Tallow Creek Sustainability Assessment Report

June 2007

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EXECUTIVE SUMMARY

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Tallow 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 Tallow Creek CLAM for each node and also provides an assessment of key data gaps identified by Jennita Gay and Angus Fergusson in putting the Tallow Creek CLAM together. These gaps are:

- Total area of potential development
- Location and height of all weirs
- Effects of entrance opening on ICOLL ecology including prawn and fish populations, with sensitivity to effects of duration and season of opening on spawning and other relevant life cycle events.
- Septic tank and small STP discharges into the creeks and ICOLL
- Pollutant concentrations in the Golf course pond, and ground water movement from the pond.
- Water level monitoring within the lake.
- Better estimation of water budgets for each subcatchment during all flow conditions.

This report examines the impact of five groups of scenario options, as recommended following a workshop held at Byron Shire Council in May 2007:

- Entrance management
- Artificial weirs
- Urban development
- Catchment reforestation
- High Conservation Value (HCV) vegetation

These are a small number of the total scenario combinations available in the Tallow 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

Two entrance management options were considered and compared to the base case– opening at a trigger value of 1.65 m AHD and removing artificial opening:

- Entrance management affects lake depth and flushing as expected – opening at a trigger of 1.65 AHD leads to a large decrease in flushing and a moderate decrease in depth, while removing artificial opening has little impact on depth but leads to a large increase in flushing times;
- The change in flushing has impacts on water quality such that opening the lake at a lower level corresponds with decreases in TN and pH (small) while removing artificial opening leads to increases in TP (small) and pH (very small);
- Changing the entrance opening regime leads to both positive and negative ecological effects – opening the lake at 1.65m AHD leads to small increases in melaleuca forest, sedgeland and wetland fauna; moderate increases in bird populations and large increases in prawns but a very small increase in fish kills and algal blooms and a very small decrease in shell fish. Removing entrance management has a negligible effect on many ecological parameters (sedgeland, melaleuca forest, wetland fauna, bird populations, shell fish) and only small or very small effects on other variables such as algal blooms. It does lead to a large decrease in prawns.
- Opening the lake at 1.65m AHD is also associated with social and economic benefits such as a small increase recreational fishing but a very small decrease in swimming and visual amenity but a large decrease in aboriginal values associated with water and thus total aboriginal values. Removing entrance opening is also associated with social and economic benefits but these are generally much smaller in size – a very small increase in

visual amenity, moderate increases in aboriginal values associated with water; as well as a large decrease in recreational fishing.

Artificial weirs
Two options for the management of artificial weirs are considered and compared with the base case – removing weirs and modifying them for fish passage:
- Both removing weirs and modifying them for fish passage have benefits for aboriginal values associated with the built environment, recreational fishing, ICOLL aquatic diversity, bird populations, prawn and fish mobility, prawns and total aboriginal values although the benefits are generally greater when weirs are removed rather than being modified;
- Removing the weirs also reduced black water inputs while modifying weirs for fish passage has a negligible effect;
- These benefits come at the cost of riparian vegetation such that removing weirs leads to a large decrease in riparian vegetation while modifying weirs has a negligible impact on this node.

Urban Development
An option of low density urban development is considered:
- Urban development is associated with several large costs – a large decrease in aboriginal built environment values, terrestrial fauna and total aboriginal values and a large increase in the urban flood risk as well as a moderate decrease in native vegetation connectivity;
- Impacts of urban development are fairly small with TN loads increasing slightly but a negligible effect on final concentrations, and pathogen inputs and final concentrations decreasing slightly.

Catchment reforestation
The option of reforestation of the catchment is considered:
- Many benefits are associated with catchment reforestation including a large increase in native vegetation area, native vegetation connectivity, riparian vegetation, terrestrial fauna, visual amenity, swimming, aboriginal values associated with vegetation and total aboriginal values as well as a small decrease in TSS inputs, a very small decrease in pathogen inputs and final concentrations and a very small increase in shellfish;
- These benefits come at the cost of a large increase in council expenditure.

High conservation value vegetation
Two options for managing high conservation value vegetation are considered – placing a 50m buffer around HCV vegetation and reforesting corridors:
- Both options lead to a moderate increase in native vegetation area and visual amenity, a large increase in terrestrial fauna and a small increase in swimming values;
- Only reforestation of corridors has an effect on native vegetation connectivity;
- Buffers are the preferred option in terms of aboriginal values associated with vegetation and total aboriginal values with reforestation of corridors being associated with negligible impacts in both cases; and
- Both options are associated with large costs to council.

Summary
Overall these results show that there are options for improving both terrestrial and aquatic outcomes in the catchment. These generally come at a cost in terms of council expenditure but in many cases have a wide range of benefits that would make them worth considering.

1 INTRODUCTION

This Sustainability Assessment report is based on results from the Coastal Lake Assessment and Management (CLAM) tool for Tallow 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 Tallow Creek CLAM tool and are intended to:

- document the quality of data used in the Tallow 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 Tallow 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 Tallow Creek CLAM workshop with the Byron 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 Tallow 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 Tallow 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 Tallow Creek CLAM.

It should be noted that the scenarios presented in this report are not exhaustive. Additional scenarios are presented in the Tallow 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 Tallow 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 TALLOW CREEK

Tallow Lake is situated immediately south of Cape Byron in north eastern New South Wales. The catchment area is 487.84ha, and is bounded by a steep escarpment to the southwest, grading to an indistinct ridge to the northwest, and a hilly dunal system to the east. The waterways within the Tallow Lake catchment cover 11.13 hectares. Tallow Lake itself is surrounded by an extensive wetland system comprising both open sedgeland and swamp sclerophyll forest. Currently 49% of the catchment remains forested while 34% has been urbanised. The urban area of Suffolk park has been developed around the wetland area and lake of the eastern area, while the more recent urban developments of Baywood Chase and Byron Hills Estate are situated on the lower escarpment to the west. The 2001 census found that there were 10 698 people in the Suffolk Park, Baywood Chase and Byron Hills Estate area. Tallow Creek has been modified to a large extent due to urbanisation. The coastal dunes and waterways of the catchment have also been modified by historical sand mining.

Tallow Creek and its catchment are shown in Figure 2.

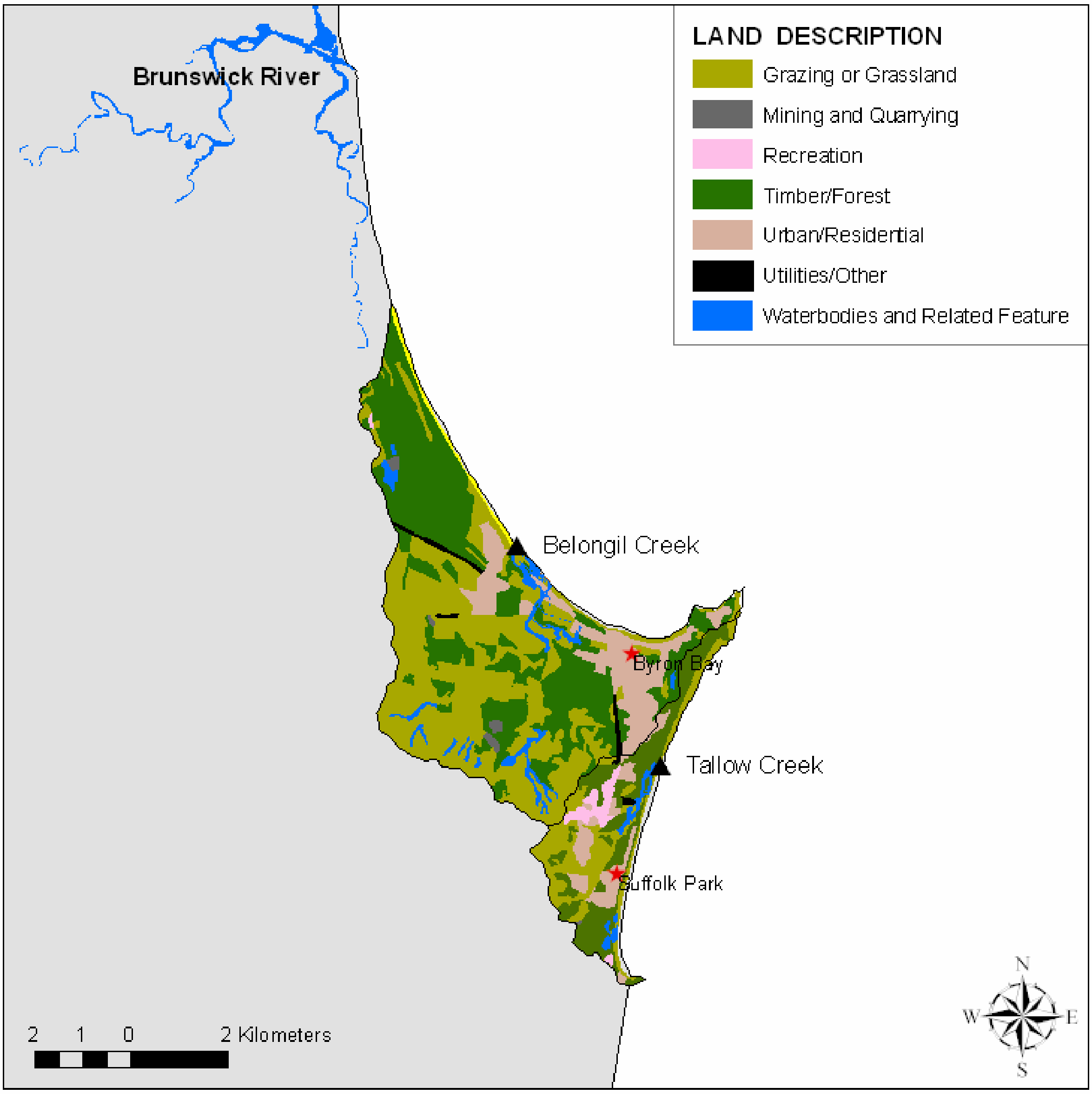

Figure 2. Tallow Creek and its catchment

2.1 Entrance conditions

Tallow Lake remains predominantly closed. There is currently no management plan for artificial opening of the lake entrance, however the entrance is opened when there are complaints from residents adjacent to the lake. Council is required to advise Arakwal national park officers prior to artificial opening of the lake entrance.

2.2 Vegetation communities

Upland forests in the catchment are dominated by rainforest (37 ha) and dry sclerophyll (30ha) with some brushbox (5 ha) and camphor (0.4 ha). Wetland areas are comprised mainly of melaleuca forests (swamp forest 64 ha). Sedge/fern/grass vegetation areas (5.9 ha) include saltmash species, mangrove fern and weedy grass species. Other vegetation types in the catchment include Acacia (12 ha) and Heath (84 ha).

2.3 Key economic industries

The major economic industry in the catchment is recreation and tourism, with several large tourist resort style developments mainly positioned around the lake. There are also lower key tourist facilities adjacent to the lake, including a caravan park and holiday rentals in urban areas

2.4 Key threats

Aboriginal and ecological values for the lake and its catchment are very significant. Pressure from urban and tourist developments are likely to continue to represent key threats to environmental and cultural values of Tallow Lake in the future.

Since the South Byron Sewage Treatment Plant was decommissioned in 2005, nutrient inputs to the lake have diminished significantly, however catchment loads (dominated by urban runoff) remain a concern. Artificial weirs in the creek, weed infestations around the lakes foreshores and artificial opening of the entrance need to be managed with sensitivity to the ecology and Aboriginal values of the lake, surrounding wetlands and creeks in particular.

3 TALLOW CREEK CLAM

3.1 Conceptual framework

The Tallow 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.

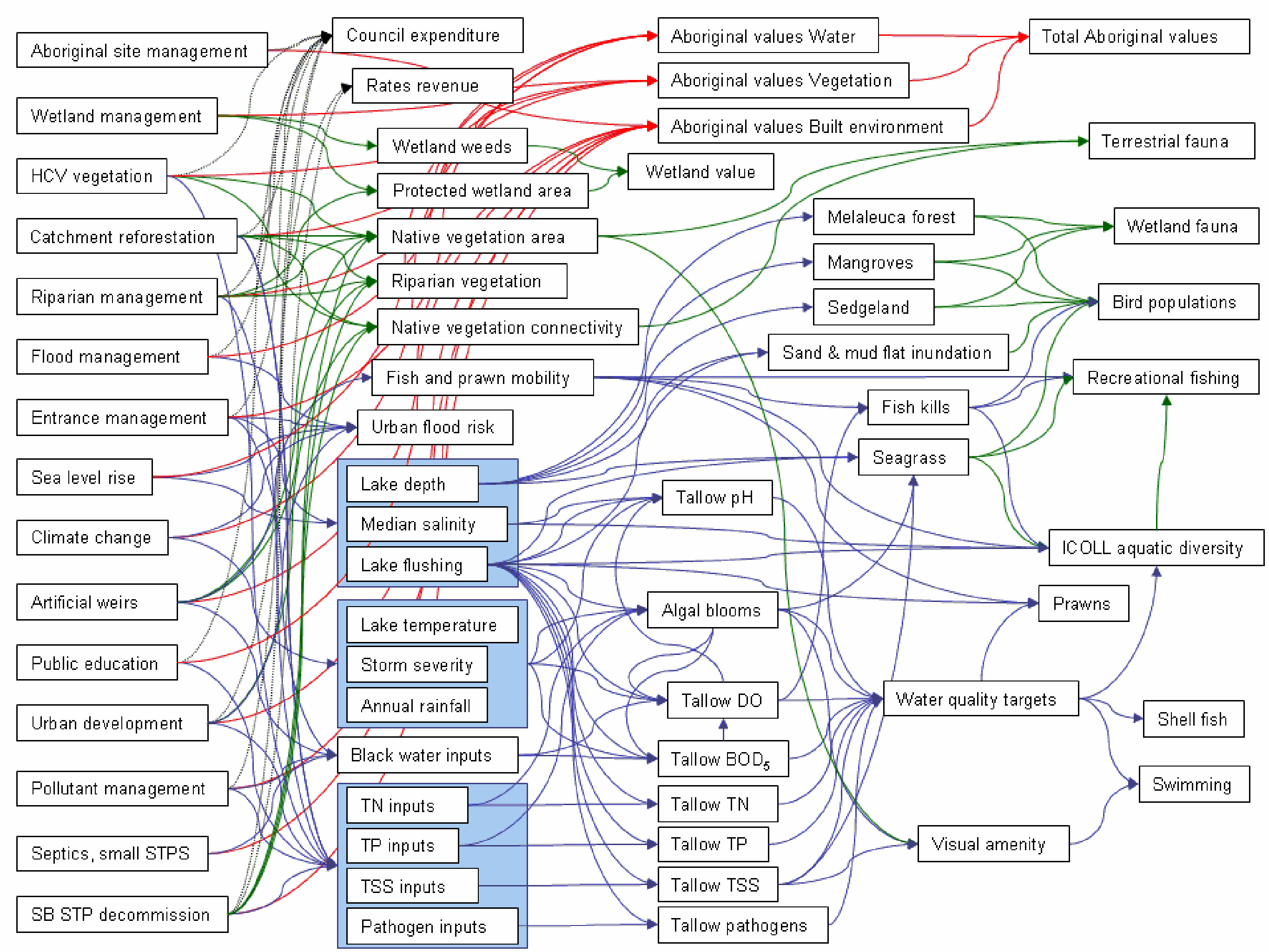

Figure 3. **Tallow Creek conceptual framework used to underpin the Tallow Creek CLAM. Arrows show dependency between nodes.**

3.2 Consultation undertaken to develop the Tallow Creek CLAM

The framework and scenarios contained in the Tallow Creek CLAM were developed in consultation with various stakeholder groups. The conceptual framework, scenarios, scenario options and state variables for Tallow Creek have been based on discussions with a broad range of catchment stakeholders. Stakeholder engagement was enhanced through a public consultation meeting.

Prior to the public consultation meeting Diana Liptrot from Byron United tourism organisation was provided with information and an invitation to publish in the Byron United news letter. Helen Brown (Suffolk Park Dune Care) was contacted by phone and the Green and Clean group was contacted. Also contacted by email and/or telephone were the following government department officers who preferred not to come to the meeting but gave any input over the phone or email: Richard Hagley, Tim Rabbidge and John Nagle – DNR (now the Department of Environment and Climate Change); Chrissy Clay – DPI Lands (now DECC); Marcus Riches – DPI Fisheries (now DECC); Roger Stanley – NRCMA; Sue Walker – National Parks and Wildlife (now DECC); and, Ian Kerr – EPA.

ABER were advised by Council that invitations to the following people who are already engaged in representing the community in the Tallow Lake catchment would be more effective than posting a general advertisement for the meeting in a local news paper. Also the timing of the meeting was deemed by Council to give insufficient time for general advertisement due to deadlines to post advertisements and availability of staff to organise the meeting.

First Name	Surname	Salute	Organisation
Dudley	Legget	Mr	BEACON
David	Saunders	Mr	Byron Environment Centre
Paul	Orrock	Mr	
Jerry	Bennette	Mr	
Helen	Brown	Ms	Suffolk Park Progress Association
Helen	Brown		Landcare groups
Jan	Barham	Mayor	Byron Shire Council
John	Lazarus	Cr	Byron Shire Council
Chin	Toong	Mr	DNR (now DECC)
Sue	Walker	Ms	Headland Trust
Noel	McAviney	Mr	State Emergency Service
Andrew	Page	Mr	Cape Byron Marine Park
Teresa	Heal	Ms	Green & Clean Awareness team
Evon	Stewart	Ms	Indigenous liaison
Kay	Delta	Ms	Indigenous liaison
Des	Wiliams		Tweed Byron Land Council
Diana	Liptrot	Ms	Tourism representatives
Ken	Thurlow	Mr	Recreational fishing groups
Arther	Malin		Recreational fishing groups
John	Nagle	Mr	NRCMA
Roger	Stanley	Mr	NRCMA

The public meeting led to ongoing consultation with several people:

- Chin Toong - Provided information on hydrology and flooding
- Norman Greham (Arakwal National Park/ Representative of Arakwal people). Norm was present at the meeting through consultation with Sue Walker, he organised for CLAM

consultation at the Arakwal National Park monthly meeting at which detailed input from the Arakwal representatives and National Parks representatives was gathered.

Various Council staff also gave input over the course of the project through four meetings at Byron Shire Council and ongoing email contact: Phyliss Jones, James Flockton, Michael Bingham, Dave Clark, and Lisa Wrightson.

Another 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.

The CLAM user training workshops held in May 2007 provided an opportunity for feedback on the Tallow 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 Tallow Creek is then given. This statement was provided by Jennita Gay who put together the data for the Tallow Creek CLAM.

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

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

Node	Quality of Data	Reason	Suggested improvements
Aboriginal values Built Environment	Average	Local knowledge and local expert knowledge used	Review of results
Aboriginal values vegetation	Average	Local knowledge and local expert knowledge used	Review of results
Aboriginal values Water	Average	Local knowledge and local expert knowledge used	Review of results
Algal blooms	Good	Local data and knowledge used	ICOLL response model would improve results. Review.
Annual rainfall	Average	Based on assumptions	Review of results
Bird populations	Poor	Based on assumptions with little local data	Locally relevant data collected. Review of results.
Black water inputs	Good	Local data used	More analysis of primary drivers of black water inputs is required
Council expenditure	Poor	Based on unverified assumptions	Review of assumptions and local data
Fish and prawn mobility	Poor	Based on assumptions and expert opinion	Locally based data and review of results
Fish kills	Poor	Based on unverified assumptions	Locally based data, expert opinion and review
ICOLL aquatic diversity	Poor	Based on assumptions and local expert knowledge	Locally based data. Review of impacts
Lake depth	Average	Based on assumptions and local study	Review of impacts by expert. More detailed specific local study.
Lake flushing	Average	Based on assumptions and local study	Long term monitoring of runoff coefficients. Expert review of data.
Lake temperature	Poor	Based on assumptions and uncertain, non-local report	Revision of results with improvements in predictions. Expert review.
Mangroves	Average	Based on assumptions and local knowledge	Expert review
Median salinity	Average	Based on assumptions and local report	Expert review and more detailed locally based study
Melaleuca forest	Poor	Based on unverified assumptions	Local data and expert review required
Native vegetation area	Good	Based on interpretation of local data	Effect of weir removal on riparian vegetation should be locally verified. Expert review
Native vegetation connectivity	Good	Based on local data and some assumptions	Method for calculating connectivity of vegetation requires review and updating with specialised expert opinion
Pathogen inputs	Average	Based on uncalibrated model	Local data for model input, verification of model results using monitoring data
Prawns	Poor	Based on assumptions	Local data and expert review
Protected wetland area	Excellent	Based on local data	Use of topographic GIS data layers for some areas

Rates revenue	Average	Based on assumptions and some local knowledge	Local data and expert review
Recreational fishing	Poor	Based on assumptions	Local data and expert review
Riparian vegetation	Good	Based on local data and some assumptions	Expert review
Sand and mud flat inundation	Poor	Based on assumptions	Expert review and local data
Seagrass	Poor	Based on assumptions	Expert review and local data
Sedgeland	Poor	Based on assumptions	Expert review and local data
Shell fish	Poor	Based on assumptions	Expert review and local data
Storm severity	Poor	Based on assumptions	Expert review and update with new climate predictions
Swimming	Poor	Based on assumptions	Expert review and local data
Tallow BOD5	Average	Based on assumptions and local monitoring data	Development of an ICOLL response model
Tallow DO	Average	Based on assumptions and local monitoring data	Development of an ICOLL response model
Tallow pathogens	Average	Based on assumptions and local monitoring data	Long term monitoring data
Tallow pH	Average	Based on assumptions and local monitoring data	Catchment runoff estimates coupled with an estuarine mixing model
Tallow TN	Average	Based on assumptions and local monitoring data	Long term monitoring data and expert review
Tallow TP	Average	Based on assumptions and local monitoring data	Long term monitoring data and expert review
Tallow TSS	Average	Based on assumptions and local monitoring data	Long term monitoring data and expert review
Terrestrial fauna	Poor	Based on assumptions	Local data and expert review
TN inputs	Poor	Based on uncalibrated model	Small STP and septics not currently included.
Total Aboriginal values	Average	Local knowledge and local expert knowledge used	Review of results
TP inputs	Poor	Based on uncalibrated model	Small STP and septics not currently included.
TSS inputs	Poor	Based on uncalibrated model	Small STP and septics not currently included.
Urban flood risk	Average	Based on assumptions and some local knowledge	Flood modelling and expert review
Visual amenity	Average	Based on assumptions and local knowledge	More detailed local survey information
Water quality targets	Average	Based on definitions	Effective method for combining effects of different parent nodes. Expert review

Wetland fauna	Poor	Based on assumptions	Local data and exert review
Wetland value	Poor	Based on assumptions	Local data and exert review
Wetland weeds	Poor	Based on assumptions	Local data and exert review

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 Jennita Gay are:

- Total area of potential development
- Location and height of all weirs
- Effects of entrance opening on ICOLL ecology including prawn and fish populations, with sensitivity to effects of duration and season of opening on spawning and other relevant life cycle events.
- Septic tank and small STP discharges into the creeks and ICOLL
- Pollutant concentrations in the Golf course pond, and ground water movement from the pond.
- Water level monitoring within the lake.
- Better estimation of water budgets for each subcatchment during all flow conditions.

4 SCENARIOS

In order to develop this Sustainability Assessment analysis a relatively small subgroup of scenarios were selected from the 5,248,800 available in the Tallow Creek CLAM. In was decided to focus on the following scenarios combinations:

- Entrance Management
- Artificial weirs
- Urban development
- Catchment reforestation
- HCV vegetation

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

This scenario is intended to provide information on the effects of management options for artificial opening of the Tallow Lake entrance.

The impacts of these options have been assessed by ABER based on review of the Tallow Creek Flood Study (Water Studies 2002) and the Tallow Creek Floodplain Risk Management Study (2006), and GIS analysis. Currently, the entrance of Tallow Lake is artificially opened only when flood waters encroach on private property. The recommendations of SKM (2006) are for the artificial maintenance of the entrance beach berm level at 1.4 - 1.8m AHD, so that flood-induced breaching occurs within this range.

The management options are:

- No change (artificially open the entrance once flood waters encroach on property)
- Open at trigger AHD (1.6 AHD)
- No artificial opening

4.2 Artificial weirs

This scenario is intended to provide information on the effects of artificial weirs and their removal on Tallow Lake water quality and ecology.

There are currently a number of artificial weirs on Tallow Creek (downstream of Broken Head Road), and other minor tributaries (e.g. waterways within the Everglades) draining into Tallow Lake itself. The effects of artificial weirs on Tallow Lake ecology have been based on expert opinion from the Department of Environment and Climate Change (formerly Department of Primary Industries – Fisheries). Effects on water quality are based on ABER's extensive experience in this area.

The management options are:

- No change
- Remove weirs
- Modify weirs for fish passage

4.3 Urban Development

This scenario is intended to provide information on the effects of urban development on Tallow Lake water quality, native vegetation and Aboriginal values.

The effects of urban development have been based on the area of future possible development outlined in the Local Environment Plan (BSC 1988) and information from Byron Shire council. The vales used were extracted from GIS layers by Wetland Care Australia. The impacts on water quality due to development of these areas are based on assumptions, the impact on native vegetation was calculated from GIS layers, and the impact on Aboriginal values was based on consultation.

The management options are:

- No change
- Develop available land to Low Density (DLW)

4.4 Catchment reforestation

This scenario is intended to provide information on the effects of reforestation of all land in the Tallow catchment that is private, cleared and not already developed.

The area of undeveloped cleared land has been extracted from GIS maps by WetlandCare Australia based on information supplied by the Byron Shire Council. A map of the areas of land included is provided within the CLAM interface maps section.

The management options are:

- No change
- Reforest catchment

4.5 HCV vegetation

This scenario is intended to provide information on the effects of management options relating to High Conservation Value (HCV) vegetation.

Byron Shire Council GIS layers were used to provide information on the area of HCV vegetation and native vegetation corridors in the Tallow Lake catchment. Data extraction was provided by WetlandCare Australia. The area for a 50m buffer around HCV vegetation and the proportion of buffers that are not developed and therefore represent a viable option for reforestation as a buffer were calculated. The forested, cleared and developed areas within corridors were also calculated.

The management options are:

- No change
- 50m buffers for HCV
- Reforestation of corridors

5 RESULTS FROM SCENARIO RUNS

5.1 Entrance management

Two entrance 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 management on likely state values for impacted nodes

No change	Open at trigger AHD (1.65 AHD)	No artificial opening
Lake flushing	large decrease	large increase
Aboriginal values Water	large decrease	moderate increase
Total Aboriginal values	large decrease	small increase
Prawns	large increase	large decrease
Lake depth	moderate decrease	negligible
ICOLL aquatic diversity	moderate increase	large decrease
Bird populations	moderate increase	negligible
Median salinity	negligible	large decrease
Tallow pathogens	negligible	very small increase
Mangroves	small decrease	negligible
Sand & mud flat inundation	small decrease	negligible
Tallow TN	small decrease	small increase
Tallow pH	small decrease	very small increase
Recreational fishing	small increase	large decrease
Melaleuca forest	small increase	negligible
Sedgeland	small increase	negligible
Wetland fauna	small increase	negligible
Urban flood risk	very small decrease	negligible
Tallow DO	very small decrease	negligible
Water quality targets	very small decrease	negligible
Swimming	very small decrease	negligible
Shell fish	very small decrease	negligible
Visual amenity	very small decrease	very small increase
Black water inputs	very small increase	negligible
Fish kills	very small increase	negligible
Algal blooms	very small increase	very small decrease
Tallow BOD5	very small increase	very small decrease

These scenarios had no or a negligible impact on 22 nodes: TP inputs; Aboriginal values Built environment; TN inputs; Native vegetation area; Council expenditure; TSS inputs; Pathogen inputs; Protected wetland area; Rates revenue; Tallow TSS; Tallow TP; Seagrass; Native vegetation connectivity; Fish and prawn mobility; Riparian vegetation; Terrestrial fauna; Wetland weeds; Wetland value; Lake temperature; Storm severity; Annual rainfall; and, Aboriginal values Vegetation.

The table shows:

- Entrance management affects lake depth and flushing – opening at a trigger of 1.65 AHD leads to a large decrease in flushing and a moderate decrease in depth, while removing artificial opening has little impact on depth but leads to a large increase in flushing times;
- The change in flushing has impacts on water quality such that opening the lake at a lower level corresponds with decreases in TN and pH (small), while removing artificial opening leads to increases in TP (small) and pH (very small);
- Changing the entrance opening regime leads to both positive and negative ecological effects – opening the lake at 1.65m AHD leads to small increases in melaleuca forest, sedgeland and wetland fauna; moderate increases in bird populations and large increases in prawns but a very small increase in fish kills and algal blooms and a very small decrease in shell fish. Removing entrance management has a negligible effect on many ecological parameters (sedgeland, melaleuca forest, wetland fauna, bird populations, shell fish) and only small or very small effects on other variables such as algal blooms. It does lead to a large decrease in prawns.
- Opening the lake at 1.65m AHD is also associated with social and economic benefits such as a small increase recreational fishing but a very small decrease in swimming and visual

amenity but a large decrease in aboriginal values associated with water and thus total aboriginal values. Removing entrance opening is also associated with social and economic benefits but these are generally much smaller in size – a very small increase in visual amenity, moderate increases in aboriginal values associated with water; as well as a large decrease in recreational fishing.

The impacts of changes in entrance management on lake flushing are shown in Figure 4.

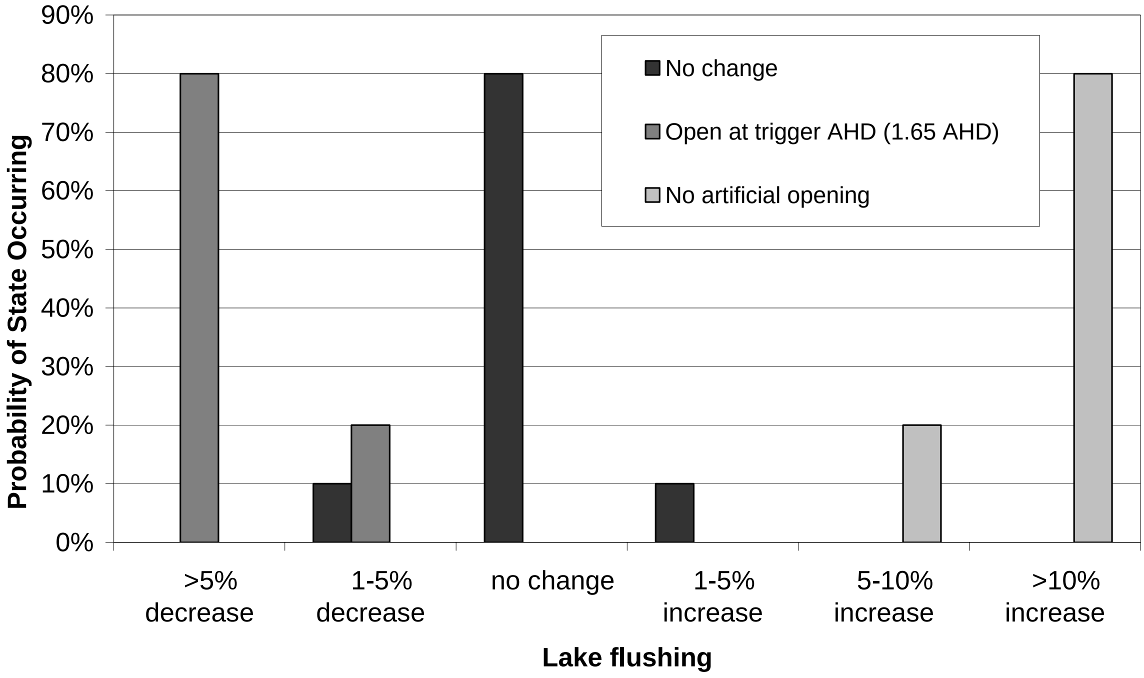

Figure 4. Probability of different changes in lake flushing under entrance management scenarios

This figure shows that changes to entrance management have large effects on the flushing regime. Opening at a trigger value of 1.65m AHD leads to a substantial shift towards decreasing lake flushing times, with an 80% chance of a greater than 5% decrease. Removing artificial opening leads to a large probability of >10% increase in flushing times (80%) and a 20% chance of a 5-10% increase.

These changes in flushing have impacts on water quality. Figure 5 illustrates the impact of these changes in flushing on TN concentrations.

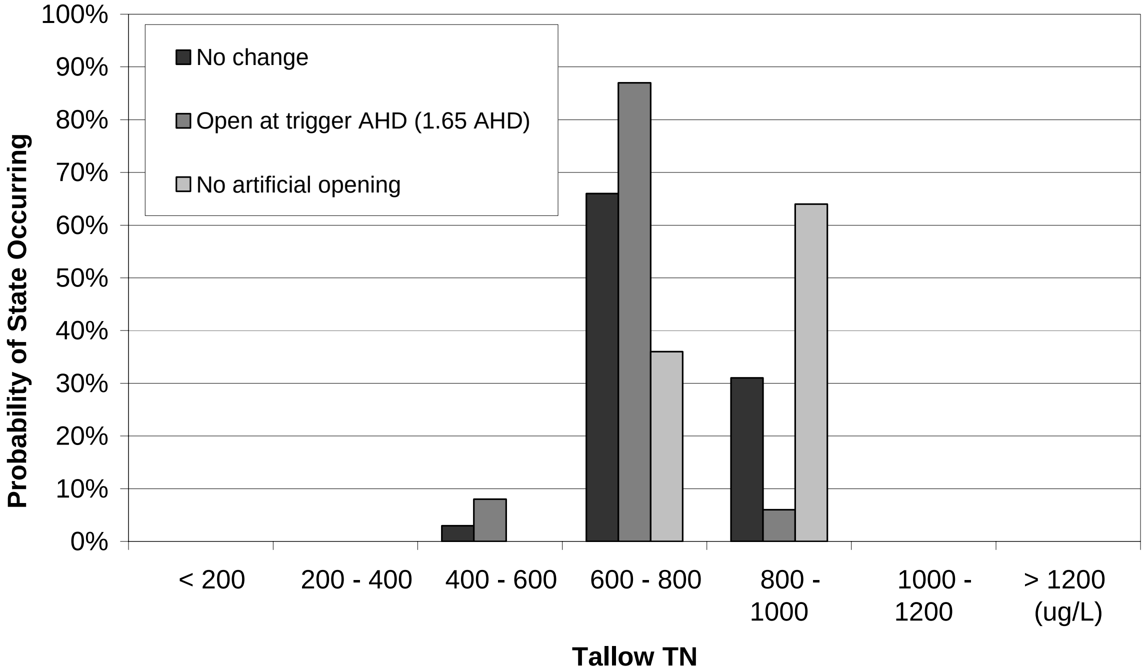

Figure 5. Probability of different changes in Tallow TN under entrance management scenarios

This figure shows that opening the entrance at a lower trigger value shifts the probability of 600-800 µg/L from over 60% to over 80%. It also reduces the chance of TN being in the 800 to 1000 µg/L range from greater than 30% to less than 10%. By contrast removing artificial opening removes any chance of TN being in the 400 to 600 µg/L range, reduces the chance of TN being in the 600 to 800 µg/L range to less than 40% and increases the chance of 800 to 1000 µg/L to greater than 60%.

5.2 Artificial weirs

Two options for managing artificial weirs were considered in addition to the base case option: removing the weirs altogether; or, managing them for improved fish passage. Table 3 summarises impacts on impacted nodes.

Table 3. Impacts of artificial weir management on likely state values for impacted nodes

	Remove weirs	**Modify weirs for fish passage**
Aboriginal values Built environment	large increase	moderate increase
Black water inputs	small decrease	negligible
Recreational fishing	large increase	large increase
Fish kills	large decrease	small increase
ICOLL aquatic diversity	large increase	large increase
Bird populations	large increase	very small increase
Fish and prawn mobility	large increase	moderate increase
Riparian vegetation	large decrease	negligible
Prawns	large increase	moderate increase
Total Aboriginal values	large increase	small increase

These options have no or a negligible impact on 39 nodes: Urban flood risk; TP inputs; TN inputs; Native vegetation area; Lake depth; Lake flushing; Median salinity; Council expenditure; TSS inputs; Pathogen inputs; Protected wetland area; Rates revenue; Tallow TN;

Mangroves; Tallow pH; Melaleuca forest; Sedgeland; Tallow TSS; Tallow pathogens; Wetland fauna; Algal blooms; Tallow TP; Tallow DO; Tallow BOD5; Seagrass; Native vegetation connectivity; Sand & mud flat inundation; Terrestrial fauna; Water quality targets; Visual amenity; Swimming; Shell fish; Wetland weeds; Wetland value; Lake temperature; Storm severity; Annual rainfall; Aboriginal values Water; and, Aboriginal values Vegetation.

This table shows that the effects of artificial weir management are quite simple and limited to relatively few nodes:

- Both removing weirs and modifying them for fish passage have benefits for aboriginal values associated with the built environment, recreational fishing, ICOLL aquatic diversity, bird populations, prawn and fish mobility, prawns and total aboriginal values although the benefits are generally greater when weirs are removed rather than being modified;
- Removing the weirs also reduced black water inputs while modifying weirs for fish passage has a negligible effect;
- These benefits come at the cost of riparian vegetation such that removing weirs leads to a large decrease in riparian vegetation while modifying weirs has a negligible impact on this node.

Thus the trade-offs becomes one of considering the reduced benefits from modifying weirs when compared to their removal versus no impact on riparian vegetation and cost differences.

5.3 Urban Development

There is one option for urban development to compare with the base case option. This option involves developing land to low density. Impacts of the option on impacted nodes are given in Table 4.

Table 4. Impacts of urban development on likely state values for impacted nodes

No change	Develop land to Low Density (DLW)
Aboriginal values Built environment	large decrease
Terrestrial fauna	large decrease
Total Aboriginal values	large decrease
Urban flood risk	large increase
Native vegetation connectivity	moderate decrease
Pathogen inputs	very small decrease
Tallow pathogens	very small decrease
TN inputs	very small increase

This option had no or a negligible impact on 41 nodes: Native vegetation area; Lake depth; Lake flushing; Median salinity; Council expenditure; TSS inputs; Black water inputs; Protected wetland area; Rates revenue; Mangroves; Tallow pH; Melaleuca forest; Sedgeland; Tallow TSS; Wetland fauna; Algal blooms; Tallow TP; Tallow DO; Fish kills; ICOLL aquatic diversity; Bird populations; Seagrass; Fish and prawn mobility; Tallow BOD5; Riparian vegetation; Sand & mud flat inundation; Visual amenity; Shell fish; Wetland weeds; Wetland value; Lake temperature; Storm severity; Annual rainfall; Aboriginal values Water; Aboriginal values Vegetation; TP inputs; Tallow TN; Recreational fishing; Swimming; and Water quality targets.

This table shows that urban development impacts on relatively few nodes, although in many cases the magnitude of the impact on these nodes is substantial:

- Urban development is associated with several large costs – a large decrease in aboriginal built environment values, terrestrial fauna and total aboriginal values and a large increase in the urban flood risk as well as a moderate decrease in native vegetation connectivity;
- Impacts of urban development are fairly small with and TN loads increasing slightly but a negligible effect on final concentrations, and pathogen inputs and final concentrations decreasing slightly.

5.4 Catchment Reforestation

Reforestation of the catchment is compared to the base case option. Impacts on impacted nodes are shown in Table 5.

Table 5. Impacts of catchment reforestation on likely state values for impacted nodes

No change	Reforest catchment
Aboriginal values Vegetation	large increase
Council expenditure	large increase
Native vegetation area	large increase
Native vegetation connectivity	large increase
Riparian vegetation	large increase
Swimming	large increase
Terrestrial fauna	large increase
Total Aboriginal values	large increase
Visual amenity	large increase
TSS inputs	small decrease
Pathogen inputs	very small decrease
Tallow pathogens	very small decrease
Shell fish	very small increase

This option had no or a negligible impact on 36 nodes: Aboriginal values Built environment; Aboriginal values Water; Algal blooms; Annual rainfall; Bird populations; Black water inputs; Fish and prawn mobility; Fish kills; ICOLL aquatic diversity; Lake depth; Lake flushing; Lake temperature; Mangroves; Median salinity; Melaleuca forest; Prawns; Protected wetland area; Rates revenue; Recreational fishing; Sand & mud flat inundation; Seagrass; Sedgeland; Storm severity; Tallow BOD5; Tallow DO; Tallow pH; Tallow TN; Tallow TP; Tallow TSS; TN inputs; TP inputs; Urban flood risk; Water quality targets; Wetland fauna; Wetland value; and Wetland weeds.

This table shows that catchment reforestation impacts on more nodes than urban development but impacts are still relatively simple:

- Many benefits are associated with catchment reforestation including a large increase in native vegetation area, native vegetation connectivity, riparian vegetation, terrestrial fauna, visual amenity, swimming, aboriginal values associated with vegetation and total aboriginal values as well as a small decrease in TSS inputs, a very small decrease in pathogen inputs and final concentrations and a very small increase in Shell fish;
- These benefits come at the cost of a large increase in council expenditure.

5.5 High Conservation Value Vegetation

Two options are considered in addition to the base case: 50m buffers for HCV vegetation; and, reforestation of corridors. Impacts on impacted nodes are summarised in Table 6.

There are 41 nodes for which no impact or a negligible impact was experienced: Urban flood risk; TP inputs; Aboriginal values Built environment; Lake depth; TN inputs; Lake flushing; Median salinity; Pathogen inputs; TSS inputs; Black water inputs; Protected wetland area; Rates revenue; Tallow TN; Mangroves; Tallow pH; Melaleuca forest; ICOLL aquatic diversity; Tallow TSS; Tallow pathogens; Recreational fishing; Wetland fauna; Algal blooms; Sedgeland; Tallow TP; Tallow DO; Fish kills; Bird populations; Seagrass; Fish and prawn mobility; Tallow BOD5; Riparian vegetation; Sand & mud flat inundation; Water quality targets; Shell fish; Prawns; Wetland weeds; Wetland value; Lake temperature; Storm severity; Annual rainfall; and, Aboriginal values Water.

Table 6. Impacts of HCV vegetation on likely state values for impacted nodes

No change	50m buffers for HCV	Reforestation of corridors
Native vegetation area	moderate increase	moderate increase
Council expenditure	large increase	large increase
Native vegetation connectivity	negligible	large increase
Terrestrial fauna	large increase	large increase
Visual amenity	moderate increase	moderate increase
Swimming	small increase	small increase
Aboriginal values Vegetation	moderate increase	negligible
Total Aboriginal values	small increase	negligible

This table shows that the impacts of managing High Conservation Value vegetation are relatively simple and largely based around effects on the terrestrial environment, although some water based recreation effects are also experienced:

- Both options lead to a moderate increase in native vegetation area and visual amenity, a large increase in terrestrial fauna and a small increase in swimming values;
- Only reforestation of corridors has an effect on native vegetation connectivity;
- Buffers are the preferred option in terms of aboriginal values associated with vegetation and total aboriginal values with reforestation of corridors being associated with negligible impacts in both cases; and
- Both options are associated with large costs to council.

6 DISCUSSION OF THE RESULTS

This sustainability assessment report has provided a sample of results for management of the entrance, artificial weirs, urban development, catchment reforestation and HCV vegetation. These options are a small subset of the total number of scenarios which can be considered by the Tallow 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.

The results looked at interventions aimed at improving water quality and terrestrial outcomes, such as changes to entrance management, management of artificial weirs, catchment reforestation and management of high conservation value vegetation. These actions are seen to have different effects on a range of terrestrial and aquatic ecological and environmental values. Entrance management effects water quality and ecological values by changing flushing. Catchment reforestation and HCV vegetation change terrestrial vegetation values and also impact to a smaller extent on the loads of pollutants delivered to the estuary. Managing artificial weirs has negative impacts on terrestrial biodiversity values but reduces the export of pollutants into the lake, thus improving aquatic ecology outcomes.

The effects of urban development are also considered. The results show that low density urban development has relatively small effects on water quality, but is associated with significant costs to the terrestrial environment, with large decreases in terrestrial fauna and moderate decreases in the connectivity of native vegetation. This development also increases to risk of urban flooding.

Overall these results show that there are options for improving both terrestrial and aquatic outcomes in the catchment. These generally come at a cost in terms of council expenditure but in many cases have a wide range of benefits that would make them worth considering.

7 ACKNOWLEDGEMENTS

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The CLAM model presented in this report has been developed by Jennita Gay and Angus Fergusson. They wrote scenario and output node descriptions and compiled maps used in this report.

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

Node	Description	Output States	Units
Aboriginal values Built Environment	Changes in aboriginal values associated with management decisions relating to the built environment in the Tallow Lake catchment	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Aboriginal values vegetation	Changes in aboriginal values associated with management options relating to vegetation in the Tallow lake catchment	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Aboriginal values Water	Changes in aboriginal values associated with management options relating to water processes and climate change in the Tallow lake catchment	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Algal blooms	Variation in the biomass of algal blooms in Tallow Lake	<5, 5-10, 10-15, 15-20, 20-25, >25	μg chlorophyll-a.L^{-1}
Annual rainfall	Qualitative change in the median annual rainfall total for the Tallow Lake catchment due to climate change scenarios	No change, decrease	
Bird populations	Habitat value for birds	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Black water inputs	A qualitative change in the severity of low oxygen, high BOD runoff events to Tallow lake	Moderate decrease, small decrease, no change, small increase, moderate increase	
Council expenditure	The change in expense to council associated with management options	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Fish and prawn mobility		Small decrease, no change, small increase, large increase	
Fish kills	Fish kills are generally described as increasing or decreasing in frequency and/or severity	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	

ICOLL aquatic diversity	Changes to the intrinsic ecological diversity of Tallow Lake as an Intermittently Closed and Opened Lake of Lagoon (ICOLL)	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Lake depth	Change in median lake depth (m AHD) due to changes in sea level and/or entrance management scenarios	0.5-1, 1-1.5, 1.5-2.0	M
Lake flushing	Change in lake flushing time (% change from current) due to changes in sea level and/or entrance management scenarios	>5% decrease, 1-5% decrease, no change, 1-5% increase, 5-10% increase, >10% increase	
Lake temperature	Qualitative change in water temperature of Tallow Lake due to climate change scenarios	No change, increase	
Mangroves	Qualitative change in the extent of mangrove forest coverage in the Tallow creek catchment due to variation in lake depth	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Median salinity	Change in median ICOLL salinity (PSU) due to changes in sea level and/or entrance management scenarios	4-5,5-6,6-7,7-8,8-9,9-10	PSU
Melaleuca forest	Qualitative change in the extent of Melaleuca forest coverage in the Tallow creek catchment due to changes in lake depth	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Native vegetation area	Area of native vegetation in the tallow ICOLL catchment	10-20% decrease, 5-10% decrease, <5% decrease, no change, <5% increase, 5-10% increase, 10-20% increase	
Native vegetation connectivity	The connectivity of native vegetation corridors in the Tallow ICOLL catchment	10-20% decrease, 5-10% decrease, <5% decrease, no change, <5% increase, 5-10% increase, 10-20% increase	
Pathogen inputs	Pathogens entering Tallow Lake from point sources and diffuse sources	<14, 14-75, 75-150, 150-300, 300-500, 500-1000, >1000	CFU/100ml
Prawns	Prawn habitat value	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	

Protected wetland area	The area of wetlands in the Tallow ICOLL that are protected under SEPP14 and LEP88 (7(a)) legislation	10-30,30-40,40-50,50-60,60-70,70-80,80-90	Ha
Rates revenue	The change in revenue to council associated with management options	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Recreational fishing		Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Riparian vegetation	Describes changes in the area of riparian vegetation	<60, 60-62, 62-64,64-66,66-68,68-70,70-72	Ha
Sand and mud flat inundation	Describes a qualitative change in the area of unvegetated sediments that are subject to periodic (tidal and longer period) inundation and exposure due to variations in freshwater flow and entrance conditions	Decrease, no change, increase	
Seagrass	Describes changes in extent of seagrass as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Sedgeland	Describes a qualitative change in the extent of Sedgeland coverage in the Tallow creek catchment due to changes in lake depth	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Shell fish	Shell fish habitat value is described as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Storm severity	Describes a qualitative change in the severity of storm events (ie. rainfall intensity, rainfall event totals, flooding, storm surges and wave setup) for the Tallow lake catchment due to climate change scenarios	No change, increase	
Swimming	Amenity for swimming is described as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	

Tallow BOD5	Describes the change in median ICOLL biochemical oxygen demand (BOD5)	<0.5,0.5-1.0, 1.0-1.5, 1.5-2.0,2.0-2.5,>2.5	mg O_2/L
Tallow DO	Describes the change in median ICOLL dissolved oxygen (DO)	<4,4-5,5-6,6-7,7-8,>8	mg O_2/L
Tallow pathogens	Describes the median pathogen concentration in Tallow lake	<14, 14-75, 75-150, 150-300, 300-500, 500-1000, >1000	CFU/100ml
Tallow pH	Describes the change in median ICOLL pH	<6.0,6.0-6.5,6.5-7.0,7.0-7.5,7.5-8.0,>8.0	
Tallow TN	Describes the median total nitrogen concentration in the Tallow lake	<200, 200-400, 400-600, 600-800, 800-1000, 1000-1200, >1200	$\mu g.L^{-1}$
Tallow TP	Describes the median total phosphorus concentration in the Tallow lake	<80, 80-160, 160-240, 240-320, >320	$\mu g.L^{-1}$
Tallow TSS	Describes the median total suspended sediment concentration in the Tallow lake	<3, 3-12, 12-23, 23-33, >33	$g.L^{-1}$
Terrestrial fauna	Terrestrial fauna population numbers are generally described as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
TN inputs	The total nitrogen load to Tallow lake	<1000,1000-1500,1500-2000,2000-2500,2500-3000,>3000	Kg/year
Total Aboriginal values	Changes in aboriginal values associated with all management options	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
TP inputs	The total phosphorus load to Tallow lake	<100,100-150,150-200,200-250,250-300,>300	Kg/year
TSS inputs	The total suspended sediment load to Tallow lake	<10000,10000-15000, 15000-20000,20000-25000,25000-30000,>30000	Kg/year
Urban flood risk	Describes a qualitative change in the area of flood prone urban land	Moderate decrease, small decrease, no change, small increase, moderate increase	
Visual amenity	Visual amenity is described as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	

Water quality targets	Compliance to water quality targets is described as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Wetland fauna	The robustness of wetland fauna diversity and numbers are generally described by an increase or decrease in overall value	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Wetland value	Describes changes in overall wetland value as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Wetland weeds	Describes changes in extent of weed infestations as increasing or decreasing	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	

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

There are ten additional scenario groups available in the Tallow creek CLAM tool.

Aboriginal site management
This scenario is intended to provide information on the effects of Aboriginal site management options on Aboriginal values.

Suggestions were made during initial consultation stages that an option for Aboriginal site management was to improve access and buildings. During consultation with Arakwal representatives it was stated that any improvement in access or construction of buildings would decrease rather than increase Aboriginal values.

The management options are:

- No change
- Improved access & buildings

Public education
This scenario is intended to provide information on the effects of implementing comprehensive public education programs aimed at reducing urban pollutant loads to Tallow Lake.

Public education programs to reduce pollutant loads from urban areas include elements of information provision, persuasion, and/or involvement by the target audience (Taylor & Wong 2002). Various strategies include fostering awareness of the connectivity between urban drains and natural water courses (e.g. stencilled messages on stormwater drains), providing information about environmentally sensitive cleaning products and approaches to common household/garden activities (e.g. washing cars on grassed areas), creation of comprehensive environmental awareness education programs in schools. This scenario assumes the implementation of a comprehensive public education program designed to target the issues and demographic within the Tallow Creek catchment.

The management options are:

- No change
- Implement programs

References
Taylor, A. and Wong, T. (2002) Non-structural stormwater quality best management practices – A literature review of their value and life cycle costs. Technical Report 02/13 Cooperative Research Centre for Catchment Hydrology, Victoria.

SB STP decommission
This scenario is intended to provide information on the effects of management options relating to the South Byron (SB) Sewerage Treatment Plant (STP) which historically operated in Tallow Lake catchment and discharged treated effluent into Tallow Lake. The SB STP was decommissioned in December 2005 and all sewage from the Tallow Creek catchment sewerage system is pumped to the West Byron STP and either discharged into Belongil Creek or recycled.

The site of the SB STP is immediately adjacent to Tallow Lake, the large ponds closest to the lake are referred to here as the tertiary polishing ponds. The option for Full Site Decontamination (FSD) at the time of writing was believed to refer to decontamination of all contaminated soils on the STP site, including sediments in the tertiary polishing ponds. Under the Wetland restoration options, these ponds and the area immediately around them would undergo restoration to form wetland areas.

The effects of management options for SB STP decommission on Aboriginal values are based on consultation, council expenditure and rates revenue are based on assumptions, and impacts on pollutant inputs have been modelled based on changes to landuse areas.

The management options are:

- No change
- Full Site Decontamination (FSD)
- FSD + All restored to wetland and reforested
- FSD + Wetland restoration < 1% AEP > low density
- FSD + Wetland restoration < 1% AEP > medium density

Septics and small STPs

This scenario is intended to provide information on the effects of management options relating to septic systems and small Sewerage Treatment Plants (STPs) operating in Tallow Lake catchment. All sewage from the council sewerage system is pumped to the West Byron STP and either discharged into Belongil Creek or recycled.

However septic systems and small, private STPs in the Tallow Lake catchment may have some input of raw sewage or treated sewage into Tallow Lake. Information on the number of septic systems in proximity to the lake or water ways entering the lake was not available. Similarly information on small STPs and possible inputs to the lake and is waterways was not available. The impact of septics and small STPs on Total Nitrogen (TN), Total Phosphorus (TP) and Pathogens was not included in this version of the Tallow CLAM due to the lack of information at the time of construction. However we recommend that this should be reviewed and that if the CLAM is to be used effectively this information needs to be included.

The effects of management options for septics and small STPs on Aboriginal values, council expenditure, and black water inputs have been based on assumptions and consultation.

The management options are:

- No change
- Reduce loadings from septics
- Reduce loading from small STPs

Wetland management

This scenario is intended to provide information on the effects of management options for Wetland management on Wetland weeds, Protected wetland area and Aboriginal values.

Data has been extracted from GIS maps by WetlandCare Australia, providing information on the areas of wetlands and protected wetlands. Approximately same areas protected by SEPP14 and LEP88 (7(a)). Information on impacts on Aboriginal values is based on consultation. There was no data or information currently available on wetland weeds and their removal in Tallow Lake, this node of the model was therefore based on assumptions.

The management options are:

- No change
- Protect all wetlands
- Remove weeds from water ways

References

WCA wetlands layer (includes swamp forest, constructed wetlands, water, riparian)
BSC wetlands/veg layer (no water)

Climate change
This scenario is intended to provide information on the effects of climate change (other than sea level rise) on Tallow Lake and its surrounding environments.

There are numerous predicted impacts of climate change reported in the international literature (see IPCC 2007), however only impacts most relevant to a low lying coastal catchment have been included in this model effects. These are:

Increased storm severity + frequency
The frequency and intensity of extreme storm events (defined by factors such as rainfall intensity, rainfall event totals, flooding, storm surges and wave setup) is expected to increase in south eastern Queensland (especially during summer) by 2100 (CSIRO 2002). This is thought to be in response to a warmer, moister atmosphere which is more conducive to the development of thunderstorms.

Increased temperature
One of the principal predicted impacts of climate change is an increase in average global temperatures by 1.1 °C to 6.4 °C between 1990 and 2100 (IPCC 2007). This is likely to have various ramifications for other global systems, including sea temperatures and ocean currents, although these flow on effects are extremely hard to predict. The number of days with extreme temperatures (exceeding 35 °C) during summer are also predicted to increase from 3 at present, to between 4 and 35 in 2100 (CSIRO 2000).

Decreased annual rainfall
There is currently uncertainty about the responses of Australian rainfall patterns to climate change over the next century. Recent models (CSIRO 2002) have predicted net annual decreases in annual rainfall for south-eastern Queensland (–10% to +5% by 2030 and –35% to +10% by 2070). Decreases are most pronounced in winter and spring. Some eastern coastal areas may become wetter in summer (–5% to +10% by 2030 and –10% to +35% by 2070).

The climate change options are:
- No change
- Increased storm severity + frequency
- Increased temperature
- Increased storm severity + frequency and temperature
- Decreased annual rainfall

References
CSIRO (2002) Climate change and Australia's coastal communities. CSIRO Atmospheric Research. Aspendale, Victoria.

IPCC (2007) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change (2007-02-05).

Flood management
This scenario is intended to provide information on the effects of flood management options in the Tallow Lake catchment currently under consideration by Byron Shire Council.

The impacts of these options have been assessed by ABER based on review of the Tallow Creek Flood Study (Water Studies 2002) and the Tallow Creek Floodplain Risk Management Study (2006), and GIS analysis. The primary option under consideration by council is to upgrade the culvert under Broken Head Road, which has been assessed by SKM (2006) to reduce flood levels in urban areas immediately upstream by 0.5m in a 1 in 10 year ARI flood and provide flood immunity to the road itself (thereby ensuring access by essential services during floods).

The management options are:
- No change
- Enlarge culvert under Broken Head Road

References
SKM (2006) Tallow Creek Floodplain Risk Management Study. Report to Byron Shire Council.
Water Studies (2002) Tallow Creek Flood Study. Report to Byron Shire Council.

Pollution management
This scenario is intended to provide information on the effects of pollution management initiatives on water quality in Tallow Lake.

The effects of pollution management have been based on assumptions.

The management options are:
- No change
- Improve sediment traps
- Reduce reticulation infiltration

Riparian management
This scenario is intended to provide information on the effects of vegetation buffers around Tallow Lake.

The area of buffers, changes in areas of land use and changes in vegetation area due to the buffers has been extracted from GIS maps by WetlandCare Australia. A map of the areas of land included is provided within the CLAM interface maps section.

The management options are:
- No change
- 50m buffer
- 3m AHD + 50m ICOLL buffer

Sea level rise
This scenario is intended to provide information on the effects of predicted sea level rise on Tallow Lake and its surrounding environment.

Sea level is predicted to rise in the future due to climate change. The climate change scenarios used in this model 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 are:

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 triangular distribution is assumed to describe the probabilities of rates of sea level rise, with the minimum and maximum sea level rise for 2030, 2050 and 2100 defined from the low and high rates defined by Whetton and Holper (2001).

The sea level rise options are:

- No change
- 2030
- 2050
- 2100

References

Whetton, P. and Holper, P. (2001) More droughts, more flooding rains, CSIRO Media release Reference: 2001/111, May 07 2001. downloaded 12/11/2004, http://www.csiro.au/index.asp?type=mediaRelesase&id=ClimateHotter.