TAMAR ESTUARY AND
ESK RIVERS PROGRAM

Environment, flooding and aesthetics; sediment in the kanamaluka/Tamar estuary

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Executive summary

Sedimentation is a natural process in the upper kanamaluka/Tamar estuary, with early accounts describing a relatively shallow channel surrounded by extensive tidal flats and low tide wetlands. Sedimentation of the estuary has been a concern of residents since early European settlement. Work to improve navigation began in the upper estuary in the 1830's with the establishment of the Port of Launceston. From as early as the 1880's, letters to the editor have made calls to 'get rid of the mud'.

There is a long history of modification to the estuary which has impacted on the natural processes of the estuary:

- Infilled wetlands around Invermay, the West Tamar, lower North Esk and Royal Park and construction of an extensive levee system.
- A straightened and confined North Esk River channel.
- Extensive dredging of the estuary for over 70 years (until 1965) with sporadic smaller dredge campaigns conducted many times in the years since.
- Rice grass that was introduced in 1947 to trap sediment.
- Construction of Trevallyn Dam and Power Station in 1955 saw a diversion of some South Esk flows from Cataract Gorge to the Tailrace and an increase in freshwater input by the addition of flows from Poatina Power Station.

Recently sediment raking was trialled to manage sedimentation but ceased after an extensive review that found it ineffective in reducing the rate of sedimentation and that it had negative impacts on navigation and water quality. As the estuary channel restores its pre-raking depth, sediment that had been pushed below the low tide level has reaccumulated into visible mudflats. These changes have led to renewed community concern over sedimentation with many proposed alternative solutions.

Purpose of this report

The Tamar Estuary and Esk Rivers Program was commissioned by purpose of this report is to provide the Tamar Estuary Management Taskforce to conduct a comprehensive and independent analysis of the challenges, impacts and magnitude of costs of various proposed sedimentation management options for the kanamaluka/Tamar estuary. That evaluation is presented in this report.

The evaluation uses a scientifically robust, best practice and evidence-based approach, with analysis of primary data, where possible, and informed by technical experts across the range of criteria, which include:

- legislative and feasibility challenges;
- cost;
- impacts on bathymetry;
- impacts on flooding;
- impacts on environmental values and water quality; and
- impacts on recreation and navigation.

Environmental values associated with the estuary provide context for the environmental impact assessment framework. Key commercial and recreational uses of the upper estuary are also documented and impacts on these values are assessed considering relevant changes in bathymetry, access and water quality.

The report considers the nature of the issue posed by sedimentation in the upper estuary, to understand whether sedimentation should be managed for environmental, flood risk, or social reasons. This provides the context in which to consider the evaluation of potential actions to manage sedimentation. Sections of the report include a summary of the history and management of sedimentation in the estuary, with a review of the natural processes that influence sedimentation, which provide context to the report.

What are the options for sediment management that have been reviewed?

This report considers a broad range of sedimentation management, and in some cases options at a range of scales, that have been proposed by various proponents. Options considered are:

- *No intervention* – considers the effects of allowing the natural process of sediment accumulation, scour and channel formation to continue without any management intervention.
- *Accelerated restoration of intertidal habitat* – a small-scale intervention aimed at hastening the reformation of mudflats and vegetated intertidal habitats and natural processes of channel deepening.
- *Restoration of wetlands and the tidal prism in the North Esk* – considers the effects of removing informal levees on the North Esk and rehabilitating wetland areas that have been infilled. The process of informal levee construction and infill of wetlands is currently ongoing so the effects of ceasing this action are also considered.
- *Dredging of the upper estuary* – involves the mechanical removal and disposal of contaminated sediments from the upper estuary.
- *A tailrace canal* – a canal along the West Tamar between the Trevallyn Power Station and the estuary near Kings Bridge aimed at increasing tidal prism and freshwater flows through the Yacht Basin and Home Reach.
- *Increased flows down the South Esk* – considers the effects on targeted flow releases from Lake Trevallyn.
- *Barrages and weirs* – considers three alternative lake/weir proposals, including a large lake formed by a barrage at Point Rapid near Rowella, a smaller lake formed by a barrage at Freshwater Point, and a weir across the North Esk at its confluence with the kanamaluka/Tamar estuary.
- *Sediment raking* – considers four options involving agitation of sediments from mudflats or channels with the aim of increasing movement of these sediments downstream.
- *Various concept proposals* – including reconfiguration of the North Esk through a bypass channel and hard channelisation of the upper estuary.

Evaluation summary

The evaluation of sedimentation management options was undertaken through a structured approach to compare costs[1], challenges to feasibility, the extent to which bathymetric objectives are met in the upper estuary (reduced visible mudflats, deep channels), flood risks, environmental and social impacts.

In summary of the evaluation[2]:

- Very few management options achieve bathymetric objectives of reduced visible mudflats and deeper channels in all parts (Yacht Basin, Home Reach, Lower North Esk) of the upper estuary.
- Actions focused on restoring tidal prism in the North Esk, through the removal of informal tidal levees or restoration of wetlands, will effectively reduce sedimentation in the North Esk and, to a lesser extent, Home Reach and can achieve environmental and many social objectives in the upper estuary.
- Costs and feasibility of wetland restoration depend on the scale and location of action, with challenges associated with restoring the floodplain's privately owned areas.
- Accelerated restoration of intertidal vegetation in the upper estuary can achieve environmental and some social objectives around aesthetics at a relatively low cost. However, extensive mudflats will remain a feature of the estuary under this approach and social impacts in terms of current recreational users will largely remain as they are.
- Engineering focused actions such as the construction of a tailrace canal or barrages and weirs are associated with very high costs, significant challenges with feasibility, and extensive environmental impacts, with a mix of results in terms of bathymetric objectives and related social impacts.
- Large scale dredging of the upper estuary is very expensive, with ongoing annual costs in the order of tens of millions of dollars largely due to costs of treatment and disposal of dredge spoilt that is potential acid sulfate and Level 2 contaminated waste. Technical constraints on the scale of dewatering ponds for dredge spoil that would be required in close proximity to the upper estuary would likely make large scale dredging infeasible. It would not impact on the extent of visible mudflats.
- Sediment raking and increased flow releases from Lake Trevallyn come at a lower economic cost but fail to address bathymetric and related social objectives. In the case of sediment raking, the option is associated with significant environmental impacts.

[1] The costs provided in this report are not comprehensive - a full feasibility assessment, design and detailed costing of each option would be required to accurately assess costs, feasibility and effectiveness.
[2] Refer to Appendix 6 of the report for the detailed methodology used to create the final evaluation summary matrix.

Option		Cost		Feasibility challenges	Channel depth			Extent of visible mudflats[3]				Flood risk	Environmental impact	Social impact
		Capital	Operational		Lower North Esk	Yacht Basin	Home Reach	Lower North Esk - Seaport	Lower North Esk – Town Point	Yacht Basin	Home Reach			
No intervention[4]		None	None	None	No change	No change	No change	Moderate increase	No change	No change	No change	Negligible	Slightly positive impact	No change
Accelerated restoration	Restoration of intertidal vegetation	Low	Low	Low	No change	No change	No change	Moderate increase	No change	No change	No change	Negligible	Slightly positive impact	Slightly positive impact
Accelerated restoration	Remediation of West Tamar silt ponds	Low	Low	Medium	No change	No change	No change	Moderate increase	No change	No change	No change	Negligible	Slightly positive impact	No change
North Esk tidal prism, informal levees and	Cease informal levee construction	None	None	Medium	No change	No change	No change	Small reduction	Small reduction	No change	Small reduction	Very small decrease (avoided increase)	Significant positive impact	Slightly positive impact
North Esk tidal prism, informal levees and	Remove informal tidal levees	Low	Low	Medium	Moderate increase	No change	Small increase	Moderate reduction	Moderate reduction	No change	Moderate reduction	Very small decrease	Significant positive impact	Slightly positive impact
North Esk tidal prism, informal levees and	Wetland restoration - small program	Medium	Low	Medium	Small increase	No change	No change	Small reduction	Small reduction	No change	Small reduction	Negligible	Significant positive impact	Slightly positive impact
North Esk tidal prism, informal levees and	Wetland restoration - large program	Very high	Low	High	Large increase	No change	Moderate increase	Large reduction	Large reduction	No change	Large reduction	Very small decrease	Extreme positive impact	Slightly positive impact
Dredging	Small scale dredge program	Medium	Very high	High	No change	Moderate increase	Moderate increase	No change	No change	No change	No change	Negligible	Moderately negative impact	No change
Dredging	Large scale dredge program	High	Very high	High	Large temporary increase	Large temporary increase	Large temporary increase	No change	No change	No change	No change	Negligible	Significant negative impact	No change
Tailrace canal		Very high	High	Very high	No change	Small increase	Small increase	No change	No change	No change	No change	Very small increase	Significant negative impact	No change
Lakes and barrages	North Esk weir	Medium	Medium	High	Small loss	No change	Moderate loss	Large decrease	Large decrease	No change	Large increase	Small increase	Significant negative impact	Moderately negative impact
Lakes and barrages	Small lake	Very high	High	Very high	Small loss	Small loss	Small loss	Large reduction	Large reduction	Large reduction	Large reduction	Small increase	Extreme negative impact	Significant negative impact
Lakes and barrages	Large lake	Very high	High	Very high	Small loss	Small loss	Small loss	Large reduction	Large reduction	Large reduction	Large reduction	Small increase	Extreme negative impact	Significant negative impact
Sediment raking		None	Low	High	Moderate loss	Moderate loss	Moderate loss	Small reduction	Small reduction	Small reduction	Small reduction	Negligible	Significant negative impact	Slightly negative impact
Increased flows[5]		None	Low	Low	No change	No change	No change	No change	No change	No change	No change	Negligible	No change	No change

[3] Colour refers to social objective of reduced extent of visible mudflats. Increased mudflat extent does not negatively impact on environmental values and may improve such values in some cases.
[4] Change relative to end of sediment raking program in 2019.
[5] Cost for this option is based on 8,640 ML released over a 2 to 5 day period. Multiple or continuous flow releases in a year would cost significantly more (potentially millions of dollars per year), assuming they are feasible given constraints on water availability.

Why is sedimentation perceived to be a problem?

In considering this evaluation it is first worth considering why, how and to whom sedimentation is an issue.

Three commonly cited reasons for sediment management in the kanamaluka/Tamar estuary are that:

- mudflats are a sign of an unhealthy, ‘clogged up’ estuary – that is, they are an environmental problem;
- mudflats and sedimentation pose an increased flood risk; and,
- mudflats and sedimentation impact on those wanting to use the estuary for recreation and are associated with poor amenity (access, visual and odour).

In evaluating potential options, it is worth considering the validity of these reasons.

Are mudflats and sedimentation an environmental problem?

Mudflats and sedimentation of the upper kanamaluka/Tamar estuary are not an environmental problem. They contribute substantially to the estuary’s environmental values and ecosystem health and underpin its international recognition as a Key Biodiversity Area.

Mudflats are important for intertidal habitat and an essential foundation of estuarine ecosystems, providing important services and habitat function. Mudflats are a natural feature of the upper kanamaluka/Tamar estuary. Early European explorers documented extensive areas of mudflats and wetlands in and around Launceston. The upper estuary’s early navigation charts from 1833 depict an area dominated by extensive mudflats and wetlands (swamp) with relatively narrow channels.

Does sedimentation increase flood risks in and around Launceston?

The perceived impact of sediment accumulation on flood risk has motivated efforts to reduce sediment in the past. Evidence, however, suggests that sedimentation is likely to, at most, only lead to small increases in flood levels and unlikely to pose a significant change in flood risk to Launceston.

Large flood events are known to induce significant scouring of sediments in the estuary channels and mudflats, with rapid scouring once critical flow thresholds are exceeded. This extensive scour and the flood levee system that is already in place mean that potential small increases in flood levels for smaller floods would pose minimal, if any, increase in flood risk.

How does sedimentation impact on community values?

Community concerns about economic and social impacts of sedimentation are generally focused on three key issues:

- impacts on recreational users of the upper estuary such as rowing clubs and the Tamar Yacht Club;
- impacts on navigation around Home Point for the tourist boat and into the Seaport Marina, and the accumulation of sediment in the marina; and
- the aesthetic values of the mudflats, including their look and the perception that they are not visually appealing to tourists; and
- their odour, with community reports of mudflats smelling.

Infrastructure associated with key recreational uses of the upper kanamaluka/Tamar estuary were first built during periods when dredging was undertaken to allow the navigation of large ships into the Port of Launceston. Tamar Yacht Club clubhouse and slipway at Royal Park, for example, was built in 1891, the Tamar Rowing Club in 1877 and the North Esk Rowing Club in 1902. Regattas were held at Stephenson's bend (near the Launceston Grammar Boatsheds) until 1925 when they were moved to Royal Park. With the cessation of large-scale dredging in 1965, increased sediment levels mean that there are accessibility challenges for these recreational activities during low and, in some cases, mid tides.

Management actions that seek to mitigate sedimentation can create trade-offs between different social objectives, particularly where sediment bound in mudflats is redistributed into channels and impacts on navigability, as occurred under the sediment raking program.

Challenges with access to the Seaport Marina, for example, are posed whenever there is reduced channel depth at the confluence of the North Esk River. The Seaport Marina is also affected by an accumulation sediment under berths, particularly those immediately adjacent to the boardwalk.

The Home Point tourist boat has experienced similar challenges when there is reduced channel depth in the Yacht Basin and Home Reach, due to the redistribution of sediment out of mudflats that occurred with sediment raking.

The final concern raised by the community is around the appearance and odour of the mudflats. Mudflats can give off an unpleasant odour due to the release of hydrogen sulphide gas by some of the microbes that live in the sediment. Odours around Royal Park, however, are likely to be contributed by the Margaret Street combined sewer overflow or vent stack (sewage smell) which is not associated with sediment accumulation. Odours from this source are likely to improve through investments currently being made in the combined sewage-stormwater system.

Community perceptions of the mudflats are likely to play a role in whether they are viewed positively or negatively. Some perceive them as unattractive and a sign of a degraded estuary, where others perceive them positively in terms of the environmental values they support, particularly the presence of wading birds.

Global trends

In recent decades there has been a strong movement away from hard engineered approaches to managing issues relating to natural processes such as sedimentation, tidal inundation, and flooding (see for example, Sayers *et al.*, 2013). The kanamaluka/Tamar estuary provides numerous examples of the use of such traditional approaches, where informal and formal flood protection levees, wetland infilling and land reclamation, as well dredging and raking have been used to deliver the social and economic outcomes sought by the community at the time. This report demonstrates that these types of actions can come at a significant cost in terms of environmental impact and other unintended consequences and can have relatively short-lived outcomes.

Many of the actions that were applied in the past are now impractical. This is due to improved understanding of natural processes, changes in legislation and cost, and an awareness of taking a more sustainable approach to address trade-offs between economic and social outcomes with environmental values.

Alternative approaches such as *Integrated Coastal Zone Management* (Clarke and Johnson, 2016) or *Strategic Flood Risk Management* (Sayers *et al.*, 2013) have become more common place, seeking solutions that balance the scale and nature of the issues with the impacts of potential solutions on social, economic, and environmental values. These approaches emphasise the importance of working with natural processes and matching the scale of action with the magnitude and nature of the problem.

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List of acronyms

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
CAMBA	China-Australia Migratory Bird Agreement
CBD	Central Business District
CoL	City of Launceston Council
cumecs	cubic meters per second
DEM	Digital elevation Model
DEWHA	Department of Environment, World Heritage and the Arts
DPIPWE	Department of Primary Industries, Parks, Water and the Environment
DV	Depth x Velocity
EDO	Environment Defenders Office
EMPCA	Environmental Management and Pollution Control Act 1994
EPA	Environment Protection Authority
EPBC	Environment Protection and Biodiversity Conservation Act 1999
FORM	First Order Morphological Response Model
GIS	Geographic Information Systems
IBA	Important Bird Area
ICZM	Integrated Coastal Zone Management
IUCN	International Union for the Conservation of Nature
JAMBA	Japan and Australia Migratory Bird Agreement
KBA	Key Biodiversity Area
LOA	Length Overall
MAST	Marine and Safety Tasmania
MBO	Monosulfidic Black Ooze
MLW	Mean Low Water
MSL	Mean Sea Level
MW	MegaWatts
MWhrs	MegaWatt hours
NVA	Natural Values Atlas
PASS	Potential Acid Sulfate Soils
RL	Reduced Level
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
TEER	Tamar Estuary and Esk Rivers Program
TEMT	Tamar Estuary Management Taskforce
TNVC	Threatened Native Vegetation Communities
TSS	Total Suspended Solids
WWTP	Wastewater Treatment Plant

1 Introduction

Sedimentation is a natural process in the upper kanamaluka/Tamar estuary with early accounts of the estuary describing a relatively shallow channel surrounded by extensive mudflats and wetlands at low tide. Early charts show that mudflats and sediment in the upper estuary have been present since the early explorers arrived, and the presence of sediment in the estuary is a natural feature of the kanamaluka/Tamar estuary (and many other estuaries worldwide), influenced by water movement and the morphology of the estuary. There is a long history of modification to the estuary which has impacted on the natural processes of the estuary:

- Wetlands around Invermay, the West Tamar, lower North Esk and Royal Park have been infilled and an extensive levee system constructed.
- The channel of the North Esk River has been straightened and confined; extensive dredging of the estuary occurred for over 70 years until 1965 with sporadic smaller dredge campaigns conducted many times in the years since.
- Rice grass was introduced in an attempt to trap sediment.
- Construction of Trevallyn Dam and Power Station in 1955 saw a diversion of some South Esk flows from Cataract Gorge to the Tailrace and an increase in freshwater input by the addition of flows from Poatina Power Station.

Most recently sediment raking was attempted as a solution to the issue of sedimentation but was ceased after it was found to be ineffective in reducing the rate of sedimentation as well as being associated with negative impacts on navigation in the upper reaches and water quality throughout the length of the estuary. Since sediment raking ceased, mudflats that were pushed below the low tide level have re-accumulated and the channel has restored its pre-raking depth. These visible changes in sedimentation have led to renewed community concern over sedimentation with many alternative solutions being proposed.

1.1 Purpose of this report

This report has been commissioned by the Tamar Estuary Management Taskforce (TEMT) to assist in decision making regarding management of sediment in the kanamaluka/Tamar estuary. It provides a pre-feasibility triple bottom line assessment of the impacts and challenges associated with various potential sedimentation management options that have been proposed by community members. The report is intended to inform decisions around sedimentation management by providing context and a high-level evaluation of options. It does not provide recommendations and the overall evaluations are qualitative in nature.

1.2 Report structure

The report begins with a brief summary of the history of sedimentation and its management and a review of the processes that drive sedimentation to provide context to current issues. Environmental values associated with the estuary are summarised based on available data sets to inform the evaluation of environmental impacts of the various options. Key commercial and recreational uses of the upper estuary are also documented so impacts on these values can be assessed. Options are evaluated against several criteria:

- legislative and feasibility challenges;
- costs;
- impacts on bathymetry;
- impacts on flooding;
- impacts on environmental values and water quality; and
- impacts on recreation and navigation.

The report has been informed by technical experts across the range of criteria; it considers and builds on existing published work and provides comprehensive analysis of primary data where possible. A simple summary evaluation across all options has also been provided for ease of interpretation. The report provides a general overview of the magnitude and nature of costs, issues and impacts. More detailed costing, feasibility studies and impact assessments would be required for many options if they were to be further pursued. Information on legislation and permitting requirements is general and provided to give a sense of the relative complexity of implementing options rather than being a comprehensive summary of permitting requirements.

In considering this evaluation it is first worth considering why, how and to whom sedimentation is perceived to be a problem.

1.3 Why is sedimentation perceived to be a problem?

There are three key reasons that are commonly cited to justify the perception that sedimentation and mudflats are problem in the kanamaluka/Tamar estuary:

- mudflats are a sign of an unhealthy, ‘clogged up’ estuary – that is, they are labelled as an environmental problem;
- mudflats and sedimentation more generally pose an increased flood risk; and,
- mudflats and sedimentation impact on those wanting to use the estuary and surroundings for recreation and are associated with poor amenity (visual and odour).

In evaluating potential options, it is first worth exploring which of these reasons are true.

1.3.1 Are mudflats and sedimentation an environmental problem?

Mudflats are a natural feature of the upper kanamaluka/Tamar estuary, with early European explorers documenting extensive areas of mudflats and wetlands in and around Launceston. Early navigation charts of the upper estuary from the 1830’s showing the area dominated by extensive mudflats and wetlands (swamp) with relatively narrow channels (see Figure 1).

Figure 1. Early kanamaluka/Tamar estuary navigation charts from the 1830's showing extensive areas of mudflats and wetland/swamp.

As will be summarised in Section 4 and Appendix 1 of this report, mudflats are a key component of intertidal habitat helping to store and cycle nutrients, providing food for small organisms that in turn feed other animals such as frogs, fish and wading birds. In the upper kanamaluka/Tamar estuary they also protect water quality and protect vegetated components of intertidal habit such as reeds, rushes, saltmarsh and *Melaleuca ericifolia* swamp forest from erosion.

The upper kanamaluka/Tamar estuary is internationally recognised as a Key Biodiversity Area for the high numbers and diversity of wading birds, particularly migratory species, which rely on mudflats and the intertidal zone for food and habitat. The mudflats of the kanamaluka/Tamar estuary support populations of migratory birds and threatened bird species protected by the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC).

They also act to trap pollutants such as nutrients, sediments and heavy metals entering the estuary from the catchment and surrounding foreshore (including point sources). In this way they improve water quality, which affects animals such as migratory fish as well as plant species in subtidal habitats (such as seagrass) that require good water clarity to access sufficient light for photosynthesis.

Mudflats also provide other environmental benefits including carbon sequestration, with carbon stored in intertidal zones now referred to as 'blue carbon' and considered to be a substantial and important control on carbon helping to mitigate climate change. Wetlands and mudflats provide flood protection by reducing the impact of storm surge in the coastal zone.

Mudflats and sedimentation of the upper kanamaluka/Tamar estuary are not an environmental problem and mudflats contribute substantially to the environmental values and health of the estuary.

1.3.2 Does sedimentation increase flood risks in and around Launceston?

Previous efforts to reduce sediment accumulation in the upper kanamaluka/Tamar estuary have been motivated by the perceived impacts of sediment accumulation on flood risks.

However large flood events are known to induce major scour of sediments in channels and, to a lesser extent, mudflats. For example, the 2016 floods were estimated to have scoured over 265,000 m^3 of sediment from the upper estuary. Smaller events before the period of sediment raking removed 20,000 m^3 to over 30,000 m^3 of sediment from the Yacht Basin alone. A previous flood modelling study (McAlister *et al.*, 2009) estimated the effects of high levels of sediment following a long dry period (2008) on flood levels relative to both historical bathymetry (reflecting conditions from 1889 to 1914) and scenarios where sediment had been removed from the channel and mudflats though dredging. This study suggested that sediment accumulation would have very little impact on flood levels during large flood events (13 cm at the Charles St Bridge for 1:200 year and 1:500 year events in both the South Esk and the North Esk Rivers). It also found a 55 cm decrease in flood levels at the Charles St Bridge for the 1:100 year flood event, the largest of the impacts seen across all the scenarios. Launceston is protected by a series of flood levees that offers protection to the city for floods up to the 1:200 year level flood in the South Esk River[6] . This means that increased flood levels for smaller floods don't increase the flood risk to Launceston's formal flood levee protected areas. WMAWater (2021) conducted a further analysis of flood levels for this report and found pre-flood bathymetry had little to no impact on flood levels due to the large volume of sediments scoured in the early stages of a flood.

The best available evidence suggests that sedimentation is likely to lead to, at most, small increases in flood levels and that these changes are unlikely to pose a significant flood risk to Launceston given the flood levee system that is already in place. Sediment levels are highest after extended dry periods. High flow and flood events scour accumulated sediment from the channel. Thus any increase in flood level and associated increase in flood risk will depend on the sediment conditions leading up to the flood event, and its size.

1.3.3 How does sedimentation impact on community values?

Community concerns about economic and recreational impacts of sedimentation are generally focused on three key issues:

- impacts on recreational users of the upper estuary such as rowing clubs and the Tamar Yacht Club;
- impacts on navigation around Home Point for the tourist boats and into the Seaport Marina; and
- the aesthetic values of the mudflats, including their look and the perception that they are visually unappealing; and
- their odour, with community reports of the unpleasant smell of mudflats.

[6] Note that the levee system was designed to provide protection for 0.5 per cent Annual Exceedance Probability (AEP) flood using the flood model available at the time (equivalent to these results). A recent update to the model has re-estimated the level of protection to 1 per cent AEP. This reflects the model results rather than any change to the levee system.

Infrastructure associated with key recreational uses of the upper kanamaluka/Tamar estuary were first developed during periods where significant levels of dredging were being undertaken to allow the navigation of large ships into the port at Launceston. Public information and statements of the navigation and access issues experienced by recreational users have been summarised here.

The Tamar Yacht Club was established in 1837 with jetty and clubhouse facilities developed in Royal Park from 1891 (with 1955 the last addition to this site). In 1996 the Tamar Yacht Club purchased the Beauty Point Marina in part due to issues with navigability and access to its facilities at Royal Park caused by sedimentation, as well as degraded water quality. The Tamar Rowing Club was established in 1876 with the first facilities developed in 1877 (moved to present location to allow for the Paterson Bridge construction), while rowing in the North Esk Rowing Club was established in 1899 with the first facilities developed in 1902 and their current site was developed in 2006. Regattas were held at Stephenson’s bend (near the Launceston Grammar Boatsheds) until 1925 when they were moved to Royal Park. This move was enabled by the broad and deep channel created by the large-scale dredge programs of the time. Since the cessation of large-scale dredging in 1965, accumulation of sediment in these previously dredged areas has created difficulties for access to the channel from recreational facilities during low and in some cases mid tides.

Challenges with access to the Seaport Marina and Home Point tourist boats are posed by reduced channel depth at the confluence of the North Esk River, and for the tourist boat, channel depth from Home Point towards the Cataract Gorge. The Seaport Marina is also affected by an accumulation of sediment under berths, particularly those immediately adjacent to the boardwalk. Sediment accumulation in the Seaport Marina has continued in spite of numerous dredging and prop washing efforts in the marina because this is a natural sedimentation zone and the infrastructure acts as a trap for sediments in the lower North Esk River. A large bar of sediment formed at the entrance to the North Esk River as a result of prop washing campaigns undertaken as part of the sediment raking program, with bathymetric surveys showing sediment prop-washed out of the marina settled in the channel of the North Esk River and into a mudflat off Town Point (Riverbend). Sediment raking also had the effect of moving sediment previously stored in visible mudflats into the main channel. An analysis of the effects of the sediment raking program found it had significant impacts on channel depths in the Home Point area. Bathymetric surveys conducted since sediment raking ceased show that the estuary is undergoing a process of restoring channel depths with mudflats re-establishing. Anecdotal accounts suggest that this is resolving issues with navigation that were experienced by the end of the sediment raking program due to this loss of channel depth. Sedimentation in the Seaport Marina will continue given the natural tendency of this area to act as a sediment trap.

The final concern raised by the community is around the appearance and odour of the mudflats. Mudflats can give off an unpleasant smell due to the release of hydrogen sulfide gas by some of the microbes that live in the sediment. Odours around Royal Park are likely to be contributed by the Margaret Street Pump Station's combined system vent stack or outfall (sewage smell) which is not associated with sediment accumulation. Odours from this source are likely to be improved through investments currently being made in the combined sewage-stormwater system.

Community perceptions of the mudflats and their values are likely to play a role in whether they are perceived as ugly and a sign of a degraded estuary or whether they're perceived positively in terms of the environmental values they support, particularly the presence of wading birds. The current aesthetic of the mudflats along the West Tamar has been impacted by the destabilisation caused by sediment raking which resulted in erosion of the banks and foreshore vegetation. It may be that restoration of a more natural transition from water, through mudflat, reeds and rushes, to *Melaleuca ericifolia* swamp forest provides for improved visual amenity of these mudflats. The intertidal habitat will gradually restore as the natural process of sedimentation continues.

1.4 Process of report preparation

Given the extensive range of options and impacts considered in this report a broad range of technical and scientific expert input was sought to inform the evaluations. The report was developed with input from:

- an expert working group who helped develop the scope of the report and provided detailed feedback on draft sections of the review and evaluation;
- a selection of technical experts targeted for their specific knowledge in key areas such as engineering infrastructure, flood risk and environmental values;
- peer review of the entire report by a panel of scientists and experts as part of the Tamar Estuary and Esk Rivers (TEER) Program process for endorsing scientific outputs from the project; and
- external peer review by a panel of expert scientists.

1.5 Overview of report structure

The report has the following structure:

- *Sections 2 and 3* – background information on the history of sedimentation in the kanamaluka/Tamar estuary and sedimentation processes in the estuary.
- *Sections 4 and 5* – information on key environmental, social and economic values that impacts will be assessed on.
- *Sections 6 to 15* – an introduction to the evaluations followed by detailed assessments of each of the potential options.
- *Section 16* – a summary of the evaluation criteria and the resulting evaluation matrix that synthesises the findings of the detailed evaluations.

Appendices provide detailed information on environmental values associated with the estuary, relevant legislation referred to in the evaluations, and a detailed description of the method for deriving the evaluation matrix, which have been kept separate to aide in the readability of the report. Detailed assessments have also been written to allow them to be read in isolation to the rest of the report.

2 History of sedimentation and sedimentation management in the estuary

Ellison and Sheehan (2013) provide a comprehensive overview of the history of sedimentation and the way it has been managed in the kanamaluka/Tamar estuary. Quotes and the timeline of events provided here are taken from this source unless otherwise referenced.

The first Europeans to explore the upper estuary were Symons, Collins and Clarke in 1804. Early descriptions stated that while the lower estuary was *"good and navigable for the largest vessels"* that beyond Tamar Island the channel was "*only for small craft*"' with the areas around Home Reach described "*The River is very shallow with broad mud banks and reedy swamps beyond them."*

Ellison and Sheehan (2013) provide a summary of the accounts of explorer experiences and observations in this and a later expedition in 1804 by Collins, Clarke and Paterson and find:

'In summary, analysing the early descriptions of Collins, Clark and Paterson, along with the chart of Welsh showing Home Reach depths of 1.8—3.6 m below a high water mark, it seems that the upper Tamar was at the time … to feature a narrow and shallow main channel surrounded by extensive mud banks. This was very difficult to navigate through with a 1.7 m draft vessel.'

Figure 2 shows an early navigation chart for the upper estuary from 1833. This shows a narrow channel with wide mudflats on the western shoal, north bank, lower North Esk and the area where Royal Park is today. The confluence between the North Esk and the kanamaluka/Tamar estuary shows multiple channels marked with rapids. Areas surrounding the estuary are marked as swamp.

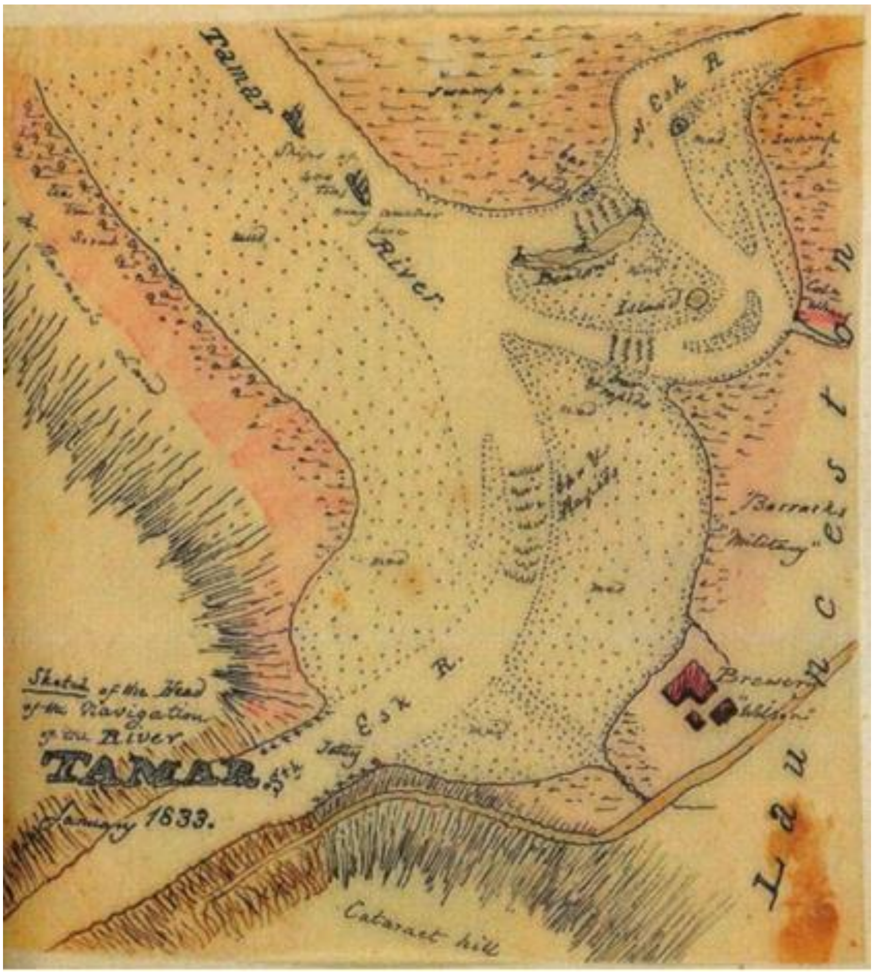


Figure 2. Early kanamaluka/Tamar estuary navigation chart from 1833

Following this early European exploration, Launceston was settled by Europeans in 1805. The first sea going vessel was launched from Launceston in 1826 and the Port of Launceston developed throughout the 1830’s. In 1834 community concern led to a petition to the Governor regarding navigation in the estuary to the Port. The Launceston Marine Board formed in 1857 with works focused on improving the navigability of the channel. A spoon dredge was procured in 1878 with dredging extending further down the estuary in the 1880s as larger ships were arriving. In 1893 dredging created a 61 m channel with a minimum depth of 4.57 m. Dredging continued until 1965 focused on providing sufficient channel depth to accommodate larger vessels. Early dredging focused on the areas adjacent to Kings Wharf and the mouth of the North Esk, increasing channel depth in Home Reach from 2 m to 3 m in 1889 and to 5 m during the 1900’s. After the mid-1900’s, dredging was extended to the main channel as far as Rowella to allow for larger vessels to enter the Port of Launceston.

A consulting engineer recommended removal of rocks and other obstructions in the main channel in 1912 as well as straightening the upper estuary by excavating a canal of 4 m depth at low tide called Hunter’s Cut, to avoid Stephenson’s Bend near Mowbray. Work on this canal commenced in 1919 but was later abandoned as completion proved too expensive, with the dredged channels later silting up.

Lake Trevallyn was constructed on the South Esk in 1955. This is a relatively small storage which is used for hydro-electric power generation, town water supply, a commercial fishery and recreation. Water is diverted through a tunnel to the Trevallyn Power Station and discharged through the Tailrace. In addition to natural inflows to Lake Trevallyn, water from the yingina/Great Lake catchment is diverted into the South Esk catchment through the Poatina Power Station to the Brumbys-Lake catchment, feeding into Lake Trevallyn. The storage is relatively small with flood events in the catchment generally spilling over the dam wall and entering the kanamaluka/Tamar estuary through Cataract Gorge. Flow data for Lake Trevallyn and its catchment provided by Hydro Tasmania covering the period from 1986 to 2009 showed that more than 35 percent of flows into Lake Trevallyn via the South Esk River were delivered from the Great Lake catchment through Poatina Power Station. Roughly 70 percent of inflows to Lake Trevallyn passed through Trevallyn Power Station and were discharged through the Tailrace with the remaining flows being passed down Cataract Gorge. Environmental flows during the period increased from 0.5 cumecs to 1.5 cumecs and were increased again in 2011 to 2.5 cumecs. Irrigation takes have also increased since this period impacting on inflows to Lake Trevallyn. Most flows down Cataract Gorge pass as high flow events. This means that in some years the dam will spill frequently while in others there are no spills (note Section 3 provides a detailed analysis of flow data to show the impacts Lake Trevallyn has had on inflows to the estuary).

Regular maintenance dredging ended in 1965 after the relocation of the daily Tasmania to Melbourne ferry service to Devonport and major cargo activity to the new, deeper Bell Bay wharves. Previously dredged areas began to revert to their natural state of a low-capacity channel and extensive intertidal mudflats. Figure 3 shows a comparison of cross sections from:

- before extensive dredging of Home Reach (1889-1914);
- during the period of dredging before the construction of Lake Trevallyn (1936 to 1955);
- during dredging after the construction of Lake Trevallyn (1957);
- the highest level of sedimentation during the period of sediment raking (June 2016 immediately before the 2016 flood); and
- the most recent survey in spring 2020 (October) showing cross-section after the sediment raking program ceased.

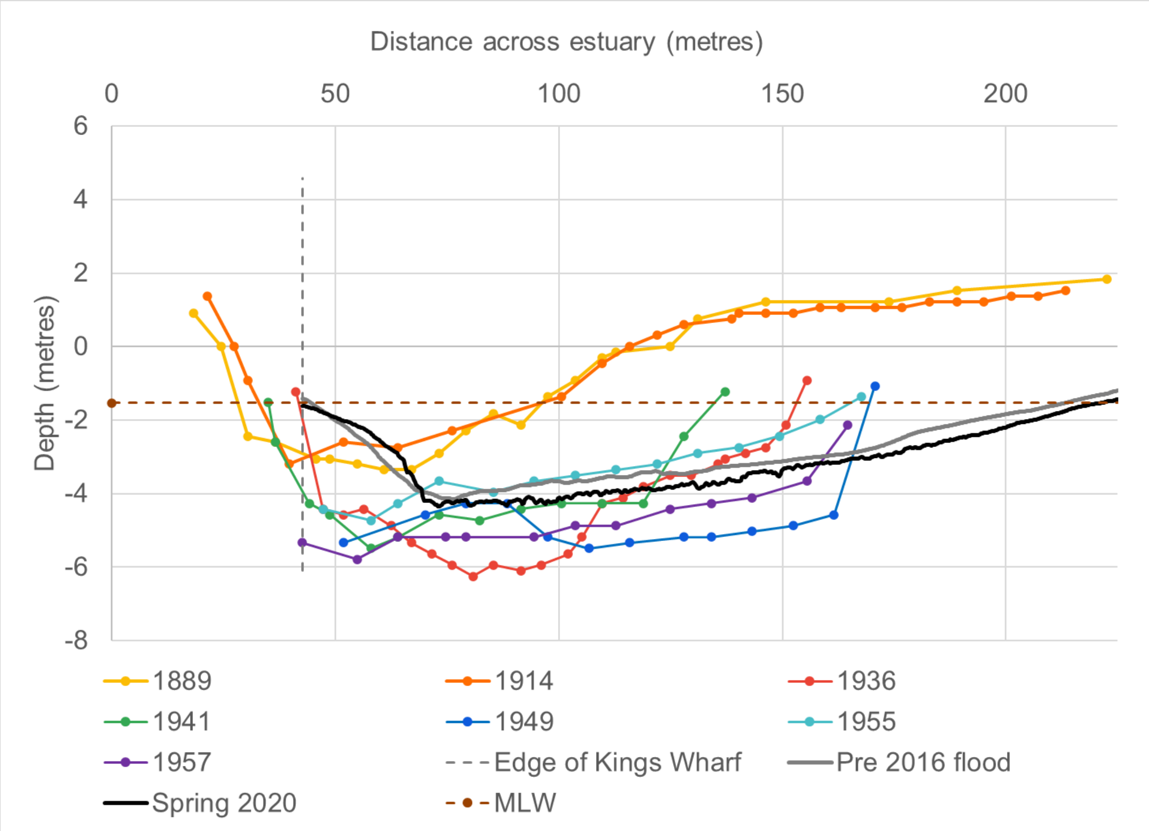


Figure 3. Cross sections of Home Reach at Kings Wharf – comparison pre-dredging (1889), dredged (1936), dredged after the installation of Trevallyn Dam (1957), sediment raked immediately before 2016 flood, and spring 2020 post sediment raking. MLW refers to the mean low water level, or low tide. Sections above this line would on average be visible at low tide. Distance across the estuary increases from east to west.

Figure 3 shows that dredging created a wide, deep channel (note the shift in channel to the right with the construction of Kings Wharf). This was to maintain adequate channel depth and width for large ships using the wharf. Only one survey is available during the period of dredging after Trevallyn Dam was constructed (1957). This shows that cross-sectional area at this time maintained the dredged shape. The cross-section from 2016 before the 2016 flood shows a return to the shape from before dredging, although mudflats are lower and the channel is deeper than the original surveys. Since sediment raking ceased the channel has deepened (by approx. 0.5 m and up to 2.3 m) but the general shape of the estuary at this point remains similar to pre-dredging and during raking.

Community concern began to focus on perceived increase in flood risk due to the lower capacity channel and public perceptions that mud is not as aesthetically pleasing as open water. Dredging of Home Reach recommenced in the 1980's to enlarge the channel to maintain navigability, access and for visual amenity. From 1988 to 2007 an average of approximately 42,000 m^3 of material was removed each year from the upper estuary and disposed of in floodplains located near Trevallyn, at Ti Tree Bend and at Stephenson's Bend (*pers. comm*, City of Launceston).

The introduction of rice grass in the estuary near Rosevears in 1947 led to increased sedimentation and large changes to the intertidal zone with sand and gravel beaches and rocky shorelines converted to silty habitats.

Figure 4 summarises some of the key modifications to the upper estuary. Early modifications were made to encourage sediment deposition in the shipping channel at the Tamar Island wetlands, closing this off using timber piling and sunken ships sometime between 1897 and 1912 (Foster *et al.,* 1986). Extensive infill of wetlands has occurred with areas around Royal Park, Invermay and Trevallyn converted from swamp and mudflats to land. In the 1980's dredge spoil was used to infill areas around Ti Tree Bend, Stephenson's Bend and Trevallyn. Early embankments to protect from flooding were originally built following flooding in 1809. The embankment along Invermay was raised and made more substantial using dredge materials in the 1880's. Flood protection levees were then extended along the North Esk in 1910. Further major levees were constructed in 1960 with a substantial levee rebuilding program in 2015.

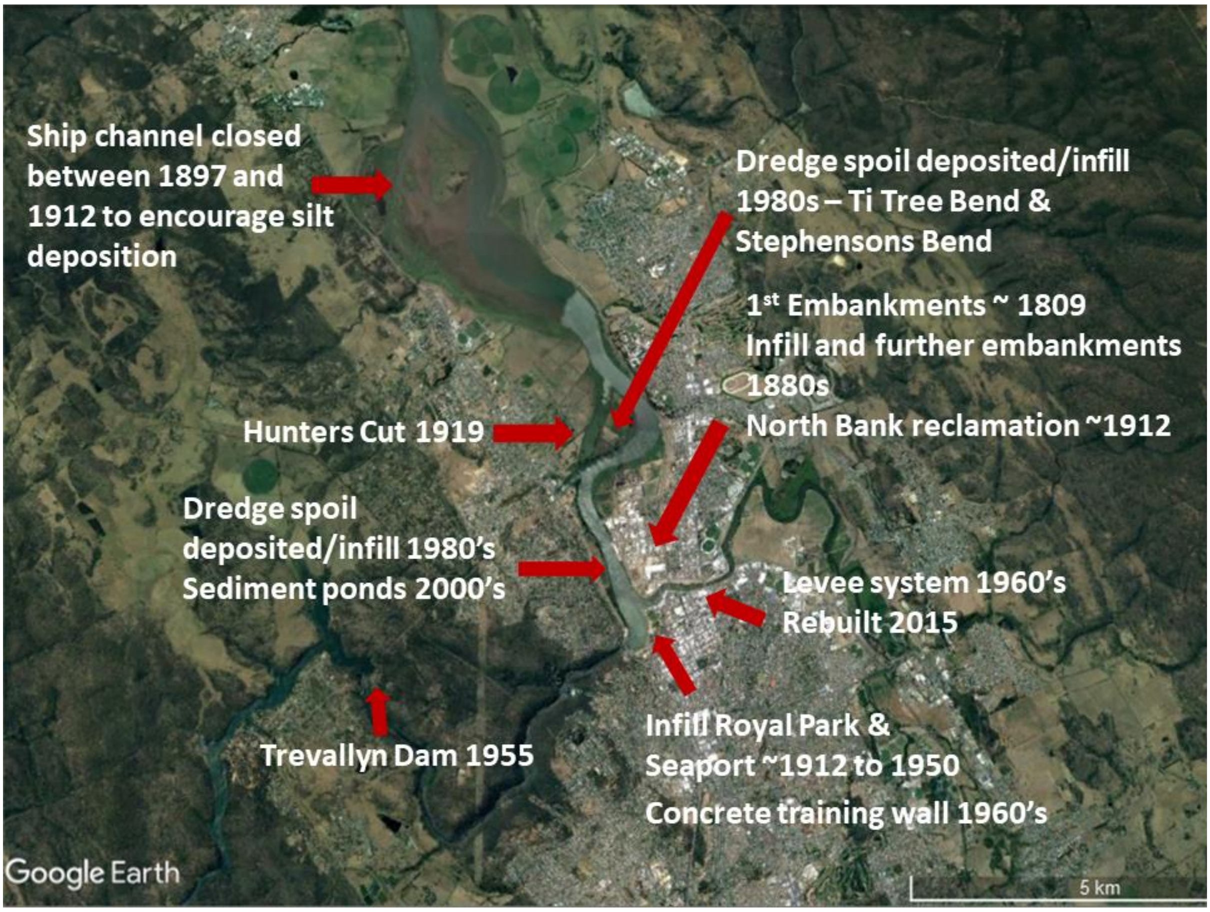


Figure 4. Key modifications to the upper kanamaluka/Tamar estuary.

Following the 1929 flood, during which low lying areas including Invermay were inundated with several metres of water, there were proposals to create a canal diverting the lower North Esk behind Invermay to enter the estuary at Stephenson's Bend. This idea was rejected as being too expensive, with flood levees being increased instead. A similar diversion proposal was presented in 1950 and again rejected.

Proposals for barrages to create a freshwater lake in the upper estuary were first made in 1911 and then later re-examined in 1939, the 1970's, the 1990's and 2013. A report from 1975 assessed the 1970 barrage proposal listing potential benefits as 'water supply, a constant level freshwater lake for recreation, increase in property values, a bridge crossing and improvement to deep water navigation in the upper Tamar' (Ellison and Sheehan, 2013) with possible disadvantages 'siltation of navigation channels and bays in the lower Tamar due to reduction in tidal scour, algae and weed growth in the upper reaches, progressive siltation of the upper reaches, the need for sewage treatment in the upper reaches and the lifting of groundwater levels which could exacerbate landslip movement in critical areas' (Ellison and Sheehan, 2013). Sections of Invermay have an elevation below high tide. Lifting of the groundwater table in the suburb of Invermay is likely to lead to significant long-term impacts, with the very real probability of groundwater expressed at the surface throughout low-lying areas of the suburb. Ellison and Sheehan note that this report was written at a time before biodiversity values of the estuary were understood so the focus of the report was on aesthetics and navigability.

Ellison and Sheehan summarise the three alternative scenarios which are prevalent in future visions for the upper kanamaluka/Tamar:

'1. Barrage conversion to freshwater lake: this recurrent proposal as reviewed above is increasingly against contemporary community views that value natural biophysical conditions.

2. Create more open water by clearing the silt, by increasing flows down Cataract Gorge (Davis and Kidd 2012) and/or raking silt deposits to promote natural clearance in floods. This is the prevalent view also supported by the amenity value and reduction of flood risk provided by wider channels and more open water, but is subject to the removal of the silt not causing problems through remobilisation of contaminants.

3. Tolerate the silt better. This review of the early history establishes that when Europeans first visited the upper Tamar it was heavily silted, hence what is viewed as a nuisance is actually the natural state. Community memory has a view of open water normality that is more perhaps from the period of dredging through last century.'

3 Processes of the kanamaluka/Tamar estuary that influence sedimentation and bathymetry

An estuary is a body of water where one or more rivers meet an ocean or sea. Estuarine waters are a changing mixture of fresh and salt water, and they receive sediments from both river and marine sources. As such, estuaries are influenced by tide, wave and river processes.

The kanamaluka/Tamar estuary is unusual in Tasmania in that it extends a long way inland, approximately 70 km, and has a major population centre, the city of Launceston, at its head. Figure 5 shows a map of the estuary, with the extent of the tidal influence marked. Tidal influences extend beyond Launceston to the Cataract Gorge at the end of the South Esk River, and approximately 12 km upstream to St Leonards Picnic Grounds in the North Esk from the confluence of the North and South Esk Rivers.

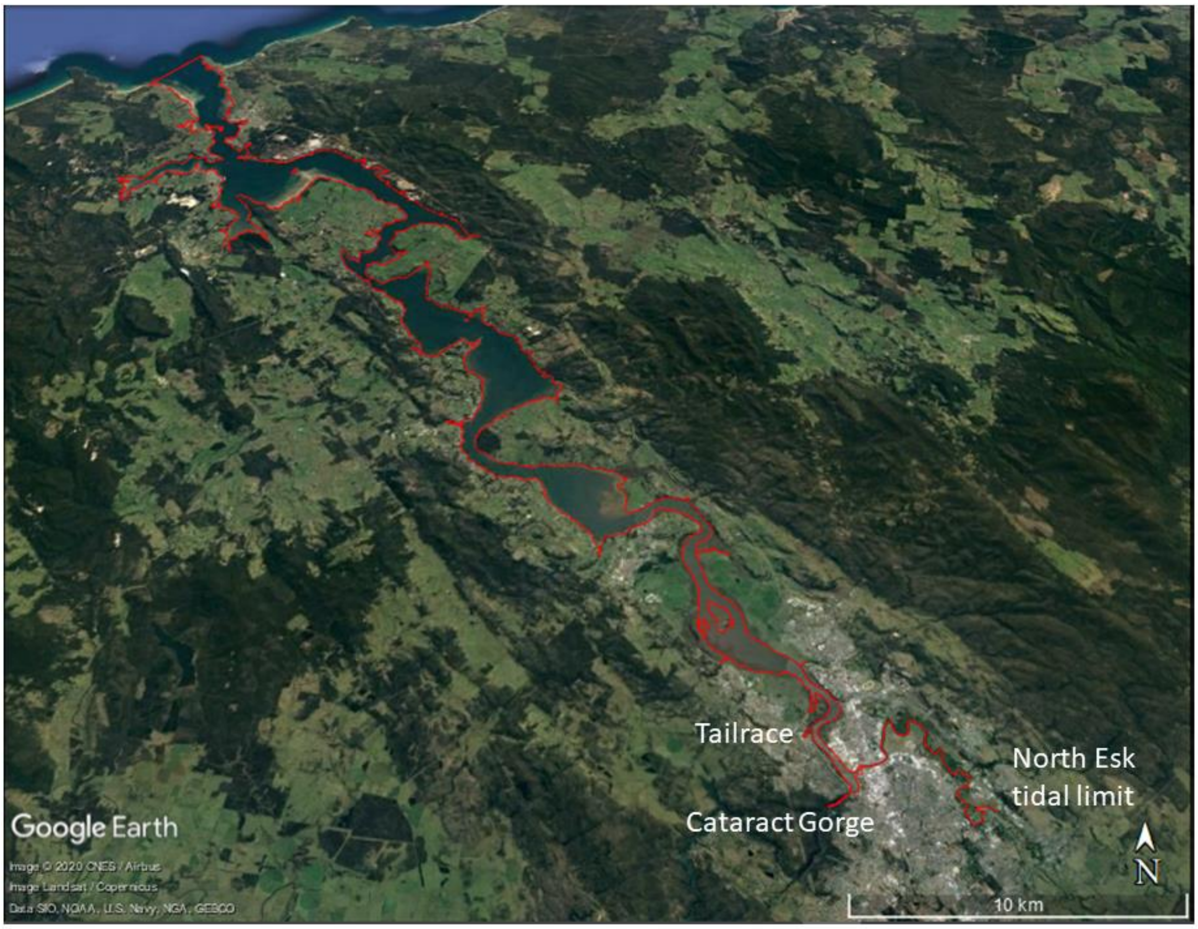


Figure 5. Extent of tidal influence in the kanamaluka/Tamar estuary.

3.1 Tide dominated estuaries

The kanamaluka/Tamar estuary has a tidal range of approximately 2.3 m at the mouth to 3.25 m at Launceston (BMT WBM 2008), which is considerably larger than estuaries in eastern, southern and western Tasmania. It has been classified as a tidal-dominated estuary by Oz Coasts, Australian Online Coastal Information portal available at: http://www.ozcoasts.gov.au/search_data/detail_result.jsp

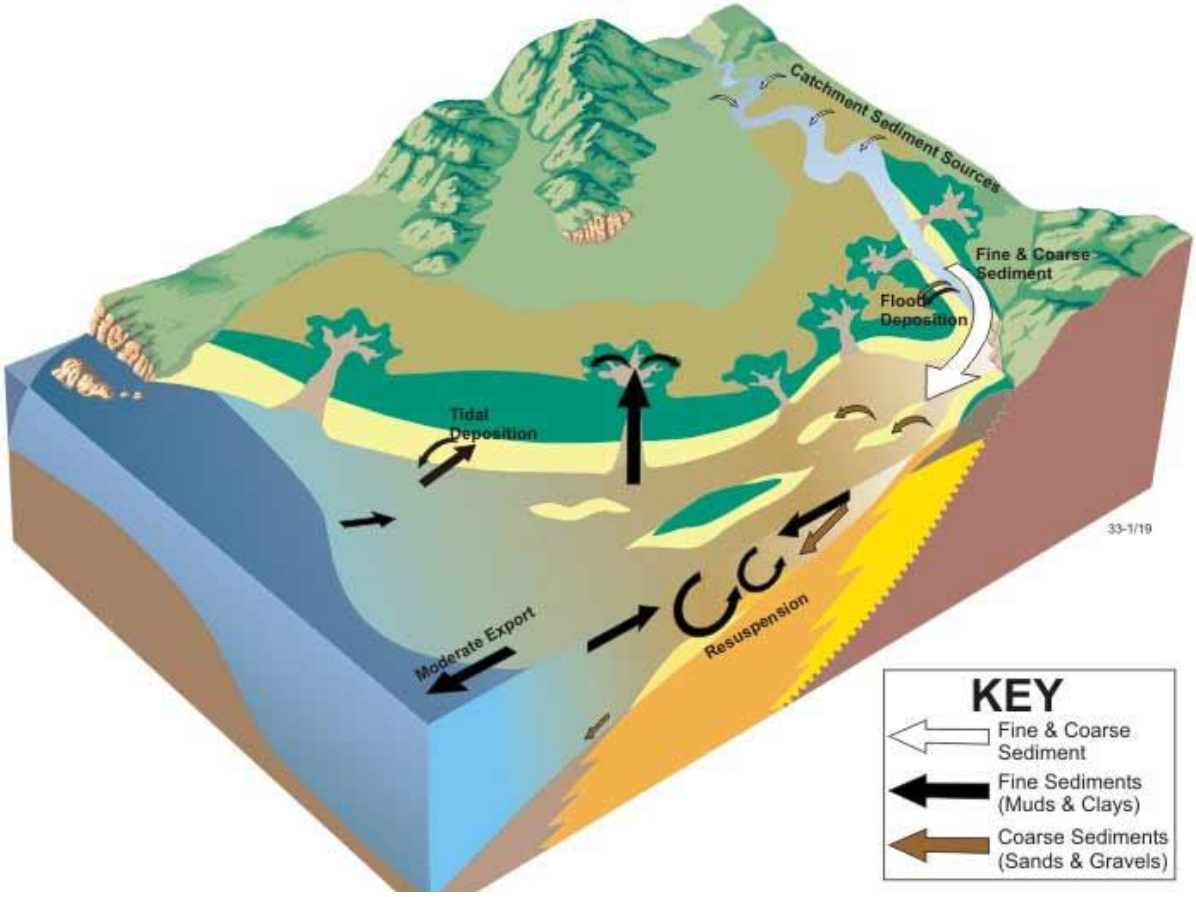


Figure 6. A conceptual diagram of sediment transport in a tidal-dominated (and unmodified) estuary (source Oz coasts, available at https://ozcoasts.org.au/conceptual-diagrams/science-models/geomorphic/tde/tde_sed_trans/)

In a tidal-dominated estuary (Figure 6) fine and coarse sediments transported from inland and marine sources flocculate out in the estuarine channels where the saltwater meets freshwater. Tidal-dominated estuaries are naturally highly turbid because these sediments are continually resuspended and reworked by strong tidal currents. They pool temporarily within channels, forming tidal sand banks, and in areas with high sediment loads they can produce 'fluid muds', a low density muddy sediment which may be stationary or mobilised by tidal currents.

The kanamaluka/Tamar estuary is a drowned river valley, an estuary formed when rising sea levels flooded an existing river valley. This has created a long, sinuous estuary which is tidally dominated, where there is poor flushing of sediments from the upper estuary to the sea. While mudflats and sediment accumulation primarily occur in the freshwater sections of the estuary, the interaction of salt and freshwater is also important to sedimentation processes. Fine silts carried in freshwater flocculate and settle when they hit saline water, and then are carried upstream on the tide. This process contributes to the retention of sediments in the upper estuary. Sheehan (2008) provides a comprehensive description and classification of the kanamaluka/Tamar estuary.

3.2 Key processes impacting sedimentation in upper kanamaluka/Tamar estuary

There are two key processes that affect the level of sediment in the upper estuary:

- sediment accumulation due to tidal processes; and
- scour of sediments during freshwater flow events from the catchment.

3.2.1 Impacts of tidal processes on sediment accumulation

As shown in Figure 6, moderate export of sediment to the ocean generally occurs in tidal-dominated estuaries. However, in the kanamaluka/Tamar estuary this export has been reduced because major human-induced alterations to the upper reaches of the estuary have altered tidal water volumes and flow, and hence the natural equilibrium of sediment transport. In particular, infilling of wetlands around Launceston for urban expansion, building tidal levees, draining of tidal wetlands, particularly in the North Esk, for urban and agricultural development, and extraction and redirection of water for hydroelectricity generation and town water supplies have modified the volume of water flowing into and from the upper estuary and the sediment load that it carries. The introduction of rice grass into the estuary has also had significant impacts on sedimentation processes, particularly in the mid-estuary (Sheehan, 2008).

The critical factor affecting sediment accumulation in the upper estuary is the volume of tidal water flowing up the estuary on each high tide, which is referred to as the 'tidal prism' and measured as the difference between mean high tide and mean low tide levels. Before extensive modifications to the upper estuary occurred, a much larger volume of tidal water was able to flow up the North Esk and expand out on the wetlands (see Figure 7). However, this volume of tidal water flowing to the upper reaches was significantly restricted following infilling and levee installation. This has resulted in significantly reduced flushing of the upper estuary and consequently increased sedimentation.

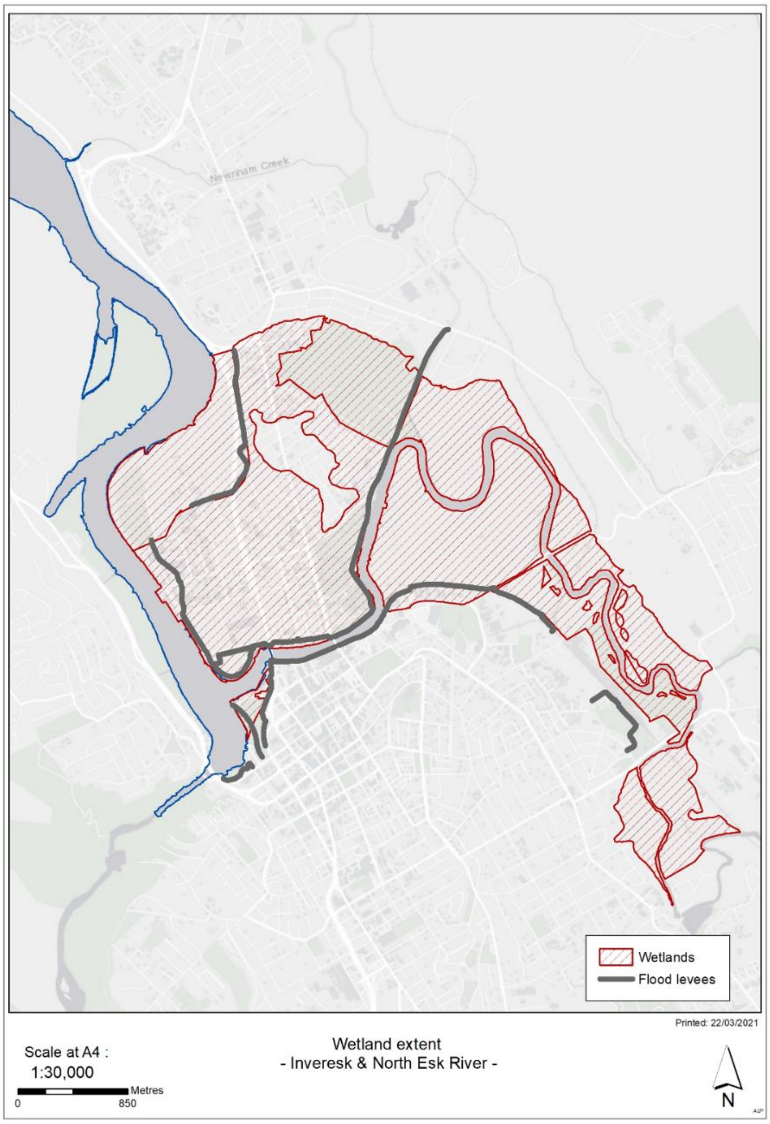


Figure 7. Map of original tidal extent in the upper estuary before construction of Launceston's flood levee system, infill of Invermay, Inveresk, West Tamar and Royal Park, and construction of informal tidal levees and infill of the North Esk floodplain. Thick grey lines show the formal flood levee system. Hashed areas were originally wetland.

The reverse is also true – actions that increase the tidal prism reduce sedimentation because of the increased volume of tidal waters that flow to and from the upper estuary and transport sediment. According to *Kidd et al.* (2017) who investigated the causal factors of sedimentation in the kanamaluka/Tamar, 'any increase in the tidal prism equates to the same volume of silt lost from the inter-tidal zone'. The kanamaluka/Tamar estuary has been subject to numerous interventions which have reduced the tidal prism and resulted in increased sedimentation of the upper estuary. This includes dredging, where dredge spoil was used to infill wetlands and increase the elevation of land around Inveresk, Invermay and Ti Tree Bend; the West Tamar; Royal Park and lower Margaret St; and the lower North Esk; as well as the introduction of rice grass to the estuary.

It has been estimated that the tidal prism at Kings Wharf, Launceston has decreased by approximately 30 percent (i.e., 1,500,000 m^3) from 1830 to 2011 (Davis and Kidd, 2012). Additionally, construction of informal tidal levees on private and public land in the North Esk floodplain and along the kanamaluka/Tamar foreshore in recent years will have reduced the tidal prism even further since this estimate was made. However, reduction of the tidal prism in the South Esk has been minimal because of the natural topography of the Cataract Gorge with steep cliffs.

Differences in the velocity of flood and ebb tides in the kanamaluka/Tamar estuary also contribute to the movement and deposition of sediment in the upper sections of the estuary when freshwater inflows are low, although to a much lesser extent. Flood tides that travel upstream from Low Head to Launceston and into the North Esk have a higher velocity than ebb tides, which carry water back downstream to the coast. This difference in tides is referred to as tidal asymmetry. Kidd *et al.* (2017) provide detailed information on tidal velocities in the estuary.

3.2.2 Inflows, scour and upstream migration of sediments

The second process that affects the level of sediment in the upper estuary is scour from flow events. The upper section of the kanamaluka/Tamar estuary receives freshwater inflows from three main sources – the North Esk River, spills and environmental flow releases from Lake Trevallyn down Cataract Gorge, and releases of water from Lake Trevallyn through the Tailrace for hydroelectric power production. Note there is some addition of flows from sewage treatment plants discharging to the upper estuary but volumes are relatively small, with minimal suspended solid loads, and unlikely to have any significant impact on sedimentation. Inflows from the North Esk are low compared to the combined discharge at Cataract Gorge and the Tailrace because the North Esk catchment area is much smaller.

Figure 8 shows an estimate of 'natural' flows that would have been expected to occur through Cataract Gorge, versus flows under current spill and environmental flow conditions using data from 2008 to 2018. 'Natural' flows are estimated based on streamflow gauge data from Meander River at Strathbridge (852), 164 Liffey at Carrick bridge (164), 18312 Macquarie River d/s Elizabeth (18312) and 181 South Esk River at Perth (181). Flow statistics from these flows are shown in Table 1.

Table 1. Statistics of flow under 'natural' conditions versus 'current' Cataract Gorge flows using data from 2008 to 2018.

Statistics	Natural flows	Current Cataract flows	Change from natural
Minimum flow (cumecs)	1.0	2.5	1.5
Days with flows under 2.5 cumecs	11.3	0	11.3
Days of scouring flows (>150 cumecs) per year	19.0	13.9	-5.1
Average daily flow (cumecs)	41.0	21.3	-19.8
Days over 290 cumecs per year	7.3	7.3	0
Maximum flow (cumecs)	2177.5	2151.0	-26.5

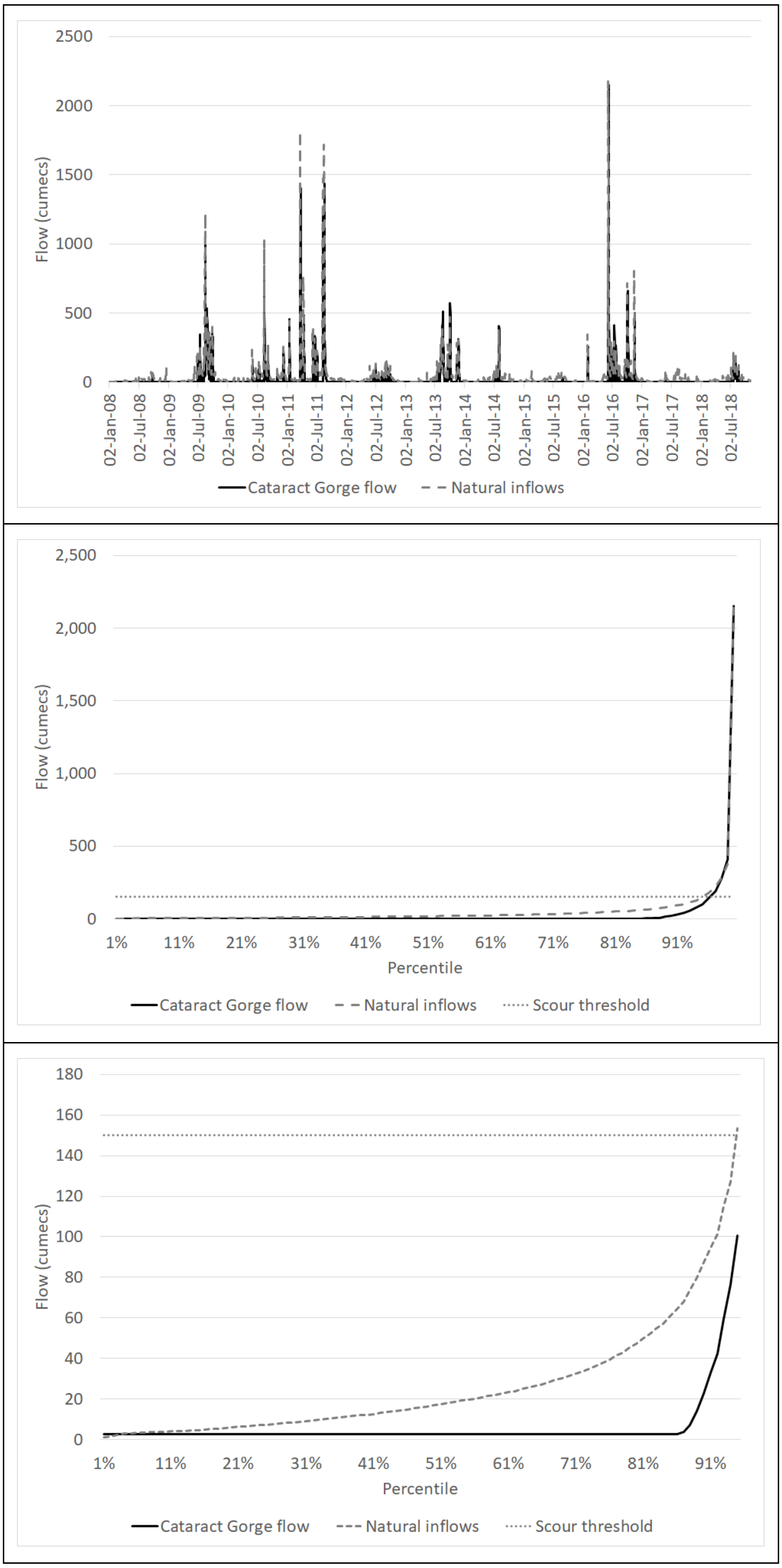


Figure 8. Estimated 'natural' flows (dashed line) versus current flows (solid line) down Cataract Gorge - Jan 2008 to November 2018. The percentile shows the percentage of flows that are smaller than flows of a given size.

Lake Trevallyn was constructed in 1955, with flows used for power production passing into the estuary through the Tailrace, which is 2.5 km downstream of where the South Esk naturally flows into the estuary through Cataract Gorge. As can be seen in Figure 8, Lake Trevallyn is a relatively small storage which passes all moderate to large flood events down through the Cataract Gorge, while capturing smaller events. The lake and power station have changed inflows into the estuary in several ways:

- Flows into the estuary have increased with the addition of flows diverted through Poatina from yingina/Great Lake (flow that naturally would have flowed into the Derwent River). Apart from times when natural flows would have been below 2.5 cumecs, these flows enter the estuary through the Tailrace. Average flows though the Tailrace during the period analysed were 48.7 cumecs, with total inflows from the South Esk River increased from 41 cumecs under natural conditions to 70 cumecs – an increase in the volume of flows entering the upper estuary of 29 cumecs or approximately 70 percent above natural conditions.
- Low flows during very dry periods have increased to a minimum of 2.5 cumecs due to environmental flow releases down Cataract Gorge. Under natural flow conditions just over 3 percent of days (~11 days per year) would be expected to have flows down Cataract Gorge less than this value.
- Average flows entering the estuary through Cataract Gorge are almost half those of natural flow conditions. This average is due to decreases in flows below 290 cumecs, with the greatest impact on flows between 10 and 40 cumecs (143 days) and 40 to 150 cumecs (52 days). There are on average 5 fewer days per year with flows between 150 and 290 cumecs. There is no change in the number of days with flows over 290 cumecs or in the distribution or magnitude of events above this threshold.

It should be noted that while many authors quote a historic 'baseflow' of 30 cumecs to the estuary through Cataract Gorge (e.g., Davis and Kidd, 2012), this estimate was based on the change in observed average annual flows before the dam (1901-1955) versus the period after (1956-1970) using analysis from Foster *et al.* (1986). This average annual flow does not represent 'baseflow' conditions as it captures a diverse range of high and medium flow events in each year. As such comparison with environmental flow releases as a modified 'baseflow' is erroneous. As can be seen in the analysis the lowest flows under 'natural' conditions would have been below current environmental flow release levels. Direct comparison of average annual flows before and after construction of the dam is also influenced by annual variability in climatic regime in the two periods that were not considered. The comparison here uses the same climatic period and reconstructs the variability of daily flows which is a better representation of impacts on both lower and higher flow conditions through Cataract Gorge. Notably, days of scouring flows between 150 cumecs and 290 cumecs are 27 percent lower than under natural flow conditions (approx. 5 fewer days per year).

Figure 9 demonstrates changes in sediment levels, as a consequence of changing freshwater inflows, seen in the mudflats and main channel and overall changes. This is based on bathymetry data collected between Kings Bridge and just below the confluence with the North Esk from January 2008 to April 2012. Note that there was also some dredging in this period, so not all observed changes in sediment levels can be attributed to flow – this gives an upper bound of the change in sediment level that could be expected from inflow events.

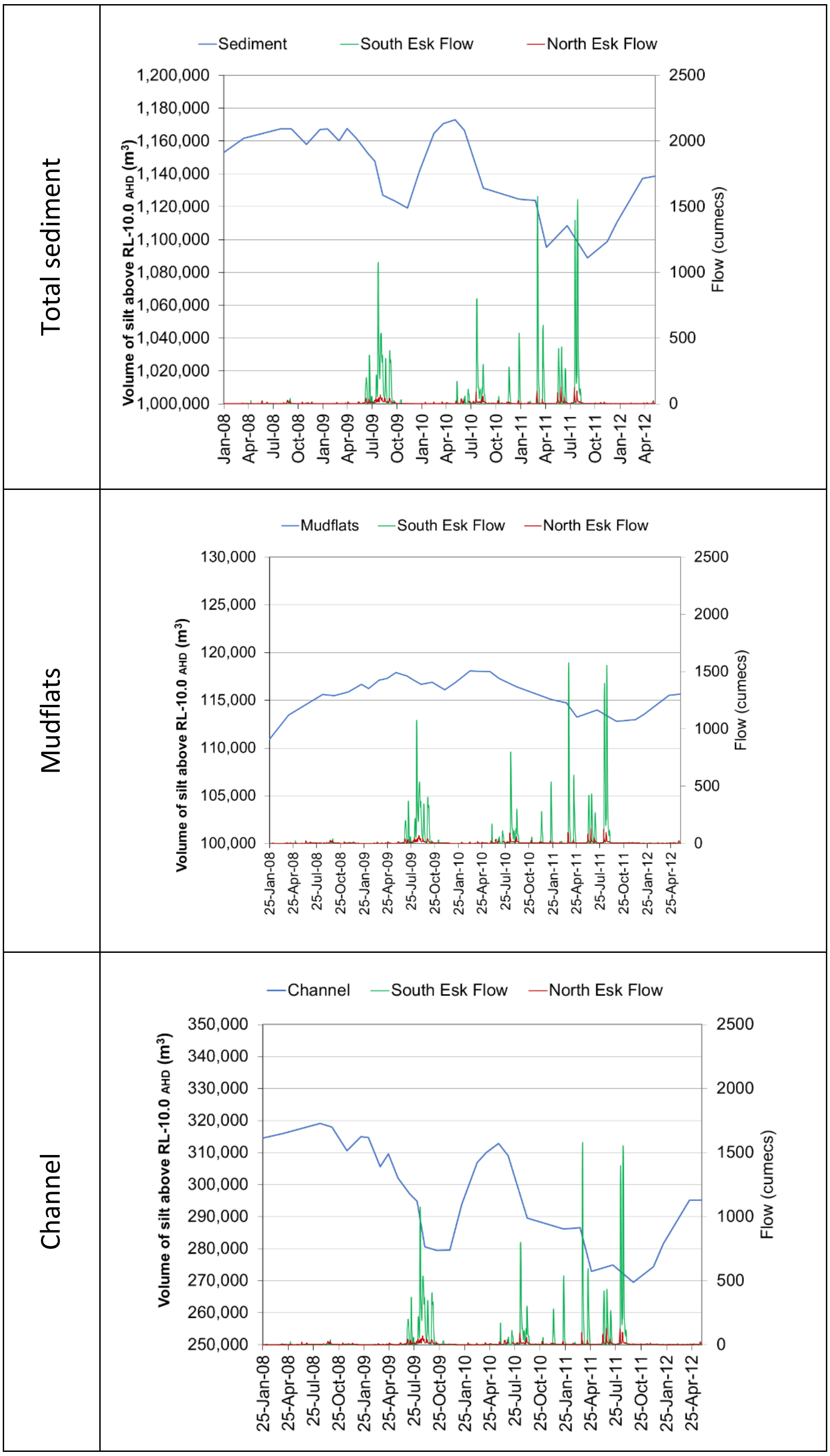


Figure 9. Sediment level in the section from Kings Bridge to just below the North Esk confluence, split into mudflats and channels. North Esk and South Esk flows through Cataract Gorge are also shown. Note the data shown is from 2008 – 2012, before sediment raking commenced but includes the effects of some dredging. Data from Kelly (2019).

The data shown in Figure 9 commences at the end of the millennium drought – a period of very low inflows to the estuary where sediment accumulation was high. The figure shows flows entering from the South Esk are much greater than those from the North Esk. It also shows rapid decreases in sediment levels coinciding with flow events down the South Esk (e.g., July 2009, July -10, April 2011). These decreases in sediment level are greatest in the channel, with mudflats remaining more stable over time. Periods of low flow between these high flow events see a rapid return of sediment to the levels experienced previously (e.g., January 2010 and January 2012). Foster *et al.* (1986) estimated that flows of 150 cumecs were required to induce scour of sediments. Analysis of the data shown in Figure 9 provides an estimate for this section of the upper estuary to just below the confluence with the North Esk (primarily the Yacht Basin) of:

- 6,400 m^3 of sediment scoured by a 154 cumec flow on 2 June 2010.
- 35,000 m^3 of sediment scoured by an 800 cumec flow on 14 August 2010.

Inflows change sediment accumulation in two ways:

1) large flow events induce scour of the channel and mud flats; and

2) inflows reduce upstream migration of sediments.

McAlister *et al.* (2009) modelled sedimentation processes in the estuary and found flows from both the Tailrace and through Cataract Gorge acted to slow upstream migration of sediments. They found only 'marginal' benefits in the Yacht Basin (9 percent) and smaller benefits in Home Reach (3 percent) from increasing environmental flows to 10 cumecs – that is, increasing smaller magnitude flows through Cataract Gorge has minor impacts on sediment migration and thus sediment accumulation in the upper estuary. By comparison, the addition of flows from Poatina Power Station into the kanamaluka/Tamar estuary at the Tailrace were found to decrease sedimentation through decreased upstream sediment migration by 30 percent. They found that 'natural' flows increased Home Reach siltation by 11 percent but decreased Yacht Basin sedimentation by 14 percent illustrating the complex nature of changes in sedimentation due to changes in flow regime.

4 Environmental values of the estuary

The kanamaluka/Tamar estuary and its foreshore are associated with a wide variety of environmental values. The estuary is long and provides a diverse range of conditions and habitat types that support numerous ecosystems and flora and fauna species. Edgar *et al.* (2000) found that of 111 estuaries studied in Tasmania, the kanamaluka/Tamar was the second most diverse, with 116 species of invertebrates and 41 species of fish recorded. Lara and Neira (2003) found that the estuary provides spawning habitat for 30 species of fish. Parsons (2011) states that the estuary is the only known location to support over 300 species of algae. As shown in Figure 10, the upper estuary, from above Launceston to Rowella, is internationally recognised as Key Biodiversity Area/Important Bird Area, primarily due to the importance of its mudflats and intertidal vegetation to migratory and other wading bird species. This section of the estuary is also protected under state legislation as a Conservation Area, acknowledging it's unique and important environmental values.

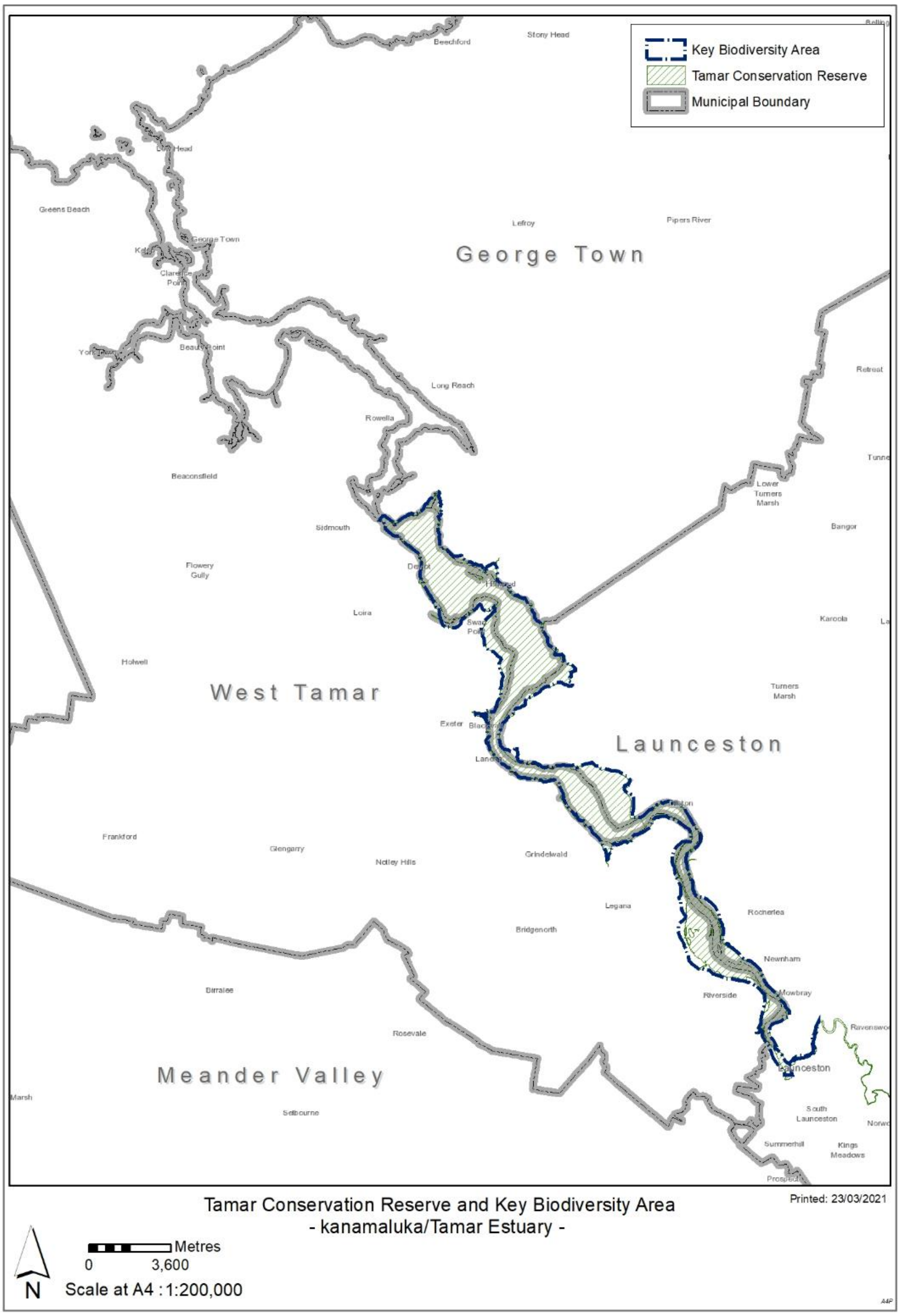


Figure 10. Map showing boundaries of Key Biodiversity Area and Tamar River Conservation Area extending from above Launceston at the head of the estuary to Rowella.

4.1 Framework for evaluating impacts on environmental values

The evaluation of potential sediment management options in this report considers impacts on habitat provided by the estuary – both in intertidal and subtidal areas. Water quality is also a key component of ecosystem health which is considered. These impacts are then used to assess impacts on the special values provided by the estuary including migratory fish, state and federally listed threatened species and communities and federally protected migratory bird species. Where these impacts are large enough, they may have the potential to impact on the internationally recognised status of the kanamaluka/Tamar estuary. This evaluation framework for environmental impacts is summarised in Figure 11.

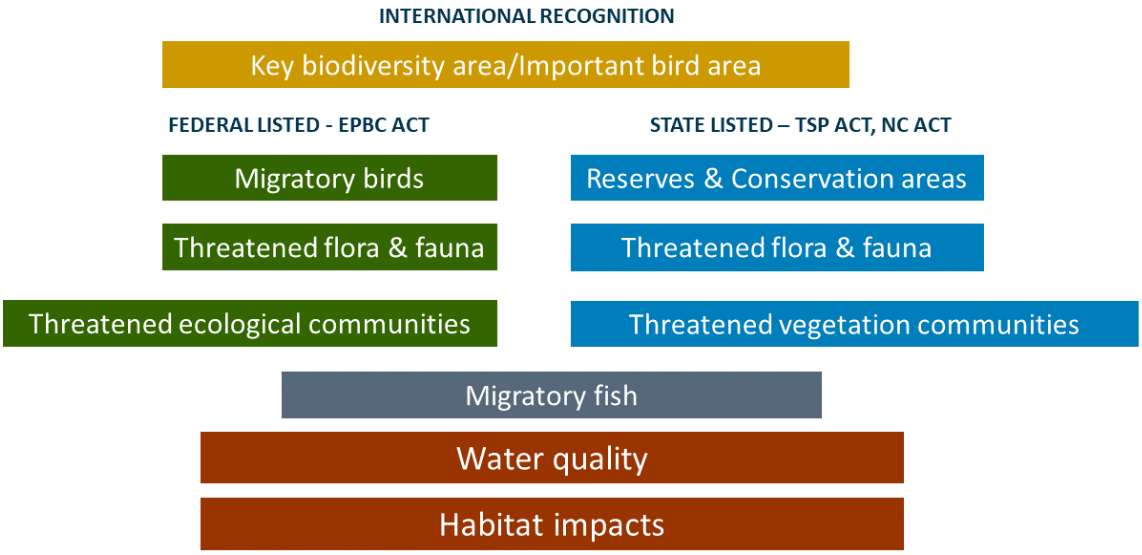


Figure 11. Evaluation framework for assessing impacts on environmental values.

These values are very briefly described in this section. Appendix 1 provides a comprehensive summary of the special values of the estuary with supporting primary data provided in Appendices 2 to 4.

4.2 Habitat types

Habitat refers to an area where an organism lives, which provides food, shelter, water and space. There are two types of habitat provided by the estuary – intertidal habitat and subtidal habitat.

4.2.1 Intertidal habitat

The intertidal zones refers to the areas of the estuary that lie between the high tide and low tide levels. This zone is subject to multiple flooding and drying cycles, providing a dynamic environment for the plants and animals there. Many of the special values associated with the kanamaluka/Tamar estuary are dependent on the health and function of the intertidal zone, including the mudflats that form a key component of intertidal habitat in the upper estuary. A conceptual model of the role of intertidal habitats in the kanamaluka/Tamar estuary has been developed to illustrate the interdependence of the natural values of the estuary on intertidal habitats (Figure 12).

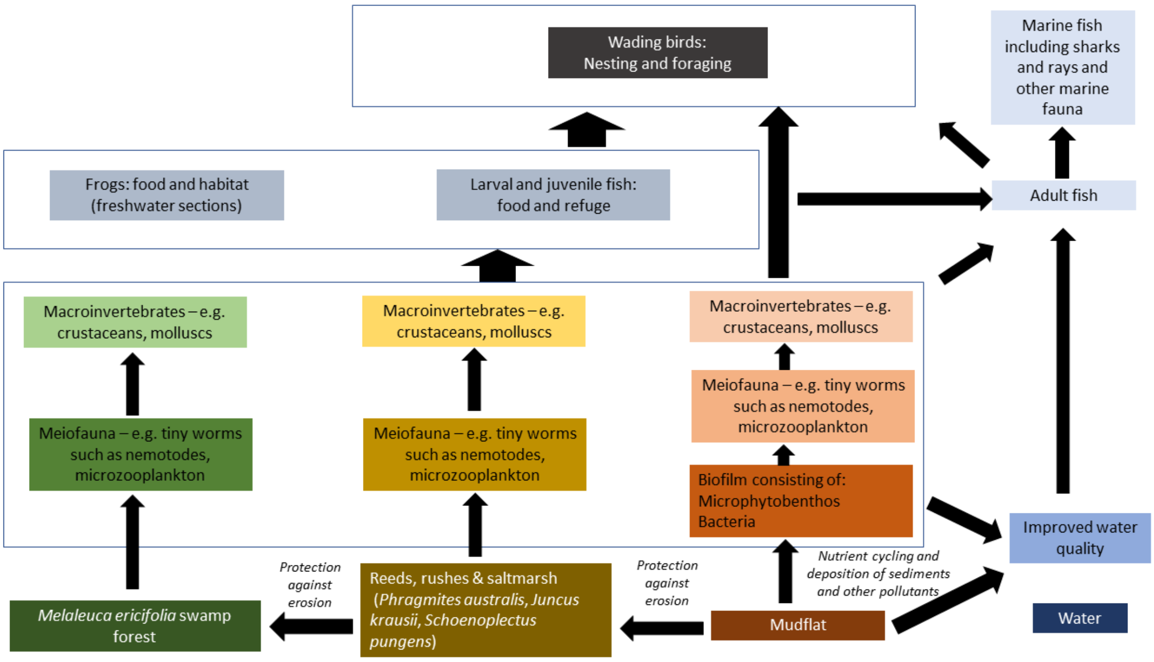


Figure 12. Conceptual model of the role of intertidal habitats in nutrient cycling and the food web.

Mudflats play an important role in nutrient cycling in estuaries, supporting high biomass of micro and infaunal organisms (see for example Dineen, J., 2010). They are areas of high primary productivity that support many of the ecological functions of the estuary and which protect saltmarsh and swamp forest areas from erosion. They provide a food source for wading birds, macroinvertebrates and fish. In the kanamaluka/Tamar estuary they support populations of migratory birds protected by the EPBC and international agreements such as JAMBA, CAMBA and ROKAMBA[7]. They also act to trap pollutants such as nutrients, sediments and heavy metals entering the estuary from the catchment and surrounding foreshore (including point sources). In this way they improve water quality, which affects animals such as migratory fish as well as plant species in subtidal habitats (such as seagrass) that require good water clarity to access sufficient light for photosynthesis.

Intertidal habitats with natural vegetation include areas of saltmarsh, *Melaleuca ericifolia* swamp forest, saline and freshwater sedgeland and rushland. These areas support a diverse range of flora and fauna species including threatened flora and fauna and migratory birds. They provide habitat for fish during larval and juvenile phases, and in freshwater sections in the upper estuary and fringing wetlands, for tadpoles and frogs, which in turn provide food for wading birds and fish that enter the intertidal areas during high tides. Saltmarshes are often referred to as fish nurseries given their importance in the larval and juvenile phases of fish life, which supports adult populations of estuarine and marine fish species. Research has shown the importance of seascape, that is multiple habitat types abutting each other, in sustaining marine and coastal ecosystems (e.g., Olds *et al.*, 2012 a, 2012b; Olds *et al.*, 2014).

[7] Japan (JAMBA), China (CAMBA) and the Republic of Korea (ROKAMBA) Australia Migratory Bird Agreements

Saltmarsh and mudflat habitats are increasingly being recognised for their importance in carbon sequestration (blue carbon). This is an emerging value that should begin to be assessed and tracked in the Tamar.

4.2.2 Subtidal habitat

As summarised by Maynard and Gaston (2010) subtidal habitats in the kanamaluka/Tamar estuary can be grouped into five major types:

- cobble – cobble stone substrate which supports fish and crabs;
- rocky reef – consisting of rock platforms that support kelp, algae, sponges, ascidians, urchins and sea stars, molluscs, rays and fishes, anemones and soft corals. The most prominent kelp is the giant kelp *Macrocystis angustifolia*;
- sand – consisting of mobile soft sediment substrate supporting rays and fishes, crabs, worms and molluscs;
- seagrass – vegetated soft sediment substrate providing food, shelter and habitat for fish, crustaceans, molluscs, other invertebrates and plants; and
- silt – consisting of very mobile fine particle soft sediment substrate supporting animals that dig and burrow into the sediments (infauna) and animals that live on top of the sediments (epifauna).

Subtidal habitat in the upper estuary is dominated by silt while subtidal habitats in the lower estuary are more diverse, encompassing sand, seagrass, rocky reefs and cobble. These habitats support a rich and diverse range of plants and animals, including threatened species and vegetation communities, with new species previously unknown to science found as recently as 2015 (see Dykman and Maynard, 2015).

4.3 Threatened species and communities

Four federally listed threatened vegetation communities occur in or adjacent to the estuary:

- *Eucalyptus ovata-calitris oblonga* forest;
- giant kelp forests of South East Australia;
- lowland native grasslands of Tasmania; and
- saltmarsh.

Saltmarsh is an important component of intertidal habitat in the estuary, extending as far upstream as Hunters Cut. Lowland native grasslands of Australia are particularly important in the North Esk tidal floodplain while giant kelp forests rely on subtidal habitats at the estuary mouth.

A further eight state listed threatened vegetation communities are represented on the estuary foreshore. Amongst these *Melaleuca ericifolia* and wetlands are key components of intertidal habitat in the upper estuary around Launceston.

4.4 Threatened flora and fauna

There are 63 threatened flora species and 36 threatened fauna species listed at either or both state and federal levels in and immediately adjacent to the estuary. The area along the West Tamar from Cataract Gorge to the Tailrace, while only small, is particularly rich in threatened species, containing at least 6 threatened flora and 4 threatened fauna species as well as two state listed threatened vegetation communities. Threatened species occur for the entire length of the estuary with fauna encompassing mammals, reptiles, birds and amphibians. The threatened migratory fish, the Australian grayling, uses the entire length of the estuary as it migrates from marine into freshwater systems and back.

4.5 Migratory birds

The kanamaluka/Tamar estuary forms part of the East Asian – Australian flyway, a migratory corridor extending thousands of kilometres from breeding grounds in the Russian Tundra, Mongolia and Alaska to nonbreeding grounds in the southern hemisphere. Migratory birds using this flyway are protected under federal legislation. The kanamaluka/Tamar estuary provides habitat to over 20 migratory bird species. Many of these rely on wetlands and mudflats in the upper estuary, with 16 species identified within the Tamar Key Biodiversity Area that extends into Launceston.

4.6 Migratory fish

Migratory fish spend part of their life cycle in one habitat/region before moving to another habitat for other parts of their life cycle, often starting their life in one system before migrating to another to mature then returning to spawn and die. Estuarine environments are often a key area of transition between marine and freshwater systems for migratory species. Many migratory fish species use the kanamaluka/Tamar estuary to migrate from marine waters to freshwaters including multiple species of galaxidae. These species can be adversely impacted by barriers to their movements (such as weirs), changes in water quality, particularly increased turbidity which can make movement and feeding more difficult, and by changes which impact on food sources. There are at least 10 species of migratory fish that use the estuary during part of their life cycle including the federally listed threatened Australian grayling.

5 Key commercial and recreational values of upper estuary

This section provides an overview of the location and nature of key pieces of infrastructure and commercial and recreational users of the upper estuary. Community concerns about economic and recreational impacts of sedimentation are generally focused on three key issues:

- impacts on recreational users of the upper estuary such as rowing clubs and the Tamar Yacht Club;
- impacts on navigation around Home Point for the tourist boats and into the Seaport Marina; and
- the aesthetic values of the mudflats, including their look and the perception that they are unappealing; and
- their odour, with community reports of the unpleasant smell of mudflats.

In addition, there is significant built infrastructure around the upper estuary, including Trevallyn Power station, the West Tamar Highway, the flood protection levee system, and wastewater treatment plants that may be affected by issues such as flooding or some of the management actions themselves.

Impacts on these values are considered in two ways:

- Through the framework for evaluating impacts on social and economic values described in Section 5.2 below.
- Throughout detailed evaluations as required where actions themselves or changes that occur as a result of those actions may have direct or indirect impacts on users or infrastructure. This is particularly the case for flooding impacts, risks associated with construction for some options, or where options have the potential to impact on the operation of Trevallyn Power Station.

5.1 Location and nature of key infrastructure, commercial and recreational users of the upper estuary

There are many commercial operators, infrastructure assets and public utilities that are located adjacent to the upper estuary which are impacted by various proposals to manage sedimentation in the upper estuary (see Figure 13). Hydroelectricity generation is reliant on water from Lake Trevallyn for generation at Trevallyn Power Station which is discharged to the Tailrace. Large vessel repair and maintenance is reliant on navigation and access to the Ship lift at Kings Wharf. Discharge of treated wastewater into the estuary occurs at multiple locations in the upper estuary including Ti Tree Bend Wastewater Treatment Plant (WWTP), Riverside WWTP and Newnham WWTP. Hoblers Bridge WWTP and Norwood WWTP discharge to the North Esk. Prospect WWTP discharges to the South Esk below the Trevallyn Dam. Tourism operators, including Tamar River Cruises and to a lesser extent Launceston Kayak Tours, are reliant on navigation at Home Reach. Hospitality businesses are located at Stillwater Restaurant and Seven, Hallams Waterfront, the Seaport Marina and Silos Hotel and are affected by visual and other amenity values associated with the upper estuary and mudflats.

In addition, the kanamaluka/Tamar estuary supports other aquaculture and tourism operations further down the estuary, such as the salmon farm at Rowella, abalone farm at Clarence Point, and Seahorse World at Beauty Point.

Figure 13. Commercial and recreational uses in the upper estuary.

Several recreational uses are also supported by infrastructure in the upper estuary, such as boating, rowing and sailing. These users of the estuary are reliant on navigation access and access from shore-based facilities such as pontoons to the main channel. Key recreational infrastructure in the upper estuary includes the Seaport Marina, North Esk Rowing Club, Tamar Rowing Club and the Tamar Yacht Club (see Figure 13). There are also boat ramps at Royal Park and Tailrace Park. Recreational boat repair facilities are reliant on access to the Tamar Marine and Tamar Yacht Club slipways. Recreational use of the foreshore also includes walking, running and bike riding, and access to the regional playgrounds at Tailrace Park and Riverbend.

Recreational users further down the estuary include recreational fishers who may be impacted by changes in riverside access, water quality and ecological changes.

Many of the commercial and recreational users such as Tailrace Centre, Ship lift, Ti Tree Bend WWTP, Seaport Marina, Stillwater Restaurant, Hallams restaurant, Home Point, the Silos Hotel, the rowing clubs, Tamar Yacht Club, and Tamar Marine are directly adjacent to the estuary and are not protected by the city's flood levees. These facilities would be impacted by any change in low or high-water levels or flood levels.

5.2 Framework for evaluating social impacts

The framework for evaluating social impacts of the sedimentation management options is provided in Figure 14. It is largely focused on users in the upper estuary around Launceston given that many relate to community concern and impacts on recreational users in this part of the estuary. Some options have unintended impacts on factors such as water quality and odour or fish stocks through large scale changes in fish habitat. These impacts and their implications for user groups such as recreational fishers are noted where relevant. Recreational users such as rowing clubs and the Tamar Yacht Club are affected both by the navigability of channels and their access to the channel at low tide from their shore-based or near shore facilities. The Home Point tourist boats are affected by navigability of the channels in the Yacht Basin and Home Reach while boats using the Seaport Marina are affected by mudflats and sediment accumulation in the marina itself as well as by the navigability of the channel, particularly in the lower North Esk.

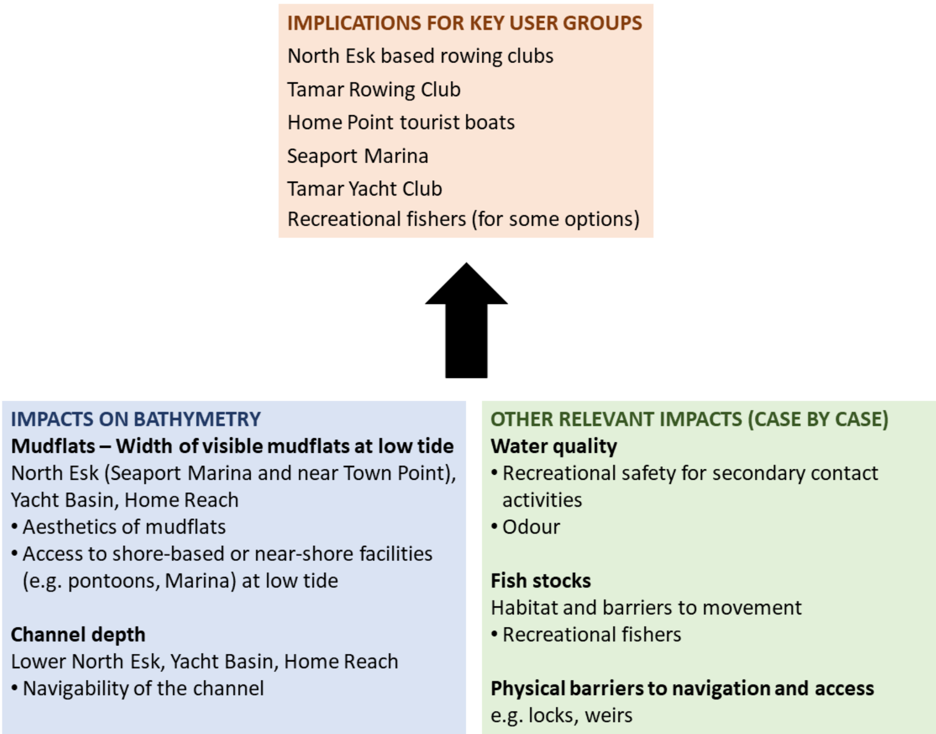


Figure 14. Framework for evaluating social impacts of potential sedimentation management options in this report.

Given much of the focus of community concerns around aesthetics relates to the extent of visible mudflats at low tide, impacts on aesthetic value is captured through changes in visible mudflats. In some cases, changes to aesthetics through the appearance of vegetation is also discussed. It should be noted that perceptions of aesthetic values are not fixed either across individuals within a community or within individuals themselves. Aesthetic values held by communities for both natural and modified systems often vary significantly depending on their understanding of the purpose and natural values associated with different aspects of the appearance of the system.

Research shows that community perceptions of a space are influenced by many factors including the perceived naturalness of the space. Hoyle *et al.* (2019) conducted a study of community members reactions to several restoration and planting projects. They found that participants' aesthetic appreciation was positively related to their perceived naturalness of the space, and their perceptions of the plant and invertebrate biodiversity values it contains. They also found that perceived naturalness related to participants' educational qualifications, gender and nature-connectedness, with women and more nature-connected participants perceiving significantly greater levels of naturalness in the spaces in the study. They found a negative relationship between perceived naturalness and perceived tidiness and care. These results are relevant for the upper estuary where much of the concern about the appearance of the mudflats is expressed in terms of perceptions of them as evidence of a degraded environment, rather than an important habitat underpinning many of the significant natural values of the estuary.

6 Evaluation of sedimentation management options

This report considers a broad range of potential sedimentation management options for the estuary, and in some cases options at a range of scales. Sedimentation management options considered are:

- *No intervention* – considers the effects of allowing the natural process of sediment accumulation, scour and channel formation to continue without any management intervention.
- *Accelerated restoration of intertidal habitat* – a small-scale intervention aimed at hastening the reformation of mudflats and vegetated intertidal habitats and natural processes of channel deepening.
- *Restoration of wetlands and the tidal prism in the North Esk* – considers the effects of removing informal levees on the North Esk and rehabilitating wetland areas that have been infilled. The process of informal levee construction and infill of wetlands is currently ongoing so the effects of this action are also considered.
- *Dredging of the upper estuary* – involves the mechanical removal and disposal of contaminated sediments from the upper estuary.
- *A tailrace canal* – a canal along the West Tamar between the Trevallyn Power Station and the estuary near Kings Bridge aimed at increasing tidal prism and freshwater flows through the Yacht Basin and Home Reach.
- *Increased flows down the South Esk* – considers the effects on targeted flow releases from Lake Trevallyn.
- *Barrages and weirs* – considers three alternative lake/weir proposals, including a large lake formed by a barrage at Point Rapid near Rowella, a smaller lake formed by a barrage at Freshwater Point, and a weir across the North Esk at its confluence with the kanamaluka/Tamar estuary.
- *Sediment raking* – considers four options involving agitation of sediments from mudflats or channels with the aim of increasing movement of these sediments downstream.
- *Various concept proposals* – including reconfiguration of the North Esk through a bypass channel and hard channelisation of the upper estuary.

The evaluation considers:

- legislative and feasibility challenges (Appendix 5 describes key legislation referred to in these assessments) including permitting requirements, technical challenges, safety issues and impacts on surrounding infrastructure that would need to be managed in design and construction;
- broadscale evaluation of capital and ongoing operational costs;
- impacts on bathymetry including the extent of visible mudflats and the depth of channels in the Yacht Basin, Home Reach and lower North Esk;
- impacts on flooding, both in areas protected by the formal levees and non-levee protected areas;
- impacts on environmental values and water quality; and
- impacts on recreation and navigation.

Environmental values associated with the estuary provide context for the environmental impact assessment framework. The framework for assessing impacts on social values is used to describe impacts on community objectives for sedimentation management.

7 Management option - no intervention

This option considers how the estuary will change if sedimentation management ceases. It is essentially a 'do nothing' option against which other active management options can be assessed.

7.1 Legislative and feasibility challenges

7.1.1 Legislative and permitting requirements

There are no legislative or permitting requirements.

7.1.2 Feasibility challenges

There are feasibility issues to consider.

7.2 Estimated costs

There are no costs associated with this action.

7.3 Impacts on bathymetry, visible mudflats and navigation

The kanamaluka/Tamar estuary has a long history of modification through infill and reclamation of tidal areas, changes in volumes and locations of freshwater inflows from the South Esk, dredging and most recently raking. The impact of modifications on different areas of the upper estuary can be considered separately to some extent to give an indication of what 'no intervention' looks like:

- *Yacht Basin* – key modifications affecting the Yacht Basin were reclamation and infilling of Royal Park (change in tidal prism), historic dredging campaigns from 1890 to 1965 (not as extensive as in Home Reach but sometimes conducted into the Yacht Basin during these campaigns) followed by intermittent dredging until 2010, construction of Trevallyn Dam in 1955 and subsequent changes in baseflows (licensed environmental flows through Cataract Gorge of 0.47 cumecs have been progressively raised to their current voluntary level of 2.5 cumecs) and sediment raking from 2013 to 2019.
- *Home Reach* – infilling of the wetlands in Invermay, sustained dredging programs from the early 1900's to 1965 to create a deep and wide (capable of turning ships) navigation channel and sediment raking along the West Tamar mudflats from 2013 to 2019.
- *Town Point and the lower North Esk* – the North Esk has been heavily modified and channelised, with early modifications removing natural meanders, infilling of intertidal areas including Invermay and Royal Park

The significant modifications of the past mean that the upper estuary will never return to its natural pre-European settlement state. Ceasing efforts to modify sedimentation processes and accumulation would allow the estuary to reach a new 'regime equilibrium'. It should be noted that even if this equilibrium is reached the system will remain dynamic with sediment levels fluctuating significantly as a result of flood events.

Figure 16 shows a comparison of cross-sectional area of the estuary in recent years at several locations in the upper estuary. Cross sectional area refers to the area below a given level when depth of the estuary is plotted across a straight line intersecting the estuary from one bank to another (see Figure 15). This has been estimated using bathymetry surveys collected by the Launceston Flood Authority using the area under 0m AHD (in line with the approach applied by McAlister *et al.* (2009)). Data used in this analysis include:

- Bathymetric data from 2 June 2016 (before 2016 flood), after the 2016 flood (18 June 2016), the end of the raking program (May 2019), autumn 2020 (April 2020) and spring 2020 (October 2020) collected by the Launceston Flood Authority.
- Bathymetric surveys for the North Esk from March 2017 used as part of the TUFlow flood modelling undertaken by City of Launceston used to calculate the tidal prism within the North Esk channel.
- A half metre contour converted to a 1 m digital elevation model for the North Esk floodplains, used to calculate their contribution to tidal prism downstream.

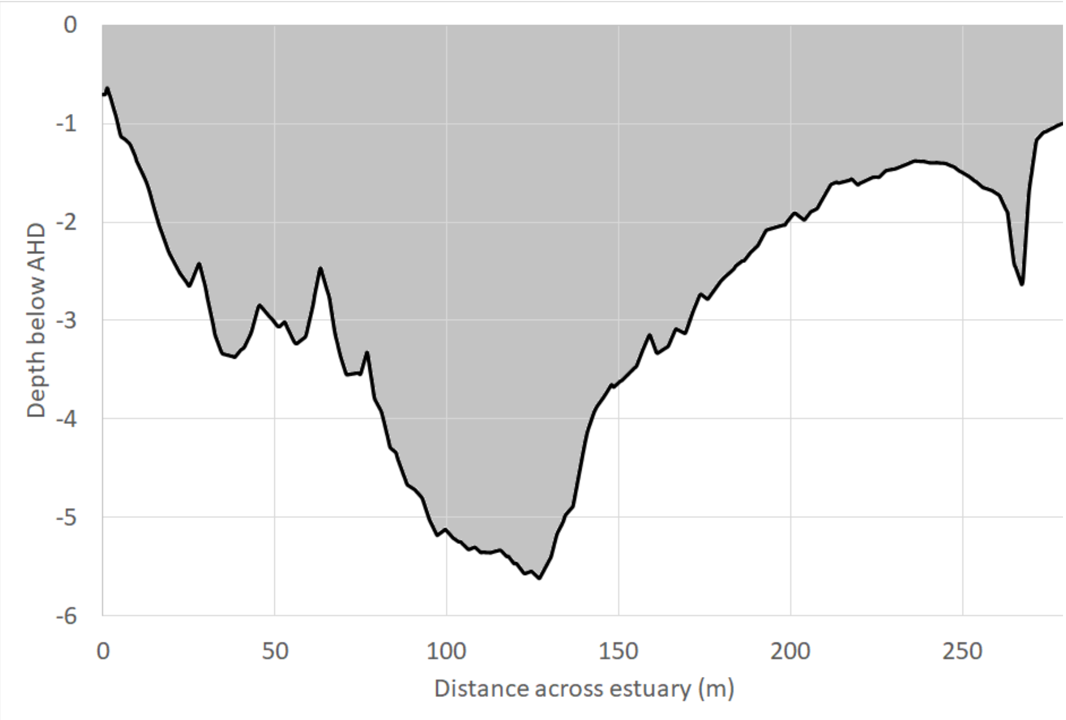


Figure 15. Example of cross sectional area, from one bank of the estuary to the other.

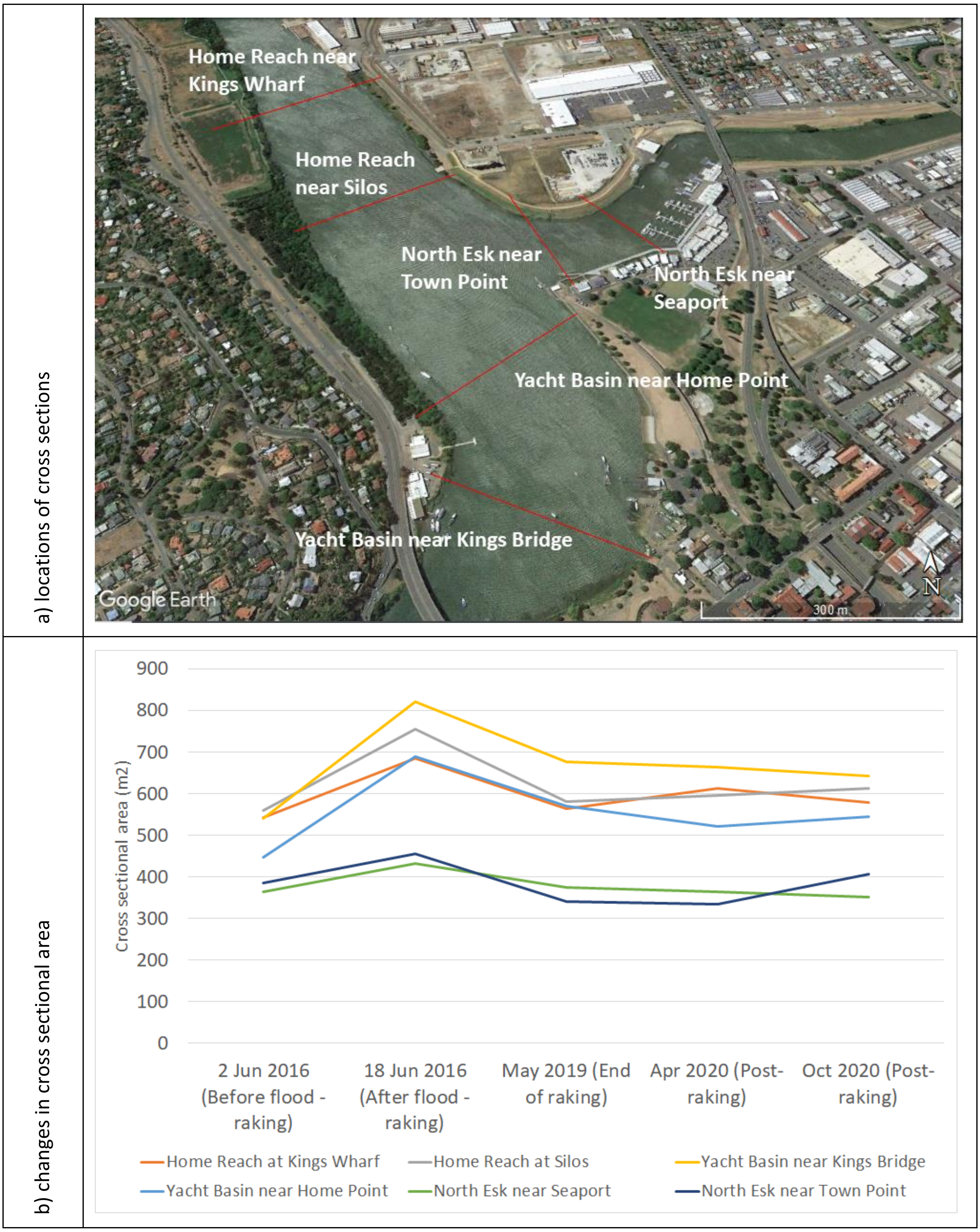


Figure 16. Analysis of cross sectional areas in the upper estuary showing a) locations of cross sections and b) changes in cross sectional area (below zero AHD) for bathymetry collected before the 2016 flood with raking (2 June 2016), after the 2016 flood (18 June 2016), the end of the raking program (May 2019), autumn 2020 (April 2020) and spring 2020 (October 2020).

This figure shows that apart from the 2016 flood, cross sectional areas have been very stable between 2016 and 2020. Even immediately after the 2016 flood, the cross sections in the North Esk were fairly stable, though it appears sediment is accumulating near the Seaport and scouring from closer to Town Point. This is likely to be associated with the cessation of prop washing in the Seaport that saw significant slugs of sediment, that were moved out of Seaport by prop washing, being deposited in the channel and forming a barway in the mouth of the North Esk. McAlister *et al.* (2009) estimated cross sectional areas in 2005-2008 and found similar estimates to those shown here from more recent data[8].

McAlister *et al.* (2009) analysed cross sectional area relative to tidal prism to assess the degree to which the estuary was near 'regime' condition - that is, the point at which the estuary would settle in terms of sedimentation based on tidal movement and without the influence of scour and flood events. They compared values in 2005-2008 with a 'regime' cross sectional area using an equation relating tidal prism and cross-sectional area in the estuary:

$$A = 3.1 \times 10^{-3} P^{0.81}$$

where P is the tidal prism and A the cross-sectional area.

The assessment by McAlister *et al.* (2009) of cross-sectional area versus tidal prism found:

- *'Parts of the estuary upstream from Section 18A (Northern end of Kings Wharf), including Section 17 in Home Reach, and especially 27 in the Yacht Basin are out of equilibrium, prompting persistent siltation there'; and*
- *'Sections along and downstream of the Home Reach (Sections 20, 21 and 24) are essentially in equilibrium and minimal ongoing siltation would be expected.'*

This analysis was repeated for the data from 2016 to 2020 to assess what, if any, changes had occurred relative to the 2005-2008 period. Figure 17 shows the equivalent chart to that produced in McAlister *et al.* (2009) comparing cross sectional area with estimated 'regime' cross sectional area based on tidal prism for all the cross-section locations shown in Figure 16. Note x and y axes have been reversed here compared to the chart in the original report.

[8] Note that cross sections here correspond with those used in McAlister *et al.* (2009) as follows: Home Reach at Kings Wharf - 17a; Home Reach at Silos - 17; Yacht Basin near Kings Bridge - 25; Yacht Basin near Home Point - 27; North Esk near Seaport - 13; North Esk near Town Point – 12.

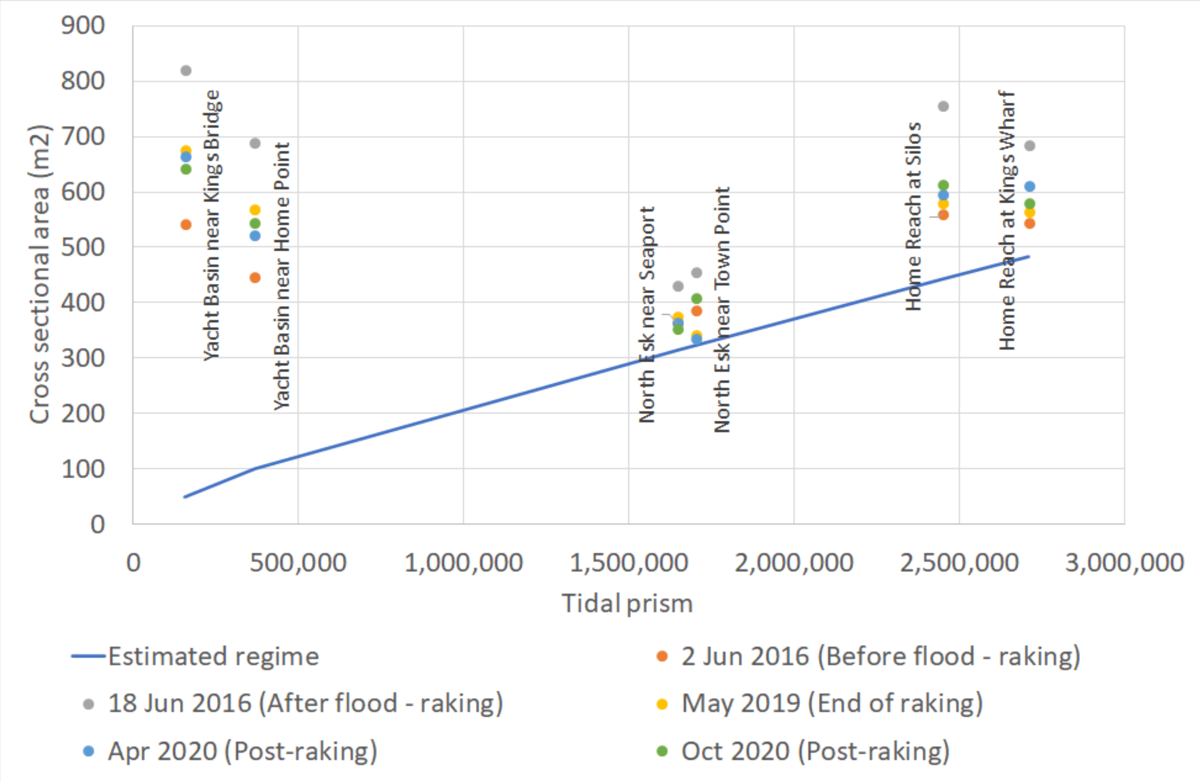


Figure 17. Comparison of current cross section with estimated 'regime' cross sectional area based on tidal prism.

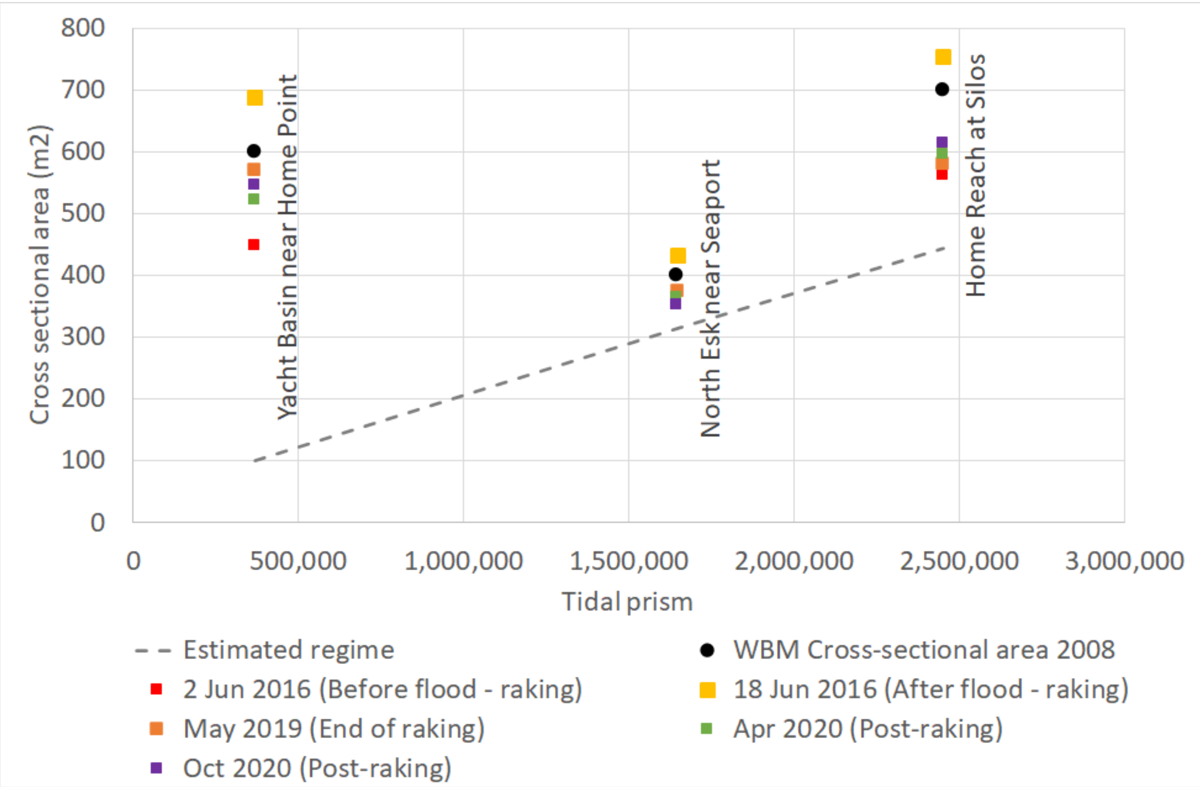


Figure 18. Comparison of cross-sectional area estimated by McAlister *et al.* (2009) from 2008 bathymetry, with recent bathymetric surveys at three locations with comparative data.

Figure 18 shows a comparison of these recent cross-sections with values from 2008 taken from McAlister *et al.* (2009) at three locations where data was available for comparison in their report. Values from McAlister *et al.* (2009) have been estimated by visual inspection of the chart (log-scale) in their report so are approximate.

These figures show the same general pattern of results as were found by McAlister *et al.* (2009). Cross sectional area changes based on recent flood and high flow events but the general pattern relative to 'regime' remains the same as what was found in McAlister *et al.* (2009).

7.3.1 Yacht Basin

McAlister *et al.* (2009) suggested that the Yacht Basin would be expected to be subject to ongoing sedimentation given that cross-sectional area is well above regime condition. However, this ongoing sedimentation doesn't appear to have occurred. There were decreased cross-sectional areas seen before the 2016 flood (with raking). Cross-sectional areas have now settled back to a more stable state, between the extremes before and after the flood, that is consistent with values estimated by McAlister *et al.* (2009) from 2005 to 2008. Analysis of cross-sectional areas in the Cataract Gorge show that this relative stability appears to relate to the sustained high cross-sectional area in Cataract Gorge, rather than being related to tidal prism.

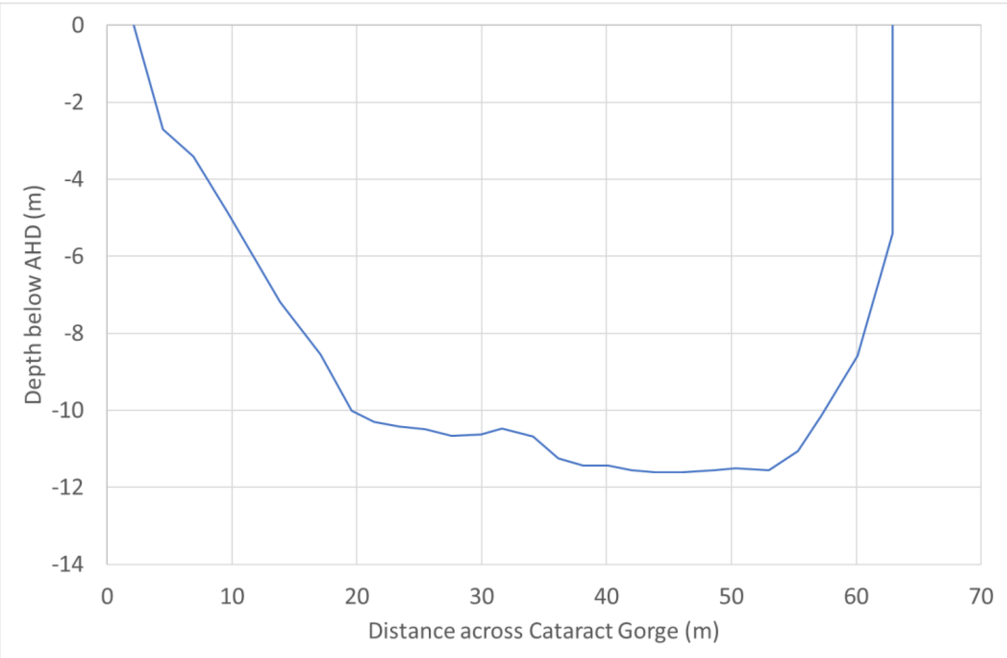


Figure 19. Cross-section of Cataract Gorge immediately upstream of Kings Bridge.

Figure 19 shows the cross-section of Cataract Gorge just before it enters the estuary (just upstream of Kings Bridge) on 2 June 2016 immediately before the 2016 flood, calculated using bathymetric survey data collected by the Launceston Flood Authority. This chart shows the large depth of water in the Cataract Gorge above Kings Bridge (nearly 12 m). This cross section has an area of 561 m^2, greater than cross sections at both the Yacht Basin locations. Cross sections in the Yacht Basin decrease with distance from Cataract Gorge but remain above 541 m^2 downstream of Kings Bridge and above 447 m^2 at the site closer to Home Point, regardless of the small but increasing tidal prism at these points. This relationship is demonstrated in Figure 20 using data from 2 June 2016. This shows a clear linear trend of decreasing cross-sectional areas moving downstream from Cataract Gorge through the Yacht Basin (the blue dotted line), with cross-sectional areas remaining substantially higher than would be the case under the tidal regime equilibrium (shown by the grey dotted line).

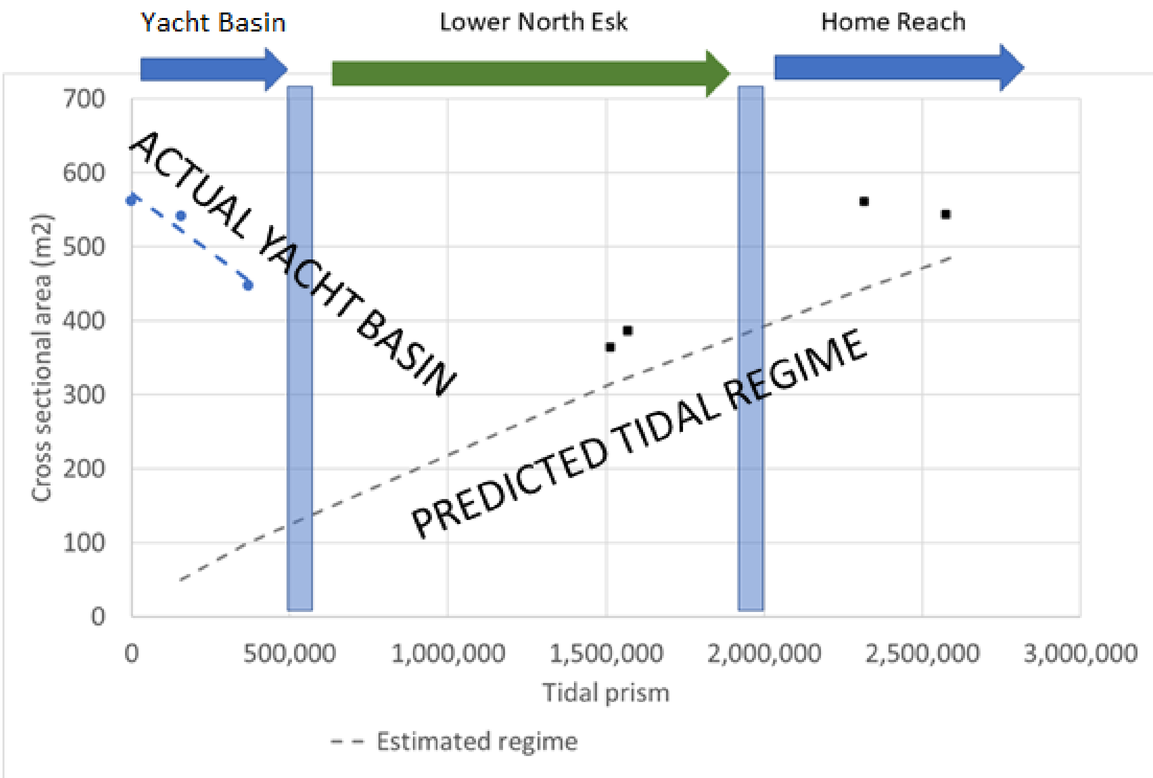
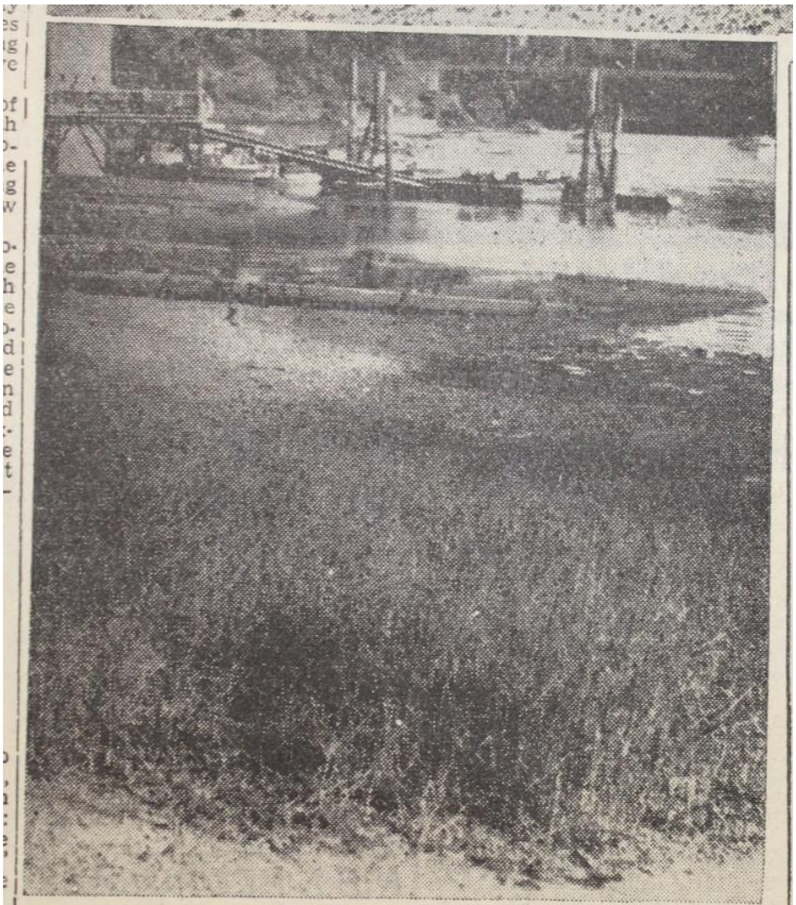


Figure 20. Comparison of cross-sectional area (below zero meters AHD) and tidal prism with estimated regime using data from 2 June 2016, immediately before the 2016 flood. Data corresponds to cross sections in Figure 15, with increases in tidal prism on the x-axis equivalent to moving downstream from the head to the mouth of the estuary in each section. The blue dotted line is the line of best fit for observations in Cataract Gorge and the Yacht Basin. Vertical blue bars indicate a break between different sections of the upper estuary that are not connected in a straight line – the Yacht Basin, North Esk and Home Reach

It is clear that cross sectional area in the Yacht Basin is sustained and dominated by the high cross-sectional area of Cataract Gorge. This relates to the significantly greater velocities of flood flow events exiting through this confined channel rather than the upstream tidal prism. The influence of Cataract Gorge cross sections is reduced as water moves downstream and slows down through the broad water of the Yacht Basin, but is still seen to dominate cross sectional area near Home Point where the North Esk joins the main estuary. Sediment accretion does occur on the mudflats in the Yacht Basin during periods of low flow but this accumulated sediment does not come close to returning the cross-sectional area to estimated regime conditions that would be expected based on tidal prism alone. Recent bathymetry suggests the Yacht Basin has settled into a fairly stable cross-sectional area with relatively small deviations since sediment raking ceased. This stable cross-sectional area is approximately 100 m^2 greater than the lowest cross-sectional area (experienced immediately before the 2016 flood) and 150 m^2 less than the peak cross-sectional area seen immediately after the flood. Cross-sectional areas in the Yacht Basin in 2019 and 2020 are close to those estimated for 2005-2008 by McAlister *et al.* (2009). These differences over time suggest that the Yacht Basin is likely to be at or near a 'regime' condition, with variations around this cross-sectional area likely to occur temporarily with very large flood events. The Yacht Basin returns to this 'regime' condition relatively rapidly after flood events.

Previous studies have assumed a link between cross-sectional area in the Yacht Basin and changes in flow brought about by construction of Trevallyn Dam. Both community members and some authors associate changes in the visual appearance of the estuary, characterised by open water from before Trevallyn Dam was constructed, to the more heavily sedimented appearance now, with changes in flow regime brought about by construction of the dam. For example, Kidd *et al.* (2017) conclude that *'the detrimental bathymetric effect in the Yacht Basin caused by the flow diversion is visually striking and of general community concern (Davis and Kidd, 2012; Ellison and Sheehan, 2014; Foster and Nittim, 1987), but further downstream, the effect is counteracted by the ''new'' tidal prism created by the Tailrace flow diversion*'. Several observations can be made with regard to this conclusion. There is no bathymetric data for the Yacht Basin that is not impacted by the dredging campaigns of the early 1900's and infilling of Royal Park on which to make the inference that Trevallyn Dam has had a detrimental effect on bathymetry. The community associations of the 'open water' appearance of the upper estuary with the period before the dam was built were due to dredging, with sediment naturally accumulating once dredging ceased. Photographs published before the dam was constructed, such as the one from 1946 shown in Figure 21 from the Examiner, show significant levels of sediment off Royal Park, with corresponding levels of concern by the community about its presence.

Further, this statement implies that the controlling factor on cross-sectional area and width in the Yacht Basin is tidal prism and baseflow conditions down Cataract Gorge. Data analysed in this section show that this relationship does not hold in the Yacht Basin and that cross-sectional areas here relate to the very large cross-sectional area and deep water of the confined channel of Cataract Gorge meeting the more expansive flood plain and channel of the Yacht Basin. An analysis of the impacts of Trevallyn Dam on flow regime in Cataract Gorge shows it has had minimal impact on peak flow events with impacts largely confined to smaller flows.



The little beach near the yacht club on the Royal Park foreshore, a favourite summer playground for children, is slowly turning into a morass of mud and reeds. Pictures show how mud is covering the sand dumped there some years ago by the City Council and how reeds are spreading near the bank. A few loads of fresh sand before the summer would probably greatly improve the spot.
—Burrows.

Figure 21. Photograph of sediment off Royal Park from the Examiner newspaper from 1946 talking about the 'morass of mud and reeds' accumulating over the sand that had previously been deposited there, before the construction of Trevallyn Dam.

7.3.2 Home Reach

Cross-sectional areas in Home Reach more closely fit the regime model moving away from Cataract Gorge but remain higher than expected closer to the confluence of the North Esk. This is potentially due to a continuing influence of the large cross-sectional area of Cataract Gorge and its floodplain. Cross-sectional areas at the locations in Home Reach remain stable across the periods sampled indicating this section of the estuary has also stabilised, with variations due to flood events.

7.3.3 North Esk

The tidal regime model provides a good explanation for cross-sectional areas in the North Esk. Cross-sectional areas in the North Esk align relatively closely with the tidal prism model, with fluctuations as a result of flood events. It appears that sediment levels in the North Esk are close to regime. Some variations are expected following flood events, due to scour followed by sediment accumulation back towards the regime. This result assumes no further infilling of wetlands in the North Esk floodplain or construction of informal tidal levees. Continuation of these activities will reduce tidal prism and lead to further sedimentation in the lower North Esk (this is described further in Section 9 on wetland restoration).

7.3.4 Channel depth and mudflat extent

Examples of the cross sections for locations within the three main sections of the upper estuary are shown in Figure 22 using three locations – Yacht Basin near Kings Bridge, the North Esk near Town Point and Home Reach near Kings Wharf.

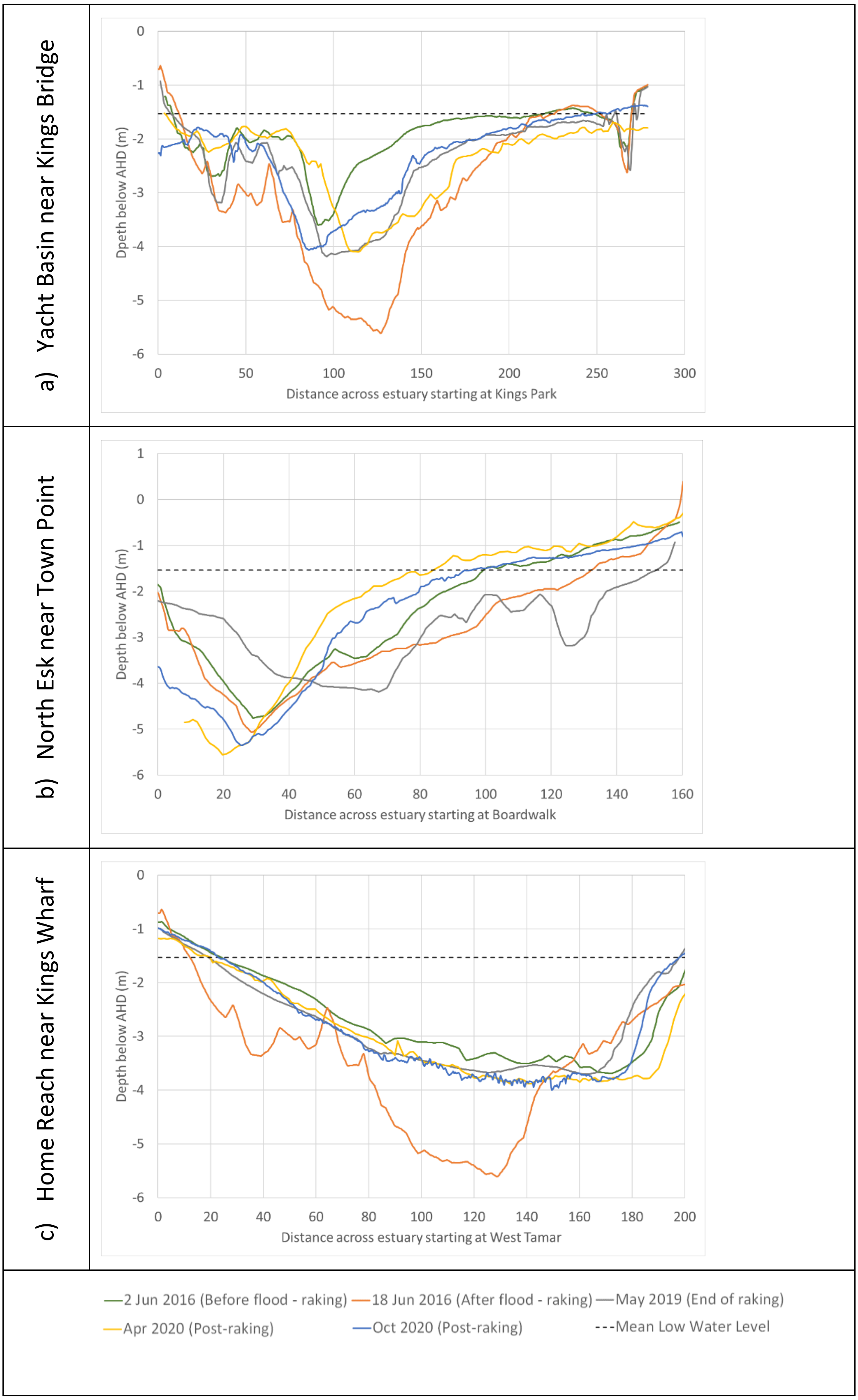


Figure 22. Comparison of recent cross sections pre- and post-raking at a) Yacht Basin near Kings Bridge b) the North Esk near Town Point and c) Home Reach near Kings Wharf.

Kelly (2019) conducted a review of the sediment raking program which found raking activities were associated with infilling of the channel and reduced visible mudflats but no overall long-term decrease in sediment levels in the upper estuary. Cross sections for all 3 locations also reflect this result (see Figure 22). Since sediment raking has ceased, a deeper channel has re-established with greater extent of visible mudflats particularly in the Yacht Basin and lower North Esk. The relative stability of this form, and small differences in cross-sectional areas from the end of raking to spring 2020 suggest this is likely to be the form of the estuary associated with 'regime' conditions. Further scour occurs during peak flow events following by rapid re-accumulation of sediment on mudflats in the Yacht Basin and lower North Esk. Deeper channels have been sustained since the cessation of sediment raking. Note that data from the end of sediment raking in the lower North Esk show a large sediment slug that settled in the North Esk channel and formed a bar-way near the mouth of the North Esk. This followed a prop washing (see Section 14 for an explanation of prop washing) campaign in the Seaport in the previous month from when this bathymetric survey was undertaken.

Apart from the large amount of scour evident in Home Reach following the 2016 flood, cross sections in this part of the estuary are quite stable. There has been some deepening of the channel and increased accumulation of sediment on the mudflats since raking ceased, but these changes are less dramatic than in the Yacht Basin and lower North Esk, presumably in part due to the more complex set of drivers for channel form and sediment accumulation in Home Reach. McAlister *et al.* (2009) found that the addition of flows from Poatina through the Tailrace reduced the rate of sediment accretion in Home Reach. It is possible that this factor also has a role in the relative stability of cross-sections in this part of the estuary.

Figure 23 shows photos of the upper estuary for three periods – 1983, 2001, 2020. Note that flow and tide conditions in these photos are not known so these are provided to provide general impressions of change and are not suitable for quantification of changes in extent of mudflats or channel widths over time. These photos suggest that the visible appearance of channels and mudflats has not significantly differed over these three periods, supporting the theory that the visible form of the estuary is relatively stable since the completion of large-scale dredging.

	West Tamar shoal from Royal Park	Yacht Basin from Kings Park	Town Point and lower North Esk
1983			
2001			
2020			

Figure 23. Comparison of mudflat appearance and extent post the cessation of large-scale dredging- 1983, 2001 and 2020. Note specific time, date, freshwater inflow and exact tide level unknown for early photos so direct measurement and comparison of mudflat extent is inappropriate but all time slices show extensive mudflats with a confined channel when the tide is out.

7.3.5 Summary of impacts on bathymetry

Table 2 summarises the likely impacts of 'no intervention' on bathymetry.

Table 2. Summary of likely impacts of 'no intervention' on bathymetry.

Area of concern	Impacts of no intervention on bathymetry
Channels	
Lower North Esk	Deep channel of 4.5-5 m maximum depth maintained. Minimal increase in channel depth following flood events expected.
Yacht Basin	Channel approximately 4 m deep and 50 m wide maintained with additional depth and width scoured following flood events.
Home Reach	Stable channel up to 4 m deep and 100 m wide maintained with significant scour followed by rapid re-accretion of sediments in the channel following large flood events.
Mudflats	
Seaport Marina	Continued accretion of sediment in marina as it acts as a sediment trap.
West Tamar	Mudflats relatively stable in their current form. Scour during large flood events followed by rapid return to current condition as sedimentation occurs. No intervention is likely to result in an accumulation of debris on the flats that might require some grooming/clean up e.g., wheels, trolleys and bits of pipe.
Yacht Basin - Royal Park	Mudflats relatively stable in their current form. Scour during large flood events followed by rapid return to current condition as sedimentation occurs. No intervention is likely to result in an accumulation of debris on the flats that might require some grooming/clean up e.g., wheels, trolleys and bits of pipe.
Town Point	Mudflats relatively stable in their current form. Scour during large flood events followed by rapid return to current condition as sedimentation occurs. No intervention is likely to result in an accumulation of debris on the flats that might require some grooming/clean up e.g., wheels, trolleys and bits of pipe.

7.4 Impacts on flood risk

Previous efforts to reduce sediment accumulation in the upper kanamaluka/Tamar estuary have been motivated by the perceived impacts of sediment accumulation on flood risks. Large flood events are known to induce major scour of sediments in channels and mudflats. For example, the 2016 floods were estimated to have scoured over 265,000 m^3 of sediment from the upper estuary. McKenzie *et al.* (2009) estimated the effects of high levels of sediment following a long dry period (2008) on flood levels relative to both historical bathymetry (reflecting conditions from 1889 to 1914) and scenarios where sediment had been removed from the channel and mudflats through dredging. The study suggested that sediment accumulation would have very little impact on flood levels during large flood events (13 cm at the Charles St bridge for 1:200 year and 1:500 year events). They found a 55 cm decrease in flood levels at the Charles St bridge for the 1:100 year flood event, the largest of the impacts seen across all their scenarios. This had no impact on flood risk in areas protected by the flood levee system.

This report has considered the impacts on flood risk of 'no intervention' using the revised TUFlow flood model developed by BMT WBM in 2018. Note that design flood levels were modified in the 2018 flood study[9], with the result that the levee system is now considered to protect against a 1 percent AEP flood compared to a 0.5 percent AEP flood in previous studies. The analysis by WMAWater considered flood levels using bathymetry for immediately before and after the June 2016 flood. The report notes that the 2016 flood was associated with large volumes of sediment scour - in the main channel there was over 1.5 m depth of erosion with many areas having 1 m depth of erosion. Few areas show sedimentation, with the exception being on the perimeter of the channel and in the Seaport Marina, but the depth of sedimentation is generally less than 0.3 m. WMAWater (2021) found that this change in bathymetry is associated with changes in peak flood levels of up to 0.4 m for the 5 percent AEP flood (1 in 20 year) or up to 0.7 m in the 1 percent and 0.5 percent floods. It is noted that the modellers who developed the TUFlow model for the 2018 flood study assumed that the bed level adopted for the design is closer to that after the 2016 flood than before, and thus erosion of the bed is assumed to occur during the course of the flood. This means that the pre-flood bathymetry is considered to have little bearing on the resulting peak flood levels. The analysis above (in section 7.3.1) also showed that the cross-sectional area of the Yacht Basin and Home Reach before the 2016 flood was lower (indicating a more heavily sedimented state) than any of the other surveys including that from 2008 so the 'no scour' analysis by WMAWater can be considered an extreme estimate of flood level impact of sedimentation.

Launceston is protected by a series of flood levees that offers protection to the city for floods approximately 1 percent AEP flood event. This means that increases in flood levels for small floods don't generally increase flood risk inside levee protected areas of Launceston. Low lying infrastructure that are outside the flood protection levees such as the West Tamar highway are most likely to be impacted by any change in flood level for smaller flood events.

The best available evidence suggests that 'no intervention' is likely to lead to at most small increases in flood levels and that these changes are unlikely to pose a significant flood risk to Launceston given the flood levee system that is already in place. Substantial scour is induced by major flood events which means that the pre-flood bathymetry has little effect on flood levels.

7.5 Impacts on water quality and environmental values

Mudflats and intertidal habitat are associated with significant environmental values. They underpin many of the values of the upper estuary that see it internationally recognised as a Key Biodiversity Area and Important Bird Area. Mudflats and intertidal habitat are an important habitat for migratory and other wading birds that use the upper estuary. They also stabilise the threatened vegetation communities of *Melaleuca ericifolia* that line the West Tamar foreshore in the upper estuary, where numerous threatened flora and fauna

[9] This reflects a change in modelling methodology not a change in the levee system or the water levels they protect against.

species live. Water quality improvements associated with cessation of the sediment raking program are likely to be maintained under a scenario of no intervention.

Table 3 summarises impacts of ‘no intervention’ on environmental values.

Table 3. Key environmental impacts of a ‘no intervention’ option for sedimentation management noting shift from sediment raked baseline.

Environmental value	**Impacts of no intervention**
Water quality	Improvement of water quality in particular in terms of heavy metals and dissolved nutrients since sediment raking ceased expected to continue without other influences.
Intertidal habitats	Mudflats and intertidal vegetation re-establish in the upper estuary increasing the extent and condition of intertidal habitat. Potential for colonisation by weeds.
Subtidal habitats	Subtidal habitats benefit from improvements in water quality and lack of physical disturbance since sediment raking ceased.
Migratory fish	Migratory fish are likely to benefit from improvements in intertidal habitat and mudflats and improvements in water quality, particularly lower turbidity and reduced heavy metal concentrations, since the sediment raking program ceased.
Threatened flora, fauna, vegetation communities and ecological communities	Stabilisation of mudflats in the upper estuary particularly where reeds re-establish along foreshores are likely to reduce the impacts of erosion on *Melaleuca ericifolia* along the West Tamar shoal and *Schoenoplectus tabernaemontani* and *Bolboschoenus caldwellii* along the rest of the foreshore. This may have some benefits both to this threatened vegetation community and threatened flora and fauna species that use this corridor.
Migratory birds	Increased use of the upper estuary around Launceston as mudflats and intertidal vegetation re-establish.
Reserves and conservation areas	Values associated with reserves generally unimpacted. Values associated with the Tamar River Conservation Area expected to improve as intertidal habitat and mudflats are restored. Improvement of water quality since sediment raking ceased also likely to improve natural values for the full extent of the estuary.
Key Biodiversity Area/ Important Bird Area	KBA/IBA values associated with mudflats and intertidal habitat improve as mudflats re-establish post-sediment raking. Over time establishment of intertidal vegetation on mudflats such as reeds and expansion of *Melaleuca ericifolia* likely to increase extent and condition of intertidal habitat in the upper estuary.

7.6 Impacts on recreation and navigation

The significant modifications of the past mean that the upper estuary will never return to its natural pre-European state. Ceasing efforts to modify sedimentation processes and accumulation would allow the estuary to reach a new ‘regime equilibrium’. These changes in bathymetry and water quality will have impacts on recreational and tourism users of the estuary (Table 4).

Table 4. Impacts of ‘no intervention’ on key recreational and tourism users of the upper kanamaluka/Tamar estuary

User	Impacts of no intervention
Rowing – Access to North Esk from pontoons and navigability of the North Esk	Good channel depth and width in the North Esk are likely to benefit rowers navigating the North Esk. Improved channel depths in Home Reach and the Yacht Basin will also benefit navigation in these areas. Sediment accumulation in mudflats may increase accumulation under pontoons and on inside bends of the estuary over time, creating access challenges, and may pose a risk to rowers.
Tamar Rowing Club	Good channel depth and width in Home Reach and the Yacht Basin are likely to benefit rowers. Sediment accumulation in mudflats may increase accumulation under pontoons over time and may pose a risk to recreational users. No access from the pontoon to the main channel at low tide due to mudflats which will influence training activities at certain times.
Home Point tourist boats	Consistent channel depths and widths re-establishing since the end of the sediment raking program have benefited navigability for boats leaving Home Point. Given these channels are likely to be sustained under a ‘no intervention’ option it is expected that this benefit will continue.
Seaport Marina	Sediment is likely to continue to accumulate in the Seaport Marina such that some bays will have visible sediment at low tide and some berthed vessels will rest on exposed flats. As Seaport Marina is not an articulated structure, this may compromise the integrity of the marina. Improved consistent channel depth in the lower North Esk will benefit those exiting or entering the North Esk to access the Seaport Marina.
Tamar Yacht Club	Consistent channel depths and widths re-establishing since the end of the sediment raking program have benefited navigability for small boats in the main channel. Given these channels are likely to be sustained under a ‘no intervention’ option it is expected that this benefit will continue. Sediment accumulation on mudflats near Royal Park will limit access from Tamar Yacht Club facilities to the main channel at low tide.
Recreational fishers	Water quality has improved since sediment raking ceased, particularly in terms of heavy metals. These changes in water quality are expected to continue without further intervention. This may benefit fish stocks and consequently recreational fishing through reduced toxicity from heavy metals (note public health advice is that wild shellfish harvested from the kanamaluka/Tamar estuary are unsafe to eat).

7.7 Summary and key findings

The upper estuary is likely to be close to 'regime' condition in its current state. In summary:

- If no further sedimentation intervention was to occur, it is likely that mudflats and channels would stabilise to approximate current conditions with significant flood events scouring mudflats and channels followed by a relatively rapid return to current conditions of extensive mudflats and a deep channel.
- Over time, as mudflats stabilise, it is likely that intertidal vegetation such as reeds will re-establish on mudflat areas closest to the shoreline. This would lead to improvement of the environmental values associated with the upper estuary.
- Recreational users will experience a mixture of impacts. Increased channel depths benefit navigation but increased accumulation of sediments in mudflats and under pontoons and the marina are likely to reduce access from this infrastructure to the main channel during low tides.

8 Management option - accelerated restoration and revegetation of mudflat and intertidal zone

This management option focuses on restoring intertidal habitat values in the upper estuary to improve natural and aesthetic values of the estuary around Launceston. Figure 24 shows focus area for actions.

Actions would be focused on:

- *West Tamar mudflats* – stabilising the foreshore edge and restoring intertidal habitat transition from water through mudflat, reeds and *M. ericifolia*. This mudflat was destabilised by dredging and sediment raking activities with significant erosion and *M. ericifolia* seen to be falling in. Willows are also established along this area and would need to be managed as part of the restoration of intertidal habitat. The area of *M. ericifolia* along this western foreshore is a biodiversity hotspot containing a threatened vegetation community and several state and federally listed threatened flora and fauna species.
- *Town Point* – process of restoration of reeds to intertidal zone is occurring naturally in this area. Action in this area would be to continue to allow this restoration to occur and do targeted revegetation along the shoreline at the toe of the levee to provide visual amenity and environmental value.
- *Town Point to Kings Wharf* – restoration of reed and *M. ericifolia* vegetation.
- *West Tamar silt ponds* – these ponds would be remediated and restored to wetland. These could be used to either restore tidal function to this area or use of this area for stormwater treatment has been proposed by community members.

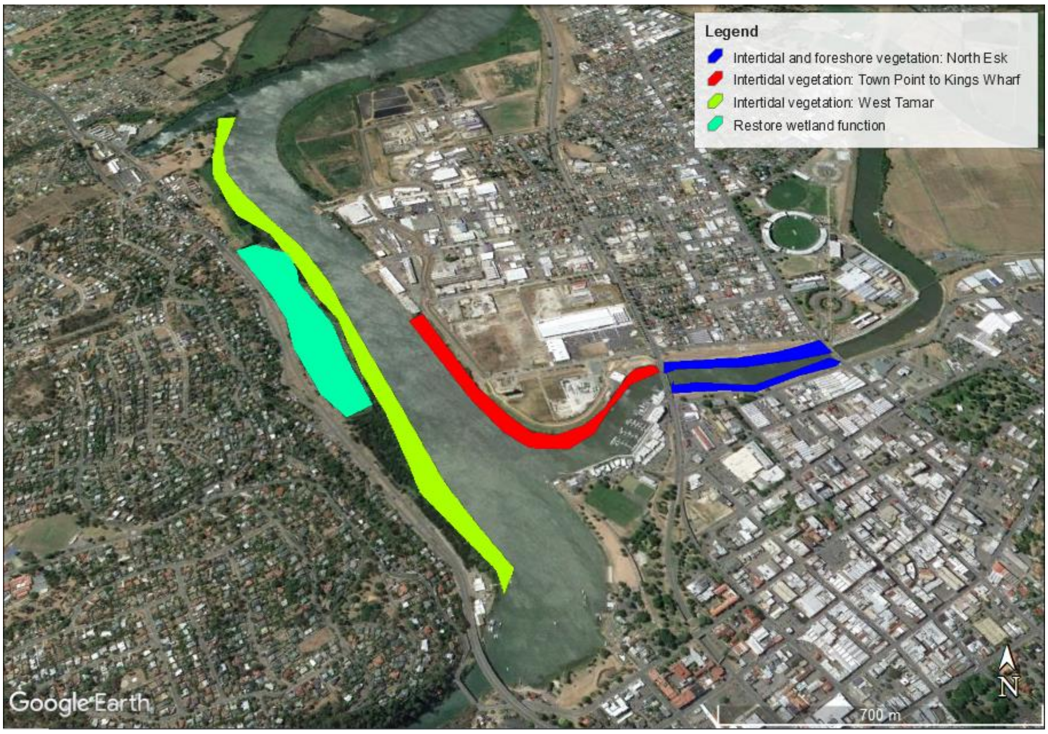


Figure 24. Focus areas for intertidal habitat restoration.

Figure 25 provides photos showing the current condition of these areas and Figure 26 shows examples of the types of intertidal vegetation that may be used in restoration activities. Soft bunding or brush fencing would be required to stabilise existing foreshore vegetation and fringing mudflats to allow reeds and other vegetation to re-establish more quickly. Targeted revegetation would be used to more rapidly return the environmental values and visual amenity of the target areas.

<table>
<tr><td>West Tamar mudflats</td><td>Town Point</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Town Point to Kings Wharf</td><td>West Tamar silt ponds</td></tr>
<tr><td></td><td></td></tr>
<tr><td>North Esk between Tamar and Charles St bridges</td><td></td></tr>
<tr><td>
</td><td></td></tr>
</table>

Figure 25. Current condition of target areas for accelerated restoration.

Tamar wetlands (high tide) showing transition between water, reed and *M. ericifolia.* Note at low tide there is mudflat visible between the water line and reeds. These mudflats are heavily used by wading birds with reeds used as habitat and for nesting sites.	
Area near Stillwater (Kings Park) where tea tree piling with interwoven tea tree saplings have been used to stabilise the mudflat and allow reeds to re-establish.	
Tamar wetlands (low tide) – mudflat and reeds.	
Area near Tailrace Park, West Tamar – natural recolonisation of wetland after changing management practices.	

Figure 26. Examples of intertidal vegetation that would be expected with restoration works.

8.1 Legislative and feasibility challenges

8.1.1 Legislative and permitting requirements

There are minimal permitting requirements for accelerated restoration of intertidal habitat in the upper estuary. Land tenure is a mix of council owned land (Launceston and West Tamar) and Crown land. There are leases on parts of this land.

Rehabilitation of the West Tamar silt ponds would require treatment of dredge spoil currently contained in these ponds, which is both acid sulphate and contaminated with heavy metals. A full assessment of alternatives for onsite treatment versus excavation and off-site treatment of these sediments would need to be undertaken. Options such as liming, summer cropping, ploughing and composting might be used to neutralise soils before water is returned. This would involve a sequence of testing soils, treating, testing, planting and then letting water flow in once soils reach an acceptable quality to avoid risks to estuary water quality. Permitting requirements will depend on the option selected. Onsite treatment is likely to be substantially less expensive and complex than excavation and off-site treatment of sediments but would still be subject to environmental permits:

- disposal of excavated material and potentially onsite treatment would be managed under the *Environmental Management and Pollution Control (Waste Management) Regulations 2000* ; and
- *Water Management Act 1999* and the *Water Management (Safety of Dams) Regulations 2015* which are likely to apply to the weir and other structures.

Disposal of Level 2 contaminated waste on land requires approval by the Director of the EPA subject to the *Environmental Management and Pollution Control (Waste Management) Regulations 2000* and requires:

- Sampling to characterise type and level of contamination.
- Disposal of Level 2 contaminated waste is possible at putrescible and solid land fill sites. There are five landfill sites in Tasmania capable of receiving Level 2 contaminated waste including Launceston Waste Centre.

Note that additional requirements and limitations exist where contaminated soils are potential acid sulfate (see Simpson *et al.*, 2018). An acid sulfate soil management plan would be required which would detail the technical feasibility of measures to manage risks. These risks would be generated both by any excavation of contaminated soils or by runoff or leachate during the remediation process.

Controls may be required to prevent the distribution of Declared Weeds under the *Weed Management Act 1999*.

8.1.2 Feasibility challenges

Feasibility and costs of this action have been broken into two key components of the work as they have different constraints:

- restoration of intertidal vegetation; and

- remediation of the West Tamar silt ponds and restoration of wetland values.

8.1.2.1 Restoration of intertidal vegetation

Rapid restoration of intertidal vegetation is likely to require active revegetation works with site preparation and planting. Establishment of reeds and restoration of mudflats along the foreshore is likely to require soft bunding (e.g., use of fallen tea tree to create a natural bund to stabilise sediments and provide a base for reeds to establish more quickly). The challenges associated with installation and maintenance under high flow conditions under such bunding will vary between sites and would need to be considered carefully in any design.

8.1.2.2 Remediation of the West Tamar silt ponds and restoration of wetland values

CRC CARE (2018) provide an example of using restoration of a tidal wetland to treat acid sulfate soils in Trinity Creek near Cairns using a method they call Lime Assisted Tidal Exchange (LATE)[10]. In its case study, a 740 ha tidal wetland was drained in the 1970's to create land for cane growing. The outcome of this was oxidisation of acid sulfate soils, a severely degraded landscape and frequent fish kills when acid ran off the site after rain. The research team estimated traditional treatment of soils would cost over $300 million. The approach to remediation used floodgates to control tidal inundation of the wetland along with application of lime to both soils and tidal waters to buffer acid runoff. Gradual increases in water table levels through the return of tidal waters stopped acidification processes while treatment with lime mitigated risks to the receiving water of acidity of tidal waters. Water levels were controlled through manually operated flood gates using the existing levee system. Tidal water in the East Trinity case was seawater and due to the higher salinity levels had an additional buffering capacity above that of freshwater. The tidal water in Launceston is likely to be significantly less saline than is the case in the East Trinity case, which may impact on the amount of natural buffering provided by tidal waters and the volume of lime that would be required to mitigate the risks of acid runoff in tidal exchange. If this option were to be pursued, opportunities for onsite remediation of acid sulfate soils such as LATE would need to be investigated in more detail. The West Tamar silt ponds have a good system of low levee walls and interconnecting gates that could be utilised in this approach. It is likely that the costs of implementing such a program would be lower than traditional offsite treatment but funding would be required for ongoing monitoring and management of the site for at least a decade. Restoration of the silt ponds to wetland would also require monitoring of water quality and runoff, and active revegetation works. Once restored these wetlands could be used either to increase tidal prism through tidal flushing or for treatment of stormwater before it is discharged to the estuary. Restoration of the West Tamar silt ponds is likely to be complex and would require significantly more development and testing of detailed plans before it could be implemented.

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[10] There are also significant examples of this type of work in NSW, e.g. https://www.wrl.unsw.edu.au/research/big-swamp-restoration-project; https://www.wrl.unsw.edu.au/research/tomago-wetland-restoration-project

8.2 Estimated costs

Costs for remediating the West Tamar silt ponds are likely to vary substantially depending on whether acid sulfate soils are treated *in situ* or excavated, treated and disposed of off-site. Key components of cost for the restoration of intertidal habitat would include:

- materials such as tea tree bundles and labour for edge stabilisation;
- vegetation with matting on less stable, wet areas;
- revegetation for the top of bank where relevant;
- any necessary willow and weed removal;
- treatment of acid sulfate soils; and
- any costs associated with excavation and disposal of soils.

A rough estimate of these costs for restoration of intertidal vegetation is $3 to $4 million with the magnitude of costs depending heavily on the extent of edge stabilisation and vegetation matting along the West Tamar mudflat.

Costs associated with remediation of the West Tamar silt ponds and restoration to wetland are much more difficult to estimate. The greatest source of uncertainty is the cost of treating potential acid sulfate soils and any ongoing monitoring requirements. Costs of vegetation would also need to be considered. This component of the project could vary between $1 million and $10 million.

It should be noted that these actions have the potential to return income through carbon credits once the Commonwealth's carbon accounting methodology for estuarine and freshwater wetlands are signed off as they help with carbon uptake and storage (blue carbon).

8.3 Impacts on bathymetry, visible mudflats and navigation

It is expected that this option will have the same impacts on bathymetry as the 'no intervention' option with the main impact being a change in visual amenity and environmental values associated with the intertidal zone. As such Table 5 below contains the same impacts on bathymetry as 'no intervention' from Section 7.3.

Table 5. Likely impacts of 'accelerated restoration' on bathymetry

Area of concern	Impacts of accelerated restoration on bathymetry
Channels	
Lower North Esk	Deep channel of 4.5-5 m maximum depth maintained. Minimal increase in channel depth following flood events expected.
Yacht Basin	Channel approximately 4 m deep and 50 m wide maintained with additional depth and width scoured following flood events.
Home Reach	Stable channel up to 4 m deep and 100 m wide maintained with significant scour followed by rapid re-accretion of sediments in the channel following large flood events.
Mudflats	
Seaport Marina	Continued accretion of sediment in marina as it acts as a sediment trap.
West Tamar	Mudflats relatively stable in their current form. Scour during large flood events followed by rapid return to current condition as sedimentation occurs. Accelerated restoration is likely to result in an accumulation of debris on the flats that might require some grooming/clean up e.g., wheels, trolleys and bits of pipe.
Yacht Basin - Royal Park	Mudflats relatively stable in their current form. Scour during large flood events followed by rapid return to current condition as sedimentation occurs. Accelerated restoration is likely to result in an accumulation of debris on the flats that might require some grooming/clean up e.g., wheels, trolleys and bits of pipe.
Town Point	Mudflats relatively stable in their current form. Scour during large flood events followed by rapid return to current condition as sedimentation occurs. Accelerated restoration is likely to result in an accumulation of debris on the flats that might require some grooming/clean up e.g., wheels, trolleys and bits of pipe.

8.4 Impacts on flood risk

The impact of restored mudflats and associated vegetation on flood levels will depend upon the extent, magnitude and location of these actions. In general re-vegetation will reduce the hydraulic conveyance of the channel and in this way will increase flood levels. However, the increase is likely to be minor, as over time the estuary will respond to changes in the bed form and vegetation, just as it will respond to periods of drought, flood, increased sediment inflows, sea level rise and many other inputs. If restoration of mudflats results in reduced cross-sectional area of the channel or provides areas of hardened surface with more resistance to erosion, then it is likely that the hydraulic conveyance will reduce and result in increased flood levels. As with re-vegetation, these effects will likely be minor and likely be subject to change over time as the estuary responds.

8.5 Impacts on water quality and environmental values

Restoration of intertidal vegetation and remediation and restoration of wetlands on the West Tamar silt ponds would be associated with improved environmental values. Intertidal vegetation provides significant habitat value for a range of species including migratory birds. Reducing the impacts of erosion on the *M. ericifolia* swamp forest along the West Tamar foreshore and stabilising this vegetation with an interface of reeds can be expected to improve the resilience and values of this important biodiversity hotspot. Both wetlands and *M. ericifolia* swamp forest are listed as threatened vegetation communities in Tasmania so any improvement in condition or extent of these as a result of restoration activities provides environmental benefits. This action would also help with carbon uptake and storage (blue carbon). There is potential for Blue Carbon credits to be obtained once the Commonwealth's carbon accounting methodology for estuarine and freshwater wetlands are signed off. Other impacts are similar to 'no intervention'. Table 6 summarises the impacts of accelerated restoration works on water quality and environmental values.

Table 6. Key environmental impacts of a 'accelerated restoration' option for sedimentation management.

Environmental Values	**Impacts of accelerated restoration**
Water quality	Improvement of water quality, in particular in terms of heavy metals and dissolved nutrients, since sediment raking ceased can be expected to continue without other influences. Restoration of wetlands on the West Tamar silt ponds and increased intertidal vegetation are expected to improve water quality. If ponds are used as constructed wetlands to treat urban stormwater this would result in reduced pollutants entering estuary.
Intertidal habitats	Mudflats and intertidal vegetation are restored in the upper estuary increasing the extent and condition of intertidal habitat.
Subtidal habitats	Subtidal habitats benefit from improvements in water quality and lack of physical disturbance since sediment raking ceased.
Migratory fish	Migratory fish are likely to benefit from improvements in intertidal habitat and mudflats and improvements in water quality, particularly reduced turbidity and heavy metals concentrations, since the sediment raking program ceased.
Threatened flora, fauna, vegetation communities and ecological communities	Stabilisation of mudflats in the upper estuary particularly with planting of reeds and *M. ericifolia* along foreshores, is likely to reduce the impacts of erosion on existing native vegetation along the West Tamar shoal. Local threatened species such as *Schoenoplectus tabernaemontani* and *Bolboschoenus caldwellii* could be used to revegetate along the foreshore. This will have some benefits both to this threatened vegetation community and threatened flora and fauna species that use this corridor. Creation of new areas of wetland habitat and corridor vegetation are likely to benefit the green and gold frog, which is known to occur in wetlands immediately north of the West Tamar silt ponds. Habitat loss is an identified threatening process for this species.
Migratory birds	Increased use of the upper estuary around Launceston as mudflats and intertidal vegetation are restored and habitat value is improved.

Reserves and conservation areas	Values associated with reserves generally un-impacted. Values associated with Tamar River Conservation Area expected to improve as intertidal habitat and mudflats are restored. Improvement of water quality since sediment raking ceased and with restoration of wetlands and intertidal vegetation also likely to improve natural values for the full extent of the estuary.
Key Biodiversity Area/ Important Bird Area	KBA/IBA values associated with mudflats and intertidal habitat improve as mudflats re-establish post-sediment raking. Rapid establishment of intertidal vegetation on mudflats such as reeds and expansion of *M. ericifolia* likely to increase extent and condition of intertidal habitat in the upper estuary.

8.6 Impacts on recreation and navigation

Changes in bathymetry and water quality will have impacts on recreational and tourism users of the estuary. Impacts from accelerated restoration on recreational users and navigation are likely to be very similar to 'no intervention'. It is expected that visual amenity associated with the mudflats and foreshore will improve much more rapidly than would be the case under the 'no intervention' option. These are summarised in Table 7.

Table 7. Impacts of 'accelerated restoration' option on key recreational and tourism users of the upper kanamaluka/Tamar estuary

User	Impacts of accelerated restoration
Rowing – Access to North Esk from pontoons and navigability of the North Esk	Good channel depth and width in the North Esk are likely to benefit rowers navigating the North Esk. Improved channel depths in Home Reach and the Yacht Basin will also benefit navigation in these areas. Sediment accumulation in mudflats may increase accumulation under pontoons and on inside bends of the estuary over time impacting access and may pose a risk to rowers.
Tamar Rowing Club	Good channel depth and width in Home Reach and the Yacht Basin are likely to benefit rowers. Sediment accumulation in mudflats may increase accumulation under pontoons over time and may pose a risk to recreational users. No access from the pontoon to the main channel at low tide due to mudflats.
Home Point tourist boats	Consistent channel depths and widths re-establishing since the end of the sediment raking program have benefited navigability for boats leaving Home Point. Given these channels are likely to be sustained under a 'no intervention' option it is expected that this benefit will continue.
Seaport Marina	Sediment is likely to continue to accumulate in the Seaport Marina such that some bays will have visible sediment at low tide and some berthed vessels resting on exposed flats. As Seaport Marina is not an articulated structure, this may compromise the integrity of the marina. Improved consistent channel depth in the lower North Esk will benefit those exiting or entering the North Esk to access the Seaport Marina.
Tamar Yacht Club	Consistent channel depths and widths re-establishing since the end of the sediment raking program have benefited navigability for small boats in the main channel. Given these channels are likely to be sustained under a 'no intervention' option it is expected that this benefit will continue. Sediment accumulation on mudflats near Royal Park will limit access from Tamar Yacht Club facilities to the main channel at low tide.
Recreational fishers	Water quality has improved since sediment raking ceased, particularly in terms of heavy metals. These changes in water quality are expected to continue without further intervention. This may benefit fish stocks and consequently recreational fishing through reduced toxicity from heavy metals.

8.7 Summary and key findings

The impacts of accelerated restoration on the bathymetry of the upper estuary are likely to be similar to 'no intervention'. Key areas of difference are a more rapid improvement in environmental values associated with intertidal vegetation and improved visual amenity with a softening of the interface between water, mudflat and foreshore at low tide. Restoration of the West Tamar silt ponds would require treatment of potential acid sulfate soils. *In situ* treatment options may be possible and would require further investigation and costing, comparing with traditional offsite treatment methods. Onsite treatment is likely to be substantially simpler and less costly than offsite treatment of these soils. Revegetation works would not require significant permits or face legislative barriers, though in some areas there may be technical challenges associated with working in such a dynamic environment.

9 Management option – protection and restoration of North Esk tidal prism and wetland restoration

Restoration of the tidal prism and wetland areas in the North Esk considers the effects of removing informal levees on the North Esk and rehabilitating some areas of wetland that have been infilled. Mapping indicates that some 250 ha of land in Inveresk-Invermay was reclaimed prior to 1956, and that since 1956 a further 330 ha of intertidal floodplain has been reclaimed or infilled. This represents approximately 75 percent of the North Esk River floodplain between the Kings Meadows Rivulet and Mowbray Hill. Figure 27 shows the extent of wetlands under natural conditions, before infilling and flood defence levee construction. The process of informal levee construction and infill of wetlands is currently ongoing so the effects of halting this action are also considered.

Several strategies for increasing the tidal prism have been proposed by Kidd *et al.* (2017), as methods of changing bathymetry in the upper kanamaluka/Tamar estuary. Some of these strategies are considered in this section, however, construction of a meander in a section of the North Esk is not considered here, given the specific nature of this proposal and the additional technical challenges it poses separate to other more general methods of increasing tidal prism in the North Esk. The meander is discussed separately in Section 15.

This section considers the costs, feasibility and impacts of floodplain and wetland restoration along the North Esk River considering three components:

- ceasing current practices of infilling and tidal levee construction;
- removal of existing informal tidal levees; and
- restoration of tidal prism in constructed wetlands.

Note that these components could be undertaken in isolation, or as a partial or complete set and could be staged. Results for wetland restoration and removal of existing informal tidal levees assume no further infilling or tidal levee construction occurs (i.e., they are relative to current conditions).

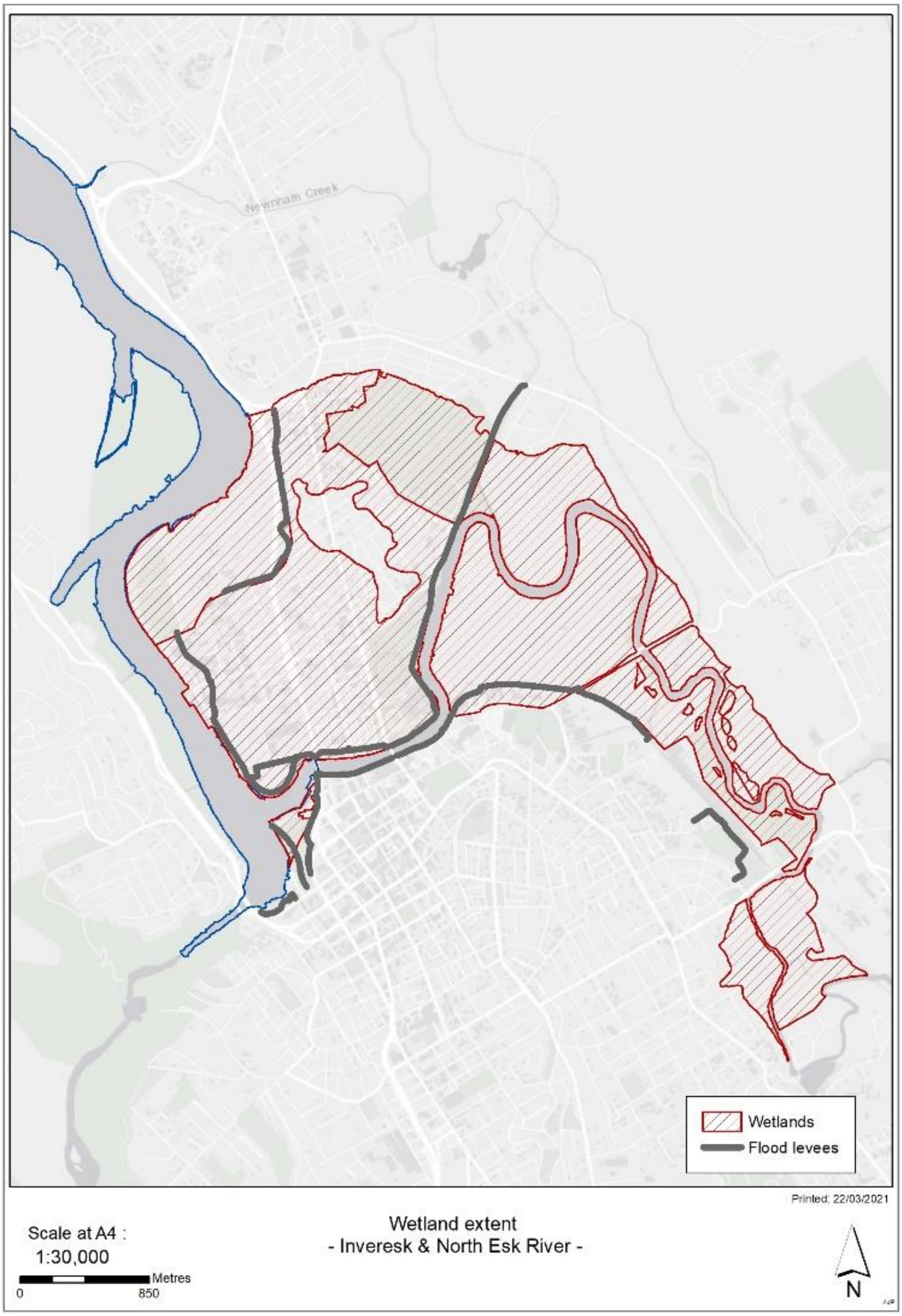


Figure 27. Original areas of wetlands in the upper estuary. Thick black lines indicate areas where Launceston's flood defence levees have been constructed and behind which wetlands have been infilled. Informal tidal levees and infilling of wetlands have further reduced tidal prism outside the flood levee protection system.

Ceasing the ongoing practice of infilling wetlands will avoid further reductions in tidal prism and increases in sedimentation. The primary anthropomorphic pressure on wetlands is cumulative and incremental clearing and infilling (Prahalad *et al.*, 2019). There are seven properties on the North Esk floodplain (downstream of Kings Meadows Rivulet confluence) where infilling is currently active, with a further two properties with a high probability of infilling in the near future. Approximately 100 ha of wetland community remains in this area according to TasVeg 4.0 mapping. Figure 28 shows remaining areas of wetlands within the North Esk floodplain.

Figure 28. TasVeg 4.0 Remnant wetlands in the North Esk River floodplain are hatched in green.

In addition to floodplain reclamation, informal intertidal levees (RL 2.2-3.0 m AHD) have been constructed to protect reclaimed agricultural land along the North Esk River. Removal of these informal levees could increase tidal prism by more than 200,000 m^3.

Wetlands act as filtering systems, removing sediment, nutrients and pollutants from water, and by spreading out and slowing down flows they reduce erosion and prevent sediment being transported downstream. Australia has a legacy of degraded floodplain and wetland habitats during the 200 years of urban/industrial development and agricultural intensification (Waltham *et al.* 2019). The environmental values of the North Esk River floodplains, and the impact of infilling and tidal levees on the downstream mudflats, are not immediately obvious to the general public. There is an increasing global movement to halt wetland loss and degradation, and to undertake large-scale programs to repair and restore wetlands. Large-scale restoration has a long history in north America, such as Delaware Bay (Morrison, 2019) and China plans to invest $1 billion on more than 50 large programs by 2030 (Waltham *et al.*, 2019). Constructed wetlands compensate for the loss of wetlands as a result development, attenuate flood flows, provide habitat for aquatic life and provide recreational amenity (DPLG 2010).

9.1 Legislation and feasibility challenges

9.1.1 Legislation and permit requirements

The three components of wetland and floodplain restoration have different legislative implications. Constructed wetland restoration would require excavation and treatment of potential acid sulfate soils that are potentially contaminated with heavy metals and high nutrient levels. There are several pieces of legislation that would affect the feasibility of floodplain restoration. There are also legislative and permitting requirements that affect floodplain reclamation activities including the construction of informal tidal levees.

9.1.1.1 Floodplain reclamation and construction of informal tidal levees

Floodplain reclamation and the construction of informal tidal levees on the North Esk River floodplains requires:

- Assessment against the Launceston Interim Planning Scheme 2015 for either a Development Application or a determination that no permit is required (*Land Use and Planning Approvals Act 1993*).
- Assessment for the presence of wetlands to determine if the activity will disturb or clear state-listed threatened vegetation (wetlands). There are two key pieces of legislation that would affect this activity:
    - the *Forest Practices Act 1985* and the *Forest Practices Regulations 1997* prohibit forest clearing on defined ‘vulnerable land’ (such as stream-side reserves, drainage lines and swamps, and threatened vegetation communities) without a Forest Practices Plan. An exemption applies if the works are authorised under a permit issued under the *Land Use and Planning Approvals Act 1993*; and
    - the *Nature Conservation Act 2002* which lists threatened native vegetation communities that are to be protected under the forest practices system.

- Assessment by a developer of the intended works against the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) which protects federally listed threatened species and ecological communities. There are several federally listed threatened species known to occur on the North Esk River floodplains, particularly the critically endangered Australasian bittern. Taking action that has or will have a significant impact on regulated species and or communities without Commonwealth ministerial approval renders developers liable to large penalties.
- A permit under section 51 of the *Threatened Species Protection Act 1995* (Tas)*,* is required to take (which includes to kill, injure, damage or destroy) listed threatened flora or fauna, and that taking is not otherwise authorised by a relevant plan or permit. Several state-listed threatened flora and fauna species are known to occur in the area where works would be undertaken, and vegetation and habitat removed.
- Permits under the *Nature Conservation Act 2002* if native (non-threatened) species or their nests/dens are likely to be impacted (e.g., platypus, rakali etc.).

Dams and levees are regulated under the *Water Management Act 1999* (Tas) and associated regulations. Under s3 of the *Water Management Act 1999* (Tas) a dam is defined, inter alia, as *'an artificial levee or bank that holds back or diverts water in a watercourse'.* The practice of constructing informal tidal levees on the North Esk River may trigger assessment against this instrument. Construction of informal levees and floodplain reclamation activities without requisite permits in place is a compliance issue and opens the potential for some restoration activities to be considered through the lens of compliance.

9.1.1.2 Wetland and floodplain restoration

There are several legislative instruments that would affect the feasibility of wetland and floodplain restoration:

- *Environmental Management and Pollution Control Act 1994* (Tas) – in areas of past deposition and infilling, the sediments are contaminated with heavy metals and high nutrient concentrations and may amount to controlled waste under that act. Removal and or disposal of any controlled waste is regulated and may only occur under a relevant authority (for example a planning permit issued for a Level 2 activity, and environmental protection notice, or an environmental licence) or pursuant to a management method approved by the Director of the EPA.
- The North Esk River floodplain contains potential and actual acid sulfate soils. Additional requirements and limitations exist where contaminated soils are potential acid sulfate (see Simpson *et al.*, 2018). An acid sulfate soil management plan would be required which would detail the technical feasibility of measures to manage risks. Sediments transported offsite would require treatment to address acid sulfate properties before it could be disposed of lawfully in landfill. This would likely require storage on a fully lined pad, with acid leachate captured and disposed of as trade waste. Lime or other neutralising agent would need to be added to neutralise acids to a level where the spoil can be disposed of in landfill.
- *Forest Practices Act 1985*, *Nature Conservation Act 2002, Threatened Species Protection Act 1995* and *Environment Protection and Biodiversity Conservation Act*

1999 (Cth) – similar to above, wetland restoration projects would require an assessment against natural values management acts.

- *Weed Management Act 1999* – controls may be required to prevent the distribution of declared weeds, such as crack willow and Canadian pondweed, that are known to occur on the North Esk River floodplains.

9.1.2 Feasibility challenges

The three components (stages) of wetland and floodplain restoration also have differing challenges and risks which impact on their feasibility.

9.1.2.1 Ceasing current practices

Ceasing the current practice of floodplain/wetland infilling and the construction/renewal of informal tidal levees is constrained by a lack of clear statutory responsibility and a clear policy position. It is a relatively simple action but complex both socially and legislatively.

Infilling of the floodplain is a long-standing practice in Launceston, while the understanding of the natural values of the wetlands and floodplains and the impact on the tidal prism and mudflat formation is relatively recent. The activity is exempt from the Launceston Interim Planning Scheme if the proposed use and development relates to an agricultural use, which is identified as a 'no permit required' use within the Rural Resource zone.

As detailed above, there are other legislative instruments a developer should have regard to, however the pathway for assessment is unclear and relies heavily on the project proponent understanding their obligations, and access to reliable data for decision-making. For example, removal of known habitat for the Australasian bittern requires referral to the Commonwealth under the *EPBC Act*. Most often referrals are lodged by the project proponent undertaking the activity. Infilling the floodplain and conversion of wetlands to agricultural pasture has been practiced for decades and there would be limited awareness in the community of the need for any environmental assessments for this process.

Filling the floodplain and constructing intertidal levees does not impact on Launceston City's flood levees. The City of Launceston and/or the Launceston Flood Authority does not impose controls on these activities. However, incremental infilling reduces floodplain storage volume, increasing the frequency of spring tide/minor flood events impacting local infrastructure (e.g., approaches to the bridge on Henry Street).

A clear policy position on floodplain infilling and tidal levee construction is required to provide guidance for decision-makers and information for landowners in order to cease current practices.

9.1.2.2 Removal of existing informal levees

Similarly, removal of existing informal tidal levees is constrained by a lack of clear statutory responsibility and a clear policy position. Properties protected by existing informal levees are likely to have higher agricultural productivity and value. Many levees have been in place for decades. Creation of tidal levees was amongst the earliest modifications undertaken on Launceston's floodplains following European settlement. There is no obvious mechanism to compel landowners to remove levees (or obtain retrospective permits). It is likely that an alternative pathway where agencies work collaboratively with landowners for restoration works may lead to positive outcomes. The potential for landowners to benefit from carbon credits through blue carbon could be explored once this scheme is operating.

9.1.2.3 Wetland and floodplain restoration

Wetland and floodplain restoration pose risks during the wetland construction phase, with an ongoing maintenance period likely to last for several years post construction. A major impediment in the success of restoration projects is ongoing competing land uses (e.g., agricultural development) as the majority of the land is in private ownership. Much of the North Esk floodplain wetland loss is not readily reversible. Two options have been considered for this report: a smaller program of wetland restoration on public land; and a larger, more comprehensive program of wetland restoration across the lower North Esk River floodplain.

9.1.2.4 Wetland restoration - small program

Two large parcels of land within the North Esk River floodplain are in public ownership, making these sites most suitable for immediate wetland and floodplain restoration (Figure 29). The Council-managed North Esk Trail has an existing network of shallow basins, constructed as part of Landcare's Ribbon of Blue project. A section of this area has become overgrown with willows and other woody weeds in recent years. Wetland restoration in this section will require a significant weed removal program and replanting.

Figure 29. Potential focus area(s) for wetland and floodplain restoration. Restoration would involve construction of a series of shallow basins. Land affected is all in public ownership.

Construction of additional shallow basins to continue and extend the works of the Ribbon of Blue and increase the tidal prism, the North Esk floodplain would need to be excavated and soils treated before disposal. These are known to be potential acid sulfate soils and are likely to contain elevated concentrations of nutrients and heavy metals. Ideally the design and location of wetland restoration activities would be informed by soil testing to determine the level of contamination and extent of treatment for PASS required.

Excavated excess sediments would need to be transported off site, treated for acid sulfate and then disposed of, most likely in land fill as Level 2 waste. The volume of sediments to be excavated and treated would depend on the design. Using the indicative design presented above, the wetlands would require excavation of approximately 60,000 m^3 of sediment.

9.1.2.5 Wetland and floodplain restoration - large-scale program

A large area on the North Esk floodplain is undeveloped land. It is a mixture of public open space, utility, agricultural land and privately owned swamp and wetland, covering approximately 255 ha. The lack of infrastructure, housing and commercial businesses make this area the most suitable for large-scale wetland and floodplain restoration. Scotch Oakburn College's Environmental Association has actively restored approximately 10 ha of wetland within the floodplain. Of the 255 ha of undeveloped land, approximately 120 ha would require restoration.

Floodplain and wetland restoration in this area will require removal of informal tidal levees, removal of fill and construction of wetlands and interconnected waterways. As with the small-scale wetland restoration option, the area is known to contain potential acid sulfate soils, and they are likely to contain elevated concentrations of nutrients and heavy metals, as well as clean fill rubble such as concrete and rock.

Excavated excess sediments would need to be transported off site, treated and then disposed of, most likely in land fill as Level 2 waste. The volume of sediments to be excavated and treated would depend on the design. Informal tidal levees may be breached at strategic locations, rather than being removed in their entirety. Much of the floodplain containing fill has been raised to 2.5-3.0 m AHD. Assuming the floodplain will need to be lowered by 1.25 m approximately 1,500,000 m^3 of sediment will need to be removed and remediated. Given the very large area and high volume of sediment for remediation, a large-scale wetland restoration program would need to be staged.

9.2 Estimated costs

9.2.1 Ceasing current practices

Ceasing infilling of wetlands and construction of informal levees on the North Esk floodplain is not associated with any cost.

9.2.2 Removal of existing informal levees

Removal of existing informal tidal levees would require:

- An assessment of the level of contamination and potential acid sulfate soils (PASS) status of sediments to be disturbed. This would inform the treatment and disposal options available for soils removed as part of the levee removal process.
- Costs of revegetation of areas left exposed once soils used to construct the levees are removed.

Assuming soils require treatment for PASS and that they require disposal to landfill due to levels of contamination, the cost of removing informal levees is expected to be in the order of $2 million.

9.2.3 Wetland restoration

The two wetland restoration options considered here vary significantly in terms of scale and complexity. Costs for these options would include:

- excavation of sediments, treatment for PASS and disposal to landfill as required by their level of contamination. Soil testing would need to be conducted on all areas being excavated to determine requirements; and
- planting and ongoing maintenance costs associated with tasks such as weed management.

Without knowing the full volume of sediments that would need to be excavated or the nature of these soils it is difficult to provide accurate estimates, but it is likely that the cost of the small-scale restoration project would be in the order of $10 million, while the large-scale restoration project would likely cost closer to $250 million. Land tenure may also influence final costs if land acquisition becomes necessary to ensure works are undertaken on lands that are currently in private hands. Ongoing costs of managing this land as public open space would need to be considered. These costs may be offset with income from carbon credits once the Australian Governments Blue carbon scheme becomes operational.

9.3 Impacts on bathymetry, visible mudflats and navigability

The three stages of wetland restoration and restoration of tidal prism on the North Esk floodplain are intended to reduce sedimentation by increasing tidal prism. Estimates of the impacts of these stages on tidal prism have been made using GIS analysis. This estimate was then used to model a change in cross-sectional area at four locations in the estuary (two in the lower North Esk and two in Home Reach) as shown in Figure 30. Note that no impact is expected in the Yacht Basin as the North Esk does not impact on tidal prism in this part of the estuary.

Figure 30. Location of cross sections used in analysis of North Esk tidal floodplain scenarios. Note there is no change in the tidal prism of the Yacht Basin so it is expected these options will not impact on cross-sections in that location.

This additional tidal prism has then been added to existing tidal prism already calculated for the four cross-sections. New regime equilibrium cross-sectional area has then been estimated using:

$$A = 3.1 \times 10^{-3} P^{0.81}$$

where *P* is total scenario tidal prism and *A* is scenario cross-sectional area below zero meters AHD. See Section 7.3 for more information on the source of this regime equation.

These changes have then been superimposed over recent bathymetric data to see what this change in cross-sectional area is likely to imply in terms of changes in channel depth and visible mudflats relative to data collected in October 2020. This model assumes that the change in regime cross-sectional area will directly relate to the same change relative to current cross-sectional area. It is provided to illustrate the nature and magnitude of changes that could be expected rather than predict final outcomes of such an investment. Note that the information provided in this section is intended to estimate the magnitude and direction of impacts. Calculation of tidal prism can be difficult to achieve without a hydrodynamic model. Off channel inter-tidal storage areas may not completely fill during a tidal cycle due to limited connectivity with main flow path. Significant changes to off-channel inter-tidal storage can result in changes to tidal propagation signal (i.e., water level timeseries) in the main channel.

If these options were to be considered for future investment more detailed modelling and soil sampling of potential locations for works would be desirable to optimise investment outcomes.

A new cross-sectional area for comparison with October 2020 bathymetry is then calculated as:

$$A_{s2020} = A_{2020} + (A_r - A_{sr})$$

where A_{2020} is the measured cross-sectional area in October 2020, A_r is the current regime cross-sectional area and A_{sr} is the new regime cross-sectional area for the wetland restoration scenario.

In order to give an idea of the effects of this change in cross-sectional area on visible mudflats and channel depth, a simple model of change where additional cross-sectional area is assumed to be distributed relative to current cross-sectional area across the section is used. This estimate is not predictive of the impact of changes but provides an indication of the nature and magnitude of changes that might be expected.

9.3.1 Cease infill and informal tidal levee development

This option considers avoiding further impact – that is, there would be no reduction in sedimentation from current levels, but it would avoid further loss of tidal prism and additional sedimentation from the current practice of infilling and tidal levee development. Current infilling practices are anticipated to fill all areas of privately owned floodplain between Kings Meadows Rivulet and the Inveresk to 2.5 m AHD. The scenario assumes the maximum extent possible of informal levee development and infill (i.e. all remaining areas).

Table 8 shows the maximum loss of tidal prism and consequently cross-sectional area that could be expected from continued infilling and informal tidal levee development (i.e., assuming all remaining areas without informal levees are developed). Tidal prism in areas currently without tidal levees has been estimated using a 1 m digital elevation model (DEM) that was developed using half-metre contour data covering the North Esk tidal floodplain. Mean low tide has been assumed at -1.537 m and mean high tide at 1.674 m using data from Palmer *et al.* (2019). This table shows that allowing continued informal tidal levee construction and infilling of the tidal floodplain would see a loss of up 185,000 m^3 of tidal prism compared to the current situation. This translates into lost cross-sectional area of just under 10 m^2 at each of the sites.

Table 8. Current and modelled scenario tidal prism and regime cross-sectional areas for ceasing infill and tidal levee development option. Note this option relates to the avoided reduction in tidal prism (increase in sedimentation) and cross-sectional area.

Cross-section location	Tidal prism (m^3)		Regime cross-sectional area (m^2)	
	Current	Scenario	Current	Scenario
North Esk near Seaport	1,647,230	1,462,536	314	306
North Esk near Town Point	1,703,814	1,519,120	324	315
Home Reach at Silos	2,452,335	2,267,641	444	436
Home Reach at Kings Wharf	2,710,418	2,525,724	483	476

The change in visible mudflats and channel depth as a result of this loss of cross-sectional area has been modelled and is summarised in Table 9, showing that continued levee development and infilling of the tidal floodplain is likely to lead to minor, if any, loss of depth in channels. Increases in visible mudflats in the North Esk of 1-2 m can be expected. Increases in visible mudflats are smaller in Home Reach, estimated to be between 0.3 m and 0.6 m, with the greatest breadth closest to the confluence with the North Esk.

Table 9. Modelled change in maximum depth and mudflat extent for cross-section locations for continued infilling and development of tidal levees scenario. Note figures are loss of channel depth and increase in breadth of visible mudflats if infilling and tidal levee construction continues. Estimates of current depth and breadth of visible mudflats are based on bathymetry data from October 2020.

Cross-section location	Maximum channel depth (m)		Mudflat breadth visible at low tide (m)	
	Current	Loss of depth	Current	Change from scenario
North Esk near Seaport	-4.19	0.03	17.4	0.9 (5%)
North Esk near Town Point	-5.35	0.04	64.6	1.8 (3%)
Home Reach at Silos	-4.23	0.02	92.3	0.6 (1%)
Home Reach at Kings Wharf	-4.00	0.01	27.8	0.3 (1%)

9.3.2 Remove informal tidal levees

The scenario to remove informal tidal levees assumes a change in tidal prism and resulting total tidal prism at each of the cross-sectional locations as shown in Table 10. Tidal prism in areas that already have tidal levees has been estimated using a 1 m DEM that was developed using half-metre contour data covering the North Esk tidal floodplain. Low tide has been assumed at -1.537 m and high tide at 1.674 m.

Table 10 shows that removal of existing informal tidal levees would generate approximately 246,000 m^3 of additional tidal prism. This translates into increases of cross-sectional area of approximately 60 m^2 at each of the sites with increases greater in the North Esk than Home Reach.

Table 10. Current and modelled scenario tidal prism and regime cross-sectional areas for removal of informal tidal levees option.

Cross-section location	Tidal prism (m^3)		Regime cross-sectional area (m^2)	
	Current	Scenario	Current	Scenario
North Esk near Seaport	1,647,230	1,893,251	314	377
North Esk near Town Point	1,703,814	1,949,835	324	386
Home Reach at Silos	2,452,335	2,698,356	444	502
Home Reach at Kings Wharf	2,710,418	2,956,439	483	540

Table 11 summarises current maximum channel depth and width of visible mudflats and the modelled change in these two variables under the removal of existing tidal levees scenario. This option is estimated to lead to small increases in channel depth (approx. 20-30 cm in the North Esk; 10 cm in Home Reach). Decreases in the extent of visible mudflats at low tide vary between 4 and 8 m in the North Esk, and nearly 6 m at in Home Reach near the Silos and close to 2 m near Kings Wharf.

Table 11. Modelled change in maximum depth and mudflat extent for cross-section locations for removal of existing tidal levees scenario. Estimates of current depth and breadth of visible mudflats are based on bathymetry data from October 2020.

Cross-section location	Maximum channel depth (m)		Mudflat breadth visible at low tide (m)	
	Current	Increase from scenario	Current	Change from scenario
North Esk near Seaport	-4.19	-0.21	17.4	-4.3 (-25%)
North Esk near Town Point	-5.35	-0.30	64.6	-8.0 (-12%)
Home Reach at Silos	-4.23	-0.12	92.3	-5.8 (-6%)
Home Reach at Kings Wharf	-4.00	-0.11	27.8	-2.2 (-8%)

9.3.3 Restoration of wetlands – small program

This option assumes that wetland restoration focuses on developing shallow basins as shown in Figure 29. An average depth of 2 m below high tide (1.674 m) has been assumed (note this is below the current minimum depth and would require excavation). The addition in tidal area has been calculated using the area times the average depth (2 m), minus current tidal prism. Using this method, it is estimated that approximately an additional 59,000 m^3 of tidal prism could be created.

Table 12 summarises the current and estimated tidal prism and cross-sectional areas for the four cross-sections based on the wetland restoration scenario. This table shows that the additional tidal prism could be expected to generate approximately 30 m^2 of additional cross-sectional area at each location.

Table 12. Current and modelled scenario tidal prism and regime cross-sectional areas for wetland restoration option.

Cross-section	Tidal prism (m^3)		Regime cross-sectional area (m^2)	
	Current	Scenario	Current	Scenario
North Esk near Seaport	1,647,230	1,706,614	314	346
North Esk near Town Point	1,703,814	1,763,198	324	356
Home Reach at Silos	2,452,335	2,511,719	444	474
Home Reach at Kings Wharf	2,710,418	2,769,802	483	513

Table 13 summarises current maximum channel depth and width of visible mudflats and the modelled change in these two variables under the wetland restoration scenario.

The small wetland restoration scenario indicates small increases in depth at each location. It can be expected that there will be approximately 2 m less mudflat visible at low tide at the North Esk near Seaport compared with 17 m currently, and nearly 4 m less near Town Point compared with approximately 65 m currently. It is estimated there would be approximately 5 m less visible mudflat at low tide in Home Reach near the Silos compared with over 90 m currently.

The effects of increased tidal prism are less apparent at the Kings Wharf location, with only approximately 1 m less of visible mudflat at low tide, though this is for a reduced mudflat breadth of just under 30 m compared with the other Home Reach site.

Table 13. Modelled change in maximum depth and mudflat extent for cross-section locations for wetland restoration scenario. Estimates of current depth and breadth of visible mudflats are based on bathymetry data from October 2020.

Cross-section location	Maximum channel depth (m)		Mudflat breadth visible at low tide (m)	
	Current	Increase from scenario	Current	Change from scenario
North Esk near Seaport	-4.19	-0.11	17.4	-2.0 (-11%)
North Esk near Town Point	-5.35	-0.15	64.6	-3.6 (-6%)
Home Reach at Silos	-4.23	-0.06	92.3	-4.6 (-5%)
Home Reach at Kings Wharf	-4.00	-0.06	27.8	-1.4 (-5%)

9.3.4 Restoration of wetlands – large program

The large restoration of wetlands program assumes that restoration focuses on developing shallow basins as shown in Figure 29. An average depth of 2 m below high tide (1.674 m) has been assumed (note this is below the current minimum depth and would require excavation). The addition in tidal area has been calculated using the area times the average depth (2 m), minus current tidal prism. Using this method, it is estimated that approximately an additional 1.5 million m^3 of tidal prism could be created.

Table 14 summarises the current and estimated tidal prism and cross-sectional areas for the four cross-sections and shows that the additional tidal prism could be expected to generate approximately 240-250 m^2 of additional cross-sectional area at each location.

Table 14. Current and modelled scenario tidal prism and regime cross-sectional areas for large program wetland restoration option.

Cross-section	Tidal prism (m^3)		Regime cross-sectional area (m^2)	
	Current	Scenario	Current	Scenario
North Esk near Seaport	1,647,230	3,147,230	314	568
North Esk near Town Point	1,703,814	3,203,814	324	577
Home Reach at Silos	2,452,335	3,952,335	444	684
Home Reach at Kings Wharf	2,710,418	4,210,418	483	720

Table 15 summarises current maximum channel depth and width of visible mudflats and the modelled change in these two variables under the wetland restoration scenario.

The analysis shows that the large increase in tidal prism can be expected to have significant effects on the extent of visible mudflats and channel depth. It can be expected that there will be approximately 12 m less mudflat visible at low tide at the North Esk near Seaport compared with 17 m currently, and nearly 30 m less near Town Point compared with approximately 65 m currently. It is estimated there would be approximately 28 m less visible mudflat at low tide in Home Reach near the Silos compared with over 90 m currently. The effects of increased tidal prism are less apparent but still substantial at the Kings Wharf location, with approximately 8 m less of visible mudflat at low tide compared to approximately 30 m currently.

Table 15. Modelled change in maximum depth and mudflat extent for cross-section locations for wetland restoration scenario. Estimates of current depth and breadth of visible mudflats are based on bathymetry data from October 2020.

Cross-section location	Maximum channel depth (m)		Mudflat breadth visible at low tide (m)	
	Current	Increase from scenario	Current	Decrease from scenario
North Esk near Seaport	-4.19	-0.86	17.4	-12.0 (-69%)
North Esk near Town Point	-5.35	-1.21	64.6	-29.6 (-46%)
Home Reach at Silos	-4.23	-0.50	92.3	-28.2 (-31%)
Home Reach at Kings Wharf	-4.00	-0.45	27.8	-8.1 (-29%)

9.3.5 Summary of impacts on bathymetry

Table 16 summarises the likely impacts of wetland restoration options on the bathymetry of the estuary. These options do note change tidal prism of the Yacht Basin and would not be expected to have a direct impact on cross-sectional area in this location. However there is a risk that having a more active (higher tidal prism) tidal regime immediately adjacent to the Yacht Basin could lead to increased sedimentation rates during low fluvial flow periods. Sediment would be mobilised in association with the changed tidal regime and this sediment would tend to accumulate in relatively quiescent areas out of the main tidal flow paths.

Table 16. Likely impacts of North Esk floodplain restoration options on bathymetry.

Locations	**Cease infill & tidal levee development**	**Remove informal tidal levees**	**Restoration of wetland**	**Large-scale floodplain restoration**
Channels				
Lower North Esk	Minor to no change.	Moderate increase in depth (~20-30 cm).	Small increase in channel depth (~15 cm).	Large increase in channel depth (~1 m).
Royal Park	No primary impact.	No primary impact.	No primary impact.	No primary impact.
Home Point to Ti Tree Bend	Minor to no change.	Small increase in depth (~10 cm).	Very small increase in channel depth (max. estimated approx. 6 cm).	Moderate increase in channel depth (0.5 m).

Channels in the middle and lower estuary	Minor to no change.	Minimal impact.	Minimal impact.	Increases in channel depth likely to extend further down estuary than smaller programs but unlikely to impact into lower estuary.
Mudflats				
Seaport Marina	Avoid approx. 1 m additional mudflat developing (i.e., avoid increased sedimentation in Seaport Marina).	Reduced visible mudflats in lower North Esk (approx. 4 m at low tide). Reduced sedimentation pressure on Marina, though actual impact will depend on interaction of infrastructure with sedimentation processes.	Reduced visible mudflats in lower North Esk (approx. 2 m at low tide). Reduced sedimentation pressure on Marina, though actual impact will depend on interaction of infrastructure with sedimentation processes.	Reduced visible mudflats in lower North Esk (approx. 12 m at low tide). Reduced sedimentation pressure on Marina, though actual impact will depend on interaction of infrastructure with sedimentation processes.
West Tamar	Avoid approx. 0.5 m of additional mudflats developing (avoid increased sedimentation along West Tamar shoal).	Reduced visible mudflats at low tide (estimate ~2-6 m, with greater impact closer to Town Point).	Reduced visible mudflats at low tide (estimate ~1-4 m, with greater impact closer to Town Point).	Reduced visible mudflats at low tide (estimate ~18-30 m, with greater impact closer to Town Point).
Royal Park/Yacht Basin	No primary impact.	No primary impact.	No primary impact.	No primary impact.
Town Point	Avoid approx. 2 m of additional mudflat developing (avoid additional sedimentation around Town Point).	Reduced visible mudflat (estimate approx. ~8 m at low tide).	Reduced visible mudflat (estimate approx. ~3 m at low tide).	Reduced visible mudflat (estimate approx. ~30 m at low tide).

Intertidal areas in the middle to lower estuary	No impact.	Impact expected to dampen as move towards the lower estuary - minimal impact by mid to lower estuary based on Home Reach estimates.	Impact expected to dampen as move towards the lower estuary - minimal impact by mid to lower estuary based on Home Reach estimates.	Impact expected to dampen as move towards the lower estuary but given large impacts for Home Reach these are likely to extend significantly further down the estuary than other options.

9.4 Impacts on flood risk

The effects of informal tidal levees in the North Esk floodplain have been modelled using the TUFLOW model. This modelling assumed uniform levee height of 2.3 m (compared with the formal flood levee system in the same vicinity of 4.9-5.1 m), though in reality crest height varies. The impact of removal of these levees with a crest at 2.3 m AHD has been assessed for the 5 percent, 1 percent and 0.5 percent AEP events. These results show that removal of levees will reduce flood levels downstream by up to 0.1 m in a 5 percent AEP event but in the 1 percent and 0.5 percent AEP events there is minimal change in peak flood level as informal levees are overtopped in larger flood events. These changes would have no impact on flood risk in formal flood levee system protected areas and at most very small benefits on non-levee protected areas for smaller floods.

9.5 Impacts on water quality and environmental values

Restoration of wetlands in the North Esk tidal floodplain is associated with significant environmental benefits in this area (Table 17). There are several threatened species that use the area for habitat with wetlands themselves a state-listed threatened vegetation community. Additionally, with flows from the North Esk being filtered through wetlands the improved water quality will benefit areas downstream.

Table 17. Key environmental impacts of North Esk floodplain options

Environmental values	**Cease infill & informal tidal levee development**	**Remove informal tidal levees**	**Small-scale wetland restoration**	**Large-scale floodplain restoration**
Water quality	Small avoided decline in water quality (turbidity and nutrients) as sediment run-off from newly filled or constructed areas likely to decrease. Ongoing – avoided decline in water quality as inundated floodplains slow flow to filter water and reduce erosion.	Construction phase – Risks from contaminated run-off if site not well-managed and weed dispersal. Ongoing – improved water quality as inundated floodplains slow flow to filter water and reduce erosion.	Removal phase - Risks from oxidisation of potential acid sulfate soils, contaminated run-off and weed dispersal if site not well-managed. Ongoing – improved water quality as wetlands slow flow to filter water and reduce erosion.	Construction phase - Risks from oxidisation of potential acid sulfate soils, contaminated run-off and weed dispersal if site not well-managed. Ongoing – improved water quality as wetlands slow flow to filter water and reduce erosion.
Intertidal habitats	Avoided increase in rate of deposition of sediments downstream.	Reduced deposition of sediments downstream.	Reduced deposition of sediments downstream.	Reduced deposition of sediments downstream.
Subtidal habitats	Avoided increase in rate of deposition of sediments downstream.	Reduced deposition of sediments downstream.	Reduced deposition of sediments downstream.	Reduced deposition of sediments downstream.
Migratory fish	May experience small benefits from reduction in turbidity (e.g., reduced gill scour). Continued access to wetlands and associated food sources.	Likely to be benefited by reduction in turbidity (e.g., reduced gill scour). Improved ecosystem health, including abundance and diversity of aquatic macroinvertebrates, likely to benefit migratory fish	Likely to be benefited by reduction in turbidity (e.g., reduced gill scour). Improved ecosystem health, including abundance and diversity of aquatic macroinvertebrates, likely to benefit migratory fish.	Likely to be benefited by reduction in turbidity (e.g., reduced gill scour). Improved ecosystem health, including abundance and diversity of aquatic macroinvertebrates, likely to benefit migratory fish.

Threatened flora, fauna, vegetation communities and ecological communities	Halt to loss of threatened wetland vegetation community and threatened flora from infilling and conversion. Halt to loss of habitat for wetland-dependent species such as the green & gold frog and the Australasian bittern.	Potential restoration of habitat connectivity for threatened fauna due to periodic inundation of more area of floodplain. Potential recolonisation of riparian zone with threatened wetland flora (e.g., river clubsedge).	Restoration and creation of new areas of habitat for threatened wetland vegetation community, flora and fauna. Improved habitat connectivity. Potential recolonisation of riparian zone with threatened wetland flora (e.g., river clubsedge)	Restoration and creation of significant new areas of habitat for threatened wetland vegetation community, flora and fauna. Improved habitat connectivity. Recovery of sub-populations of threatened fauna expected – restoration would represent a doubling of available habitat for the critically endangered Australasian bittern in the North Esk floodplain. Potential recolonisation of riparian zone with threatened wetland flora (e.g., river clubsedge)
Migratory birds	Halt to loss of habitat for wetland-dependent species.	Potential restoration of habitat connectivity due to periodic inundation of more area of floodplain. Increased use of the upper estuary around Launceston as fringing intertidal vegetation re-establishes.	Improved ecosystem health, including abundance and diversity of aquatic macroinvertebrates, likely to benefit migratory birds. Increased use of the upper estuary around Launceston as vegetation re-establishes.	Improved ecosystem health, including abundance and diversity of aquatic macroinvertebrates, likely to benefit migratory birds. Increased use of the upper estuary around Launceston as vegetation re-establishes.
Reserves and conservation areas	Reduced/avoided impact on Tamar River Conservation Area.	Values associated with conservation area expected to improve as fringing intertidal habitat restored.	Values associated with conservation area expected to improve as wetland and intertidal habitat restored.	Values associated with conservation area expected to improve as wetland and intertidal habitat restored.

Key Biodiversity Area/Important Bird Area	Avoided impact on KBA/IBA.	Values associated with habitat improve. Over time establishment of fringing intertidal vegetation such as reeds likely to increase extent and condition of habitat and connectivity in the upper estuary.	Establishment of wetland vegetation such as reeds likely to increase extent and condition of habitat in the upper estuary. Improved habitat, including foraging habitat, as abundance and diversity of aquatic macroinvertebrates likely to increase.	Establishment of significant area of wetland vegetation such as reeds likely to increase extent and condition of habitat in the upper estuary. Improved habitat, including foraging habitat, as abundance and diversity of aquatic macroinvertebrates likely to increase.

9.6 Impacts on recreation and navigation

Any changes in bathymetry and water quality can have impacts on recreational and tourism users of the estuary. In addition to the impacts on the waterways, floodplain and wetland restoration could be expected to increase amenity for users of the North Esk trail and create a new area for bird-watching between the Tamar Island Wetlands and Queechy Lake. These impacts are summarised in Table 18.

Table 18. Impacts of North Esk floodplain restoration on key recreational and tourism users of the upper kanamaluka/Tamar estuary.

User	Cease infill & tidal levee development	Remove informal tidal levees	Small-scale restoration of wetland	Large-scale floodplain restoration
Rowing - Access to North Esk from pontoons and navigability of the North Esk	Avoid further increases in sedimentation in the North Esk which would impact on access. Also avoid any further decline in water quality which could be expected from additional loss of tidal wetlands.	Moderate increased channel breadth at low tide and reduced sedimentation of pontoon. Some improvements in visual water clarity.	Small to moderate increased channel breadth at low tide and reduced sedimentation of pontoon. Some improvements in visual water clarity.	Large increase in channel breadth at low tide and reduced sedimentation of pontoon. Some improvements in visual water clarity.
Tamar Rowing Club	No impact (Yacht Basin unaffected).	No impact (Yacht Basin unaffected).	No impact (Yacht Basin unaffected).	No impact (Yacht Basin unaffected).
Home Point tourist boats	Avoid loss of channel breadth through reduced infilling. No significant loss of channel depth.	Decrease mudflat extent around Town Point and Home Reach, increase navigable width of river at low tide. Small increases in channel depth unlikely to be material given current depths are sufficient for navigation.	Decrease mudflat extent around Town Point and Home Reach, increase navigable width of river at low tide. Small increases in channel depth unlikely to be material given current depths are sufficient for navigation.	Large decrease mudflat extent around Town Point and Home Reach, increase navigable width of river at low tide. Significant increases in channel depth unlikely to be material given current depths are sufficient for navigation.
Seaport Marina	Avoid increased sedimentation in Marina and loss of channel breadth at low tide into/out of North Esk.	Moderate reduced sedimentation of Marina. Increase channel breadth at low tide into/out of Marina.	Small to moderate reduced sedimentation of Marina. Increase channel breadth at low tide into/out of Marina.	Large reduction in sedimentation of Marina. Increase channel breadth at low tide into/out of Marina.

Tamar Yacht Club	No impact.	No impact.	No Impact.	No Impact.

9.7 Summary of key findings

Four options for the North Esk tidal floodplain have been evaluated:

1) the avoided impacts associated with ceasing current infilling and informal levee construction activities;

2) removal of existing tidal levees;

3) restoration of 5 ha of tidal wetlands on state-owned land in the North Esk floodplain through construction of a series of shallow basins; and

4) restoration of 120 ha of wetlands in the North Esk floodplain through the removal of infill and construction of a series of shallow basins. In summary:

- All options are associated with environmental benefits, both in terms of direct benefits of protecting and/or increasing the area of threatened wetland vegetation communities and the flora and fauna that use them as habitat, and through improvements in water quality downstream.
- There are several legislative, social and feasibility challenges associated with each of the options. A lack of clarity over policy position on floodplain infilling and tidal levee construction has led to ongoing tidal levee construction and infilling of wetlands in the North Esk.
- Actions that require excavation of lands to restore wetlands face construction and cost constraints associated with treatment and disposal of potential acid sulfate soils which may also be contaminated with heavy metals and nutrients.
- Removal of existing tidal levees on private land is complicated and may require lands to be acquired, as it is unclear to what extent it would be possible to compel landowners to remove levees.
- Costs of options are difficult to estimate due to the unknown nature of soils to be excavated and potential land acquisition costs. There are challenges to removal of existing levees on private land. Land acquisition, with an associated additional cost, may be required to overcome these in some cases.
- All options would have impacts on visible mudflats in the lower North Esk and Home Reach. No additional tidal prism is created in the Yacht Basin so there is no change in any bathymetry in this section of the estuary.
- Changes in the extent of mudflats in the lower North Esk and Home Reach to Kings Wharf would mean a wider channel at low tide which would benefit recreational users, such as rowing clubs using the North Esk pontoons. Reduced sedimentation would also likely have benefits for access to pontoons at low tide. The Tamar Yacht Club and Tamar Rowing Club would experience no benefits in the Yacht Basin (increases in channel breadth in Home Reach at low tide may be of benefit).

- Increased amenity in the North Esk floodplain is expected to benefit users of the North Esk Trail and provide new opportunities for bird-watching.
- A climate change risk assessment is required to determine what effect if any, higher tidal levels will have on any restored wetland areas.

10 Management option - dredging of the upper estuary

Various options for dredging the kanamaluka/Tamar estuary have been proposed by various members of the community. These are often focused on removal of visible mudflats at low tide as well as navigation access for larger vessels. Legislation largely restricts dredging operations to improvement of navigation or for environmental rehabilitation. This report considers the costs, feasibility, and impacts of two dredging options that focus on increasing channel depth and width:

1) a reduced campaign focused on maintaining small vessel (low draft) low tide navigable channels in and around Home Reach and the Yacht Basin; and
2) a full campaign which extends this navigable channel into the lower North Esk and joins the two ends of the proposed dredging from the reduced campaign with a wider channel and flatter banks.

These options are based on a recent investigation conducted by City of Launceston (CoL) and GHD (GHD, 2020) that considered a channel dredge program to restore depth of the navigation channel to 5 m (-5 m AHD) with no dredging of Seaport Marina or other pontoons. Neither of these options considers the removal of the intertidal mudflats given the legislative constraints. They both focus on navigation for small commercial and recreational vessels, not large commercial vessels. Figure 31 shows the areas which would be dredged under each option. Note that small-scale dredge programs targeted towards specific recreational values (e.g., providing improved access to recreational facilities at low tide) are not considered here. These options would require similar permitting arrangements as large-scale programs but may face reduced challenges to feasibility if they were able to be designed within the capacity of the existing sediment ponds. Evaluation of such programs would require detailed case by case planning and assessment, rather than the broad-scale assessment of impacts provided here. Larger-scale dredging programs targeting the extent of mudflats are also not considered specifically due to the significant legislative challenges such programs would face in obtaining permits. However, costs and feasibility constraints of such a program would likely be substantially greater than those of the programs assessed in this report, due to the larger volume of sediment that would need to be dredged to have a discernible impact on the extent of visible mudflats.

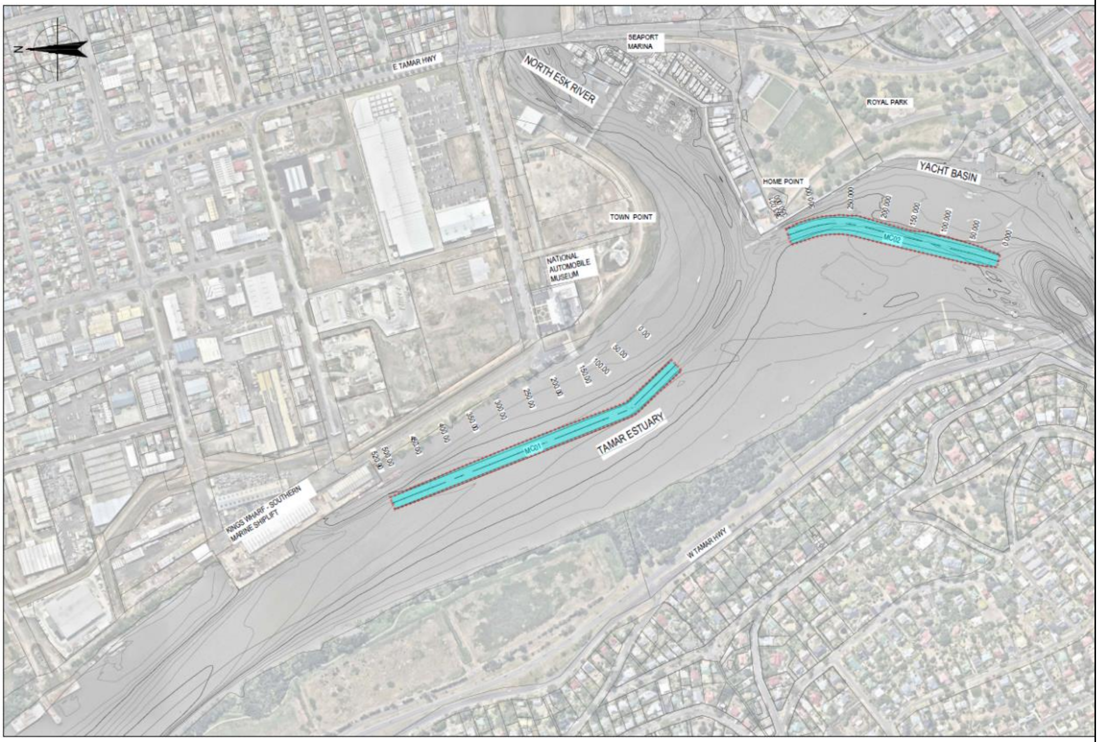
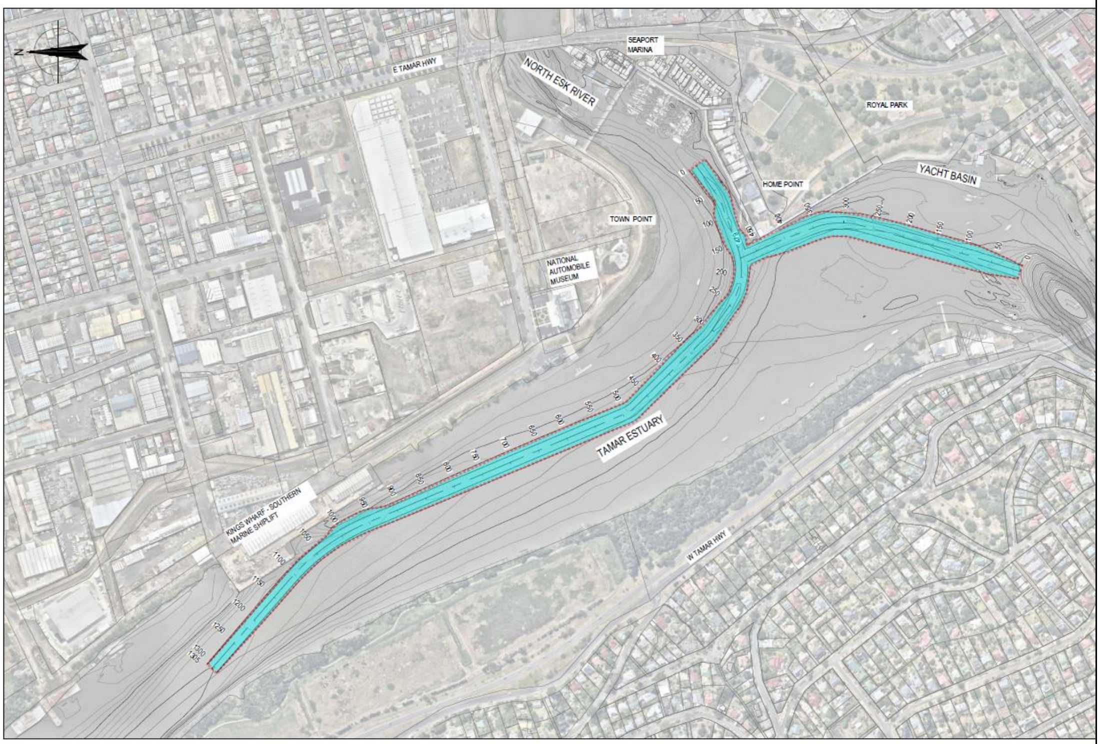
Option 1. Reduced campaign	
Option 2. Full campaign	

Figure 31. Areas in which dredging activities would be undertaken under the two dredge scenarios.

Table 19 provides a summary of the characteristics for each of these dredge campaigns.

Table 19. Summary of dredging options considered for upper kanamaluka/Tamar estuary.

Characteristics	Option 1. Reduced campaign	Option 2. Full campaign
Volume of sediment dredged	66,000 m^3	169,000 m^3
Design Level (m AHD)	-5 m	-5 m
Navigable width	20 m	20+ m
Length (m)	880	1800
Time to complete dredge program	14 weeks	37 weeks
Areas impacted by dredging	No sediment removed from Seaport, Silos Hotel pontoon, West Tamar mudflats, Tamar Rowing Club, rowing facilities on the North Esk, Tamar Marine slip yard or Tamar Yacht Club. Potential improved navigability from Home Point for tourist boats noting post-sediment raking channel depth has naturally restored to navigable levels.	No sediment removed from Seaport Marina or rowing facilities on the North Esk, Tamar Rowing Club pontoon. Potential benefit – Silos Hotel pontoon, tourist boats, Ship lift, Tamar Yacht Club through increased depth and width of navigation channel. Access from Tamar Yacht Club facilities to channel unchanged. Note that post-sediment raking channel depth has restored to navigable depths so actual impact on navigability may be minor.

10.1 Legislation and feasibility challenges

10.1.1 Legislation and permit requirements

The kanamaluka/Tamar estuary has a long history of dredging with extensive and increasing dredging from 1890 to 1965 to allow the passage of large vessels into the Port of Launceston. Smaller scale dredge programs were then undertaken from the mid-1980's to 2010. Large-scale dredge campaigns undertaken to 1965 were undertaken at a time where there were no legislative constraints on either dredging or dumping of dredge spoil. Much of the dredge spoil from these dredging campaigns was used to infill wetlands and reclaim land in Inveresk-Invermay and around Royal Park, as well as the channel on the western side of Tamar wetlands, with no consideration of any environmental impact associated with this. There was limited, if any, understanding of the effects of these changes on the function or value of the estuary. It is only relatively recently that environmental regulation has been adopted at local, state and Commonwealth government levels (e.g., *EMPCA 1994*), and activities such as dredging are heavily regulated and should avoid environmental harm.

There are several legal and administrative issues that would need to be considered if dredging were to be used to manage sedimentation in the upper kanamaluka/Tamar estuary. Sediments in the upper estuary are known to be contaminated with heavy metals and are Potential Acid Sulfate Soils (PASS) meaning that they have the potential to leach acid if they are exposed to air. There are no discretionary or minimum work limits in any legislation applying to dredging. The process of dredging and the handling of dredge spoil are subject to several levels of assessment and permitting. Information in this section is taken from DPIPWE (Paige and Thorn, 2010) unless otherwise noted. Note that even though this document is now 10 years old, it largely reflects current requirements.

Firstly, legislation limits the purpose for which dredging can be conducted stating it should only be undertaken for the purposes to obtain sediment for environmental rehabilitation or dredging of channels and barways for navigation purposes[11]. Any dredging of channels and barways for navigation purposes must be approved and supervised by Marine and Safety Tasmania (MAST).

A license to dredge must be obtained from DPIPWE Property Services within Tasmania's Parks and Wildlife Service. It requires an environmental assessment, which may include sampling of flora and fauna before and after dredging. Video sampling of the estuary bed may be needed, and core sampling of the sediment may be required to test for heavy metals and other potential pollutants as well as fauna living in the sediment. Previous sampling of sediments from the proposed dredge area in the upper kanamaluka/Tamar estuary indicate elevated levels of heavy metals such as arsenic, cadmium, manganese and zinc (Marine Solutions Pty Ltd., 2020).

Advice and/or authorisation from the EPA is needed if the activity is likely to degrade the marine environment (e.g., disturbing or depositing material on the seabed, or interfering with fish, animals or plants on the seabed). Given the contamination of sediments in the upper estuary and potential impacts on EPBC listed threatened species such as Australian grayling, dredging in the kanamaluka/Tamar estuary may require threatened species permits.

Two options have been proposed for disposal of dredge spoil from the upper kanamaluka/Tamar estuary:

- disposal to sea via a barge to Bass Strait; or
- disposal on land.

If deposition of contaminated material is approved on the shoreline or seabed, it must be decontaminated beforehand, capped with a coarser material to prevent leaching of contaminants and movement after extreme natural hazards and events, or diluted to minimise adverse effects on marine animals and plants. The *Environment Protection (Sea Dumping Act) 1981* regulates the deliberate loading and dumping of wastes and other matter at sea and would apply to the marine disposal of dredge spoil. Disposal of dredge spoil at sea in Australian waters (beyond 3 km of the coast) would require a Sea Dumping Permit from the Australian Government including a dredge management plan and a sediment sampling and analysis plan which would both require Australian Government approval. The activity would require monitoring pre, during and post dredging and dumping, marine fauna monitoring including of reefs and seagrass and potentially dredge plume monitoring using satellite imagery. It is considered unlikely that approval would be given for sea dumping of dredge spoil from the kanamaluka/Tamar estuary as the small particle size is

[11] *Tasmanian Coastal Works Manual 2010, Works Guidelines for Dredging*

likely to cause plumes that don't settle and cause unacceptable impacts on marine environments. Sea dumping in areas closer to the coast including within the estuary would be regulated as a Level 2 activity under *Environmental Management and Pollution Control Act 1994* and require EPA assessment. Due to flocculation fine sediments may be deposited on the bottom in previously unsedimented reaches. Fine sediment also tends to get remobilised very easily and will move upstream and down-stream with tidal movement. Given the constraints on sea-based disposal of dredge spoil this section focuses on the costs and feasibility of land-based disposal.

If dredge spoil from the kanamaluka/Tamar estuary were to be disposed of on land, two issues would need to be considered:

1) The dredge spoil is considered Level 2 contaminated waste given the concentration of heavy metals and other pollutants.
2) Dredge spoil consists of Potential Acid Sulfate Soils (PASS) which have the potential to release acid leachate when oxidised. Acid leachate in turn releases metals previously bound to sediments, increasing the soluble (bioavailable) metals concentrations. Dewatering of dredge spoil and disposal of dewatered waste would both need to be managed to minimise risks associated with potential for acid leachate and runoff of acid, toxicants and nutrients.

Disposal of Level 2 contaminated waste on land requires approval by the Director of the EPA subject to the *Environmental Management and Pollution Control (Waste Management) Regulations 2000*, which includes:

- sampling to characterise type and level of contamination; and
- disposal of Level 2 contaminated waste at putrescible and solid land fill sites.

There are five landfill sites in Tasmania capable of receiving Level 2 contaminated waste, the closest being the Launceston Waste Centre. Note that additional requirements and limitations exist where contaminated soils are potential acid sulfate (see Simpson *et al.*, 2018).

An acid sulfate soil management plan would be required regardless of which approvals process applies (DPIPWE, 2009). This would detail the technical feasibility of measures to manage risks. These risks would be generated both by the dewatering process where acid and a range of toxicants could leach from dredge spoil during the dewatering process and re-enter the estuary, and from the dewatered contaminated soil which would need to be disposed of in such a way (e.g., neutralisation) as to mitigate any ongoing risks.

10.1.2 Feasibility challenges

Historic dredging campaigns were not constrained by environmental regulation. Dredge spoil was disposed of into wetlands and used for land reclamation activities to create agricultural lands and suburbs such as Invermay. This affected both the cost and feasibility of dredging with dredge spoil being allowed to be disposed of in any location and no requirements on dewatering prior to dumping to limit impacts on water quality in the estuary.

Dredge programs now require careful design and management of dewatering facilities, treatment of potential acid sulfate soil and disposal of dewatered spoil to landfill due to the level of heavy metal contamination. Dredge spoil cannot be used on gardens or agricultural land.

Recent past dredge campaigns have utilised ponds along the West Tamar and Ti Tree Bend to dewater dredge spoil. Figure 32 shows the location and configuration of these ponds. The silt ponds at Ti Tree Bend are proposed for redevelopment to store overflow from the combined sewage-stormwater system and improve treatment at Ti Tree Bend as part of the Tamar Estuary River Health Action Plan. Thus, these ponds would be unavailable for dewatering dredge spoil from future dredge campaigns. The current available capacity of the West Tamar ponds is 46,000 m^3 with total capacity of 110,000 m^3 when empty. Material pumped into the ponds using a cutter suction dredge is approximately 15 percent sediment and 85 percent water (*pers. comm*, Langdon, R. from Dengate, C GHD). Other types of dredging that have a smaller water volume exist. One requires sea dumping of spoil and others are generally for larger volumes of sediment. Relatively small local dredging campaigns can be achieved by a barge mounted excavator that removes wet solids leaving most of the water behind.

There are strict environmental standards with regard to the quality of water that may be discharged from the ponds, which require sufficient time between dredging operations for sediment to settle out of the water before discharge back to the estuary. Water quality would need to be monitored, with water potentially requiring treatment with lime to return pH to acceptable discharge limits. Usually, two summer seasons are required to dewater dredge spoil enough to be excavated and transported off site (LFA, 2010; *pers. comm*. Langdon, R.). There are techniques which can aide in the dewatering process but these come at an additional cost.

The capacity of the West Tamar ponds means that the effective available volume for dredged solids using existing infrastructure at the West Tamar silt ponds is:

- 6,900 m^3 without emptying the ponds (some pond maintenance would be required); or
- 16,500 m^3 after emptying. This volume would be available once every 3 years to allow for dewatering of dredge spoil to occur before transport off site (one year to fill, two years to dewater).

The West Tamar silt ponds have been subject to minimal repair since the last dredge program ceased and it is expected that repair and rectification works to existing silt ponds would be required before dredging could commence. This includes all earthworks and associated discharge infrastructure such as pipelines, weirs and valves.

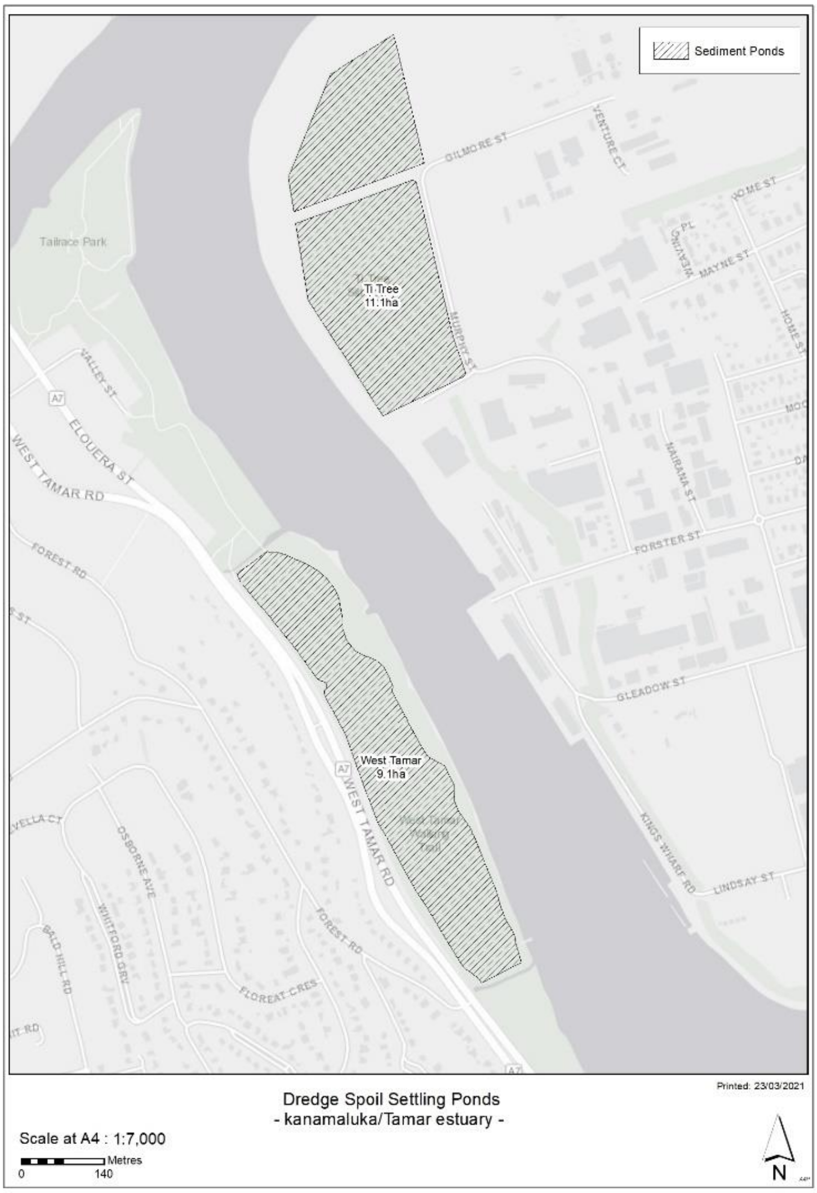


Figure 32. Location of silt ponds used in previous dredging campaigns – West Tamar and Ti Tree Bend

Even if the West Tamar silt ponds are emptied their capacity is well below what would be required for either of these campaigns for one year, with the additional complication associated with dewatering such that, once filled, the ponds cannot be used for another two years until the dried dredge spoil can be emptied. This means that new silt ponds would need to be constructed in proximity to the estuary in order to conduct either of these campaigns into the future. The approximate scale of these ponds based on volume of sediment and water dredged and the period over which dredge spoil would need to be dried has been estimated as 132 ha for the reduced dredge program and 340 ha for the full dredge program. To give an idea of the scale of such ponds areas of this size have been marked relative to the Tamar wetlands and are shown in Figure 33 (note it is not suggested that these locations are appropriate for the siting of such infrastructure).

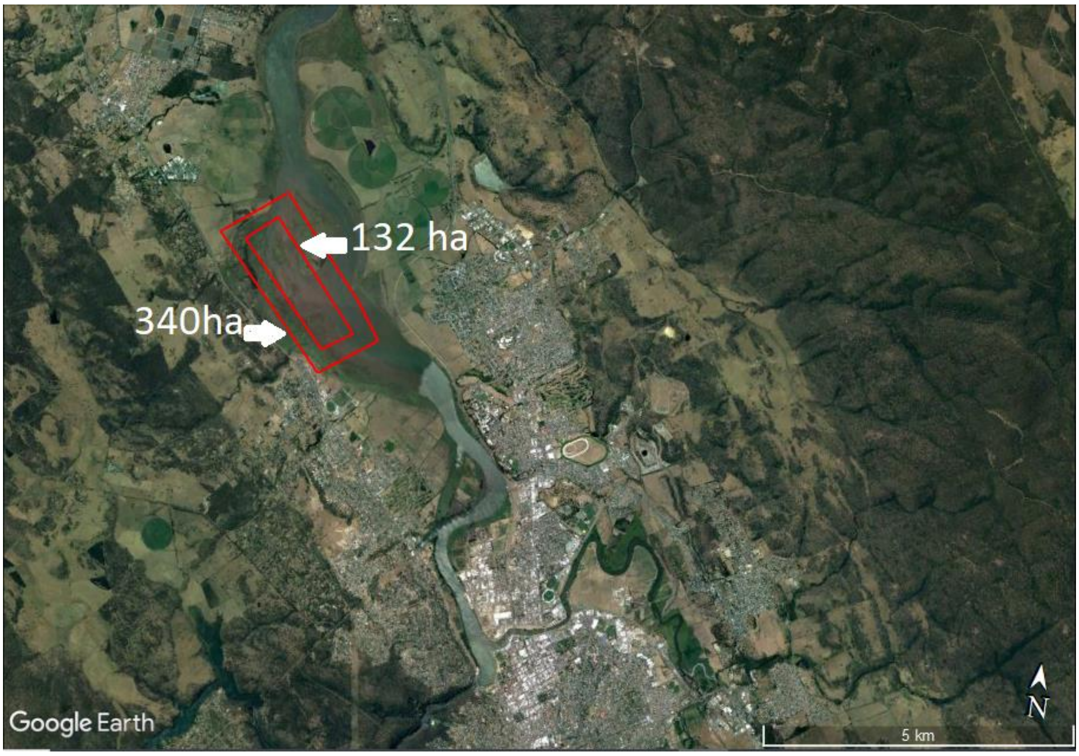


Figure 33. Indicative scale of silt ponds required for dredge campaigns relative to the Tamar wetlands. Reduced campaign requires 132 ha of ponds represented by the inner rectangle, full campaign is 340 ha represented by the larger area. Note that this map is for illustrative purposes only, to indicate the relative scale of ponds required and does not suggest a suitable location where these may be sited.

Once dredge spoil is dewatered it would be transported offsite but would require treatment to address potential acid sulfate soils before it could be disposed of in landfill as Level 2 waste. This would require storage on a fully lined pad, with acid leachate captured and disposed of as trade waste. Lime or other neutralising agent would need to be added to potential acid sulfate soils for treatment to neutralise acids to a level where spoil can be disposed of in landfill. Dear *et al.* (2014) state that each treatment pad should be for no more than 500 m^3 of sediment and sediment should be treated to a maximum depth of 300 mm to allow appropriate mixing of sediments and neutralising agents. Using these values gives a treatment pad area of 22 ha for the reduced dredge program and 56 ha for the full program. The site would be larger than this to allow for movement and equipment, bund wall and channels and pond for collecting leachate. Much of the site area would require impervious liners, and a bund wall to avoid acid runoff discharging into the environment would need to be built.

Once the sediment is treated for acid sulfate it would be able to be disposed to landfill as Level 2 contaminated waste. Treated dredge material is not able to be used as top soil, for gardening or on farm land. Some of this sediment could be used as daily cover at the Launceston Waste Centre but the total volume of sediment generated by either dredging program would far exceed its capacity for daily cover. The total waste processed at the Launceston Waste Centre in a year including daily cover is approximately 100,000 m^3, this is 1.5 times the volume of sediment to be disposed of from the reduced campaign each year, and less than the annual volume generated by the full campaign. In order to dispose of high volumes of dredge spoil additional land fill cells would be required over time (each approx. 520,000 m^3) at a cost in the order of $5-10 million each.

10.2 Estimated costs

A rough estimate of costs for the two dredge programs considered here is $15 million a year for the small-scale dredge program and $40 million a year for the large-scale program. Given that sediment returns relatively rapidly whenever dredging is ceased, these costs would be every year for as long as the resulting changes to bathymetry were to be maintained. There are expected to be significant additional costs that are unaccounted for here as well as feasibility constraints associated with finding sites in proximity to the estuary where ponds could be constructed.

10.3 Impacts on bathymetry, visible mudflats and navigability

Dredging campaigns are designed to impact the bathymetry of the upper estuary. The nature and extent of changes depends on the magnitude, location and frequency of dredging. Recreational and aesthetic concerns associated with sedimentation in the upper estuary can be linked to the extent of visible mudflats and the navigability of the channel. These concerns are summarised here as impacts on sediment levels in:

- the Seaport Marina;
- the lower North Esk channel and its confluence with the main estuary;
- the channel near Royal Park;
- the channel from Home Point to Ti Tree Bend; and
- mudflats near Royal Park, Riverbend (Town Point) and along the West Tamar.

Dredge equipment and activities themselves will obstruct the main navigation channel during the dredge program with a range of actions identified to minimise disruption to other waterway users (GHD, 2020). This means that navigation benefits associated with channel depth maintenance under dredging may not be fully realised for between 14 and 37 weeks a year.

In 2009, McAlister *et al.* undertook intensive bathymetric surveys in the Yacht Basin over the course of 17 months of dredging to estimate the sediment dynamics post dredging. From January 2008 to May 2009 there were 11 bathymetric surveys conducted and five dredge campaigns removing a total volume of 65,000 m^3 of sediment (note this is a smaller volume of sediment removed annually than assumed in the options presented here). Figure 34 shows the sediment level in the Yacht Basin over this period, with timing and locations of dredge campaigns. This figure shows that historically sediment has returned rapidly after a dredge campaign ceases, with some evidence that dredging increases the rate of sedimentation. Despite the volume of sediment dredged over the period there was net sediment accumulation in the Yacht Basin of 22,000 m^3. This figure demonstrates that the impacts of dredging on bathymetry are likely to be relatively short lived and that if dredging were to be undertaken with the objective of reducing sediment levels in the estuary it would require frequent ongoing campaigns to sustain any reductions in sediment levels.

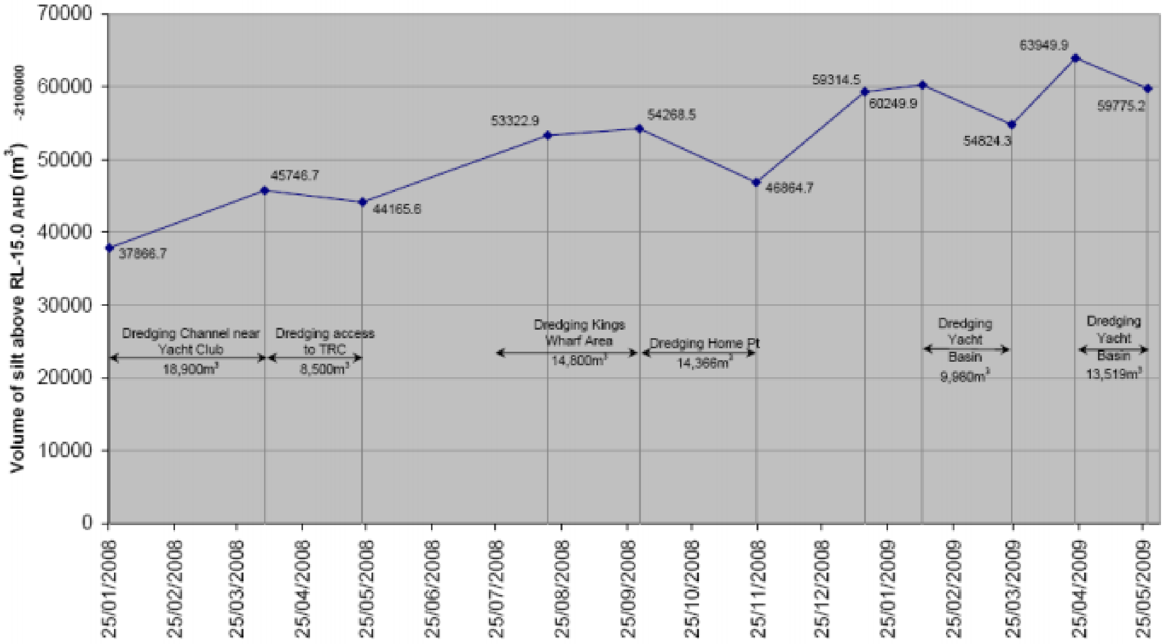


Figure 34. Yacht Basin silt level above RL-15.0 AHD (m^3) and timing and location of dredge campaigns from January 2008 to May 2009 (taken from McAlister *et al.*, 2009).

The immediate impacts of each of the dredging options on sediment levels in these zones of the upper estuary are summarised in Table 20. Note that these are the impacts immediately after dredging ceases and that sediment can be expected to return to dredge areas relatively quickly, meaning that the full impact is unlikely to be experienced for the entire period between campaigns.

Table 20. Likely impacts of dredge options on bathymetry.

	Option 1. Reduced program	Option 2. Full program
Channels		
Lower North Esk	No impact.	Channel 20 m wide, 5 m deep from Home Point to near Marina, channel into North Esk adjacent to Home Point (approx. 200 m) (current channel depth 3.5-4 m).
Yacht Basin/Royal Park	20 m wide, 5 m deep, 300 m long channel (currently 3.5 m deep).	20 m wide, 5 m deep, 300 m long channel (currently 3.5 m deep).
Home Point to Ti Tree Bend	20 m wide, 5 m deep, 520 m long channel from just past confluence with North Esk to Ship lift (current channel depth ~3.5-4 m).	20 m wide, 5 m deep, approx. 1 km long channel from Home Point to past Ship lift (current channel depth ~3.5-4 m).
Mudflats		
Seaport Marina	No impact.	No impact.
West Tamar	No impact.	Minimal impact – mudflats slightly reduced but still visible.
Royal Park	No impact.	Minimal impact – mudflats slightly reduced but still visible.
Town Point	No impact.	No impact given footprint of dredge area.

10.4 Impacts on flood risk

Dredging is a measure that temporarily removes sediment from the dredged area, with sediment returning rapidly once dredging operations cease. The change in storage volume (i.e., increase in water storage volume is equivalent to displaced sediment) resulting from a flood, such as June 2016, is significantly larger than what can reasonably be achieved by dredging. WMAWater (2021) state that pre-flood bathymetry has little bearing on resulting peak flood levels given the large scale and rapid scour that occurs during flood events. This means that it is unlikely that dredging will have any significant impact on peak flood levels. WMAWater (2021) modelled the impacts of removing 20,000 m^3 of sediment through dredging assuming no scour from the event for the 5 percent, 1 percent and 0.5 percent AEP events and found that the maximum reduction (no scour) in peak level is up to 0.1 m in the 0.5 percent AEP, up to 0.05 m in the 1 percent AEP and nil reduction in the 5 percent AEP event.

10.5 Impacts on water quality and environmental values

Dredging is associated with increases in turbidity and suspended sediments, and subsequent decreases in light penetration. Sediments which would be dispersed into the water column through dredging in the upper estuary are also known to contain elevated nutrient and heavy metals concentrations. A review of the sediment raking program in the upper estuary undertaken in 2019 (Kelly, 2019) found that sediment raking was associated with increases in suspended sediments at least as far as the mid-estuary but that there was evidence of increased heavy metal and nutrient concentrations as far as Clarence Point for at least three weeks after a raking event ceased. While a precise estimate of the impacts of dredging on water quality is not within the scope of this report it can be said that:

- dredging will increase turbidity and suspended sediments for the duration of dredging in the upper estuary with some impacts likely to be seen downstream of the dredged area; and
- dredging is likely to increase nutrient and heavy metal concentrations for the duration of the dredge program and to a greater distance downstream than increases in sediment concentrations and turbidity based on results from the sediment raking review conducted by Kelly (2019). Impacts are likely to occur for the duration of the dredge program and potentially for some period (days to weeks) after dredging ceases.

Increases in nutrients are a known driver of reduced dissolved oxygen levels in the estuary so it is likely that dredging may lead to reduced dissolved oxygen in the estuary, though the magnitude and spatial and temporal extent of these impacts is difficult to estimate.

There are also risks to water quality posed by the dewatering process given the nutrients and heavy metals contained in dredge spoil and the potential for oxidisation of potential acid sulfate soils as part of the dewatering process. There is a risk of acid and toxicant runoff to the estuary from these ponds.

Experience from previous dredge programs has shown that it is very difficult for operators to meet water quality discharge limits from the silt ponds (correspondence in 2001 indicated discharges of between three to five times higher than the limit for turbidity). The potential for discharge of acid leachate and waters contaminated with heavy metals and high nutrient levels from silt ponds is high. It is likely that any future dredging campaign would need to address similar impacts and pressures on water quality and associated licence conditions. Managing these risks would require strenuous monitoring and management regimes that would increase costs. The West Tamar silt ponds are known to have issues with acid leachate and associated heavy metals. Figure 35 shows acid leachate in newly cut open drain between two of the silt ponds in March 2008. The red colour indicates high levels of iron in this water.

Figure 35. Photo of acid leachate in newly cut open drain between two of the silt ponds in March 2008 showing high levels of iron.

Dredging is known to be associated with a range of environmental impacts. For example, Fraser *et al.* (2017) showed dredging has the potential to impact significantly on the benthos with impacts on macroinvertebrates, seagrass and macroalgae in West Australian ports. The magnitude and nature of environmental impacts of dredging depends on the scale, location and duration of dredging activities. Additional risks and impacts are posed by dewatering, acid sulfate soil treatment and disposal activities. Table 21 summarises key impacts on environmental values which could be expected from the two dredge programs being considered.

Table 21. Likely impacts of dredge option on environmental values associated with the estuary.

Environmental values	Option 1. Reduced dredge program	Option 2. Full dredge program
Water quality	Increased turbidity, increased nutrients, reduced dissolved oxygen and increased heavy metal concentrations for at least 14 weeks per year. Risks to water quality associated with silt pond discharge.	Increased turbidity, increased nutrients, reduced dissolved oxygen and increased heavy metal concentrations for at least 37 weeks per year. Risks to water quality associated with silt pond discharge.
Intertidal habitats	Impacts of poor water quality on fauna using adjacent and downstream intertidal zones. Loss of intertidal zone and associated habitat values where silt pond construction occurs. Odour from dewatering sediments.	Impacts of poor water quality on fauna using adjacent and downstream intertidal zones. Destabilisation of mudflats and erosion of intertidal habitats adjacent to dredge areas (likely small impact on mudflat extent). Loss of intertidal zone and associated habitat values where silt pond construction occurs. Odour from dewatering sediments.
Subtidal habitats	Bottom sediments removed/disturbed, limited to dredge area. Smothering of subtidal habitats outside the dredge area as disturbed sediments fall out of suspension. Slumping of adjacent subtidal habitats into dredge channel. Dredging can change the flow of the estuary up and downstream which can lead to other impacts such as erosion and bank slumping.	Bottom sediments removed/disturbed, limited to dredge area. Smothering of subtidal habitats outside the dredge area as disturbed sediments fall out of suspension. Slumping of adjacent subtidal habitats into dredge channel. Dredging can change the flow of the estuary up and downstream which can lead to other impacts such as erosion and bank slumping.
Migratory fish	Australian grayling likely to be impacted by increased difficulty in navigation due to turbidity as well as through impacts of reduced dissolved oxygen and increased toxicants, gill scour from increased suspended sediments and changes in predator avoidance behaviour related to high turbidity levels. These impacts can be mitigated through timing or through rigorous and applied monitoring and management (cease to dredge procedures).	Australian grayling likely to be impacted by increased difficulty in navigation due to turbidity as well as through impacts of reduced dissolved oxygen and increased toxicants, gill scour from increased suspended sediments and changes in predator avoidance behaviour related to high turbidity levels. The longer period of dredging would mean mitigating these risks through timing of the dredge program would be more difficult.

Threatened flora, fauna, vegetation communities and ecological communities	Australian grayling likely to be impacted, potentially mitigated by avoiding migration seasons. Australasian bittern are known to use the North Esk and Tamar floodplains and wetlands and would be impacted by a loss of wetlands for constructing silt ponds. Impacts on threatened species, vegetation communities (including wetlands) and ecological communities associated with silt pond sites (132 ha).	Australian grayling likely to be impacted, potentially mitigated by avoiding migration seasons. Australasian bittern are known to use the North Esk and Tamar floodplains and wetlands and would be impacted by a loss of wetlands for constructing silt ponds. Destabilisation of threatened vegetation community – *Melaleuca ericifolia* adjacent dredge area. Impacts on threatened species, vegetation communities (including wetlands) and ecological communities associated with silt pond sites (340 ha).
Migratory birds	Toxicants entering food webs, with biomagnification occurring in higher trophic levels, and likely entering the diet through ingestion of fish, shellfish and other higher order species. Any acid released/formed could have implications for organisms with carbonate exoskeletons such as crabs and molluscs. Potential loss of intertidal habitat if silt ponds are constructed in or near intertidal zone (likely given large extent and need for proximity to dredge areas).	Toxicants entering food webs, with biomagnification occurring in higher trophic levels, and likely entering the diet through ingestion of fish, shellfish and other higher order species. Any acid released/formed could have implications for organisms with carbonate exoskeletons such as crabs and molluscs. Potential loss of intertidal habitat if silt ponds are constructed in or near intertidal zone (likely given large extent and need for proximity to dredge areas).
Reserves and conservation areas	Impacts on Tamar River Conservation Area through habitat loss, increased toxicants and declining water quality.	Impacts on Tamar River Conservation Area through habitat loss, increased toxicants and declining water quality.
Key Biodiversity Area/Important Bird Area	Impacts on KBA/IBA through habitat loss, increased toxicants and declining water quality.	Impacts on KBA/IBA through habitat loss, increased toxicants and declining water quality.

10.6 Impacts on recreational users and navigation

Impacts on recreation and navigation likely to be associated with each of the dredge options are summarised in Table 22. These changes relate to changes in channel depth which are likely to be temporary after each dredging campaign. It should also be noted that since sediment raking has ceased, channel depths have naturally restored to navigable depths so actual benefits to users of increased depth and channel width may be fairly small.

Table 22. Impacts of potential dredge options on key recreational and tourism users of the upper kanamaluka/Tamar estuary.

User	Option 1. Reduced dredge program	Option 2. Full dredge program
Rowing - access to North Esk from pontoons and navigability of the North Esk	No change in sediment in lower North Esk.	Some improved navigability of main channel in North Esk but does not extend to North Esk pontoons.
Tamar Rowing Club	Potential improvement in navigability of channel depending on constraints caused by un-dredged channel depth. May be offset by obstructions caused by dredge operations for 14 weeks of the year. No improved access from pontoons to channel.	Potential improvement in navigability of channel depending on constraints caused by un-dredged channel depth. May be offset by obstructions caused by dredge operations for 37 weeks of the year. Potential improved access from pontoons to channel.
Home Point tourist boat	Potential improvement in navigability of channel. May be offset by obstructions caused by dredge operations for 14 weeks of the year.	Potential improvement in navigability of channel. May be offset by obstructions caused by dredge operations for 37 weeks of the year.
Seaport Marina	No change in sediment in marina.	No change in sediment in marina.
Tamar Yacht Club	Potential improvement in navigability of channel. May be offset by obstructions caused by dredge operations for 14 weeks of the year. No improved access from dock to channel.	Potential improvement in navigability of channel. May be offset by obstructions caused by dredge operations for 37 weeks of the year.

10.7 Summary of key findings

Dredging has historically been used in the upper estuary to create a wide, deep channel for dredging. Early dredge campaigns were not subject to modern environmental standards with dredge spoil used to infill wetlands and create suburbs such as Inveresk/Invermay. Modern standards for dredging impose strict limits on water quality, and disposal and treatment of dredge spoil that create very significant permitting and technical challenges to dredging, and come at a large cost:

- Dredging permits are generally restricted to restoring navigability and environmental restoration. It is unlikely that permits would be available for large scale dredging of mudflats given the environmental values associated with these areas.
- Dewatering and dredging would require very large areas of land to be set aside for silt ponds and treatment of PASS. These processes would pose risks to water quality with the potential for leachate containing acid, heavy metals and elevated nutrients from silt ponds.
- Changes in bathymetry from dredge programs are short lived implying dredging needs to be undertaken regularly (annually) to achieve targeted changes in bathymetry.
- The costs of dredging campaigns are likely to be at least $15 million a year for a smaller program and over $40 million a year for a larger program. Given mudflats are likely to remain largely unimpacted, few recreational or amenity benefits would be realised.
- Dredging is associated with substantial environmental impacts in the dredged area, and the intertidal zone would be impacted by silt pond construction and water quality decline downstream.

11 Management option – a Tailrace canal

This section considers the costs, feasibility and impacts of returning Tailrace flows to the estuary near Kings Bridge through a canal. Several versions of the Tailrace canal proposal are in circulation. The concept was proposed by Kidd (2017) who suggested using a canal to increase tidal prism in the Yacht Basin and return flows discharged through the Tailrace to the Yacht Basin. The Tailrace canal would be constructed through parts of the current mudflats, as well as removing the sediment ponds and parts of the swamp forest as shown in Figure 36. The proposal considers a channel 60 m wide, 2.2 km long and with a tidal range of 3.25 m and assumes Tailrace flows delivered through this channel would be 40 cumecs. Detailed flow data from the Tailrace and South Esk shows that discharges through the Tailrace can be up to 100 cumecs. The proposal states that the waterway should allow for reverse flow in time of major flood, possibly using a spillway at the northern end. The original proposal does not provide guidance on the level of the weir but further consultation with the proponent suggests that under this design the weir would be at least as high as spring tide level and possibly held at 2 m above high tide, and that the canal would be level, with tidal flow moving water out of the canal rather than movement being driven by a change in elevation. Kidd (2017) models this waterway in combination with other interventions.

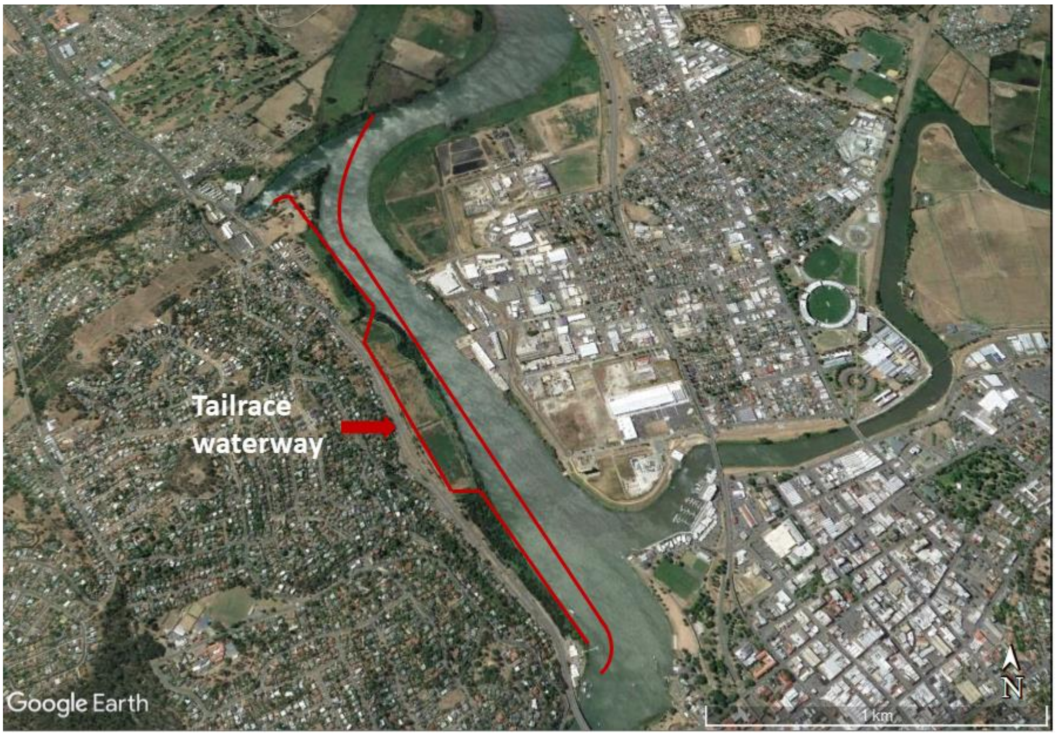


Figure 36. Proposed location of waterway to return Tailrace flows to upper estuary near Kings Bridge.

The major contribution of the canal to reducing sedimentation is proposed to be through an increase in tidal prism to the Yacht Basin. Other Tailrace canal proposals such as that by Seward (2021) shown in Figure 37 focus more on the effects of increased flows into the upper estuary. This alternative version shows flows exiting the canal into a ‘virtual lake’ with flows indicated as moving in three directions – upstream into Cataract Gorge, into the Yacht Basin and downstream, and upstream into the North Esk. It is not clear from the design how flow movements of this nature, particularly those moving upstream into Cataract Gorge, would be achieved. It is also not clear whether this option assumes some tidal influence remains in the Yacht Basin and around the Seaport given the presence of the tidal weir.

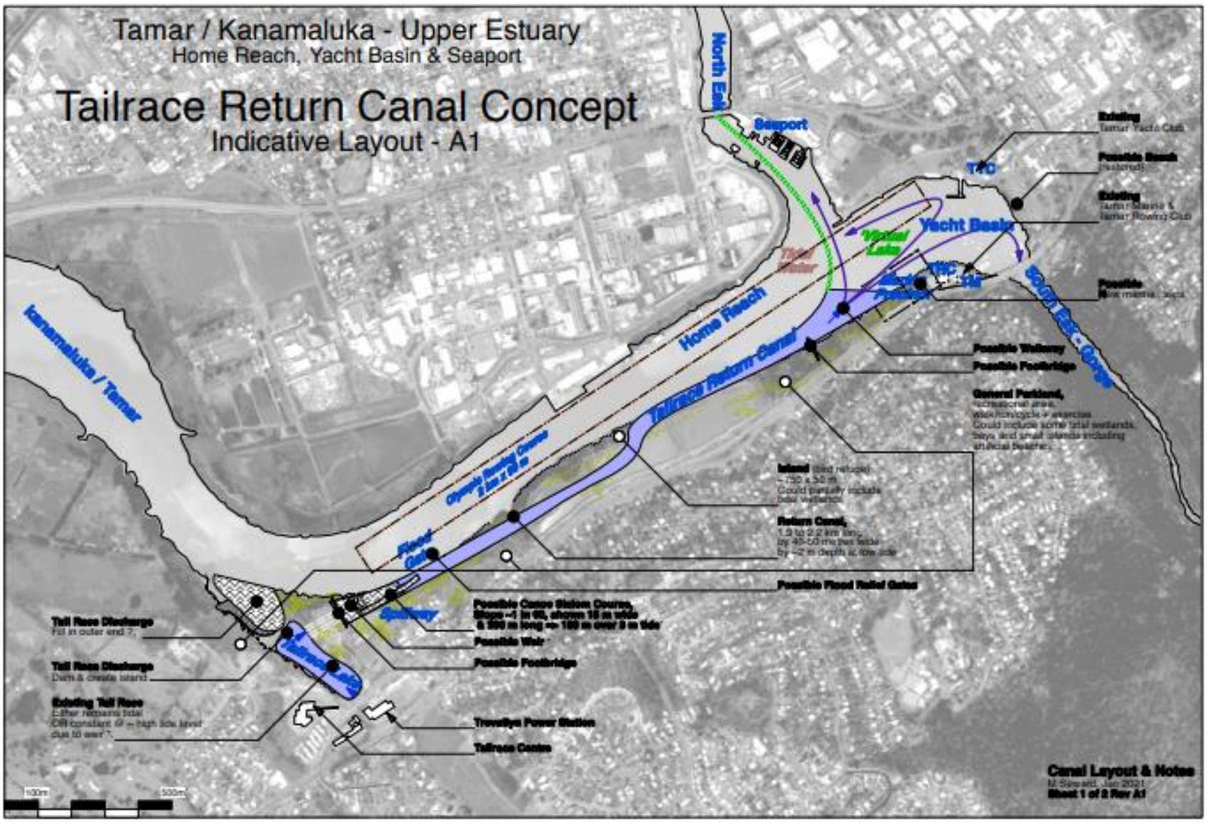


Figure 37. Alternative proposal for Tailrace canal by M. Seward, 2021 focused on increasing flows into the Yacht Basin. This design assumes that the Tailrace Lake near the Trevallyn Power Station is held above spring high tide and appears to include some sort of weir to create a 'virtual lake' in the Yacht Basin.

11.1 Legislation and feasibility challenges

11.1.1 Legislation and permit requirements

Construction of the proposed Tailrace canal would require excavation and treatment of potential acid sulfate soils that are contaminated with heavy metals and high nutrient levels. There are several pieces of legislation that would affect the feasibility of constructing such a canal:

- Construction of the canal would require disturbance or clearance of approximately 7 ha of state listed threatened vegetation (*Melaleuca ericifolia* swamp forest). There are two key pieces of legislation that would affect this activity:
  - The *Forest Practices Act 1985* and the *Forest Practices Regulations 1997* prohibit forest clearing on defined 'vulnerable land', such as stream-side reserves, drainage lines and swamps, and threatened vegetation communities without a Forest Practices Plan. An exemption applies if the works are authorised under a permit issued under the *Land Use and Planning Approvals Act 1993*.

    - The *Nature Conservation Act 2002* which lists threatened native vegetation communities that are to be protected under the forest practices system.
- The *Threatened Species Act 1995* which protects state listed threatened species. Several state listed threatened flora and fauna species are known to occur in the area where works would be undertaken, and vegetation and habitat removed.
- *Environment Protection and Biodiversity Conservation Act 1999* which protects federally listed threatened species and ecological communities. There are several federally listed threatened species that have been found in the area in which the works would be undertaken.
- The site through which the Tailrace canal would be constructed contains potential acid sulfate soils that are contaminated with heavy metals and high nutrient concentrations. Disposal of excavated material would be managed under the *Environmental Management and Pollution Control (Waste Management) Regulations 2000*.
- *Water Management Act 1999* and the *Water Management (Safety of Dams) Regulations 2015* which are likely to apply to the weir and other structures included in drawings of the Tailrace canal (proposed as flood overflow).

Disposal of Level 2 contaminated waste on land requires approval by the Director of the EPA subject to the *Environmental Management and Pollution Control (Waste Management) Regulations 2000* including:

- Sampling to characterise type and level of contamination.
- Disposal of Level 2 contaminated waste is possible at putrescible and solid land fill sites. There are five landfill sites in Tasmania capable of receiving Level 2 contaminated waste including Launceston Waste Centre. Note that additional requirements and limitations exist where contaminated soils are potential acid sulfate (see Simpson *et al.*, 2018).

An acid sulfate soil management plan would be required which would detail the technical feasibility of measures to manage risks. These risks would be generated both by the dewatering process where acid and a range of toxicants could leach from dredge spoil during the dewatering process and re-enter the estuary, and from the dewatered contaminated soil which would need to be disposed of in such as a way (e.g., neutralisation) as to mitigate any ongoing risks from these soils.

11.1.2 Feasibility challenges

The construction and maintenance of the Tailrace canal would be challenging and pose risks to surrounding infrastructure, both during the construction phase and on an ongoing basis after the channel is in operation. The canal connects the Trevallyn Power Station and related Hydro Tasmania infrastructure to the upper estuary near Kings Bridge. Key infrastructure potentially affected by the canal (see Figure 38) includes:

- *Trevallyn Power Station* – and associated infrastructure particularly where the design calls for the weir at the Tailrace end of the canal to be held above spring high tide levels.
- *West Tamar Highway* – the canal would adjoin the West Tamar Highway for 2.2 km of its length. Areas of the highway near Kings Bridge are submerged during extreme high tides and/or major river floods. Water backing up in the canal from power station releases could also potentially impact the highway (Elouera Street) near the power station. The channel and any overbank flows could potentially undermine the highway, and construction could have impacts on this road. The design of the canal would need to address these risks. Liquefaction of underlying sediments during an extensive pile-driving construction process poses a potential risk to infrastructure.
- *West Tamar Road* – a short access road (also part of the cycleway to Riverside) to Tamar Rowing Club and Tamar Marine near Kings Bridge which is often inundated during periods of high tides and/or river floods. It is not clear from conceptual drawings of the canal how it would fit between the highway and estuary foreshore in this section without impacting on West Tamar Road/West Tamar Highway, both the Kings Bridge and the Paterson Bridge, Tamar Marine and the Tamar Rowing Club.
- *Tamar Marine and the Tamar Rowing Club* – have the potential to be directly affected by the design and construction works. Tamar Yacht Club may be affected by changes in flood heights or erosion caused by changes in flow patterns.

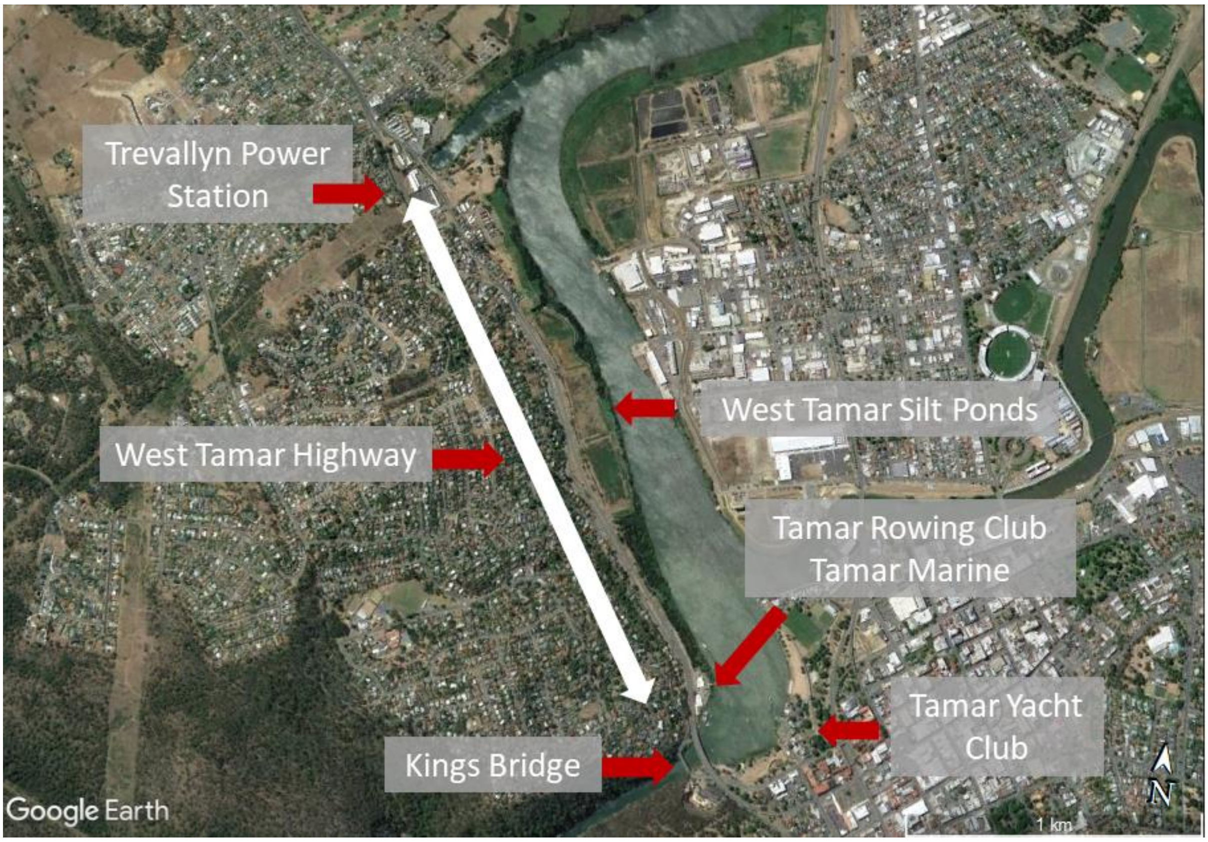


Figure 38. Key infrastructure potentially impacted by the proposed Tailrace canal. White arrow runs approximately parallel to West Tamar Highway

It is not clear from the concept drawings how the canal would fit in the space between the highway, estuary edge and buildings (Tamar Marine and the Tamar Rowing Club), or how it will allow for the recreational trail and commuter cycle route that passes through this area. The interaction between the canal and surrounding infrastructure is dependent on the height of these relative to the level of water behind the weir:

- The lowest building and carpark in the Tailrace Centre sits at a height of 5 m AHD with the 4 m contour running through the middle of Tailrace Park's lower carpark. Given this, it could be expected that the weir would be held no higher than 4 m to avoid impacts on buildings in the Tailrace Centre.
- The lowest point of the West Tamar Highway at the front of the power station is 8 m AHD.
- Heading south from the Tailrace, land is approximately 2.5 m AHD all through the silt ponds and banks.
- The Tamar Rowing Club carpark sits at approximately 2 m AHD. Flood levels of 2.5-3 m are experienced here, which are enough to cover the carpark and southbound lanes of the West Tamar Highway.

Using this level of fall (2 m over approximately 2 km) means the canal would need to be built with a grade of approximately 1 in 1000. This would be very difficult to build in swampy ground. It is also likely that water would backflow to a certain point in the canal, further increasing water heights and flood risks to the highway and other infrastructure along the canal's route. Presumably the design would need to include raising the level of the highway to address these risks.

11.1.2.1 Trevallyn Power Station and feasibility *of delivering constant base flows*

The potential impacts of the proposed Tailrace canal on the Trevallyn Power Station are considerable. The Tailrace canal proposals suggest a flow of between 40 and 100 cumecs (depending on the proposal) can be provided through the canal to the upper estuary. However, flows released from the power station are highly variable both within and between days. This can be illustrated by the frequency of hourly discharges of different volumes and the range (difference between maximum and minimum discharges) of discharge within a 24 hour period. Figure 39 shows the percentile of hourly flows from the power station from 2008 to 2018 (i.e., frequency of flows of each magnitude) and the percentile of the range of flows discharged over a 24 hour period for this same data set. Maximum discharge post refurbishment and upgrades currently underway will be about 110 cumecs.

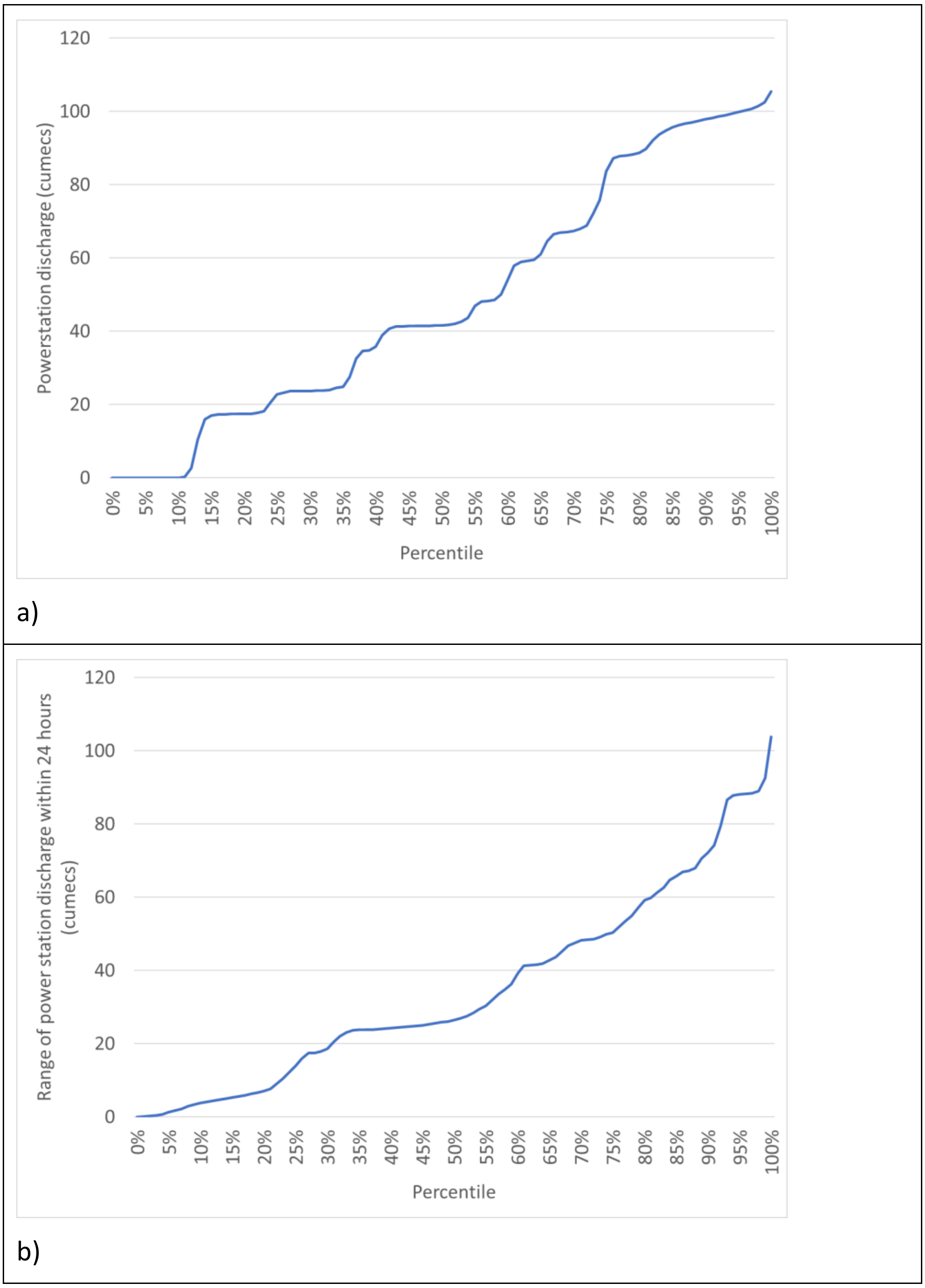


Figure 39. Percentile of power station discharge a) hourly discharge b) range (maximum minus minimum) of discharge over 24 hours from 2008 to 2018.

This figure shows that 40 percent of the time discharges from the power station are below the lower proposed Tailrace canal flow of 40 cumecs, with discharges less than 4 cumecs occurring 10 percent of the time and less than 20 cumecs more than 20 percent of the time. Discharges during a single 24 hour period also vary by at least 26 cumecs for 50 percent of the time, with the range 60 cumecs and above nearly 20 percent of the time, and 70 cumecs and above 10 percent of the time. The Tailrace canal would need to be designed to cope with this significant variability in discharge volumes. Providing a constant base flow through the power station to provide a ‘baseflow’ through the Tailrace canal would not be commercially feasible and would lead to environmental impacts in yingina/Great Lake.

Concept drawings for the Tailrace canal are simplistic and lack many details that would be required to evaluate the design, including an estimate of the height rise of the tailwater that would be required to achieve a flow upstream to Cataract Gorge. It can be assumed that it would require an increase in the tailwater to above the highwater mark of 2 km upstream and an increase to provide the driving head for the flow (provision for rafting facilities etc. would increase this). This would result in a significant increase in tailwater level. If a ‘fixed level’ is maintained by a weir arrangement as appears to be suggested by concept drawings, then the tailwater would need to be maintained permanently at a level some metres above the current maximum (king tide) tailwater level. It is not clear whether this would require the water level to be held higher than the current highway and power station level, however the level would at best be significantly closer to the highway than is currently the case. It is unclear how any of these issues would be addressed in the design.

Tailwater conditions are an important consideration in a station design for stable and efficient operation. The impact of the Tailrace canal on production and operation of the machines within the power station would be significant:

- A higher tailwater will reduce energy produced (MWhrs), and capacity (MW) significantly. Energy available for generation is a function of nett head between headwater (lake level) and tailwater, so any increase in tailwater height directly reduces machine output.
- At lower nett head (high tailwater) than designed i.e. anything over normal high tide levels, output would be further reduced by inherent constraints on the turbine runner. Turbines are designed for a specific range of nett head, and operation outside of that band is inefficient and compromised. Thus, hydraulic instability and cavitation limits on machine output will be lower, restricting i.e. preventing full station output, under either some or all operating conditions depending on the height increase required. There is a high probability the existing runner design would be inappropriate for the revised conditions. Redesign and replacement of all four runners would be cost prohibitive (tens of millions).
- The hydraulic design of the outlet would need to be carefully considered, and likely physically modelled, to ensure flow patterns did not cause additional losses, or hydraulic instability through circulating flow etc.

11.1.2.2 West Tamar silt ponds

To construct the canal, the West Tamar silt ponds would need to be excavated and soils treated for acid sulfate before disposal to landfill. These soils are known to be potential acid sulfate and contain elevated concentrations of nutrients and heavy metals.

Excavated excess sediments would need to be transported off site, treated for acid sulfate and then disposed of, most likely in land fill as Level 2 waste. The volume of sediments to be excavated and treated would depend on the design. Using the design explored by Kidd (2017) the canal would require excavation of at least 429,000 m^3 of sediment (60 m x 3.25 m x 2.2 km *in situ* volume – this can be expected to bulk up by around one-third once excavated).

11.1.2.3 Safety

The Tailrace canal could pose risks to pedestrians and those who use the bike path from the Kings Bridge to the Tailrace if not fenced[12]. The canal would carry a maximum of between 40 cumecs and 100 cumecs depending on the proposal being pursued. Flows, hence water levels through the canal would change rapidly at times due to the variability in power station discharges. Being a non-natural/constructed waterway, safety of those using the area must be considered and the design would need to address risks posed by flows were people to enter the canal. Figure 40 provides a framework for assessing hazards to children and adults of different flows based on depth multiplied by velocity (DV) from Smith *et al.* (2014). The 40 cumecs design through a 60 m wide channel would correspond to DV of 0.67 m^2/s – well above the threshold for safety for children and the elderly (0.4 m^2/s) and above the hazard threshold for adults. A 100 cumecs channel would be associated with a DV of 1.67 m^2/s, an extreme hazard to everyone. The design of a canal and surrounds would need to consider how to minimise the risks of children and adults entering the canal (noting that several designs include access for kayaking and other recreational uses of the canal).

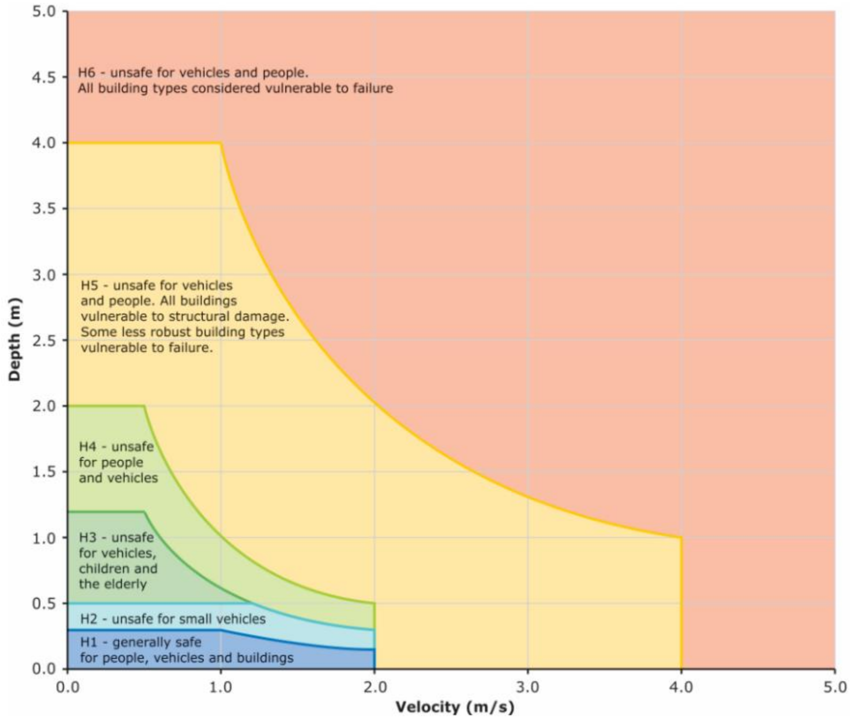


Figure 40. Combined flood hazard curves (Smith *et al.*, 2014)

[12] During May 2020 193 bike riders were recorded on a Sunday (10th) on this track, with weekday averages of 5.6-11.2 bikes per hour between 8 am-6 pm. Normal daily use is 80 per day (one way). This pathway is a key interconnection for active transport, with increasing the number of trips in Launceston undertaken via active transport a key priority in the Launceston Transport Strategy.

11.2 Estimated costs

The costs of this option are very difficult to estimate given the range of potential impacts on surrounding infrastructure that would need to be considered in the design, and the challenging environment where works would need to be undertaken. Key cost considerations would be:

- Excavation, treatment and disposal of large volumes (>400,000 m^3) of potential acid sulfate soils that are Level 2 contaminated waste. Treatment for acid sulfate and disposal of sediments to landfill would be expected to cost in excess of $70 million.
- The requirement for extensive piling into soft sediments to stabilise the canal and avoid infrastructure such as the highway subsiding into the canal. This would be expected to cost over $50 million for 2.2 km of canal.
- Extensive landscaping including fencing to address safety issues, moving pathways and cycleways, car parks, and local roads. Potential costs associated with raising sections of the highway with unacceptable levels of flood risk. This is likely to cost tens of millions of dollars.
- Lost power production from any loss of head and costs associated with reconfiguration of the Trevallyn Power Station. This would include both a capital cost upfront and potentially annual costs associated with lost power production.
- Ongoing costs of maintenance of the canal and newly built infrastructure.

While it is difficult to provide an accurate assessment of costs for these, very rough estimates suggest the canal will cost in excess of $250 million to build and at least $2 million a year in ongoing maintenance and lost power production costs. Costs may be substantially higher than this.

11.3 Impacts on bathymetry, visible mudflats and navigability

Several different versions of the Tailrace canal proposal are in circulation. These are proposed to reduce sedimentation through two different mechanisms:

- An increase in tidal prism in the Yacht Basin which is proposed would reduce sedimentation in the Yacht Basin and Home Reach.
- An increase in freshwater flows to the Yacht Basin which is proposed would flush sediment out of the Yacht Basin and Home Reach.

These two potential mechanisms are explored below.

11.3.1 Tidal prism mechanism

The original Tailrace canal proposal was developed by Kidd (2017) and evaluated using the FORM model. This model uses a simplification of a regime model first proposed by O'Brien (1931) that states that there is a power relation between the cross-sectional area (A) below the mean sea level (MSL) and the tidal prism (P) at that cross-section when the estuary is in 'regime' condition. McAlister *et al.* (2009) state that this relationship in the kanamaluka/Tamar estuary is best fit as:

$$A = 3.1 \times 10^{-3} P^{0.81}$$

where *P* is the tidal prism and *A* the cross-sectional area.

Kidd *et al.* (2016) further simplify this equation by replacing cross-sectional area with width and relating this to distance from the estuary head:

$$w_x = ax^n + w_0$$

where w_x is the width at distance *x* from the head, *a* is the site-specific constant of proportionality, *n* is the site specific 'power of axial breadth variation', and w_0 is the width of the river at the estuary head (from Kidd *et al.*, 2017). Tidal prism is then related to distance downstream using an empirical relationship giving a relationship between width and tidal prism that is used for analysing the effects of scenarios relating to changes in tidal prism.

Figure 41 shows the steps in the FORM model taken from Kidd *et al.* (2017).

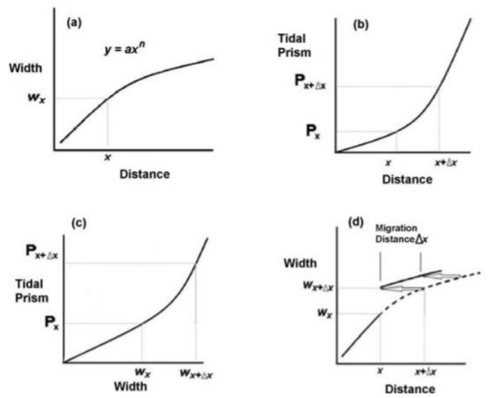


Figure 2. The steps involved in FORM. (a) The derivation of the baseline-width equation extrapolated over the length of the estuary (in this case $n < 1$). (b) The relationship between tidal prism and distance is established. The addition of a second tidal prism from a tributary creates a combined tidal prism of $P_{x+\Delta x}$ at distance $x + \Delta x$. (c) The combined tidal prisms also establishes $w_{x+\Delta x}$. (d) The width attributable to the combined tidal prism is plotted on (a) and is the starting point for the migrated width curve.

Figure 41. Steps involved in FORM taken from Kidd *et al.* (2017) showing assumptions of increasing width with distance from the head, increasing tidal prism with distance and consequently increase width with tidal prism.

Note that this model essentially assumes the estuary takes on a funnel shape, with the minimum width at the head of the estuary and consistently increasing widths moving towards the mouth of the estuary. This is said to be equivalent to the assumption of O'Brien that cross-sectional area increases with increases in tidal prism, that is moving from the head towards the mouth of the estuary.

The applicability of this regime theory of bathymetry has been tested here for the upper estuary using the following data:

- Bathymetric data from 2 June 2016 (before 2016 flood) for cross sections shown in Figure 42 to calculate cross sectional area below zero AHD and tidal prism in the Cataract Gorge and main estuary. Note this replicates the analysis of McAlister *et al.* (2009) and makes for useful comparison over time (discussed in detailed in Section 7 on No intervention).

- Bathymetric series for the North Esk from March 2017 used as part of the TUFlow flood modelling undertaken by City of Launceston used to calculate the tidal prism within the North Esk channel.
- A half metre contour converted to a 1 m digital elevation model for the North Esk floodplains used to calculate their contribution to tidal prism downstream.

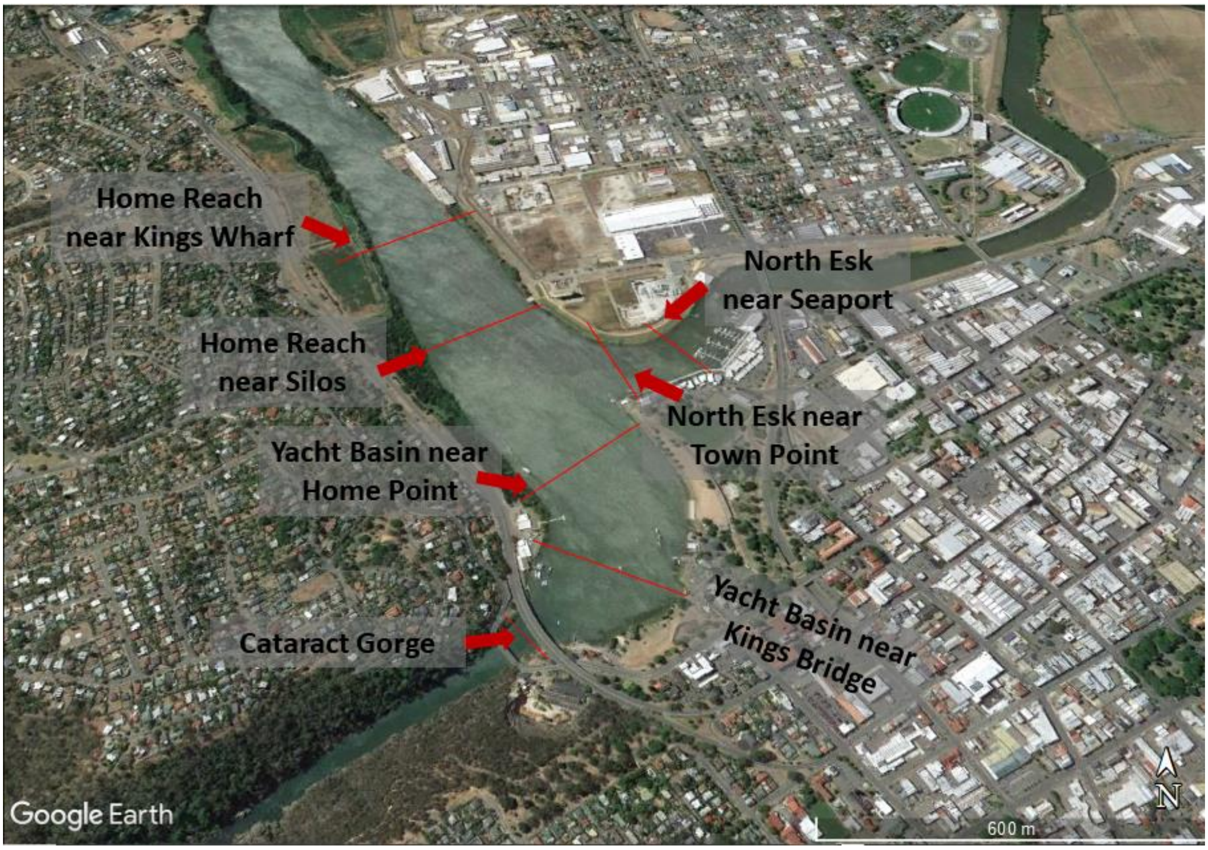


Figure 42. Location of cross sections used in analysis of tidal prism and cross-sectional area.

Visual inspection of the image of the upper estuary shown in Figure 42 provides an initial suggestion that the regime model suggested by Kidd *et al.* (2017) does not represent bathymetry in the Yacht Basin, and to a lesser extent the first section of Home Reach. Widths of the estuary clearly do not increase from the head moving downstream. The width of the upper estuary increases rapidly as it leaves Cataract Gorge into the Yacht Basin before tapering to a more stable width in Home Reach near Kings Wharf. Analysis of cross-section data and tidal prism data is shown in Figure 43. The regime equation of O'Brien derived by McAlister *et al.* (2009) is also shown in this figure as 'predicted tidal regime'.

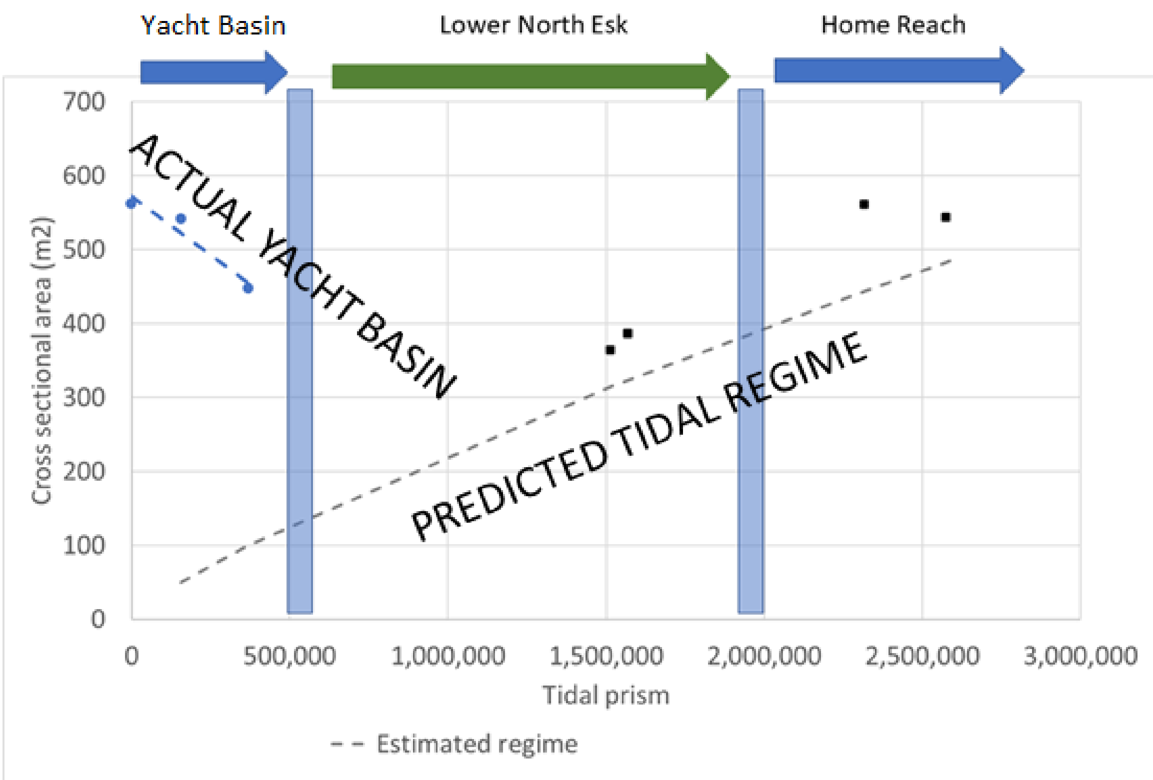


Figure 43. Comparison of cross-sectional area below zero meters AHD and tidal prism with estimated regime using data from 2 June 2016, immediately before the 2016 flood. Data corresponds to cross sections in Figure 42, with increases in tidal prism on the x-axis equivalent to moving downstream from the head to the mouth of the estuary in each section. The blue dotted line is the line of best fit for observations in Cataract Gorge and the Yacht Basin.

Data points are shown (Figure 43) for the Yacht Basin from Cataract Gorge to near Home Point, the North Esk and Home Reach. The regime equation is clearly a poor fit for cross-sections in the Yacht Basin, as they very clearly trend downwards with distance from Cataract Gorge, demonstrating the dominance of riverine floodplain processes defining bathymetry in this section of the estuary. Cross-sectional areas are maintained well above those that could be expected based on tidal prism alone in this section of the estuary. Essentially high velocity flood flows exit the confined channel width of Cataract Gorge before spreading out and slowing down as they hit the floodplain of the Yacht Basin. This influence is reduced after the confluence of the North Esk where a large addition to tidal prism from the North Esk floodplain and channel begins to affect bathymetry. Some evidence of the continuing influence of Cataract Gorge floodplain processes in Home Reach is seen at the Silos cross-section with a poorer alignment to regime at this point, although this is much less clear than was the case in the Yacht Basin. An additional cross-section (not shown here) further down Home Reach at Kings Wharf sees data align more closely to the regime equilibrium relationship indicating dominance of the tidal prism in determining cross-sectional area over riverine floodplain processes at this point. Note bathymetric data from different points in time is analysed in Section 7 on ‘No intervention’ replicating analysis undertaken by McAlister *et al.* (2009) which shows Yacht Basin cross-sectional area has not changed significantly between the periods 2005-2008 and analysis of cross sections for 2016-2020.

Given that the FORM model and the regime model of McAlister *et al.* (2009) is shown clearly to not be applicable to the Yacht Basin, the impacts of increases in tidal prism from the Tailrace canal on sedimentation in the Yacht Basin derived using these models cannot be supported. The dominance of riverine floodplain processes in defining bathymetry in this part of the estuary suggests a change in tidal prism will have limited if any impact on cross-sectional area. It is also possible that the proposed Tailrace canal could become a preferential flow channel in times of flood. If this were to happen the increased cross-sectional area implied by the canal could reduce the level of scour in the channel from high flow events in the Yacht Basin resulting in a decrease in depths in the channel in the Yacht Basin. Regardless there is no evidence that the Tailrace canal would reduce sedimentation in the Yacht Basin through increased tidal prism. The use of a model for the Yacht Basin with such poor fit to the data casts significant doubt on the validity of the proposal.

11.3.2 Increased flows mechanism

The second mechanism suggested by some proponents for the Tailrace canal is through increased freshwater inflows to the estuary near Kings Bridge with the intention of inducing additional scour of sediments from the Yacht Basin and Home Reach. In order to understand the impacts of these flows on the total inflow to the Yacht Basin and subsequently the bathymetry of the upper estuary, an analysis of historic data was conducted to assess the effects of additional flows relative to current (post-dam) flows down Cataract Gorge assuming the current environmental flows of 2.5 cumecs. Two different Tailrace canal options are considered: one that caps flows down the canal at 40 cumecs; and a second that assumes the entire Tailrace outflow is passed down the Tailrace canal. Data used for this analysis is from January 2008 to November 2018. Changes in actual environmental flows over this period are not accounted for (i.e., environmental flows are assumed to be 2.5 cumecs per day to represent ‘current’ base flow conditions).

Figure 44 shows the impact of the two Tailrace canal options compared with the current Cataract Gorge flows. Note these figures both assume the Tailrace canal operates under all flow conditions down the South Esk. Some proposals have referred to a reverse canal in times of high flow events though it is unclear from the proposals at what flow level this would operate and the risks it would pose to power station infrastructure. Using such a reverse canal would also be expected to reduce the scour of flows in the main channel, meaning high flow events would be less effective at removing sediment from the Yacht Basin and Home Reach.

Table 23 provides a comparison of the minimum flows as well as the percentage and average number of days per year falling into different flow ranges for estimated current Cataract Gorge flows and the two Tailrace canal options.

The Tailrace canal options have their greatest impacts on flows between 10 and 150 cumecs, with days that would otherwise have been 2.5 cumecs environmental flows increasing to flows within this range. The full volume channel would be expected to shift a greater number of flow days into the 150 to 290 cumecs range. The analysis assumes both versions of the canal would operate under all flow conditions in the South Esk, including flood flows, although it is unclear from the proposals available whether or not this would be possible. Under this assumption there is a small increase (0.8 days and 1.1 days per year respectively for 40 cumecs and full volume canal) in flow events greater than 1000 cumecs. Given the additional flood risk from increasing flows in events above this level it is likely that the canal would need to be designed in a way to avoid discharging additional flows into the upper estuary during high flow events. The Tailrace canal could be expected to lead to approximately 2 additional days of scouring flows above 290 cumecs per year for the 40 cumecs canal and 3.6 days for the full volume canal.

Figure 45 shows the average level of sediment in channels and mudflats in the upper estuary (Yacht Basin upstream of the confluence with the North Esk) versus South Esk and North Esk flows from 2008 to 2012. Note that while this data is from the period before sediment raking commenced, some dredging occurred in channels over this period. This means that the impacts of flows on channels based on this data is likely to be overestimated. This figure shows that the channels respond to flow events with changes in depth of 0.5 to 1 m for periods including flows over 1000 cumecs. Smaller flows are associated with smaller amounts of scour. By comparison the mudflats are much more stable in their average height of silt, responding to large flow events with changes of around 0.2 m. Small peak flows have only minor impacts on sediment levels in mudflats.

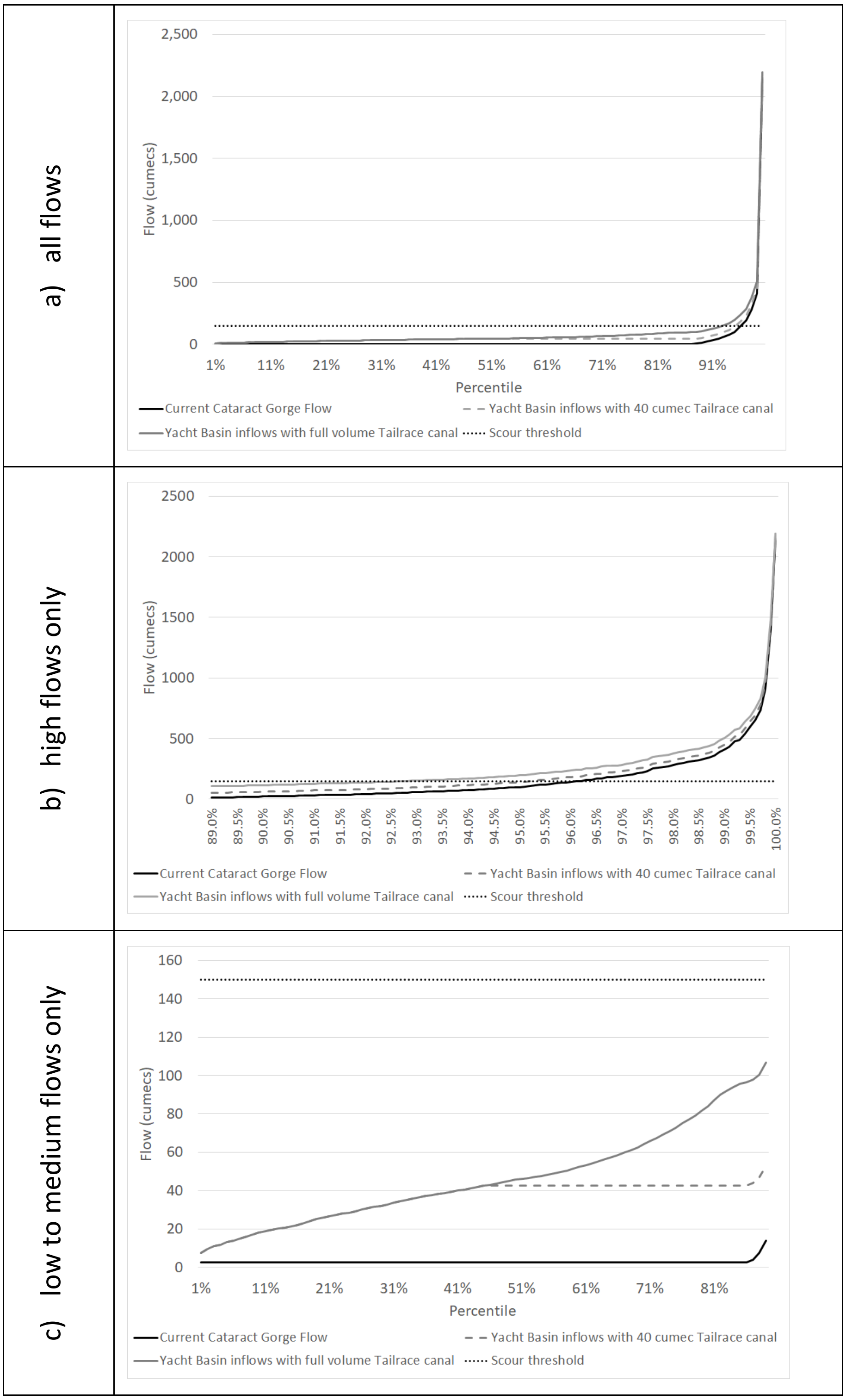


Figure 44. Comparison of current Cataract Gorge flows with potential Yacht Basin inflows including two Tailrace canal options – Option 1. Constrained to 40 cumecs of flow; Option 2. Carries full volume of Tailrace flow (flow duration curves) for a) all percentiles of flow, b) high flows only c) low and medium flows only.

Table 23. Summary of differences between current Cataract flows and two Tailrace canal options – Option 1. Constrained to 40 cumecs of flow; Option 2. Carries whole of Tailrace flow. Note that this assumes the Tailrace canal operates under all flow conditions in the South Esk including floods. Green cells indicate flows with the greatest impact.

	Current Cataract Gorge flows	Option 1 Inflows with 40 cumecs Tailrace canal	Option 2 Inflows with full volume Tailrace canal
Minimum flow (cumecs)	2.5	2.5	2.5
Percentage of days in range			
<=2.5 cumecs	85.0%	0.0%	0.0%
2.5 to 10 cumecs	3.3%	2.4%	2.4%
10 to 40 cumecs	3.5%	38.7%	38.7%
40 to 150 cumecs	4.3%	54.1%	51.7%
150 to 290 cumecs	1.9%	2.3%	4.2%
290 to 500 cumecs	1.3%	1.6%	1.9%
500 to 1000 cumecs	0.5%	0.7%	0.8%
1000 to 1500 cumecs	0.1%	0.1%	0.2%
>1500 cumecs	0.1%	0.1%	0.1%
Expected number of days per year			
<=2.5 cumecs	310.3	0	0
2.5 to 10 cumecs	12	8.8	8.8
10 to 40 cumecs	12.8	141.3	141.3
40 to 150 cumecs	15.7	197.5	188.7
150 to 290 cumecs	6.9	8.4	15.3
290 to 500 cumecs	4.7	5.8	6.9
500 to 1000 cumecs	1.8	2.6	2.9
1000 to 1500 cumecs	0.4	0.4	0.7
>1500 cumecs	0.4	0.4	0.4

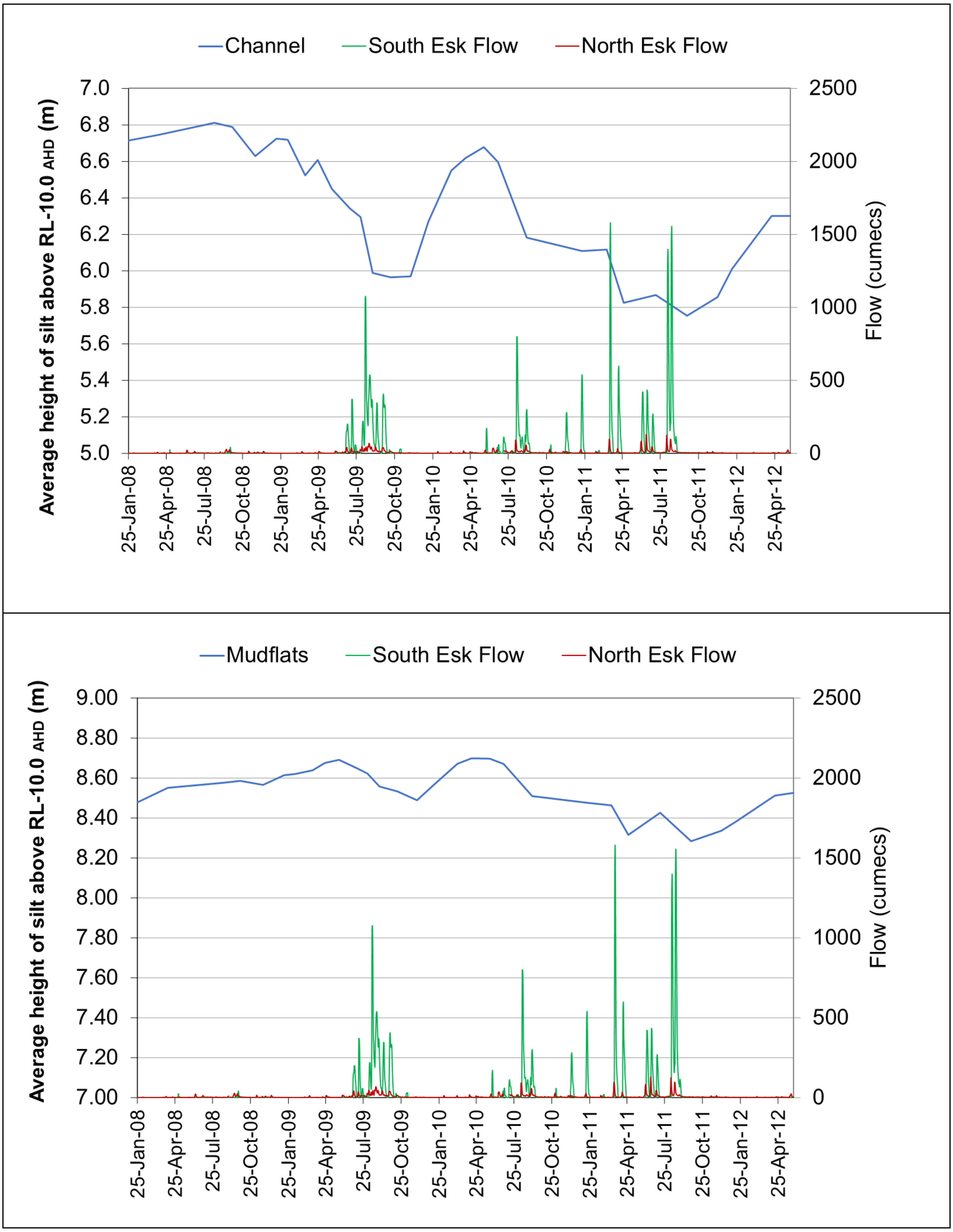


Figure 45. Sediment levels in the channels and mudflats of the estuary from Kings Bridge to just past the confluence with the North Esk River versus South Esk and North Esk river flows during the period before sediment raking commenced (from Kelly, 2019).

Without detailed 3-dimensional hydrodynamic model of scour processes it is difficult to provide a precise estimate of the effects of these changes in flow on estuary bathymetry.

An analysis of historic bathymetric data suggests impacts are likely to be focused on the channel, with significant scour of mudflats unlikely given the range of flows affected. A period of historic bathymetric data, from 30 June 2010 to 7 September 2010 included four days of flows between 150 and 290 cumecs, two days between 290 and 500 cumecs, and three days between 500 and 1,000 cumecs. These events led to an increase in depth of 40 cm in the channel and 16 cm less sediment in the mudflats. This historic period had significantly more days in all flow ranges than the 40 cumecs Tailrace canal option (1.5, 1.1 and 0.8 days respectively) and a much greater number of days in the highest flow range for the full volume Tailrace canal (1.1 days), with a greater number of days in the 150 to 290 cumec range. This suggests that any additional scour induced by either Tailrace canal option will be significantly less than the change in depth observed in the 2010 data – that is it will be relatively small in the channel and insubstantial in the mudflats. It should be noted that as is seen in Figure 45, sediment returns relatively rapidly following periods of scour so any additional depth is likely to be temporary and only observed in the period immediately after the flow event.

11.3.3 Summary of expected changes in bathymetry from Tailrace canal options

A summary of the expected changes in bathymetry in specific areas of the upper estuary is provided in Table 24.

Table 24. Likely impacts of proposed Tailrace canal on bathymetry.

Locations	**Option 1. 40 cumec Tailrace canal**	**Option 2. Full volume Tailrace canal**
Channels		
Lower North Esk	No change, or potential for increase in sediment deposition.	No change, or potential for increase in sediment deposition.
Yacht Basin	Minimal change in channel depth. Additional freshwater flow in channel during low tides when the power station is running. Any changes in sediment depth from scour will be temporary following high flow events.	Minimal change in channel depth. Additional freshwater flow in channel during low when power station is running. Any changes in sediment depth from scour will be temporary following high flow events.
Home Point to Ti Tree Bend	Minimal change in channel depth. Additional freshwater flow in channel during low tides when environmental flows only are released and additional Tailrace flows are available. Any changes in sediment depth from scour will be temporary following high flow events.	Minimal change in channel depth. Additional freshwater flow in channel during low tides when environmental flows only are released and additional Tailrace flows are available. Any changes in sediment depth from scour will be temporary following high flow events.
Mudflats		
Seaport Marina	No change, or potential for increase in sediment deposition.	No change, or potential for increase in sediment deposition.
West Tamar	Minimal scour of mudflats; construction of canal has potential to remove some intertidal areas including mudflats. Any changes in sediment depth from scour will be temporary following high flow events.	Minor increased scour of mudflats; construction of canal has potential to remove some intertidal areas including mudflats. Changes in sediment depth from scour will be temporary following high flow events.
Yacht Basin	Minimal scour of mudflats; any changes in sediment depth from scour will be temporary following high flow events.	Minor potential scour of mudflats; any changes in sediment depth from scour will be temporary following high flow events.
Town Point	Insubstantial and temporary increased scour on Tamar estuary side following high flow events, lower North Esk no change, or potential for increased sediment accumulation.	Minor and temporary increased scour on Tamar estuary side following high flow events, lower North Esk no change, or potential for increased sediment accumulation.

11.4 Impacts on flood risk

It is unclear from the various Tailrace canal options that have been presented how the canal would operate under periods of very high flows and floods. Two options have been discussed by proponents: an overflow weir and 'reverse canal' where flood flows are passed down the canal during flood flows; or, the canal operates as normal during floods. Note both these options assume that the canal is able to safely operate during high flow periods. It is very possible that the canal would become a preferential flow path during a flood and would be subject to large flood flows passing through it. Such an event could pose significant risks for surrounding infrastructure including the Trevallyn Power Station, West Tamar Highway and canal associated infrastructure.

The Tailrace canal is proposed to run through areas within and adjacent to the floodplain. From a flooding perspective a canal within the floodplain will likely increase flood levels due to a reduction in the cross-sectional area and increase in flow. A canal outside of the floodplain will likely also lead to a minor increase in flood level due to increased flows along the length of the canal. Infrastructure most impacted by the change in flood level would be along the West Tamar highway which lies outside the city's flood protection system and where sections of the highway are already impacted by the 20 percent AEP flood event. Overall, the effects of this option on flood risk would be minor and largely restricted to non-flood levee protected areas, though the operation of the canal under flood conditions would need to be considered very carefully in the design phase to avoid creating flood hazards to the West Tamar Highway and Trevallyn Power Station.

11.5 Impacts on water quality and environmental values

Impacts on water quality can be considered in two phases: during the construction phase; and, on an ongoing basis once the canal is in operation. Construction of the canal would require large volumes of sediment that is both potential acid sulfate and contaminated with high concentrations of nutrients and heavy metals to be excavated (noting that the canal runs through the West Tamar sediment ponds which have been assessed as Level 2 contaminated waste once treated for acid sulfate). Mitigation measures for risks posed by construction would need to be carefully considered. The excavation process would be likely to have impacts on turbidity, nutrients and heavy metal concentrations and, if potential acid sulfate soils are oxidised, risk acid runoff into the estuary.

Impacts on water quality once the canal is operational are difficult to estimate. This would depend on the scale of additional scour of sediment out of mudflats (likely minimal) relative to the increase in flows through the Yacht Basin and Home Reach.

Construction of the Tailrace canal would have significant impacts on the foreshore between Cataract Gorge and the existing Tailrace. This area serves as an important corridor for wildlife connecting Cataract Gorge with areas of foreshore downstream. It is a biodiversity hotspot, containing a state listed threatened vegetation communities and several state and federal listed threatened fauna and flora species. Threatened fauna species known to occur in this location include the green and gold frog, Tasmanian devil, grey goshawk, white-bellied sea eagle and the glossy grass skink. It is also within the species range and potential habitat for threatened fauna such as the Australasian bittern, eastern barred bandicoot, eastern quoll and spotted-tailed quoll. Removal of this corridor will impact not only directly on animals and plants in the area but also those relying on the corridor to connect the Cataract Gorge with areas downstream of the Tailrace. Table 25 summarises the key environmental impacts expected to result from construction and operation of the Tailrace canal. These impacts would occur regardless of whether the 40 cumecs or full volume channel is constructed.

Table 25. Key environmental impacts of construction and maintenance of a canal to return Tailrace flows to the upper estuary.

Environmental values	**Impacts of the proposed Tailrace canal**
Water quality	Construction phase – Potential increased turbidity, increased nutrients, reduced dissolved oxygen and increased heavy metal concentrations. Risks from oxidisation of potential acid sulfate soils. Ongoing – highly uncertain. Would depend on extent of additional scour of mudflats (likely small) relative to increased flows through the Yacht Basin and Home Reach.
Intertidal habitats	Adjacent intertidal habitat removed.
Subtidal habitats	Minimal impact.
Migratory fish	Potential for Australian grayling to be severely impacted during construction phase by very high levels of turbidity and toxicants if insufficient mitigation.
Threatened flora, fauna, vegetation communities and ecological communities	Potential for Australian grayling to be severely impacted during construction phase by very high levels of turbidity and toxicants if insufficient mitigation. *Melaleuca ericifolia* swamp forest (threatened vegetation community) and associated threatened species removed. Observed threatened fauna in this area – Tasmanian devil, green and gold frog, white bellied sea eagle; species range for 16 threatened species including Australasian bittern, eastern quoll, spotted tail quoll, eastern barred bandicoot and central north burrowing crayfish. Observed threatened flora – six state-listed threatened plant species, including three endangered species.
Migratory birds	Loss of intertidal habitat in upper estuary where canal is constructed.
Reserves and conservation areas	Impacts on Tamar River Conservation Area through loss of some intertidal habitat and threatened species impacts between Kings Bridge and the Tailrace.
Key Biodiversity Area/Important Bird Area	Impacts on KBA/IBA through habitat loss from loss of intertidal habitat.

11.6 Impacts on recreation and navigation

Any changes in bathymetry and water quality can have impacts on recreational and tourism users of the estuary. These are summarised in Table 26.

Table 26. Impacts of Tailrace canal in upper estuary on key recreational and tourism users of the upper kanamaluka/Tamar estuary.

User	Option 1. 40 cumecs Tailrace canal	Option 2. Full volume Tailrace canal
Rowing - Access to North Esk from pontoons and navigability of the North Esk	Uncertain – either no change or potential for increase in sedimentation in lower North Esk could imply reduced access.	Uncertain – either no change or potential for increase in sedimentation in lower North Esk could imply reduced access.
Tamar Rowing Club	Minimal to no improvement to access from foreshore to channel based on insubstantial and temporary change in surrounding mudflat sediment levels. Risks associated with construction activities and compromise of facilities depend on design and placement of canal and potential for liquefaction during construction. Possible increase in depth of water in channel at low tide may be of benefit.	Minimal to no improvement to access from foreshore to channel based on minor and temporary change in surrounding mudflat sediment levels. Risks associated with construction activities and compromise of facilities depend on design and placement of canal and potential for liquefaction during construction. Possible increase in depth of water in channel at low tide may be of benefit.
Home Point tourist boats	Minimal to no improvement in navigability of channel given current channel depth and minimal and temporary impacts on channel scour. Increased flood risk to infrastructure.	Minimal to no improvement in navigability of channel given current channel depth and minor and temporary impacts on channel scour. Increased flood risk to infrastructure.
Seaport Marina	No change, or potential increase in sediment in Marina.	No change, or potential increase in sediment in Marina.
Tamar Yacht Club	Minimal to no improvement in navigability of channel given current channel depth and minimal and temporary impacts on channel scour. Minimal to no improvement in access to channel from foreshore given insubstantial and temporary mudflat scour. Increased flood risk to infrastructure. Impacts would depend on location of outlet of the canal and would require detailed modelling to assess. Possible benefit from increase in water depth in channel during low tides.	Minimal to no improvement in navigability of channel given current channel depth and minimal and temporary impacts on channel scour. Minimal to no improvement in access to channel from foreshore given minor and temporary mudflat scour. Increased flood risk to infrastructure Impacts would depend on location of outlet of the canal and would require detailed modelling to assess. Possible benefit from increase in water depth in channel during low tides.

11.7 Summary and key findings

Evaluation of the proposed Tailrace canal presents several legislative and feasibility challenges, most likely small changes in sediment levels, and potentially negative impacts on flood risk and the environment, at a substantial cost. Proposed impacts of increases in tidal prism in the Yacht Basin are based on modelling that is demonstrated to not represent changes in bathymetry in that area of the estuary, so any impacts would come from changes in flow regime alone. These impacts are likely to be minor.

Legislative and feasibility constraints are associated with removing contaminated sediments from the existing West Tamar sediment ponds that are located in potential acid sulfate soils, and destruction of or impact on various state and federal listed threatened species and communities. Maintaining public safety and the safety and integrity of local infrastructure such as the Trevallyn Power Station and West Tamar Highway close to fast flowing water also poses substantial challenges.

The Tailrace canal:

- Is likely to have at most minor and temporary impacts on channel depth and minimal to no impacts on visible mudflats. These changes are unlikely to lead to significant benefits for recreational users or the Home Point tourist boats given current channel depths.
- Would impact on power production at Trevallyn Power Station and likely to require some redesign. It may also increase flood risks to the power station and adjoining highway if weir levels are held higher than current spring high tide levels to allow sufficient head for Tailrace flows to be diverted upstream into the Yacht Basin.
- Would require excavation, treatment and disposal of substantial volumes of potential acid sulfate soils as Level 2 contaminated waste.
- Would impact on state threatened vegetation communities and several state and federal listed threatened flora and fauna species.
- May increase flood risks to infrastructure such as the West Tamar Highway, Tamar Yacht Club, Tamar Rowing Club, and existing Tailrace dependent on the design of the canal.
- Would cost in excess of $250 million to construct, would require substantial modifications to the power station (uncosted) and have ongoing added costs to power production and operational and maintenance costs of over $2 million per year.

12 Management option - increased flows down the South Esk and/or removal of Trevallyn Dam

There is a strong perception amongst many in the community that sedimentation in the upper kanamaluka/Tamar estuary has been caused or exacerbated by the construction of Trevallyn Dam in 1955. There have been many different proposals for increasing flows down Cataract Gorge. The legally required level of environmental flows down the Cataract Gorge is 0.47 cumecs. In 2003, environmental flow releases were voluntarily increased above this requirement to 1.5 cumecs to provide habitat for important species and to better cater for recreational use. In 2011 this environmental flow was voluntarily increased again to 2.5 cumecs. Proposals for increased flow through Trevallyn Dam have ranged from removal of Trevallyn Dam (essentially removal of the drinking water storage and decommissioning of the Trevallyn Power Station) to releases varying from 10 cumecs to 100 cumecs either on a continual basis or as an intermittent release.

12.1 Legislation and feasibility challenges

Some of the options proposed for increasing flows down Cataract Gorge are not technically feasible, as there would not always be sufficient flows available to deliver such a flow on a continuing basis (Lake Trevallyn can store up to 100 cumec days of flow, such that a 20 cumecs release could only be sustained for up to five days without additional inflows and assuming no flows are diverted through the Tailrace). Devlin (2019) conducted a modelling study of a range of flow release options with a focus on options which were feasible. These scenarios modelled releases that effectively emptied Lake Trevallyn over the course of days of between 20 cumecs and 50 cumecs including with releases pulsed to coincide with outgoing tides. Given that other options proposed by community members are technically infeasible this section focuses on the impacts of one-off flow releases of the nature considered by Devlin (2019). Releases of this scale would require sufficient inflows to Lake Trevallyn as well as a period of infilling of the Lake following emptying via a targeted release.

Removal of the dam is not considered here. Section 3 provides a detailed analysis of the impacts of construction of Trevallyn Dam on flows through Cataract Gorge and found it did not impact on scouring flows and that the addition of flows from Great Lake through Poatina slowed sediment accumulation in Home Reach.

12.2 Impacts on bathymetry, visible mudflats and channel depth

Devlin (2019) found that relatively small reductions in sediment accumulated in the channel and mudflats of the upper estuary (less than 2 mm) could be expected from releases between 20 and 50 cumecs and that any sediment moved by these releases out of the upper estuary returned within three months with no net change in sediment accumulation.

12.3 Estimated costs

A release of 100 cumec days was estimated to cost approximately $110,000 although this could vary substantially depending on power prices.

12.4 Impacts on flood risk

Dams provide increased temporary floodplain storage compared to the existing channel, thus they provide some attenuation of peak flows during floods. Removal of the Trevallyn Dam would therefore increase levels downstream in a flood. However, this option is complex and impacts would depend upon the water level in the dam prior to the flood, the duration of the flood and the magnitude and shape of the inflow hydrographs. It is likely that the effect will be greater in small floods (less than the 5 percent AEP) but will have minor impacts in larger floods such as June 2016.

Increased releases from Lake Trevallyn will have no impact on flood risk. WMAWater (2021) found that flood levels relate to pre-flood bathymetry so changes in sediment levels before a flood have minimal if any impact on flood levels. Regardless, even if pre-flood bathymetry was relevant, increased releases from Lake Trevallyn have minimal impact on sediment levels so would have minimal, if any, impact on flood levels.

12.5 Impacts on water quality and environmental values

Devlin (2019) found that flow releases can be expected to lead to small increases in Total Suspended Solids (TSS) concentrations above base flow levels from the Ship lift to Legana, with the greatest impacts in Home Reach. The greatest impacts are expected at the Ship lift. Increases last for the duration of the release and can be expected to have minimal, if any, environmental impact.

12.6 Impacts on recreation and navigation

Given that feasible flow releases have no significant impact on sediment in either the channel or mudflats, they are not expected to have any impacts on recreation or navigation.

12.7 Summary and key findings

- A targeted flow release can be expected to move the equivalent of less than 2mm of sediment from key areas of concern around Launceston including mudflats and channels in the yacht Basin and Home Reach. The mobilised sediment is expected to be redeposited in the upper estuary within 3 months.
- A flow release is expected to cost at least $100,000 in terms of lost revenue from electricity that would otherwise be generated.
- Construction of Trevallyn Dam had impacts on low flows with minimal impact on scouring flows entering through Cataract Gorge. Previous studies found the addition of flows from Poatina which enter the estuary through the Tailrace slowed sedimentation in Home Reach. Changes observed in channel width and visible mudflats around the time of the dam being constructed are most likely due to the end of large-scale dredge programs in the upper estuary that occurred around the same time rather than any impacts of changes in flow through Cataract Gorge.

13 Management option - barrages and weirs

There have been a range of barrage options proposed by various members of the community dating back to 1911, then revisited in 1939, 1970 (Ellison and Sheehan, 2013), 1999 and 2013. In 2000, the Launceston City Council accepted a report on the North Esk River Weir Study and took the decision not to include a weir on the North Esk River in its long-term strategy. This section considers the costs, feasibility and impacts of building a barrage or converting the upper estuary to a freshwater lake. Three options are considered: a weir across the North Esk; a smaller lake at Freshwater Point (small lake proposal by Tamar Lake); or a larger lake at Point Rapid near Rowella (Figure 46). A barrage placed at Rowella would inundate the entire 4,433 hectares of the Tamar River Conservation Area.

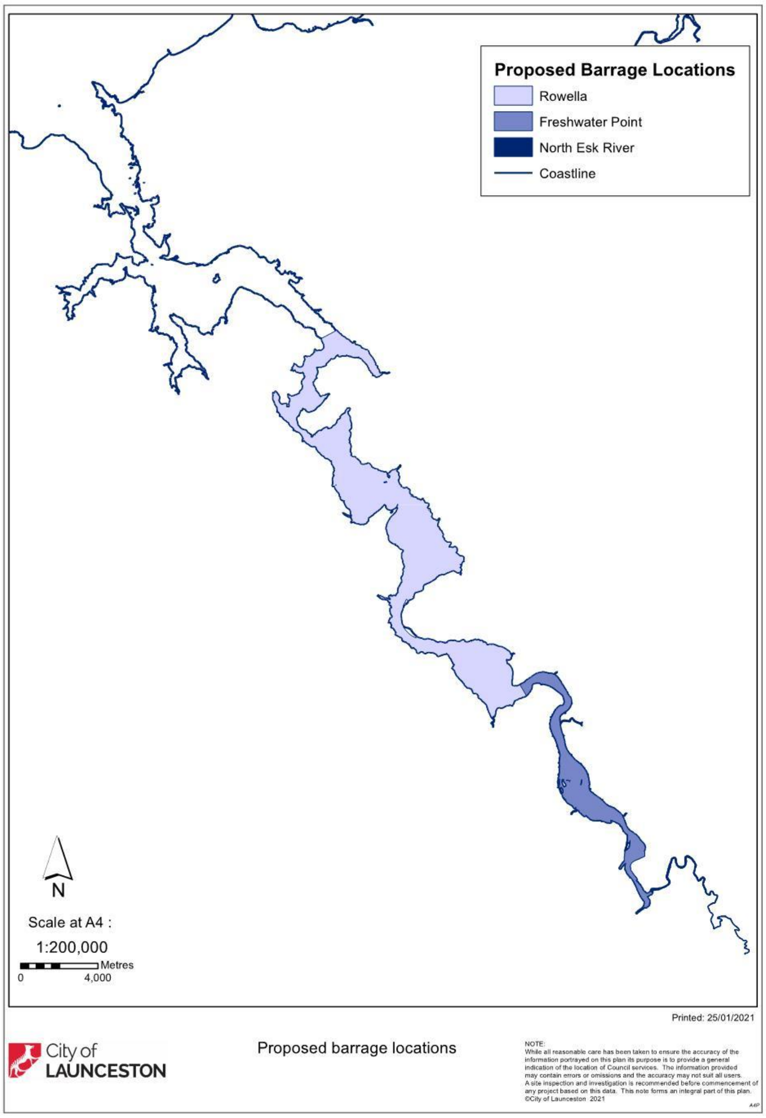


Figure 46. Proposed barrage locations in order of scale from smallest storage to largest: North Esk River, Freshwater Point, and Rowella. The Rowella option converts the entire Tamar River Conservation Area from estuary into a freshwater lake.

13.1 Legislation and feasibility challenges

13.1.1 Legislation and permit requirements

Depending on its location, construction of a barrage on the kanamaluka/Tamar estuary is a major undertaking which would require a complex set of permits and assessments. It is likely that such a project would be designated as a Major Project under the Tasmania's planning and approvals process, governed by the Land Use Planning and Approvals Act 1993. Major projects under this Act must satisfy at least two of three criteria:

a) the project will have a significant impact on, or make a significant contribution to, a region's economy, environment or social fabric;

b) the project is of strategic importance to a region; and/or

c) the project is of significant scale and complexity.

The scale and complexity of the project, including the requirement for multiple permits, impact on more than one local government area, and the broad range of potential environmental and economic impacts are likely to meet these criteria. The major projects approval process allows the project to be assessed by a Development Assessment Panel and would include coordinated assessment of land use, heritage, Aboriginal heritage, environmental, threatened species and infrastructure requirements. Construction of a weir across the North Esk is likely to be of a smaller scale and may not be subject to the same legislative and permitting constraints.

Key permits and legislation which would be part of such an assessment are:

- *Historic Cultural Heritage Act 1995* which would require an assessment of potential impacts on heritage sites. Figure 47 shows some of the key heritage sites around the kanamaluka/Tamar estuary foreshore that may need to be considered in such an assessment based on impacts from construction, increased risks from sea level rise and storm surge below the barrage or flooding or other risks above the barrage.
- *Tasmanian Aboriginal Heritage Act 1975* and *Commonwealth Aboriginal and Torres Strait Islander Aboriginal Protection Act 1984* - In undertaking an Aboriginal Heritage assessment for the Gunns pulp mill and effluent and water supply lines (from Bell Bay to Launceston along the eastern side of the estuary), Stone and Stanton (2006) found that *'proximity to the coastline (either open coast or sheltered estuary) is a prime determinant of Aboriginal site location in the Tamar estuary region. A pattern emerges of large stone artefact scatters at bay heads with reliable sources of freshwater close by. Such sites include Big Bay… and the East Arm site …. Smaller stone artefact scatters and isolated artefacts are associated more with ephemeral drainage lines (…), hinterland swamps (…) and the high-energy coast.'* Stone and Stanton (2006) also notes that *'The ongoing modification and disturbance of the Tasmanian land mass, when considered as a whole, is a matter of concern to the Aboriginal community. These changes have the potential to destroy Aboriginal values*

and conflict with Aboriginal associations with the land (with reference to the Gunns pulp mill and associated infrastructure).'

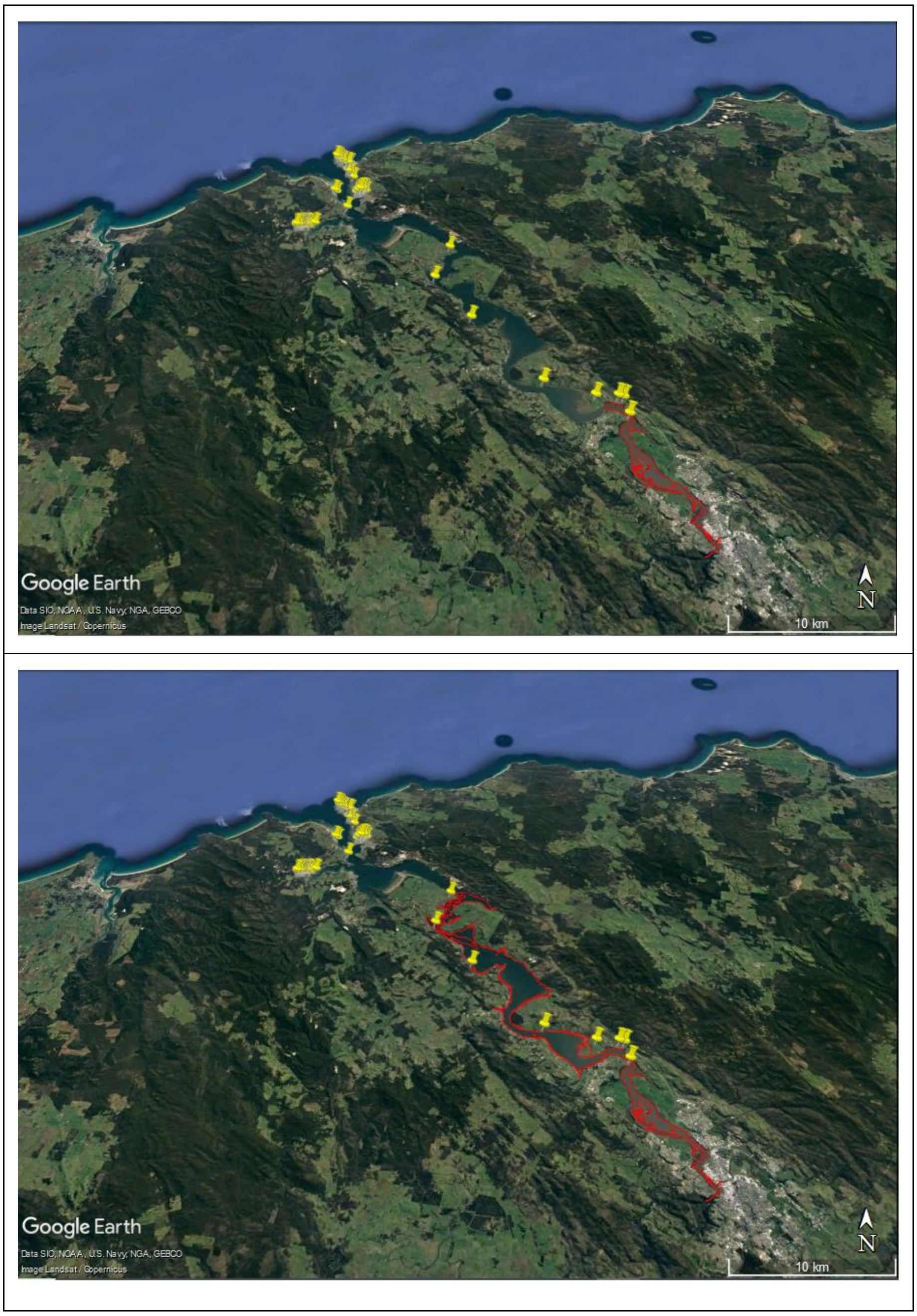


Figure 47. Tasmanian heritage sites (yellow pins) which may require assessment compared with footprint of large and small Tamar lake options. Note no Tasmanian heritage sites were identified as being impacted by a weir on the North Esk.

- The *Nature Conservation Act 2002*, *Threatened Species Protection Act 1995* and the *Environment Protection and Biodiversity Act 1999*, *National Parks and Reserves Management Act 2002*, given the significant environmental values likely to be impacted by the project including threatened species, threatened ecological

communities and threatened vegetation communities, migratory bird species and reserves and conservation areas.
- Dams, levees and weirs are regulated under the *Water Management Act 1999*. Permits and dam safety emergency plans would be required under this legislation. It is possible that requirement for a dam permit may exempt the project from requiring a Threatened Species or Nature Conversation Permit, but this is uncertain.
- *Environmental Management and Pollution Control Act 1994* requires that practical or reasonable steps must be taken to prevent or minimise environmental harm caused by an activity.

13.1.2 Feasibility challenges

The feasibility and difficulties of constructing of a barrage and reservoir on the kanamaluka/Tamar estuary would depend to some extent on the location of the barrage and scale of reservoir to be built. CIRIA *et al.* (2007) outline some of the issues to be considered in the design of closures of estuary systems versus river systems. Key features of closure construction on estuaries that add to their complexity are:

- wave attack;
- current velocities that change direction and vary with the tidal cycle as well as day to day and seasonally;
- subsoil that is nearly always easily erodible alluvium;
- generally large distances for transporting armour stone and/or concrete to reach closure sites;
- the requirement for a combination of waterborne and land-based closure operation; and
- a larger differential head during closure to cope with spring tides.

The location of barrage construction would affect these attributes. SeaMap data shows at the proposed large lake site the substrate is a mix of cobble and silt while at the small lake site the substrate is silt. Construction on silt would likely require dredging of silt materials and replacement with more suitable materials. The scale of such a dredging effort is difficult to estimate without detailed data on silt depths but recent construction on the floodplain in Invermay shows that depths of unconsolidated silt are likely to be significant. Assuming the width of the estuary where the barrage is constructed is 200 m, dredging this 200 m width over a 100 m length to a depth of 10 m would mean 200,000 m^3 of dredge spoil which would requiring approximately over 130 ha of silt ponds for dewatering. This silt is likely to be potential acid sulphate soil with unknown levels of contamination with toxicants. Treatment and disposal options are uncertain without testing sediments in the barrage location.

CIRIA *et al.* (2007) list some of the interactions that are most commonly known to endanger structures and which would need to be considered as risks in the construction of an estuary barrage:

- *'scour which may lead to slides and/or liquefaction, which in turn may endanger the stability of the rockfill closure dam;*
- *migration of materials through filters or by means of seepage/piping, which may lead to local slides and/or settlement;*
- *sedimentation during intermediate stages of closures may weaken the structure through subsequent migration of the materials such as peat or certain clay fractions may have to be removed by dredging and replaced with more suitable sand;*
- *weak subsoil - if present in the subsoil under the hydraulic structure, and to avoid major slides and/or settlement or loss of stability of the closure structure; and*
- *fine loosely packed sand – if found in the subsoil, this material may have to be compacted prior to loading by hydraulic structures*.' Alternatively grout or cut-off walls may be required to avoid sand becoming a path for piping.

They also note that estuary closures where the bed is silt or sand can only be undertaken once the bed of the estuary has been protected prior to the increase in current velocities that will occur during the closure. These velocities depend on the tidal water levels in the undisturbed situation, the wet surface area to be closed off to the sea, and the river discharge. Bed protection needs to be a filter layer that can withstand strong currents.

A further complication with estuary closure relates to the volume of materials required to be stored in proximity to the closure site. Estuary closure may have to take place rapidly, over days to weeks, so materials require storage close to the construction site, in areas accessible by barges and which can carry heavy loads. The capacity for alluvial flats along the estuary to act as storage areas for such materials would be limited and so engineering works to create suitable storage areas are also likely to be required.

Holding a lake or weir permanently at a higher water level may also impact on existing terrestrial drainage outfall pipes. The reality is that the high-water level would be limited to the lowest outfall pipe, unless drainage works were conducted. Not to do so would create drainage issues. The effects on these would need to be investigated individually.

Holding water at the level of high tides would also impact on the Trevallyn Power Station:

- A higher tailwater will reduce energy produced (MWhrs), and capacity (MW) significantly. Energy available for generation is a function of nett head between headwater (lake level) and tailwater, so any increase in tailwater directly reduces machine output.
- The hydraulic design of the outlet would need to be carefully done, and likely physically modelled, to ensure flow patterns did not cause additional losses, or hydraulic instability through circulating flow etc.

Tailwater conditions are an important consideration in a station design for stable and efficient operation. It is possible that construction of either the small lake or large lake option would require some refurbishment of the power station due to changes in tailwater conditions.

Maintaining navigation access to the upper estuary would require construction of a lock to allow vessels to pass through the barrage. Operational costs for this lock would also need to be considered. The size of the lock would be determined by the vessel size accessing Launceston. At the moment it would need to accommodate the Statesman (LOA 53 m, width 10 m, draught 2.3 m) and the King Islander (LOA 63 m, width 14.6 m, draught 2.8 m).

Holding lake levels at a constant level equivalent to the high tide is also likely to impact on water table levels under Invermay and Inveresk. The water table is already very close to the surface in Inveresk and Invermay with areas in these suburbs below high tide levels. Over time, a constant higher water level is likely to result in a higher water table and groundwater will be expressed at the surface in low-lying sections of Invermay, potentially rendering homes unliveable and commercial properties unviable. It is likely that a higher water table would further reduce the extremely low bearing capacity of the soils in Inveresk and Invermay and similar areas adjoining the estuary. This has the potential to impact on existing structures as well as the costs of future development and construction in these areas. It may also impact on Launceston's flood levee system.

Teakle (2012) found that for the smaller lake at Freshwater Point, the gates of the barrage would need to extend most, if not all, the width of the river to be large enough to let the 0.5 percent AEP flood through.

13.2 Estimated costs

Tamar Lake Inc. has released a cost estimate for construction of the large barrage (Rowella) of $320 million in capital costs and claim benefits of $553 million. Two economic reports were completed as part of their pre-feasibility assessment (Houston, 2013; Rees, 2014). Findings in these reports have been released but full reports are not publicly available and the detailed assumptions behind these cost and benefit assessments are not clear. Tamar Lake list out key findings as:

- *'Over the 3 years of construction, the combined capital works from barrage construction and construction of the irrigation scheme, would contribute approximately $315.5 Million in net additions to Gross State Product (value added) and support the employment of 856 jobs.*
- *Over the subsequent 15 years, the capital works relating to irrigation scheme connections by the users, combined with the expenditure from operations of the barrage, suppliers and users of the irrigation schemes would initially contribute approximately $10.28 Million per annum, rising to $19.64 Million per annum in net additions to Gross State Product (value added) and support the initial employment of 67 jobs rising to 128 jobs per annum, as the irrigation scheme becomes fully subscribed and operational, and*
- *The favourable impact on tourism would more than offset the adverse impact on the existing fisheries, and in net terms, will contribute $112.5 Million per annum in net additions to Gross State Product (value added) and support the employment of an additional 716 jobs.*

In summary, over the 3 years of construction of the barrage and the following 15 years of operations in agriculture and tourism, the State will benefit from the support of 856 jobs in the construction phase and a further 844 jobs per annum in direct and dependent industries at the end of the 15 year modelling period.

It should be noted that these economic benefits result only from the construction of the barrage, and subsequent operations in the agriculture and tourism sectors over the 15 years.

The NERA economic study carried out for Tamar Lake Inc forecast a net increase in residential and commercial property values in Launceston and the upper Tamar Valley at $333 Million over the same period due to the formation of the Tamar Lake. The substantial boost to construction and the service industries resulting from this perceived increase in household net asset values, has not been included in the KPMG results.'

It is unclear from the report's summary the extent to which the complexities of constructing the barrage in an estuary setting have been accounted for and the basis for assumptions relating to tourism, irrigation and increased property values. It is also noted that these studies were conducted in 2013 and 2014 before the implications of the lake on water quality and odour were understood (i.e., prior to the water quality modelling study) and that construction costs would now likely be higher due to inflation. In particular:

- What is the mechanism by which a lake would increase tourist potential over and above an intact estuary which is associated with high conservation values? It is difficult to find a justification for large increases in tourist numbers over and above those who already visit the Tamar valley to experience its vineyards, wetlands, beaches and natural environments particularly in light of some of the water quality challenges posed by conversion of the estuary to a freshwater lake. There is a lack of evidence that visible mudflats in the upper estuary offer a significant disincentive to tourism in and around Launceston particularly given natural assets such as Cataract Gorge are known to attract tourists to the area.
- How is the increase in property prices calculated? What is the justification for increasing property prices outside of the immediate area where tidal flats are currently visible, given that those downstream currently front a wide estuary with significant aesthetic and natural values? How are they actualised and to what extent do increased property prices create an actual economic benefit to the state given the social impacts of inflated house prices, subsequent increases in rent and a housing affordability crisis? Current median house prices in the West Tamar are $439,000 with over 8 percent increase in a year and 18 percent in two years[13]. To what extent would conversion of the estuary to a lake create a greater increase in property prices over and above this trend and what is the net social and economic effect of such an increase? Assuming a 10 percent increase on the median house price, $333 million

[13] https://www.realestateinvestar.com.au/property/tasmania/west+tamar

equates to increased prices on 7,500 homes. Is there a market for such an increase in price over such a significant number of houses?

- How is the increase in Gross State Product from agriculture calculated? What is the demand for irrigation water within the Tamar Valley? It is unclear how much water will be sold to potential irrigators, or who would manage and operate the irrigation scheme. The Tamar Irrigation Scheme currently under investigation by Tasmanian Irrigation relies on the elevation at Lake Trevallyn for distribution of water under gravity pressure for all irrigators on the West Tamar, and via boost pump for those east of East Arm Road. The lower head of a lake would require pumping to distribute water to agricultural users. It is unclear whether costs of associated infrastructure and ongoing costs of pumping have been incorporated in the assessment of economic benefits.

Water quality modelling conducted by BMT WBM in 2016 also assumes a 10 to 20 cumecs environmental flow to increase flushing of the Yacht Basin and promote movement of sediments out of the Yacht Basin and Home Reach with the justification that 'the huge economic benefits from the Tamar Lake implementation more than justifies the loss of between 1 to 2 percent of the state's hydro generating capacity'. A conservative estimate of the costs of lost power production from diverting Tailrace flows through Cataract Gorge is in the order of $4 to $8 million a year, every year[14]. It is not immediately apparent from the summary report that these costs have been included. Baseflows of this magnitude through Cataract Gorge would also see the causeway covered in water and end safe swimming in First Basin. Environmental water requirements in yingina/Great Lake also mean that during dry periods there is unlikely to be 10 to 20 cumecs of water available for environmental releases.

Ongoing costs associated with operations of the floodgates and maintenance of the barrage do not appear to have been considered (the report references construction costs with no mention of ongoing operational and maintenance costs or depreciation expenses). In order to manage flood risks associated with holding the lake level at high tide (necessary to minimise the exposure of the current mudflats) the proponents suggest drawing down the lake to mid tide over a 4 to 12 hour period. Managing such procedures and risk proofing operations so as not to increase flood risks and risks of failure is an ongoing operational cost. Sedimentation behind the barrage (and potentially in new deposition sites downstream of the barrage) may also require dredging to restore depth at some point in time, which does not appear to have been costed (this would include the cost of dredge operations, transport, dewatering, treatment and disposal). The design of floodgates to allow lake levels to be reduced rapidly in advance of a flood is unclear, particularly for the small lake and North Esk weir options where the availability of land adjacent to the barrage is likely to present a constraint. Mitigating flood risks from a weir on the North Esk through

[14] Assuming the same electricity price assumptions applied by Devlin (2019) where a 100 cumec day release was costed at $110,000.

flood gate opening would be challenging given the significantly shorter travel time in the North Esk river catchment.

Additionally, thermal destratification methods have been investigated following analysis of water quality impacts and while the proponents acknowledge that they have been unable to determine a destratification technology that could address the issues, it is clear that if one were able to be identified both the initial costs and ongoing operational and monitoring costs associated with such a system would need to be considered as part of the assessment.

Petuna's salmon farm (~$25 million annual production; ~$35 million asset value) would also be jeopardised by the change in water regime. They benefit from freshwater pulses (disease control), and lower salinity/temperature (reduced mortality) currently afforded by the natural estuary system. These would be lost if the barrage was installed and potentially by changes in sedimentation caused by the barrage.

Assessments of the Cardiff Bay barrage that was predicted to lead to large increases in employment and economic growth have found that many benefits failed to materialise. Best (2005) states that the barrage cost £200 million to construct and now costs the taxpayer £20 million a year to operate (costs at 2005).

The cost of the North Esk weir was estimated at $25 million in 2013 (see Poskitt 2013).

13.3 Impacts on bathymetry, visible mudflats and navigability

The construction of a barrage on the estuary would have significant impacts on the bathymetry of the system, both above and below the barrage. Above the barrage, tidal influences would be removed and a relatively constant water level maintained. Barrages on the main kanamaluka/Tamar estuary would create a downstream flow path for flows from the North Esk, South Esk through Cataract Gorge and the Tailrace path. Sediment would be expected to settle within the lake particularly when high flow events move larger sediment particles which drop out when they reach the slower moving lake. Some fine sediments would be passed through the barrage into the lower estuary while others may settle within the lake itself. Sediments that pass through the barrage would flocculate when they interact with the saline waters of the estuary, depositing sediments below the barrage, potentially creating new intertidal mudflats and smothering existing habitats. The Elwha dam, in Washington State, provides an example of the broad scale of potential impacts of barrage construction on the lower estuary. This dam affected sediment deposition and erosion for a stretch of 30 km of coastal foreshore and impacted significantly on how far the estuarine environment extended into the sea (see for example Warrick *et al.*, 2019). It can be expected that the large lake will have extensive impacts on bathymetry in the lower estuary while the smaller lake will impact significantly on bathymetry in the middle estuary and potentially into the lower estuary.

Fondriest Environmental Inc. (2014) describe some of the drivers of sediment transport and deposition and the ways in which these might be altered by dams and reservoirs. Sediment is likely to be deposited behind a barrage, leading to a loss of storage capacity, reduced depths and potentially increasing flood risks. It is also possible that holding the lake at a constant level with less channelisation of flows and sediment accumulation on mudflats will lead to a levelling of sediment levels within the lake as sediment banks slump into the main channel. This may have the effect of reducing channel depths. Below the barrage the reduction in sediment can lead to increased coastal erosion as well as deposition in areas which are not currently deposition zones. The impacts of a barrage on the lower kanamaluka/Tamar estuary are likely to be complex and difficult to predict but may include impacts on coastal infrastructure due to increased coastal erosion as well as smothering of subtidal habitats through deposition in new areas. Table 27 summarises the likely potential impacts of different barrage and lake options on the bathymetry of the estuary.

13.3.1 Summary of impacts on bathymetry

Table 27. Likely impacts of barrage and weir options on bathymetry.

Location	**North Esk weir**	**Small lake**	**Large lake**
Channels			
Lower North Esk	Short term: constant water level. Medium to long term: infill of channel with deposition of sediments behind weir, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris upstream of weir during flood such as large logs and boulders.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increased sediment deposition, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increase sediment deposition, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders.

Royal Park/Yacht Basin	No or minimal change.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increased sediment deposition, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders and slumping of sediments currently contained in mudflats into the current channel reducing channel depth.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increase sediment deposition, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders.
Town Point to Ti Tree Bend	Increased sedimentation due to reduced tidal prism in the North Esk.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increased sediment deposition, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increase sediment deposition, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders.

Channels in the middle and lower estuary	Potential for increased sedimentation into middle estuary with reduced tidal prism in the North Esk.	Short to medium term: constant water level. Medium to long term: potential for increased sedimentation behind barrage, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders (Ti Tree Bend to Freshwater Point) reducing channel depth; loss of tidal prism below barrage increase sedimentation in middle estuary.	Short to medium term: constant water level. Medium to long term: potential for increased sedimentation, slumping of sediments currently contained in mudflats into the current channel and deposition of large debris behind barrage during flood such as large logs and boulders behind barrage (Swan Point to Rowella) reducing channel depth; loss of tidal prism below barrage increase sedimentation in lower estuary.
Mudflats			
Seaport Marina	Short term: increased water level. Medium to long term: infill of Seaport Marina with deposition of sediments upstream of weir.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increased sediment deposition.	Short to medium term: Constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increase sediment deposition.
West Tamar	Potential increase in mudflats along West Tamar due to reduced tidal prism in the North Esk.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increased sediment deposition.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream. Medium to long term: loss of depth due to increase sediment deposition.

Royal Park/Yacht Basin	Minimal change as not impacted by change in tidal prism in North Esk.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream and deposition of large debris such as logs and boulders during floods. Medium to long term: loss of depth due to increased sediment deposition and deposition of large debris such as logs and boulders during floods.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream and deposition of large debris such as logs and boulders during floods. Medium to long term: loss of depth due to increased sediment deposition and deposition of large debris such as logs and boulders during floods.
Town Point	Potential increase in mudflats on estuary side of Town Point due to loss of tidal prism in North Esk, constant water level in lower North Esk with medium to long term additional sediment accumulating, and deposition of large debris such as logs and boulders during floods due to deposition behind the weir.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream and deposition of large debris such as logs and boulders during floods. Medium to long term: loss of depth due to increased sediment deposition and deposition of large debris such as logs and boulders during floods.	Short to medium term: constant water level; potential for scour from large flood events moving sediments downstream and deposition of large debris such as logs and boulders during floods. Medium to long term: loss of depth due to increased sediment deposition and deposition of large debris such as logs and boulders during floods.
Intertidal areas in the middle to lower estuary	Small potential changes in bathymetry due to changes in tidal prism of the North Esk.	Increased deposition of sediments in the middle estuary with development of extensive mudflats in the middle and lower estuary. Potential for increased coastal erosion in lower estuary.	Increased deposition of sediments in the lower estuary with development of extensive mudflats in parts of the lower estuary. Potential for increased coastal erosion in lower sections around estuary mouth.

13.4 Impacts on flood risk

Impacts on flood risk are considered separately for the North Esk weir and the two Tamar lake options.

13.4.1 North Esk weir

The location of this weir would increase flood risks to all areas upstream of the weir whenever flood waters back up. Given the relative speed with which floods travel from the catchment to estuary through the North Esk operation of any flood gates or mitigation measures is likely to be challenging. This would mean increased risk of flooding of the Seaport, settlements and infrastructure on the lower North Esk including closure of the bridges into Invermay, Ravenswood and Waverley, and increased risk of failure of the flood levee system protecting Invermay and the CBD. Sediment and large debris from the North Esk is also likely to accumulate behind the weir, reducing the weir volume and further increasing flood risks over time.

13.4.2 Large and small Tamar lake options

One of the suggested benefits of either lake is that it will reduce the impacts of sea level rise at Launceston. The other suggested benefit is that the large lake will potentially reduce flood levels by up to 1 m for all events from the 20 percent AEP event to the 0.5 percent AEP. It is acknowledged on the web site that the small lake may increase flood levels at Launceston but no detailed investigation has been undertaken.

Examples of such barrages are at Cardiff in Wales, on the Thames River at London in England, at Venice in Italy. No review of the purpose and benefits of these barrages for flood mitigation has been undertaken. The Thames and Venice barrages are intended to prevent inundation from elevated levels (due to storm surge) in the North Sea and the Adriatic Sea, respectively. However, they would also reduce the impact of sea level rise during these events. The Cardiff barrage was not constructed as a flood mitigation measure but rather to create a lake upstream with the intention of creating benefits to the community.

13.4.2.1 Reduction in impact of Sea Level Rise

During non-flood periods: Both schemes will potentially provide some benefit in reducing the impact of sea level rise during non-flood times, as the barrage will prevent high tides (elevated further by sea level rise) from reaching Launceston. However, this is a complex problem to assess with many issues that need detailed consideration, three of these are listed below.

Firstly, it should be noted that Launceston is protected by a levee system, thus for all protected areas there will be no benefit in terms of providing protection from sea level rise in non-flood times (assuming say a 0.8 m sea level rise by 2100). An assessment of the non-protected areas is therefore required to investigate the magnitude of the benefit afforded to these areas.

Secondly, the impact of sea level rise on the tidal regime is not well understood in the estuary due to its 70 km length. Palmer *et al.* (2019) have studied the effects of predicted sea level rise on tides and geomorphic change in the kanamaluka/Tamar estuary. This new information has yet to be incorporated into flood studies, a task that is outside the scope of this report.

Thirdly, the mean water level in the lake may mean that land previously only affected in high tides becomes permanently inundated. The significance of this potential impact is unknown at this time.

During floods: In many events an elevated ocean level occurs as part of the same meteorologic event that causes intense rainfall and thus flooding. Raising of the ocean in this manner is called storm surge. The effect of sea level rise on flooding (in the absence of climate change rainfall increase) at Launceston has not been evaluated in the latest TUFLOW modelling. It is unknown therefore if either barrage scheme will reduce flood levels in flood events affected by sea level rise.

In considering planning for adapting to and mitigating climate change impacts it should be noted that there are many alternative options which may be better suited, and provide protection without the risks imposed by a barrage, that would have lower environmental impacts, and overall, than a barrage system. Were protection from sea level rise to be considered a primary goal of the barrage a comprehensive assessment of alternative options would be required.

13.4.2.2 Effects on Flooding

Tamar Lake (2020) indicates that a report on flooding has been prepared for the large lake. This presumably indicates the 1 m reduction in flood levels noted above. However, this report is not available for review. The comments below on the effects of the barrages on flooding are therefore very general and not specific to either barrage.

- It is not possible to evaluate the effects on flooding for either barrage without undertaking detailed hydraulic modelling.
- All floods are different and thus a range of historical and design events need to be investigated. It is likely that in some events there may be a reduction in peak level but in other events there may be an increase in peak level.
- It is likely that if there is any reduction in flood level it will be in the smaller more frequent events. However, as Launceston is protected by a recently upgraded levee system the reduction in peak levels in these smaller events will likely provide no tangible benefit to the protected areas. The tangible benefit in the unprotected areas is unknown.
- Floods happen rarely and thus a general principle of floodplain management is that any mitigation measures must be "fail safe". For the barrages to act as a flood mitigation measure to lower flood levels at Launceston will require the timely operation of the flood gates in the barrage, that will need to account for tides to avoid tidal surge back into the lake. It is unlikely that a "fail safe" procedure is possible as operation requires a complex mix of electronic, human, mechanical and other types of systems which have been shown to fail during large floods in Australia (WMAWater, 2021).

In a flood which exceeds the capacity of the barrage system to mitigate flooding (it is unknown the AEP of this event) the barrage will increase flood levels upstream at Launceston. As noted by Smits *et al.* (2006) the tendency for populations to build greater levels of infrastructure in areas 'protected' by barrages given the sense of safety they provide, means that while the probability of flooding may be reduced, the damage that results when defences are breached is much greater. They stress the importance of not allowing large investments in areas that are vulnerable.

13.5 Impacts on water quality and environmental values

The Elwha dam provides an example of the long-term environmental impacts of constructing a barrage in an estuary system (George *et al.*, 2008; Warrick *et al.,* 2019). This dam is on the Elwha river in the State of Washington, USA, and was constructed in 1913 to generate power for local populations and industry. The dam severely restricted access for fish species that migrate between marine and freshwater environments as part of their life cycle. It resulted in the loss of over 99 percent of salmon and trout which returned to the estuary each year, with 90 percent of their habitat lost and habitat downstream of the dam degraded. In 2011 a project to remove the Elwha dam was commenced (complete 2012) and a second dam further upstream (Glines Canyon dam) was also moved. Within four years significant benefits were seen in terms of not only fish numbers but also birds, otters and other mammals. Coastal erosion had increased with reduced sediment supply from the river due to the dam. This erosion had converted the bed of the estuary below the barrage to armoured cobbled substrate and had resulted in significant shoreline erosion (0.6 m/yr during the latter half of the 20th century – 160 m of shoreline retreat between 1939 and 2006) for at least 30 km along the coast (Warrick *et al.*, 2019; Dudda *et al.*, 2011). This illustrates the significant impacts an estuary barrage can have on geomorphic and biological processes, impacting areas well outside the footprint of the resulting lake.

A second barrage worth considering is the barrage on Cardiff Bay which was developed as part of a waterfront rejuvenation strategy, justified on the basis of economic and social benefits of the associated recreational and waterfront developments. In an assessment of the effects of this barrage on waterbirds using Cardiff Bay, Burton *et al.* (2003) found that following closure of the barrage, the majority of wading birds that used the bay were displaced. A smaller diversity and number of freshwater species were seen to use the new freshwater system in their place. Birds that were displaced were generally not found to successfully settle in new sites and population numbers declined. The winter survival rate of adult redshanks fell following their displacement. Given that the kanamaluka/Tamar estuary is internationally recognised as an Important Bird Area (IBA) hosting a number of migratory and threatened wading bird species and the very large scale of this habitat compared with other estuaries in Tasmania, these results suggest conversion of the estuary to a freshwater lake would have major effects on estuarine bird species both within the estuary and more broadly in Tasmania.

Tamar Lake's summary of the environmental impact for a barrage concludes that "*while there will be some displacement of natural ecological values (which will have to be managed), no listed species will be threatened and the freshwater habitats (including the Tamar Island Wetlands) will be greatly expanded*." This report demonstrates clearly that the claim is inaccurate, with many threatened species and communities impacted by a barrage and subsequent conversion of the estuary to a freshwater lake.

Rissik (2014) provided a peer review of the Tamar Lake proposal (large lake). The findings are still relevant and, in many cases, apply equally to the small lake option given the processes that will be impacted. Rissik (2014) summarised key environmental impacts associated with the lake proposal and stated that there was a need to consider risks and impacts in the following areas:

- '*Water quality*
  - *high nutrients and potential algal blooms including blue green toxic algae;*
  - *high bacteria loading and loss of recreational amenity;*
  - *sedimentation of the lake requiring on-going dredging of acid sulphate soils;*
  - *transition state of lake from estuarine to freshwater resulting in release of sulfur and other elements;*
  - *pollutant loads from diffuse sources which will continue particularly in light of irrigation development in the catchment and fast dairy industry expansion; and*
  - *implications of the possible exposure of Potential Acid Sulfate Soils.*
- *Ecology*
  - *threats to listed species including (but not limited to); Australian grayling, green and gold frog, swamp paperbark and saltmarsh communities;*
  - *major expansion of habitat for the DPIPWE listed invasive freshwater species Gambusia (currently isolated in Tasmania at the Tamar Island Wetlands and several adjacent connected waterways);*
  - *loss of regularly exposed mudflats to support feeding by shore birds;*
  - *implications for marine biodiversity hotspot at Low Head including soft coral reefs, seahorses, kelp forests, etc. resulting from a changed flocculation zone to further downstream; and*
  - *implications on the ecology of the estuary and region resulting from a substantial alteration of the extent of the estuary.*
- *Hydrology and sedimentation:*
  - *ability of the barrage to alleviate sedimentation impacts on the upper estuary and impacts below the barrage due to change in truncated tidal prism and flocculation zone;*
  - *potential impacts due to hydrological changes e.g. flood risk; and*
  - *residence time of lake water and potential to 'trap sediment, nutrient and other pollutants'.*
- *Climate change:*
  - *implications of a barrage in relation to predicted climate change projections, sea level rise and expected increased sediment loss from the catchment.*
- *Geomorphology:*
  - *increased wind generated wave action causing erosion of banks on lake'*.

The impacts of a barrage on water quality will occur over several time scales. In the initial construction phase there are risks of sediment and other pollutants being mobilised from the construction site, potentially smothering downstream environments including sponge gardens and seagrass beds. Once the barrage is operational the current saline environment of the middle and upper estuary (depending on the placement of the barrage) will become freshwater. The intertidal zone will also be flooded and subject to a relatively constant water level. Species of plants in the intertidal zone that depend on a saline tidal environment such as rice grass and saltmarsh will die off, leading to a large pulse of nutrients into the system and potentially leaching of nutrients and other pollutants such as heavy metals currently bound in intertidal sediments and vegetation into the water column. Reduced flushing combined with lower salinity and increased nutrient loads will increase the risk of algal blooms and be associated with decreased dissolved oxygen. There is also a risk of monosulfidic black ooze (MBO) developing in parts of the lake. MBOs are black gel-like materials with an oily appearance which can form thick (greater than 1 m) accumulations within acid sulphate soil landscapes (Sullivan and Bush, 2002). Monosulfidic black oozes generally also have a distinct ‘rotten egg’ gas odour resulting from the reduction of sulfate to hydrogen sulfide (H_2S). Sullivan *et al.* (2018) note that MBOs can accumulate in large quantities in slow flowing waterways and wetlands affected by one or a combination of acid sulfate soil processes, eutrophication and salinisation. Page and Thorp (2010) state that MBOs can occur in low energy environments including ‘freshwater drains and watercourses, or on the floor of sheltered bays, coastal lagoons and estuaries’. Sullivan *et al.* (2012) notes that MBO accumulation has only recently been recognised as a process that presents severe environmental hazard with disturbance of MBOs by flood flows or boat traffic leading to deoxygenation of water, severe acidification and the release of toxicants such as heavy metals, metalloids such as arsenic and high levels of nutrients into the water column. These types of events can lead to fish kills. Even with tidal flushing, the Yacht Basin is a relatively low energy area of the estuary under low flow conditions. Removal of tidal flushing from this zone would increase the risk of MBOs forming in this area which would then be disturbed during high flow events down the Cataract Gorge releasing a range of pollutants and odours.

Tamar Lake Inc. commissioned a study into water quality impacts of the barrage by BMT WBM (2016) using a hydrodynamic model of the estuary. This study found *‘the proposed lake presents water quality behaviour that is consistent with that often observed and modelled in deep fresh (usually water supply) water bodies. This includes the following broad attributes:*

- *Strong summertime thermal stratification. This is the fundamental issue at the heart of the water quality dynamics predicted by the model, leading to the risk of algal blooms and reduced dissolved oxygen.*
- *Significant subsequent depletion of dissolved oxygen at depth, with the development of ecologically toxic anoxic waters.*
- *Remineralisation of organic matter within and on top of bottom sediments – this occurs to distances of several kilometres upstream of the barrage.*
- *Supply of nutrients to the water surface where their abundance, together with light and warm temperatures leads to significant primary production and algal activity’.*

Tamar Lake Inc. commissioned a further study into potential measures to destratify the lake waters to reduce the risk of algal blooms but found 'that because the size and depth of the Tamar Lake, the effectiveness of these measures would be limited, and the capital and running cost too prohibitive to consider this as a solution to the destratification requirements'[15]. This modelling study assumed that base flows down Cataract Gorge could be increased from 2.5 cumecs to 10 - 20 cumecs to increase flushing of this area and promote movement of sediments out of the Yacht Basin and Home Reach with the justification that 'the huge economic benefits from the Tamar Lake implementation more than justifies the loss of between 1 to 2 percent of the state's hydro generating capacity'. Figure 48 shows the maximum potential flow release down the Cataract Gorge based on releases through the Tailrace and Cataract Gorge flows with the y-axis capped at 20 cumecs based on average daily flows. This figure shows that there are very substantial periods of time where an environmental flow of 20 cumecs is not possible. For example, during the dry period between January 2008 and June 2009 combined flows were less than 20 cumecs for over 40 percent of days. From March to May 2008 there were 63 days where flows were less than 20 cumecs for all except three isolated days. Between January and early June 2009 out of 152 days there were 124 (82 percent) where combined flows were below 20 cumecs, with many of these below 10 cumecs. Delivery of environmental flows of this magnitude is essentially infeasible during dry periods which is when pressures on lake water quality from high temperatures and stratification are likely to be greatest. Even if this level of environmental flow were possible it would come a very substantial cost. This means that long periods of low flows down Cataract Gorge into the Yacht Basin can be expected to coincide generally with high temperature drought conditions. This combination could be expected to promote the development of Monosulfidic Black Ooze (MBOs) in this area as well as increase the risk of algal blooms in the upper estuary.

[15] Note that this estimate was made by Tamar Lake and has not been validated in this study.

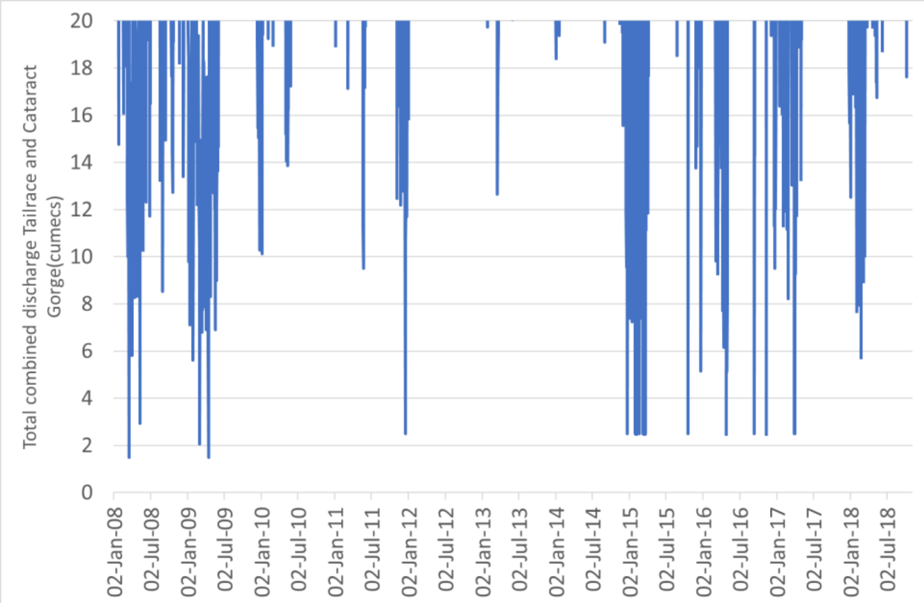


Figure 48. Combined flows from the Tailrace and down Cataract Gorge representing maximum feasible Cataract Gorge flows (cumecs). Note y-axis scale is capped at 20 cumecs to illustrate periods below Tamar Lake Inc. recommended minimum Cataract Gorge flows.

The framework for considering environmental impacts of sedimentation management options used in this report (see Section 4) shows the interrelations between water quality, the intertidal zone and flora and fauna species. Construction of a freshwater lake can be expected to impact on ecological values through:

- construction of a barrier to the movement of migratory fish;
- degraded water quality including increased nutrients and toxicants and reduced dissolved oxygen;
- a change from brackish/saline to freshwater that disadvantages species requiring an estuarine environment;
- a loss of intertidal habitat and the species that depend on it within the lake;
- degradation of downstream intertidal habitats and geomorphologies such as sand/gravel and boulder beaches, as was seen with the Elwha dam; and
- changes in subtidal habitat and communities both within the lake and downstream.

Estuaries are acknowledged to be key areas of biodiversity, providing a diverse range of habitats that underpin both environmentally and economically important values such a fisheries (for example the kanamaluka/Tamar estuary is acknowledged as an important shark and ray nursery). Man-made freshwater lakes are not associated with the same range of values and tend to promote and advantage weed and pest species over native flora and fauna species. For example, Havel *et al.* (2015) state that one key factor in the success of invasive species is the extent and diversity of native species in the environment and that reservoirs provide a stepping-stone to other uninvaded habitats as well as being more prone to invasion due to their altered habitats. The presence of populations of *Gambusia* in the Tamar wetlands and the North Esk along with significant habitat alteration through conversion of the estuary into a freshwater system would create an ideal environment for growth in *Gambusia* populations and upstream range extension as well as other aquatic pest and weed species.

The intertidal zone along the kanamaluka/Tamar estuary contains saltmarsh, a federally listed threatened ecological community, and state listed *Melaleuca ericifolia* threatened vegetation community. Salter *et al.* (2010) found that flooding with freshwater prohibits establishment of *M. ericifolia*, implying that conversion of the intertidal zone to a continuously flooded freshwater environment is likely to have significant impacts on the survival of *M. ericifolia* communities and the plant and animal species that depend on them for habitat. Saltmarsh communities depend on both salinity and intermittent flooding and drying cycles and will be lost if subject to a regime of continuous freshwater flooding. Prahalad *et al.* (2018) found that Tasmanian saltmarshes provide the highest density of fish of all Australian studies of saltmarsh and that saltmarshes provide important habitat for many fish species, including those of recreational and commercial significance. This means that the loss of saltmarsh communities can also be expected to impact on fish (including recreational and commercially important species) and invertebrates and the birds that depend on them for food, including a range of EPBC listed migratory and threatened species.

The extent, location and magnitude of impacts of barrage on the estuary would depend to on the location of the barrage. Table 28 summarises the likely impacts of three potential barrage options on key environmental values.

Table 28.Key environmental impacts of construction and maintenance of a barrage or weir in the upper estuary.

Environmental values	**North Esk weir**	**Small lake**	**Large lake**
Water quality	Loss of flushing exchange with the estuary and loss of estuarine processes.	Degraded water quality for the extent of the small lake: low dissolved oxygen, increased risks of algal blooms, potential for MBOs to accumulate with impacts of acidification, dissolved oxygen and toxicants, potential high pathogen concentrations; increased turbidity and sedimentation of the estuary below the barrage.	Severely degraded water quality for the extent of the large lake: low dissolved oxygen, increased risks of algal blooms, potential for MBOs to accumulate with impacts of acidification, dissolved oxygen and toxicants, potential high pathogen concentrations; increased turbidity and sedimentation of the estuary below the barrage.
Intertidal habitats	Loss of intertidal habitats upstream of the weir, downstream intertidal habitat impacted by changes in morphology due to changes in sediment delivery, tidal flushing and tidal prism.	Loss of intertidal habitats and salt and brackish environments upstream of the barrage, downstream intertidal habitat impacted by changes in morphology due to changes in sediment delivery, tidal flushing and tidal prism.	Loss of intertidal habitats and salt and brackish environments upstream of the barrage, downstream intertidal habitat impacted by changes in morphology due to changes in sediment delivery, tidal flushing and tidal prism.
Subtidal habitats	Subtidal habitats upstream of barrage modified by change from estuarine to freshwater Downstream of the weir impacted by changes in geomorphology, tidal prism and tidal flushing.	Subtidal habitats upstream of barrage modified by the change from saline to freshwater, downstream of the barrage impacted by changes in geomorphology, tidal prism and tidal flushing: potential sediment smothering rocky reefs and seagrass beds in some areas, potential increase in coastal erosion in others.	Subtidal habitats upstream of the barrage modified by change from saline to freshwater, downstream of the barrage impacted by changes in geomorphology, tidal prism and tidal flushing: potential sediment smothering rocky reefs and seagrass beds in some areas, potential increase in coastal erosion in others.
Migratory fish	Barriers to movement through barrage, loss of food sources through loss of intertidal habitat and food web, degraded water quality and low dissolved oxygen cause fish kills and loss of habitat.	Barriers to movement through the barrage, loss of food sources through loss of intertidal habitat and food web, degraded water quality and low dissolved oxygen cause fish kills and loss of habitat.	Barriers to movement through the barrage, loss of food sources through loss of intertidal habitat and food web, degraded water quality and low dissolved oxygen cause fish kills and loss of habitat.

Threatened flora, fauna, vegetation communities and ecological communities	Loss of tidal wetlands (threatened vegetation community). Australian grayling: impacted by barriers to movement, degraded water quality, loss of intertidal zone and food web, potential increase in pest species such as *Gambusia*. Australasian bittern, great crested grebe, curlew sandpiper, white bellied sea eagle: impacted by loss of food sources through degraded water quality and loss of habitat.	Saltmarsh: 57.7 ha of saltmarsh communities will die off with change to freshwater and lack of tide (Ti Tree Bend to Freshwater Point). Saltmarsh communities downstream of the barrage will be impacted by changes in geomorphology. Australian grayling: impacted by barriers to movement, degraded water quality, loss of intertidal zone and food web, potential increase in pest species such as *Gambusia*. Australasian bittern, great crested grebe, curlew sandpiper, white bellied sea eagle: impacted by loss of food sources through degraded water quality and loss of habitat.	Saltmarsh: 110 ha of saltmarsh communities die off with change to freshwater and lack of tide (Ti Tree Bend to Rowella). Saltmarsh communities downstream of the barrage will be impacted by changes in geomorphology. Australian grayling: impacted by barriers to movement, degraded water quality, loss of intertidal zone and food web, potential increase in pest species such as *Gambusia*. Australasian bittern, great crested grebe, curlew sandpiper, white bellied sea eagle: impacted by loss of food sources through degraded water quality and loss of habitat.
Migratory birds	The critically endangered Australasian bittern known to occur in the North Esk River floodplain. These would be impacted by the loss of intertidal zone and degraded water quality which would reduce habitat and food sources.	16 species of migratory birds are listed as being found in the KBA/IBA from Launceston to Batman Bridge. These would be impacted by the loss of intertidal zone and degraded water quality which would reduce habitat and food sources.	16 species of migratory birds are listed as being found in the KBA/IBA from Launceston to Batman Bridge. These would be impacted by the loss of intertidal zone and degraded water quality which would reduce habitat and food sources.

Reserves and conservation areas	Tamar River Conservation Area impacted – Conservation Area extends up the North Esk River to Johnson's Road Bridge at St Leonards.	Tamar River Conservation Area and Tamar Island reserve impacted.	Tamar River Conservation Area and Tamar Island reserve severely impacted (entire Tamar Conservation Area converted from estuary to freshwater lake). Native Point Nature Reserve impacted. Potential impacts on downstream reserves and conservation areas through changes in geomorphology, coastal erosion, sea level rise and associated storm surge.
Key Biodiversity Area/Important Bird Area	KBA/IBA would be partially converted to a freshwater lake with many listed values impacted. Loss of intertidal habitats would have an impact on KBA/IBA values.	KBA/IBA would be partially converted to a freshwater lake with many listed values impacted. Loss of intertidal habitats and Tamar Island wetland would shave significant impacts on KBA/IBA values.	IBA would be converted to a freshwater lake with listed values impacted. Likely loss of KBA/IBA status.

13.6 Impacts on recreation and navigation

Changes in bathymetry and water quality with barrage and weir proposals will have impacts on recreational and tourism users of the estuary, that are summarised in Table 29. Decay of vegetation and potentially processes associated with potential acid sulphate soils and development of monosulfidic black ooze will produce odours which may also impact on recreational and aesthetic values of the estuary. The nature and location of these impacts is uncertain and they are not included in the table.

Table 29. Impacts of barrage and weir options on key recreational and tourism users of the upper kanamaluka/Tamar estuary

User	North Esk weir	Small lake	Large lake
Rowing – Access to North Esk from pontoons and navigability of the North Esk	Constant water level in the North Esk offset by sedimentation behind weir which may reduce channel depth; lock system required to access main estuary will impact on speed of access to rowing channels; potential loss of channel depth in lower North Esk and increased sediment deposition in Home Reach due to loss of North Esk tidal prism; potential for degraded water quality to impact on recreational safety for secondary contact activities.	Constant water level may improve access to rowing channel from pontoons under some conditions; degraded water quality may impact on recreational safety for secondary contact activities.	Constant water level may improve access to rowing channel from pontoons; degraded water quality may impact on recreational safety for secondary contact activities.
Tamar Rowing Club	Potential loss of channel depth and access in Home Reach due to increased sedimentation from loss of North Esk tidal prism.	Constant water level may improve access to rowing channel from pontoons; degraded water quality may impact on recreational safety for secondary contact activities.	Constant water level will improve access to rowing channel from pontoons; degraded water quality may impact on recreational safety for secondary contact activities.

Home Point tourist boats	Potential loss of channel depth in Home Reach due to increased sedimentation from loss of North Esk tidal prism.	Current channel is sufficient for navigation from Home Point. Constant water level may provide continued access but infill from slumping of current mudflats into the channel and deposition of large debris during floods may lead to loss of channel depth in the medium to long term. Access past Freshwater Point requires navigation of lock system.	Current channel is sufficient for navigation from Home Point. Constant water level may provide continued access but infill from slumping of current mudflats into the channel and deposition of large debris during floods may lead to loss of channel depth in the medium to long term.
Seaport Marina	Constant water level may improve navigability in short to medium term. Medium to long term: potential loss of channel depth in North Esk and increase in sediment accumulation in marina as sedimentation and deposition of large debris during floods occurs behind weir; access to main estuary channel would require a lock with subsequent delays in access.	Constant water level may improve navigability from marina to main estuary in short term. Medium to long term: potential loss of channel depth in North Esk as existing mudflats slump into channel, sedimentation and deposition of large debris during floods occurs behind barrage; degraded water quality may impact on recreational safety for secondary contact activities; access to lower middle and lower estuary would require a lock system.	Constant water level may improve navigability from marina to main estuary in short term. Medium to long term: potential loss of channel depth in North Esk as existing mudflats slump into channel sedimentation and deposition of large debris during floods occurs behind barrage; degraded water quality may impact on recreational safety for secondary contact activities; access to lower middle and lower estuary would require a lock system.
Tamar Yacht Club	Potential loss of channel depth in Home Reach due to increased sedimentation from loss of North Esk tidal prism.	Constant water level may improve navigability from facilities to main estuary; degraded water quality may impact on recreational safety for secondary contact activities; access to middle and lower estuary would require a lock system; some loss of channel depth may occur as sediment in current mudflats slumps into main channel and large debris is deposited during floods.	Constant water level may improve navigability from facilities to main estuary channel; degraded water quality may impact on recreational safety for secondary contact activities; access to lower middle and lower estuary would require a lock system; some loss of channel depth may occur as sediment in current mudflats slumps into main channel and large debris is deposited during floods.

Recreational fishers	Minimal impact given limited impact on intertidal zone habitats.	Loss of saltmarsh and estuarine environment will likely reduce estuary and marine fish stocks impacting on recreational and commercial fishers (smaller impact than large lake); poor lake water quality and impacts on fish species will limit recreational fishing opportunities in the lake. Pest fish species such as *Gambusia*, redfin perch, tench and goldfish will compete with trout and are likely to limit its success.	Loss of saltmarsh and estuarine environment will likely reduce estuary and marine fish stocks impacting on recreational and commercial fishers (large loss of estuarine habitat); poor lake water quality and impacts on fish species will limit recreational fishing opportunities in the lake. Pest fish species such as *Gambusia*, redfin perch, tench and goldfish will compete with trout and are likely to limit its success.

13.7 Summary and key findings

Evaluation of proposed barrages and weirs present several legislative and feasibility challenges, major changes in sediment dynamics, varied impacts on flood risk, and broad scale and extreme negative impacts on the environment, at a substantial cost. The scale and nature of these depends to some extent on whether the weir is on the North Esk or on the main kanamaluka/Tamar estuary. Recreational benefits are likely to be offset by poor water quality, making the lake unsafe for primary and secondary contact activities, and odours associated with rotting vegetation, algal blooms and potentially monosulfidic black ooze.

13.7.1 North Esk weir

- The North Esk weir is likely to increase flood levels above the weir, impacting on risks to Invermay, the Central Business District (CBD) and Newstead. Risks are greatest to areas currently not protected by the flood levee system but still exist where levees are in place.
- The impacts of the weir and constant water levels in the lower North Esk on the levee system are not well understood. There is a potential for changes in the water table to impact on levee stability.
- The weir is likely to increase sedimentation in Home Reach and areas past Ti Tree Bend as the tidal prism is significantly reduced by the loss of the North Esk floodplain.
- Recreational users are likely to be impacted by restricted access to the main estuary from the North Esk (e.g., requiring navigation through a lock system) and by increased sedimentation in Home Reach. In the short term there is likely to be improved access from the foreshore to the channel but over time infill of the channel through sedimentation behind the weir and deposition of large debris during peak flows may impact on navigation.

- Environmental impacts can be expected from restricted movement of migratory fish and changes to sedimentation below the weir.
- Previous cost estimates of $25 million are out of date and don't include operational costs for operating the lock system and any flood mitigation measures associated with the weir.

13.7.2 Large and small Tamar lake options

There are significant feasibility and legislative challenges associated with both the large and small Tamar lake options. Proposed economic benefits are also doubtful based on other projects of a similar nature and the limited basis of costs included in the proposals (which exclude ongoing operational costs of locks and flood gates, any destratification measures and maintenance costs):

- Legislative constraints are associated with the large scale and significant environmental impacts of these proposals, which would require permitting under various pieces of state and federal legislation.
- Feasibility constraints are associated with the appropriate handling of dredge spoil during construction, engineering complexities of constructing weirs or barrages in estuaries, availability of additional flows and economic impacts from lost power generation.
- Downstream impacts are likely to include increased sediment accumulation immediately below the barrage and increased coastal erosion further downstream, as well as increased impacts of sea level rise and storm surge.
- Costs are very large and the assumptions for calculating claimed benefits are not available and difficult to substantiate.
- Proposals may result in improved navigational access to the channel from the foreshore in the short term, but not in the long-term due to ongoing sedimentation behind the barrage and potential infill of channels through mudflats slumping into the channel, sediment deposition and deposition of large debris during peak flows.
- Recreational users are also likely to be impacted by poor water quality in the lake which may impact on the safety of secondary contact activities. Those using the lake or boating activities would also need to navigate a lock system to move between the upper and lower estuary.
- Flood impacts are not well understood and would require comprehensive assessment of a broad range of flood events. Impacts would differ between levee protected and on-levee protected areas. Reduced flood levels are most likely for small scale floods for which Launceston is already protected by a flood levee system.
- It is likely that flood control measures such as flood gates on the barrage will fail at some point leading to significant flood impacts. In a flood which exceeds the capacity of the barrage system to mitigate flooding (it is unknown the AEP of this event) the barrage will increase flood levels upstream at Launceston. The effects of increased

water table levels in Invermay is not well understood but will potentially reduce the load bearing of soils in this area, impacting on existing flood levees and other buildings in the suburb.

- Environmental impacts of the lake(s) can be categorised as extreme. Substantial and broad scale negative impacts on water quality would occur during construction and operation, as well as destruction of various threatened species and communities, migratory birds, impacts on reserve status and biodiversity, and negative impacts on ecosystem functions.

14 Management option - sediment raking

Sediment raking is the process of disturbing bottom sediments using a raking implement such as a scallop dredge (as was used in the most recent sediment raking program in the estuary), suspending sediments into the water column with the intention that disturbed sediments are carried on either outgoing tides or river flows out of the upper estuary[16]. A second sediment raking activity that has been used in the estuary is 'prop washing' that was used under the Seaport Marina. This action involves tying off a large vessel to the marina and using the propeller at speed to disturb sediments.

This section considers the impacts of a range of sediment raking options. These options are:

- prop washing of the Seaport Marina;
- sediment raking of mudflats;
- sediment raking of channels in low flow conditions; and
- sediment raking of channels in high flow conditions.

A sediment raking program was conducted from 2013 to 2019 that included a mix of all raking options. This section breaks sediment raking activities into these separate actions to consider the impacts of each piece to inform decision making around the range of alternatives a future program could consider. The alternatives capture the key elements of sediment raking activities currently being proposed by some members of the community.

14.1 Legislative and feasibility challenges

14.1.1 Legislative and permit requirements

Sediment raking activities are known to impact on water quality through the suspension of sediment and attached toxicants and nutrients into the water column. Sediment raking is subject to the issuing of a permit by the Tasmania Parks and Wildlife Service, with conditions informed by the EPA. It is expected that any permit would require an assessment of water quality and aquatic ecology impacts of the raking activity as well as evidence of the likely effectiveness of the activity in achieving sedimentation management objectives. The permit for sediment raking under which the previous sediment raking campaign was conducted has ceased. The findings of a review of the program (Kelly, 2019) informed the decision not to apply for renewal of this permit. The review found:

- Sediment raking did not reduce overall sediment levels in the upper estuary long-term. Any reductions in sediment were temporary and sediment returned rapidly rising to higher levels than previously. This means that sediment raking is also unlikely to reduce flood risks in the upper estuary.
- Sediment raking led to significant infill of channels with large impacts on navigability, particularly around Home Point into the Yacht Basin.

[16] Note that from the 1960s to the 1980s the Port of Launceston Authority raked with a specially constructed steel frame (an oversize ladder) towed behind the PLA tugboat.

- Sediment raking had significant adverse impacts on water quality that extended into the lower estuary (at least as far as Clarence Point) for weeks after raking activities ceased. The concentrations of toxicants such as aluminium and arsenic and dissolved nutrients increased significantly, and it was associated with impacts on ecosystem health.

It can be expected that any permit for a new campaign would need to demonstrate that raking would not impact on navigation and the environment.

14.1.2 Feasibility challenges

Sediment raking has been practiced in the estuary before. Apart from the legislative and permitting requirements there are no other substantial feasibility constraints of this option.

14.2 Estimated costs

Previous sediment raking campaigns cost approximately $5,000 per day of raking. Additional costs would be associated with water quality monitoring and bathymetric surveys required to assess the impacts of any program. The full cost of any program would depend on the number of days of raking that were undertaken each year.

14.3 Impacts on bathymetry, visible mudflats and navigation

Impacts on bathymetry would depend on the target areas and timing for raking activities. These are described below for each of the sediment raking options.

14.3.1 Prop washing of the Seaport Marina

Detailed bathymetry data collected before and after a prop washing campaign held in 2019 provides good information on the impacts of this activity. Figure 49 shows the change in depth between bathymetric surveys undertaken before (30 April) and after (31 May) a prop washing campaign that was conducted in 2019. Green areas are those where depth of water increased while red areas were subject to a loss of depth. Note that only the first two bays were prop washed before the second survey. An additional survey was conducted at the completion of the marina prop washing (June 2019).

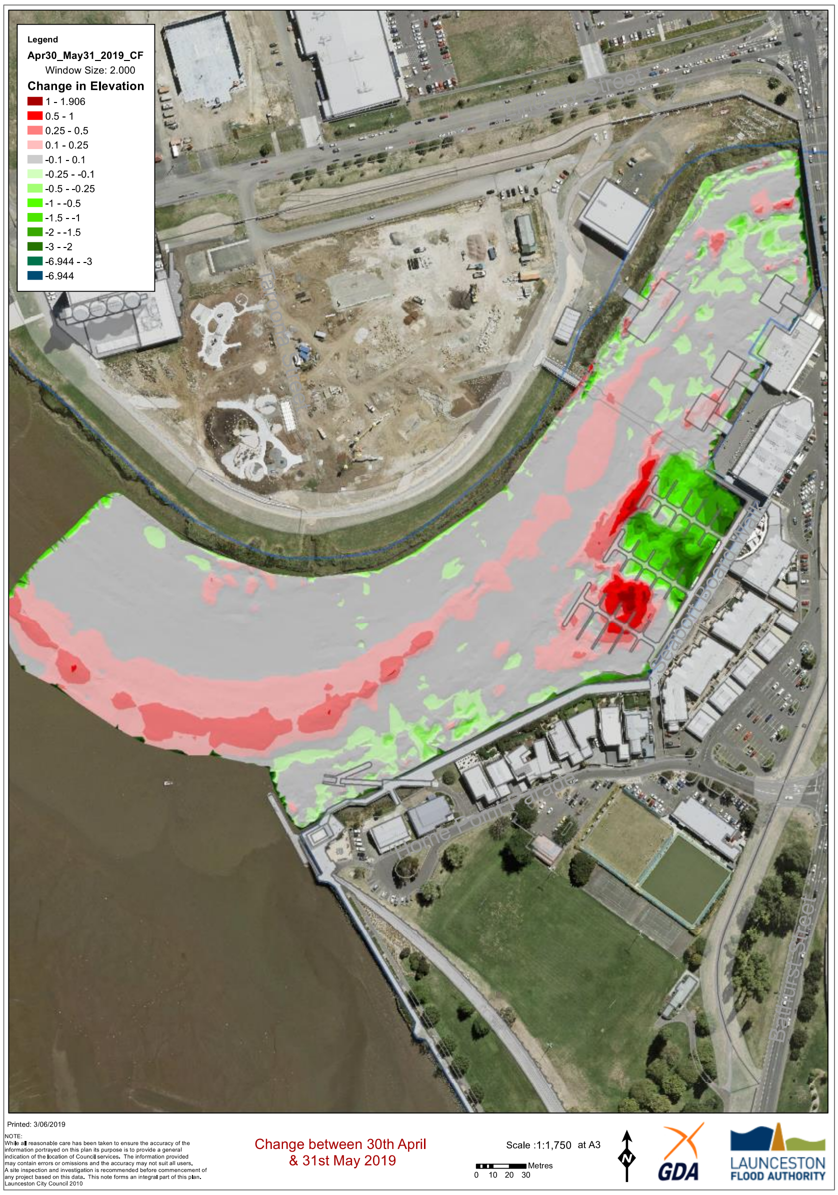


Figure 49. Effects of prop washing in the Seaport Marina on bathymetry in the lower North Esk between 30 April and 31 May 2019 shown as difference in depth. Red areas show a loss of depth with green areas having increased depth. Note that prop washing on this occasion ceased before the third bay was prop washed as the additional prop washing required days greater than the permit conditions allowed.

As expected, the bays in the Seaport Marina where prop washing occurred experienced a significant increase in water depth of 1.5-2 m. Most of the disturbed sediment settled in the channel of the lower North Esk. There was a loss of depth of 0.5-2 m at the edge of the prop washed bays through which boats in those bays would need to navigate in order to access the channel. The mid-program survey indicated that 90 percent of the sediment disturbed by prop washing remained within the surveyed area. A further survey undertaken in June 2019 showed areas of significant deposition at Town Point and along Home Reach. Thus while prop washing did lead to water under bays in the Seaport Marina at low tide, it did this at the cost of channel depth, access to the channel from the prop washed bays and the increased extent and height of the mudflat at Town Point, at the confluence of the North

Esk and main Tamar estuary. Additional agitation of sediments to resuspend sediments from the channels was outside of the permitted days for raking.

14.3.2 Sediment raking of mudflats

The sediment raking program of 2013 to 2019 focused heavily on raking of the mudflats to bring them below the low tide level so as to reduce their visibility. The sediment raking review (Kelly, 2019) showed clear evidence that much of the sediment raked out of mudflats settled in the adjacent channel. Figure 50 shows the average level of sediment in the channel near Home Point and Town Point covering 3 periods: 1) before sediment raking, 2) during sediment raking before the 2016 flood, and 3) during sediment raking after the 2016 flood.

This figure shows that sediment raking led to a sustained increase in sediment levels in this section of the channel with an average loss of depth of at least 0.5 m. The 2016 flood was a large flood for both the North Esk and South Esk Rivers and could be expected to induce major scour in the channels, however even this event failed to reduce channel sediment levels back to their pre-raking levels with minimum depths at least half a metre shallower than before raking began.

Sediment levels on the mudflats, which before raking were very stable, dropped rapidly with the commencement of raking but did experience sharp increases between raking events as shown in Figure 51. Continued raking efforts were able to sustain mudflats at a lower level than pre-raking.

a) time series of channel depth

b) percentiles of sediment

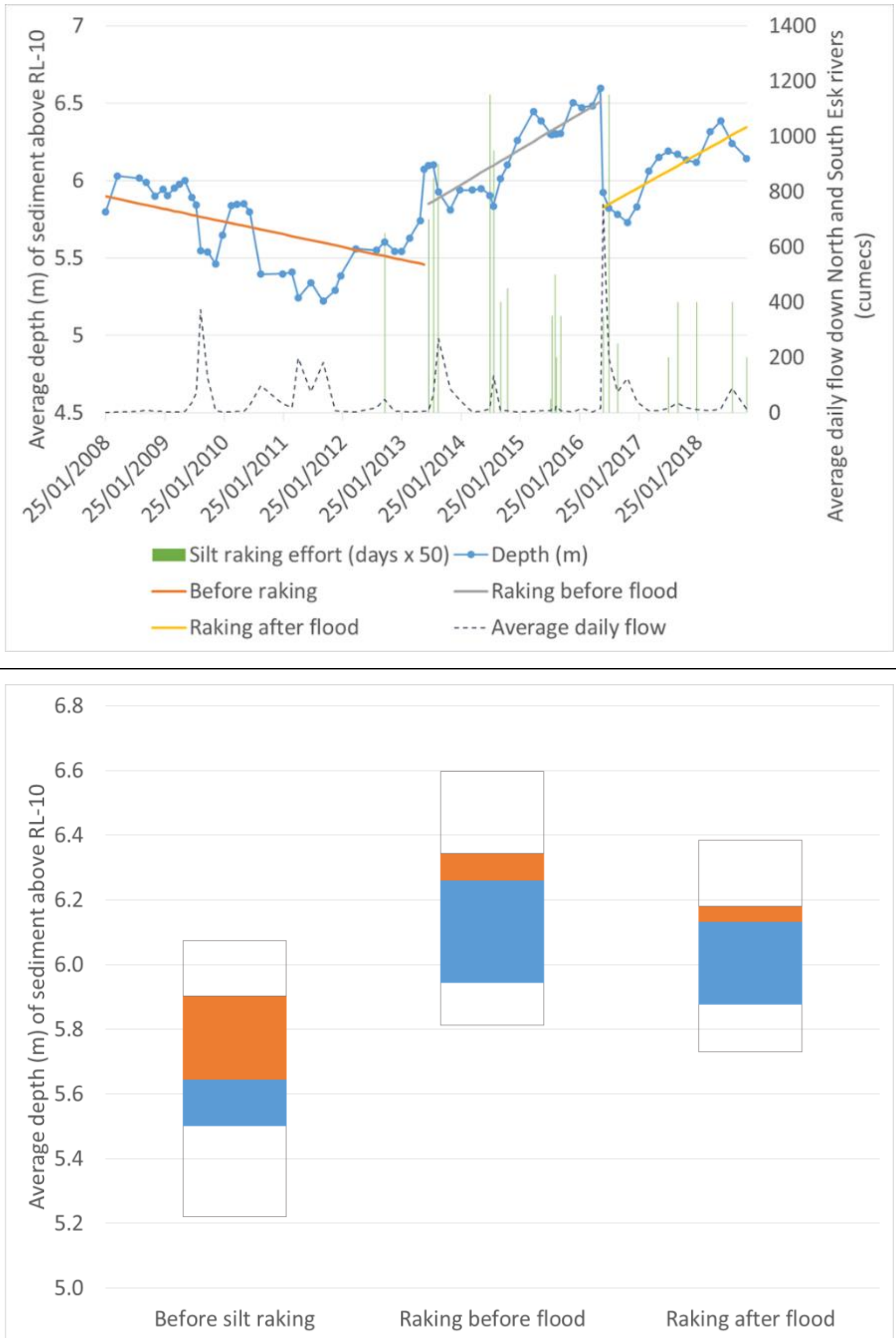


Figure 50. Impacts of sediment raking on sediment levels in the channel around the Home Point and Town Point a) time series of average channel depth versus raking effort and average daily flows in the period, showing linear trend of sediment levels in each period b) median (where orange and blue sections meet), 25th (bottom of blue box) and 75th percentile (top of orange box) and range (extremes of clear boxes) of sediment levels in pre- and post-raking periods before and after the 2016 flood (Kelly, 2019).

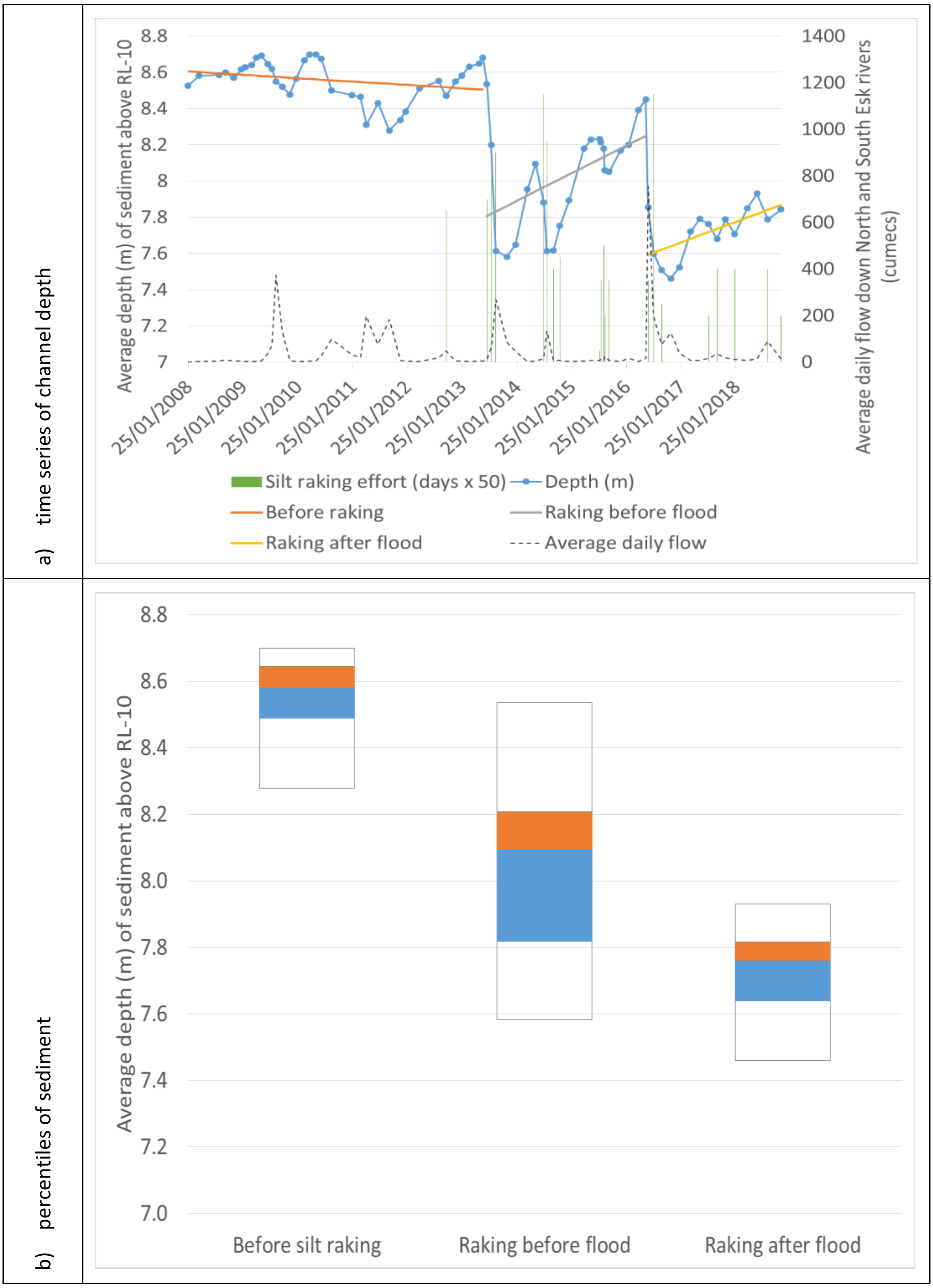


Figure 51. Impacts of sediment raking on sediment levels in the West Tamar mudflats a) time series of average channel depth versus raking effort and average daily flows in the period, showing linear trend of sediment levels in each period b) median (where orange and blue sections meet), 25th (bottom of blue box) and 75th percentile (top of orange box) and range (extremes of clear boxes) of sediment levels in pre- and post-raking periods before and after the 2016 flood (Kelly, 2019).

Devlin (2019) used a 3-dimensional hydrodynamic model of the estuary to consider the effects of sediment raking of the West Tamar shoal under various flow regimes through Cataract Gorge. Similar to the results described above, this report found that sediment raking of the mudflats essentially infills the channels. They also found raking mudflats under low flow conditions increased sediment levels around Royal Park and in the North Esk and Seaport. There was a greater total volume of sediment in the upper estuary after raking than without raking under baseflow (2.5 cumec environmental flows only) conditions. Sediment raking of the mudflats under higher flow conditions (a natural spill event of approx. 138 cumecs) did move some sediment out of the estuary above Ti Tree Bend, but this all returned within three months. Almost half the sediment mobilised from the mudflats in this scenario settled immediately in adjacent channels.

The recent sediment raking campaign focused on the mudflats has left the mudflats looking 'tidier' with significantly less visible debris.

14.3.3 Sediment raking of channels in low flow conditions

Edwards (1983) summarises the results of previous efforts to use sediment raking to maintain or restore channel depths in the estuary. After dredging ceased in the mid-1960's, raking was used in Home Reach and areas further down the estuary in an attempt to improve scour and maintain depths between large flow events. No sounding data, with and without raking, was available to assess the influence of raking on depth, but the observations of tugboat masters who undertook the work of raking were used. Edwards found that raking on the ebb tide alone was 'questionable' and did not appear to lead to any increase in channel depth. He found that flows of approximately 425 cumecs were 'sufficient to warrant raking and where deepening is urgently required raking is normally commenced at about this flow'. Flow velocities associated with tides only are not high enough to redistribute sediments downstream with incoming tides returning any disturbed sediments on the next tidal cycle. Destabilisation of channel sides using the sediment rake may lead to some slumping of sediments into the channel where raking occurs with low flows although the extent of such impacts is difficult to estimate. Overall, raking channels during low flows will not lead to deeper channels or reduced sedimentation in the upper estuary.

14.3.4 Sediment raking of channels in high flow conditions

Foster *et al.* (1986) found that flows greater than 150 cumecs are necessary to induce scour but that once critical scour velocity is exceeded, 'scour is rapid' with 'typical erosion rates being between 100 mm/hr and 200 mm/hr'. Edwards (1983) summarises the experience of raking campaigns from the mid-1960's to 1980's that were conducted in Home Reach, focused on increasing channel depth. This report found the minimum flow at which raking was warranted was approximately 425 cumecs with flows of 850 cumecs found to be 'most effective in achieving significant results' (by comparison the 20 percent AEP flood event is 1147 cumecs). These observations were made using the accounts of tugboat masters who had experience of raking the system and did not use any measurement of depth to provide an objective measure of the effectiveness of raking under these conditions versus the effectiveness of flows only. Analysis of data from 2008 to 2018 shows a total of five events with nine days of flow where flows were greater than 850 cumecs. Four of these events occurred within a two year window with nearly five years gap before the final event. There were 36 days with flows over 425 cumecs in this period in 13 separate events, with the longest gaps between events of this size two to three years long. Without objective data measuring the impact of raking channels in high flows, observations from Edwards on the flows required for raking to be of benefit and Foster on the rapid rate of scour once critical flow velocities are exceeded, raking the channel during high flow events is unlikely to lead to significant increases in channel depth beyond those that occur naturally. Sediment accumulation generally occurs during dry periods when peak flow events don't occur. Note that raking mudflats in the 2016 flood was associated with reduced benefits of scour on channel depth.

14.3.5 Summary of impacts on bathymetry

Table 30 summarises the likely impacts of various sediment raking activities on bathymetry.

Table 30. Likely impacts of 'sediment raking' on bathymetry.

Location	Prop washing	Raking the mudflats	Raking the channel in low flows	Raking the channel in high flows
Channels				
Lower North Esk	Infill channel.	No impact unless Town Point mudflat targeted. Raking in other areas has the potential to increase sediment accumulation in the lower North Esk.	No impact.	Minimal impact if targeted. No impact if outside target zone.
Yacht Basin	N/A	Infill channel.	No impact.	Minimal impact if targeted. No impact if outside target zone.
Home Reach	N/A	Infill channel.	No impact.	Minimal impact if targeted. No impact if outside target zone.
Mudflats				
Seaport Marina	Increase depth of water under boats in the Seaport Marina. Reduce access to channel from bays with sediment accumulation at end of bay. Reduced access to North Esk River with sediment accumulation at confluence.	Minimal impact – some potential increase in sediment if mobilised sediments are carried into the North Esk with the tide.	No impact.	No impact.
West Tamar	N/A	Reduce level of sediment in mudflats if raked.	No impact.	No impact.
Yacht Basin - Royal Park	N/A	Reduce level of sediment in mudflats if raked.	No impact.	No impact.
Town Point	Increase mudflat level and extent, loss of navigation channel at low tide.	Reduce level of sediment in mudflats if raked.	No impact.	No impact.

14.4 Impacts on flood risk

The sediment raking review (Kelly, 2019) found that the sediment raking program had led to no net decrease in sediment levels in the upper estuary. There was more sediment in the upper estuary immediately before the 2016 flood after sustained raking programs than at any time surveyed before raking. The 2016 flood induced significant levels of scour, although channel depths were not fully restored to pre-raking levels. WMAWater (2021) also found that flood levels were largely unaffected by pre-flood bathymetry given the large scour induced by flood events. The options here can be expected to have no impact on flood risk, either in combination or isolation.

14.5 Impacts on water quality and environmental values

The sediment raking review (Kelly, 2019) assessed the impacts of the previous raking program on water quality at both local (around the raking boat) and whole of estuary scales. This review showed that the raking program had significant impacts on water quality, particularly heavy metals and dissolved nutrients for at least three weeks after each day of raking and as far as Clarence Point. Immediate increases in heavy metals were in many cases very large, increasing concentrations well over default guideline values. The analysis also looked at the role of river flows in mediating or exacerbating these impacts and found that flow had a protective effect – raking in low flow conditions led to significantly worse water quality outcomes than raking in high flow conditions. Possible explanations for this observation are the dilution from increased flows or faster transport to marine waters decreasing time available for contaminants to be released as dissolved fraction from sediment particles. It should be noted that while tidal flows and low river inflows were not sufficient to move sediment out of the upper estuary, toxicants and dissolved nutrients mobilised by raking activities were carried by the tides all the way into the lower estuary. Impacts of the sediment raking options on environmental values are summarised in Table 31.

Table 31. Key environmental impacts of sediment raking options.

Environmental values	Prop washing	Raking the mudflats	Raking the channel in low flows	Raking the channel in high flows
Water quality	Decline in water quality through increase in turbidity, nutrients and heavy metals and any associated decreases in dissolved oxygen.	Estuary wide decline in water quality; increase in dissolved nutrients and heavy metals and any associated decreases in dissolved oxygen.	Estuary wide decline in water quality increase in dissolved nutrients and heavy metals, and any associated decreases in dissolved oxygen.	Minimal given high flow event likely to mobilise channel sediments without raking.

Intertidal habitats	Minimal. Some impact of declining water quality on aquatic fauna, both sessile and mobile.	Loss of intertidal habitat through removal of mudflats and destabilisation of intertidal vegetation. Impacts of declining water quality on aquatic fauna, both sessile and mobile.	Impacts of declining water quality on aquatic fauna, both sessile and mobile.	Minimal.
Subtidal habitats	Water quality impacts in localised subtidal habitat and fauna, both sessile and mobile. Smothering of subtidal habitat.	Water quality impacts on subtidal habitat and fauna, both sessile and mobile. Physical disturbance of raking; smothering of subtidal habitat.	Water quality impacts on subtidal habitat and fauna, both sessile and mobile.	Minimal.
Migratory fish	Impacted negatively by increase in toxicant and dissolved nutrient concentrations and any associated decreases in dissolved oxygen. Behaviour changes (predator avoidance) and gill scour due to elevated turbidity. Elevated turbidity may also prevent migration if raking activities occur during migration seasons.	Impacted negatively by increase in toxicant and dissolved nutrient concentrations and any associated decreases in dissolved oxygen. Behaviour changes (predator avoidance) and gill scour due to elevated turbidity. Elevated turbidity may also prevent migration if raking activities occur during migration seasons.	Impacted negatively by increase in toxicant and dissolved nutrient concentrations and any associated decreases in dissolved oxygen. Behaviour changes (predator avoidance) and gill scour due to elevated turbidity. Elevated turbidity may also prevent migration if raking activities occur during migration seasons.	Minimal.

Threatened flora, fauna, vegetation communities and ecological communities	Australian grayling likely impacted by increased toxicants and dissolved nutrients. Behaviour changes (predator avoidance) and gill scour due to elevated turbidity Elevated turbidity may also prevent migration if raking activities occur during migration seasons.	Australian grayling likely impacted by increased toxicants and dissolved nutrients. Behaviour changes (predator avoidance) and gill scour due to elevated turbidity. Elevated turbidity may also prevent migration if raking activities occur during migration seasons. Destabilisation of foreshore habitat for *M. ericifolia* and threatened reed species.	Australian grayling likely impacted by increased toxicants and dissolved nutrients. Behaviour changes (predator avoidance) and gill scour due to elevated turbidity. Elevated turbidity may also prevent migration if raking activities occur during migration seasons.	Minimal.
Migratory birds	Impacted by increase in toxicants in the food chain.	Impacted by increase in toxicants in the food chain and loss of mudflats and intertidal habitat.	Impacted by increase in toxicants in the food chain.	Minimal.
Reserves and conservation areas	Some impact on conservation values due to decline in water quality.	Impacts on conservation values due to decline in water quality and associated ecosystem impacts; to a lesser extent impact by the loss of intertidal habitat. Destabilisation of foreshore habitat for *M. ericifolia* and threatened reed species.	Impact on conservation values due to decline in water quality and associated ecosystem impacts.	No impact.
Key biodiversity area/Important Bird Area	Minor impact.	Moderate impact on KBA through impacts on migratory birds through toxicants and impacts on fish and invertebrate food sources; loss of mudflats and intertidal habitat.	Moderate impact on KBA through impacts migratory birds through toxicants and impacts on fish and invertebrate food sources.	No impact.

14.6 Impacts on recreation and navigation

Impacts on recreational users differ significantly between the sediment raking options (Table 32). These impacts arise out of changes in channel depth and associated navigability, access to shore-based facilities and changes in water quality.

Table 32. Impacts of raking options on key recreational and tourism users of the upper kanamaluka/Tamar estuary.

User	Prop washing	Raking the mudflats	Raking the channel in low flows	Raking the channel in high flows
Rowing: Access to North Esk from pontoons and navigability of the North Esk	Negative: Reduced navigability and channel depth in lower North Esk.	Mixed: potential loss of navigability in the Yacht Basin and Home Reach with channel infill; broad water with some depth over mudflats may benefit rowing.	No impact.	No impact.
Tamar Rowing Club	No impact.	Mixed: potential increase in access from pontoon to channel; some loss of channel depth but unlikely to be sufficient to impact rowing activities.	No impact.	No impact.
Home Point tourist boats	Moderate impact: may be some loss of channel depth around Town Point and channel to Home Reach; creation of barway at North Esk confluence.	Negative: channel infill. Previous program focused on mudflats saw boat stranded in the mud at low tide.	No impact.	No impact.
Seaport Marina	Mixed: increase water under bays at low tide; reduced access to the channel and mouth of the North Esk due to deposition at the end of bays and in the North Esk channel.	Minimal impact: potential increase in sedimentation due to sediments mobilised being carried up the North Esk and depositing in the marina at low tide.	No impact.	No impact.
Tamar Yacht Club	No impact.	Mixed: potential increase in access from facilities to channel; potential loss of navigability in the Yacht Basin and Home Reach with channel infill.	No impact.	No impact.
Recreational fishers	Negative: increase in toxicant and dissolved nutrient concentrations	Negative: increase in toxicant and dissolved nutrient concentrations	Negative: increase in toxicant and	No impact.

	potentially impact on fish stocks through chronic and acute toxicity.	likely to impact on fish stocks through chronic and acute toxicity.	dissolved nutrient concentrations likely to impact on fish stocks through chronic and acute toxicity.	

14.7 Summary and key findings

Several different options for sediment raking have been assessed:

- prop washing of the Seaport Marina;
- sediment raking of mudflats;
- sediment raking of channels in low flow conditions; and
- sediment raking of channels in high flow conditions.

It was found:

- None of these options were found to be able to move sediment out of the upper estuary long-term.
- Sediment raking of the mudflats can reduce the visible extent of mudflats in the upper estuary. Recent raking campaigns have made the mudflats that have re-established look ‘tidier’ with less visible debris.
- Options focused on the mudflats and Seaport Marina were found to have significant negative impacts on channel depth and navigability which have the potential to negatively impact on recreational and commercial users of the upper estuary.
- Sediment raking is known to impact significantly on water quality in terms of heavy metal and dissolved nutrient concentrations well into the lower estuary. Sediment raking during low flow conditions has the worst impacts on water quality.
- Water quality impacts are likely to be associated with very significant impacts on environmental values.
- Options which target mudflats also reduce intertidal habitat and have the potential to impact on migratory birds and other species that rely on them for food and habitat.
- Sediment raking would require a permit issued by the Tasmania Parks and Wildlife Service, with conditions informed by the EPA. It is likely that impacts on water quality and a lack of evidence of efficacy of sediment raking activities in achieving sedimentation management objectives would be challenges to a permit being issued.

15 Other community concept proposals

Community engagement and interest in sedimentation management in the kanamaluka/Tamar estuary has always been high. This interest has resulted in a large number of community generated proposals for managing sedimentation which have often been provided directly to members of state or local government. Many of these proposals build on other ideas evaluated in this report, such as weirs and canals but often incorporate a large number of elements. Proposals of this nature often lack the technical information that would be required to conduct a pre-feasibility assessment and are often based on a limited understanding of the natural processes of the estuary. Given that they often contain elements of other options considered in this report, many would face similar challenges and costs and have some of the same environmental impacts. The composite nature of some of the proposals mean that costs and challenges as well as environmental impacts from more than one option evaluated in this report would be faced were the option to be implemented. This section considers at a high level the costs, feasibility and impacts of other proposals that have been submitted to government by the community. Various other ideas have been suggested but are not captured here, such as pipelines along the length of the estuary utilising tidal flows to reduce sedimentation rates. These often lack a basic understanding of how the estuary works, and its values, and are not evaluated as there is a lack of detail that would allow such evaluation even at a conceptual level. Several proposals put forward by the community are conceptual and have not tested any feasibility assumptions in any detail. However, four proposals have been mapped out as concepts and provided directly to government for consideration, these are outlined below. Given the lack of technical information to fully consider these options this section focuses on a simpler conceptual evaluation of the proposed ideas.

15.1 Hard surfacing and channelisation of the upper estuary

This proposal involves installation of a concrete channel through existing wetlands, infilling existing areas of estuary, and installation of a bridge. Figure 52 shows the diagram provided to describe this option.

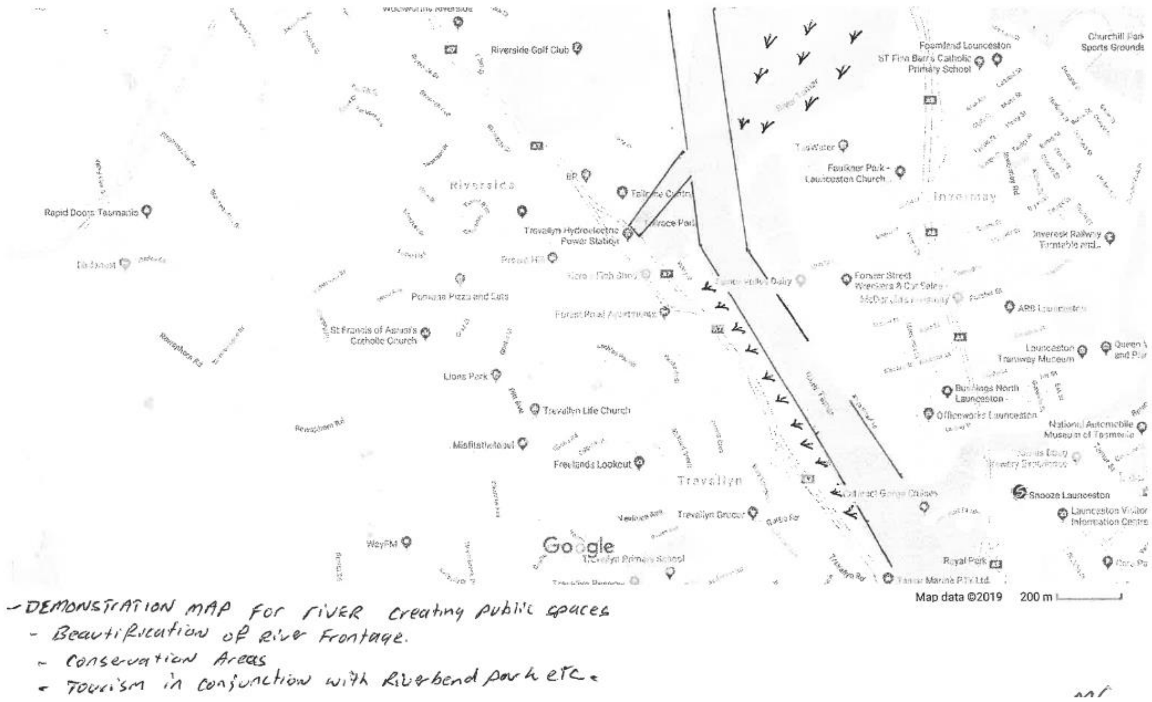


Figure 52. Concept drawing provided by a community member for hard surfacing and channelisation of the kanamaluka/Tamar estuary.

15.1.1 Legislation and feasibility challenges

Legislation and permitting required for this proposal has similarities to other proposals such as the Tailrace canal (Section 11) and lakes and barrages (Section 13).

There are also significant risks associated with large flood events having the potential to undermine any concrete structure where floods are not fully contained within the channel, potentially leading to parts of the channel breaking away and being pushed by floodwaters downstream.

15.1.2 Costs

The construction of a hardened channel in the kanamaluka/Tamar estuary would be very challenging. Construction projects in Invermay have required piling to depths of 40 m. It is expected that a hardened channel would require large numbers of piles or sheet piling sunk to a significant depth. For example, a 4.7 km channel that is 500 m wide would require in the order of 95,000 piles. At an assumed cost of $10,000 each the cost of piles alone for such a project would be close to $1 billion. This does not include the costs of actual channel construction, the costs of remediating or disposing of contaminated sediments that would need to be dredged to allow the channel to be constructed (acid sulphate soils with high heavy metal and nutrient concentrations – see dredging for treatment and disposal requirements). The volume of sediments that would need removal and treatment under this option substantially exceeds either of the dredging options considered in this report. There would be significant feasibility constraints imposed by land requirements for dewatering contaminated sediments and treatment of acid sulphate soils and disposal to landfill. It could be expected that multiple landfills the size of a new cell in the Launceston Waste Centre would be required to dispose of sediments removed for channel construction. It is expected that sediment would accumulate in such a channel over time and would require regular removal, imposing costs similar or greater than the dredging options outlined in this report. A detailed costing has not been developed but a simple assessment suggests costs well in excess of $1 billion for this option.

15.1.3 Impacts on bathymetry, visible mudflats and navigability

The upper estuary would have a fixed channel, though where sediment would be expected to build up due to sediment returning with the incoming tide or through delivery of sediment loads from the catchment is unknown. It is expected that mudflats would either be removed to install the channel or become a more consolidated foreshore. So long as the hardened channel is deep enough and removal of accumulated sediments occurs on a regular basis the hardened channel would potentially provide consistent navigability of Home Reach. It is unlikely to improve navigability into the North Esk and sedimentation would still occur in the Seaport Marina. It is possible that sedimentation in the lower North Esk could increase with fewer deposition areas around Home Reach and the Yacht Basin. There would also be a loss of tidal prism through infilling of areas around Ti Tree Bend which could be expected. This option could also be expected to increase deposition of sediments below the channel with increased mudflat formation and reduced channel width and depth likely to occur downstream of Stephenson’s Bend including around Legana and the Tamar Wetlands.

15.1.4 Impacts on flood risk

From a flooding perspective, if the same cross-sectional area of the estuary at high tide is maintained, the hydraulic conveyance will be increased which will likely result in a significant reduction in flood level in the channelised area. The lack of detail in this proposal means that impacts on flood risk are difficult to predict. This option would require modelling with the TUFLOW model to assess the reduction in flood level and impacts on flood risk further downstream where increased flow velocity could potentially lead to increased flood risks.

15.1.5 Impacts on water quality and environmental values

The intertidal zone including mudflats provides an important service in capturing and storing pollutants such as toxicants and recycling nutrients into the food chain. Removing mudflats and intertidal vegetation can be expected to lead to declining water quality as this ecosystem service is no longer provided. Construction of the hardened channel would be expected to have major negative impacts on water quality with bottom sediments resuspended with the consequence of very high levels of turbidity and resuspension of toxicants and other pollutants currently stored in the mudflats into the water column. Sediments removed for construction of any hardened channel would be acid sulphate and contaminated and would require the same treatment as dredged sediments and pose significant risks to water quality in the event of acid leachate reaching the estuary.

Construction of a hardened channel in the upper Tamar would be associated with very significant environmental impacts, both during the construction phase and on an ongoing basis. Natural values associated with the section of the estuary converted to a hardened channel would be removed with mudflats and intertidal zones removed as part of the construction and all benthic life forms would be lost. This would include loss of threatened vegetation communities (*Melaleuca ericifolia*) and the threatened species that rely on this habitat. As described in Appendix 1 the benthos underpins the food chain for all fish and wading birds using the upper estuary. Degraded water quality would also have significant impacts on a range of species including the threatened Australian grayling. It is expected that Australian grayling migration would be severely disrupted during construction of such a channel. The long-term impacts of the channel on migratory fish are unknown. Environmental impacts on the upper estuary of such a project can be expected to be extreme and may impact on the Key Biodiversity Area status of the estuary.

15.1.6 Impacts on recreational and navigation

Impacts on recreational users are difficult to predict. It is possible that a hardened channel may provide consistent navigation. However, a deep channel sufficient for navigation purposes has been restored naturally through scour since sediment raking ceased so the benefits of this for navigation are likely to be marginal at best. It is possible that sedimentation may increase in the lower North Esk which could lead to detrimental impacts on recreational users.

15.2 Tailrace weir and lock proposal

In the words of the proponent, this proposal (see Figure 53) is a five-tier project with the following elements:

‘1. Build a new power station at Trevallyn Dam at the base of the dam using the latest technology and the total flow of the South Esk River. This would increase the electricity output substantially and the water flow would be increased substantially by what is now being used at Trevallyn Hydro.

2. Build a weir just south of the tailrace with floodgates opening to just below low tide level. At flood times these doors can be opened to completely clean the Tamar Basin. The weir to be used also as the base for a new road access for light to medium heavy vehicles from east to west Tamar. As part of the weir build a revolving loch so that vessels can enter and leave the basin as tide allows.

3. The present Trevallyn power station should be decommissioned but all pipes and gates kept in place so that any silt build up from the weir down stream can be flushed down past the Grammar School rowing shed. This will give a great deal of protection for low lying areas at flood times and enhance the already well developed flood protection scheme. These gates may be opened to allow heavy flood waters to be released.

4. In addition to the silt management work being done by Council and others on the North Esk river (see the Mayor report in the Launceston City Deal annual progress report 2020) at least two silt collection stations should be developed on that river. They should be such that *they can be emptied and cleaned at least three times per year after floods and at other times as necessary.*

5. To further increase the flow in the basin a retainer wall should be erected on the west bank of the river from the rowing club to the weir.

All sewage and effluent must be removed from the rivers and basin before the weir is built. Item 3 may assist with removing the sewage and effluent.'

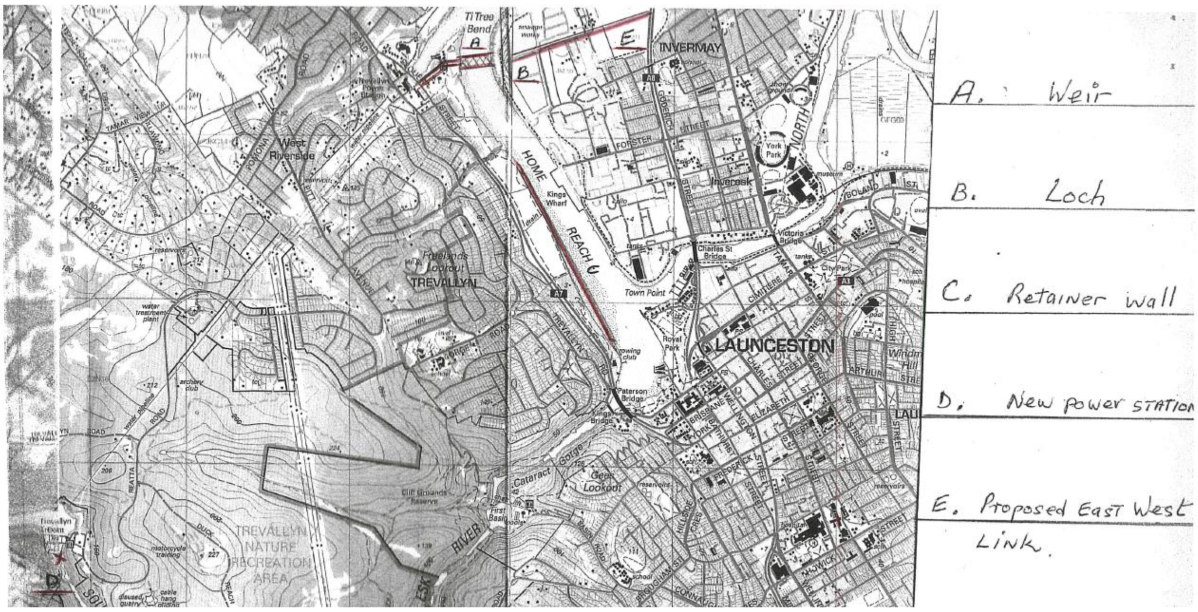


Figure 53. Concept drawing provided by a community member for Tamar weir and lock proposal.

It should be noted that this description has been quoted directly. There are numerous assumptions around process and impacts in this description that contradict evidence of how the estuary works and the way in which various components of the proposal would work in practice.

15.2.1 Legislation and feasibility challenges

Legislation and permitting required for this proposal have similarities to other proposals such as the Tailrace canal (Section 11) and lakes and barrages (Section 13).

This proposal includes major infrastructure projects such as a new power station, a new wastewater treatment plant and a new road and bridge including weir and lock, as well as a retaining wall in the upper estuary. Each of these projects would come at substantial cost with complex technical feasibility considerations. Impacts on power production would be significant. The generation at Trevallyn Power Station is approximately 4-5 times as high (depending on lake levels) per cubic metre per second than could be achieved with a power station at the dam due to the head difference. A power station at the dam would have a maximum head of 24 m compared to Trevallyn Power Station with a rated head of 113 m.

The proposed lock and east west link are located at the existing Ti Tree Bend WWTP. The existing WWTP would need to be decommissioned, an appropriate location for a new WWTP sought, and construction of the WWTP and associated sewage infrastructure costed.

TasWater are currently undertaking the long-term planning for Ti Tree Bend and other plants in and around Launceston, including assessing the potential to upgrade infrastructure at the existing location. As their planning is not complete, this evaluation will not attempt to address the cost and feasibility of relocating Ti Tree Bend WWTP or other treatment plants, but this proposal would be subject to the final configuration of TasWater's Launceston Sewage Improvement Plan (LSIP). Complete separation of sewage and stormwater networks would be required to eliminate all sewer overflows from the upper estuary as required in this proposal. This has previously been costed in excess of $500 million. Removal of all treated effluent discharge from the rivers and estuary in the greater Launceston area is not likely to be possible, but options for rationalisation of WWTPs are being evaluated in the LSIP.

Similarly, the feasibility and cost of constructing a new power station has not been evaluated in detail here, given some of the other constraints associated with this proposal. It is not clear how electricity output would be increased by this proposal, as the higher elevation of a power station at the base of Trevallyn Dam would result in a loss of head pressure for electricity generation. The inflows to Trevallyn Dam are utilised for power generation in the existing power station at the capacity required to meet energy demand.

Construction of an approximate 1 km road and a lock in a decommissioned wastewater treatment plant (built on piling) would have major geotechnical challenges associated with the stability and contamination of the substrate. Construction of a retaining wall in Home Reach alongside the West Tamar silt ponds is likely to have similar feasibility constraints and costs as the construction of the Tailrace canal, which are analysed more fully in Section 11. Construction of a weir at the Tailrace is likely to have similar feasibility constraints as construction of a barrage near Freshwater Point, albeit at a smaller scale, which is documented more fully in the evaluation of the lakes and barrages section in Section 13.

Costing for construction of the road, retaining wall, lock and weir, and silt collection stations would need to include management of contaminated dredge spoil and the associated dewatering, management of potential acid sulphate soils, and geotechnical stability. Costing would also need to consider the operational costs for the silt collection stations, management and disposal of the potentially contaminated sediments, and management of the decommissioned power station for flood diversion. The feasibility of using the current power station for flood diversion is questionable given that the current capacity of the power station is 100 cumecs and floods can be 2500 cumecs or more. Diversion of flood flows through an alternative pathway would also pose new flood risks given Launceston’s flood levee system has been designed to address risks from current flow pathways.

15.2.2 Costs

While a full costing of this option is impossible, a basic assessment of key elements suggest a cost well in excess of $1 billion with substantial ongoing costs.

15.2.3 Impacts on bathymetry, visible mudflats and navigability

This proposal assumes changes in bathymetry to reduce visible mudflats based on increasing flows down Cataract Gorge. The assessment of the Tailrace canal proposal (Section 11), the

Trevallyn Flow Releases Study (Section 12) and the scenario of no intervention (Section 7) provide an in-depth analysis of the effect of increasing flows from the South Esk down Cataract Gorge. This analysis concludes that directing the low flow events, currently used for power generation, through Cataract Gorge does not change bathymetry in the Yacht Basin.

It is also reasonable to assume that the installation of the weir and lock at the Tailrace is likely to result in sediment infilling upstream and downstream of the weir, driven by river and estuarine processes, as discussed in the lakes and barrages section, Section 13.

15.2.4 Impacts on flood risk

It is reasonable to assume that the flood risks evaluated in the lakes and barrages section (Section 13) would also apply to the installation of a weir and lock across the Tailrace. In particular, the flood risks associated with the weir in the North Esk are likely to be exacerbated by the installation of a weir downstream of the confluence with the North and South Esk rivers.

The proposal suggests that infrastructure from the existing power station would be decommissioned and used to divert flows from Trevallyn Dam through the existing Tailrace to flush out sediment accumulating downstream of the proposed weir, presumably on a semi-regular basis. This infrastructure is also proposed to be used to divert flood flows through the Tailrace. While the operational capacity of decommissioned infrastructure is not described and cannot be fully understood at this time, downstream flood risk on low lying areas of the east and west Tamar would need to be carefully evaluated.

15.2.5 Impacts on water quality and environmental values

Slowing down flows and increasing residence time with the installation of a weir is likely to have negative impacts on water quality, as discussed in the lakes and barrages section (Section 13). Impacts on environmental values are likely to be substantial and impacts associated with installation of a retaining wall alongside the West Tamar silt ponds are likely to be similar to those detailed in the Tailrace canal proposal (Section 11), while impacts associated with the weir and lock are likely to be similar to those detailed in the lakes and barrages section (Section 13), potentially on a smaller scale. Weirs present barriers to the migration of fish and conversion of sections of the estuary to freshwater lakes can be expected to have significant environmental impacts and impact on its status as a Conservation Area and Key Biodiversity Area.

15.2.6 Impacts on recreational users and navigability

It is not clear what the impacts of this option would be for recreational users and navigability but weirs present a barrier to recreational users. Channel depth is currently sufficient for navigation so any additional channel depth is unlikely to provide any benefits to recreational users. The requirement to navigate a weir and lock system would pose a barrier and additional time constraint on tours to tourist boat operators and others navigating the upper estuary.

15.3 Lake Batman

A further option combining barrages on the kanamaluka/Tamar and North Esk with reconfiguration of the North Esk River, referred to as Lake Batman, was also proposed around year 2000 (see Kidd, 2017). This proposal involved development of a freshwater lake in the upper estuary extending into the lower North Esk with the North Esk River then diverted to join the estuary at Stephenson's Bend below the barrage on the kanamaluka/Tamar estuary, as shown in Figure 54.

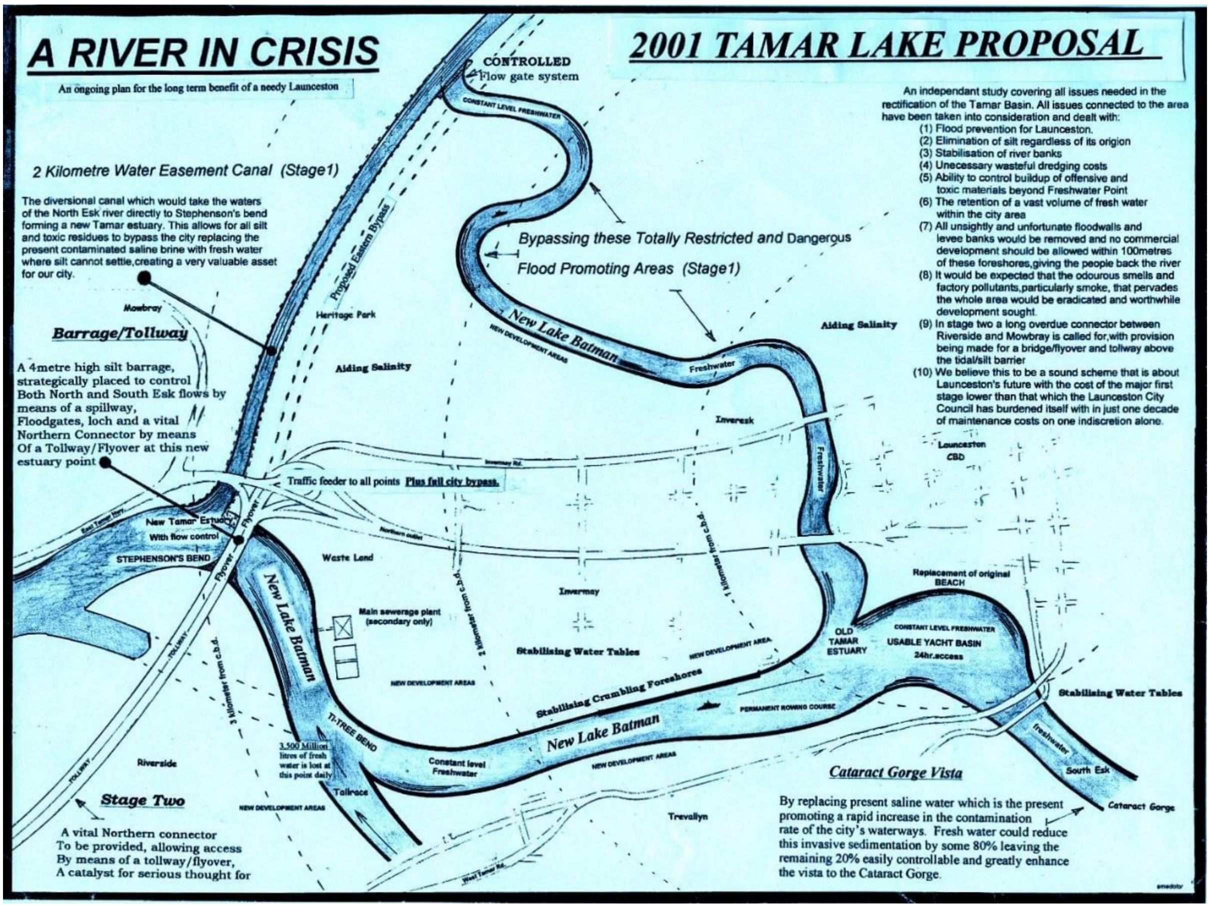


Figure 54. Lake Batman proposal concept 2001.

It should be noted that many of the assumptions and assertions made in the proposal are not supported by the known function and processes of the estuary and are not credible.

15.3.1 Legislation and feasibility challenges

Legislation and permitting required for this proposal has similarities to other proposals such as the Tailrace canal (Section 11) and lakes and barrages (Section 13). Note that the North Esk Diversion Channel would be likely to pass through Heritage Forest and Churchill Park sporting facilities. This site is a decommissioned municipal landfill for Launceston and there are likely to be significant permitting requirements and legislative constraints to excavating through the contaminated waste and underlying old swamp in this site and for its disposal.

Construction of an approximately 2 km channel through a decommissioned landfill site on a floodplain, along with two barrages in tidal estuaries would have major geotechnical challenges associated with the stability and contamination of the substrate, constraints are likely to be similar to construction of a barrage near Freshwater Point, albeit at a smaller scale, which is documented more fully in the evaluation of the lakes and barrages section (Section 13).

Costing for construction of the road, lock and weir, and dredging would need to include management of contaminated dredge spoil and the associated dewatering, management of potential acid sulphate soils, and geotechnical stability. Costing would also need to consider the operational costs for ongoing dredging, management and disposal of the potentially contaminated sediments, which is evaluated in greater detail in the section on dredging (Section 10).

High tide level is actually higher than some of the low-lying parts of Invermay and Inveresk. Groundwater levels in Invermay are already high and holding water levels in the upper estuary at high tide levels would likely increase the water table further. This could be expected to lead to pipes and other infrastructure 'floating' with significant damage to roads and pipes as a result. It may also lead to 'piping' under the flood protection levees and undermine the city's flood defence system.

The existing flood levee height at the Churchill Park end is RL 5.0. Surface levels through the park area start at RL 2.75 and are as high as RL 5.0 in the 'thickest' part of the old landfill. The surface level then drops to RL 2.5 - 2.75 through the industrial area and across Invermay Road. The levee height at the end of Hope St is RL 3.75. The East Tamar Highway is around RL 3.0 where the channel would need to cross it. Design and construction of structures to allow the two main roads to cross over and the channel to presumably pass under them would be extremely challenging.

15.3.2 Costs

Given the significant engineering challenges of such an option and the potential impacts on infrastructure around Launceston an option such as this could be expected to cost well in excess of $1 billion to implement. It would also require significant (and expensive) land acquisition to resume land for the diversion channel.

15.3.3 Impacts on bathymetry, visible mudflats and navigability

This proposal assumes changes in bathymetry to reduce visible mudflats based on the concept of weirs and barrages with the addition of occasional dredging. The assessment of the lakes and barrages (Section 13) and dredging section (Section 10) provide an in-depth analysis of these proposals on bathymetry and concludes that sediment will accumulate upstream and downstream of the weirs driven by river and estuary processes.

15.3.4 Impacts on flood risk

It is reasonable to assume that the flood risks evaluated in the lakes and barrages section (Section 13) would also apply to the installation of two weirs and a lock across the North Esk and Tamar estuary. There would be additional flood risks in Invermay and Mowbray posed by redirecting North Esk flows through these suburbs.

15.3.5 Impacts on water quality and environmental values

Slowing down flows and increasing residence time with the installation of a weir is likely to have negative impacts on water quality, as discussed in the lakes and barrages section (Section 13). Impacts on environmental values associated with the weir and lock are likely to be similar to those detailed in the lakes and barrages section (Section 13). This option would be expected to be associated with extreme environmental impacts.

15.4 Extension of the North Esk River

Proposals to construct an upstream tidal lake and to reinstate what the proponents identify as a historic meander system in the North Esk have been proposed by Kidd *et al* (2017) (Figure 55). The meander involves excavation of approximately 1.5 km of channel through floodplain and wetlands in an area formerly known as Mowbray Swamp. It is unclear from the information available if the intent is to send all North Esk River water through the extension, or if the intent is to provide additional volume for the tidal prism.

The proposed location for the upstream tidal lake is the outer bend of the estuary near Hoblers Bridge (Figure 55a).

Proposals for restoration of tidal prism in the North Esk have been evaluated in this report as the restoration of wetlands in Section 9.

(a)

(b)

Figure 55. Proposed location of (a) tidal lake and (b) historical meander, taken from Kidd *et al.* (2017).

15.4.1 Legislation and feasibility challenges

Legislation and permitting required for this proposal has similarities to other proposals such as the Tailrace canal (Section 11).

Construction of an approximately 1.5 km channel through a floodplain, or a tidal lake, would have some geotechnical challenges associated with the stability and contamination of the substrate. Constraints are likely to be similar to construction of a Tailrace canal or wetland reconstruction, which are documented more fully in the evaluation of the Tailrace canal section (Section 11) and wetland reconstruction (Section 9). Land tenure is an additional constraint for this project, with the proposed projects shown on land that is currently privately owned.

Engineering requirements for construction of these waterbodies could include training walls or other structures to maintain the excavated channels.

15.4.2 Costs

Costing would need to include management of contaminated soil and the associated dewatering, management of potential acid sulphate soils, and geotechnical stability. Due to the elevated water table and fine sediments, the channel would be relatively easy to construct but it may be difficult to achieve a stable form. Costing would also need to consider the operational costs for ongoing management, particularly for weeds and stability. The long lengths and tight confines are likely to slow the water, and the constructed channel may eventually silt up and become a billabong or oxbow lake.

15.4.3 Impacts on bathymetry, visible mudflats and navigability

These proposals assume changes in bathymetry to reduce visible mudflats due to the additional volume for tidal prism. The assessment of the floodplain and wetland restoration (Section 9) provides an in-depth analysis of this proposal on bathymetry and concludes that cross-sectional area will increase in the North Esk near Seaport/Town Point and Home Reach. The options are estimated to lead to small increases in channel depth and a reduction of visible mudflats at low tide, however the extent of these changes are dependent on the final design.

15.4.4 Impacts on flood risk

It is reasonable to assume that the flood risks evaluated in the floodplain and wetland restoration section (Section 9) would also apply to the construction of an extension to the North Esk River or a tidal lake. Increased storage volume may reduce the frequency of minor flood impacts on local infrastructure (e.g., approaches to the bridge on Henry St inundated less often). There may be additional flood risks in Mowbray posed by redirecting the North Esk River closer to these homes and additional scour eroding the northern bank.

15.4.5 Impacts on water quality and environmental values

Increasing tidal prism may have positive impacts on water quality, as discussed in the floodplain and wetland restoration section (Section 9). Construction impacts will need to be carefully managed to ensure no downstream impacts due to sediment run-off or acid leachate. Extending the North Esk River or construction of a tidal lake will result in clearing and converting some of the North Esk's remaining wetland vegetation, which is likely to impact on threatened species reliant on this habitat, such as the Australasian bittern. This option would be expected to be associated with a mixture of positive and negative environmental impacts.

16 Evaluation of sedimentation management options

This sediment management review sought to evaluate options for sediment management against a consistent set of criteria related to cost, legislative and feasibility challenges, changes in bathymetry, flood risk, environmental impacts and social impacts.

16.1 Evaluation criteria

Previous sections analyse the proposals across several specialist disciplines, and those analyses are summarised as evaluations against a common set of criteria for each discipline. The evaluation criteria in each of these disciplines is intended to provide a relative comparison of proposals and reduce complex analyses to simple evaluations commensurate with the scale of the proposals and to determine their associated impacts and benefits.

16.1.1 Cost

The analysis in this report does not seek to fully scope or quantify the costs of each proposal. It provides an initial estimate of the relative magnitude of costs for the purpose of evaluating the anticipated scale of these proposals. Cost estimates are focused on management of sediments and contaminants which is closely related to the technical complexity of the proposals. Construction costs are largely unassessed, given the limited design detail available for the proposals, but will also be strongly linked to the technical complexity of the proposals.

Costs have been categorised by scale for capital expenditure based on the range of costs across the proposals:

- Low <$10 million;
- Medium $10 – $50 million;
- High $50 - $100 million; and
- Very high >$100 million.

Annual operating expenditure is also categorised:

- Low <$1 million/yr
- Medium $1 - $5 million/yr
- High $5 - $10 million/yr
- Very high >$10 million/yr

Note these categories do not reflect an analysis of value for money, or a good investment, or which level of government would carry the assets on their books and provide for the ongoing operating expenditure (including depreciation and eventual renewal), they are simply applied to differentiate between relative magnitude of costs associated with the proposals.

16.1.2 Legislative and feasibility challenges

Assessment of feasibility of the proposals is focused on challenges associated with legislation, logistics and operations in an estuarine environment, and the specific location of proposed infrastructure. This includes consideration of:

- complexity of legislative and permitting requirements;
- technical complexity of designing and implementing the option including handling of potential acid sulfate soils and contaminated waste;
- operation of proposed infrastructure and its interaction with existing infrastructure; and
- public safety considerations.

The complexity of each of the proposals is categorised as high, medium and low based on the greatest level of complexity in any of the areas.

16.1.3 Bathymetry

Impacts on the bathymetry are assessed relative to attributes in the evaluation framework for social impacts. Changes in the breadth of visible mudflats and depth of channels in three sections of the upper estuary – the Yacht Basin, lower North Esk and Home Reach – are scored and an average of values calculated across all to estimate the extent to which the option addressed these community objectives. Average effectiveness is included in the table.

16.1.4 Flood risk

Floodplain consultants WMAWater were engaged to provide expert assessment of the impacts of each of the sedimentation management options on flood levels and a discussion of the implications for riverine flood risk (WMAWater, 2021). This assessment used a mix of qualitative expert opinion utilising previous flood studies in the estuary and analysis of results from City of Launceston's TUFLOW flood model. A description of key findings on impacts on flood risk for each of the options was provided in the detailed evaluations. For the evaluation matrix the change in flood risk is summarised into one of several categories of increasing, unchanging or decreasing risk:

- Negligible impact on flood risk – little to no change in risk for floods of any volume to areas both inside and outside the formal flood levee system.
- Very small impact on flood risk – some change in risk in non-levee protected areas primarily during smaller floods.
- Small impact on flood risk – some change in risk in formal flood levee system protected areas for some flood events, changes in risk on non-levee protected areas potentially greater but not substantial.
- Moderate impact on flood risk – some change in risk in formal flood levee system protected areas for flood events, changes in risk on non-levee protected areas substantial.
- Large impact on flood risk – substantial impacts on flood risk in both formal flood levee system protected and non-levee protected areas.

- Very large impact on flood risk – extreme impacts on flood risk in both formal flood levee system protected and non-levee protected areas.

It should be noted that these evaluations of flood risk impacts are qualitative and, in many cases, highly uncertain without significantly more quantitative analysis. As with the other components of the evaluation, they are intended to give an indication of the nature, direction and magnitude of change rather than provide a detailed and accurate assessment of flood risk, which is outside the scope of this report.

16.1.5 Environmental impacts

A rapid impact assessment matrix has been used to evaluate environmental impacts (see Ijäs *et al.*, 2010). Impacts can be positive or negative and the evaluation criteria include importance of impact, magnitude of change, permanence of the impact causing activity, reversibility of the impact, cumulative impacts or synergies of the impact, and sensitivity of the target environment. The cumulative impacts or synergies of the impact have been assessed with regard to other projects that will impact on environmental values in the upper estuary, such as the investments to improve water quality. Appendix 6 provides detail on the way in which these values are calculated and the definition of criteria.

16.1.6 Impacts on user groups

The rapid impact assessment matrix has also been used to evaluate social impacts. Impacts can be positive or negative and the evaluation criteria include importance of impact, magnitude of change, permanence of the impact causing activity, reversibility of the impact, cumulative synergism of the impact, and sensitivity of the target environment.

The expected changes in bathymetry are used to assess the magnitude of change, and the cumulative impacts or synergy have been assessed with regard to other projects that will change social use and impacts in the upper estuary. Susceptibility of the target area was not considered applicable as there were no sensitive social values, such as schools or hospitals, located near the upper estuary.

Impacts have not been assessed in consultation with the user groups. They are provided as an indication only based on current knowledge of user needs. Consultation with user groups would better inform this assessment and would allow the effects of expected changes in channels, mudflats and aesthetics on each user group to be explored more fully.

16.2 Evaluation matrix

An evaluation matrix using these evaluation criteria and information provided in the detailed assessment of each option has been populated comparing the various sedimentation management options (Table 33). The assessment of each option against evaluation criteria used to create values in this summary matrix is detailed in Appendix 6. This matrix shows:

- Actions focused on restoring tidal prism in the North Esk, through the removal of informal tidal levees or restoration of wetlands, will effectively reduce sedimentation in the North Esk and, to a lesser extent, Home Reach and can achieve environmental and many social objectives in the upper estuary.

- Costs and feasibility of wetland restoration depend on the scale and location of action, with challenges associated with restoring the floodplain's privately owned areas.
- Accelerated restoration of intertidal vegetation in the upper estuary can achieve environmental and some social objectives around aesthetics at a relatively low cost. However, extensive mudflats will remain a feature of the estuary under this approach and social impacts in terms of current recreational users will largely remain as they are.
- Engineering focused actions such as the construction of a tailrace canal or barrages and weirs are associated with very high costs, significant challenges with feasibility, and extensive environmental impacts, with a mix of results in terms of bathymetric objectives and related social impacts.
- Large scale dredging of the upper estuary is very expensive, with ongoing annual costs in the order of tens of millions of dollars largely due to costs of treatment and disposal of dredge spoilt that is potential acid sulfate and Level 2 contaminated waste. Technical constraints on the scale of dewatering ponds for dredge spoil that would be required in close proximity to the upper estuary would likely make large scale dredging infeasible. It would not impact on the extent of visible mudflats.
- Sediment raking and increased flow releases from Lake Trevallyn come at a lower economic cost but fail to address bathymetric and related social objectives. In the case of sediment raking, the option is associated with significant environmental impacts.

Table 33. Evaluation matrix comparing sedimentation management options using evaluation criteria.

Option		Cost		Feasibility challenges	Channel depth			Extent of visible mudflats[17]				Flood risk	Environmental impact	Social impact
		Capital	Operational		Lower North Esk	Yacht Basin	Home Reach	Lower North Esk - Seaport	Lower North Esk – Town Point	Yacht Basin	Home Reach			
No intervention[18]		None	None	None	No change	No change	No change	Moderate increase	No change	No change	No change	Negligible	Slightly positive impact	No change
Accelerated restoration	Restoration of intertidal vegetation	Low	Low	Low	No change	No change	No change	Moderate increase	No change	No change	No change	Negligible	Slightly positive impact	Slightly positive impact
Accelerated restoration	Remediation of West Tamar silt ponds	Low	Low	Medium	No change	No change	No change	Moderate increase	No change	No change	No change	Negligible	Slightly positive impact	No change
North Esk tidal prism, informal levees and restoration	Cease informal levee construction	None	None	Medium	No change	No change	No change	Small reduction	Small reduction	No change	Small reduction	Very small decrease (avoided increase)	Significant positive impact	Slightly positive impact
North Esk tidal prism, informal levees and restoration	Remove informal tidal levees	Low	Low	Medium	Moderate increase	No change	Small increase	Moderate reduction	Moderate reduction	No change	Moderate reduction	Very small decrease	Significant positive impact	Slightly positive impact
North Esk tidal prism, informal levees and restoration	Wetland restoration - small program	Medium	Low	Medium	Small increase	No change	No change	Small reduction	Small reduction	No change	Small reduction	Negligible	Significant positive impact	Slightly positive impact
North Esk tidal prism, informal levees and restoration	Wetland restoration - large program	Very high	Low	High	Large increase	No change	Moderate increase	Large reduction	Large reduction	No change	Large reduction	Very small decrease	Extreme positive impact	Slightly positive impact
Dredging	Small scale dredge program	Medium	Very high	High	No change	Moderate increase	Moderate increase	No change	No change	No change	No change	Negligible	Moderately negative impact	No change
Dredging	Large scale dredge program	High	Very high	High	Large temporary increase	Large temporary increase	Large temporary increase	No change	No change	No change	No change	Negligible	Significant negative impact	No change
Tailrace canal		Very high	High	Very high	No change	Small increase	Small increase	No change	No change	No change	No change	Very small increase	Significant negative impact	No change
Lakes and barrages	North Esk weir	Medium	Medium	High	Small loss	No change	Moderate loss	Large decrease	Large decrease	No change	Large increase	Small increase	Significant negative impact	Moderately negative impact
Lakes and barrages	Small lake	Very high	High	Very high	Small loss	Small loss	Small loss	Large reduction	Large reduction	Large reduction	Large reduction	Small increase	Extreme negative impact	Significant negative impact
Lakes and barrages	Large lake	Very high	High	Very high	Small loss	Small loss	Small loss	Large reduction	Large reduction	Large reduction	Large reduction	Small increase	Extreme negative impact	Significant negative impact
Sediment raking		None	Low	High	Moderate loss	Moderate loss	Moderate loss	Small reduction	Small reduction	Small reduction	Small reduction	Negligible	Significant negative impact	Slightly negative impact
Increased flows[19]		None	Low	Low	No change	No change	No change	No change	No change	No change	No change	Negligible	No change	No change

[17] Colour refers to social objective of reduced extent of visible mudflats. Increased mudflat extent does not negatively impact on environmental values and may improve such values in some cases.
[18] Change relative to end of sediment raking program in 2019.
[19] Cost for this option is based on 8,640 ML released over a 2 to 5 day period. Multiple or continuous flow releases in a year would cost significantly more (potentially millions of dollars per year), assuming they are feasible given constraints on water availability.

16.3 Global approaches to managing trade-offs in the coastal zone

In recent decades there has been a strong movement away from traditional approaches to managing natural systems. In previous generations, actions focused on attempts to transform natural systems, using hard engineering approaches in an attempt to minimise flood risk, create navigation channels or protect community infrastructure from the pressures of natural processes such as sedimentation, tidal inundation or flooding (see for example Sayers *et al.*, 2013). The kanamaluka/Tamar estuary provides an example of such a system, where informal and formal flood protection levees, wetland infilling and land reclamation, as well dredging and raking have been used to deliver the social and economic outcomes sought by the community at that time. This report demonstrates that these types of actions can come at a significant cost in terms of environmental impact and other unintended consequences, and can have relatively short-lived outcomes.

Changes in legislation and an awareness of the importance of taking a more sustainable approach to addressing trade-offs between economic and social outcomes and environmental values make many of the actions that were applied in the past impractical. Approaches such as *Integrated Coastal Zone Management* (e.g., Clarke and Johnson, 2016) or *Strategic Flood Risk Management* (Sayers *et al.*, 2013) focus on seeking solutions that balance the scale and nature of the problems with the impacts of potential solutions on social, economic and environmental values. The overarching aim of an approach such as *Integrated Coastal Zone Management* (ICZM) is sustainability, where the best possible outcomes are achieved for both large-scale and local-scale issues concerning society, the environment and the economy. Clarke and Johnson (2016) state that ICZM seeks *'to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics'.* They summarise the principles of ICZM as being:

- *'transparent;*
- *based on risk assessment;*
- *inclusive of a social aspect;*
- *appropriate to the scale of the issues being addressed;*
- *underpinned by sound ecological understanding; and*
- *able to provide clear structures among agencies to streamline the entire process.'*

Section 1 of this report explored the nature of sedimentation as a problem in the kanamaluka/Tamar estuary. While the upper estuary has been heavily modified since European settlement, extensive mudflats in and around Launceston have always been a feature of the estuary. Previous actions such as dredging have temporarily changed the shape of the upper estuary but, once ceased, natural processes drive the re-establishment of the natural form of the upper estuary, consisting of a channel deep enough for the navigation of smaller vessels, and extensive mudflats. As has been shown in this report, mudflats are not an environmental problem or a sign of an unhealthy 'clogged up' estuary – they are a natural feature of the upper estuary that underpin its many very significant environmental values, including its international recognition as a Key Biodiversity Area. Sedimentation does not pose significant increases in flood risk. Floods induce significant levels of scour and large-scale erosion of the estuary bed, meaning pre-flood bathymetry has little, if any, impact on flood levels. Sediment does not continue to accumulate on an infinite trajectory – the estuary settles into a state of sedimentation that can be considered to be in dynamic equilibrium, with relatively short periods of reduced sediment from the significant levels of scour induced by flood events, followed by re-accretion of sediments back towards this 'equilibrium'. This means that flood mitigation strategies can be considered within this envelope of sedimentation condition while understanding the substantial role that the flood itself plays in scouring sediment and reducing flood levels below what would otherwise be the case under 'equilibrium' conditions.

Sedimentation, in particular the large extent of visible mudflats, does however continue to be a source of significant concern for sections of the community. These concerns vary from perceptions of the mudflats as being a sign of a degraded system, to impacts on aesthetic values with strong preferences from many for an 'open water' view of the estuary, perhaps more aligned with memories of a heavily dredged estuary. Impacts of sedimentation on recreational users of the upper estuary are also a concern, with infrastructure such as rowing pontoons, the Seaport Marina and Tamar Yacht Club slip yard being stranded due to sediment levels at low tide. An alternative to the more traditional approaches evaluated in this report would be an approach such as *Integrated Coastal Zone Management*. This approach could be used to engage the community in developing solutions that address the social concerns for the upper estuary within the context of natural dynamics, using actions appropriate to the nature and scale of the issues being faced. Considerations that have not been addressed in this report, such as mitigating risks of climate change including changes in extreme rainfall and flood events and sea level rise, as well as the impacts and interactions of proposed actions on Aboriginal cultural values, would form part of this comprehensive planning approach. This approach would align with international best practice and could be used to seek new economic and social opportunities and benefits whilst also protecting, enhancing and celebrating the significant environmental values of the upper estuary.

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Appendix 1. Environmental values of the kanamaluka/Tamar estuary

This appendix provides a comprehensive summary of special environmental values associated with the kanamaluka/Tamar estuary. These values inform the evaluation framework for assessment of environmental impacts that was described in Section 4. Where possible, environmental values have been summarised for regions of the kanamaluka/Tamar estuary and foreshore as shown in Figure 56. Summarising values in this way allows for the direct and indirect impacts of various sedimentation options to be more easily assessed and evaluated. The area around Launceston is broken into three smaller regions to allow direct impacts of the specific options to be evaluated. Other regions capture major functional zones and roughly align with the reporting zones used in the TEER Program's Tamar Estuary Report Card. Tables of data used in this summary are provided in separate appendices for ease of reading.

Figure 56. Regions for which environmental values data and information has been summarised.

A1.1. Habitat types in the estuary

The kanamaluka/Tamar estuary has a wide variety of subtidal, intertidal and foreshore habitats.

A1.1.1. Subtidal habitats

As summarised by Maynard and Gaston (2010) subtidal habitats in the kanamaluka/Tamar estuary can be grouped into five major types:

- Cobble – cobble stone substrate which supports fish and crabs.
- Rocky reef – consisting of rock platforms that support kelp, algae, sponges, ascidians, urchins and sea stars, molluscs, rays and fishes, anemones and soft corals. The most prominent kelp is the giant kelp *Macrocystis angustifolia*.
- Sand – consisting of mobile soft sediment substrate supporting rays and fishes, crabs, worms and molluscs.
- Seagrass – vegetated soft sediment substrate providing food, shelter and habitat for fish, crustaceans, molluscs, other invertebrates and plants.

- Silt – consisting of very mobile fine particle soft sediment substrate supporting animals that dig and burrow into the sediments (infauna) and animals that live on top of the sediments (epifauna).

The distribution of these subtidal substrates and habitats in the estuary is show in Figure 57.

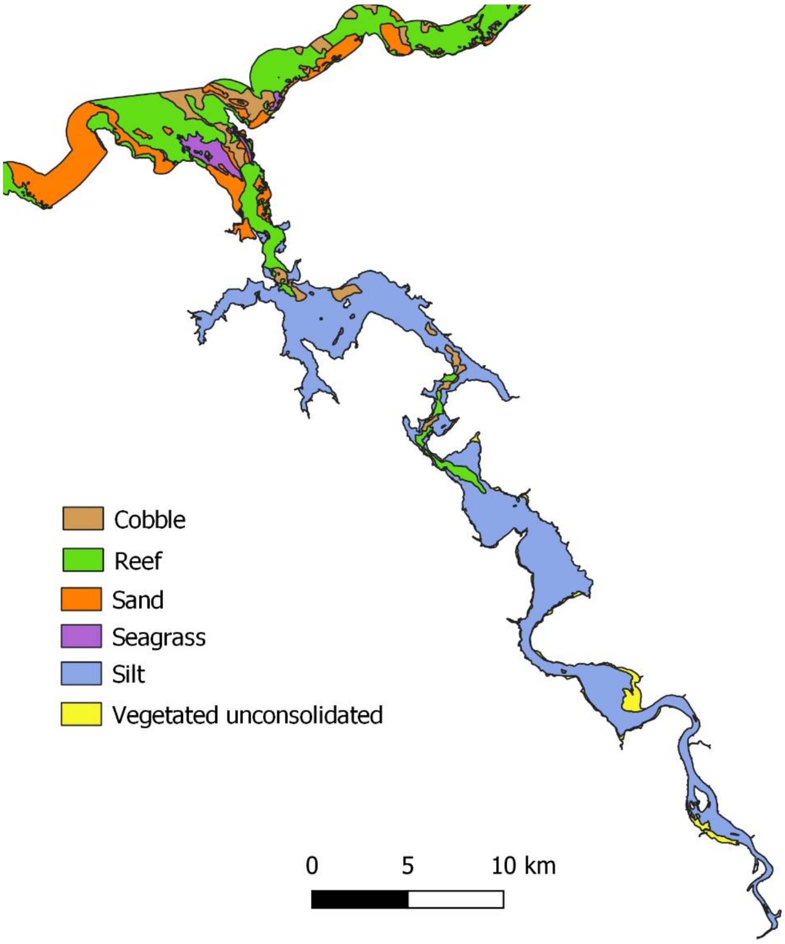

Figure 57. Subtidal substrates and habitats in the kanamaluka/Tamar estuary – SeaMap (Lucieer, 2017).

Table 34 summarises the area of each substrate type in the regions of the kanamaluka/Tamar used in this evaluation. Note that data on substrate in the lower North Esk is not available but can be assumed to be predominantly silt.

Table 34. Area of subtidal substrate habitat types in kanamaluka/Tamar estuary regions (ha) calculated from SeaMap data (Lucieer, 2017).

Region	Cobble	Land	Reef	Sand	Seagrass	Silt	Vegetated unconsolidated
West Tamar to Tailrace	1.4	0	0	0	0	23.1	0
Royal Park to Ti Tree Bend	0.9	0	0	0	0	39.4	0
Ti Tree Bend to Freshwater Point	4.1	0	0	0	0	609.2	91.6
Freshwater Point to Rosevears	0	0	0	0	0	828.8	197.9
Rosevears to Swan Point	2.6	2	1.4	0	0	1402.8	92.2
Swan Point to Rowella	91.8	0	260.4	0	0	1500	56.3
Rowella to Clarence Point	203.7	0.8	90.6	0	17.2	2825.9	1
Clarence Point to Low Head	146.1	0	1493.9	708.9	326.6	58	0

This figure and table show that the upper estuary is dominated by silt and vegetated unconsolidated subtidal substrates and habitats. From Swan Point there is a gradual increase in reef and cobble substrates with some seagrass seen downstream of Rowella before Clarence Point. Subtidal habitats are very diverse from Clarence Point to Low Head with reef the most common followed by sand then seagrass. A small area of silt is found in this region corresponding to 2 percent of the area.

Dykman and Maynard (2015) conducted a survey of rocky reefs in the lower kanamaluka/Tamar estuary developing a detailed understanding of rocky reef benthic community structure at five surveyed sites. They found that the community structure depended on depth and distance from the estuary mouth, with depth the primary determinant. Shallow waters (<17 m) were found to be dominated by macroflora – brown and red macroalgae with some green macroalgae and seagrass. Deep waters are dominated by complex sessile invertebrate complexes – comprising mainly of sponges, but also included ascidians, bryozoans, octocorals and hydroids. Dykman and Maynard found six previously unknown species of soft coral.

A1.1.2. Intertidal habitats

The intertidal zone consists of the area between the permanent water level at low tide and the area that is underwater at high tide. Flora and fauna inhabiting the intertidal zone of an estuary are adapted to coping with extreme conditions with variations in salinity, the rise and fall of the tides and differences in substrate. The intertidal zone of the kanamaluka/Tamar estuary consists of intertidal flats and saltmarsh and saltflat geomorphic habitat environments as shown in Figure 58.

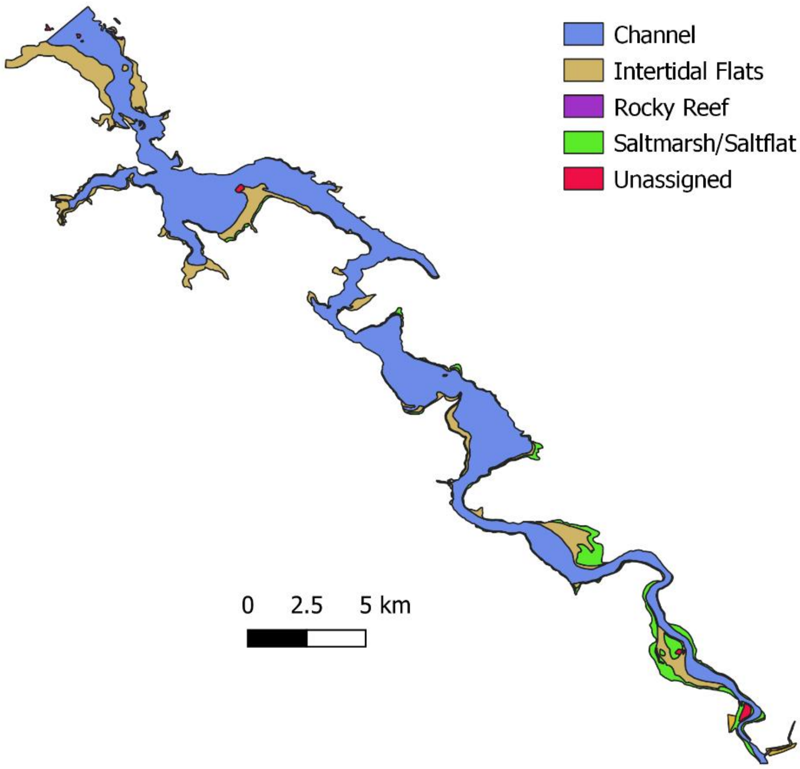

Figure 58. Intertidal geomorphic habitat environments based on Tasmanian coastal waterways geomorphic habitat mapping (Dyall *et al.*, 2005).

Mapped areas outside the channel have been combined with the TASVEG 4.0 data set to estimate the area of natural vegetated (including saltmarsh, swamp forest and other wetlands), natural unvegetated (mud or sand flat), rice grass infestation and modified lands in each of the regions used for assessing the impacts of potential sedimentation management options. A summary of the area of each of these habitat types is given in Table 35. Detailed data combining geomorphic habitat environment types and TASVEG4.0 vegetation codes is given in Appendix 2.

Table 35. Estimated area (ha) of intertidal habitat as mapped in Figure 58 classified using TASVEG4.0 data set.

Region	Natural habitat - vegetated	Natural habitat - unvegetated	Ricegrass	Modified lands (urban and agriculture)	Total
Lower North Esk	0	11.9	0	3.6	15.5
West Tamar to Tailrace	8	2.3	0	13.1	23.4
Royal Park to Ti Tree Bend	5.7	4.5	0	0.8	11
Ti Tree Bend to Freshwater Point	426.4	164.5	0	34.1	625
Freshwater Point to Rosevears	19	202.6	185.2	15.1	421.9
Rosevears to Swan Point	18.4	104.1	101.5	18	242
Swan point to Rowella	16.7	100.5	55.3	9.7	182.2
Rowella to Clarence Point	80.6	494.6	5.6	17.3	598.1
Clarence Point to Low Head	8	385.1	0	20.9	414

This data demonstrates the large area of mudflats and sandflats (58 percent) and natural vegetated habitats (23 percent) throughout the estuary. There is a substantial rice grass infestation evident between Freshwater Point and Clarence Point (14 percent) with 5 percent of the intertidal zone attributed to modified land types such as urban or agriculture.

A conceptual model of the role of intertidal habitats in the kanamaluka/Tamar estuary has been developed to illustrate the interdependence on the natural values of the estuary on intertidal habitats Figure 59).

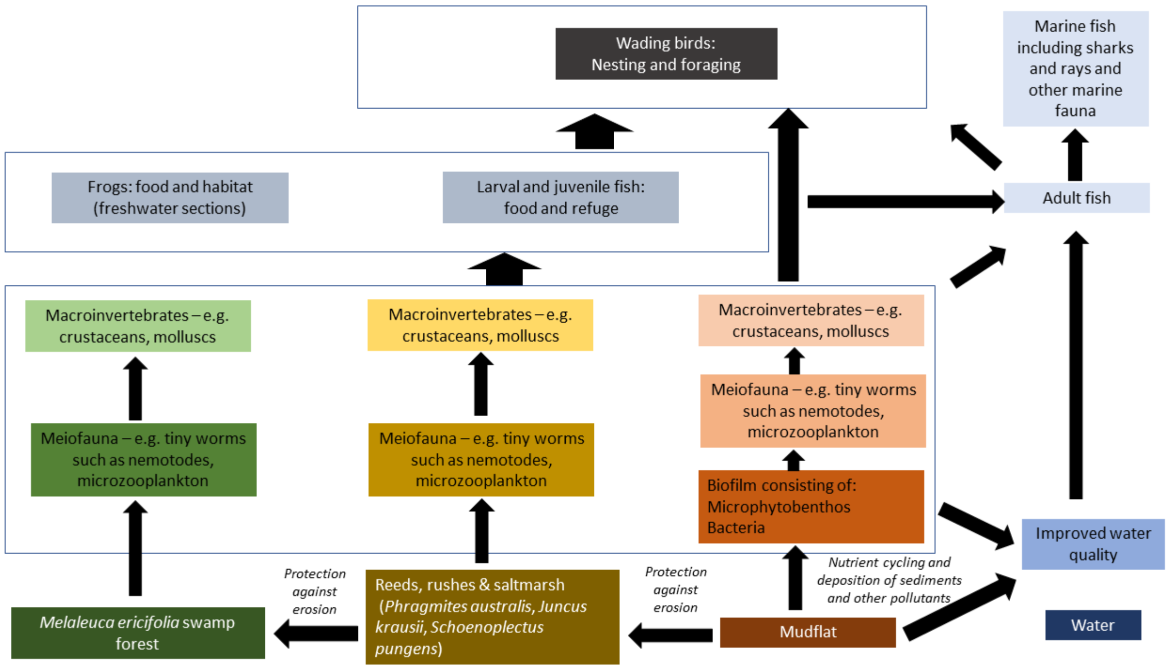

Figure 59. Conceptual model of the role of intertidal habitats in nutrient cycling and the food web.

Mudflats play a range of important roles in the estuary ecosystem:

- they protect vegetated intertidal habitats such as reeds, saltmarsh and swamp forest from erosion;

- they support a high biomass of micro and infaunal organisms ((see for example Dineen, J., 2010) and play a key foundational role in nutrient cycling;
- they provide a food source for wading bird, macroinvertebrates and fish;
- they trap pollutants such as nutrients and heavy metals entering the estuary from the catchment and foreshore, including from point sources protecting water quality; and
- their role in protecting water quality also means they benefit animals such as migratory fish and subtidal habits such as seagrass that require good water clarity to access sufficient light for photosynthesis.

In the kanamaluka/Tamar estuary they support populations of migratory birds protected by the *Environment Protection and Biodiversity (EPBC) Act 1999* and underpin its internationally recognised status as a Key Biodiversity Area/Important Bird Area.

Smith (1997) conducted an extensive survey of intertidal invertebrate fauna in the kanamaluka/Tamar estuary and found that the presence of varied intertidal fauna assemblages over the extent of the estuary indicated that the estuary was generally in good health (Table 36).

Table 36. Summary of the number of intertidal macroinvertebrate species in regions of the kanamaluka/Tamar estuary collected by Smith (1997).[20].

Invertebrate group	South of Freshwater Point	Freshwater Point to Rosevears	Rosevears to Swan Point	Swan Point to Rowella	Rowella to Clarence Point	Clarence Point to Low head
Grid cells from Smith (1997)	18,19, 20, 21	16, 17	11, 12, 13, 14, 15	7, 8, 9, 10	2, 3, 4, 5, 6	1
Platyhelminthes	0	0	0	1	1	1
Annelida - polychaeta	0	0	0	0	1	1
Mollusca - polyplacophora	0	0	1	1	1	1
Mollusca - bivalvia	0	1	4	6	6	4
Mollusca - gastropoda	3	4	6	13	15	15
Crustacea - cirripedia	0	1	1	1	1	1
Crustecea - decapoda	2	4	5	5	6	5
Echinodermata - asteroidea	0	0	0	1	1	1

A1.2. Conservation areas, reserves and international recognition of environmental values of the kanamaluka/Tamar estuary

A1.2.1. Conservation areas and reserves

Protected areas in Australia are defined under categories set out by the International Union for the Conservation of Nature (IUCN). The kanamaluka/Tamar estuary contains several protected areas listed as either IUCN Category IV or IUCN Category V.

[20] Note that data from Smith (1997) have been summarised to approximately align with regions of the estuary used in this review shown in Figure 57. Smith uses a 4 x 4 km grid covering the estuary to collect and summarise the samples. Grid cells used for each region are provided in the Table.

The IUCN classification of protected area defined class IV as those where the primary objective is to *'maintain, conserve and restore species and habitats'*.[21] The IUCN state that these protected areas *'usually help to protect, or restore: 1) flora species of international, national or local importance; 2) fauna species of international, national or local importance including resident or migratory fauna; and/or 3) habitats*.' They note that *'as category IV protected areas often include fragments of an ecosystem, these areas may not be self-sustaining and will require regular and active management interventions to ensure the survival of specific habitats and/or to meet the requirements of particular species'*.

The IUCN classification of protected areas defines class V as *'A protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values'*.[22]

The IUCN states that essential characteristics of Category V protected areas are:

- *'landscape and/or coastal and island seascape of high and/or distinct scenic quality and with significant associated habitats, flora and fauna and associated cultural features;*
- *a balanced interaction between people and nature that has endured over time and still has integrity, or where there is reasonable hope of restoring that integrity; and*
- *unique or traditional land-use patterns, e.g., as evidenced in sustainable agricultural and forestry systems and human settlements that have evolved in balance with their landscape'.*

In addition to this, desirable characteristics are:

- *'opportunities for recreation and tourism consistent with life style and economic activities;*
- *unique or traditional social organizations, as evidenced in local customs, livelihoods and beliefs;*
- *recognition by artists of all kinds and in cultural traditions (now and in the past);*
- *potential for ecological and/or landscape restoration; and*
- *role in the landscape/seascape'.*

The *Nature Conservation Act 2002* defines classes of protected areas in alignment with the IUCN categories. This sets out the values and purposes of each reserve class. These are then managed under the *National Parks and Reserves Management Act 2002* according to management objectives for each class. The kanamaluka/Tamar estuary contains both Nature Reserves and Conservation areas.

A nature reserve is an area of land that contains natural values that:

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[21] https://www.iucn.org/theme/protected-areas/about/protected-areas-categories/category-iv-habitatspecies-management-area

[22] https://www.iucn.org/theme/protected-areas/about/protected-areas-categories/category-v-protected-landscapeseascape

- contribute to the natural biological diversity or geological diversity of the area of land, or both; and,
- are unique, important or have representative value.

The objectives of management of nature reserves are the conservation of the natural biological diversity or geological diversity of land, or both, and the conservation of natural values of that land that are unique, important or have representative value.

A conservation area is an area of land predominantly in a natural state and the management objectives for these areas are the protection and maintenance of the natural and cultural values of the area of land and the sustainable use of the natural resources of that area of land including special species of timber harvesting.

An historic site is an area of land of significance for historic cultural heritage and the management objectives for these areas are the conservation of the historic features of the area of land and the presentation of those features for public appreciation and education.

Figure 60 shows the areas in the kanamaluka/Tamar estuary and along its foreshore that are protected under the *National Parks and Reserves Management Act 2002*. A summary of areas present in each of the regions used for this impact assessment is given in Table 37.

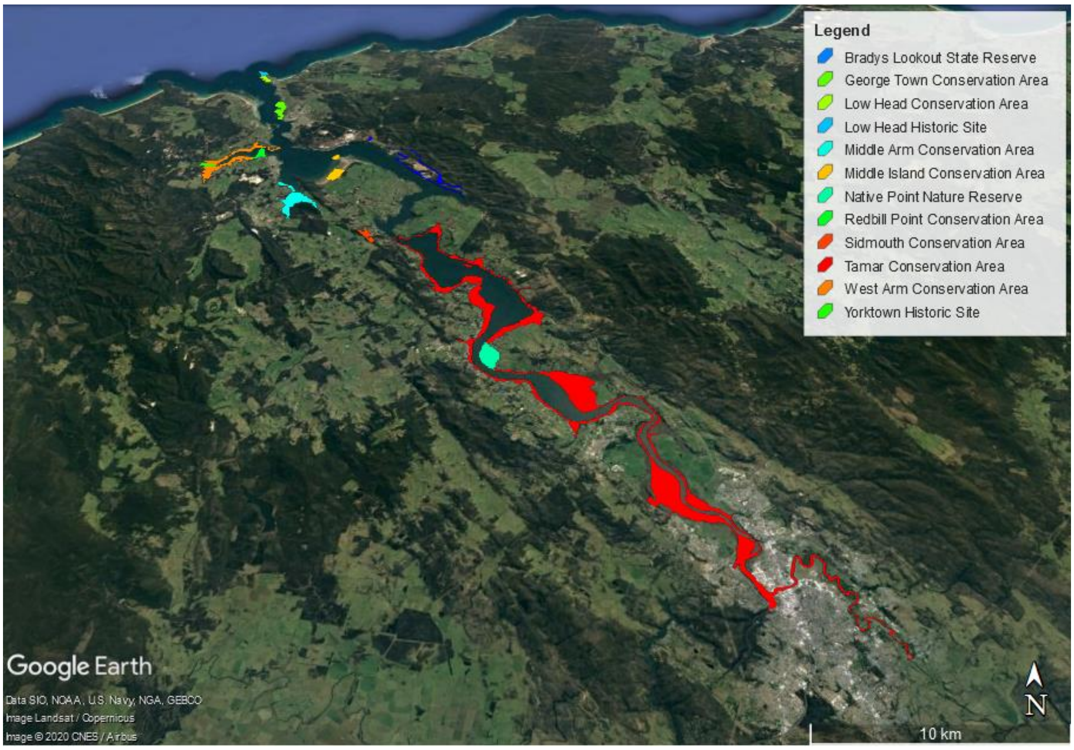

Figure 60. Areas protected by the *Nature Conservation Act 2002* in the kanamaluka/Tamar and on its foreshore.

Table 37. Areas protected under the *Nature Conservation Act 2002* in regions used for the assessment.

Region	George Town Conservation Area	Low Head Conservation Area	Low Head Historic Site	Middle Arm Conservation Area	Middle Island Conservation Area	Native Point Nature Reserve	Redbill Point Conservation Area	Tamar Conservation Area	West Arm Conservation Area	Yorktown Historic Site
Lower North Esk								x		
West Tamar to Tailrace								x		
Royal Park to Ti Tree Bend								x		
Ti Tree Bend to Freshwater Point								x		
Freshwater Point to Rosevears								x		
Rosevears to Swan Point						x		x		
Swan Point to Rowella								x		
Rowella to Clarence Point				x	x		x		x	x
Clarence Point to Low Head	x	x	x							

Protected areas are described in more detail below.

Tamar River Conservation Area

The kanamaluka/Tamar estuary from St Leonards to Batman Bridge is listed as a Conservation Area under IUCN V classification based on waterfowl and its estuary environment.

Tasmania Parks and Wildlife Service manage the kanamaluka/Tamar estuary as a conservation area.

Tamar Island Wetland Reserve

The Tamar Island Wetland Reserve lies within the Tamar River Conservation Area. The reserve is managed by Tasmania Parks and Wildlife Service and contains a visitor centre. The wetlands contain a diverse range of species. Over 60 species of birds have been identified in the wetlands including species of duck, black swan, egrets, cormorants and swamp harriers, and migratory birds (DSEWPC, 2012). The reserve is an important breeding site for the green and gold frog, a nationally listed threatened species. A threatened species of skink, the glossy grass skink also lives in the wetlands. The reserve contains one of the largest remaining areas of vegetation dominated by *Phragmites australis* (common reed) as well as state listed threatened vegetation community swamp paperbark forest (*Melaleuca ericifolia*).

Other protected areas

The estuary contains nine other protected reserves, historic sites and conservation areas, reflecting the significant natural and cultural values associated with the mid to lower estuary[23]:

- Native Point Reserve – IUCN IV, listed 1976.
- Low Head Conservation Area – IUCN V, listed 1983.
- Low Head Historic Site – IUCN V, listed 2000.
- Yorktown Historic Site – IUCN IV, listed 1951.
- Middle Island Conservation Area – IUCN V, listed 2011.
- Middle Arm Conservation Area – IUCN IV, listed 2011.
- West Arm Conservation Area – IUCN V, listed 2011.
- Red Bill Point Conservation Area – IUCN VI, listed 1989.
- George Town Conservation Area – IUCN VI, listed 1987.

A1.2.2. Protected Shark Refuge Area

All areas of the kanamaluka/Tamar estuary south of a line between Low Head and West Head are included in a Protected Shark Refuge Area. This recognises the importance of the estuary as a habitat for breeding of school and gummy sharks, skates and rays. This classification prohibits the taking of any shark, skate or ray.

A1.2.3. Important Bird Area (IBA)/Key Biodiversity Area (KBA) recognition

Birdlife International has listed the water and intertidal mudflats of the kanamaluka/Tamar estuary from Launceston to Batman Bridge as an Important Bird Area (IBA). This listing recognises the importance of the mudflats to shorebirds, in particular the chestnut teal (*Anas castanea*) and pied oystercatcher (*Haematopus longirostris*), with this IBA holding over 1 percent of the global population of these species on a regular or predictable basis. With the transition over to listing Key Biodiversity Areas (KBA) the area from Launceston to Batman Bridge has been listed as the Tamar Wetlands Key Biodiversity Area. This listing is under the biological processes criterion (D) identifying sites contributing significantly to the persistence of demographic aggregations (D1): a) ‘An aggregation representing ≥1 percent of the global population size of a species, over a season, and during one or more key stages of its life cycle.’. This listing is for the pied oystercatcher and chestnut teal (KBAP, 2020)[24].

A1.3. Migratory species

Australia is signatory to several international conventions and agreements on the protection of migratory animals. Migratory species receive national protection as a matter of national

[23] https://parks.tas.gov.au/Documents/Reserve%20Listing.pdf

[24] Key Biodiversity Areas Partnership (2020) *Key Biodiversity Areas factsheet: Tamar Wetlands*. Extracted from the World Database of Key Biodiversity Areas. Developed by the Key Biodiversity Areas Partnership: BirdLife International, IUCN, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Global Wildlife Conservation, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, World Wildlife Fund and Wildlife Conservation Society. Downloaded from http://www.keybiodiversityareas.org/ on 09/11/2020.

environmental significance in the *Environment Protection and Biodiversity Conservation Act 1999*.

A1.3.1. Migratory birds

Most migratory birds in Australia make an annual return journey of thousands of kilometres along the East Asian – Australian flyway – a migratory corridor extending from breeding grounds in the Russian Tundra, Mongolia and Alaska to non-breeding grounds in the Southern hemisphere, including Australia and New Zealand (Department of Environment, 2015). Australia protects migratory bird species under the *EPBC Act* (Department of Environment, 2020). These comprise of migratory species which are native to Australia and either:

- included in the appendices to the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals Appendices I and II);
- included in annexes established under the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA); and/or
- identified in a list established under, or an instrument made under, an international agreement approved by the Minister, such as the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

The kanamaluka/Tamar estuary provides habitat to over 20 migratory bird species. Many of these rely on wetlands and mudflats in the upper estuary and are impacted by a loss of habitat when wetlands and mudflats are infilled or when food sources are impacted through human activities or changes in water quality.

Table 38 summarises the 16 migratory bird species and their listings found within the Tamar Island Key Biodiversity Area (Launceston to Batman Bridge) which are observed in the Birdata data base.

Table 38. EPBC Act listed migratory bird species observed in the Birdata data base (Birdlife Australia, 2020) in the Tamar Wetlands Key Biodiversity Area (KBA).

Common Name	**Scientific Name**	**EPBC Act**	**Bonn**	**CAMBA**	**JAMBA**	**ROKAMBA**
Common sandpiper	*Actitis hypoleucos*	Listed	A2H	Listed	Listed	Listed
Fork-tailed swift	*Apus pacificus*	Listed		Listed	Listed	Listed
Sharp-tailed sandpiper	*Calidris acuminata*	Listed	A2H	Listed	Listed	Listed
Curlew sandpiper	*Calidris ferruginea*	Listed	A2H	Listed	Listed	Listed
Pectoral sandpiper	*Calidris melanotos*	Listed	A2H		Listed	Listed
Red-necked stint	*Calidris ruficollis*	Listed	A2H	Listed	Listed	Listed
Double-banded plover	*Charadrius bicinctus*	Listed as Charadriidae	A2H			
White-winged tern, white-winged black tern	*Chlidonias leucopterus*	Listed		Listed	Listed	Listed
Latham's snipe, Japanese snipe	*Gallinago hardwickii*	Listed	A2H		Listed	Listed
White-throated needletail	*Hirundapus caudacutus*	Listed		Listed	Listed	Listed
Caspian tern	*Hydroprogne caspia*	Listed			Listed	
Whimbrel	*Numenius phaeopus*	Listed	A2H	Listed	Listed	Listed
Pacific golden plover	*Pluvialis fulva*	Listed	A2H	Listed	Listed	Listed
Grey plover	*Pluvialis squatarola*	Listed	A2H	Listed	Listed	Listed
Crested tern	*Thalasseus bergii*	Listed			Listed	
Common greenshank, greenshank	*Tringa nebularia*	Listed	A2H	Listed	Listed	Listed

A further seven migratory species are found in the lower estuary, below the Key Biodiversity Area, as summarised in Table 39.

Table 39. EPBC Act listed migratory bird species observed in the Birdata data base (Birdlife Australia, 2020) in the lower estuary.

Common Name	**Scientific Name**	**EPBC Act**	**Bonn**	**CAMBA**	**JAMBA**	**ROKAMBA**	**Present in the KBA surveys?**
Ruddy turnstone	*Arenaria interpres*	Listed	A2H	Listed	Listed	Listed	No
Sharp-tailed sandpiper	*Calidris acuminata*	Listed	A2H	Listed	Listed	Listed	Yes
Red knot, knot	*Calidris canutus*	Listed	A2H	Listed	Listed	Listed	No
Curlew sandpiper	*Calidris ferruginea*	Listed	A2H	Listed	Listed	Listed	Yes
Red-necked stint	*Calidris ruficollis*	Listed	A2H	Listed	Listed	Listed	Yes
Double-banded plover	*Charadrius bicinctus*	Listed as Charadriidae	A2H				Yes
Latham's snipe, Japanese snipe	*Gallinago hardwickii*	Listed	A2H		Listed	Listed	Yes
White-throated needletail	*Hirundapus caudacutus*	Listed		Listed	Listed	Listed	Yes
Caspian tern	*Hydroprogne caspia*	Listed			Listed		Yes
Bar-tailed godwit	*Limosa lapponica*	Listed	A2H	Listed	Listed	Listed	No
Satin flycatcher	*Myiagra cyanoleuca*	Listed as Muscicapidae	A2H				No
Eastern curlew, far eastern curlew	*Numenius madagascariensis*	Listed	A1	Listed	Listed	Listed	No
Whimbrel	*Numenius phaeopus*	Listed	A2H	Listed	Listed	Listed	Yes
Pacific golden plover	*Pluvialis fulva*	Listed	A2H	Listed	Listed	Listed	Yes
Little tern	*Sternula albifrons*	Listed	A2S	Listed	Listed	Listed	No
Black-browed albatross	*Thalassarche melanophris*	Listed	A2S*				No
Crested tern	*Thalasseus bergii*	Listed			Listed		Yes
Grey-tailed tattler	*Tringa brevipes*	Listed	A2H	Listed	Listed	Listed	No
Common greenshank, greenshank	*Tringa nebularia*	Listed	A2H	Listed	Listed	Listed	Yes

Bird counts from survey data in the Birdata database for each of the regions shown in Figure 56 are given in Appendix 3. It should be noted that surveys in the Birdata database are not comprehensive and some areas may have limited numbers of surveys. This means that while the data shows the presence of particular migratory species in each area of the estuary it does not mean that species not appearing in the database for that region implies the species is absent from that area.

A1.3.2. Migratory fish

Migratory fish spend part of their life cycle in one habitat/region before moving to another habitat for other parts of their life cycle, often starting their life in one system before migrating to another to mature then returning to spawn and die. Estuarine environments are a key area of transition between marine and freshwater systems for migratory species. Many migratory fish species use the kanamaluka/Tamar estuary to migrate from marine waters to freshwaters including multiple species of galaxidae. These species can be adversely impacted by barriers to their movements (such as weirs), changes in water quality, particularly increased turbidity which can make movement and feeding more difficult, and by changes which impact on food sources.

Hydro Consulting (1999) summarised the migratory fish species in the South Esk - Great Lake catchment (see Table 40). They state that barriers to fish migration include weirs and dams, including Lake Trevallyn, as well as altered flow regimes and water quality. High flows can make upward migration difficult as fish struggle to swim against high flow velocities, while low flows can make small barriers impassable. Low dissolved oxygen or changed water temperature (both high and low) can create a barrier to movement of fish.

Table 40. Migratory fish species using South Esk River and kanamaluka/Tamar estuary (adapted from Hydro Tasmania, 1999).

Common Name	Scientific Name	Tasmanian distribution	Conservation status (from Hydro Tasmania, 1999)	IUCN red list status (2020)
Short-headed lamprey	*Mordacia mordax*	Widespread around state	Note listed in State or Federal. Abundant throughout the State	Least concern
Pouched lamprey	*Geotria australis*	Widespread around state	Note listed in State or Federal. Widespread	Data deficient
Short-finned eel	*Anguilla australis*	Widespread around state	Note listed in State or Federal. Abundant throughout the State	Near threatened
Long-finned eel	*Anguilla reinhardtii*	North-east Tasmania	Note listed in State or Federal. Abundant along northern and easter coasts of the state	Least concern
Australian grayling	*Prototroctes maraena*	State-wide coastal rivers	Vulnerable (TSPA &EPBC) Widely distributed along north and east coasts of Tasmania and occasionally on the west coast	Vulnerable
Spotted galaxias	*Galaxias maculatus*	Locally abundant throughout the state	Not listed in state or federal legislation. Some self-sustaining landlocked populations	Least concern
Tasmanian mudfish	*Neochanna cleaveri*	Lower reaches of rivers and estuaries around the state except east coast	Not listed in state or federal legislation. Swamp drainage and reclamation threaten populations	Endangered
Tasmanian whitebait	*Lovettia sealii*	Lower reaches of rivers and estuaries around the state except east coast	Not listed in state or federal legislation. Abundance declined with overfishing closure of fishery has allowed populations to increase	Least concern
Tasmanian smelt	*Retropinna tasmanica*	State-wide in lower reaches of rivers and coastal streams	Not listed in state or federal legislation. Fragmented distribution may form landlocked	Least concern

			populations in lowland areas	
Sandy (tupong or freshwater flathead)	*Pseudaphritis urvillii*	State-wide in lower reaches of rivers and coastal streams	Note listed in State or Federal. Widespread and abundant	Least concern

Three of these migratory fish species, rated as near threatened, vulnerable and endangered on the IUCN Red List are described in more detail below.

Short-finned eel

The short-finned eel (*Anguilla australis*) travels from the kanamaluka/Tamar estuary to spawn in the Coral Sea near New Caledonia (de Salis, 2014; Boxall *et al.*, 2003; Hydro Tasmania, 2019). This eel is not considered endangered in Australia but similar species are listed as threatened in the northern hemisphere. Eel larvae are swept south from the Coral Sea in the east Australian current, with eels entering the kanamaluka/Tamar estuary between March and November as tiny glass eels. These eels travel up the estuary into freshwater lakes and rivers where they grow to maturity – adult males between 8 and 12 years old and females from 10 to 20 years of age. Once they reach maturity the eels travel downstream through the estuary and begin their migration back to the Coral Sea where they spawn and die. Hydro Tasmania has recently invested in a new eel bypass to allow the downstream migration of eels from Trevallyn Dam. A commercial eel fishery operates in Lake Trevallyn.

Australian grayling

The Australian grayling spawns in freshwater, with larvae drifting downstream to the sea, where they spend four to six months before returning to freshwater as juvenile fish (Koster and Gilligan, 2019; Threatened species section, 2020). Australian grayling are known to migrate through the kanamaluka/Tamar estuary to the North Esk River. It is thought that Australian grayling require increased flows to initiate spawning and that high flows are likely to be important to facilitate the migration of larvae and juveniles from coastal marine areas into rivers. Changes in water quality, particularly reduced dissolved oxygen, increased nutrients and turbidity, toxicants and physical barriers impact on the species. Australian grayling are listed under the Tasmanian *Threatened Species Protection Act 1995* and the *Environment Protection and Biodiversity Conservation Act 1999* as vulnerable.

Tasmanian mudfish

Tasmanian mudfish (also known as Australian mudfish) live in freshwater habitats which are semi-permanent, shallow and often muddy with dense vegetation. They can burrow into mud or shelter in moist substrates under rocks and debris to survive for short periods of time without surface water. They spawn in late winter with newly hatched larvae being washed downstream before spending their first two to three months at sea or in the estuary. Juveniles then migrate upstream from estuaries into freshwater habitats. The IUCN recently listed this species as endangered on the IUCN Red List with key threats related to loss of wetland habitats and barriers to migration.

A1.4. Threatened ecological and vegetation communities

An ecological community refers to a group of native plants, animals and other organisms that interact in a unique habitat (DAWE, 2020). The term 'threatened ecological community' refers to an ecological community that is at risk of extinction where its natural composition and function have been significantly depleted across its full range. The Tasmanian state government also lists threatened native vegetation communities that are protected under the *National Parks and Reserves Management Act 2002*.

Federally listed threatened ecological communities

Federally listed threatened ecological communities are protected under the *EPBC Act 1999*. The Act states that 'those activities that may require referral under the EPBC Act include, but are not restricted to:

- *changes to natural drainage regimes, such as the diversion of water, affecting the ecological community;*
- *clearing of the ecological community, dumping of spoil, construction of structures fragmenting the community or impeding natural water balances (e.g. causeways, raised fence lines);*
- *clearing of native vegetation adjacent to the listed community or in the immediate upstream catchment such that drainage regimes supporting the ecological community are affected;*
- *land reclamation and/or dredging in areas where a listed ecological community occurs, or in the vicinity of the ecological community such that parameters critical to the survival of the ecological community are affected;*
- *significant and adverse changes in management regimes affecting the community, including too frequent or too infrequent fire;*
- *new weed management regimes that pose significant risk to the listed community (e.g. aerial spraying); and*
- *allowing new access for domestic stock and other grazing animals (e.g. where there has previously been no access) or significant intensification in the numbers of animals with access to the ecological community'.*

Federally listed threatened ecological communities that occur in and around the kanamaluka/Tamar estuary are:

- *Eucalyptus ovata – Callitris oblonga* forest – vulnerable;
- giant kelp marine forests of south east Australia – endangered;
- lowland native grasslands of Tasmania – critically endangered; and
- subtropical and temperate coastal saltmarsh – vulnerable.

A1.4.1. *Eucalyptus ovata – Callitris oblonga* forest

There is a small area of *Eucalyptus ovata – C. oblonga* forest near First Basin in Cataract Gorge. This area supports approximately 20 mature *C. oblonga* and is considered important due to it being disjointed from other more extensive tracts of the community along the upper South Esk, St Pauls and Apsley Rivers.

A1.4.2. Giant kelp marine forests of south east Australia

The giant kelp forests of south east Australia ecological community is defined as giant kelp (*Macrocystis pyrifera*) growing typically at depths greater than eight metres below sea level (bsl) and forming a closed or semi-closed surface or sub-surface canopy. This ecological community extends from the substrate to the sea surface and includes a diversity of fauna on the seafloor, in the understory and throughout the water column (TSSC, 2012; DSEWPC, 2012). This ecological community is classified as endangered with the ecological community reduced to 5 percent of their previous range.

Giant Kelp forests are present on areas of rocky reef at the mouth of the kanamaluka/Tamar estuary. Mapping of the specific locations and extent of giant kelp in the lower estuary is not available but this ecological community can be assumed to be associated with rocky reef substrate habitats in the region near Clarence Point to Low Head (mostly around the Shear Reef/Pilot Station breakwater area).

A1.4.3. Lowland native grasslands of Tasmania

As defined in DEWHA (2010), the Lowland Native Grasslands of Tasmania ecological community is comprised of two grassland sub-types:

- lowland *Poa labillardierei* (silver tussock grass) Grassland; and
- lowland *Themeda triandra* (kangaroo grass) Grassland.

A small area (4.7 ha) of *Poa/Austrostipa low tussock grassland* (GPL) is mapped in the lower North Esk region (see Figure 61). There are additional lowland grass complexes mapped elsewhere in the kanamaluka/Tamar foreshore area but mapping does not distinguish whether these are part of the listed threatened lowland native grasslands ecological community (note that all lowland grasslands have to be assessed against the criteria in the policy statement 3.18 to determine EPBC status).

Figure 61. Extent of critically endangered lowland native grasslands of Tasmania in lower North Esk region of kanamaluka/Tamar estuary and foreshore (NVIS, 2018).

A1.4.4. Saltmarsh

The kanamaluka/Tamar estuary contains large areas of saltmarsh communities that extend from the upper estuary between Ti Tree Bend and Freshwater Point out to Low Head (see Figures 62 and 63 for distribution of saltmarsh in the upper and mid to lower estuary respectively). Over 50 ha of saltmarsh occurs between Ti Tree Bend and Freshwater Point, over 40 ha from there to Rosevears and a further 70 ha from Rowella to Clarence Point (see Table 41).

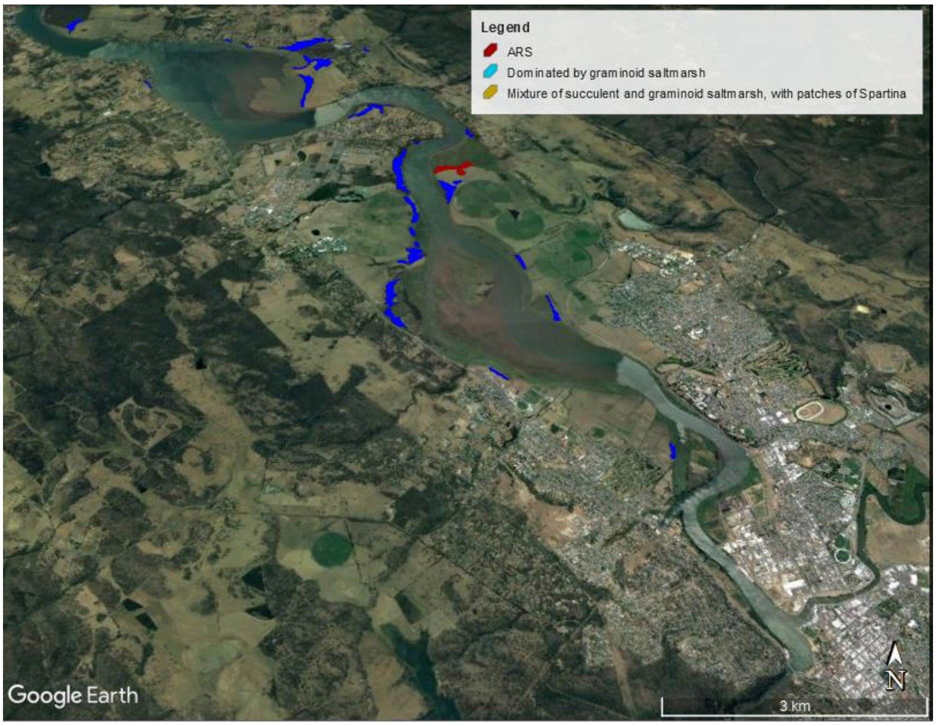

Figure 62. Saltmarsh extent in the upper kanamaluka/Tamar estuary 2018 (Prahalad, 2018).

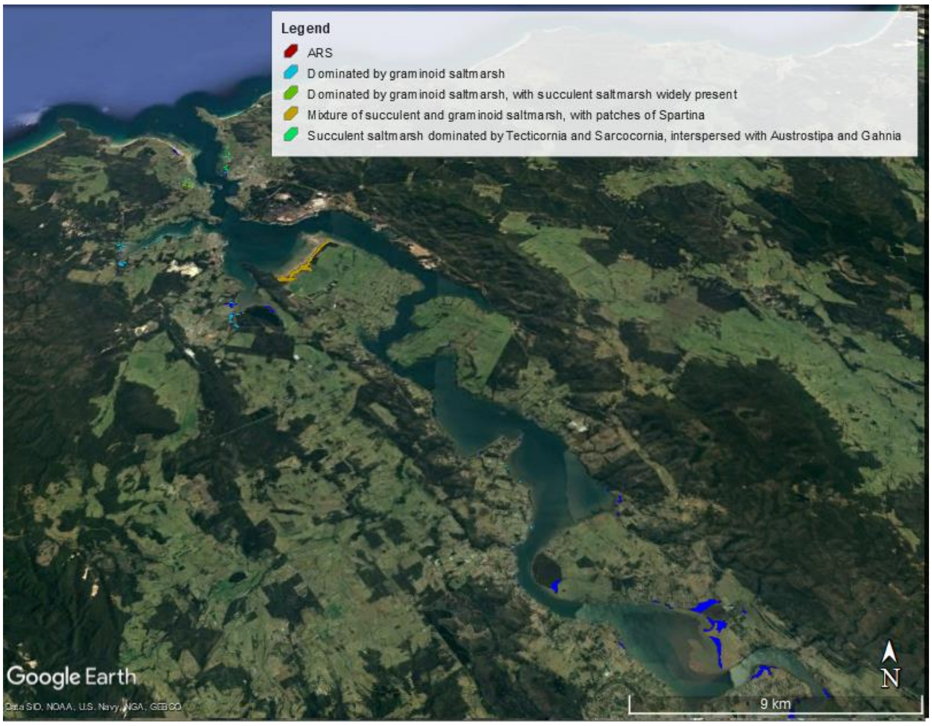

Figure 63. Saltmarsh extent in the mid to lower kanamaluka/Tamar estuary 2018 (Prahalad, 2018).

Table 41. Area of saltmarsh in each region of the kanamaluka/Tamar estuary.

Region of estuary	Area (ha)
Ti Tree Bend to Freshwater Point	57.7
Freshwater Point to Rosevears	44.6
Rosevears to Swan Point	6.7
Swan Point to Rowella	0.6
Rowella to Clarence Point	71
Clarence Point to Low Head	11.3
Total	191.9

A1.4.5. State listed threatened vegetation communities

There are eight state listed vegetation communities represented on the kanamaluka/Tamar estuary foreshore. Areas of each of these threatened vegetation communities have been estimated for each of the mapped regions of the estuary and foreshore using the Threatened Native Vegetation Communities (TNVC 2014) data set (see Table 42).

Table 42. Area in hectares of state listed threatened vegetation communities mapped regions of the kanamaluka/Tamar estuary and foreshore (TNVC, 2014).

Area	***Allocasuarina littoralis* forest**	***Eucalyptus amygdalina* forest and woodland on sandstone**	***Eucalyptus amygdalina* inland forest and woodland on cainozoic deposits**	***Eucalyptus ovata* forest and woodland**	***Eucalyptus viminalis - Eucalyptus globulus* coastal forest and woodland**	***Melaleuca ericifolia* swamp forest**	**Riparian scrub**	**Wetlands**
Lower North Esk	0	0	0	0	0	0	0	31.9
West Tamar to Tailrace	0	0	0	0	0	7.2	0	0
Ti Tree Bend to Freshwater Point	0	0	9.7	1.9	0	19.9	0.2	74.5
Freshwater Point to Rosevears	0	0	10.5	0.4	0	13.2	0	10.6
Rosevears to Swan Point	0	0.2	0	0	0	17.3	0	1.2
Swan Point to Rowella	0	0	0	2.5	0	41.8	0.9	0
Rowella to Clarence Point	0	87.3	0	166.8	0	50.6	0	7.4
Clarence Point to Low Head	5.1	0	0	4.4	2.1	12.5	1.1	0
Total	*5.1*	*87.5*	*20.2*	*176*	*2.1*	*162.5*	*2.2*	*125.6*

This table shows the large areas of *Eucalyptus ovata* and woodland, *Melaleuca ericifolia* swamp forest and wetlands that extend in distribution from the upper to lower estuary. The spatial distribution of these threatened vegetation communities is shown in the upper and mid to lower estuary in Figures 64 and 65 respectively. As can be seen on these figures both the upper estuary around Launceston and the region from Rowella to Clarence Point are hotspots for threatened vegetation communities along the estuary foreshore.

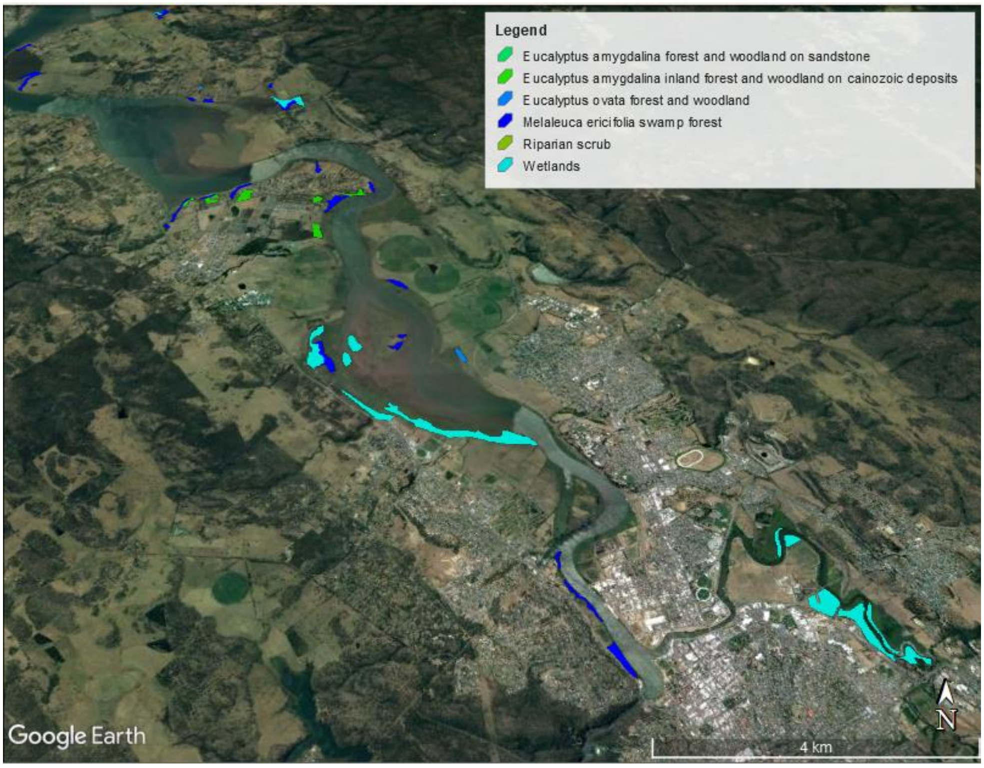

Figure 64. State listed threatened vegetation communities on the foreshore of the upper kanamaluka/Tamar estuary.

Figure 65. State listed threatened vegetation communities on the foreshore of the mid to lower kanamaluka/Tamar estuary.

Melaleuca ericifolia swamp forest is of particular relevance to sedimentation management given its proximity to Launceston, its relationship to mudflats in the estuary, and the direct impact of some sedimentation management options on this threatened native vegetation community. DPIPWE (2017) states that there are 8,900 ha of the community in Tasmania with 35 percent in the Tasmanian Reserve Estate. There are approximately 240 ha of *Melaleuca ericifolia* swamp forest adjacent to the kanamaluka/Tamar estuary, stretching from the upper estuary around Launceston alongside the sediment ponds on the West Tamar to the mouth of the estuary.

A1.5. Threatened flora

The Natural Values Atlas (NVA) records 63 threatened flora species listed as being recorded at either a state or federal level in the areas shown on Figure 56. The number of threatened flora species recorded in each area with a break down to state and federally listed (noting some species are listed under both) is given in Table 43. A full list of threatened flora record in the Natural Values Atlas in each area is given in Appendix 4.

Table 43. Number of threatened flora species recorded in areas in and around the kanamaluka/Tamar estuary in the Natural Values Atlas.

Area	Total	State listed	Federally listed
West Tamar to Tailrace	6	6	0
Lower North Esk	4	4	0
Royal Park to Ti Tree Bend	3	3	0
Ti Tree Bend to Freshwater Point	8	8	2
Freshwater Point to Rosevears	4	4	0
Rosevears to Swan Point	10	10	0
Swan Point to Rowella	15	15	2
Rowella to Clarence Point	30	30	7
Clarence Point to Low Head	18	18	2

A1.6. Threatened fauna

The Natural Values Atlas shows observations of 36 threatened fauna species in the areas mapped in Figure 56 covering the estuary and its foreshore. Table 44 summarises the number of state and federally listed threatened fauna species observed in each mapped section of the kanamaluka/Tamar estuary and its foreshore. These have also been split into state and federally listed and to animal kingdoms. A detailed list of threatened fauna species observations is given in Appendix 4.

Table 44. Summary of number threatened fauna observed in mapped areas of the estuary and its foreshore.

Area	Total	State listed	Federal listed	Bird	Mammal	Fish	Reptile	Amphibian
West Tamar to Tailrace	4	4	3	1	1	1	0	1
Lower North Esk	5	5	4	3	0	1	0	1
Royal Park to Ti Tree Bend	5	4	3	2	1	1	1	0
Ti Tree Bend to Freshwater Point	11	8	6	5	3	0	2	1
Freshwater Point to Rosevears	10	8	7	6	3	0	0	1
Rosevears to Swan Point	12	9	9	6	5	0	0	1
Swan Point to Rowella	11	8	10	5	5	0	0	1
Rowella to Clarence Point	10	8	9	2	8	0	0	0
Clarence Point to Low Head	24	15	23	16	6	0	1	1

Appendix 2. Intertidal habitat environment and vegetation

Table 45. Area of geomorphic habitat types (Dyall *et al.*, 2005) by TASVEG 4.0 vegetation codes (m^2)

Geomorphic habitat types	TASVEG 4.0 Vegetation code	Lower North Esk	West Tamar to Tailrace	Royal Park to Ti Tree Bend	Ti Tree Bend to Freshwater Point	Freshwater Point to Rosevears	Rosevears to Swan Point	Swan Point to Rowella	Rowella to Clarence Point	Clarence Point to Low Head
Natural habitat - vegetated										
Intertidal Flats	(AHL) Lacustrine herbland								4,187	
	(ARS) Saline sedgeland / rushland								107,820	13,521
	(ASF) Fresh water aquatic sedgeland and rushland				833,465	41,035	75,213		2,765	
	(ASS) Succulent saline herbland								65,292	43,377
	(AUS) Saltmarsh (undifferentiated)								192	
	(DAC) *Eucalyptus amygdalina* coastal forest and woodland						15,905	23,235	25,932	200
	(DAD) *Eucalyptus amygdalina* forest and woodland on dolerite				965		703	47,859	52,058	
	(DAM) *Eucalyptus amygdalina* forest on mudstone								34,069	
	(DAS) *Eucalyptus amygdalina* forest and woodland on sandstone								56,655	
	(DOB) *Eucalyptus obliqua* dry forest								3,181	

	(DOV) *Eucalyptus ovata* forest and woodland								36,790	
	(DSC) *Eucalyptus amygdalina* - *Eucalyptus obliqua* damp sclerophyll forest							3,791	8,642	
	(DVG) *Eucalyptus viminalis* grassy forest and woodland							33,840	7,201	
	(GHC) Coastal grass and herbfield									168
	(NAV) *Allocasuarina verticillata* forest									367
	(NBA) *Bursaria* - *Acacia* woodland								2,083	
	(NME) *Melaleuca ericifolia* swamp forest					566	10,674	14,204	36,732	483
	(SAL) *Acacia longifolia* coastal scrub									18,032
	(SMR) *Melaleuca squarrosa* scrub								79	214
	(SRE) Eastern riparian scrub							219		
Saltmarsh/Saltflat	(ASF) Fresh water aquatic sedgeland and rushland	80	16,675	57,109	3,158,056	136,224	9,535			
	(ASS) Succulent saline herbland								276,019	
	(DAC) *Eucalyptus amygdalina* coastal forest and woodland						58,534	3,617		
	(DAD) *Eucalyptus amygdalina* forest and woodland on dolerite						5,176	4,582		

	(DAZ) *Eucalyptus amygdalina* inland forest and woodland on Cainozoic deposits				6,147	5,144				
	(DVG) *Eucalyptus viminalis* grassy forest and woodland				1,578			22,701		
	(NAD) *Acacia dealbata* forest							323		
	(NME) *Melaleuca ericifolia* swamp forest		62,896		101,853	6,763	8,545	5,347	7,342	
Unassigned	(ASF) Fresh water aquatic sedgeland and rushland				133,711					
	(DAC) *Eucalyptus amygdalina* coastal forest and woodland							3,196	17,131	
	(DAD) *Eucalyptus amygdalina* forest and woodland on dolerite							3,677		
	(GHC) Coastal grass and herbfield								62,068	3,730
	(NME) *Melaleuca ericifolia* swamp forest				28,399					
Natural habitat - unvegetated										
Intertidal Flats	(OAQ) Water, sea	52,454		9,458	1,425,633	1,998,445	935,193	972,711	1,651,645	3,676,125
	(OSM) Sand, mud						3,360	1,180	3,250,203	166,738
Sa lt m	(OAQ) Water, sea	66,403	22,906	36,021	218,920	27,509	91,204	24,681	462	

	(OSM) Sand, mud								19,690	
Unassigned	(OAQ) Water, sea						11,356	6,873	2,438	8,485
	(OSM) Sand, mud								21,886	
Ricegrass										
Intertidal Flats	(FSM) *Spartina* marshland					265,467	513,525	323,202	41,716	
Saltmarsh/Saltflat	(FSM) *Spartina* marshland					1,586,886	497,712	229,518	14,079	
Unassigned	(FSM) *Spartina* marshland						3,839			
Modified lands										

Intertidal Flats	(FUM) Extra-urban miscellaneous								50	9,989
	(FUR) Urban areas	14,393		1,744		1,919	46,216	34,960	6,890	126,886
	(FWU) Weed infestation	9,236		1,813					2,895	2,267
	(FAG) Agricultural land				714	9,631	9,608	14,065	77,388	51,751
	(FPS) Plantations for silviculture - softwood								361	
	(FPU) Unverified plantations for silviculture								104	
	(FRG) Regenerating cleared land							349	85,336	
Saltmarsh/Saltflat	(FUM) Extra-urban miscellaneous		14,070		5,925					
	(FUR) Urban areas	6,428	6,600	2,786	14,821	33,112	65,530	4,109		
	(FWU) Weed infestation	5,758	1,997	1,882	15,573	1,387				
	(FAG) Agricultural land		108,076		135,976	104,219	58,852	37,661		
	(FPU) Unverified plantations for silviculture					642				
Unassigned	(FUM) Extra-urban miscellaneous									17,774
	(FUR) Urban areas						234			
	(FAG) Agricultural land				162,578					
	(FRG) Regenerating cleared land							6,036		
	(FWU) Weed infestation				5,094					

Appendix 3. Migratory birds

Bird count data from the Birdata data base compiled by Birdlife Australia has been interrogated and summarised against migratory bird species listed in the EPBC Act. Counts of each bird in each are of the estuary are provided in Table 46. Note that surveys are not comprehensive and have not been conducted for all areas of the estuary. This table gives an indication of the migratory bird species that have been observed in the estuary but does not mean that these or other species are not using areas where they haven't been recorded.

Table 46. Observations of EPBC listed[25] migratory birds from the Birdata data base[26].

Common Name	Scientific Name	EPBC Act	Bonn	CAMBA	JAMBA	ROKAMBA	Key Biodiversity Area	Kings bridge to Tailrace	Lower North Esk	Royal Park to Ti Tree Bend	Ti Tree Bend to Freshwater Pt	Freshwater Pt to Rosevears	Rosevears to Swan Pt	Swan Pt to Rowella	Rowella to Clarence Pt	Clarence Point to Low head
Common sandpiper	*Actitis hypoleucos*	Listed	A2H	Listed	Listed	Listed	14	0	0	0	15	0	0	0	0	0
Fork-tailed swift	*Apus pacificus*	Listed		Listed	Listed	Listed	1	0	0	0	1	0	0	0	0	0
Ruddy turnstone	*Arenaria interpres*	Listed	A2H	Listed	Listed	Listed	0	0	0	0	0	0	0	0	0	251
Sharp-tailed sandpiper	*Calidris acuminata*	Listed	A2H	Listed	Listed	Listed	107	0	0	0	151	0	0	0	0	16

[25] Department of the Environment (2020). SPRAT EPBC Migratory List in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed 2020-11-09T14:22:26.

[26] Birdlife Australia, https://birdata.birdlife.org.au/, accessed 9 November 2020

Red knot, knot	*Calidris canutus*	Listed	A2H	Listed	Listed	Listed	0	0	0	0	0	0	0	0	0	26
Curlew sandpiper	*Calidris ferruginea*	Listed	A2H	Listed	Listed	Listed	3	0	0	0	6	0	0	0	0	182
Pectoral sandpiper	*Calidris melanotos*	Listed	A2H		Listed	Listed	1	0	0	0	1	0	0	0	0	0
Red-necked stint	*Calidris ruficollis*	Listed	A2H	Listed	Listed	Listed	13	0	0	0	17	0	0	0	0	295
Double-banded plover	*Charadrius bicinctus*	Listed as Charadriidae	A2H				66	0	0	0	73	0	0	0	0	158
White-winged tern, white-winged black tern	*Chlidonias leucopterus*	Listed		Listed	Listed	Listed	1	0	0	0	1	0	0	0	0	0
Latham's snipe, Japanese snipe	*Gallinago hardwickii*	Listed	A2H		Listed	Listed	56	0	0	0	119	0	0	0	0	1
White-throated needletail	*Hirundapus caudacutus*	Listed		Listed	Listed	Listed	13	0	0	0	13	0	0	0	1	1
Caspian tern	*Hydroprogne caspia*	Listed			Listed		126	0	0	0	132	0	19	0	1	35
Bar-tailed godwit	*Limosa lapponica*	Listed	A2H	Listed	Listed	Listed	0	0	0	0	0	0	0	0	0	187
Satin flycatcher	*Myiagra cyanoleuca*	Listed as Muscicapidae	A2H				0	0	0	0	0	0	0	0	6	0
Eastern curlew, far eastern curlew	*Numenius madagascariensis*	Listed	A1	Listed	Listed	Listed	0	0	0	0	0	0	0	0	0	212
Whimbrel	*Numenius phaeopus*	Listed	A2H	Listed	Listed	Listed	1	0	0	0	1	0	0	0	0	108
Pacific golden plover	*Pluvialis fulva*	Listed	A2H	Listed	Listed	Listed	3	0	0	0	4	0	0	0	0	63

Grey plover	*Pluvialis squatarola*	Listed	A2H	Listed	Listed	Listed	1	0	0	0	0	0	1	0	0	0
Little tern	*Sternula albifrons*	Listed	A2S	Listed	Listed	Listed	0	0	0	0	0	0	0	0	0	2
Black-browed albatross	*Thalassarche melanophris*	Listed	A2S*				0	0	0	0	0	0	0	0	1	0
Crested tern	*Thalasseus bergii*	Listed			Listed		171	0	0	1	155	3	44	0	8	147
Grey-tailed tattler	*Tringa brevipes*	Listed	A2H	Listed	Listed	Listed	0	0	0	0	0	0	0	0	0	74
Common greenshank, greenshank	*Tringa nebularia*	Listed	A2H	Listed	Listed	Listed	43	0	0	0	48	0	0	0	0	160

Appendix 4. Threatened species lists by area of the kanamaluka/Tamar estuary and its foreshore

This Appendix contains detailed information on observations of threatened flora and fauna species recorded in the Natural Values Atlas (NVA) for areas as mapped in Figure 66. It should be noted that species may be recorded in the NVA which are no longer present in the area. Many areas have not been surveyed in detail so it is also likely that threatened species may exist in areas for which there are no recorded observations.

Figure 66. Areas of the kanamaluka/Tamar estuary and its foreshore for which threatened species observations in the Natural Values Atlas have been summarised.

A4.1. Threatened Flora

Table 47. Number of observations of threatened flora recorded in the Natural Values Atlas by Area of the kanamaluka/Tamar estuary and its foreshore. (SS = state significance: rare, vulnerable, endangered, x, pv), (NS = national significance, VU, PEN, EN) (Bio = biogeographic origin; n= native, e=endemic)

Species	Common name	SS	NS	Bio	West Tamar to Tailrace	Lower North Esk	Royal Park to Ti Tree Bend	Ti Tree Bend to Freshwater Point	Freshwater Point to Rosevears	Rosevears to Swan Point	Swan Point to Rowella	Rowella to Clarence Point	Clarence Point to Low Head
Acacia ulicifolia	Juniper wattle	r		n									3
Alternanthera denticulata	Lesser joyweed	e		n	12	1	1						
Anogramma leptophylla	Annual fern	v		n							2		
Apehlia gracelis	Slender fanwort	r		n								3	
Apehlia pumilio	Dwarf fanwort	r		n								21	
Asperula minima	Mossy woodruff	r		n								1	
Austrostipa blackii	Crested speargrass	r		n						1			
Bolboschoenus caldwellii	Sea clubsedge	r		n	3			8	2				
Brunonia australis	Blue pincushion	r		n					2		1	8	
Caladenia filamentosa	Daddy longlegs	r		n									1
Caladenia patersonii	Patersons spider orchid	v		n									1
Calendia caudata	Tailed spider orchid	v	VU	e								2	1
Calendia congesta	Black tongued finger orchid	e		n								1	
Callitriche sonderi	Matted waterstarwort	r		n									1
Calystegia sepium subsp. sepium	Swamp bindweed	r		n	11	7	9	24		1	1		
Carex gunniana	Mountain sedge	r		n						1			1
Carex longebrachiata	Drooping sedge	r		n							1	1	

Chorizandra enodis	Black bristlesedge	e		n									10
Coopernookia barbata	Purple native-primrose	x		n								1	
Cyrtostylis robusta	Large gnat-orchid	r		n									2
Desmodium gunnii	Southern ticktreoil	v		n							2		
Deyeuxia minor	Small bentgrass	r		n									1
Dianella amoena	Grassland flaxlily	r	EN	n							1		
Diurus palusttris	Swamp doubletail	e		n				1					
Epacris exserta	South Esk Heath	e	PEN	e							6	2	
Epacris virgata (Beaconsfield)	Twiggy heath	pv	EN	e								2	
Glycine microphylla	Small-leaf glycine	v		n							2	2	
Hibbertia virgata	Twiggy guineaflower	r		n							1		
Hyalosperma demissum	Moss sunray	e		n						1			
Juncus amabilis	Gentle rush	r		n		1		5				2	
Lepidium hyssopifolium	Soft peppercress	e	EN	n				1					
Lepodisperma viscidum	Sticky swordsedge	r		n								35	1
Limonium australe var. australe	Yellow sea-lavender	r		n						13	8	5	2
Lotus australis	Australian trefoil	r		n								1	2
Lycopus australis	Australian gypswort	e		n	12			17					
Lythrum salicaria	Purple loosestrife	v		n	9								
Mircotidium atratum	yellow onion-orchid	r		n									1
Orthoceras strictum	Horned orchid	r		n						1			
Persicaria subsessilis	Bristly waterpepper	e		n	7								
Phyllangium distylis	Tiny mitrewort	r		n									1
Pimelea flava subsp. Flava	Yellow riceflower	r		n							10	224	3
Poa mollis	Soft tussock grass	r		e							2		
Pomaderris pilifera subsp. Talpicutica	Moleskin dogwood	e-v	VU	e								3	

Prostanthera rotundifolia	Roundleaf mintbush	v		n					8	2			
Pultenaea mollis	Soft bushpea	v		n								1	
Rumex bidens	Mud dock	v		n				8					
Ruppia megacarpa	Largefruit seatassel	r		n						1			
Schoenoplectus tabernaemontani	River clubsedge	r		n			5						
Scutellaria humilis	Dwarf skullcap	r		n								6	
Senecio campylocarpus	Bulging fireweed	v		n		3							
Senecio psilocarpus	Swamp fireweed	e	VU	n				2					
Senecio squarrosus	Leafy fireweed	r		n							1	3	
Solanum opacum	Greenberry nightshade	e		n								3	
Spyridum parvifoliumv var parvifolium	Coast dustymiller	r		n								27	2
Stylidium beaugleholei	Blushing triggerplant	r		n								3	
Stylidium despectum	Small triggerplant	r		n								3	4
Teucrium corymbosum	Forest germander	r		n					1	1	2		
Theylmitra holmesii	Bluestar sun-orchid	r		n								2	
Tricoyne elatior	Yellow rushlily	v		n								1	
Veronica plebeia	Trailing speedwell	r		n						2	5	47	
Xanthorrhea bracteata	Shiny grasstree	v	EN	e								58	1
Xanthorrhoea aff. Bracteata	Shiny grasstree	pv	PEN	e								2	
Xanthorrhoea arenaria	Sand grasstree	v	VU	e								2	

A4.2. Threatened Fauna observations

Table 48. Observations of threatened fauna in the Natural Values Atlas by mapped areas of the kanamaluka/Tamar estuary and its foreshore. (SS = state significance: rare, vulnerable, endangered, x, pv), (NS = national significance, VU, PEN, EN) (Bio = biogeographic origin; n= native, e=endemic)

Species	**Common name**	**SS**	**NS**	**Bio**	**West Tamar to Tailrace**	**Lower North Esk**	**Royal Park to Ti Tree Bend**	**Ti Tree Bend to Freshwater Point**	**Freshwater Point to Rosevears**	**Rosevears to Swan Point**	**Swan Point to Rowella**	**Rowella to Clarence Point**	**Clarence Point to Low Head**
Accipter novehollandaie	Grey goshawk	e		n				1		3			
Aquila audax	Wedge tailed eagle	pe	PEN	n							2		
Aquila audax subsp. Fleayi	Tasmanian wedge tailed eagle	e	EN	e							1	7	4
Arctocephalus tropicalis	Sub-antarctic fur seal	e	VU	n								1	
Botaurus poiciloptilus	Australiasian bittern		EN	n				1					2
Calidris canutus	Red knot		EN	n									3
Calidris canutus subsp. Canutus	Red knot		PEN	n									14
Calidris ferruginea	Curlew sandpiper		CR	n					1				40
Charadrius mongolus subsp. Mongolos	Mongolian plover		PEN	n									2
Dasyrurus maculatus	Spotted tail quoll	r	VU	n					2	4	3	3	1
Dasyrurus maculatus subsp. Maculatus	Spotted tail quoll	r	VU	n						1	4	4	4
Dasyurus viverrinus	Eastern quoll		EN	n			1	2		1	3	1	
Dermochelys coriacea	Leatherback turtle	v	VU	n									1
Diomedea cauta subsp. Cauta	Shy albatross	pv	PVU										1
Eagle sp.	Eagle	e	EN	n						1			
Eubalaena australis	Southern right whale	e	EN	mbe								1	9

Haliaeetus leucogaster	White bellied sea eagle	v		n	1	1	2	3	10	13	9	10	7
Hirundapaus caudactus	White throated needletail		VU	n						1	1		5
Lathamus discolor	Swift parrot	e	CR	mbe		1	1		14				
Limosa lapponica subsp. Baueri	Western Alaskan bar tailed godwit		VU	n									32
Litoria raniformis	Green and gold frog	v	VU	n	3	1		2	7	9	2		6
Macronectes giganteus	Southern giant petrel	v	EN	n									1
Megaptera novaeangliae	Humpback whale	e	VU	mbe								3	17
Numenius madagascariensis	Eastern curlew	e	CR	n									48
Pachyptila turtursubantarctica	Southern fairy prion	e	VU										6
Perameles gunnii	Eastern barred bandicoot		VU	n				1	3	4	13	4	2
Podiceps cristatus	Great crested grebe	v		n				1	2	1			
Podiceps cristatus subsp. Australia	Great crested grebe	pv							2				
Prototroctes maraena	Australian grayling	v	VU	ae	1	1	2						
Pseudemoia pagenstecheri	Tussock skink	v		n				1					
Pseudemoia rawlinsoni	Glossy grass skink	r		n			2	1					
Sarcophilus harrisii	Tasmanian Devil	e	EN	e	2			1	4	12	13	8	8
Sterna nereis subsp. Nereis	Fairy tern	pv	PVU										8
Sternula nereis subsp. Nereis	Fairy tern	v	VU	n									6
Thirnornis rubricollis	Hooded plover		VU	n									20
Tyto novaehollandiae	Masked owl	pe	PVU	n		2		3	1	2	1		

A4.3. Threatened Fauna ranges

Table 49. Threatened fauna based on range (P=Potential, C=Core). (SS = state significance: rare, vulnerable, endangered, x, pv), (NS = national significance, VU, PEN, EN) (Bio = biogeographic origin; n= native, e=endemic)

Species	Common name	SS	NS	BO	West Tamar to Tailrace		Lower North Esk		Royal Park to Ti Tree Bend		Ti Tree Bend to Freshwater Point		Freshwater Point to Rosevears		Rosevears to Swan Point		Swan Point to Rowella		Rowella to Clarence Point		Clarence Point to Low Head	
					P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C
Accipter novaehollandiae	Grey goshawk	e		n	1		1		1		1		1		1	2	1	6	1	1	1	
Antipodia chaostola	Chaostola skipper	e	EN	ae							7		3		2		2		8		2	
Aquila audax subsp. Fleayi	Tasmanian wedge-tailed eagle	e	EN	e	1		1		1		1		1		1		1		1		1	
Catadromus lacrodairei	Green-lined ground beetle	v		n	1				1													
Dasyurus maculatus subsp. Maculatus	Spotted tail quoll	r	VU	n	1	0	1		1		1		1		1		1		1		1	
Dasyurus viverrinus	Eastern quoll		EN	n		1		1		1		1		1		1		1		1		1
Engaeus ranulatus	Central north Burrowing crayfish	e	EN	e	1										1		1		1		1	
Galaxiella pusilla	Eastern dwarf galaxias	v	VU	n	1				1		1		1		1		1		1		1	
Haliaeetus leucogaster	White bellied sea eagle	v		n	2		2		2		2		2		2		2		2		3	
Lathamus discolor	Swift parrot	e	CR	mbe							1		1		1		1		1		1	
Limnodynastes peroni	Striped marsh frog	e		n	1		1		1		1		1		1				1	1	1	
Litoria raniformis	Green and gold frog	v	VU	n	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Migas plomleyi	Plomley's trapdoor spider	e		e	1				1													
Pasmaditta jungermanniae	Cataract Gorge pinhead snail	v		e	1	0	1		1		1		1		1							
Perameles gunni	Eastern barred bandicoot		VU	n	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Prototroctes maraena	Australian grayling	v	VU	ae	1	0	1		1		7		1		3		8		12		10	
Pseudomys novaehollandiae	New holland mouse	e	VU	n									1		2		2		2		2	
Pseunemoia pagenstecheri	Tussock skink	v		n	1	0	1		1		1		1		1		1		1		1	
Sarcophilus harrisii	Tasmania devil	e	EN	e	1		1		1		1		1		1		1		1		1	

Tyto novaehollandiae subsp. Castanops	Masked owl (Tasmanian)	e	VU	e	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1

Appendix 5. Relevant Legislation

There are several key pieces of legislation which regulate activities with the potential to impact on the estuary and its foreshore. Much of this legislation relates to impacts on environmental values of the estuary and foreshore and in some cases legislation implements a range of commitments Australia has made in signing various international treaties and agreements. Other legislation governs permitting around construction of dams and levees and activities that require disposal of contaminated waste or pose risks through pollution. In most cases there are pathways through the permitting process that allow permits to be obtained subject to constraints, but in many cases this would add to the costs of projects through requirements for environmental impact assessments, ongoing monitoring programs or handling requirements for contaminated waste. This section briefly summarises key pieces of legislation that would affect the sedimentation management options evaluated in this report. It is not intended to be a comprehensive account of all legislation and permitting processes that may relate to the various management options.

A5.1. Water Management Act 1999

The objectives of the Water Management Act 1999 are to further the objectives of the resource management and planning system of Tasmania and to provide for the use and management of the freshwater resources of Tasmania having regard to the need to:

‘(a) promote sustainable use and facilitate economic development of water resources; and

(b) recognise and foster the significant social and economic benefits resulting from the sustainable use and development of water resources for the generation of hydro-electricity and for the supply of water for human consumption and commercial activities dependent on water; and

(c) maintain ecological processes and genetic diversity for aquatic and riparian ecosystems; and

(d) provide for the fair, orderly and efficient allocation of water resources to meet the community's needs; and

(e) increase the community's understanding of aquatic ecosystems and the need to use and manage water in a sustainable and cost-efficient manner; and

(f) encourage community involvement in water resource management.’

Under the Water Management Act 1999, there are three separate sets of regulations: the *Water Management Regulations 2019*, the *Water Management (Safety of Dams) Regulations 2015* and the *Water Management (Electoral and Polling) Regulations 2019*. Of these regulations two are most relevant to this evaluation:

- The *Water Management Regulations 2019* set limits on the taking of water for specific uses.
- The *Water Management (Safety of Dams) Regulations 2015* set the level of competency required for construction teams to be authorised to work on dams of different hazard categories and dimensions.

A5.2. Environment Protection and Biodiversity Conservation Act 1999 – Federal Legislation

The *EPBC Act 1999* is the primary piece of environmental legislation aimed at protecting and managing national and internationally important flora, fauna, ecological communities and heritage places. Information in this section is taken from Commonwealth Department of Environment (2013).

The nine matters of national environmental significance to which the EPBC Act applies are:

- world heritage properties;
- national heritage places;
- wetlands of international importance (often called 'Ramsar' wetlands after the international treaty under which such wetlands are listed);
- nationally threatened species and ecological communities;
- migratory species;
- Commonwealth marine areas;
- the Great Barrier Reef Marine Park;
- nuclear actions (including uranium mining); and
- a water resource, in relation to coal seam gas development and large coal mining development.

The objectives of the *EPBC Act* are to:

- provide for the protection of the environment, especially matters of national environmental significance;
- conserve Australian biodiversity;
- provide a streamlined national environmental assessment and approvals process;
- enhance the protection and management of important natural and cultural places;
- control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife;
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;
- recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and
- promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

A5.3. Nature Conservation Act 2002 and National Parks and Reserves Act 2002 – Tasmanian Legislation

The *Nature Conservation Act 2002* provides for the conservation and protection of the fauna, flora and geological diversity of Tasmania and for the declaration of national parks and other reserved land. This legislation:

- provides for declaration of national parks and reserves;
- sets up regulations for taking and trading in native wildlife; and

- lists threatened native vegetation communities that are to be protected under the forest practices system (see EDO Tasmania, 2019).

National Parks and Reserves Management Act 2002 supports the Nature Conservation Act through providing a framework for the management of reserved lands by:

- establishing management plans for reserved areas;
- restricting use and development in reserved areas; and
- requiring authorisation to impact on flora, fauna and geological features on reserved land.

A5.4. Threatened Species Protection Act 1995 – Tasmanian Legislation

Threatened Species Protection Act 1995 sets out special protection measures for native plants and animals considered threatened. Flora and fauna species are listed in the schedules of the Act based on the nature of their threatened status:

- endangered: extinct or in danger of extinction;
- vulnerable: likely to become endangered; and
- rare: a small population that is not immediately vulnerable but is still at risk.

The *Threatened Species Act* makes it illegal to 'take' a listed threatened species without a special permit. To 'take' is defined in the Act as to: "kill, injure, catch, damage, destroy or collect" and may also include the destruction of habitat (EDO Tasmania, 2019).

A5.5. Environmental Management and Pollution Control Act 1994 – Tasmanian Legislation

The *Environmental Management and Pollution Control Act (EMPCA) 1994* is the key legislation in Tasmania for dealing with pollution. The objectives of the Act are:

- 'to protect and enhance the quality of the Tasmanian environment; to prevent environmental degradation and adverse risks to human and ecosystem health by promoting pollution prevention, clean production technology, reuse and recycling of materials and waste minimization programmes;
- to regulate, reduce or eliminate the discharge of pollutants and hazardous substances to air, land or water consistent with maintaining environmental quality;
- to allocate the costs of environmental protection and restoration equitably and in a manner that encourages responsible use of, and reduces harm to, the environment, with polluters bearing the appropriate share of the costs that arise from their activities;
- to require persons engaging in polluting activities to make progressive environmental improvements, including reductions of pollution at source, as such improvements become practicable through technological and economic development;
- to provide for the monitoring and reporting of environmental quality on a regular basis;

- to control the generation, storage, collection, transportation, treatment and disposal of waste with a view to reducing, minimizing and, where practicable, eliminating harm to the environment;
- to adopt a precautionary approach when assessing environmental risk to ensure that all aspects of environmental quality, including ecosystem sustainability and integrity and beneficial uses of the environment, are considered in assessing, and making decisions in relation to, the environment;
- to facilitate the adoption and implementation of standards agreed upon by the state under inter-governmental arrangements for greater uniformity in environmental regulation;
- to promote public education about the protection, restoration and enhancement of the environment; and
- to co-ordinate all activities as are necessary to protect, restore or improve the Tasmanian environment'.

EMPCA spells out the requirements for Environmental Impact Assessments which cover a wide range of environmental values and potential impacts:

- noise emissions;
- air emissions and air quality;
- natural values (including flora and fauna, weeds and diseases and geoconservation);
- water emissions and quality (including storm water and marine water quality);
- groundwater;
- waste management – including liquid, solid waste and controlled wastes;
- management of environmentally hazardous materials;
- land contamination;
- monitoring; and
- decommissioning and rehabilitation.

Appendix 6. Development of evaluation matrix

This appendix provides detailed scores used to create the final evaluation matrix provided in Section 16.2 to compare different sedimentation management options.

A6.1. Categories for cost, feasibility, effectiveness and flood risk

Costs provided in this report are not comprehensive. They are provided as a simple indicative measure of the scale of the project to allow differentiation between options. A full feasibility assessment, design and detailed costing of each option would be required to accurately assess costs, feasibility and effectiveness.

Costs are categories by scale for capital expenditure which includes costs of building infrastructure associated with the action as well as other upfront costs such as those associated with acquiring permits or licences based using broad cost ranges:

- None Zero capital costs
- Low <$10 million;
- Medium $10 – $50 million;
- High $50 - $100 million; and
- Very high >$100 million.

Annual operating expenditure and ongoing costs associated with eg. maintenance, running expenses or lost power production is also categorised (where costs are able to be estimated):

- None Zero ongoing or operating costs
- Low <$1 million/yr
- Medium $1 - $5 million/yr
- High $5 - $10 million/yr
- Very high >$10 million/yr

Assessment of feasibility of the proposals is focused on challenges associated with legislation, logistics and operations in an estuarine environment, and the specific location of proposed infrastructure. This includes consideration of the legislative and permitting requirements, complexities of managing sediment and contaminants, operation of proposed infrastructure and its interaction with existing infrastructure, and public safety considerations. The complexity of each of the proposals is categorised as high, medium and low based on the greatest level of complexity in any of the areas.

Effectiveness of the proposals is evaluated by the expected changes in bathymetry in the channels and mudflats of the estuary. The degree to which bathymetric objectives are met is based on a rating of change in the extent of visible mudflats and channel depth in the Yacht Basin, Home Reach and Lower North Esk. A score between -3 and 3 is given to each area for the change in mudflat extent and channel depth where -3 is a large increase in mudflat extent or decrease in channel depth, 0 indicates no change and 3 indicates a large decrease in mudflat extent or increase in channel depth. Impacts on bathymetric objectives are provided in full in the evaluation matrix.

Floodplain consultants WMAWater were engaged to provide expert assessment of the impacts of each of the sedimentation management options on flood levels and a discussion of the implications for riverine flood risk (WMAWater, 2021). This assessment used a mix of qualitative expert opinion utilising previous flood studies in the estuary and analysis of results from City of Launceston's TUFLOW flood model. A description of key findings on impacts on flood risk for each of the options was provided in the detailed evaluations. For the evaluation matrix this change in flood risk is summarised into one of several categories of increasing, unchanging or decreasing risk:

- Negligible impact on flood risk – little to no change in risk for floods of any volume to areas both inside and outside the formal flood levee system.
- Very small impact on flood risk – some change in risk in non-levee protected areas primarily during smaller floods.
- Small impact on flood risk – some change in risk in formal flood levee system protected areas for some flood events, changes in risk on non-levee protected areas potentially greater but not substantial.
- Moderate impact on flood risk – some change in risk in formal flood levee system protected areas for flood events, changes in risk on non-levee protected areas substantial.
- Large impact on flood risk – substantial impacts on flood risk in both formal flood levee system protected and non-levee protected areas.
- Very large impact on flood risk – extreme impacts on flood risk in both formal flood levee system protected and non-levee protected areas.

It should be noted that these evaluations of flood risk impacts are qualitative and, in many cases, highly uncertain without significantly more quantitative analysis. As with the other components of the evaluation, they are intended to give an indication of the nature, direction and magnitude of change rather than provide a detailed and accurate assessment of flood risk, which is outside the scope of this report.

A6.2. Rapid Impact Assessment Matrix categories and scores used for environmental and social values

The Rapid Impact Assessment Matrix methodology is frequently used to make an early assessment of environmental and social impacts of large projects prior to project planning and formal assessment (Kuitunen, *et al*., 2008; Ijas, *et al.*, 2010). The categories are outlined in Table 50 and have been used to provide a broad assessment of the environmental and social impacts of the sediment management proposals.

Table 50. Rapid Impact Assessment Matrix categories and scores (Kuitunen, *et al*., 2008; Ijas, *et al*., 2010).

	Scores	Description
A1 – Importance of impact	4	Important to national / international interests. Here the impact coverage area was understood as being almost the whole nation or a larger area, or that the impact target was seen as being nationally or internationally important.
	3	Important regionally. Here the coverage area was a single region or several regions.
	2	Important to areas immediately outside the local context. Here the coverage area was larger than that of point formed impact. Usually the area included more than one municipality.
	1	Important only in the local context. Here the impact was only point formed.
	0	No geographical or other recognized importance.
A2 – Magnitude of change and effect	+3	Major positive benefit
	+2	Significant improvement in status quo
	+1	Improvement in status quo
	0	No change in status quo
	-1	Negative change to status quo
	-2	Significant negative disadvantage or change
	-3	Major disadvantage or change
B1 – Permanence of the impact causing activity	4	Permanent. The project or activity causing impact is meant to be a permanent one (10-15 years).
	3	Temporary and medium term. The project or activity causing impact is temporal (1-10 years).
	2	Temporary and short term. The project or activity causing impact is temporal (weeks or months).
	1	No change.
B2 – Reversibility of impact	4	Irreversible impact. The impact is irreversible as the original state is not restored after the impact causing activity is finished (10-15 years).
	3	Slowly reversible impact. Impact has changed the environment slowly but restoration can be observed. Total recovery will last for many years (1-10 years).
	2	Reversible impact. The impact is reversible if the original state will be restored after the activity is finished (weeks or months).
	1	Not applicable.
B3 – Accumulation of impact	3	Impact is cumulative or synergistic. The project or activity probably has combined impact with other projects or impacts in the same area.
	2	The impact is non-cumulative.
	1	No change / Not applicable.

B4 – Susceptibility of the target environment	4	The target area is extremely sensitive to environmental changes and / or has intrinsic values with regional or national significance.
	3	The target area is sensitive to environmental changes and / or it has locally significant values (outside the actual target area).
	2	The area is stable for the environmental changes caused by the planned project and does not have significant environmental values that should be considered during the evaluation process.
	1	No change / not applicable.

These scores are used to calculate an environmental score as follows:

$$ES = A_1 \times A_2 \times (B_1 + B_3 + B_4)$$

When evaluated against these criteria, the scores result in the following classification shown in Table 51. Note that additional categories of 'extreme' positive and negative impacts have been added to the evaluation in this report to capture the very large scale of differences in environmental impacts between different options.

Table 51. Environmental impact classification based on scores in Rapid Impact Assessment.

Range	Score	Classification
+192 to +164	+5	Extreme positive impact
+163 to +108	+4	Major positive impact
+107 to +54	+3	Significant positive impact
+53 to +31	+2	Moderately positive impact
+1 to +30	+1	Slightly positive impact
0	0	No change/status quo/not applicable
−30 to −1	–1	Slightly negative impact
−53 to −31	–2	Moderately negative impact
−107 to −54	–3	Significant negative impact
−163 to −108	–4	Major negative impact
−192 to −164	-5	Extreme negative impact

A6.3. Calculations for evaluation scores for each sedimentation management option

Tables of scores under each criteria for different sedimentation management options are provided below. These are based on the detailed assessment of each option.

A6.3.1. Cost

	No intervention	Accelerated restoration		North Esk tidal prism, informal levees and wetlands				Dredging		Tailrace canal	Lakes and barrages			Sediment raking	Increased flows[27]
		Restoration of intertidal vegetation	Remediation of West Tamar silt ponds	Cease informal levee construction	Remove informal tidal levees	Wetland restoration - small program	Wetland restoration - large program	Small scale dredge program	Large scale dredge program		North Esk weir	Small lake	Large lake		
Capital expenditure															
Approximate cost	0	~$3 m - 4 m	~$1 m - 10 m	0	~$2 m	~$10 m	~$250 m	~$30 m	~$80 m	>$130 m	>$25 m	~$500 m	~$500 m	0	0
Category	None	Low	Low	None	Low	Medium	Very high	Medium	High	Very high	Medium	Very high	Very high	None	None
Operating costs (per year)															
Approximate cost	$	<$1 m	<$1 m	0	<$1 m	<$1 m	<$1 m	>$10 m	>$30 m	>$5 m	>$2 m	>$5 m	>$5 m	~$200 k	~$200 k
Category	None	Low	Low	None	Low	Low	Low	Very high	Very high	High	Medium	High	High	Low	Low

[27] Cost for this option is based on 8,640 ML released over a 2 to 5 day period. Multiple or continuous flow releases in a year would cost significantly more (potentially millions of dollars per year), assuming they are feasible given constraints on water availability.

A6.3.2. Feasibility

Complexity	No intervention	Accelerated restoration		North Esk tidal prism, informal levees and wetlands				Dredging		Tailrace canal	Lakes and barrages			Sediment raking	Increase flows
		Restoration of intertidal vegetation	Remediation of West Tamar silt ponds	Cease informal levee construction	Remove informal tidal levees	Wetland restoration - small program	Wetland restoration - large program	Small scale dredge program	Large scale dredge program		North Esk weir	Small lake	Large lake		
Legislative	None	Low	Low	Medium	Medium	Medium	Medium	High	High	Medium	High	Very high	Very high	High	Low
Technical	None	Low	Medium	Low	Low	Medium	High	Medium	High	Very high	High	Very high	Very high	Low	Low
Infrastructure	None	Low	Low	Low	Low	Low	Low	Low	Low	High	High	High	High	Low	Low
Safety	None	Low	Low	Low	Low	Low	Low	Low	Low	High	Medium	Medium	Medium	Low	Low
Highest complexity rating	*None*	*Low*	*Medium*	*Medium*	*Medium*	*Medium*	*High*	*High*	*High*	*Very high*	*High*	*Very High*	*Very High*	*High*	*Low*

A6.3.3. Impacts on bathymetry, visible mudflats and channels

	No intervention	Accelerated restoration	North Esk tidal prism, informal levees and wetlands				Dredging		Tailrace canal	Lakes and barrages			Sediment raking	Increased flows
			Cease informal levee construction	Remove informal tidal levees	Wetland restoration - small program	Wetland restoration - large program	Small scale dredge program	Large scale dredge program		North Esk weir	Small lake	Large lake		
Score														
Channels														
Lower North Esk	0	0	0	2	1	3	0	3	0	-1	-1	-1	-2	0
Yacht Basin	0	0	0	0	0	0	2	3	1	0	-1	-1	-2	0
Home Reach	0	0	0	1	0	2	2	3	1	-2	-1	-1	-2	0
Mudflats														
Lower North Esk - Seaport	-2	-2	1	2	1	3	0	0	0	3	3	3	1	0
Lower North Esk - Town Point	0	0	1	2	1	3	0	0	0	3	3	3	1	0
Yacht Basin	0	0	0	0	0	0	0	0	0	0	3	3	1	0

Home Reach	0	0	1	2	1	3	0	0	0	-3	3	3	1	0
Expected change														
Channel depth														
Lower North Esk	No change	No change	No change	Moderate increase	Small increase	Large increase	No change	Large (temporary) increase	No change	Small loss	Small loss	Small loss	Moderate loss	No change
Yacht Basin	No change	No change	No change	No change	No change	No change	Moderate increase	Large (temporary) increase	Small increase	No change	Small loss	Small loss	Moderate loss	No change
Home Reach	No change	No change	No change	Small increase	No change	Moderate increase	Moderate increase	Large (temporary) increase	Small increase	Moderate loss	Small loss	Small loss	Moderate loss	No change
Extent of visible mudflats														
Lower North Esk - Seaport	Moderate increase	Moderate increase	Small reduction	Moderate reduction	Small reduction	Large reduction	No change	No change	No change	Large decrease	Large reduction	Large reduction	Small reduction	No change
Lower North Esk - Town Point	No change	No change	Small reduction	Moderate reduction	Small reduction	Large reduction	No change	No change	No change	Large decrease	Large reduction	Large reduction	Small reduction	No change
Yacht Basin	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	Large reduction	Large reduction	Small reduction	No change
Home Reach	No change	No change	Small reduction	Moderate reduction	Small reduction	Large reduction	No change	No change	No change	Large increase	Large reduction	Large reduction	Small reduction	No change

A6.3.4. Flood risk

	No intervention	Accelerated restoration	North Esk tidal prism, informal levees and wetlands	Dredging	Tailrace canal	Lakes and barrages	Sediment raking	Increased flows
Formal flood levee protected area	Negligible impact	Negligible impact	No impact	No impact	No impact	Some increase in very small likelihood, high consequence risk due to lack of fail-safe flood management system	No impact	No impact
Non-formal flood levee protected area	Negligible impact	Negligible impact	Very small decrease in risk	No impact	Minor increase in flood risk	Some increase in very small likelihood, high consequence risk due to lack of fail-safe flood management system	No impact	No impact
Impact on flood risk	*Negligible impact*	*Negligible impact*	*Very small decrease in risk*	*Negligible impact*	*Very small increase in flood risk*	*Small increase in flood risk*	*Negligible*	*Negligible*

A6.3.5. Environmental impacts

Criteria	No intervention	Accelerated restoration	North Esk tidal prism, informal levees and wetlands				Dredging		Tailrace canal	Lakes and barrages			Sediment raking	Increased flows
			Cease informal levee construction	Remove informal tidal levees	Wetland restoration - small program	Wetland restoration - large program	Small scale dredge program	Large scale dredge program		North Esk weir	Small lake	Large lake		
A1 Importance of the impact	2	2	2	2	2	4	2	3	3	3	4	4	3	2
A2 Magnitude of change	1	1	2	2	2	3	-2	-2	-2	-2	-3	-3	-2	0
B1 Permanence	4	4	4	4	4	4	2	2	4	4	4	4	2	2
B2 Reversibility	3	3	4	4	4	4	3	3	4	4	4	4	3	2
B3 Synergies or cumulative impact	3	3	3	3	3	3	2	2	2	1	2	3	2	2
B4 Susceptibility of environment	4	4	4	4	4	4	4	4	4	4	4	4	4	1
ES	28	28	60	60	60	180	-44	-66	-84	-78	-168	-180	-66	0
Score	1	1	3	3	3	5	-2	-3	-3	-3	-5	-5	-3	0
Category	Slightly positive impact	Slightly positive impact	Significant positive impact	Significant positive impact	Significant positive impact	Extreme positive impact	Moderately negative impact	Significant negative impact	Significant negative impact	Significant negative impact	Extreme negative impact	Extreme negative impact	Significant negative impact	No change

A6.3.6. Social impacts

Criteria	No intervention	Accelerated restoration	North Esk tidal prism, informal levees and wetlands				Dredging		Tailrace canal	Lakes and barrages			Sediment raking	Increased flows
			Cease informal levee construction	Remove informaltidal levees	Wetland restoration - small program	Wetland restoration - large program	Small scale dredge program	Large scale dredge program		North Esk weir	Small lake	Large lake		
A1 Importance of the impact	1	1	1	1	1	1	1	1	1	2	3	3	2	2
A2 Magnitude of change	0	1	1	2	1	2	0	0	0	-2	-2	-2	-1	0
B1 Permanence	3	3	4	4	4	4	2	2	4	4	4	4	2	2
B2 Reversibility	3	3	3	3	3	3	2	2	4	4	4	4	2	2
B3 Synergies or cumulative impact	3	3	3	3	3	3	3	3	3	3	3	3	2	2
B4 Susceptibility of environment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ES	0	10	11	22	11	22	0	0	0	-48	-72	-72	-14	0
Score	0	1	1	1	1	1	0	0	0	-2	-3	-3	-1	0
Category	No change	Slightly positive impact	Slightly positive impact	Slightly positive impact	Slightly positive impact	Slightly positive impact	No change	No change	No change	Moderately negative impact	Significant negative impact	Significant negative impact	Slightly negative impact	No change