BLIGH TANNER

2020.0659-RP01- IMPROVING THE WATER QUALITY OF EMILY BAY, NORFOLK ISLAND

REPORT

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CONTENTS

FIGURES

TABLES

APPENDICES

1 INTRODUCTION

The coral reefs at Norfolk Island's Emily and Slaughter Bays are in poor health, due to historic and ongoing wastewater management issues. A recent stormwater event has highlighted the issue of polluted water upstream of Emily Bay.

It is believed that the damage to the reefs may be irreversible should a major algal bloom occur during the 2020/21 summer. This is possible given the summer will likely bring increased rainfall associated with a predicted la Nina cycle. Increased rainfall could further mobilise pollutants in both surface waters and groundwater. Models suggest the possibility that warmer than average sea-water temperatures may also eventuate, contributing to both poor coral health (possible bleaching event), and rapid algal overgrowth (preventing recovery).

A collapse in the health of the reef could then result in its structural degradation which could expose Emily Bay to erosive coastal processes.

Emily and Slaughter Bays are part of Norfolk Marine Park and are an important community and tourism asset. They are directly adjacent to an internationally significant UNESCO World Heritage site.

Parks Australia has commissioned this report as an early first step in what will need to be a catchment management approach addressing stormwater pollution in the KAVHA catchment. Their role is to provide for:

- the protection and conservation of biodiversity and other natural, cultural and heritage values of Norfolk Marine Park (Temperate East network); and
- the ecologically sustainable use and enjoyment of the natural resources within Norfolk Marine Park (Temperate East network), where this is consistent with the above.

Parks Australia seeks to work with land managers to support action upstream of the marine park (on land outside their jurisdiction).

This report investigates options for the management of polluted water to protect the health of the lagoon at Emily and Slaughter Bay.

1.1 Context

Norfolk Island is an external Australian territory located 1400 km east of the Australian coastline. The island is a region with high cultural value, with a deep and complex history of Polynesian and British Settlement, and home to the *UNESCO World Heritage Kingston and Arthur Vale's Historical Area (KAHVA).* Large parts of the island also discharge into Emily Bay which is part of Norfolk Marine Park and has high conservation value, consisting of multiple species and habitats protected under the Environment Protection and Biodiversity Conservation Act (1999).

Burnt Pine is the island's primary township.

Emily and Slaughter Bay on the southern coast receives runoff from the Upper Cascade Creek and Watermill Creek catchments, which are two of the largest catchments on the island. Town Creek is one of the lowest parts of the island and discharges into the bay when the plug is open. Historically, Town Creek drained into a swamp which prevented the direct outflow of surface waters into the bay. This swamp filtered surface water as it percolated into the groundwater system. The channel was first cut to drain the swamp in 1789 (GML Heritage and Context, 2019).

The island is also underlain by an aquifer, which is used for domestic, commercial, and agricultural purposes. Groundwater generally flows south and upwells at the intertidal zone on Emily Bay.

Figure 1: Norfolk Island context map (aerial image provided by CSIRO).

1.2 Existing Water Quality

1.2.1 Sewerage Treatment Plant

The island's sewerage treatment plant (STP) is located west of *Norfolk Island International Airport* (Figure 1). This is a secondary treatment plant, consisting of a rotating biological contractor and clarifier, but is in extremely poor condition such that "treated effluent quality is only marginally higher quality than raw waste" (Balmoral Group Australia and Public Works Advisory, 2019). Effluent is released into an ocean outfall at Headstone Reserve and undergoes dilution with surrounding ocean waters.

The STP services approximately 250 properties in the Burnt Pine township as part of the Water Assurance Scheme.

Pollution Incident

In late July 2020, a combination of floating pump failure and tree root penetration resulted in an isolated release of sewerage onto the surrounding grass. Both the floating pump and damaged sewerage assets have been repaired and effluent is now being discharged to the ocean outfall. Overflowing sewerage was released to the gravelled surface surrounding the STP.

Most properties on the island are not connected to the *Water Assurance Scheme* and operate private septic tanks. Of the approximate 1000 tanks installed on the island, Norfolk Island

Regional Council (NIRC) believes that up to a quarter may be failing, and that most would not satisfy required setback distances from waterways and boreholes. Areas where septic tanks may be suspected of contributing to the poor quality of surface and groundwater are presented below. NIRC believes that there are 138 septic tanks (excluding the KAVHA site itself) that directly discharge effluent into the KAVHA boundary (Figure 2).

The poor condition of these systems, as well as their proximity to waterways, has led to groundwater contamination, and poses a risk to the health of Slaughter and Emily Bays downstream.

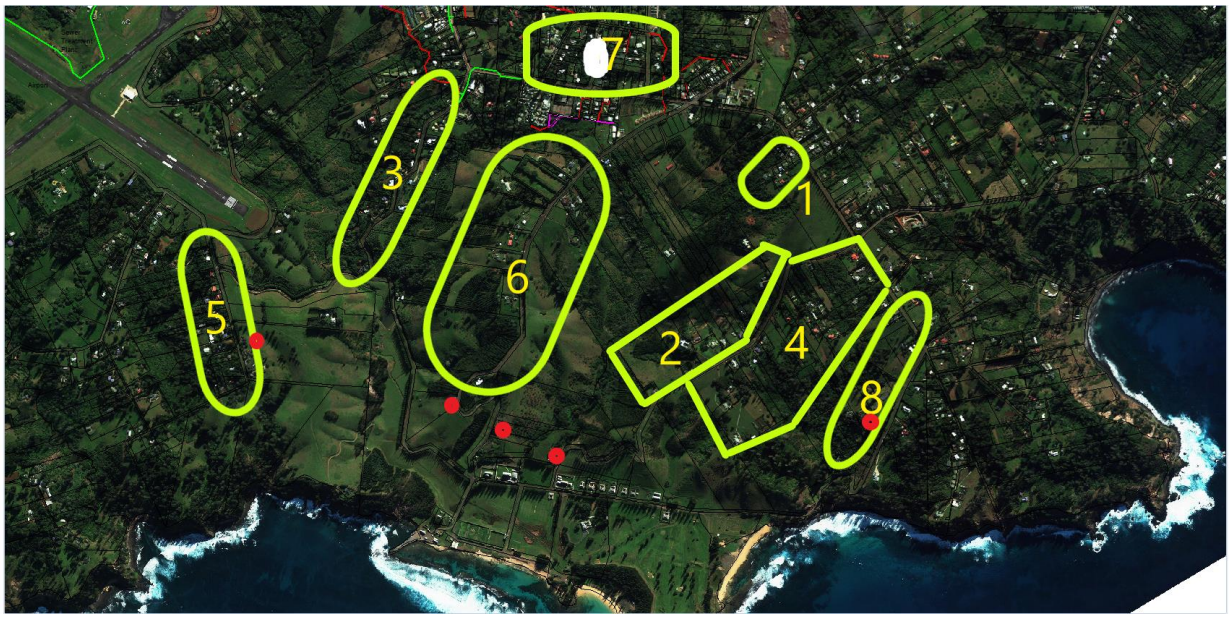


Figure 2: Areas at high risk of septic tank leaks (NIRC). Red dots indicate tourist accommodation properties.

1.2.2 Groundwater

The behaviour and condition of the groundwater systems on Norfolk Island are poorly studied.

Dye tracer tests undertaken by the Department of Local Government and Department of Housing and Construction (1982) identified very rapid groundwater flows (up to 40 m/hr), representing a residence time of several hours. The study recognised that the test boreholes were likely located above a preferential flowpath, which contributed to the high velocities. However, as Norfolk Island is underlain by multiple complex geologic systems, the calculated residence times are unlikely to be representative of the whole-of-island groundwater system (per comms Peterson, 2020). That is, the residence time of groundwater is uncertain.

The extent to which pollutants are attenuated within the aquifer systems is also unknown. CSIRO recently tested the water quality of 20 existing boreholes on the island, some of which have been previously investigated as part of a 2007 Council study. Cross referencing the datasets demonstrated some capacity for groundwater quality improvement. However, the extent of improvement, the pollutants attenuated, and the location of these samples cannot be disclosed.

Lastly, groundwater samples collected by CSIRO also detected the presence of PFAS in the Mission Creek catchment area (adjacent to Norfolk Island International Airport). The extent of potential PFAS contamination and remediation strategies are currently being investigated by the Department of Infrastructure, Transport, Cities and Regional Development, Senversa, and Council.

1.2.3 Surface Waters

Most surface water on the island flows south via Upper Cascade Creek, Watermill Creek, and Town Creek. The high presence of agricultural activities, in combination with previous unrestricted livestock access, contributes to poor surface water quality. It is noted that recent cattle restrictions near Watermill Creek has anecdotally encouraged vegetation regrowth along the waterway.

These creeks converge at Town Creek Wetland in the Kingston Common area. A sluice gate has been installed upstream of the Emily Bay plug to prevent ongoing release of this water. Nutrient concentrations of Town Creek (downstream of the wetland) are low, although previous investigations have highlighted high nutrient concentrations in the wetland itself (Wilson, 2017).

Cross sections were produced to understand the cross-sectional geometry of Watermill and Town Creek. This indicates that the creek depth ranges from 1.1 m (upstream of Bounty Road) to 0.2 m (upstream of the Emily Bay plug). The wetland is approximately 70 m at its widest. Refer to the Figure 3 for indicative cross sections.

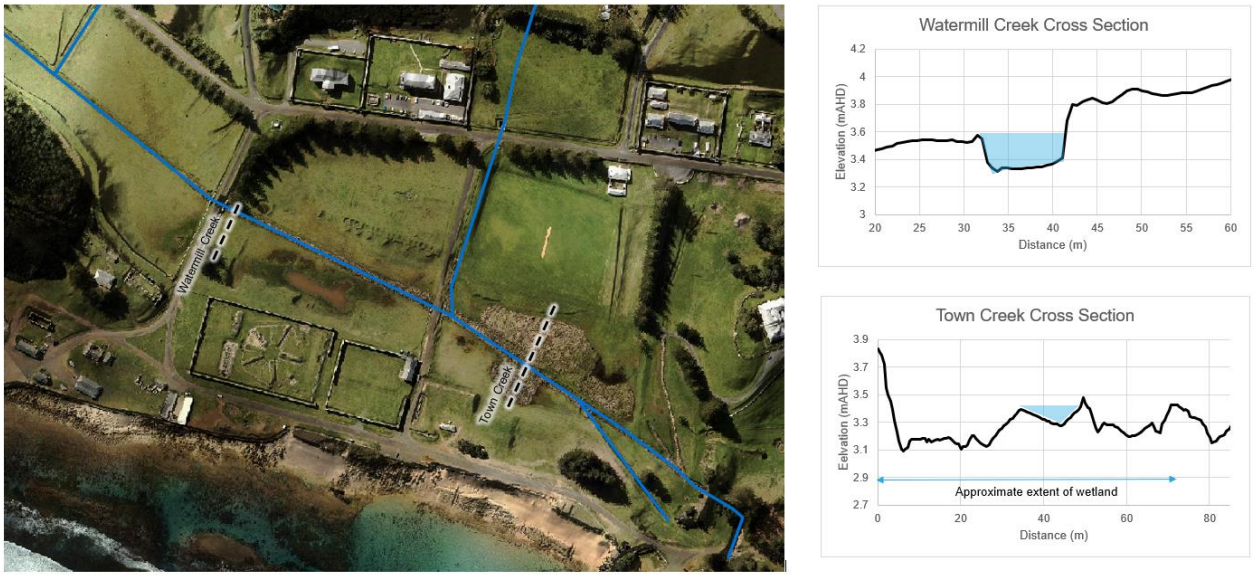


Figure 3: Cross sections of Town Creek and the wetland

1.3 Water Quality in the Bay

Council has increased the frequency of its water quality monitoring regime as of the 31 July 2020 event. Tests are undertaken at six sites along Town Creek and Emily and Slaughter Bays (Figure 4).

However, water quality testing is undertaken using freshwater monitoring equipment. As the salts found in marine environments can impact nutrient recordings, only the bacteria readings would be reflective of actual water quality conditions. Of the six sites, only Town Creek and the Emily Bay Outlet contain freshwater. The nutrient concentrations at these sites would be more characteristic of actual conditions.

The observed algae in the marine park suggests that nutrient concentrations would be high, although the precise numbers are unknown.

Figure 4: Water quality testing point locations (NIRC)

Nitrogen and phosphorus concentrations in Town Creek are below the recording limit of equipment. Interestingly, recordings in the Emily Bay Outlet are higher (Figure 5). This indicates that there could be another source of contamination, such as groundwater seepage.

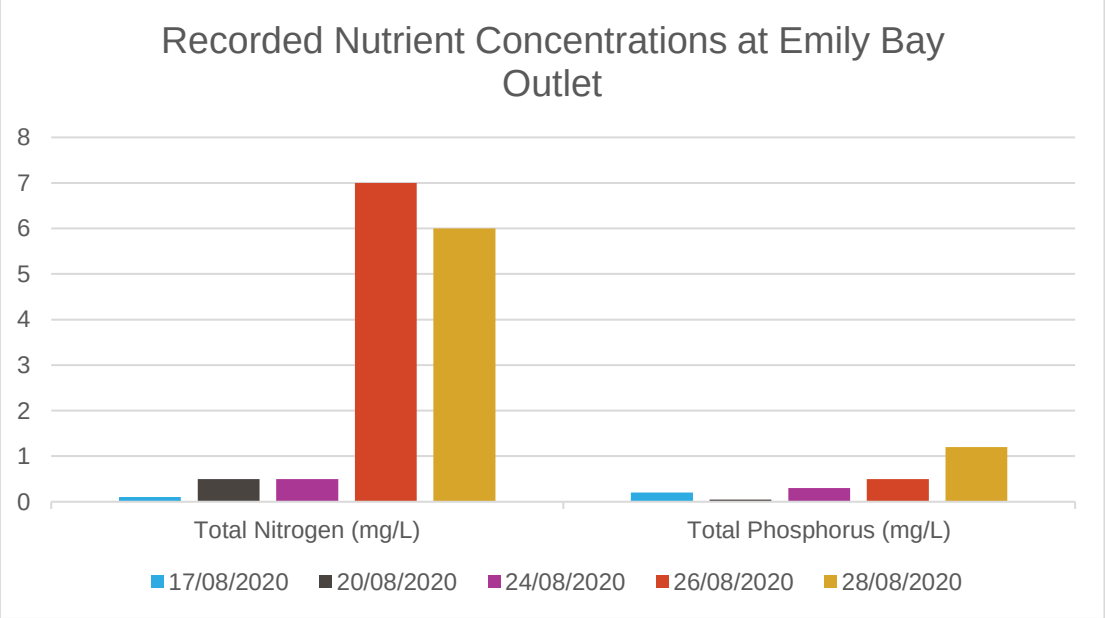


Figure 5: Recorded nitrogen and phosphorus concentrations at Emily Bay (NIRC, 2020).

Parks Australia has received advice that continued overflows from the wetland may cause irreversible damage to the surrounding reefs. This is of particular concern as the West Pacific is expecting to experience warmer water and wetter conditions this summer due to la Nina.

Preventing overflows from the wetland and treating the contaminated groundwater may alleviate some stress on the reef during this period of increased temperatures. However, catchment-wide interventions are also required to address the chronic groundwater contamination.

1.4 Our Understanding

Bligh Tanner has reviewed the water quality data available and engaged with stakeholders from Parks Australia, NIRC, Department of Infrastructure, Transport, Regional Development and Communications, and CSIRO. We believe that the water quality issues on Norfolk Island can be summarised as below. These understandings have informed the identification and evaluation of options, which are discussed in Section 2.

- Emily Bay suffers from poor water quality as evidenced by algae blooms and coral bleaching.
- Groundwater is contaminated, principally due to ongoing use of septic tanks and soakage trenches.
- There is limited water quality data that can reliably characterise nutrient concentrations in both surface and groundwaters.
- Borehole samples undertaken by CSIRO, which also reflected some testing sites from a 2007 study, indicates that there has been some improvement to groundwater quality. The extent of improvement, the pollutants improved, and the location of these samples are unknown.
- Groundwater naturally upwells at Emily and Slaughter Bays.
- Dye tracer tests suggests that the residence time of groundwater to the point of discharge is in the order of hours (Department of Local Government and Department of Housing and Construction, 1982). However, discussions with CSIRO indicate that these boreholes were close to a preferential flowpath within the rock. The proximity of these two boreholes and complexity of the underlying geology signifies that these behaviours are unlikely to be representative of the whole-of-island groundwater system.
- The quality of surface water from the Upper Cascade and Watermill Creek catchments should see progressive improvements due to recent restrictions on livestock access to waterways.
- Town Creek has good riparian vegetation that should be providing some treatment to the surface waters.
- The water in Town Creek has a low nutrient concentration, but high Enterococcus concentration. This indicates that there may be a connection between groundwater and the wetland.
- Reefs are normally resilient to incidental pollution events. The continual deterioration of the reef indicates that there is a combination of stressors. It is likely that contaminated groundwater is acting as a chronic source of pollutants and incidental outbursts of the Emily Bay plug are the ‘trigger’ to noticeable health incidents. This is further exacerbated by increased temperatures.

2 OPTIONS

The table below presents the several opportunities for the treatment or management of the polluted water.

Option	Option	Commentary	Implementable before summer	Effectiveness at protecting Emily Bay
Interception	Groundwater dam	This prevents the intrusion of polluted groundwater by installing an impermeable sheet or bentonite filled trench to limit the flow of groundwater into Emily Bay. In isolation, this measure would lead to raised groundwater levels and so would need to be coupled with a treatment and disposal measure. This option would require excavation works within KAVHA which could involve complex and lengthy approvals, although the finished works would be largely invisible. Appropriate erosion and sediment control should prevent the large release of sediments into the bay during construction.	N	M
Treatment	Package Plant	Several containerised water treatment plants are capable of advanced nutrient removal and producing water of suitable quality for release. A key challenge will be the transportation and delivery of the package plant. The plant would be most effective treating a consistent flow of water and may not provide effective treatment in larger storm events. Treated water would likely need to be used for golf course irrigation and any excess discharged into the bay. It could also be used to treat wastewater from the KAVHA properties.	N	H
	Denitrification trenches	An experimental technology which passes water through a carbon rich, anaerobic trench. This water completes the dentification cycle and converts nitrates and ammonia to nitrogen gas. Trials in Queensland sugarcane farms show promising results, with up to 44% nitrate removal efficiency and averaging 3.4g/m³/day nitrate with a 2.5 hr residence time. The CLMP notes an issue with excess Norfolk Pines in KAVHA, so those trees could be used as the source of woodchips. This option would require excavation works within KAVHA which could involve complex and lengthy approval, although the finished works would be largely invisible.	N	M

Wetland	A portion of the Kingston Commons or Lowlands areas could be re-established as wetlands, similar to pre-European settlement. This wetland will be able to treat surface water from the upstream catchment and provide some detention to prevent uncontrolled release of freshwater into the bay. Groundwater could also be pumped and circulated through the wetland. A wetland would also take up to two years to establish, and water quality performance is variable. The CRC Water Sensitive Cities recently reported that it is unclear whether constructed wetlands effectively remove a significant amount of nitrogen from stormwater over time. This option would require excavation works within KAVHA which could involve complex and lengthy approval.	N	L
Nualgi/diatomix	There are a range of proprietary products that can be used to stimulate diatom growth in water bodies, thereby drawing down nutrient levels and limiting nuisance algal growth. There is limited data on the efficacy of treating larger scale waterbodies or more complex ecological systems, as these are commonly used in ornamental ponds. Parks Australia believes that this option would trigger an Environmental Impact Assessment. This treatment could be applied to the existing ponded water at KAVHA, and groundwater could also be pumped and circulated through the waterbody prior to release. It would likely be a relatively cheap measure with limited side effects, and could be implemented quickly as a short-term no-regrets measure. The product comes in 5 L jerry cans, and needs to be continually dosed. Assuming a dosage of about 5 l/week based on suppliers estimates, the cost would be about $1,000/week. A solar powered automated dosing system costs about $10,000 ex Brisbane.	N	Unknown
Macro algae	Remediation of wastewater by macroalgae is a process whereby a suitable species of freshwater algae are deliberately grown to remove nutrients (nitrogen and phosphorus) from contaminated water. There are some recent full scale trials (for example at Home Hill in Burdekin Shire Council) where a particular species of macroalgae (believed to be Oedogonium) is being used to remove nutrients from secondary treated wastewater to minimise the export of nutrients to the Great Barrier Reef. Our concept would be to construct a temporary pond through which water	N	M

		is circulated to “feed” the algae. Treated water could be directly discharged to the reef lagoon or recirculated within the wetland. Algae when grown can be used as a fertiliser or sent to landfill.		
	Aeration	This is a strategy that is often implemented in ponds in urban cities, although their ability to reduce nutrient concentrations is not well studied. It is unlikely that much denitrification would occur and so the benefits to Emily Bay are likely to be limited. This option would require a pump to operate.	Y	L
Disposal of surface / groundwater	Golf course	There is over 10 ha of turf that could be irrigated. Care would be required to ensure that no ponding or runoff occurs. Deep drainage could still discharge into Emily Bay and Cemetery Bay, which anecdotally remains in good condition. Public access presents a significant limitation to this option (the club may need to close). NIRC will need to produce an agreement contract with the property owner.	N	H
	Plantation	Two plantations totalling 7 ha have been identified near Rooty Hill Road and Country Road, which will have high potential for water uptake. Consideration into effluent storage will be required. Low public exposure. PFAS mobilisation was flagged as an issue. NIRC will need to produce an agreement contract with the property owner. It is recommended for MEDLI modelling to be undertaken to better understand the impacts of irrigation with effluent on the underlying soils and groundwater.	N	H
	Emily Bay tidal release	The outfall will need to be placed deep underwater to ensure that sufficient dilution occurs and will need to withstand ocean currents. Likely to have significant implications on design and cost of outfall. If progressed, it is recommended that a coastal engineer be engaged to provide technical advice regarding the feasibility and engineering requirements of the outfall to prevent the risk of backwashing into Emily Bay or impacting on adjacent marine environments.	N	M
	Irrigation of airport green space	Excess runoff could be managed by irrigating the surrounding land (2 ML over 20 ha). This does not provide substantial improvements to water quality, and percolation into the groundwater system may still discharge into the bay.	N	H

		As elevated levels of PFAS have been detected adjacent to the airport, there is a risk of mobilising PFAS with irrigation. Low public exposure. It is recommended for MEDLI modelling to be undertaken to better understand the impacts of irrigation with effluent on the underlying soils and groundwater.		
	Headstone Reserve discharge	Environmental Authority could allow for emergency release jurisdiction. The existing ocean outfall allows for the rapid dilution of polluted water. Reduced environmental risk.	N	H
Preventative Measures	Leaky weir system	As recommended in *Water Quality in the KAHVA Catchment,* leaky weir systems could be installed downstream of Watermill Dam. This would help attenuate surface runoff, promote infiltration and minimise waterway erosion, thereby reducing sediment loads (not noted as a pressing issue). The benefits to Emily Bay are likely be modest, as polluted water infiltrating into the groundwater would still ultimately discharge into the bay, and there is no evidence to suggest much nutrient attenuation would occur within the groundwater system. This option is permitted under the existing Cultural Landscaping Management Plan.	Y	L
	Septic tank pump out	There is potential for septic tanks to be frequently pumped out and transferred to the STP, which will reduce land disposal and prolonged system leakages. There are currently two 2.5 kL pump out trucks on the island, and Council estimates that there are 138 properties that discharge near Town Creek. Conversations with local operators suggest that these tanks could be emptied within a fortnight, assuming ten pump outs per day. We have also estimated that each septic tank would reach full capacity in ten days. This means that this pumping regime would be very time sensitive and have minimal allowance for delays. Importing additional trucks is recommended to increase pump out capacity. This strategy does not address the existing body of polluted water in the Town Creek Wetland. There is also likely to be a significant lag between starting the pump out scheme and observable improvements in water quality in Emily Bay due to existing groundwater contamination. Future assessment of logistics and operating costs and CO_2 emissions is recommended.	Y	M*

	Extend sewer network		N	H*
	Upgrade STP		N	H
Other	Flushing of Emily Bay	There is already nutrient rich water in Emily Bay as shown by the deterioration of the reef. The Draft SIMS report found "evidence of high seawater turnover within the Slaughter and Emily Bay lagoons, with low residence time, high tidal variation (at time of survey) and connectivity between the inshore and offshore lagoonal waters." A pumping system that transfers this water beyond the reef where it might be dispersed by ocean currents (or conversely, pumping cooler cleaner water from offshore to displace the warmer, polluted water) could mitigate this issue. The volumes of water would be substantial although the pumping head is low. The system would involve significant technical investigations to determine its feasibility, including understanding coastal dynamics, pipeline and pumping system design.	N	Unknown

**Significant lag in water quality improvements expected*

3 RECOMMENDATIONS

3.1 No regrets strategies

Parks Australia has been advised that the uncontrolled release of surface waters into Emily Bay may cause irreversible damage to the reef. Options to improve the water quality of both the surface and groundwater before the 2020/21 summer are limited by resources and time.

Most options that treat or transfer the surface water upstream of the bay necessitate earthworks, which will trigger development approvals, at the very least. These options cannot be implemented before the 2020/21 summer.

The below options are recommended for Parks Australia to commence discussions with key stakeholders. These are 'no regrets' options, which can be readily undertaken with the resources present on the island. However, Bligh Tanner cannot report on the efficacy of these options to immediately improve the water in Emily Bay.

It is noted that there are a significant number of considerations that are still uncertain including:

- the quality of surface water, marine water, and groundwater
- the connectivity between surface waters and the groundwater system
- the extent to which the aquifer can improve water quality
- the residence time of groundwater.

Leaky weirs and the septic tank pump outs are the two 'no regrets' strategies that are recommended for implementation. Note that if only the leaky weir and septic pump out strategies are implemented, and no measures are put in place to address existing groundwater contamination, then the corals in Emily Bay will likely be subjected to ongoing high nutrient loads for a few years. Ongoing irreversible damage to the corals could occur during this time.

3.1.1 Leaky Weirs

Leaky weirs could be installed downstream of Watermill Dam to attenuate stormwater runoff from the upstream catchment. Leaky weirs can stabilise creek beds to prevent further incising of the creek and reduce sediment runoff. Although sediments have not been highlighted as a key issue, this will provide some relief to the reef. Most notably, this option will not require a development approval or trigger a referral under the EBPC. Lead times should be short, allowing weirs to be installed before December 2020.

Figure 6: Erosion in Watermill Creek (Wilson, 2020).

Attenuation of flows

Leaky weirs may also reduce the quantity of surface water discharging into the Town Creek wetland and may minimise the occurrence of uncontrolled outbursts into Emily Bay. The amount of water held back will be largely determined by the placement and design of the weirs. Waters that infiltrate into the groundwater system will still likely discharge to Emily Bay, especially if the weirs are located near preferential flowpaths. There is limited evidence of pollutant concentrations being reduced within the groundwater system.

Assuming a channel width of 2.5 m and 2 m tall, wooden leaky weirs are installed, roughly 1000 m^3 could be detained and slowly released. This was indicatively based on the below weir locations, indicative channel widths, and LIDAR data.

Figure 7: Potential locations to install weirs within Watermill Creek

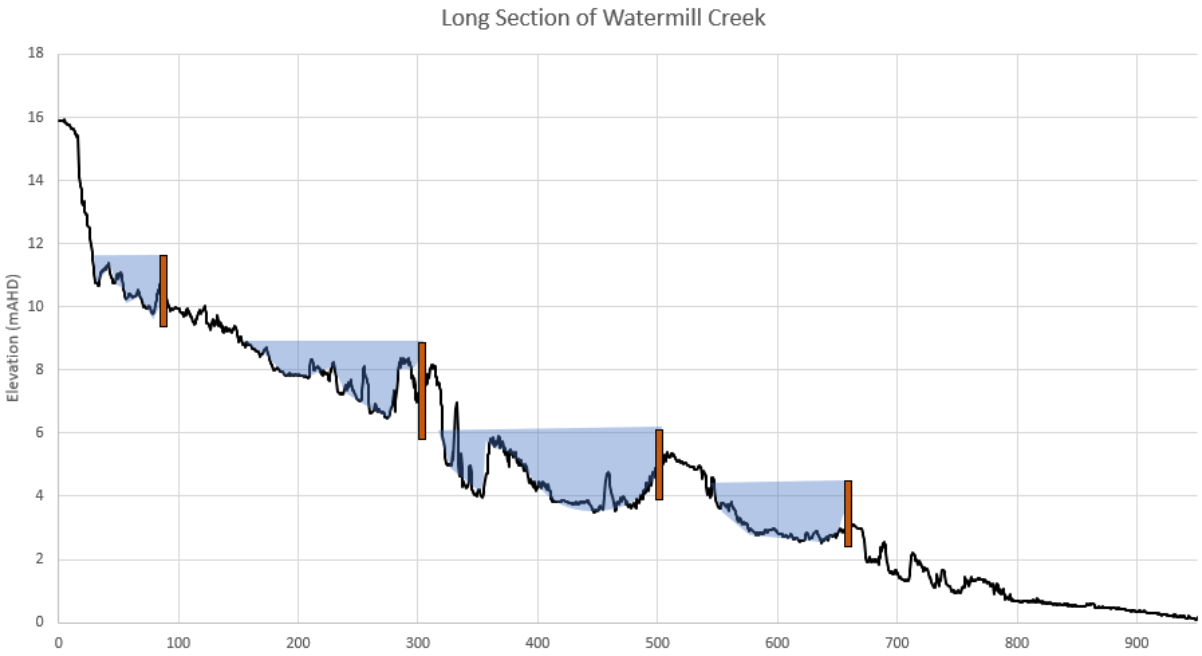


Figure 8: Indicative channel cross section with leaky weirs

Leaky weirs are considered as a 'no regrets' strategy. Even if they do not significantly reduce the frequency of the Emily Bay plug bursting, Watermill Creek will be better protected from further erosion. This is an achievable near-term option which requires relatively simple engineering design and could be quickly constructed using equipment and materials currently on the island.

3.1.2 Septic pump outs

NIRC has identified 138 houses that are suspected to discharge into the KAVHA catchment and therefore, impact Emily Bay. Conversations with local operators suggest that up to ten pump outs could be undertaken daily, using the two 2.5 kL trucks on the island. This would signify that the catchment of concern could be emptied within 10 days. However, we have also estimated that each septic tank would reach full capacity in ten days, assuming each household produces 350 L/day. There may be the occasional overflow. Regardless, there will be a significant reduction in the volume of sewerage percolating into aquifer.

This option is unlikely to yield any immediate relief to Emily Bay, as the groundwater residence time is largely unknown and may be in the order of years. However, reducing the discharge of sewerage into the groundwater system will inherently be a positive environmental outcome and eventually result in improvements to groundwater in the long-term.

It has high operational costs and should be coupled with plants to connect more dwellings to the *Water Assurance Scheme.*

3.2 Intermediate solutions

3.2.1 Groundwater

Emily Bay likely experiences a chronic loading of pollutants from the natural upwelling of groundwater.

This strategy aims to improve the quality of shallow groundwater discharging into the bay. Bligh Tanner proposes for a series of denitrification trenches to be installed across the catchment to treat shallow groundwater. Filled with a carbon source, denitrification trenches intercept groundwater and target inorganic nitrogen, such as nitrates and ammonia. Trials in Queensland sugarcane farms show promising results, with up to 44% nitrate removal efficiency and averaging 3.4g/m³/day nitrate with a 2.5 hr residence time.

At the first instance, it is recommended for these trenches to be installed immediately upstream of the bay, to prevent contaminated water entering the bay. Trenches can then be progressively installed upstream to provide ongoing groundwater treatment across the catchment.

This is likely to be the only strategy available to address the chronic groundwater pollution and delivery water quality improvements in the short term. Further inquiries should be made to see if there is a mechanism for expedited approvals given the environmental risk.

The Design

The denitrification trenches are a cost-effective option and have minimal impact on the local amenity. Some problematic Norfolk Pines within the KAHVA boundary, as discussed in the CLMP, could be mulched, and used as the carbon source.

However, this is an experimental technology. While trials in Queensland have indicated positive results for nitrogen removal, adverse outcomes, such as increased DO concentrations, could result. The efficacy of the trench also depends on the residence time, which may be difficult to achieve in the steep, upstream catchments.

Approvals

This option will require a Development Application and will likely trigger a referral under the EPBC Act. It is noted that the KAVHA Development Control Plan permits the earthworks activities. The trenches can also be re-turfed to reflect the surrounding environment. As such, this option is unlikely result in the “major change of use to a historically significant building or ruin or heritage element within KAVHA”. This approval process means that the works may require input from a range of stakeholders.

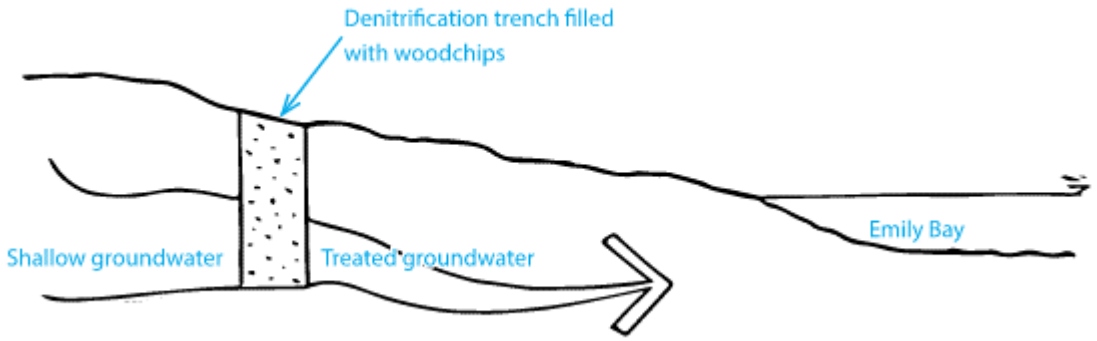


Figure 9: Indicative denitrification trench section treating shallow, contaminated groundwater

3.2.1 Surface Waters

There are limited opportunities to treat the existing surface waters

The re-establishment of the wetlands in the Kingston Common area may provide some level of treatment, although the efficacy of wetlands to improve water quality in the long term is debatable (Roberts, Rahman, Wong, Cook, & Grace, 2018).

The most effective option would be to redirect the existing surface waters to another outlet (Headstone Reserve) or for direct application to land (at the golf course or at the pine plantations). Alternatively, novel treatment technologies, such as NuAlgi, could be adopted. These would likely trigger development approvals, environmental impact assessments, and referrals under the EPBC. These options are therefore suited as intermediate solutions.

3.3 Sewer the catchment

The 'ultimate vision' is to prevent the future contamination of surface and groundwater.

Poor water quality in Slaughter and Emily Bays is a recurring issue. To enhance the resilience of these bays, catchment-wide strategies for stormwater and wastewater management are required. While individual septic tanks could be repaired, the proximity of these systems to water sources signifies that any failure or overflows from poor maintenance will have damaging impacts on downstream environments.

Lack of appropriate regulatory checks and balances should be addressed. Currently, there appears to be no regulatory framework to govern catchment processes impacting health and terrestrial and marine environmental values.

It is recommended for NIRC to expand the *Water Assurance Scheme* to service all properties on the island. Connecting the remaining properties to the STP prevents future contamination of groundwater and allows the denitrification trenches to address the legacy pollution impacts. Should attainment of funding to sewer the entire island be an issue, it is recommended that the high-risk houses in the KAVHA catchment are connected first (Figure below). Indicative costings are provided in Table 1.

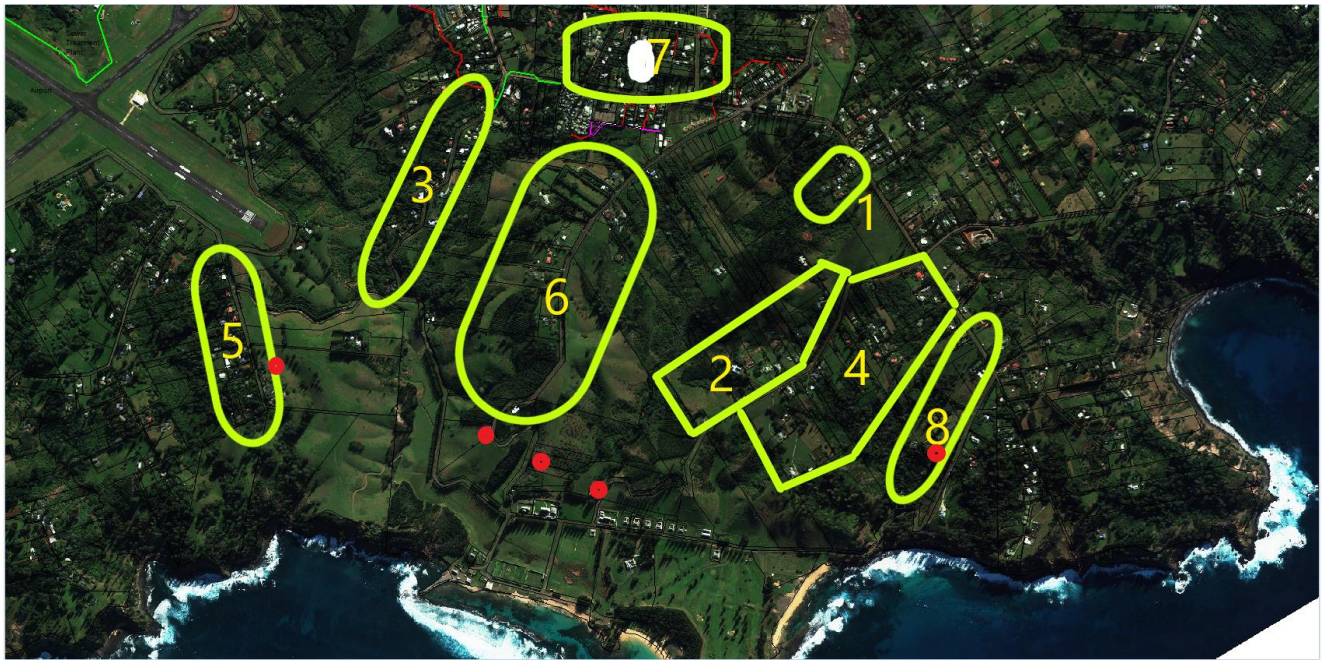
Figure 10: Assumed pipeline alignments (proposed alignment is dashed, existing is solid)

Table 1: Estimated cost of servicing areas of high risk. We have not allowed for the upgrade of the existing sewerage network.

Item	Details	Estimated cost
Pipelines	Connecting areas of concern only Assume $150/m to supply, trench, and lay ~10 km, DN150 pipeline	$1,500,000
Pumps	Assume $35,000 per pump	$105,000

APPENDIX A
CRITICAL SEPTIC CATCHMENTS

BLIGH TANNER



Hi Fran,

Please find a map showing the priority areas for pump outs and the numbered areas below correlate to the map.

1 Little Cutters Corn :- 12 houses
2 Rooty Hill Road Left Hand side:- 13 houses
3 Taylors Road :- 17 houses
4 Rooty hill Right/Collins Head Rd :- 23
5 Long Ridge :- 19 Houses 1 tourist accommodation
6 Middlegate Road :- 13 houses
7 Short Ridge : 19 Houses
8 Driver Christian Road:- 9 houses 1 tourist accommodation

Also find 5 red dots that are tourist accommodations that need to be considered:

Tourist Accommodation In Kingston – Panorama, Islander Lodge, Kingston Cottages, Coast and Crest Apartments.

Kind Regards,

NORFOLK ISLAND REGIONAL COUNCIL

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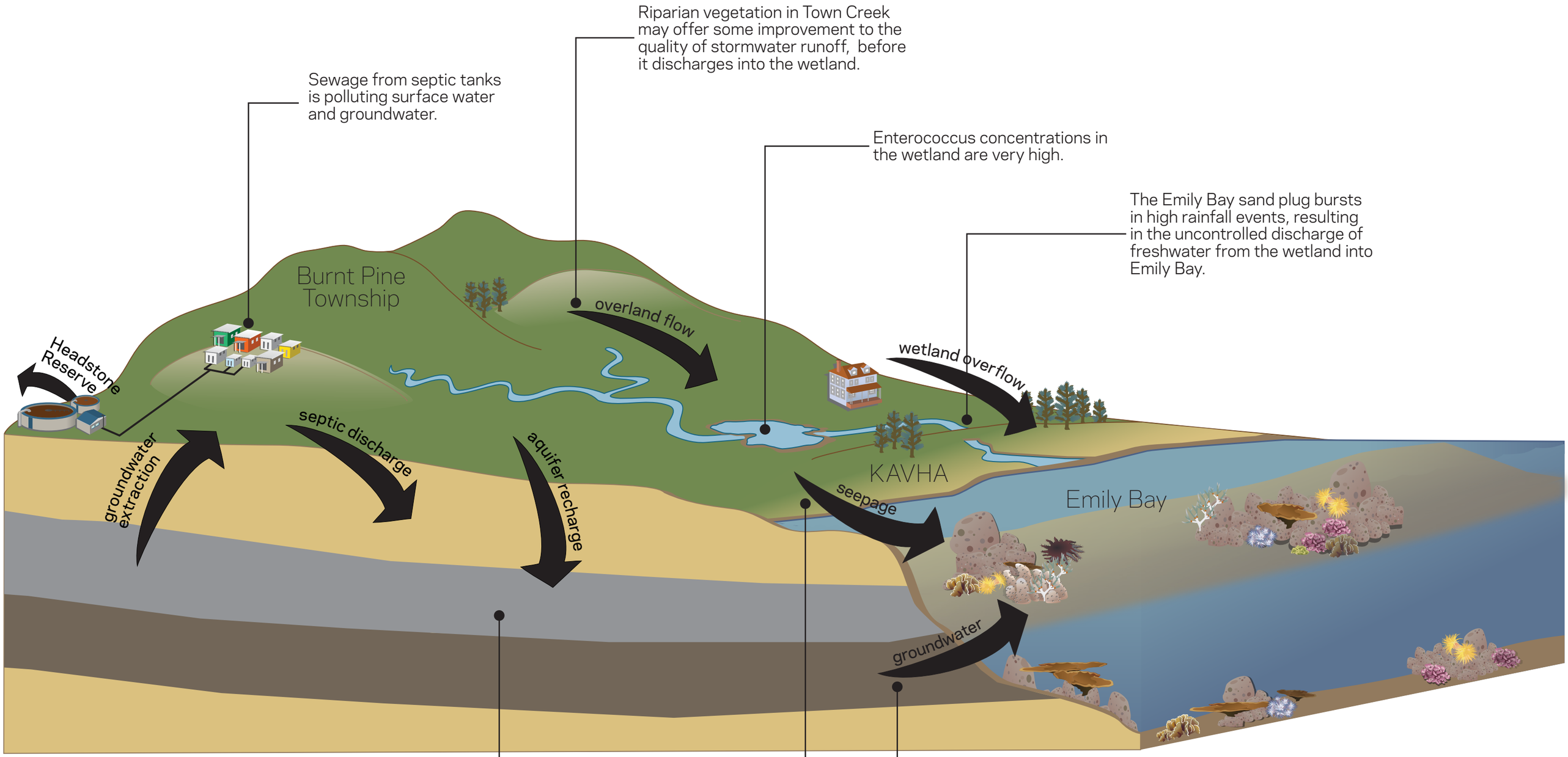
BLIGH TANNER

PRESSURES ON EMILY BAY, NORFOLK ISLAND

Emily Bay is a critical tourist and environmental asset for Norfolk Island. However, a chronic loading of polluted groundwater, the uncontrolled release of contaminated surface water, and increased temperatures have resulted in significant algal overgrowth and coral bleaching in the Emily Bay reef. Immediate action is required to protect the reef from further damage.



BLIGH TANNER

Version 1.1. Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

MANAGEMENT OPTIONS
FOR EMILY BAY, NORFOLK ISLAND

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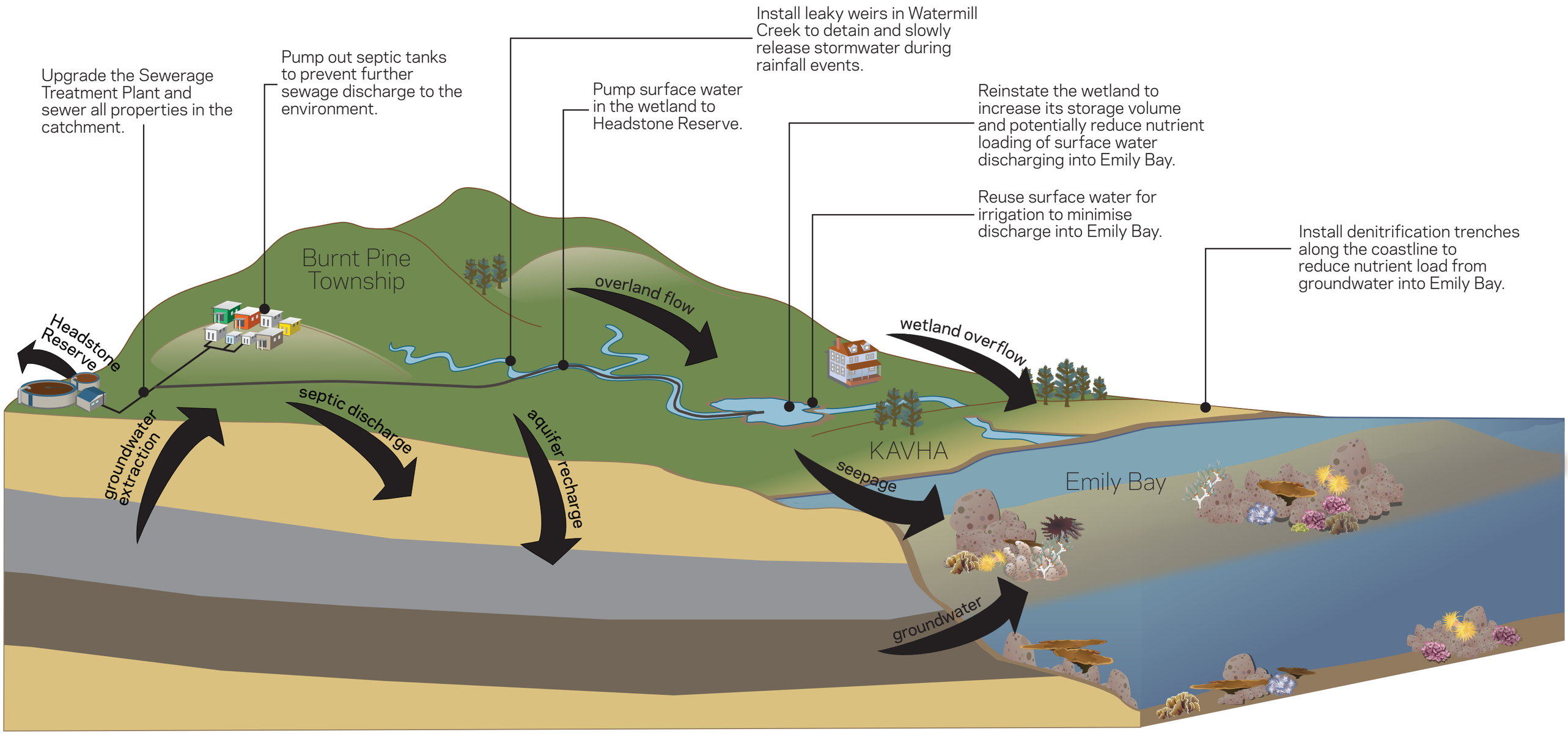

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