Back Creek South West Rocks Sustainability Assessment Report

June 2007

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Integrated Catchment Assessment and Management (iCAM) Centre
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EXECUTIVE SUMMARY

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Back Creek. This tool was developed as part of the Northern Rivers Catchment Management Authority (CMA) funded project entitled 'Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers (CLAM project)'.

The report summarises the quality of data in the Back Creek CLAM for each node and also provides an assessment of key data gaps identified by Damon Telfer in putting the Back Creek CLAM together. These gaps are:

- Stormwater – data on nutrient, pathogen and sediment inputs into estuary from stormwater.
- Nutrients in sediment – nitrogen was relatively high in the water column in the system but no information was available on what amounts of nitrogen and phosphorus are locked up in sediments.

This report examines the impact of three groups of scenario combinations which combine options for a broader range of scenario groups, as recommended following a workshop held at Kempsey Shire Council in May 2007: entrance management and channel management; upgrade maintenance road with entrance and channel management; and, combinations of estuary management, channel management and road upgrade with development, foreshore management, stormwater management and sewerage management.
These are a small number of the total scenario combinations available in the Back Creek CLAM but provide a useful insight in themselves into the management of the lake. Key conclusions from this analysis are summarised below.

Entrance management and channel management
Three entrance and channel management options were considered in addition to the 'do nothing' option. Results from these scenarios show:

- Increasing the rate of drag lining is expected to lead to a large increase in flushing time in the upper creek, channel and at the entrance while dredging a channel between the training walls and the boat ramp would be expected to lead to a moderate increase;
- Removing entrance management could be expected to have no impact on the flushing of the upper creek or the channel but would be expected to lead to a moderate increase in flushing time at the entrance;
- Dredging a channel or increasing the rate of drag lining can be expected to lead to declining water quality in al parts of the creek with increases in the rate of drag lining leading to the biggest increases in total nitrogen, phosphorus and suspended sediment concentrations of the two options;
- Removing entrance management can be expected to have no impact on any water quality parameter in the channel or upper creek but is associated with impacts on water quality at the entrance – a moderate increase in TSS and TN concentrations, a small increase in TP concentrations but no impact on pathogens
- Channel navigability is subject to a large decrease when line dragging is increased and when a channel is dredged, while little impact is expected when entrance management is removed;
- Entrance navigability increases moderately when the rate of line dragging is increased and decreases moderately when entrance management is removed;
- Boat amenity is negatively impacted by dredging a channel and by removing entrance management with a moderate decrease expected for each option, while it can be expected to undergo a very small increase if the rate of line dragging were to increase;
- Many ecological parameters are unaffected but both increasing the rate of drag lining and dredging a channel can be expected to lead to decreases in the extent of seagrasses and aquatic fauna;
- Recreational amenity is positively impacted by an increase in the rate of line dragging or dredging a channel but is not affected by removing entrance management; and,

- These options come at a cost to Council – both dredging a channel and increasing the rate of drag lining are expected to lead to a moderate increase in the cost of public works.

Road upgrade with channel and entrance management
Channel and entrance management options were then considered in combination with the possibility of widening a culvert on Macleay road. The results for these scenarios show:

- Widening the culvert is likely to lead to:
    - a moderate decrease in TP, TN and TSS concentrations in the upper part of Back creek, but will have little effect on concentrations at the entrance or in the channel due to a moderate decrease in flushing time in the upper creek;
    - no impact on flushing times in the channel or entrance, however the depth at the entrance is expected to moderately increase, leading to a moderate increase in entrance navigability, boat amenity and tourism;
    - improvements in boating amenity which come at the cost of a large increase in the cost of public works;
- Combining the action of widening the culvert with removing entrance management leads to complex results showing signs of cumulative impacts for some values, cancelling out for others and some values being the same as for either option in isolation;
    - Values for which the impact of combined actions of removing entrance management and widening the culvert shows a cumulative effect are TP concentration in the channel, shoaling, flushing in all three areas of the creek, channel navigation, pathogen at the entrance, seagrass and the exceedence of ANZECC guidelines at the entrance;
    - Nodes for which increases and decreases cancel each other out with removal of entrance management and widening of the culvert are entrance navigation, boating amenity, depth at the entrance, TP concentration at the entrance, tourism and local revenue – in these cases the combined effect of actions is negligible;
- Combining these two actions with dredging a channel creates a negligible or very small impact on 16 nodes – only five nodes have a larger impact: channel navigability which experiences a moderate decrease, recreational amenity which undergoes a moderate increase, sedimentation and shoaling which decrease moderately and the cost of public works which experiences a large increase;
- Combining widening the culvert with increasing the rate of drag lining and dredging a channel was associated with only four positive outcomes: a large decrease in shoaling; a very small increase in entrance navigability; a large decrease in sedimentation; and, a moderate increase in recreational amenity.
- These positives come at the cost of declining water quality in all parts of the creek in terms of phosphorus, nitrogen and sediment caused by an increase in flushing times, a moderate increase in the cost of public works, a very small decrease in boating amenity and a large decrease in channel navigability, but negligible impact on aquatic ecology parameters such as the extent of seagrass.

Development and stormwater management
The effects of maximum development allowed under the LEP, recycling of 40% wastewater, removing dune discharge and installing pollutant traps at stormwater outlets were all tested in isolation:

- Maximum development allowed under the LEP leads to:
    - a moderate increase in TSS load, TN load and pathogen load and a very small increase in TP load;
    - no impact on flushing but changes in pollutant loads lead to changes in the concentration of these pollutants such these changes in load lead to either a negligible impact (TP, TSS) on water quality or a small increase (for pathogen, TN in the entrance) or a moderate increase (TN in the upper creek or channel) in terms of concentrations;

    - a negligible impact on seagrasses and aquatic fauna but a moderate increase in the exceedence of ANZECC guidelines in the channel and a small increase in the upper creek;
    - a moderate decrease in terrestrial habitat;
- Recycling 40% of wastewater leads to:
    - substantial decreases in TP, TN and TSS concentrations in all parts of the creek due to the large decreases in loads of these pollutant – the largest decreases in pollutants occur in the upper creek and channel;
    - few impacts on other nodes;
- Removing dune discharge leads to:
    - larger improvements in water quality at the entrance than recycling 40% of wastewater (pathogen loads and concentrations also decrease) but smaller or no improvements in the channel and in the upper creek;
    - fewer ANZECC exceedence events in the upper creek and at the entrance but has a negligible effect in the channel;
    - a small decrease in seagrass extent and a very small decrease in aquatic fauna;
- Installing pollutant traps at stormwater outlets leads to:
    - a moderate increase in terrestrial habitat and a moderate decrease in the cost of public works; and,
    - reduced pathogen loads and concentrations (upper and channel) and reduced sediment load but a negligible effect on concentration in any part of the creek.

Combination of all actions

Options where development was combined with road upgrades, stormwater, STP, foreshore, channel and entrance management were then considered. These results show:

- The actions of widening the culvert, improving the boat ramp facility, installing pollutant traps at stormwater outlets and recycling 40% of wastewater in combination lead to:
    - Large to moderate decreases in TN and TP loads and concentrations;
    - Moderate decreases in TSS concentrations in the upper creek but a negligible impact in other parts of the creek;
    - A negligible impact on pathogen loads and concentrations
    - A moderate decrease in flushing times in the upper creek but negligible impacts on flushing in other parts of the creek;
    - A moderate increase in tourism, recreational amenity and local revenue but a large increase in the cost of public works; and,
    - A negligible impact on ecological outcomes such as extent of seagrass, aquatic fauna or terrestrial fauna.
- Improving the boat ramp facility, installing pollutant traps and allowing development to the maximum extent of the LEP in combination lead to:
    - A very small increase in TP load and moderate increases in TN, TSS and pathogen loads;
    - Negligible impacts on TP and TSS concentrations, small (entrance) to moderate increases in TN concentrations (channel, upper), and negligible (entrance), small (upper) and moderate (channel) increases in pathogens;
    - Moderate increases in recreational amenity but decreases in terrestrial habitat;
    - Large increases in the cost of public works.
- Undertaking these changes as well as removing the dune discharge leads to:
    - Large (upper and channel) to moderate (entrance) decreases in TP and TN concentrations due to the large decrease in the load of these pollutants;
    - A very small decrease in TSS load (down from a moderate increase) but negligible impacts on TSS concentrations;
    - A very small increase in tourism and a moderate increase in recreational amenity;

    - A small decrease in seagrass and moderate decrease in wetlands as well as a very small decease in aquatic fauna.
- Undertaking these changes as well as widening the culvert, increasing the rate of drag lining and dredging a channel lead to:
    - A large to moderate decrease in TP and TN concentrations due to a large decrease in the loads of these pollutants;
    - A large decrease in shoaling and sedimentation and a moderate increase in the depth of the entrance;
    - A negligible impact on flushing in the channel and upper creek but a moderate increase in flushing of the entrance;
    - A large decrease in channel navigability but a moderate increase in entrance navigability;
    - A moderate decrease in terrestrial habitat, a small decrease in seagrass, a very small decrease in aquatic fauna and a moderate decrease in wetlands;
    - A moderate increase in local revenue but a large increase in the cost of public works.

Conclusions
These results show the complexity of interactions between processes in the creek. In many cases one action cancels out the effect of another. In some cases (eg. the cost of public works) the effects of the action are cumulative. The impacts of development could be partially offset by actions such as removing dune discharge. These options can help to reduce pollutant discharges and pressures on water quality; however they can't completely offset the impacts of such development, such as the impact on terrestrial habitat.

Engineering works such as dredging a channel or increasing the rate of drag lining are seen to largely cancel each other out. In most cases these actions do not lead to widespread improvements in water quality and in some cases are associated with negative effects on aquatic ecology and water quality outcomes. Where theses actions do have impacts they are often localised, eg. contained in the upper creek or in the channel, rather than being widespread throughout the creek system. All these actions are associated with substantial increases in the cost of public works.

1 INTRODUCTION

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Back Creek. This tool was developed as part of the Northern Rivers Catchment Management Authority (CMA) funded project entitled 'Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers (CLAM project)'. The CLAM approach was developed in a joint effort by the Australian National University and the Department of Natural Resources. Its objective was to fill the need for Sustainability Assessments of coastal lake systems identified in the Healthy Rivers Commission Independent Inquiry into Coastal Lakes. It is considered to be a key tool to assist in management and planning processes such as the Local Environmental Planning review and development of Estuary Management Plans.

Scenarios presented in this report were identified as an important primary focus during workshops held with Council staff and other stakeholders in May 2007. These scenarios represent a relatively small subset of the complete range of options available in the Back Creek CLAM tool and are intended to:

- document the quality of data used in the Back Creek CLAM and key data gaps which are a priority for data collection
- provide a useful analysis of options of first concern to Council and other key stakeholders which can be incorporated in decision making and other planning activities on these issues; and,
- illustrate the way in which the CLAM tool can be used to show the trade-offs involved in managing the lake system.

This report is not a management plan and cannot take the place of activities associated with the development of such a plan. In particular this report did not include scope for comprehensive community consultation. It can however be used to inform such a planning process. When this occurs, results in this report must be critically evaluated and open to criticism from members of the public. This needs to occur within the context of the supporting documentation provided in the input pages of the CLAM tool. These pages provide comprehensive documentation of the assumptions underlying data used to derive the results in this report. This information is provided to allow users to assess for themselves the varying quality of data sources underlying the CLAM tool and its relevance to the decisions being made.

1.1 What is CLAM?

The Coastal Lake Assessment and Management (CLAM) tool was developed to allow stakeholders to assess the social, economic, environmental and ecological trade-offs associated with development, remediation, and use options for coastal lakes and estuaries. A population shift towards the coastal fringe in NSW has seen substantial pressures being placed on these coastal systems. Catchment areas are subject to a variety of activities including urban developments, forestry and agricultural activities, recreation and tourism, and fishing and aquaculture activities. Remediation of impacts through better controls on developments and estuary activities, as well as replanting of riparian areas and fringing wetlands, are frequently being considered by State and Local authorities.

The CLAM tool shows the multitude of impacts arising from such pressures and potential remediation measures. It is most appropriate for strategic planning purposes such as the development of estuary management plans or coastal zone management plans. It delivers a high level of community participation and an open and transparent modelling tool, which provides full detail of assumptions made and data used in its population.

The CLAM approach is based on the concept of Bayesian networks but provides additional decision support through tailored interfaces and in-model documentation of model assumptions and design process. More details on the development and use of CLAM models can be found in Merritt *et al.* (2007), Brydon *et al.* (2007) and Ticehurst *et al.* (2007).

There are six main benefits which the CLAM is able to capture for strategic decision making and management activities:

- It allows integration of existing data sets and reports;
- It documents in a transparent way data and assumptions available to be used in making a decision;
- It allows such data and assumptions to be applied repeatedly over many (often 100,000's) iterations in a consistent manner to improve the consistency and rigour of decision making;
- It provides a sound prioritisation of key data and information gaps in the management of a lake system through open documentation of data used in the CLAM system and analysis of the implications of the uncertainty of this data for decision making;
- It plays an education role, providing a tool for people to focus on learning more about the interactions between human actions and social, environmental and economic outcomes in the system;
- It provides a focus for negotiations and discussions about preferred management actions. The CLAM approach encourages people to verbalise and document why they agree or disagree with model results. This type of discourse can form a key component of any negotiation about preferred options and the nature of impacts on the system. Improved understanding and knowledge developed through such discussions and studies which come out of them can be used to update the knowledge in the CLAM system.

1.2 Context for the CLAM and this Sustainability Assessment

The Coastal Lake Assessment and Management (CLAM) approach was developed as part of a NSW Government project focused on the coastal zone, the Comprehensive Coastal Assessment. In response to the Healthy Rivers Commission's Independent Inquiry into Coastal Lakes (2002), a Statement of Intent (SOI) was released by the Cabinet Office in February 2003 stating the Government's commitment to the implementation of the *Coastal Lakes Strategy* (reported in Rissik *et. al.,* 2003). The Healthy Rivers' Report recommended the development of Sustainability Assessment and Management Plans for coastal lake systems. The CLAM approach was developed as a Sustainability Assessment tool to assist in the development of such plans. This report also classified all coastal lakes in NSW according to the level of protection and management they required. Classifications were as follows:

- Comprehensive protection – all natural ecosystem processes restored and preserved;
- Significant protection – critical natural ecosystem processes restored and preserved;
- Healthy modified condition – key natural and/or highly valued modified ecosystem processes rehabilitated and retained;
- Targeted repair – habitat conditions for selected key species established.

The first stage of the SOI was to fund the development of sustainability assessments and management strategies of eight priority coastal lakes in NSW. These were Cudgen, Myall, Wollumboola, Burrill, Narrawallee, Coila, Merimbula and Back Lakes. The main aim of the project was to ensure that there is "*no further deterioration or that there is an improvement, in the condition of coastal lakes whilst detailed assessments are conducted (if required) and Lake Management Plans developed and implemented.*" (Rissik *et al.,* 2003).

The CLAM method was developed to enable interim management frameworks to be developed rapidly using the best available knowledge to inform short-term decisions while also providing the opportunity for more information to be collected and used to inform future longer-term decisions and plans. The approach also had to be transferable to other coastal lake systems.

The Back Creek CLAM has been developed as part of the second phase of a project funded by the Northern Rivers Catchment Management Authority (NRCMA) entitled “Ensuring sustainable development in coastal lake catchments of NSW Northern Rivers”. This project was part of the Northern Rivers Catchment Management Authority (NRCMA) Coastal Management program. It addressed the draft Catchment Action Plan (CAP) Management Target C2: “By 2016 maintain and improve the condition of estuaries and coastal lakes through: completion of management plans for all estuaries (65% by 2009), and sustainability assessment and management plans for all coastal lakes (65% by 2009); and implementation of all priority NRM activities within those plans (65% by 2009)”. The project was funded by the Australian Government’s Natural Heritage Trust Strategic Reserve 2004-05.

As part of this project CLAMs have been developed for sixteen systems in the Northern Rivers CMA area: Cobaki and Terranora Broadwaters; Belongil Lake; Tallow Creek; Woolgoolga Lake; Lake Wooloweyah; Lake Cakora; Fiddamans creek; Willis creek; Coffs Creek; Urunga Lagoon; Dalhousie Creek; Deep Creek; Queens Lake; Lake Innes-Cathie; Back Creek South-West Rocks. The location of these systems is shown in Figure 1.

Figure 1. Location of the sixteen lake systems for which a CLAM tool was developed

This Sustainability Assessment report provides a summary of impacts relating three groups of scenario combinations, as recommended at the Back Creek CLAM workshop with the Kempsey Shire Council in May 2007. These impacts affect the social, economic and environmental sustainability of the lake system.

This report is primarily intended for key decision makers in the Back Creek system, including Council and CMA staff, members of the Estuary Management Committees and those in relevant State Government Agencies. It is also expected to be useful to those people involved in the development of environmental impact statements associated with future developments such as urban release areas. The report is likely to be of interest to a wider audience, particularly those likely to be affected by changes to the management of the lake system. As a companion to the Back Creek CLAM, this report is useful in demonstrating the ways in which the CLAM can be used and results from it interpreted for management purposes. As such it is recommended to any user of the Back Creek CLAM.

It should be noted that the scenarios presented in this report are not exhaustive. Additional scenarios are presented in the Back Creek CLAM and should also be considered when a Sustainability Assessment and Management Plan is developed.

1.3 How should the CLAM tool and results in this Sustainability Assessment Report be used?

The Back Creek CLAM tool and the results provided in this Sustainability Assessment report should be used sensibly. As with all models, results from the CLAM must be critically evaluated for their appropriateness before being used to make decisions. All assumptions used in populating the CLAM and any expert review of the data are documented in the input pages found with the CLAM model (refer to CD enclosed with this report). This information must be very carefully considered when using results to make decisions or recommendations. Users should ask:

- Does the CLAM consider the specific scenarios you are interested in?
- Do the impacts look reasonable? If not, why not? If yes, why?
- Do you trust the data used to populate the model? Why/why not?
- Is there other better data available that could be used in the model or used to review/validate the results?

The CLAM has a strong potential to be used in negotiations between catchment stakeholders on management actions. It is also useful in an educational and capacity building role.

2 BACK CREEK

South West Rocks Creek is located on the mid-north coast of NSW between the township of South West Rocks and the Macleay River entrance channel. It has a relatively small catchment area of approximately 540 hectares. It has no significant tributaries and no freshwater reaches. The size of the estuary is most likely explained by a former connection to the Macleay River. The creek is bounded on the eastern and southern sides by the South West Rocks township, on the western side by the Macleay River and to the north by a small coastal due system.

Back Creek and its catchment are shown in Figure 2.

Figure 2. Back Creek and its catchment

The catchment is mostly vegetated but current land use within the catchment includes:

- A part of the commercial business district of South West Rocks
- Residential Areas
- Caravan Park and camping grounds
- Extensive mangrove and saltmarsh habitat.
- Local roads
- A dune disposal site for treated effluent from the South West Rocks STP

A large proportion of undeveloped land within the catchment is currently zoned for low density residential development. Other planning zones include SEPP 14 wetlands.

No estuary management plan has been developed for the creek and the process has not yet been started. The majority of data available is in the form of studies pertaining to the use of the creek as a harbour or as a deepwater access point.

Key values associated with the lagoon and its surrounding areas include boating amenity, tourism and associated economic value, fish habitat and environmental value. Key issues identified include marine sediment ingress and the associated dangers for boating enthusiasts. Limited community concern for water quality issues is evident.

3 BACK CREEK CLAM

3.1 Conceptual framework

The Back Creek CLAM model is underpinned by the conceptual framework shown in Figure 3. This diagram shows the probable dependencies between scenarios (actions) and state variables (values or impacts). This demonstrates, for example, the way in which ecological outcomes such as total seagrass area are dependent on water quality parameters such as total suspended sediment or total nitrogen. These in turn depend on actions such as implementing new developments or riparian management. Definitions for all nodes in this conceptual framework are given in Appendix 1.

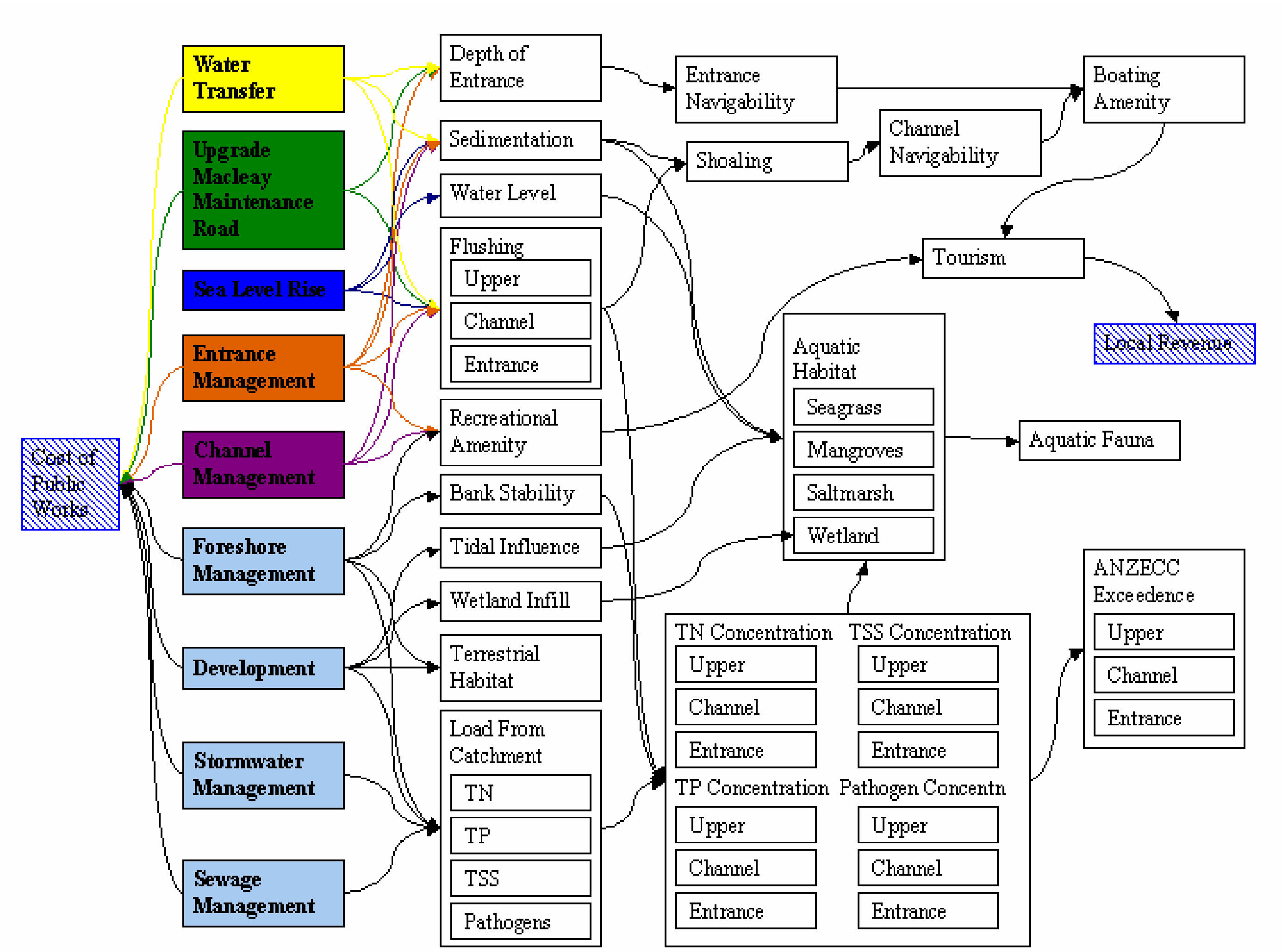

Figure 3. Back Creek conceptual framework used to underpin the Back Creek CLAM. Arrows show dependency between nodes. Coloured boxes represent scenarios which are actions, such as entrance opening strategy, or potential future drivers of the system, such as sea level rise

3.2 Consultation undertaken to develop the Back Creek CLAM

The framework and scenarios contained in the Back Creek CLAM were developed in consultation with various stakeholder groups. The conceptual framework, scenarios, scenario options and state variables for Back Creek have been based on discussions with a broad range of catchment stakeholders: Ron Kemsley, Kempsey Shire Council; Rebecca Keech, Northern Rivers CMA; Rod McDonagh, NSW Maritime; Belinda Sheather, Department of Lands; Brian Semple, Department of Lands; Natasha English, Northern Rivers CMA and Macleay Landcare; Ian Burnett, Dunecare SWR; Brian Semple, Department of Lands; Rod McDonagh, NSW Maritime; Michael Davies, Kempsey Council (Development); John Schmidt, DNR Kempsey; Peter Yarwood, Fish Rock Dive Center; South West Rocks Dive Centre; Barry Townsend, Macleay Fish Coop; David Mitchell, Commercial Fisherman; Lee Burdett, NSW Fisheries; Earl Emerson, South West Rocks Caravan Park; Terrance Hudson, Nguralla Corporation; Amy McElroy, Booroongen College; Eli Usher, Gary Smith, Kempsey Council; Kylie Rowles, Brett Douglas, Department of Commerce; Phil Mitchell, Department of Environment and Conservation EPA, Grafton Office; Rod McDonagh, NSW Maritime; Victor Buchannon, DEC, NPWS; Amy Douglas – Smith, Kempsey Council Visitor Information Centre.

A second major source of feedback was the Project Reference Group which consists of representatives of the Northern Rivers Catchment Management Authority (CMA), the Department of Natural Resources, the Department of Planning, the Department of Primary Industries and NSW Marine Parks Authority.

A community forum was also held where the Back Creek CLAM was presented to general community members. Issues and impacts were discussed during this meeting.

The CLAM user training workshops held in May 2007 provided an opportunity for feedback on the Back Creek CLAM. Attendees at this workshop included Council staff, members of the Estuary Management Committee, staff from State Government Agencies and community members.

3.3 An assessment of data quality

The CLAM model relies upon a set of conditional probabilities to define the relationship between variables. This means that for every arrow in Figure 1 a conditional probability table must be defined which estimates the nature of the relationship. The data used to derive these conditional probability tables comes from a variety of sources including literature assumptions, calibrated and uncalibrated models, expert and local knowledge and observed data. For such a broad system a variety of data qualities is to be expected. This section provides quality assessment of data quality for each node (ie. box in Figure 3). A statement of priority data collection needs for Back Creek is then given. This statement was provided by Damon Telfer who put together the data for the Back Creek CLAM.

Table 1 provides a qualitative assessment of data quality for each node in the Back Creek CLAM.

Table 1. Subjective assessment of the quality of data used in the Back Creek CLAM

Node	Quality of Data	Reason	Suggested improvements
ANZECC Guidelines - Channel	Excellent	Definition of guidelines used	None
ANZECC Guidelines – Entrance	Excellent	Definition of guidelines used	None
ANZECC Guidelines – Upper	Excellent	Definition of guidelines used	None
Aquatic Fauna	Poor	Based on assumptions	Locally relevant data could be collected. Expert review of impacts.
Bank stability	Poor	Based on assumptions	Locally relevant data could be collected. Expert review of impacts.
Boating amenity	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Channel Navigability	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Cost of public works	Average	Based on assumptions with some locally relevant data	Locally relevant data could be collected on options where this was not available. Expert review of impacts.
Depth of entrance	Excellent	Based on a locally calibrated and tested model	Expert review of impacts.
Entrance Navigability	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Flushing - Channel	Excellent	Based on a locally calibrated and tested model	Expert review of impacts.
Flushing - Entrance	Excellent	Based on a locally calibrated and tested model	Expert review of impacts.
Flushing - Upper	Excellent	Based on a locally calibrated and tested model	Expert review of impacts.
Local Revenue	Average	Based on assumptions with some locally relevant data	Locally relevant data could be collected. Expert review of impacts.
Mangroves	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Pathogen Concentration - Channel	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pathogen concentration data could be collected to calibrate the model.

Pathogen Concentration – Entrance	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pathogen concentration data could be collected to calibrate the model.
Pathogen Concentration – Upper	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pathogen concentration data could be collected to calibrate the model.
Pathogen Load	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pathogen concentration data could be collected to calibrate the model.
Recreational Amenity	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Saltmarsh	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Seagrass	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Sedimentation	Poor	Based on assumptions	Locally relevant data could be collected. Expert review of impacts.
Shoaling	Poor	Based on assumptions	Locally relevant data could be collected. Expert review of impacts.
Terrestrial habitat	Average	Based on assumptions with some local knowledge	Locally relevant data could be collected. Expert review of impacts.
Tidal influence	Good	Based on a local study	Expert review of impacts.
Total Nitrogen Concentration - Channel	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Nitrogen Concentration – Entrance	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Nitrogen Concentration – Upper	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Nitrogen Load	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.

Total Phosphorus Concentration – Channel	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Phosphorus Concentration – Entrance	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Phosphorus Concentration – Upper	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Phosphorus Load	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Suspended Sediment Concentration – Channel	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Suspended Sediment Concentration – Entrance	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Suspended Sediment Concentration – Upper	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Total Suspended Sediment Load	Good	Based on an uncalibrated model with locally relevant data. Basic information was used to partially verify model results.	Improved pollutant concentration data could be collected to calibrate the model.
Tourism	Poor	Based on assumptions	Locally relevant data could be collected. Expert review of impacts.
Water Level	Poor	Based on assumptions	Locally relevant data on tidal movements could be used to improve impacts. Expert review of impacts.
Wetland Infill	Very good	Locally relevant data used to estimate impacts	GIS layers could be validated by field visits.
Wetlands	Very good	Locally relevant data used to estimate impacts	GIS layers could be validated by field visits.

Excellent: Models based on local data, supported assumptions, expert review and calibrated/verified with measured (local) data. For direct changes in measured areas where derived from ground-truthed GIS interpretation. Simple yes/no output models.
Very good: Models based on local data, supported assumptions, expert review and calibrated/verified with measured (local) data which may be limited in extent
Good: Models supported by expert review or local data. May be calibrated/verified with measured (local) data which may be limited in extent or show some areas for improvement of model fit.
Average: Uncalibrated models or based on assumptions with some supporting local data or expert review.
Poor: Based on untested assumptions with little or no supporting local data or expert review.

Priority data collection areas identified by Damon Telfer are:

- Stormwater – data on nutrient, pathogen and sediment inputs into estuary from stormwater.
- Nutrients in sediment – nitrogen was relatively high in the water column in the system but no information was available on what amounts of nitrogen and phosphorus are locked up in sediments.

4 SCENARIOS

In order to develop this Sustainability Assessment analysis a relatively small subgroup of scenarios were selected from the 14,400 available in the Back Creek CLAM. In was decided to focus on the following scenarios combinations:

- Entrance management and channel management;
- Road upgrade with entrance and channel management; and,
- Development and Management – combinations of estuary management, channel management and road upgrade with development, foreshore management, stormwater management and sewerage management.

These sets of scenarios are considered in isolation to each other. Impacts focused on depend on the likely consequence of the scenario options. The descriptions for these scenarios taken from the CLAM tool are given below. Other scenarios available in the CLAM tool are described in Appendix 2.

4.1 Entrance management

Options in the CLAM area:
1. No Change to Current Practice
2. Increase Rate of Drag Lining
3. No Entrance Management

The shallow bar and entrance shoals in South West Rocks Creek are a hazard for recreational boaters and professional fishers that use the boat ramp facilities to access the ocean. These navigational difficulties have been one of the major focuses of the management of South West Rocks Creek.

There is a drag line currently operating in the mouth of South West Rocks Creek, removing sand on a regular basis. This scenario explores the possible effects of alternative entrance management efforts.

4.2 Channel management

Options in the CLAM area:
1. No Change
2. Dredge a Channel Between Footbridge and Boat ramp

The boat ramp is located approximately 1km from the mouth of South West Rocks Creek, just upstream of a caravan park. It's primary use is for launching boats that are heading for oceanic waters. The channel between the boat ramp and the footbridge downstream can become quite shallow. This presents a danger and a difficulty to recreational boaters.

One suggestion to alleviate this problem is to dredge a channel between the footbridge and the boat ramp. To maintain acceptable levels of navigability, the channel would have to be 20m wide and 2m deep at low water (Rod McDonagh, pers. comm.). This scenario explores the effect of these actions.

4.3 Upgrade Macleay Maintenance Road

Options in the CLAM area:

1. No Change
2. Widen the Culvert by 3 times the current width.

The shallow bar and entrance shoals in South West Rocks Creek are a hazard for recreational boaters and professional fishers that use the boat ramp facilities to access the ocean. These navigational difficulties have been one of the major focuses of the management of South West Rocks Creek.

The culvert at the point where the Macleay River breakwall maintenance road crosses South West Rocks Creek is narrow. It is a significant barrier to the movement of tidal waters into and out of the upper regions of the creek and thus retards tidal flow throughout the system. This Scenario explores the effects of widening the culvert to reduce its effect on tidal flow.

4.4 Development

Options in the CLAM area:

1. No Change
2. Develop Urban Areas to Max LEP Allowance
3. Develop Caravan Park at New Entrance
4. Develop Caravan Park at New Entrance and Rehabilitate Wetland

Under the Current LEP a there is one significant area of the South West Rocks Creek catchment that could be developed to a medium density urban environment. In addition to this, Kempsey Shire Council have received an application for the development of a small caravan park in the Maddy's Flat locality. The proposal included a suggestion that tidal flow be restored to a significant area of associated land, via the removal of floodgates under a Crown Access Road.

This scenario explores the potential effects of these developments.

4.5 Foreshore management

Options in the CLAM area:

1. No Change
2. Implement Foreshore Management Plan
3. Erosion Management
4. Weed Management
5. Improve Facilities at the Boat Ramp

The foreshore of South West Rocks Creek is valuable for a number of reasons. The numerous vegetated areas provide habitat and buffer the estuarine system from polluted runoff. There is a caravan park located near the boat ramp, which provides direct access to the creek. There is a large car park near the footbridge and a small park area providing access for residents and visitors to a very popular swimming area. Previously, a small port was located there with 30 or so boats moored on a permanent basis. There are only 2 small vessels remaining.

Kempsey Shire Council commissioned a Foreshore Management Plan for the Horseshoe Bay Area, which includes a large part of the South West Rocks Creek foreshore. Community Consultation revealed a wish for improved facilities at the boat ramp, weed management and erosion management. The foreshore management plan addresses public access and use, visual amenity and vegetative qualities. Erosion management refers to small areas particularly around the caravan park and boat ramp. Desired facilities at the boat ramp are toilets and fish bins.

4.6 Stormwater management

Options in the CLAM area:

1. No Change
2. Install Pollutant Traps at Stormwater Outlets.

One of the issues raised during community consultation was the untreated nature of stormwater entering South West Rocks Creek. The Kempsey Shire Council Stormwater Management Plan does not outline specific goals or management methods for stormwater flows into South West Rocks Creek. It is suggested here that likely tools might include settlement pits and gross pollutant traps.

This scenario explores the effects of the above stormwater management techniques.

4.7 Sewerage management

Options in the CLAM area:

1. No change.
2. Augment Plant to 12000 EP.
3. Recycle 20% of wastewater.
4. Recycle 40% of wastewater.
5. Remove Dune Discharge.

Treated sewage from the South West Rocks STP is discharged in the sand dunes behind Back Beach, within the catchment of South West Rocks Creek. The Sewage Treatment Plant is being augmented to prepare for population increases and increasing peak (holiday) loads. There is also a plan to recycle a significant proportion of wastewater to EPA standards for use on a golf course and in new residential developments to be supplied with dual reticulation.

This scenario explores the potential effects of the above management options.

5 RESULTS FROM SCENARIO RUNS

5.1 Entrance management and channel management

Three entrance and channel management options were considered including the 'do nothing' option. Impacts on impacted nodes are summarised in Table 3. This impact is a qualitative assessment of the relative magnitude and direction of change in the variable compared to the 'do nothing' option. Thus a 'small increase' means that the variable is likely to have a value that is a bit bigger than it would have been under the 'do nothing' option.

Table 2. Impacts of entrance and channel management on likely state values for impacted nodes

Node	Increase rate of drag lining	Dredge a channel between the training walls and the boat ramp.	No entrance management
Total Phosphorus Concentration - Upper	large increase	moderate increase	negligible
Shoaling	large decrease	large decrease	negligible
Total Phosphorus Concentration - Channel	large increase	moderate increase	negligible
Entrance Navigability	moderate increase	negligible	moderate decrease
Sedimentation	moderate decrease	large decrease	negligible
Boating Amenity	very small increase	moderate decrease	moderate decrease
Depth of Entrance	moderate increase	negligible	moderate decrease
Flushing - Upper	large increase	moderate increase	negligible
Flushing - Channel	large increase	moderate increase	negligible
Flushing - Entrance	large increase	moderate increase	moderate increase
Recreational Amenity	moderate increase	moderate increase	negligible
Cost of Public Works	moderate increase	moderate increase	negligible
Total Phosphorus Concentration - Entrance	moderate increase	small increase	small increase
Total Nitrogen Concentration - Upper	large increase	moderate increase	negligible
Total Nitrogen Concentration - Channel	large increase	small increase	negligible
Total Nitrogen Concentration - Entrance	moderate increase	moderate increase	moderate increase
Total Suspended Solids Concentration - Upper	large increase	moderate increase	negligible
Total Suspended Solids Concentration - Channel	large increase	moderate increase	negligible
Total Suspended Solids Concentration - Entrance	large increase	moderate increase	moderate increase
Pathogen Concentration - Entrance	negligible	negligible	negligible
Channel Navigability	large decrease	large decrease	negligible

Tourism	small increase	negligible	moderate decrease
Seagrass	moderate decrease	small decrease	negligible
ANZECC Guidelines - Entrance	negligible	negligible	negligible
Aquatic Fauna	very small decrease	very small decrease	negligible
Local Revenue	small increase	negligible	moderate decrease

These scenarios had no impact on 16 nodes: Water Level; Bank Stability; Terrestrial Habitat; Total Phosphorus Load; Total Nitrogen Load; Total Suspended Solids Load; Pathogen Load; Pathogen Concentration - Upper; Pathogen Concentration - Channel; Mangroves; Saltmarsh; Wetlands; ANZECC Guidelines - Upper; ANZECC Guidelines - Channel; Tidal Influence; Wetland Infill.

The table shows:

- Increasing the rate of drag lining is expected to lead to a large increase in flushing time in the upper creek, channel and at the entrance while dredging a channel between the training walls and the boat ramp would be expected to lead to a moderate increase;
- Removing entrance management could be expected to have no impact on the flushing of the upper creek or the channel but would be expected to lead to a moderate increase in flushing at the entrance;
- As would be expected these changes in entrance and channel management have no impact on nutrient loads but the changes in flushing mean that changes in concentrations in the creek can be expected;
- Increasing the rate of drag lining can be expected to lead to a large increase in total phosphorus and nitrogen concentrations in the channel and upper creek, and a moderate increase at the entrance due to the increased flushing time;
- Dredging a channel is expected to lead to a moderate increase in total nitrogen and phosphorus concentrations in all three areas of the creek;
- Total suspended sediments are subject to a large increase in all three regions of the creek when the rate of line dragging is increased, while dredging a channel leads to a moderate increase in TSS in all three areas of the creek;
- Removing entrance management has no impact on any water quality parameter in the channel or upper creek but is associated with impacts on water quality at the entrance – a moderate increase in TSS and TN concentrations, a small increase in TP concentrations but no impact on pathogens
- Channel navigability is subject to a large decrease when line dragging is increased and when a channel is dredged, while little impact occurs when entrance management is removed;
- Entrance navigability increases moderately when the rate of line dragging is increased and decreases moderately when entrance management is removed;
- Boat amenity is negatively impacted by dredging a channel and by removing entrance management with a moderate decrease expected for each option, while a very small increase can be expected if the rate of line dragging were to increase;
- Many ecological parameters are unaffected but increasing the rate of line dragging will lead to a moderate decrease in seagrass and dredging a channel will lead to a small decrease in seagrass, while both these options are expected to lead to a very small decrease in aquatic fauna;
- Recreational amenity is positively impacted by an increase in the rate of line dragging or dredging a channel but is not affected by removing entrance management; and,
- These options come at a cost to Council – both dredging a channel and increasing the rate of drag lining leads to a moderate increase in the cost of public works.

The impacts of entrance and channel management on entrance navigability are shown in more detail in Figure 4.

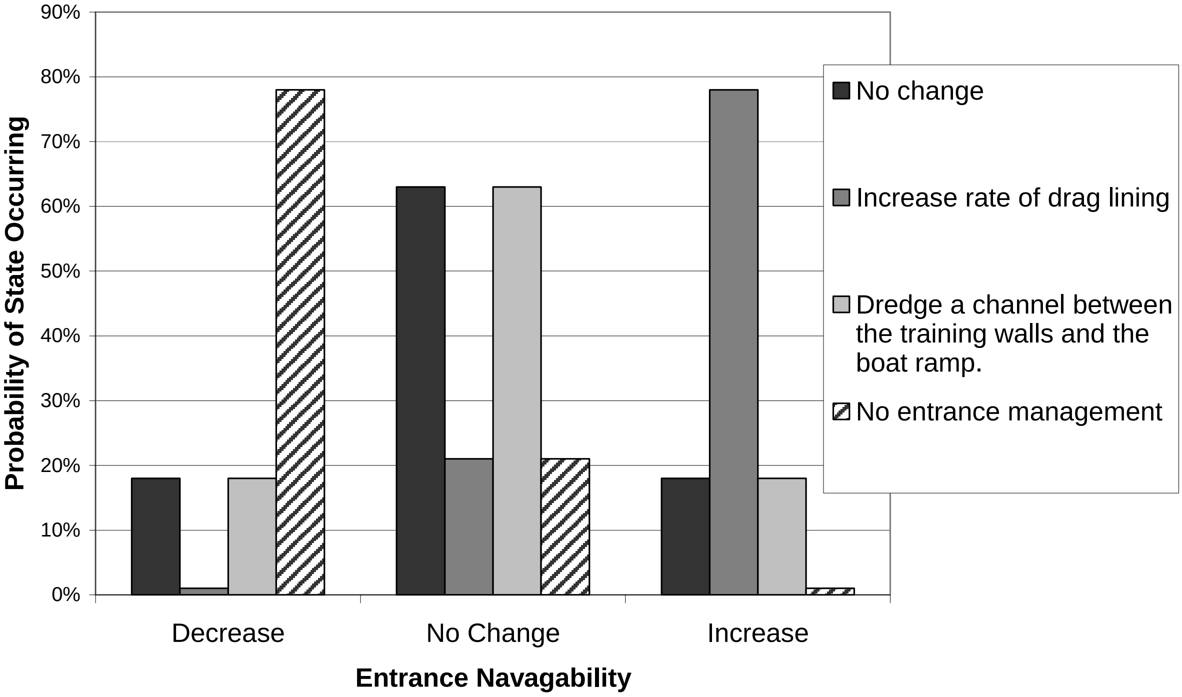

Figure 4. Probability of different changes in entrance navigability under entrance and channel management scenarios

This Figure shows that under the 'do nothing' situation, no change in entrance navigability is most likely. This is also the case for dredging a channel between the training walls and the boat ramp as this option has no impact on entrance navigability. Were the rate of line dragging to increase the most likely outcome would be an increase in entrance navigability (>75%) while the chance of a decrease would be reduced to a very small value (<2%). Removing entrance management leads to the opposite outcome such that the most likely outcome is a decrease in entrance navigability and the probability of an increase is reduced to near zero.

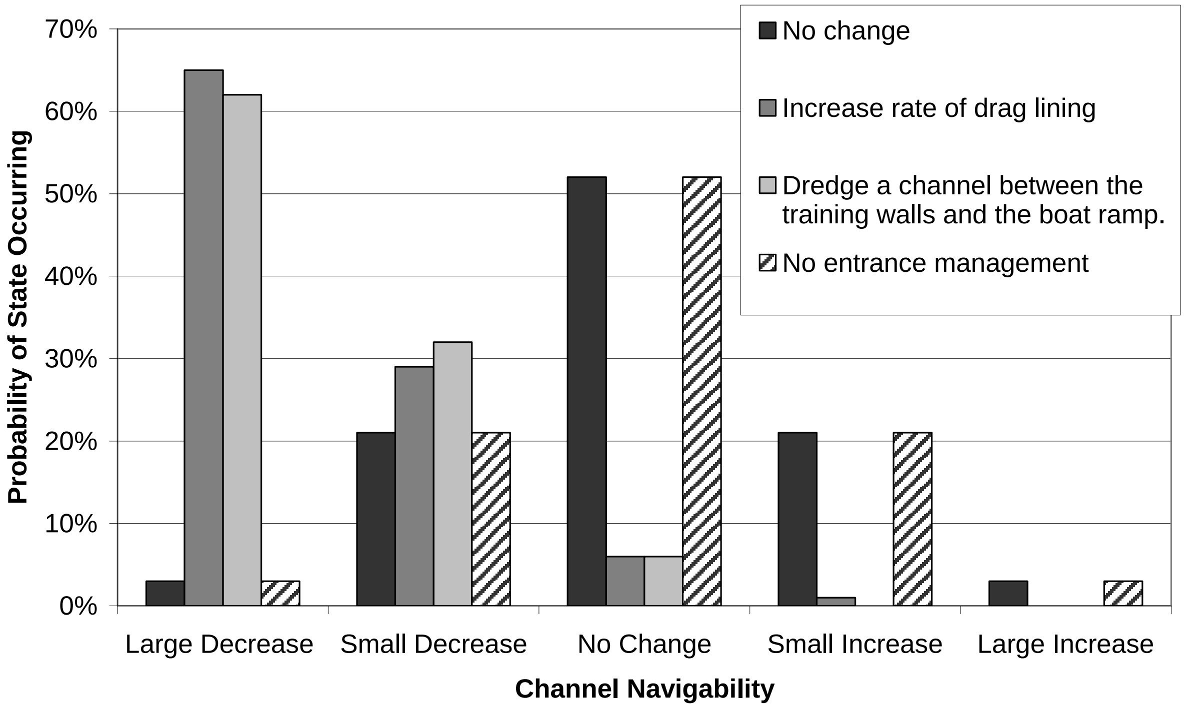

Figure 5. Probability of different changes channel navigability under entrance and channel management scenarios

Figure 5 shows the impact of the scenarios on the distributions of outcomes for channel navigability. In this case removing entrance management is shown to have no impact on channel navigability. Both increasing the rate f drag lining and dredging a channel lead to a large decrease is channel navigability, with this decrease being slightly larger for increased rate of drag lining. In both these cases the most likely outcome is a large decrease in channel navigability. Very little chance of 'no change' or any type of increase remains.

Figure 6 to 8 show the impact of these options on TN concentrations in the upper creek, channel and entrance respectively.

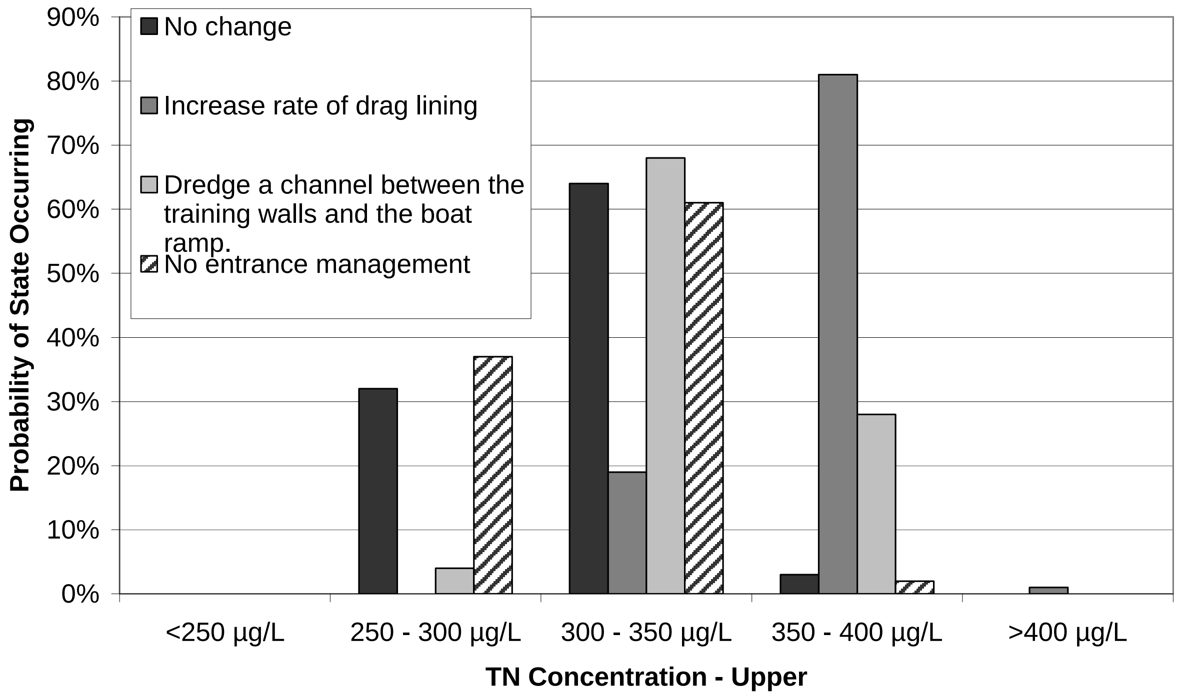

Figure 6. Probability of different levels of Total Nitrogen Concentration in the upper creek under entrance and channel management scenarios

These figures show that removing entrance management leads to a very small decrease in TN concentrations in the upper creek and the channel but a relatively large increase in the probability of higher TN concentrations in the channel. Increasing the rate of drag lining leads to a substantial increase in the probability of higher TN concentrations in the upper creek, channel and entrance while dredging a channel leads to an increase in TN concentrations in the upper creek, channel and entrance although the magnitude of these changes is smaller than was the case for an increased rate of drag lining.

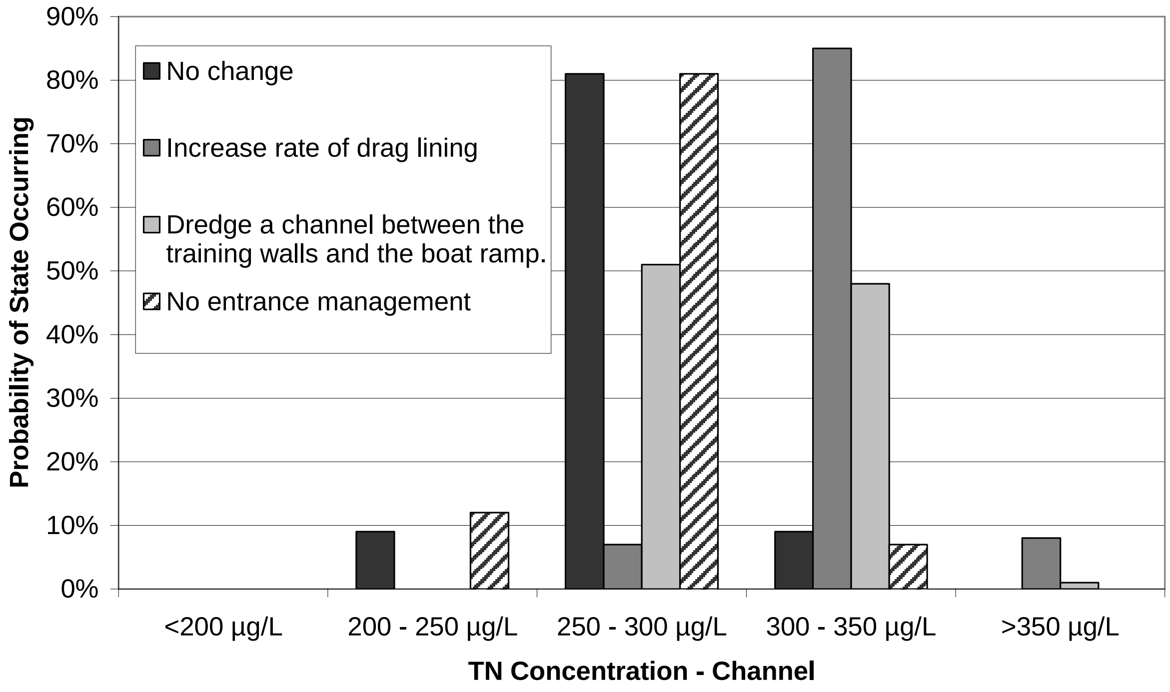

Figure 7. Probability of different levels of Total Nitrogen Concentration in the channel under entrance and channel management scenarios

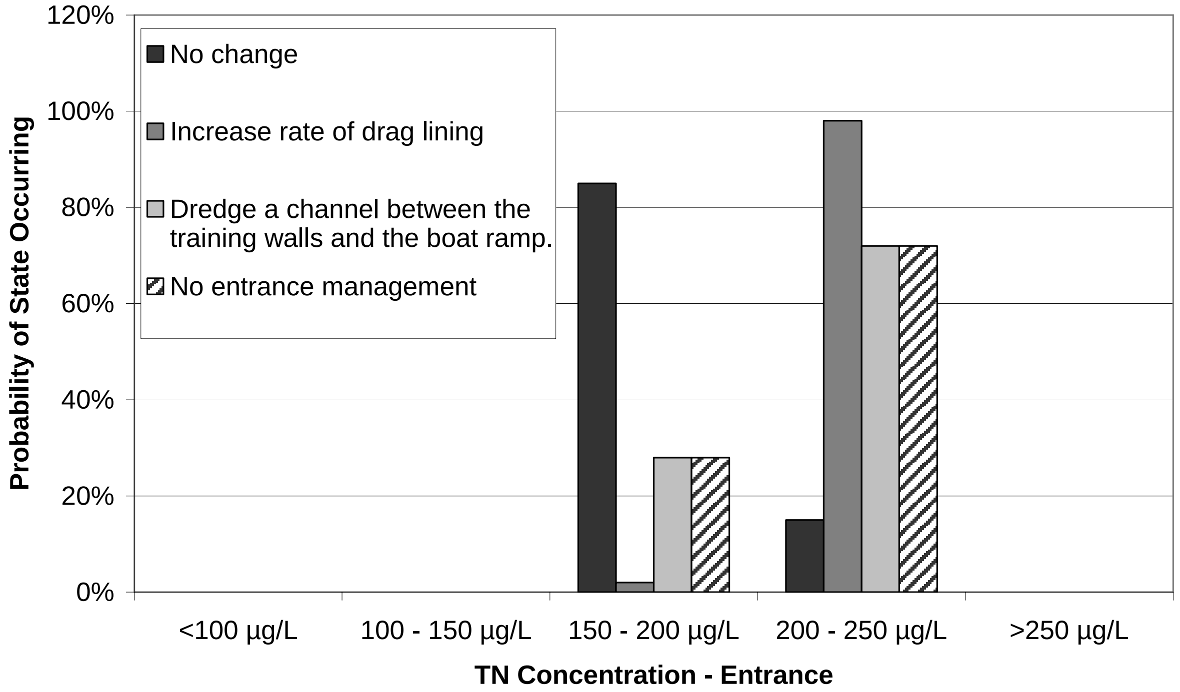

Figure 8. Probability of different levels of Total Nitrogen Concentration at the entrance under entrance and channel management scenarios

Figure 9 shows the impact of these options on recreational amenity. This figure shows that removing entrance management has no impact on recreational amenity. Increasing the rate of drag lining and dredging a channel between the training walls and the boat ramp are likely to have the same impact: shifting the most likely outcome from no change to a small increase. Both options also lead to a greater than 10% chance of a large increase and remove any chance of a decrease in recreational amenity.

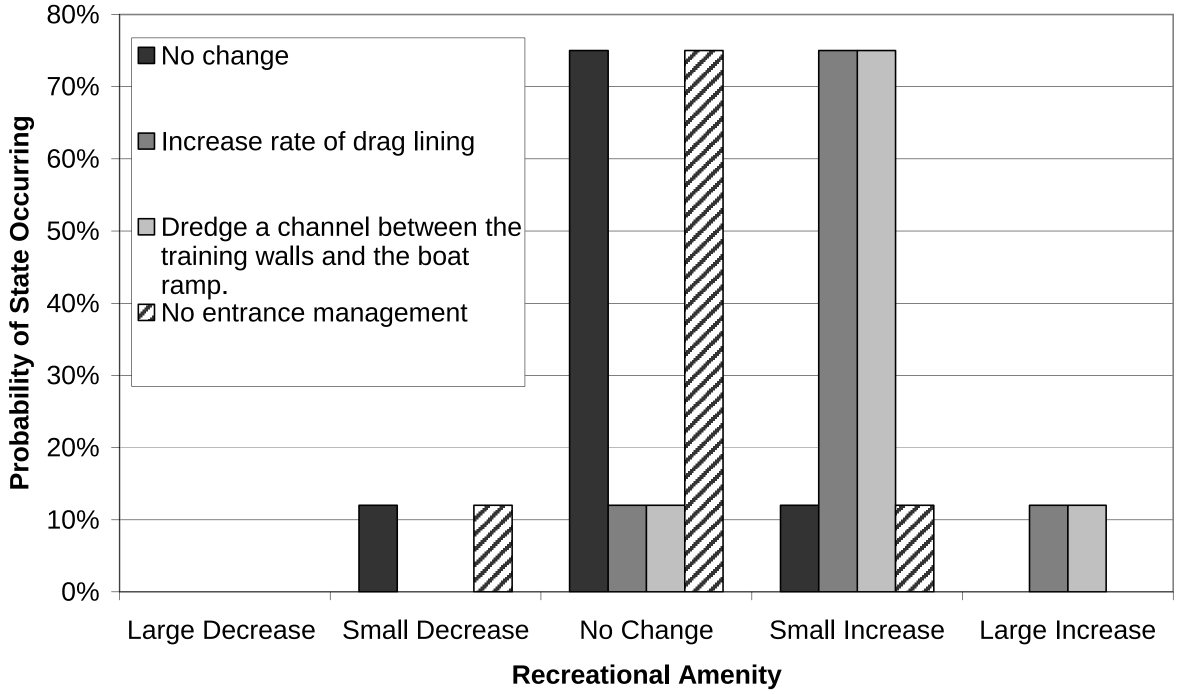

Figure 9. Probability of different changes in recreational amenity under entrance and channel management scenarios

Figure 10 shows the impact of these options on the extent of seagrasses. Removing entrance management leads to a slight reduction in the chance of a small or large decrease and corresponding slight increase in the chance of no change or of a small increase. No option has any chance of a large increase in seagrass. By contrast both increasing the rate of drag lining and dredging the channel are associated with a reduction in the likely area of seagrasses. In both cases the most likely outcome becomes a small decrease in seagrass extent while the probability of a large decrease is greater than 10% in both cases. Increasing the rate of drag lining is associated with the worst impacts on seagrasses, with the probabilities of both small and large decreases being greater for this option than dredging a channel.

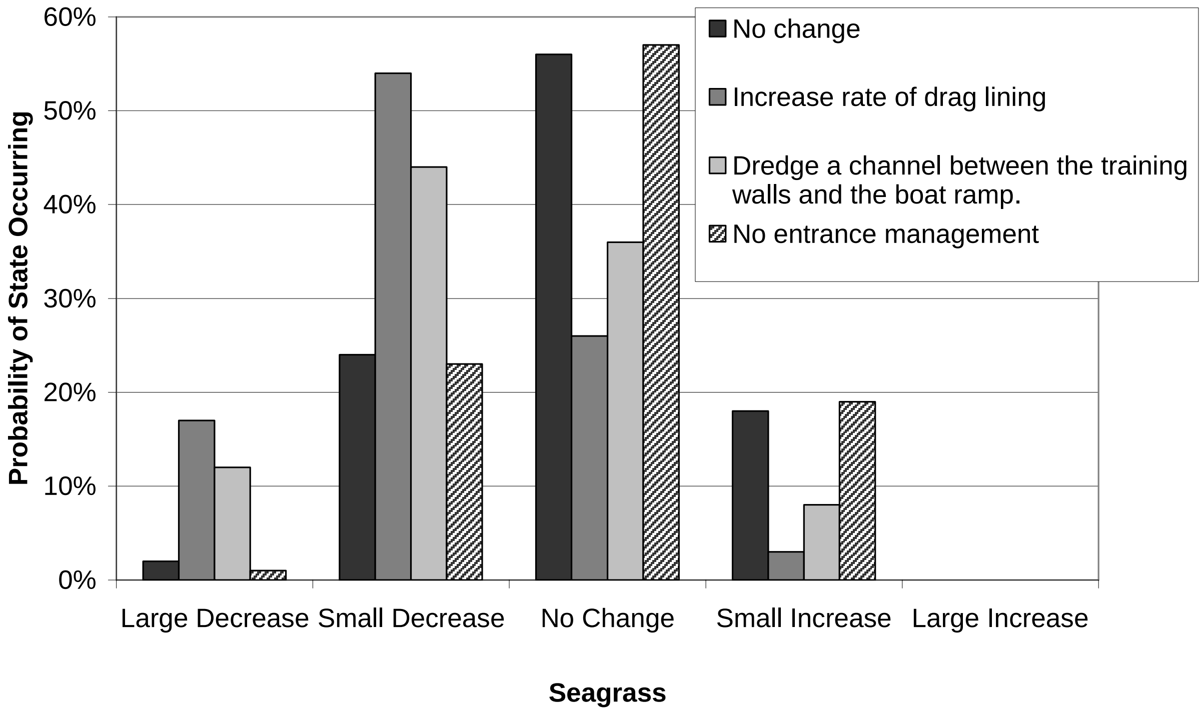

Figure 10. Probability of different changes in seagrass under entrance and channel management scenarios

Overall these scenarios show that interventions such as dredging a channel and increasing the rate of drag lining are likely to be associated with significant negative consequences for water quality and aquatic ecology. They are also expensive. They do however lead to some improvements in recreational amenity. Removing entrance management is associated with declining water quality at the entrance but slight improvements in other parts of the creek. Some improvements in aquatic ecology outcomes are also expected.

5.2 Road upgrade with entrance management and channel management

Four combinations of road upgrade with estuary and channel management options were considered in addition to the 'do nothing' case: upgrade road with no change for entrance or channel management; upgrade road with no entrance management; and, upgrade road with increased rate of drag lining and dredge channel between training walls and boat ramp.

Table 3 summarises the impact of these scenario combinations on impacted nodes.

Table 3. Impacts of road upgrade with entrance and channel management on likely state values for impacted nodes

Node	Widen the culvert under the maintenance road by 3 times	Widen culvert and no entrance management	Widen culvert, no entrance management and dredge channel	Widen culvert, increase rate of drag lining and dredge channel
Total Phosphorus Concentration - Upper	moderate decrease	moderate decrease	negligible	moderate increase
Shoaling	negligible	small increase	moderate decrease	large decrease
Total Phosphorus Concentration - Channel	negligible	moderate decrease	negligible	very small increase
Entrance Navigability	moderate increase	negligible	negligible	very small increase
Sedimentation	negligible	negligible	moderate decrease	large decrease
Boating Amenity	moderate increase	negligible	very small decrease	very small decrease
Depth of Entrance	moderate increase	negligible	negligible	very small increase
Flushing - Upper	moderate decrease	large decrease	negligible	moderate increase
Flushing - Channel	negligible	large decrease	negligible	very small increase
Flushing - Entrance	negligible	moderate decrease	negligible	moderate increase
Recreational Amenity	negligible	negligible	moderate increase	moderate increase
Cost of Public Works	large increase	large increase	large increase	moderate increase
Total Phosphorus Concentration - Entrance	negligible	moderate decrease	negligible	small increase
Total Nitrogen Concentration - Upper	moderate decrease	moderate decrease	negligible	moderate increase
Total Nitrogen Concentration - Channel	negligible	moderate decrease	negligible	very small increase
Total Nitrogen Concentration - Entrance	negligible	very small decrease	negligible	moderate increase
Total Suspended Solids Concentration - Upper	moderate decrease	moderate decrease	negligible	moderate increase

Total Suspended Solids Concentration - Channel	negligible	moderate decrease	negligible	very small increase
Total Suspended Solids Concentration - Entrance	negligible	moderate decrease	negligible	moderate increase
Pathogen Concentration - Entrance	negligible	moderate decrease	negligible	negligible
Channel Navigability	negligible	small increase	moderate decrease	large decrease
Tourism	moderate increase	negligible	very small increase	negligible
Seagrass	negligible	very small increase	negligible	negligible
ANZECC Guidelines - Entrance	negligible	moderate decrease	negligible	negligible
Aquatic Fauna	negligible	negligible	negligible	negligible

As for entrance and channel management in isolation there are no impacts on 16 nodes: Water Level; Bank Stability; Terrestrial Habitat; Total Phosphorus Load; Total Nitrogen Load; Total Suspended Solids Load; Pathogen Load; Pathogen Concentration - Upper; Pathogen Concentration - Channel; Mangroves; Saltmarsh; Wetlands; ANZECC Guidelines - Upper; ANZECC Guidelines - Channel; Tidal Influence; and, Wetland Infill.

This table shows:

- Widening the culvert is likely to lead to a moderate decrease in TP, TN and TSS concentrations in the upper part of Back creek, but will have little effect on concentrations at the entrance or in the channel;
- The effect on nutrient and sediment concentrations in the upper creek are as a consequence of a change in flushing – no change in load is experienced for any of these pollutants;
- Widening the culvert is expected to lead to a moderate decrease is flushing time in the upper back creek;
- No impact is expected on flushing times in the channel or entrance, however the depth at the entrance will moderately increase, leading to a moderate increase in entrance navigability, boat amenity and tourism;
- Improvements in boating amenity come at the cost of a large increase in the cost of public works;
- Combining the action of widening the culvert with removing entrance management leads to complex results showing signs of cumulative impacts for some values, cancelling out for others and some values being the same as for either option in isolation;
- Values for which the impact of combined actions of removing entrance management and widening the culvert shows a cumulative effect are TP concentration in the channel, shoaling, flushing in all three areas of the creek, channel navigation, pathogen at the entrance, seagrass and the exceedence of ANZECC guidelines at the entrance;
- Nodes for which increases and decreases cancel each other out with removal of entrance management and widening of the culvert are entrance navigation, boating amenity, depth at the entrance, TP concentration at the entrance, tourism and local revenue – in these cases the combined effect of actions is negligible;
- Combining these two actions with dredging a channel creates a negligible or very small impact on 16 nodes – only five nodes have a larger impact: channel navigability which

experiences a moderate decrease, recreational amenity which undergoes a moderate increase, sedimentation and shoaling which decrease moderately and the cost of public works which experiences a large increase;

- Combining widening the culvert with increasing the rate of drag lining and dredging a channel was associated with only four positive outcomes: a large decrease in shoaling; a very small increase in entrance navigability; a large decrease in sedimentation; and, a moderate increase in recreational amenity.
- These positives come at the cost of declining water quality in all parts of the creek in terms of phosphorus, nitrogen and sediment caused by an increase in flushing times, a moderate increase in the cost of public works, a very small decrease in boating amenity and a large decrease in channel navigability, but negligible impact on aquatic ecology parameters such as the extent of seagrass.

Figure 11 shows the impact of these options on entrance navigability. This figure shows that combining widening of the culvert with either no entrance management or this and dredging a channel counteracts the effect of widening the culvert such that in isolation this option would be expected to increase entrance navigability but in combination with these other two actions it would lead to no change from the base case. When combined with an increase in the rate of drag lining as well as dredging the channel entrance navigability is expected to increase with a probability of nearly 90%. The chance of a decrease is also reduced to 0%.

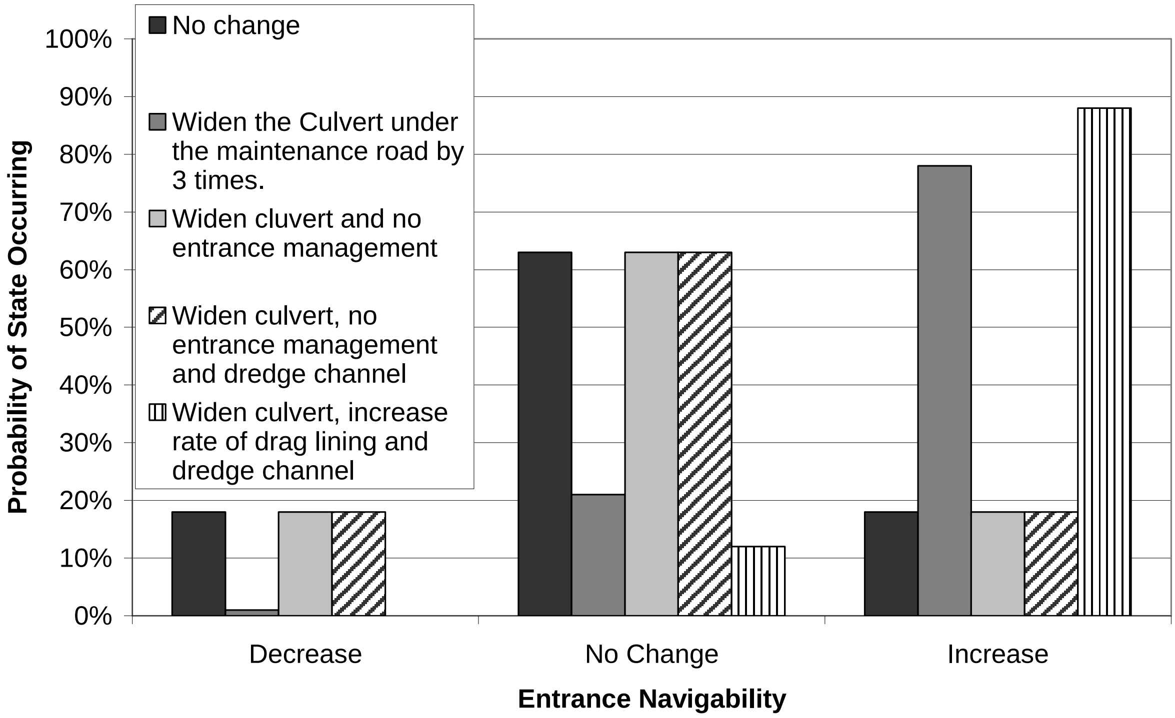

Figure 11. Probability of different changes in entrance navigability under road upgrade with entrance and channel management scenarios

Figure 12 shows the impact of these options on channel navigability. In tis case widening the culvert in isolation is expected to have no impact on channel navigability. In combination with removing entrance management channel navigability is expected to increase while in combination with dredging a channel and increasing the rate of drag lining it can be expected to decrease.

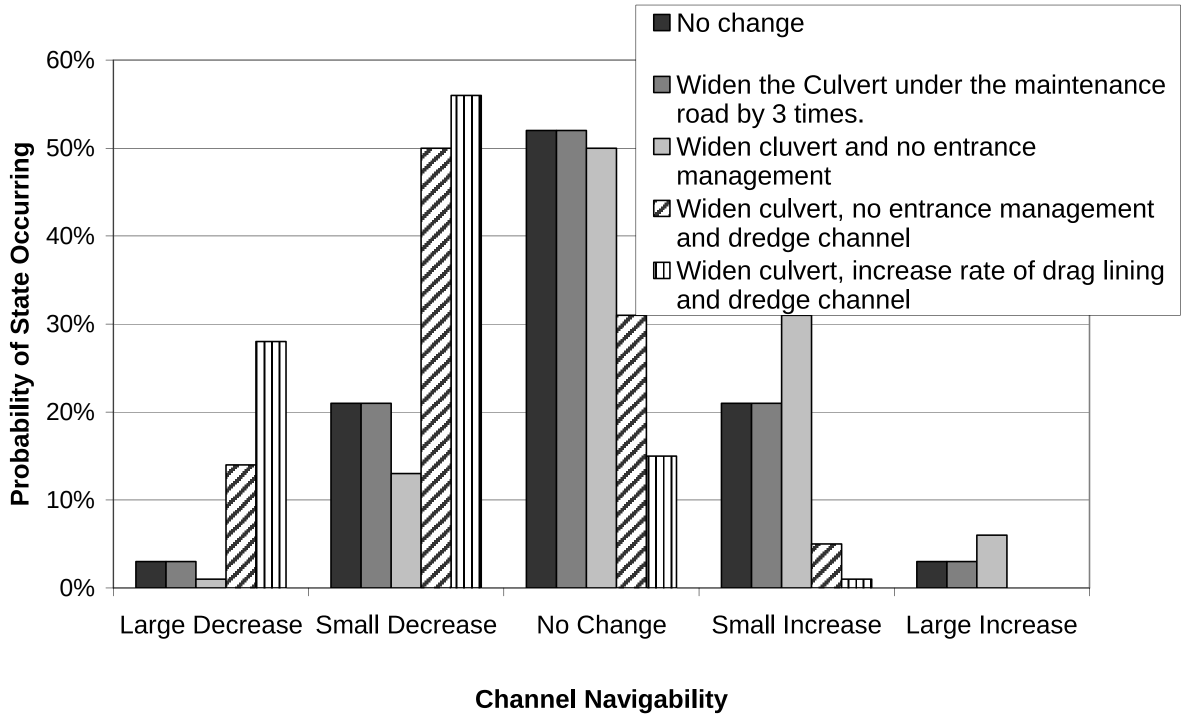

Figure 12. Probability of different changes in channel navigability under road upgrade with entrance and channel management scenarios

Figures 13 to 15 show the impact of these options on TN concentrations in the upper creek, channel and at the entrance respectively. These figures shows that widening the culvert with or without removal of entrance management is likely to lead to a decrease in TN concentrations in the upper creek and channel, although for the channel the magnitude of this decrease is much greater when entrance management is removed. At the entrance widening the culvert in isolation is expected to a relatively small increase in TN concentrations, while with removing entrance management this is expected to be a small decrease. When widening of the culvert is combined with no entrance management and dredging a channel no impact is observed on any TN concentration. If the rate of drag lining is increased in combination with dredging a channel and widening the culvert then an increase in TN concentrations is experienced in all areas of the creek.

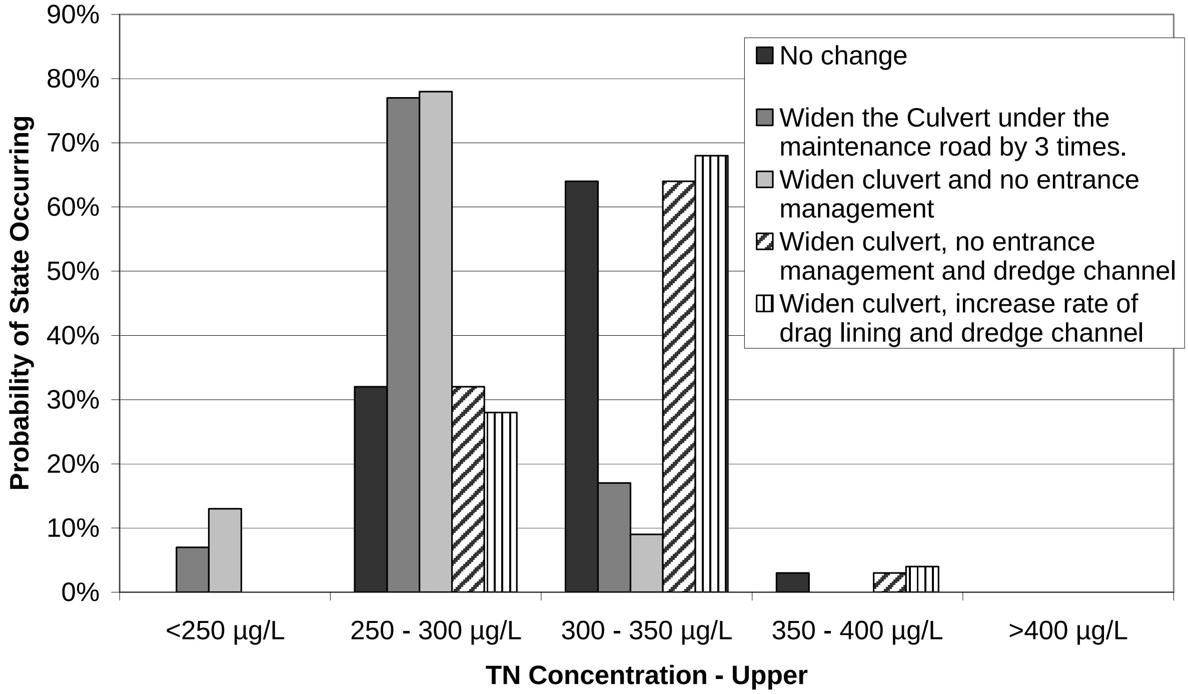

Figure 13. Probability of different levels of Total Nitrogen Concentration in the upper creek under road upgrade with entrance and channel management scenarios

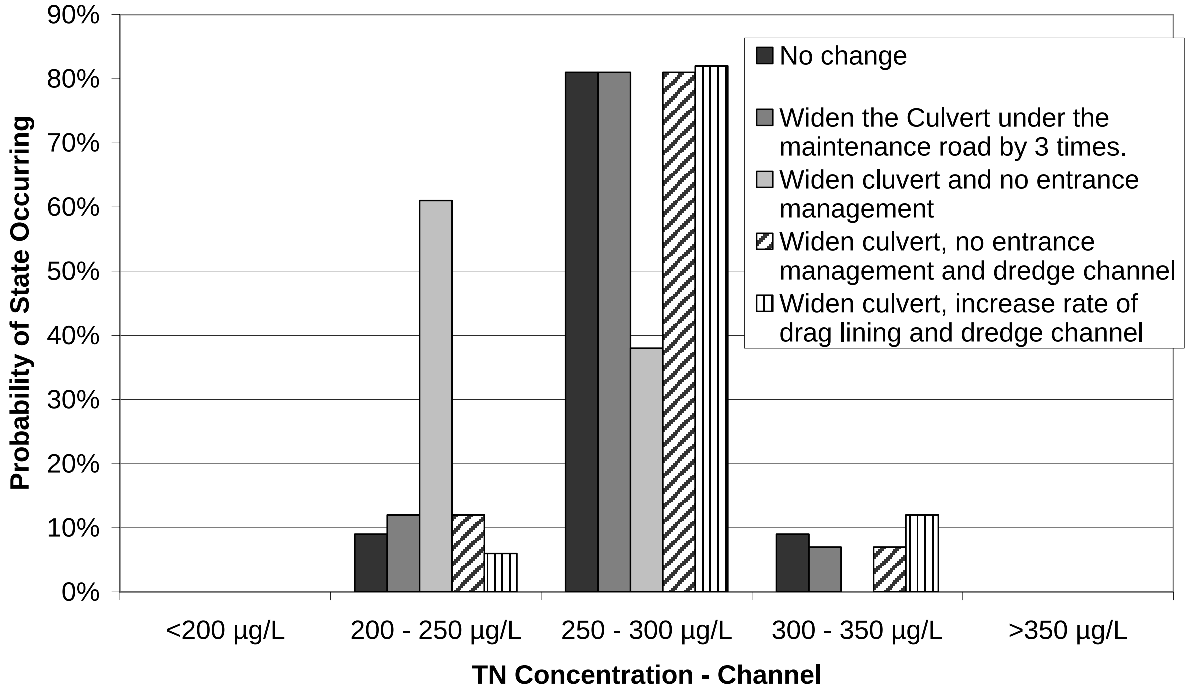

Figure 14. Probability of different levels of Total Nitrogen Concentration in the channel under road upgrade with entrance and channel management scenarios

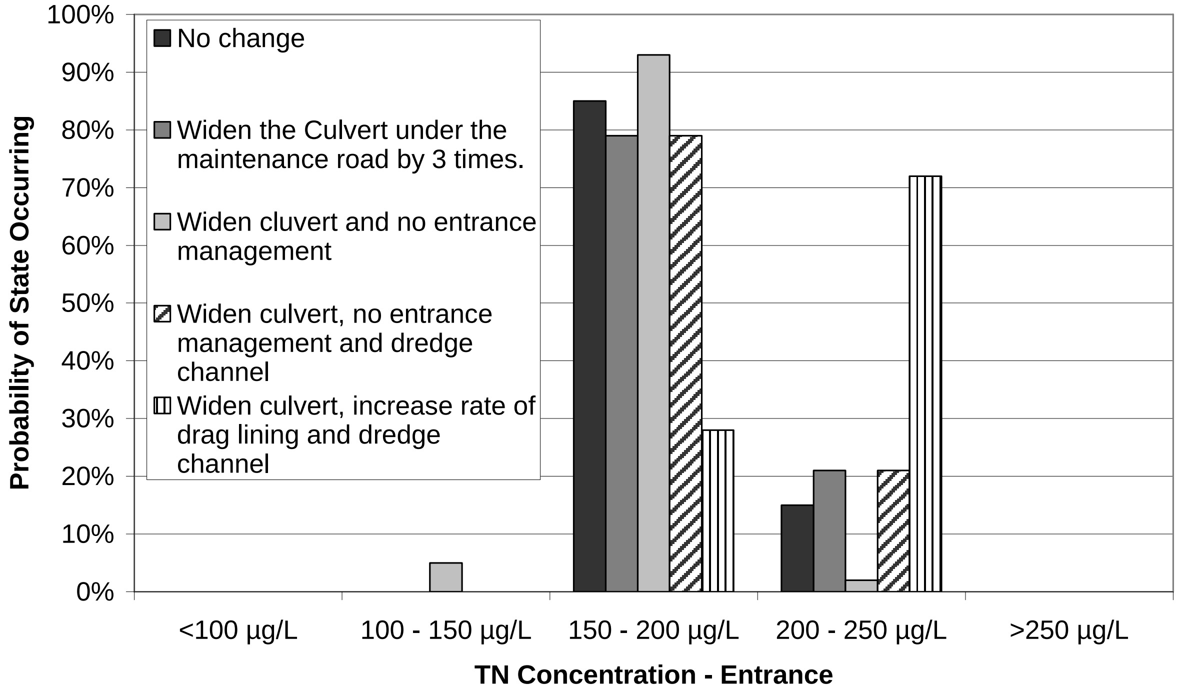

Figure 15. Probability of different levels of Total Nitrogen Concentration at the entrance under road upgrade with entrance and channel management scenarios

These scenarios show the potential for management actions to cancel each other out, such tat many of the expected of hoped for benefits are not achieved but the financial costs are still apparent.

5.3 Development, sewerage and STP management

Development, sewerage and STP management options were considered in isolation so that their combined effects could be understood (see Section 5.4). Table 4 provides a summary of impacts of these options on impacted nodes.

Table 4. Summary of impact of development, sewerage and STP management options

Node	Max development under current LEP	Recycle 40% of wastewater	Remove Dune Discharge	Install pollutant traps at stormwater outlets
Total Phosphorus Concentration - Upper	negligible	large decrease	large decrease	negligible
Total Phosphorus Concentration - Channel	negligible	moderate decrease	large decrease	negligible
Terrestrial Habitat	moderate decrease	negligible	negligible	moderate increase
Total Phosphorus Load	very small increase	large decrease	large decrease	negligible
Total Nitrogen Load	moderate increase	large decrease	large decrease	negligible
Total Suspended Solids Load	moderate increase	moderate decrease	large decrease	moderate decrease

Pathogen Load	moderate increase	negligible	moderate decrease	moderate decrease
Cost of Public Works	large increase	large increase	large increase	moderate decrease
Total Phosphorus Concentration - Entrance	negligible	moderate decrease	moderate decrease	negligible
Total Nitrogen Concentration - Upper	moderate increase	moderate decrease	large decrease	negligible
Total Nitrogen Concentration - Channel	moderate increase	moderate decrease	large decrease	negligible
Total Nitrogen Concentration - Entrance	small increase	small decrease	large decrease	negligible
Total Suspended Solids Concentration - Upper	negligible	negligible	negligible	negligible
Total Suspended Solids Concentration - Channel	negligible	negligible	negligible	negligible
Total Suspended Solids Concentration - Entrance	negligible	negligible	negligible	negligible
Pathogen Concentration - Upper	small increase	negligible	small decrease	small decrease
Pathogen Concentration - Channel	moderate increase	negligible	negligible	moderate decrease
Pathogen Concentration - Entrance	negligible	negligible	moderate decrease	negligible
Seagrass	negligible	negligible	small decrease	negligible
Wetlands	moderate increase	negligible	negligible	moderate decrease
ANZECC Guidelines - Upper	small increase	negligible	small decrease	small decrease
ANZECC Guidelines - Channel	moderate increase	negligible	negligible	moderate decrease
ANZECC Guidelines - Entrance	negligible	negligible	moderate decrease	negligible
Aquatic Fauna	negligible	negligible	very small decrease	negligible
Wetland Infill	moderate increase	negligible	negligible	moderate decrease

Overall there are 17 nodes that are unimpacted: Shoaling; Entrance Navigability; Sedimentation; Water Level; Boating Amenity; Depth of Entrance; Flushing - Upper; Flushing - Channel; Flushing - Entrance; Recreational Amenity; Bank Stability; Channel Navigability; Tourism; Mangroves; Saltmarsh; Local Revenue; and, Tidal Influence.

Table 4 shows:

- Maximum development allowed under the LEP leads to a moderate increase in TSS load, TN load and pathogen load and a very small increase in TP load;
- Development has no impact on flushing but changes in pollutant loads lead to changes in the concentration of these pollutants such these changes in load lead to either a negligible impact (TP, TSS) on water quality or a small increase (for pathogen, TN in the entrance) or a moderate increase (TN in the upper creek or channel) in terms of concentrations;
- Development has a negligible impact on seagrasses and aquatic fauna but does lead to a moderate increase in the exceedence of ANZECC guidelines in the channel and a small increase in the upper creek;
- Development also leads to a moderate decrease in terrestrial habitat;
- Recycling 40% of wastewater leads to substantial decreases in TP, TN and TSS concentrations in all parts of the creek due to the large decreases in loads of these pollutant – the largest decreases in pollutants occur in the upper creek and channel;
- Recycling 40% of wastewater has few impacts on other nodes;
- Removing dune discharge leads to larger improvements in water quality at the entrance than recycling 40% of wastewater (pathogen loads and concentrations also decrease) but smaller or no improvements in the channel and in the upper creek;
- Removing dune discharge leads to fewer ANZECC exceedence events in the upper creek and at the entrance but has a negligible effect in the channel;
- Removing dune discharge is likely to lead to a small decrease in seagrass extent and a very small decrease in aquatic fauna;
- Installing pollutant traps at stormwater outlets leads to a moderate increase in terrestrial habitat and a moderate decrease in the cost of public works; and,
- Pollutant traps reduce pathogen loads and concentrations (upper and channel) and reduce sediment load but have a negligible effect on concentration in any part of the creek.

5.4 Combination of all actions

Four combinations of development with various management options were considered in addition to the ‘do nothing’ case. These options are summarised in Table 5. In order to allow for simplicity in the captions on charts these options are referred to as “no change” and “Scenario 1” through to “Scenario 4”.

Table 5. Summary of development and management scenario combinations

	No change	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Upgrade Macleay Maintenance Road	No change	Widen the Culvert under the maintenance road by 3 times	No change	No change	Widen the Culvert under the maintenance road by 3 times
Entrance Management	No change to current practice	No change to current practice	No change to current practice	No change to current practice	Increase rate of drag lining
Channel management	No change	No change	No change	No change	Dredge a channel between the training walls and the boat ramp
Foreshore Management	No Change	Improve Facilities at the Boat Ramp	Improve Facilities at the Boat Ramp	Improve Facilities at the Boat Ramp	Improve Facilities at the Boat Ramp
Stormwater Management	No change	Install pollutant traps at stormwater outlets	Install pollutant traps at stormwater outlets	Install pollutant traps at stormwater outlets	Install pollutant traps at stormwater outlets
Sewage Management	No change	Recycle 40% of wastewater	No change	Remove Dune Discharge	Remove Dune Discharge
Development	No Change	No Change	Max development under current LEP	Max development under current LEP	Max development under current LEP

The impacts of these scenarios on impacted nodes are summarised in Table 5.

Table 6. Impacts of road upgrade with entrance and channel management on likely state values for impacted nodes

Node	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Phosphorus Concentration - Upper	large decrease	negligible	large decrease	large decrease
Shoaling	negligible	negligible	negligible	large decrease
Total Phosphorus Concentration - Channel	moderate decrease	negligible	large decrease	large decrease
Entrance Navigability	moderate increase	negligible	negligible	moderate increase
Sedimentation	negligible	negligible	negligible	large decrease
Boating Amenity	moderate increase	negligible	negligible	moderate increase
Depth of Entrance	moderate increase	negligible	negligible	moderate increase
Flushing - Upper	moderate decrease	negligible	negligible	negligible
Flushing - Channel	negligible	negligible	negligible	negligible
Flushing - Entrance	negligible	negligible	negligible	moderate increase
Recreational Amenity	moderate increase	moderate increase	moderate increase	large increase
Terrestrial Habitat	negligible	moderate decrease	moderate decrease	moderate decrease
Total Phosphorus Load	large decrease	very small increase	large decrease	large decrease
Total Nitrogen Load	small decrease	moderate increase	large decrease	large decrease
Total Suspended Solids Load	moderate decrease	moderate increase	very small decrease	very small decrease
Pathogen Load	negligible	moderate increase	negligible	negligible
Cost of Public Works	large increase	large increase	large increase	large increase
Total Phosphorus Concentration - Entrance	very small decrease	negligible	moderate decrease	moderate decrease
Total Nitrogen Concentration - Upper	moderate decrease	moderate increase	large decrease	large decrease
Total Nitrogen Concentration - Channel	small decrease	moderate increase	large decrease	large decrease
Total Nitrogen Concentration - Entrance	very small decrease	small increase	moderate decrease	moderate decrease
Total Suspended Solids Concentration - Upper	moderate decrease	negligible	negligible	negligible
Total Suspended Solids Concentration - Channel	negligible	negligible	negligible	negligible
Total Suspended Solids Concentration - Entrance	negligible	negligible	negligible	moderate increase
Pathogen Concentration - Upper	negligible	small increase	negligible	negligible

Pathogen Concentration - Channel	negligible	moderate increase	negligible	negligible
Pathogen Concentration - Entrance	negligible	negligible	negligible	negligible
Channel Navigability	negligible	negligible	negligible	large decrease
Tourism	moderate increase	very small increase	very small increase	moderate increase
Seagrass	negligible	negligible	small decrease	small decrease
Wetlands	negligible	Moderate decrease	Moderate decrease	Moderate decrease
ANZECC Guidelines - Upper	negligible	small increase	negligible	negligible
ANZECC Guidelines - Channel	negligible	moderate increase	negligible	negligible
ANZECC Guidelines - Entrance	negligible	negligible	negligible	negligible
Aquatic Fauna	negligible	negligible	very small decrease	very small decrease
Local Revenue	moderate increase	small increase	small increase	moderate increase
Wetland Infill	No change	Infill	Infill	Infill

These combined options have no impacts on only 5 nodes: Water Level; Bank Stability; Mangroves; Saltmarsh; and, Tidal Influence.

This table shows:

- The actions of widening the culvert, improving the boat ramp facility, installing pollutant traps at stormwater outlets and recycling 40% of wastewater in combination lead to:
    - Large to moderate decreases in TN and TP loads and concentrations;
    - Moderate decreases in TSS concentrations in the upper creek but a negligible impact in other parts of the creek;
    - A negligible impact on pathogen loads and concentrations
    - A moderate decrease in flushing times in the upper creek but negligible impacts on flushing in other parts of the creek;
    - A moderate increase in tourism, recreational amenity and local revenue but a large increase in the cost of public works; and,
    - A negligible impact on ecological outcomes such as extent of seagrass, aquatic fauna or terrestrial fauna.
- Improving the boat ramp facility, installing pollutant traps and allowing development to the maximum extent of the LEP in combination lead to:
    - A very small increase in TP load and moderate increases in TN, TSS and pathogen loads;
    - Negligible impacts on TP and TSS concentrations, small (entrance) to moderate increases in TN concentrations (channel, upper), and negligible (entrance), small (upper) and moderate (channel) increases in pathogens;
    - Moderate increases in recreational amenity but decreases in terrestrial habitat;
    - Large increases in the cost of public works.
- Undertaking these changes as well as removing the dune discharge leads to:
    - Large (upper and channel) to moderate (entrance) decreases in TP and TN concentrations due to the large decrease in the load of these pollutants;
    - A very small decrease in TSS load (down from a moderate increase) but negligible impacts on TSS concentrations;
    - A very small increase in tourism and a moderate increase in recreational amenity;

    - A small decrease in seagrass and moderate decrease in wetlands as well as a very small decease in aquatic fauna.
- Undertaking these changes as well as widening the culvert, increasing the rate of drag lining and dredging a channel lead to:
    - A large to moderate decrease in TP and TN concentrations due to a large decrease in the loads of these pollutants;
    - A large decrease in shoaling and sedimentation and a moderate increase in the depth of the entrance;
    - A negligible impact on flushing in the channel and upper creek but a moderate increase in flushing of the entrance;
    - A large decrease in channel navigability but a moderate increase in entrance navigability;
    - A moderate decrease in terrestrial habitat, a small decrease in seagrass, a very small decrease in aquatic fauna and a moderate decrease in wetlands;
    - A moderate increase in local revenue but a large increase in the cost of public works.

6 DISCUSSION OF THE RESULTS

This sustainability assessment report has provided a sample of results for management of the entrance, riparian management, urban development and management of the STP. These options are a small subset of the total number of scenarios which can be considered by the Back Creek CLAM and as such do not provide conclusive evidence of the 'best' way forward from the options available. They are interesting in that they illustrate the potential for actions to improve the overall condition of the lake and catchment system as well as for the potential for cumulative impacts of various options to impact on the system.

These results show the complexity of interactions between processes in the creek. In many cases one action cancels out the effect of another. In some cases (eg. the cost of public works) the effects of the action are cumulative. The impacts of development could be partially offset by actions such as removing dune discharge. These options can help to reduce pollutant discharges and pressures on water quality. However they can not completely offset the impacts of such development, such as the impact on terrestrial habitat.

Engineering works such as dredging a channel or increasing the rate of drag lining are seen to largely cancel each other out. In most cases these actions do not lead to widespread improvements in water quality and in some cases are associated with negative effects on aquatic ecology and water quality outcomes. All these actions are associated with substantial increases in the cost of public works.

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8 REFERENCES

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APPENDIX 1. SUMMARY OF NODES IN THE BACK CREEK CLAM TOOL

Node	Description	Output States	Units
ANZECC Guidelines - Channel	The output of the Pathogen Concentration – Channel node is related to relevant ANZECC guidelines	No restriction, No aquaculture, No primary contact, No secondary contact	
ANZECC Guidelines – Entrance	The output of the Pathogen Concentration – Entrance node is related to relevant ANZECC guidelines	No restriction, No aquaculture, No primary contact, No secondary contact	
ANZECC Guidelines – Upper	The output of the Pathogen Concentration – Upper node is related to relevant ANZECC guidelines	No restriction, No aquaculture, No primary contact, No secondary contact	
Aquatic Fauna	Change in the aquatic faunal biodiversity and abundance within South West Rocks Creek (qualitative)	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Bank stability	Change in the stability of the banks of South West Rocks Creek	Decrease, No Change, Increase	
Boating amenity	The ease of boating on South West Rocks Creek (qualitative)	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Channel Navigability	The ease of navigation of the channel reaches of South West Rocks Creek (qualitative)	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Cost of public works	Estimate of dollars required to complete works implied by the selected scenarios (Total $ for works to be completed). Note it does not include maintenance costs. Currently does not attempt to account for any environmental gain following the works.	$0, $1-$100000, $100000-$500000, $500000-$1000000, >$1000000	
Depth of entrance	The **approximate** average depth of the entrance channel to South West Rocks Creek (m below AHD). Note this does not include the depth of the bar at the mouth of South West Rocks Creek. At present there are no proposed management scenarios that will significantly affect the depth of the bar.	1.5, 2.0, 2.5	*M below AHD*
Entrance Navigability	This variable attempts to estimate the potential effects on entrance navigability (qualitative) of changes to the depth of the entrance channel.	Decrease, No Change, Increase	

Flushing - Channel	Flushing in the part of the estuary located between the traffic bridge and the foot bridge.	<-15%, -15% - -5%, -5% - 5%, 5 – 15%, >15%	
Flushing - Entrance	Change in the time to completely flush the part of the estuary located downstream of the footbridge (% change)	<-15%, -15% - -5%, -5% - 5%, 5 – 15%, >15%	
Flushing - Upper	Flushing in the part of the estuary located upstream of the Macleay River Training Wall maintenance road bridge.	<-15%, -15% - -5%, -5% - 5%, 5 – 15%, >15%	
Local Revenue	An estimate of the revenue to the South West Rocks community as a result of tourism to the area.	>2% Decrease, 2% Decrease, No Change, 2% Increase, >2% Increase	
Mangroves	The change in area of mangroves within South West Rocks Creek (qualitative).	Large decrease, Moderate decrease, No change, Moderate increase, Large increase	
Pathogen Concentration - Channel	Pathogen Concentration (CFU/10mL) in the middle reaches of South West Rocks Creek. CFU = Colony Forming Units	<14, 14-150, 150-1000, >1000	
Pathogen Concentration – Entrance	Pathogen Concentration (CFU/10mL) in the entrance reaches of South West Rocks Creek. CFU = Colony Forming Units	<14, 14-150, 150-1000, >1000	
Pathogen Concentration – Upper	Pathogen Concentration (CFU/10mL) in the upper reaches of South West Rocks Creek. CFU = Colony Forming Units	<14, 14-150, 150-1000, >1000	
Pathogen Load	The concentration of faecal coliforms entering the South West Rocks Creek from the catchment area as CFU/100ml, where CFU = colony forming units.	<14, 14-50, 50-150, 150-500, >500	
Recreational Amenity	The value of South West Rocks Creek as a recreational resource	Large Decrease, Decrease, No Change, Increase, Large Increase	
Saltmarsh	Change in the area of saltmarsh within South West Rocks Creek (Qualitative)	Large decrease, Moderate decrease, No change, Moderate increase, Large increase	
Seagrass	Change in the area of seagrass within South West Rocks Creek.	Large decrease, Small decrease, No change, Small increase, Large increase	
Sedimentation	The continued deposition of sediment within the body of South West Rocks Creek	Large Decrease, Moderate Decrease, No change, Moderate Increase, Large Decrease	

Shoaling	The continued deposition of sediment within the channel of South West Rocks Creek	Large Decrease, Small Decrease, No Change, Small Increase, Large Increase	
Terrestrial habitat	Trends in the quantity and quality of terrestrial habitat in the South West Rocks Creek catchment (qualitative).	Decrease, No Change, Increase	
Tidal influence	Change in the surface area within the tidal reaches of South West Rocks Creek.	No Change, 15 Ha Increase	
Total Nitrogen Concentration - Channel	Total Nitrogen (µg/L) in the channel reaches of South West Rocks Creek.	<200, 200-250, 250-300, 300-350, >350	µg/L
Total Nitrogen Concentration – Entrance	Total Nitrogen (µg/L) in the entrance reaches of South West Rocks Creek.	<100, 100-150, 150-200, 200-250, >250	µg/L
Total Nitrogen Concentration – Channel	Total Nitrogen (µg/L) in the upper reaches of South West Rocks Creek.	<250, 250-300, 300-350, 350-400, >400	µg/L
Total Nitrogen Load	Inputs of Total Nitrogen (TN) (kg/year) to South West Rocks Creek. [NOTE: Loads are used here rather than concentrations because state government are moving towards loads as being the most appropriate representation of ecosystem response].	<700, 700-1500, 1500-3000, 3000-5000, 5000-7500, 7500-10000, >10000 kg/year	Kg/yr
Total Phosphorus Concentration – Channel	Total Phosphorus (µg/L) in the middle reaches of South West Rocks Creek.	<24, 24-28, 28-32, 32-36, >36	µg/L
Total Phosphorus Concentration – Entrance	Total Phosphorus (µg/L) in the entrance reaches of South West Rocks Creek.	<7, 7-9, 9-11, 11-13, >13	µg/L
Total Phosphorus Concentration – Upper	Total Phosphorus (µg/L) in the upper reaches of South West Rocks Creek.	<46, 46-52, 52-58, 58-64, >64	µg/L
Total Phosphorus Load	Inputs of Total Phosphorus (TP) (kg/year) to South West Rocks Creek.	<250, 250-500, 500-1000, 1000-2000, 2000-3000, 3000-3500, >3500	Kg/yr
Total Suspended Sediment Concentration – Channel	Total Suspended Solids (g/m^3) in the middle reaches of South West Rocks Creek.	<11, 11-13, 13-15, 15-17, >17	g/m^3
Total Suspended Sediment Concentration – Entrance	Total Suspended Solids (g/m^3) in the entrance reaches of South West Rocks Creek.	<24, 24-28, 28-32, 32-36, >36	g/m^3
Total Suspended Sediment Concentration – Upper	Total Suspended Solids (g/m^3) in the upper reaches of South West Rocks Creek.	<11, 11-13, 13-15, 15-17, >17	g/m^3
Total Suspended Sediment Load	Inputs of Total Suspended Solids (TSS) (kg/year) to South West Rocks Creek.	<6000, 6000-9000, 9000-12000, 12000-15000, >15000	Kg/yr

Tourism	Change in tourism to South West Rocks	>2% Decrease, 2% Decrease, No Change, 2% Increase, >2% Increase	
Water Level	The level of the estuary relative to current mean level (metres)	0-0.25, 0.25-0.5, >0.5	*m*
Wetland Infill	Area of existing wetland infilled for development	No Change, Infill 10.4ha of SEPP14 wetland.	
Wetlands	Trends in the extent/distribution of freshwater wetland habitat in the South West Rocks Creek Catchment (qualitative).	No Change, Decrease	

APPENDIX 2. ADDITIONAL SCENARIO GROUPS AVAILABLE IN THE BACK CREEK CLAM TOOL

There are two additional scenario groups available in the Back creek CLAM tool: water transfer; and, sea level rise.

WATER TRANSFER

Options:

1. No Change
2. Transfer Water From Macleay on Ebb Tide

Description:

A large sandbar exists at the entrance to South West Rocks Creek and mobile shoals appear frequently in the mouth. These features are a hazard to recreational boat users and the small number of professional fishers that use the creek as an access point to the ocean. These navigational difficulties have been one of the primary management concerns.

One suggested solution to this problem is to transfer water from the Macleay River via unidirectional pipes to increase the ebb tidal flow. This scenario explores the likely effects of undertaking this action.

SEA LEVEL RISE

Options:
1. No change
2. 2030
3. 2050
4. 2100

The sea level is predicted to rise in the future due to climate change. The climate change scenarios were estimated from Whetton and Holper (2001) and reviewed by Dr Kevin Walsh, CSIRO atmospheric Research (pers. Comm. September 2004).

The options are to predict the increase in sea level in by the year 2030, 2050 and 2100. The predicted sea level rise (cm) from values in the year 2004 used here were:

Rate of sea level rise	2030	2050	2100
Low	2	3.6	7.6
Medium	11	19.8	41.8
High	20	36	76

A normal distribution was assumed to describe the probabilities of the low, medium and high rates of sea level rise. Thus the assigned probabilities were 0.25, 0.5, 0.25 respectively. The probability of the various rates in sea level rise are dependant on the amount of carbon dioxide released into the atmosphere, which in turn in reliant on the national and global policies. Research into likely policies in the future is beyond the scope of this study.

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