briefing to Councillors, GM and community education required	Is very politically palatable, acceptable to community; Minimal education required
	Meeting CMP objectives	Does not meet any CMP objectives	Meets one of the CMP objectives	Meets multiple (>1) CMP objectives
Costs	Capital Costs	High cost (>$300,000)	Moderate cost ($100,000 - $300,000)	Limited cost (<$100,000)
	On-going costs	High cost (>$150,000 p.a.)	Moderate cost ($25,000 - $150,000 p.a.)	Limited cost (<$25,000 p.a.)
	Cost-benefit distribution (public vs. private)	>80% private benefit	50% public, 50% private benefit	>80% public benefit
Approvals	Legal/ Approval Risk	Will require an EIS to implement; There is a residual risk that approval will not be obtainable for the proposed works / strategy	Will require government approvals (e.g. REF) to be implemented	No or minimal government approvals required to implement

Belongil Creek Water Quality Pollutant Source Prioritisation Matrix

		Pollutant Priority Categories - multiple lines of evidence								
ID	Pollutant Source	NSW Estuary Risk Dataset	RCAT	Background Information	Stakeholder feedback	Water Quality Data	Field observations	SCORE (all)	Average Score	RANK
E	Butler Street. Drain - poor quality stormwater			3	3	3	3	12	3.00	1
B	Byron Bay STP - increased flows and nutrient loading			3	2	3		8	2.67	2
D	Byron Bay Town Centre - poor quality stormwater	2	2	2	3	3	3	15	2.50	3
I	Intermittent sewer overflow events			3	2	2		7	2.33	4
K	Litter and marine debris			3	3		1	7	2.33	4
A	ASS impacts - low pH, increased metal concentrations			3	2	3	1	9	2.25	6
C	Byron Bay Arts and Industry Estate - poor quality stormwater	3	3	1	1	2	3	13	2.17	7
G	Agricultural runoff	3	2	2	3	2	1	13	2.17	7
L	Large-scale Salvinia blooms			2	2		2	6	2.00	9
N	Internal water quality processes (e.g. sediment interactions, nutrient cycling etc.)			2	2	2		6	2.00	9
F	Decommissioned Butler St. Landfill site (POEO Act Register listing)			1	1	2		4	1.33	11
H	Construction site runoff - ASS impacts, sediment runoff etc.			1	1	2		4	1.33	11
J	Historical dip sites (3 sites in catchment)			1				1	1.00	13
M	On-site wastewater management systems			1	1			2	1.00	13

Priority	Score
High	3
Medium	2
Low	1
none/ unknown	blank

Tallow Creek Water Quality Pollution Source Prioritisation Matrix

		Pollutant Priority Categories - multiple lines of evidence								
ID	Pollutant Source	NSW Estuary Risk Dataset	RCAT	Background Information	Stakeholder feedback	Water Quality Data	Field observations	SCORE (all)	Average Score	RANK
A	Baywood Chase Lake - blue-green algae, pathogens and bacteria, nutrients and low dissolved oxygen			3	3	3	3	12	3.00	1
B	Urban residential areas - poor quality stormwater			3	2	3	2	10	2.50	2
I	Litter and marine debris			2	3		2	7	2.33	3
G	Intermittent sewer overflow events			2	2	2		6	2.00	4
J	Internal water quality processes (e.g. sediment interactions, nutrient cycling etc.)			2	2	2		6	2.00	4
K	Large-scale Salvinia blooms				2	2		4	2.00	4
C	ASS impacts – low pH, increased metal concentrations			1	1	2		4	1.33	7
D	Decommissioned South Byron STP site			1	2	1		4	1.33	7
F	Construction site runoff (ASS impacts, sediment runoff)			1	1	2	1	5	1.25	9
E	Service Station			1				1	1.00	10
H	Historical dip sites			1				1	1.00	10
L	On-site wastewater management systems			1	1			2	1.00	11

Priority	Score
High	3
Medium	2
Low	1
none/ unknown	blank

Ti-Tree Lake Water Quality Pollutant Source Prioritsation Matrix

		Pollutant Priority Categories - multiple lines of evidence								
ID	**Pollutant Source**	**NSW Estuary Risk Dataset**	**RCAT**	**Background Information**	**Stakeholder feedback**	**Water Quality Data**	**Field observations**	**SCORE (all)**	**Average Score**	**RANK**
D	Recreational use of the lake – pollution, cultural impacts.			1	2		2	5	1.67	1
B	Decommissioned Broken Head Quarry (POEO Act Register listing)			2	1			3	1.50	2
C	Litter and marine debris			1	2		1	4	1.33	3
A	Urban residential areas - poor quality stormwater, road runoff, litter			1	1		1	3	1.00	4

Priority	**Score**
High	3
Medium	2
Low	1
none/ unknown	blank

APPENDIX 7 POTENTIAL MANAGEMENT OPTION ASSESSMENT

The qualitative assessment of potential options involved scoring against nine different criteria:

10. Effectiveness - being the ability of the option to reduce the risk for which the option has been designed or targeted, or alternatively, the provision of important data or knowledge about the target risk by the option.
11. Technical viability - to highlight where certain options may or may not be technically feasible or would require significant engineering (or other) investigations and construction / implementation capabilities.
12. Ecological sustainability – to identify options with potential for negative or positive environmental impacts in either the short or long term.
13. Stakeholder acceptability – based upon general feedback from stakeholders received and/or documented previously.
14. Meeting Coastal Management Objectives - promoting and achieving the objects of the CM Act and meeting the coastal management objectives.
15. Capital costs to implement the option initially.
16. Ongoing costs per annum.
17. Cost-benefit distribution (private vs public benefit).
18. Legal / Approval Risk - to highlight the legislative and approval requirements (or impediments) to implementing an option within the current legal framework.

The scoring system for the above criteria is outlined in Table 12. Each of the criteria were given equal weighting. The total score for each option was therefore based on a direct addition of scores against each criteria. High scores were generally assigned to options with a high chance of success, low technical difficulty, relatively low cost, and a high level of anticipated stakeholder support.

Table 12: Potential management options coarse assessment scoring system

Score:		-1	0	1
Feasibility	Effectiveness (in addressing direct risks)	Option is unlikely to be effective / substantially reduce targeted risks	Option will not necessarily reduce targeted risk(s) but will provide important knowledge / data about the risk OR Option will bring a minor reduction in the targeted risk(s)	Option will be very effective in eliminating/ reducing/ remediating its target risk(s)

Score:		-1	0	1
	Technical Viability	Is unlikely to be technically viable without substantial engineering (or other) design investigation and capabilities for implementation	Is likely to be technically viable at the site, but would require further investigations to clarify	Is technically viable at the site / location
	Ecological sustainability	Option is likely to have a negative impact on environmental values either directly or indirectly or impacts are unknown	Not expected to have any influence on environmental values	Expected to have a net positive impact on environmental values
Acceptability	Community/ Stakeholder Acceptability	Unlikely to be acceptable to community and politically unpalatable; Extensive community education, endorsement by Minister(s) and Council required	Would be palatable to some, not others (~50/50 response); Briefing to Councillors, GM and community education required	Is very politically palatable, acceptable to community; Minimal education required
	Meeting CMP objectives	Does not meet any CMP objectives	Meets one of the CMP objectives	Meets multiple (>1) CMP objectives
Costs	Capital Costs	High cost (>$300,000)	Moderate cost ($100,000 - $300,000)	Limited cost (<$100,000)
	On-going costs	High cost (>$150,000 p.a.)	Moderate cost ($25,000 - $150,000 p.a.)	Limited cost (<$25,000 p.a.)
	Cost-benefit distribution (public vs. private)	>80% private benefit	50% public, 50% private benefit	>80% public benefit
Approvals	Legal/ Approval Risk	Will require an EIS to implement; There is a residual risk that approval will not be obtainable for the proposed works / strategy	Will require government approvals (e.g. REF) to be implemented	No or minimal government approvals required to implement

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility			Feasibility total	Acceptability		Acceptability total	Cost			Cost total	Approvals	CA* score	Responsibility	Further consideration in Stage 3
					Effectiveness (at addressing risks)	Techincal Viability	Ecological Sustainability		Community/ Stakeholder Acceptability	Meeting CMP objectives		Capital Costs	Ongoing Cost	Cost benefit distribution (public:private)		Legal /approval risk			
E	1	Butler Street Drain - poor quality stormwater	• 'Source to Sea' project	Continue and/or expand 'Source to Sea' project if the trial is successful and considered sustainable.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes - dependent on outcomes of trial due to finish May 2024.
			• Illegal Dumping and Litter Education and Enforcement Plan (IDLEEP) for 2024 – 2029.	Update and implement IDLEEP for 2024-2029.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes
			• Byron Bay Drainage Strategy (under development)	Investigate feasibility of a constructed wetland located at Butler Street Drain as part of Byron Bay Drainage Strategy update.	1	0	1	2	1	1	2	0	0	1	1	-1	4	BSC	Yes
			• Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021)	Review and upgrade/improvement of urban stormwater infrastructure throughout catchment as part of Byron Bay Drainage Strategy. Includes transitioning existing concrete drainage to WSUD when road upgrade/ development occurs (e.g. rain gardens, biofiltration etc.)	1	0	1	2	1	1	2	0	0	1	1	0	5	BSC	Yes - acknowledging the Byron Bay Drainage Strategy is the appropriate mechanism for consideration of this option. Any related action should be referenced in the CMP.
			• BSC Water Quality Monitoring Program	Implement strategies A and C of BSC WSUD Policy.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
				Enhanced monitoring and maintenance of sewage infrastructure – as for I below.	Refer ID: I														
				Urban stormwater quality improvement community education campaign.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes
B	2	Byron Bay STP – increased flows and nutrient loading	• NSW EPA Licence 3404 monitoring and management, BBIWMR	Options to minimise BBSTP discharge of pollutants (primarily nutrients) to Belongil Creek including: increasing reuse of wastewater (e.g. Effluent Reuse Strategy 2017-2027). Explore options for improved effluent treatment at BBSTP, to enhance nutrient removal. Offsets through riparian / wetland restoration (e.g. on Crown land, or freehold land through agreements, or purchase of land for offsets). Consider holistic approach and integrate with floodplain restoration	1	1	1	3	1	1	2	-1	-1	1	-1	1	5	BSC - This should be considered through the current IWCM process currently underway.	Yes – acknowledging the IWCM is the appropriate mechanism for consideration of this option. Any related action considered as part of the IWCM should be referenced in the CMP.
				Investigate the potential presence and impact of EDCs on Belongil Creek ICOLL	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
D	3	Byron Bay Town Centre - poor quality stormwater	• 'Source to Sea' project	Continuation of Source to Sea project – as for E above.	Refer ID: E														
			• IDLEEP for 2024 – 2029.	Update and implement IDLEEP for 2024-2029.	Refer ID: E														
			• Byron Bay Drainage Strategy (under development).	Investigate feasibility of a constructed wetland located at Butler Street Drain as part of Byron Bay Drainage Strategy update.	Refer ID: I														
			• Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021).	Review and upgrade/improvement of urban stormwater infrastructure throughout catchment as part of Byron Bay Drainage Strategy. Includes transitioning existing concrete drainage to WSUD when road upgrades / development occurs (e.g. rain gardens, biofiltration etc.)	Refer ID: E														
			• BSC Water Quality Monitoring Program	Implement strategies A and C of BSC WSUD Policy.	Refer ID: E														
				Enhanced monitoring and maintenance of sewage infrastructure – as for I below.	Refer ID: E														
I	4	Periodic sewer overflow events	• NSW EPA Licence 3404 monitoring, maintenance, reporting and management.	Enhanced monitoring and maintenance of sewage infrastructure to minimise sewage system failures related to trade waste discharges, illegal stormwater to sewer connections, wet weather inflow and infiltration and sewage system performance. Particular attention to be given to locations in the vicinity of the sites highlighted as part of this review (e.g. SPS3001 catchment, Butler Street Drain etc).	1	1	1	3	1	1	2	0	0	1	1	1	7	BSC - This should be undertaken through the current IWCM process currently underway.	Yes – acknowledging the IWCM is the appropriate mechanism for consideration of this option. Any related action considered as part of the IWCM should be referenced in the CMP.

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility			Feasibility total	Acceptability		Acceptability total	Cost			Cost total	Approvals	CA* score	Responsibility	Further consideration in Stage 3
					Effectiveness (at addressing risks)	Techincal Viability	Ecological Sustainability		Community/ Stakeholder Acceptability	Meeting CMP objectives		Capital Costs	Ongoing Cost	Cost benefit distribution (public:private)		Legal /approval risk			
			• BSC Water Quality Monitoring Program.	Conduct a targeted microbial source tracking study to identify sources of faecal contamination (i.e. human vs. other animal sources) and assist in directing management action.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
K	4	Litter and marine debris	• 'Source to Sea' project • IDLEEP for 2024 – 2029. • Clean up campaigns by various organisation and volunteer groups (e.g. KLIS, AUS LM, Tangaroa Blue clean ups etc.) • MEM Strategy Actions	Continuation of Source to Sea project – as for E above.	Refer ID: E														
				Update and implement IDLEEP for 2024-2029.	Refer ID: E														
				Continue regular litter clean up campaigns.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC and other organisations / volunteer groups	Yes
				Continue litter surveys to monitor progress through time.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC and other organisations / volunteer groups	Yes
				Continue to develop and implement litter and illegal dumping education campaigns in collaboration with North East Waste and the NSW EPA. With specific focus on visitors and tourism sector.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC North East Waste and the NSW EPA	Yes
A	6	ASS runoff	• BSC monitoring and management of construction activities / DA condition enforcement. • BSC Water Quality Monitoring Program	Enhanced monitoring and management of construction activities involving excavation of soil within ASS risk areas, particularly large-scale developments with high risk of harm to downstream sensitive environments (e.g. Harvest/ West Byron subdivision).	1	1	1	3	1	1	2	0	0	1	1	1	7	BSC	Yes
				Investigate suitability for Blue Carbon projects on the floodplain (i.e. reintroduce tidal flows to an area of land through removal of drain/levee or other type of flow restriction). Online tools including BlueCAM can be used to calculate carbon credits.	0	0	0	0	1	1	2	0	1	1	2	1	5	BSC	Yes – acknowledging low feasibility score reflecting need for further investigations into viability and ecological impact on freshwater wetland areas.
				Modify drain morphology (e.g. drain shallowing and widening or use of rock weirs etc.) to maintain higher groundwater levels and reduce the prevalence of ASS runoff. Requires identification of suitable sites in collaboration with landholders / land managers. Locations in the vicinity of the Upper Union Drain are key areas to target.	1	1	1	3	0	1	1	0	0	1	1	1	6	BSC	Yes – acknowledging low CA score reflecting additional investigation required to clarify technical viability, likely high cost and approval requirements and low acceptability for some stakeholders.
				Long-term land use transition strategies for low-lying areas with high ASS risk.	1	1	1	3	0	1	1	-1	1	1	1	0	5	BSC	Yes
				Buy-back and wetland restoration schemes of agricultural lands with high ASS risk.	1	0	1	2	0	1	1	-1	0	1	0	1	4	BSC	Yes
				Collaborate with Belongil Catchment Drainage Board to address ASS issues.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes
C	7	Byron Bay Industrial Estate - poor quality stormwater	• Council Environmental Health Group inspections and enforcement of non-compliant practices (limited resources has prevented recent programs). • 'Source to Sea' project. • Byron Bay Drainage Strategy. • BSC Water Quality Monitoring Program.	Increased resourcing of Environmental Health Group for inspections of premises / businesses and where necessary issue of enforcement orders for non-compliance.	1	1	1	3	1	1	2	0	0	1	1	1	7	BSC	Yes
				Continuation of Source to Sea project – as for E above.	Refer ID: E														
				Update and implement IDLEEP for 2024-2029.	Refer ID: E														
				Stormwater treatment improvements within the Byron Bay Arts and Industry Estate.	1	0	1	2	1	1	2	-1	0	1	0	1	5	BSC	Yes
				Enhanced monitoring and management of construction activities involving excavation of soil within ASS risk area – as for A above.	Refer ID: A														
				Long-term land use transition strategies for agricultural land on the floodplain.	1	1	1	3	0	1	1	-1	1	1	1	0	5	BSC	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility			Feasibility total	Acceptability		Acceptability total	Cost			Cost total	Approvals	CA* score	Responsibility	Further consideration in Stage 3
					Effectiveness (at addressing risks)	Techincal Viability	Ecological Sustainability		Community/ Stakeholder Acceptability	Meeting CMP objectives		Capital Costs	Ongoing Cost	Cost benefit distribution (public:private)		Legal /approval risk			
G	8	Agricultural runoff – sediment and nutrient runoff	• BSC Water Quality Monitoring Program.	Buy-back and wetland restoration scheme for floodplain agricultural lands. Examples could include: Offset scheme for current and future WWTP nutrient export to the catchment. WWTP levy (rate payers and visitors) to fund buy back of agricultural lands. Wetland restoration as blue carbon project to sequester carbon and nutrients to offset the increasing impacts from WWTP.	1	0	1	2	0	1	1	-1	-1	1	-1	0	2	BSC	Yes
				Targeted education program working with agricultural industries on reduced fertiliser / pesticide / herbicide use.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
				Working with Belongil Catchment Union Board to improve point and diffuse source pollutants.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes
				Rehabilitate riparian zones and degraded areas including revegetation, assisted bush regeneration, and cattle exclusion from waterways where applicable. Key areas are: Upper Union Drain, Moran's Hill and mid-floodplain drains and waterways. Investigate incentive schemes/ partnerships with landholders for rehabilitation projects as part of the CMP (e.g. Grants/ River Reach programs etc.)	1	1	1	3	1	1	2	0	0	0	0	1	6	BSC	Yes
				Conduct a microbial source tracking study to identify sources of faecal contamination (i.e. human vs. cattle vs. other animal sources) and assist in directing management action.	Refer ID: I														
H	9	Construction site runoff - ASS impacts, sediment runoff	• Council oversight and enforcement of DA conditions.	Enhanced monitoring and management of construction activities involving excavation of soil within ASS risk area – as for A above. Particularly areas involving large-scale developments (e.g. Harvest/West Byron) with potential for significant water quality impacts on downstream receiving environments.	Refer ID: A														
			• Water quality monitoring program	Targeted erosion and sediment control education program run over a two year period which aims to educate and regulate the industry to effect cultural.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
F	9	Decommissioned Butler St. Landfill site (POEO Act Register listing)	Ongoing NSW EPA and BSC monitoring and management including PFAS investigations.	Continue investigations in line with NSW EPA directions. Report results and progress.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC and NSW EPA	Yes -acknowledging the EPL is the appropriate mechanism for this option. Any related action(s) should be referenced in the CMP.
J	11	Historical dip sites (POEO Act Register listing, 3 sites in catchment)	No active management	Pesticide water quality sampling and analysis within estuary to detect whether chemicals listed as used in dips are present in estuary water.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes

TALLOW CREEK POTENTIAL MANAGEMENT OPTION ASSESSMENT MATRIX

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility			Feasibility total	Acceptability		Acceptibility total	Cost			Cost Total	Approvals	CA* score	Responsibility	Further consideration in Stage 3
					Effectiveness (at addressing risks)	Techincal Viability	Ecological Sustainability		Community/ Stakeholder Acceptability	Meeting CMP objectives		Capital Costs	Ongoing Cost	Cost benefit distribution (public:private)		Legal /approval risk			
A	1	Baywood Chase Lake - blue-green algae, pathogens and bacteria, nutrients and low dissolved oxygen	• Baywood Chase Management Plan (AWC, 2018) • Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021) • Byron Bay Drainage Strategy (under development) • BSC Water Quality Monitoring Program • Byron ICOLL Research Centre initiatives including citizen science monitoring	Solar powered artificial aeration (Rank: 2 AWC, 2018)	1	1	1	3	0	1	1	1	1	1	3	0	7	BSC	Yes
				Rehabilitate sediment basin adjacent to lake (Rank: 2, AWC, 2018)	0	1	1	2	1	1	2	0	1	1	2	1	7	BSC	Yes
				Weed removal and native plantings including shade trees and habitat restoration (Rank 3, AWC, 2018)	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
				Create and install vegetated swales (Rank 4, AWC, 2018)	1	0	1	2	1	1	2	0	1	1	2	0	6	BSC	Yes
				Recirculation to treatment wetland and swale (Rank 4, AWC, 2018)	1	0	1	2	1	1	2	-1	0	1	0	1	5	BSC	Yes
				Bird management - island re-shaping/ removal (Rank 5, AWC, 2018)	0	0	-1	-1	0	0	0	0	1	1	2	1	2	BSC	Yes – noting low feasibility score reflecting need for further investigation of viability and likely negative impact on native bird habitat.
				Bioremediation tablets (Rank 5, AWC, 2018)	-1	1	0	0	0	0	0	1	1	0	2	1	3	BSC	Not recommended
				Baffle inlets (Rank 6, AWC, 2018)	0	0	0	0	0	1	1	1	1	1	3	1	5	BSC	Yes
				Install benches and plant with macrophytes (Rank 7, AWC, 2018)	1	0	1	2	1	1	2	-1	0	1	0	1	5	BSC	Yes
				Lower outlets (Rank 8, AWC, 2018)	0	0	0	0	0	0	0	1	1	0	2	-1	1	BSC	Not recommended
				Sediment treatment/ capping	1	0	0	1	0	0	0	1	1	1	3	1	5	BSC	Yes – noting further investigation required.
				Removal of contaminated sediments	1	0	0	1	0	0	0	-1	0	1	0	0	1	BSC	Not recommended
				Partial infilling or complete removal of lake and replacement with high efficiency treatment system and additional public open space.	1	1	1	3	1	1	2	-1	0	1	0	0	5	BSC	Yes
				Review and upgrade/improvement of urban stormwater infrastructure throughout catchment e. Includes transitioning existing concrete drainage to WSUD when road upgrades/ development occurs (e.g. rain gardens, biofiltration etc.)	1	0	1	2	1	1	2	0	0	1	1	0	5	BSC	Yes
				Design and implement a monitoring program for pre and post any remediation works at Baywood Chase Lake to assess effectiveness of actions.	0	1	1	2	1	1	2	1	0	1	2	1	7	BSC	Yes
B	2	Urban residential areas - poor quality stormwater	• 'Source to Sea' project	Potential expansion of Source to Sea project in Tallow Creek Catchment (if trial in Byron Bay is successful)	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes - dependent on outcomes of trial due to finish May 2024.
			• IDLEEP for 2024 – 2029.	Update and implement IDLEEP for 2024-2029.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes
			• Byron Bay Drainage Strategy (under development).	Review and upgrade/improvement of urban stormwater infrastructure throughout catchment e. Includes transitioning existing concrete drainage to WSUD when road upgrades/ development occurs (e.g. rain gardens, biofiltration etc.)	Refer ID: A														
			• Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021).	Implement strategies A and C of BSC WSUD Policy.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
			• BSC Water Quality Monitoring Program	Enhanced monitoring and maintenance of sewage infrastructure – as for ID: G below.	Refer ID: G														
			• Byron ICOLL Research Centre initiatives including citizen science monitoring	Urban stormwater quality improvement community education campaign.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes
I	3	Litter and marine debris	• 'Source to Sea' project	Potential expansion of Source to Sea project in Tallow Creek Catchment – as for B above.	Refer ID: B														
			• IDLEEP for 2024 – 2029.	Update and implement IDLEEP for 2024-2029.	Refer ID: B														
			• Clean up campaigns by various organisation and volunteer groups (e.g. KLIS, AUS LM, Tangaroa Blue clean ups etc.) MEM Strategy Actions	Continue litter clean up campaigns.	Refer ID: B														
				Continue surveys to monitor progress through time.	Refer ID: B														
				Continue to develop and implement litter and illegal dumping education campaigns in collaboration with North East Waste and the NSW EPA. With specific focus on visitors and tourism sector.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC North East Waste and the NSW EPA	Yes

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option for consideration	Feasibility			Feasibility total	Acceptability		Acceptibility total	Cost			Cost Total	Approvals	CA* score	Responsibility	Further consideration in Stage 3
					Effectiveness (at addressing risks)	Techincal Viability	Ecological Sustainability		Community/ Stakeholder Acceptability	Meeting CMP objectives		Capital Costs	Ongoing Cost	Cost benefit distribution (public:private)		Legal /approval risk			
G	4	Intermittent sewer overflow events	NSW EPA Licence 3404 monitoring, maintenance, reporting and management.	Enhanced monitoring and maintenance of sewage infrastructure within the ICOLL catchments (considered to be high value receiving environments) to minimise sewage system failures related to trade waste discharges, illegal stormwater to sewer connections, wet weather inflow and infiltration and sewage system performance.	1	1	1	3	1	1	2	0	0	1	1	1	7	BSC - This should be undertaken through the current IWCM process currently underway.	Yes – acknowledging the IWCM is the appropriate mechanism for consideration of this option. Any related action considered as part of the IWCM should be referenced in the CMP.
				Microbial source tracking to identify sources of faecal contamination (i.e. human vs. other animal sources) and assist in directing management action.	0	1	0	1	1	1	2	1	1	1	3	1	7	BSC	Yes
J	4	Internal water quality processes (e.g. sediment interactions, nutrient cycling etc.)	None	No actions reccommended															
K	4	Large-scale Salvinia blooms	Salvinia monitoring and management in accordance with Salvinia control manual/ DPI and Rous County Council recommendations	Continue Salvinia monitoring and management in accordance with Salvinia control manual/ DPI and Rous County Council recommendations (i.e. Biological control using Salvinia Weevil)	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC/ DPI/ RCC	Yes
D	7	Decommissioned South Byron STP site	• Ongoing investigations to assess impact on Tallow Creek	Further testing of sites in Tallow Creek was recommended by Cavvanba (2023) to confirm that groundwater is not having an influence on nutrient and heavy metal concentrations in Tallow Creek.	0	1	0	1	1	1	2	1	1	1	3	1	7	BSC	Yes
C	7	ASS runoff	• BSC monitoring and management of construction activities / DA condition enforcement.	Continue monitoring and management of construction activities involving excavation of soil within ASS risk areas.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC	Yes
F	9	Construction site runoff (ASS impacts, sediment runoff)	• Council oversight/enforcement of construction phase and DA conditions.	Enhanced monitoring and management of construction sites, particularly large-scale developments with potential for significant water quality impacts on downstream receiving environments.	1	1	1	3	1	1	2	0	0	1	1	1	7	BSC	Yes
E	10	Service Station (POEO Act Register listing)	• No active management – NSW EPA has determined regulation under the CM Act is not required.	No further actions recommended	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H	10	Historical dip sites (POEO Act Register listing, 1 site in catchment)	• No active management	No further actions recommended	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TI-TREE LAKE POTENTIAL MANAGEMENT OPTION ASSESSMENT MATRIX

ID	Rank	Water Quality Pollutant Source	Current/ planned management	Potential management option	Feasibility				Acceptability			Cost				Approvals	CA* score	Responsibility	Further consideration in Stage 3
					Effectiveness (at addressing risks)	Techincal Viability	Ecological Sustainability	Feasibility total	Community/ Stakeholder Acceptability	Meeting CMP objectives	Acceptibility total	Capital Costs	Ongoing Cost	Cost benefit rdistribution (public:private)	Cost Total	Legal /approval risk			
D	1	Recreational use of the lake – pollution, cultural impacts.	• Ti Tree Lake Preliminary Draft Management Plan (NPWS, 2015)	• Education regarding ecological and cultural values (e.g. signage, media campaigns etc.)	0	1	1	0	1	1	2	1	1	1	3	1	6	Jali/ NPWS/ BSC	Yes
B	2	Decommissioned Broken Head Quarry (POEO Act Register listing)	• Environmental Protection License 4860 monitoring, maintenance, reporting and management.	• Continue monitoring of sediment basin outlet, maintenance, reporting and management in line with EPL 4860.	0	1	1	2	1	1	2	1	1	1	3	1	8	EPA/ Ledonne Constructions	Yes
				• Water quality monitoring downstream of the sediment basin outlet and in Ti-Tree Lake to assist in determining any ongoing impact from the quarry site.	0	1	1	2	1	1	2	1	1	1	3	1	8	Jali/ NPWS/ BSC	Yes
C	3	Marine litter and debris	• Illegal Dumping and Litter Education and Enforcement Plan (IDLEEP) for 2024 – 2029. • Clean up campaigns by various organisation and volunteer groups (e.g. KLIS, AUS LM, Tangaroa Blue clean ups etc.)	• Update and implement IDLEEP for 2024-2029.	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes
			• MEM Strategy Actions	• Continue litter clean up campaigns.	1	1	1	3	1	1	2	1	1	1	3	1	9	BSC and other organsations and volunteer groups	Yes
A	4	Urban residential areas - poor quality stormwater	• Byron Shire Council WSUD Policy and Strategy (BMT WBM, 2021).	Review and upgrade/ improvement of urban stormwater infrastructure throughout catchment. Includes transitioning existing concrete drainage to WSUD when road upgrades/ developed occurs (e.g. rain gardens, biofiltration etc.)	0	1	1	2	1	1	2	1	1	1	3	1	8	BSC	Yes