Willis Creek Sustainability Assessment Report
June 2007

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Sections of this report are authored by the consultant Robert McKenzie and taken directly from the documentation within the Willis Creek CLAM.

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EXECUTIVE SUMMARY

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

- Water quality data – water quality data was collected for over a decade during discharge of treated wastewater into Willis Creek. The laboratory and staff resources are available at the adjacent Woolgoolga Water Reclamation Facility (WRF) but funding is required to continue this data collection. Further discussions with Coffs Harbour City Council are required to recommence this water quality sampling regime. This data would be highly valuable in identifying impacts from future changes in the catchment and the changes in water quality since the cessation of treated wastewater discharge from the WRF.
- Shorebird surveys - Advertise and undertake a community meeting to recruit volunteers from the local community to participate in shorebird surveys at the Willis Creek mouth and therefore initiate the first stage of the proposed shorebird recovery program for Willis Creek. Paul Parrimore has volunteered his time to train interested local community members in shorebird identification and assist in the development of a shorebird recovery program. In addition, NSW National Parks and Wildlife Service have indicated support and funding availability for the proposed shorebird recovery program at Willis Creek.
- Stormwater pollutant export – Further development of initial stormwater pollutant export values from the different land uses within the Willis Creek catchment (e.g. agriculture, industrial and urban) with data gathering of stormwater quality entering Willis Creek.
- Specific WSUD technologies in the existing stormwater management and Special Release Area scenarios have been included in the Willis Creek CLAM based on the catchment characteristics, treatment performance and practicality of application. Preliminary cost estimates have been provided for the existing stormwater management, however, these should be further refined if the relevant scenario options are developed further. In addition, a MUSIC model should be completed to improve confidence limits of the Willis Creek CLAM results for the proposed WSUD technologies if application of the WSUD technologies is proposed.

This report examines the four scenarios, as recommended by a workshop held at Coffs Harbour City Council on 22 May 2007:

- Recreational use of ICOLL mouth
- Agricultural land management
- Existing stormwater management
- Special release area

These are a small number of the total scenario combinations available in the Willis Creek CLAM but provide a useful insight in themselves into the management of the lake. Key conclusions from this analysis are summarised below.

Recreational use of ICOLL mouth

This scenario assesses the opportunities to increase the potential of the site for shorebird habitat and diversity while balancing the recreational use values of the site. The options considered in this scenario include seasonal or permanent fencing with signage, no 4WD access, prohibiting dogs from shorebird areas, education and awareness and all of the above measure combined

Changes to recreational use of ICOLL mouth have the following results:

- the largest benefits to the shorebird recovery program are likely to occur with implementation of all conservation measures;

- there is likely to be a moderate to large increase in shorebird recovery with no 4WD access;
- seasonal fencing or permanent fencing with signage, is likely to result in a moderate increase in shorebird recovery, as is the prohibiting of dogs from proposed shorebird areas;
- education and awareness alone (without physical restrictions of fencing, prohibiting dogs or limiting 4WD access) are likely to lead to a small to moderate increase in the shorebird recovery; and,
- all measures that lead to an increase in the shorebird recovery program also result in an increase to habitat diversity and the recreational use value of the Willis Creek area.

Agricultural land management

Nutrient and suspended solid exports from banana plantations were identified as significant in a study completed by Jelliffe (1997b). These pollutant inputs have the potential to affect the trophic status of Willis Creek and therefore the health of the system. Stormwater runoff from the catchment, which includes runoff from agriculture, is presently the primary source of pollutants into Willis Creek since the cessation of treated wastewater discharge.

The agricultural land management options considered in the Willis Creek CLAM include inter-row groundcover, sediment control dams, covering of crops after clearing, road design, nutrient management and clearing methods.

Changes to agricultural land management have the following results:

- moderate to large decreases in the input of total nitrogen (TN), total phosphorus(TP) and total suspended solids (TSS) are likely under inter-row ground cover, covering of crops after clearing, road design, and nutrient management options;
- decreases in input water quality parameters are likely to have no affect to only a very small decrease in associated creek WQ parameters – however this may be indicative of the sensitivity of the output states defined within the model and requires further study;
- a small decrease in creek flushing is likely from inter-row ground cover and sediment control dams that limit or capture runoff / inflow to the creek – the reduced flushing may be a contributor to the relatively minimal impacts of the measures to the concentration of creek WQ parameters despite the decreases in the associated input loads.

Existing stormwater management

Industrial and residential areas have been identified as major sources of faecal coliforms and to lesser extent nutrients (Jeliffe 1997a,b). To improve present water quality in Willis Creek and reach community expectations for system health, the management issue of existing stormwater management was included. In addition to the 'no change' option, this scenario provides options for stormwater wetlands, drain restoration for treatment and rainwater tanks retrofitted to industrial and urban areas.

Changes to existing stormwater management have the following results:

- the overall impact of existing stormwater management scenario options for Willis Creek nodes is very small to small;
- creek flushing is likely to experience a small decrease under the scenarios of stormwater wetland and rainwater tanks, which in turn is likely to lead to a very small and small increase in the creek water quality parameters of TN and TSS respectively;
- the small increase in creek water quality TSS under the management options of stormwater wetlands and rainwater tanks is likely to lead to a very small decrease in the ability to meet Willis Creek Water Quality Objectives. However, this trend is negligible (only 2% shift in probability between the two output states of either slightly or greatly meeting the objectives) and overall there remains a 98% probability of meeting the Willis Creek WQ objectives under all three management options.

Note that the data and assumptions used for creek flushing in Willis Creek and the resulting impacts in water quality concentrations have not been reviewed, and the consultant Robert McKenzie has questioned the trends here as perhaps representative of the data quality and model sensitivity rather than system processes – further study / review of data is required to clarify / confirm these results.

Special release area

One of the primary objectives set by Coffs Harbour City Council for the Willis Creek CLAM tool is to assess the impacts upon the ICOLL from possible future development in the catchment such as development of the special release area. The scenario options explored for the special release area include stormwater wetland, rainwater tanks, grass swales and all of these measured combined.

Changes to stormwater management in the special release area have the following results:

- overall there was likely to be a small to moderate decrease of nutrients and sediments entering Willis Creek (input TN, TP and TSS);
- however, moderate decreases in input TP and TSS and a small decrease in input TN result in no change to creek water quality TN and TP and a very small decrease in the creek TSS
- financial costs have not been calculated in this model on the implementation of these WSUD technology options

Note that as per the results for Existing Stormwater Management, the consultant Robert McKenzie has queried whether the results in creek water quality parameters are representative of data quality or model sensitivity rather than system processes and so further study / review is required to clarify / confirm these trends.

These results do not necessarily indicate negligible impact where no impact is shown, only that the impact is not noticeable given the coarseness of output values in the CLAM model. A finer resolution of output states may allow any changes to be seen more clearly. If the output states reflect the level of sensitivity of these pollutants that is of concern to the community then this is indicative that the system may not respond significantly to these management options. Otherwise a finer resolution may be necessary to ensure this is the case.

Conclusions

Overall the results indicate that agricultural land management has the potential to reduce water quality inputs into Willis Creek, however the flushing dynamics of the creek need to be considered in trying to decrease concentrations of water quality parameters of concern in the creek. Similarly, stormwater treatment of existing or new release urban areas can decrease the input of some water quality parameters but the overall impact on concentrations is again relatively small. The insensitivity of the water quality concentrations in these CLAM results has been questioned by the consultant Robert McKenzie with suggestion that the impact of creek flushing in the CLAM be re-examined and further review be required to clarify or confirm any trends.

Shorebird protection is most likely to be increased by combining all protection measures although 4WD, prohibiting dogs and seasonal or permanent fencing with signage each have potential for a moderate to large benefits for the program individually.

While improvements or impacts are often small they may still be significant and should be considered carefully. Where no impact is shown users should carefully consider whether or not the level of aggregation in the state variables (i.e. the states used to describe outputs) is appropriately detailed.

1 INTRODUCTION

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

- document the quality of data used in the Willis 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. The development of a CLAM tool involves a high level of community consultation and delivers 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.* (2006a, 2006b) and Ticehurst *et al.* (2006, 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 State 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 Willis Creek CLAM has been developed as part 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 to four key scenarios and their impacts, as recommended at the Willis Creek CLAM workshop with the Coffs Harbour City 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 Willis 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 Willis 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 Willis Creek CLAM.

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

2.1 Overview

An in-depth study of social values associated with Willis Creek catchment and estuary was completed by Glen Ewers in 2006. The resulting thesis *Baseline Community Values and Subsequent Management Options of an Intermittently Closed Estuary in New South Wales,* has informed many components of the Willis Creek CLAM. The following excerpts are from Ewers (2006: 55):

> “Willis Creek is a freshwater-dominated intermittently closed estuary located within the Coffs Harbour Local Government Area (LGA) on the New South Wales mid-north coast, Australia.”
>
> “Willis Creek is a small, easterly flowing estuary, with its headwaters in the eastern slopes of the coastal range and its mouth adjacent to Flat Top Rock (Jelliffe 1997b). The lower 1.4km of Willis Creek widens to a lagoon the depth of which is controlled by the variable level of the sand bar at the mouth. The

lagoon is shallow, rarely exceeding 1.0m in depth. An area of wetland protected under the NSW State Environment Planning Policy 14 (SEPP 14) is bisected by the Willis Creek lagoon. Water table levels within this wetland are controlled by creek levels via rainfall runoff and groundwater flows from the catchment (Jelliffe 1997b)."

The creek and its catchment are shown in figure 2.

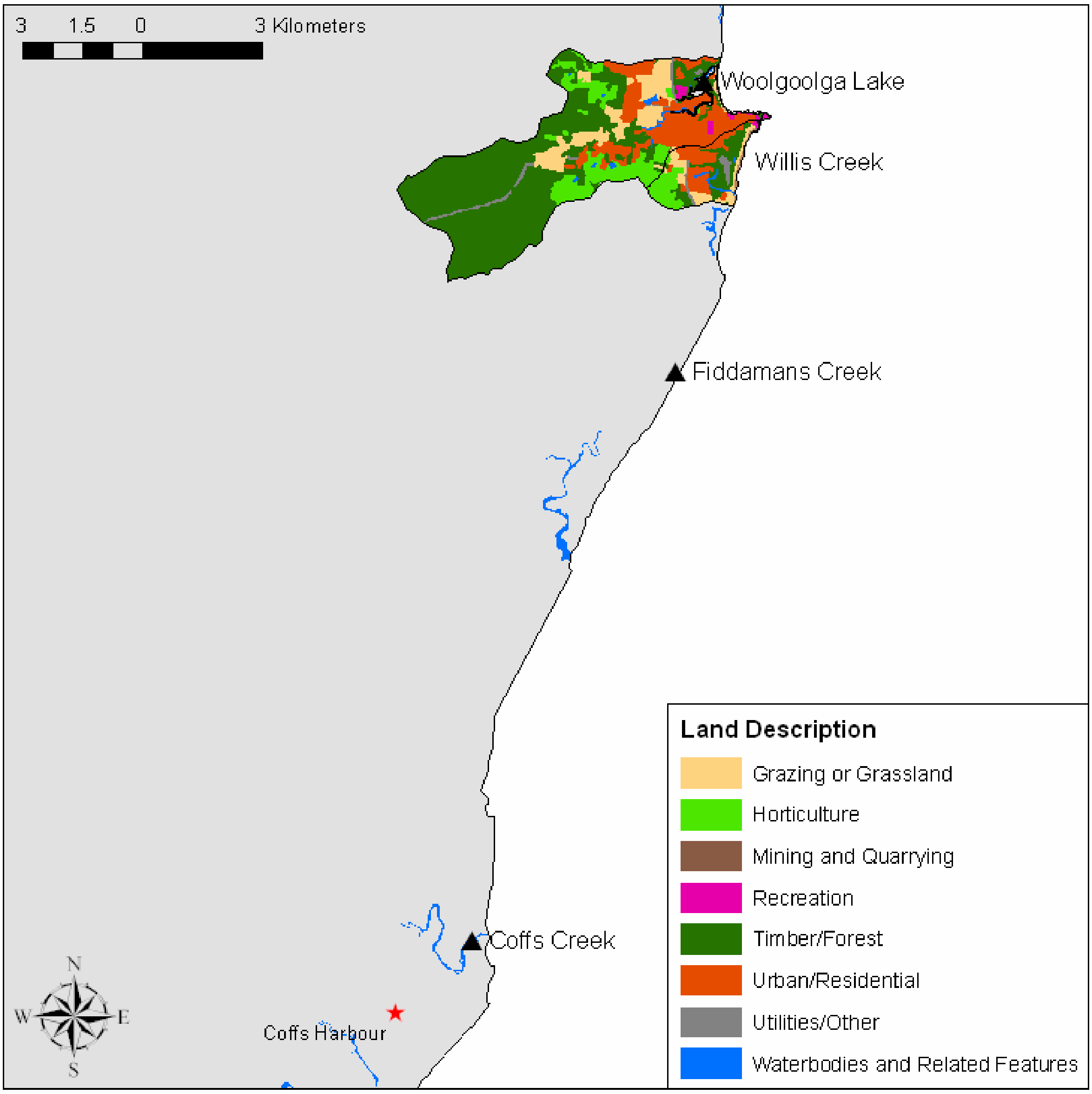

Figure 2. Willis creek and its catchment

2.2 Sewerage Treatment and Water Quality

The following excerpts are from Ewers (2006: 55)

"From 1973 until early 2005, the Woolgoolga Water Reclamation Plant (WRP) released secondary treated effluent into Willis Creek via a single outfall (CHCC 2006a; Yeates 1982). The outfall was closed in early 2005 as part of the Coffs Harbour LGA sewage upgrade strategy (CHCC 2005a). In the years before the cessation of sewage discharge, Jelliffe (1997b) records the entrance staying open for most of the time due to effluent discharge during low or baseflow periods, and stormwater and catchment runoff during periods of wet weather."

"Changes in the local estuarine ecology are almost certain to have occurred in and around Willis Creek with the introduction of the sewage outfall. The recent outfall closure is likely to have sparked further change in the absence of such a prolonged period of organic loading and modified flow. Inspection of the creek by numerous studies (Hacking, 1997; Jelliffe, 1997b; Smith, et al. 1997; Smith and Simpson, 1991a; Smith and Simpson, 1991b) found the creek to be clearly nutrient enriched to the point of eutrophication. Also reported was that the creek exhibits numerous signs of nutrient overload, including fish kills during periods of high temperature and noticeable algal blooms."

2.3 Catchment Land Use

"Catchment land-use is dominated by banana cultivation and forest in the upper catchment, residential and industrial development within the middle of the catchment, and natural SEPP 14 wetland, coastal heath and open forest in the lower catchment" (Ewers 2006:55).

In addition, the recently released Coffs Harbour LGA sewage upgrade strategy (CHCC 2005a) has identified the area under banana plantations to be investigated for urban release/industrial area and a highway upgrade is planned for the area. Each of these present and future catchment uses has specific impacts upon Willis Creek, in particular the industrial, possible future residential/industrial and agricultural development.

Table 1. Approximate areas and relative proportions for land use in the Willis Creek catchment.

Category	Area (ha)	Percentage area
Total catchment area	280.36	100
SEPP 14 wetland	12.3	4.4
SEPP 26 littoral rainforest	0.11	0.08
Coffs Harbour Regional Park	51.23	18.3
Residential areas (Zoned 2a)	51.43	18.3
Bosworth Industrial Estate	33.96	12.1
Agriculture – Banana plantations and blueberries	117.16	41.8
Residential Tourist Zone (Zoned 2e)	14.17	5.02

2.4 Community usage and values

"Swimming or primary contact [in Willis Creek] is prohibited by Council, which deters use [by community and landholders] for other activities. During storm events any public contact is not recommended, however the creek is generally suitable for secondary contact recreation during baseflow conditions (Jelliffe, 1997b). Public access to Willis Creek is possible either via a car park situated adjacent to the estuary mouth or the beach." (Ewers 2006:55).

A community survey undertaken by Ewers (2006) indicated that the local community has a positive attitude toward Willis Creek, with natural, wilderness and aesthetic values regarded as being of particular importance. Public concern was expressed regarding continued degradation of the estuary and its aesthetic value and the threat of increased catchment development. The study concluded that the focus of management should reflect these results.

3 WILLIS CREEK CLAM

3.1 Conceptual framework

The Willis 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 recreational use value is dependant on water quality parameters and habitat diversity. These in turn depend on actions such as implementing stormwater management or terrestrial weed management. Definitions for all nodes in this conceptual framework are given in Appendix 1.

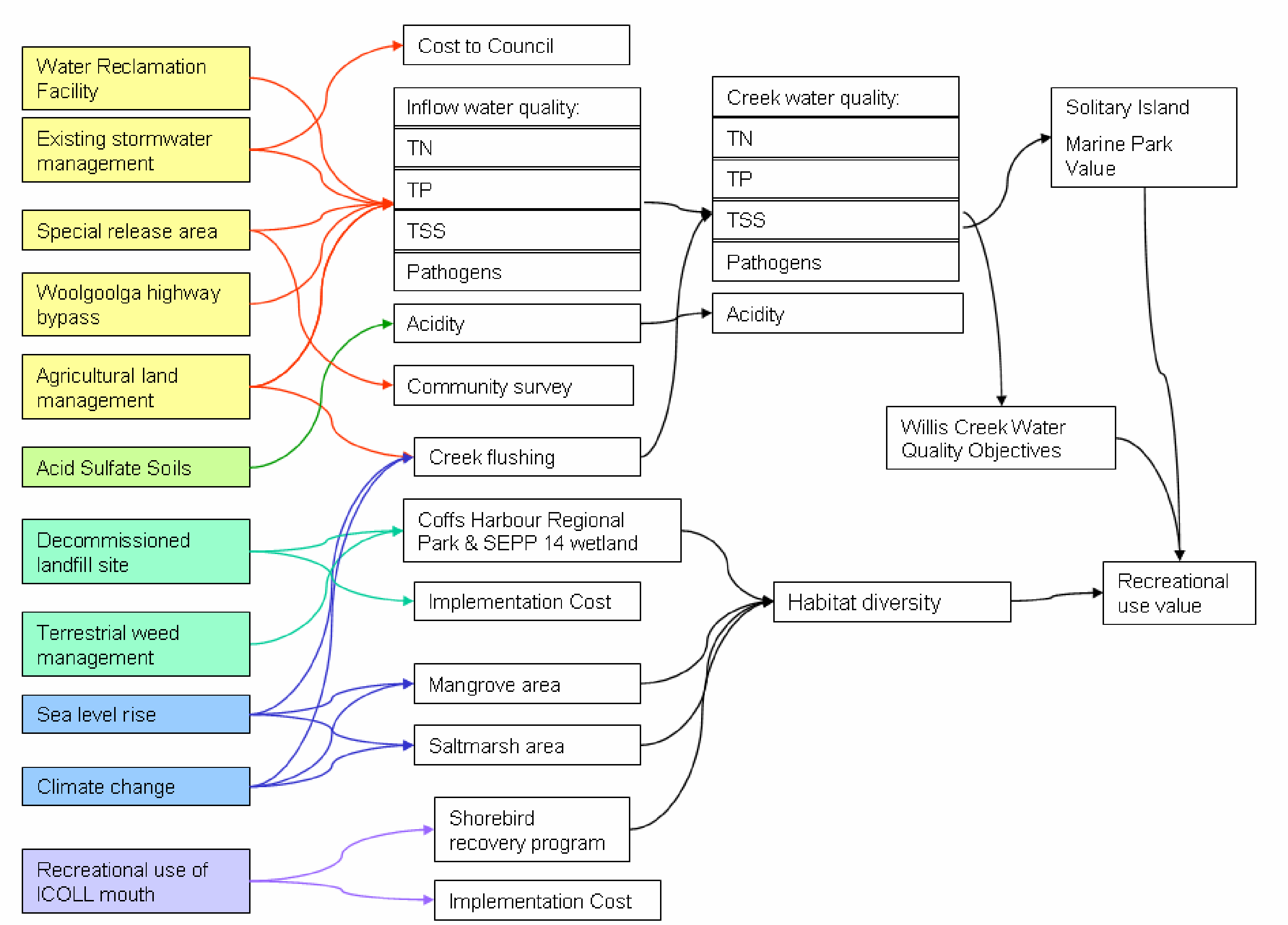

Figure 3. Willis Creek conceptual framework used to underpin the Willis Creek CLAM. Arrows show dependency between nodes. Shaded boxes represent scenarios which are actions, such as agricultural land management, or potential future drivers of the system, such as sea level rise

3.2 Consultation undertaken to develop the Willis Creek CLAM

The framework and scenarios contained in the Willis Creek CLAM were developed in consultation with various stakeholder groups. The conceptual framework, scenarios, scenario options and state variables for Willis Creek have been based on discussions with Martin Rose and Daniel Rodger from the Coffs Harbour City Council.

A consultation process with stakeholders, government agencies, experts and Coffs Harbour City Council was undertaken for the Willis Creek CLAM.

During January and February of 2007, Robert Mckenzie from EcoWater Solutions held individual meetings and telecommunications with catchment stakeholders, government department, industry groups and experts.

Government agencies, groups and experts consulted were: Stephen Smith and Annette Harrison (National Marine Science Centre); Nicky Singh (Banana Grower Representative); Damian Lett, Tom Denman, and Paul Parramore (NSW NP&WS); David Greenhalgh (Solitary Islands Marine Parks Authority); Glen Ewers (Department of Environment and Water Resources); Coasts and Estuary Advisory Group; Coffs Harbour City Council – Planning Department and City Services (Paul Shepherd, Martin Rose, Daniel Rodgers, Cherelle Brooke, and Sharon Smith); and, Peter Newley (NSW Department of Primary Industry).

Other individual stakeholders consulted were: Jaz Bunning; Dude Unwin; Geoff Unwin; Diana and Peter Davey; Russell Glover; Tony Glover; Richard Mylcreest; and, other local residents.

Key considerations for management identified by the stakeholders for inclusion in the Willis Creek CLAM are as follows:

- *Stormwater Management* – Stakeholders indicated concern over impacts of certain operations within the Bosworth Road Industrial Estate. These include car-wreckers, sawmill, waste transfer station, and overall stormwater runoff from the estate. At present the industrial estate has no stormwater management controls or significant vegetated buffer zones adjacent to Willis Creek. It was suggested that vegetated buffer zones and wetlands be incorporated into improvement works to minimise impact on Willis Creek. In addition, concerns were raised of existing stormwater quality from the existing urban areas and the proposed future highway bypass. These have been included in the Willis Creek CLAM.

- *Agricultural Land Management* – It was mentioned that the Department of Primary Industries estimate that each acre of banana plantation (under traditional management) would result in a 10 tonnes of sediment export per year. However, a previous banana plantation landholder in the area suggested that remaining topsoil at present was almost non existent due to the loss of this topsoil in the past. Erosion control and Water Sensitive Design for any future development on this land is recommended to be part of the CLAM framework.

  Banana plantations are considered to be less viable than in the past due to low prices based on competition from Queensland. A number of growers have been growing blueberries instead on the flat land with higher profit margins.

- *Coffs Harbour Regional Park* – Tom Denman and Damian Let from NSW NP&WS provided information on the weed management site plan, description of the Ecologically Endangered Communities located in the Regional Park and assisting in the development of the Willis Creek CLAM.

  During consultation several landholders expressed concern with the possible impacts of the decommissioned landfill site adjacent to the Woolgoolga Water Reclamation Facility. It is noted that adjacent to the landfill site is an area of trees that appear to be suffering from dieback. A NSW NP&WS field officer relates this dieback to exposure to the SE winds and salt spray as a result of the loss of foredune canopy, and therefore loss of protection against adverse climatic conditions. Inspection of the area discovered reasonably healthy grassland.

Access and amenities were also mentioned by stakeholders as of interest. The CLAM consultant (Robert Mckenzie) has approached Coffs Harbour City Council in relation to this interest. Council commented that Willis Creek is not considered a priority area for developing amenities on the basis of perceived low usage rate for recreational purposes.

- *Water Reclamation Facility* – In the past, the Woolgoolga Water Reclamation Facility has had a major impact on the health of the Willis Creek ICOLL. Cessation of discharge occurred in March of 2005 with anecdotal evidence of improvement in water quality since 2005. The Coast and Estuary Advisory Group expressed an interest in modelling the past and future changes to the water quality in Willis Creek based on the cessation of discharge. Therefore, this decision variable has been included in the CLAM framework.

- *Special Investigation Area* – The Willis Creek CLAM was commissioned based on the possible future development area and the impact this may have on the ICOLL. Stormwater management of the area under investigation for development was considered important by stakeholders. With an interest in assessing a number of WSD technology to minimise and control the impact of stormwater runoff on Willis Creek. This has been included in the CLAM framework. A questionnaire/survey was completed as part of the Willis Creek CLAM to gain information on the communities' perception of future development, in particular, the special investigation area.

- *Recreational Use* – Unrestricted recreational use of the beach and its impacts on the biodiversity of shorebirds at the spit has been discussed with a number of stakeholders and government departments. Ewers (2006) found that recreational use of the creek was of less importance to the local community than its preservation for future generations and as habitat for wildlife. This has been included to determine the impacts and options available for recreational use of the Willis Creek mouth.

- *Protection of Cultural Heritage* - NSW NP&WS have completed a project whereby local aboriginal leaders provided information to NP&WS on significant sites to the aboriginal people. This project included the Willis Creek catchment. Previous reports and CLAM consultation has stated there are no significant sites in the catchment. The NP&WS will provide the results from this project in the near future. This will be compared with previous work and if sites have been identified then these will be included in the CLAM framework. For example, Ewers (2006) found that the local community expressed high value toward the cultural significance of Willis Creek. The information requested from NP&WS was not provided within the timeframe for the Willis Creek CLAM. It is suggested that this decision variable be included when the information is available.

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 Willis 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 (i.e. box in Figure 3). A statement of priority data collection needs for Willis Creek is then given. This statement was provided by Robert McKenzie who put together the data for the Willis Creek CLAM.

Table 2 provides a qualitative assessment of data quality for each node in the Willis Creek CLAM.

Table 2. Subjective assessment of the quality of data used in the Willis Creek CLAM

Node	Quality of Data	Reason	Suggested improvements
Coffs Harbour Regional Park and SEPP 14 wetland	Poor	Based on assumptions and iCAM combination model	Review from local and academic experts.
Community survey	Good	Based on small scale locally based survey – Note however that the node in the CLAM model is unpopulated. Data is only contained in input page	Follow-up survey to confirm and update CLAM and previous survey results (i.e. Ewers 2006, Hearns lake estuary management plan); additional data observations
Costs to council (stormwater)	Good	Derived from existing stormwater systems and report on life cycle costing	Further economic assessment and local data would strengthen this node
Creek flushing	Poor	Based on assumptions and iCAM combination model, and a simple calculation into days of Freshwater Replacement Time (FRT) for use in iCAM estuary water quality model	Review from local and academic hydrological experts, including calculation and correlation with days of FRT
Creek input acidity	Poor	Based on assumptions and iCAM combination model	Review from local and academic experts.
Creek input pathogens	Average	Based on simple uncalibrated model derived from other situations. Model run with local data	Expert review and more comprehensive local data collection, use of local data for calibration and implementation of the more comprehensive model.
Creek inputs TN	Average	Based on a simple uncalibrated iCAM water quality model. Local data were used to run this model	Expert and local review. Could be improved by more robust modelling tools using detailed local data.

Creek inputs TP	Average	Based on a simple uncalibrated iCAM water quality model. Local data were used to run this model	Expert and local review. Could be improved more robust modelling tools using detailed local data.
Creek inputs TSS	Average	Based on a simple uncalibrated iCAM water quality model. Local data were used to run this model	Expert and local review. Could be improved more robust modelling tools using detailed local data.
Creek water quality acidity	Poor	Based on assumptions and iCAM combination model	Review from local and academic experts.
Creek water quality pathogens	Average	Uses uncalibrated iCAM estuary water quality model with some local information on flushing dynamics	Review and local water data collection for scaling and calibration of model.
Creek water quality TN	Average	Uses uncalibrated iCAM estuary water quality model with some local information on flushing dynamics	Review and local water data collection for scaling and calibration of model.
Creek water quality TP	Average	Uses uncalibrated iCAM estuary water quality model with some local information on flushing dynamics	Review and local water data collection for scaling and calibration of model.
Creek water quality TSS	Average	Uses uncalibrated iCAM estuary water quality model with some local information on flushing dynamics	Review and local water data collection for scaling and calibration of model.
Habitat diversity	Poor	Based on assumptions and iCAM combination model using some local data and observations	Review from local and academic experts; clarification of definition of habitat diversity and possibly dividing node to aide clarification
Implementation costs (revegetating decommissioned landfill site)	Good	Estimated costs derived from local bush regeneration company including 20% contingency.	Review from local and academic experts
Mangrove area	Average	Based on assumptions and iCAM combination model using local observations	Review from local and academic experts.
Recreational use value	Average	Based on assumptions and iCAM combination model using local observations	Review from local and academic experts.

Saltmarsh area	Average	Based on assumptions and iCAM combination model using local observations	Review from local and academic experts.
Shorebird recovery program	Good	Based on assumptions and iCAM combination model using local observations and expert review	Further review from local and academic experts.
Solitary Islands Marine Park Water Quality Objectives – Flat Top Head	Average	Based on assumptions and iCAM combination model using established WQ guidelines	Review from local and academic experts.
Willis Creek Water Quality Objectives	Average	Based on assumptions and iCAM combination model using established WQ guidelines	Review from local and academic experts.

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 Robert McKenzie are:

- Water quality data – water quality data was collected for over a decade during discharge of treated wastewater into Willis Creek. The laboratory and staff resources are available at the adjacent Woolgoolga Water Reclamation Facility (WRF) but funding is required to continue this data collection. Further discussions with Coffs Harbour City Council are required to recommence this water quality sampling regime. This data would be highly valuable in identifying impacts from future changes in the catchment and the changes in water quality since the cessation of treated wastewater discharge from the WRF.
- Shorebird surveys - Advertise and undertake a community meeting to recruit volunteers from the local community to participate in shorebird surveys at the Willis Creek mouth and therefore initiate the first stage of the proposed shorebird recovery program for Willis Creek. Paul Parrimore has volunteered his time to train interested local community members in shorebird identification and assist in the development of a shorebird recovery program. In addition, NSW National Parks and Wildlife Service have indicated support and funding availability for the proposed shorebird recovery program at Willis Creek.
- Stormwater pollutant export – Further development of initial stormwater pollutant export values from the different land uses within the Willis Creek catchment (e.g. agriculture, industrial and urban) with data gathering of stormwater quality entering Willis Creek.
- Specific WSUD technologies in the existing stormwater management and Special Release Area scenarios have been included in the Willis Creek CLAM based on the catchment characteristics, treatment performance and practicality of application. Preliminary cost estimates have been provided for the existing stormwater management, however, these should be further refined if the relevant scenario options are developed further. In addition,

a MUSIC model should be completed to improve confidence limits of the Willis Creek CLAM results for the proposed WSUD technologies if application of the WSUD technologies is proposed.

4 SCENARIOS

In order to develop this Sustainability Assessment analysis a relatively small subgroup of scenarios were selected from the 2,116,800 available in the Willis Creek CLAM. It was decided to focus on the following scenarios:

- Recreational use of ICOLL mouth (for shorebird recovery);
- Agricultural land management;
- Existing stormwater management; and
- Special release area.

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 given below are taken from the CLAM tool and were composed by the consultant, Robert McKenzie. Other scenarios available in the CLAM tool are described in Appendix 2.

4.1 Recreational use of ICOLL mouth

An opportunity exists to undertake a shorebird recovery program at Willis Creek. Initial community consultation has been undertaken and two shorebird experts consulted. This scenario assesses the range of different conservation measure available for a shorebird recovery program.

In a study completed by Coffs Harbour City Council (2004a) the most preferred open space destination for the majority of people in the Coffs Harbour region was beaches, coastal parks, creeks and foreshores. The three most favoured recreational activities were walking, swimming and fishing. This corresponds with the main recreational use area of the Willis Creek catchment as the Willis Creek beach area. At present walking, dog walking, swimming, surfing, 4WD usage and fishing are the favoured activities.

4WD recreational use of beaches to the north and south of Willis Creek is allowed by Council with access provided at the Willis Creek mouth and Hearns Lake mouth. The following restriction is required by Coffs Harbour City Council for 4WD usage of this area. These are as follows:

- Vehicles using the designated beach must use only officially constructed beach access tracks when entering onto the beach.
- Vehicles are to drive below the high tide mark whenever possible and during high tide drive as close to the high tide mark as possible.
- Driving on vegetated dune areas is strictly prohibited.

The provision of the Willis Creek area is considered important by Council for the exercise and socialisation of animals as well as for recreational use by owners. Dogs in this area may be exercised, unrestrained, in leash free areas.

These activities impact on the use of the Willis Creek mouth area by shorebirds. Shorebirds flock to estuaries and sandpits to feed, rest and build up their energy reserves for the long flights back. Some, like the Little Terns, nested and reared their young. Smaller estuaries and coastal lakes such as Willis Creek are biodiversity hotspots for shorebirds. The Willis Creek mouth area was considered a valuable Little Tern breeding site prior to about 40-50 years ago. The site is also used by many other species of shorebirds such as red capped plovers and sooty oyster catchers.

This scenario assesses the opportunities to increase the potential of the site for shorebird habitat and diversity while balancing the recreational use values of the site.

The scenario choices are:

1. No change
2. Seasonal fencing with signage
3. Permanent fencing with signage
4. No 4WD access
5. Prohibit dogs from proposed shorebird area
6. Education and awareness
7. All of the above conservation measures combined

4.2 Agricultural land management

Nutrient and suspended solids export from banana plantations was identified as significant in a study completed by Jelliffe (1997b). These pollutant inputs have the potential to affect the trophic status of Willis Creek and therefore the health of the system. Stormwater runoff from the catchment, which includes runoff from agriculture, is presently the primary source of pollutants into Willis Creek since the cessation of treated wastewater discharge. To improve the water quality of Willis Creek to community expectations (Ewers, 2006) it is necessary to address stormwater pollutant inputs in the Willis Creek CLAM.

The following description incorporates direct quotes from the report entitled "the control of land degradation in banana plantations" (Lyons, 1993). This is based on the specialist knowledge illustrated in the report and applicability of this report to the specific site under assessment.

"High rates of soil erosion have been consistently observed within both new and established banana plantations. Reductions in yield attributable to soil erosion have been estimated at 20%. Soil erosion in banana plantations imposes many direct and indirect costs on both growers and the community. These costs include:

– Reduced production
– Increased fertiliser costs
– Increased road, drainage and water supply maintenance costs
– Reduction in land productivity below viable levels
– Sedimentation of downstream waterbodies
– Loss of soil nutrients and applied fertilisers from plantations to downstream waterbodies
– Damage to flora and faunal communities
– Water quality degradation downstream of plantations
– Increased risk of local flooding
– Reduced public amenity" (Lyons, 1993).

"Banana plantation establishment in the Coffs Harbour region in the 1930's traditionally involved land clearing from either native vegetation from June until December. Roads and drainage were constructed and ripping completed at this time. The ground surface remained bare, with bananas planted from October to November. This practise resulted in little or no groundcover protection of the soil surface until sufficient banana mulch had accumulated, approximately eighteen months after bananas were planted. This period typically resulted in a very high level of soil loss, depending on rainfall conditions. Mulch build-up then reduced soil loss to levels comparable to long established plantations" (Lyons, 1993).

"The Plant Diseases Act, 1924, was amended in 1984 to allow ground covers to grow up to 30cm high under bananas. Prior to this time, ground covers were prohibited in banana plantations, to facilitate disease inspections and to maximise pest control" (Lyons, 1993).

"The legislative amendment on ground covers and the subsequent development of techniques for soil erosion control in bananas have resulted in the current recommendations on plantation establishment in the Coffs Harbour district. Land clearing is now recommended from June to August. A cover crop of Namoi woolly pod vetch and Saia oats, in addition to fertiliser, should be sown immediately after clearing. A cover crop provides temporary ground cover protection, in contrast to the permanent protection of a ground cover. The mulch produced by the cover crop will provide ground cover protection until banana mulch has accumulated" (Lyons, 1993).

In addition, ranges of methods were developed in 1993 by the NSW Soil Health Service, in conjunction with growers, to minimise soil erosion in banana plantations. These methods are provided in 'Controlling Soil Erosion in Banana Plantations: Growers Guide', (Hungerford *et. al.*, 1993). The Scenario Options included in the Willis Creek CLAM were sourced from this publication.

The agricultural land management options are:

1. No change
2. Inter-row groundcover
3. Sediment control dams
4. Cover crops after clearing
5. Road design
6. Nutrient management
7. Clearing method

Generation rates for total suspended solids were taken from an investigation project undertaken by Lyons, (1993) to quantify soil erosion from the steep banana plantations of the North Coast of New South Wales. Generation rates for Total Nitrogen and Total Phosphorus were taken from studies undertaken by Pont, (1998).

After-note: During an inspection (at the end of the CLAM project) of the banana plantations in the Willis Creek catchment with a representative from the NSW Department of Primary Industry and consultation with Geoff Unwin (local banana grower) it was realised that the application of the NSW Soil Conservation Service (1993) recommendations were not practical for the Willis Creek catchment to reduce pollutant loads. Based on this further information provided during final consultation it is recommended that a future update of the Willis Creek CLAM assess the advantages/disadvantages of engineered spoon drains at strategic positions within the banana plantations as recommended by Geoff Unwin.

Based on these observations and final consultation it is considered that the major pathway of pollutants from the agricultural land to Willis Creek is primarily from erosion of roads, creeks and gullies within this landuse area. The agricultural land would have historically been a considerable contributor to pollutant loads to Willis Creek. However, over recent decades management practices in the catchment most likely have reduced these pollutant loads. These management practices include the accumulation of a thick mulch ground cover and minimal fertiliser application. In addition, clearing of the banana plantations has not been undertaken for some time which has also reduced the potential for discharge of pollutants to Willis Creek.

4.3 Existing stormwater management

A study undertaken by Jelliffe (1997) identified the industrial and residential areas as major sources of pollutants. To improve present water quality in Willis Creek and reach community expectations for system health the management issue of existing stormwater management was included.

Clearing of land for development purposes can negatively change physical, chemical and biological processes in downstream aquatic ecosystems (Walsh *et. al.*, 2004). Agricultural, urban and industrial land development changes the natural hydrology of the catchment with the predominate pattern being increased surface runoff, reduced groundwater recharge and evapotranspiration. In addition, an increase in impervious area can create shorter and flashy stormwater runoff patterns. These changes increase the amount of pollutants that enter downstream aquatic ecosystems such as Willis Creek.

The degree of impact on downstream aquatic ecosystems from agricultural, urban and industrial landuses is dependent on a number of factors. These are as follows:

- Extent of the area developed,
- Quantity of stormwater runoff from drainage structures to the receiving waterbody, and
- Type of drainage systems conveying stormwater runoff to the downstream aquatic ecosystem (Walsh *et.al.*, 2004).

The conventional stormwater practise implemented in Willis Creek catchment ensures that all water draining off impervious surfaces is directly transported to the receiving waterbody. A study undertaken by Jelliffe (1997) stated "the quality of runoff from the Willis Creek catchment will need to be improved significantly in order to achieve the water quality objectives set for cessation of treated wastewater discharge to Willis Creek. The catchment contains industrial, urban and rural landuses. There are at present no specific stormwater quality management measures in place within the catchment with the exception of a small dam on one of the tributaries within Bosworth Road Industrial Estate. Industrial and residential lands are significant contributors to elevated pollutant levels during storm events, in particular faecal coliforms. In general, the study identified catchment management to be important to achieving the water quality objectives necessary to fulfil the potential beneficial uses for Willis Creek, as closure of the discharge."

The scenarios developed for the Willis Creek CLAM are:

1. No change
2. Stormwater wetlands
3. Drain restoration for treatment
4. Rainwater tanks retrofit to industrial and urban areas

Note: The *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2003), were used as a guide to select the above technologies for assessment within the Willis Creek CLAM.

4.4 Special release area

One of the primary objectives set by Coffs Harbour City Council for the Willis Creek CLAM tool is to assess the impacts upon the ICOLL from possible future development in the catchment such as development of the Special investigation area.

Willis Creek is located immediately south of Woolgoolga and adjoins the Woolgoolga Lake/Creek catchment. Part of the western portion of the Willis Creek catchment has been identified in Coffs Harbour City Councils Settlement Strategy (CHCC, 2006b) as a special investigation area.

Council has considered several options in relation to possible future land uses in the special investigation area nominated within the Willis Creek catchment, including residential/industrial uses. An industrial study has been undertaken during 2006/2007 to assist with that decision making process. Recent consultation with the Council planning department has indicated that this area is to be classified industrial land zoning in the future. Respondents to surveys by Ewers (2006) found that the increase in catchment development, loss of aesthetic and natural values and degradation of the estuary were of greatest concern to the local community.

Stormwater management practise has evolved from simple runoff using traditional storm drainage and 'end of pipe' approaches to comprehensive management approaches employing control measures, which are more ecologically sustainable solutions. The CLAM assesses a number of appropriate Water Sensitive Design technologies for possible future development of this land.

Scenario management options for the special release area are:

1. No change
2. Stormwater wetland
3. Rainwater tanks
4. Grass swales
5. All of the above WSUD technology combined

5 RESULTS FROM SCENARIO RUNS

5.1 Recreational use of ICOLL mouth

Seven options were considered in the recreational use of the ICOLL mouth scenario including the 'no change' 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 3. Impacts of recreational use of ICOLL mouth on likely state values for impacted nodes

	Seasonal fencing with signage	Permanent fencing with signage	No 4WD access	Prohibit dogs from proposed shorebird area	Education and awareness	All conservation measures combined
Habitat diversity	very small increase	very small increase	very small increase	very small increase	very small increase	very small increase
Recreation-al Use value	very small increase	very small increase	very small increase	very small increase	no change	very small increase
Shorebird recovery program	moderate increase	moderate increase	moderate to large increase	moderate increase	small to moderate increase	large increase

These scenarios had no impact on the following nodes: creek water quality TN; creek input TN; implementation costs – council; Willis Creek water quality objectives; Solitary Island Marine Park water quality objectives; creek input TP; creek water quality TP; creek input TSS; creek water quality TSS; creek input pathogens; creek water quality pathogens; creek input acidity; creek water quality acidity; Coffs Harbour Regional Park & SEPP14 wetland; creek flushing; mangrove area; community survey; saltmarsh area; and, implementation cost - landfill restoration.

The table shows:

- the largest benefits to the shorebird recovery program are likely to occur with implementation of all conservation measures;

- there is likely to be a moderate to large increase in shorebird recovery program with no 4WD access;
- seasonal fencing or permanent fencing with signage, is likely to result in a moderate increase in shorebird recovery, as is the prohibiting of dogs from proposed shorebird areas;
- education and awareness alone (without physical restrictions of fencing, prohibiting dogs or limiting 4WD access) are likely to lead to a small to moderate increase in the shorebird recovery; and,
- all measures that lead to an increase in the shorebird recovery program also result in a increase, albeit 'very small', to habitat diversity and recreational use value of the Willis Creek area.

The weightings of impacts on the shorebird recovery program were revised by the consultant Robert McKenzie after the end-user training workshop in May 2007. For further information on the weightings and reasoning used, please refer to the Input Page for Shorebird Recovery Program on the CD provided.

Note: The management options for Recreational Use at the ICOLL mouth (e.g., no dogs, no 4WD access) do not link directly into the variable 'Recreation Use Value'. In the CLAM, Recreational Use Value refers to the overall potential or value of Willis Creek for recreational use and is impacted by Habitat Diversity and how well Willis Creek and Solitary Island Marine Park water quality objectives are met. In this way, the removal of 4WD access leads to an improvement in the shorebird recovery program, and a very small increase in both habitat diversity and in recreational use value, despite 4WD being considered a recreational use of the beach. The emphasis on habitat and passive recreation correlates with Ewers (2006), who found 4WD activities to be of low value to the local community.

The impacts of recreational use on the shorebird recovery program are shown in more detail in Figure 4. This shows that the three options of prohibiting dogs from the proposed shorebird area, seasonal fencing with signage, and permanent fencing with signage are highly likely to result in a moderate increase in a shorebird recovery program. It is also highly likely that there will be a moderate to large increase in shorebird recovery if there is no 4WD access to the beach, but only a slight to moderate increase if education and awareness programs alone are implemented. Implementing all conservation measures in combination is highly likely to result in a large increase in shorebird recovery.

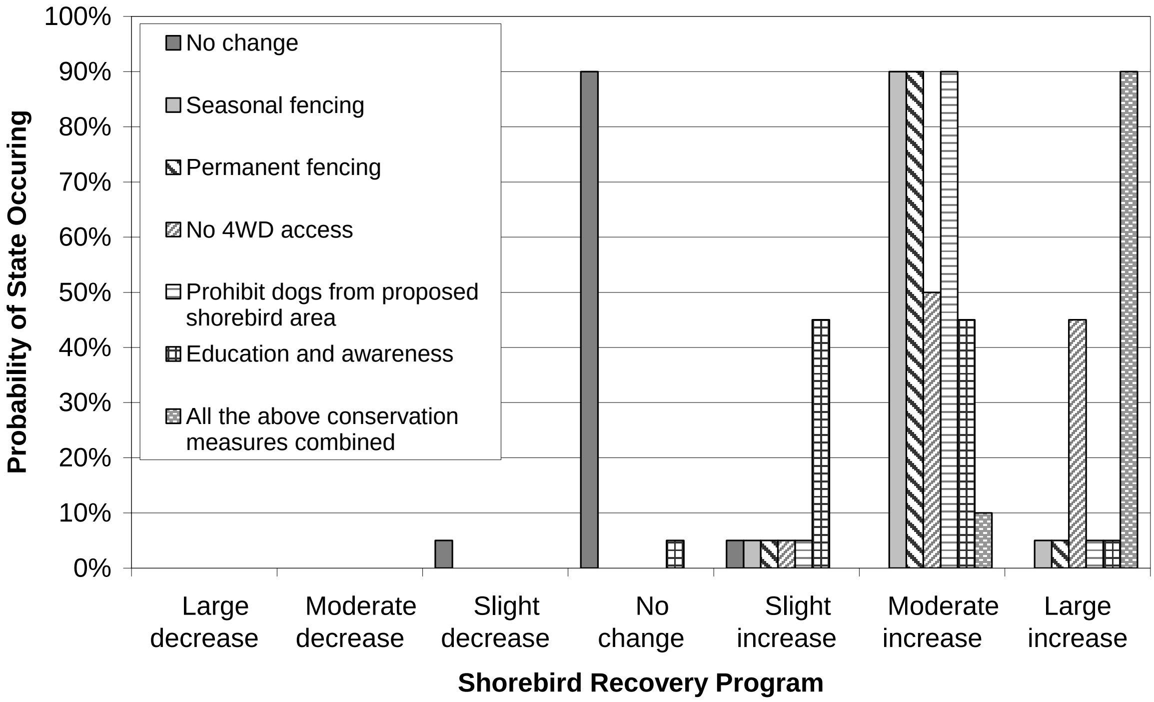

Figure 4. Probability of different states of shorebird recovery program under recreational use of ICOLL scenarios

The likely increase in shorebird recovery program has minimal impact on the overall change in habitat diversity as shown in figure 5. Note in figure 5, that under the ‘no change’ scenario for recreation use of the ICOLL mouth, there is an existing trend for a slight decrease in habitat diversity. This underlying trend for habitat diversity is not significantly altered by introducing any of the limits to the recreation use of the ICOLL mouth.

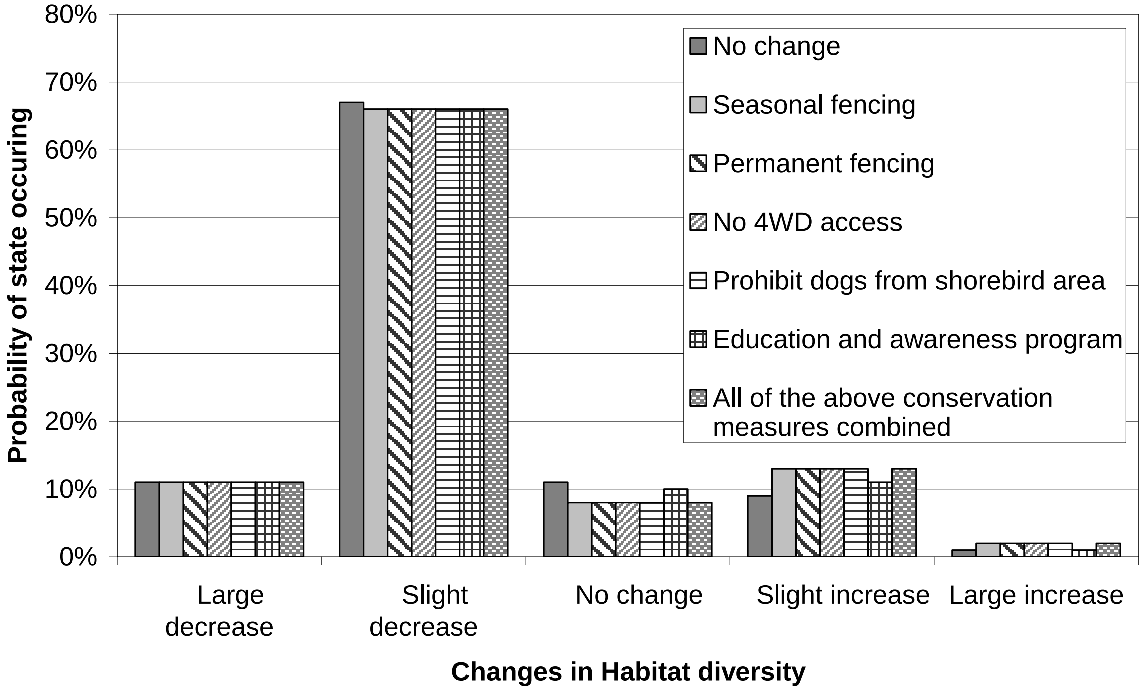

Figure 5. Probability of different levels of change in habitat diversity as a result of recreational use of ICOLL scenario options.

5.2 Agricultural land management

Seven agricultural land management options were considered including the ‘no change’ option. Table 4 provides a summary of the impacts of agricultural land management on impacted nodes. 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 4. Impacts of agricultural land management on likely state values for impacted nodes

	Inter-row Ground cover	Sediment control dams	Cover crops after clearing	Road design	Nutrient Management	Clearing method - injection
Creek flushing	small decrease	small decrease	no change	no change	no change	no change
Creek input pathogens	no change	no change	very small decrease	no change	no change	no change
Creek input TN	large decrease	small decrease	large decrease	moderate decrease	large decrease	small decrease
Creek input TP	large decrease	no change	moderate decrease	moderate decrease	large decrease	small decrease
Creek input TSS	large decrease	moderate decrease	large decrease	moderate decrease	no change	small decrease
Creek water quality pathogens	no change	no change	very small decrease	no change	no change	no change
Creek water quality TSS	no change	very small increase	very small decrease	very small decrease	no change	very small decrease
Willis Creek water quality objectives	no change	no change	very small increase	no change	no change	very small increase

Overall the agricultural land management options had no impact on 14 nodes: creek water quality TN; creek water quality TP; mangrove area; community survey; saltmarsh area; implementation cost - landfill restoration; implementation costs – council; creek input acidity; creek water quality acidity; Coffs Harbour Regional Park & SEPP14 wetland; recreational use value, Solitary Island Marine Park water quality objectives; habitat diversity; and shorebird recovery program.

The table shows:

- Moderate to large decreases in the input of total nitrogen (TN), total phosphorus(TP) and total suspended solids (TSS) are likely under inter-row ground cover, covering of crops after clearing, road design, and nutrient management options;
- Decreases in input water quality parameters are likely to have no affect to only a very small decrease in associated creek WQ parameters – however this may be indicative of thresholds used in the output states, rather than of system processes (see discussion regarding TN);
- a small decrease in creek flushing is likely from inter-row ground cover and sediment control dams that limit or capture runoff / inflow to the creek – the reduced flushing may be a contributor to the relatively minimal impacts of the measures to the concentration of creek WQ parameters despite the large decrease in the associated input loads.

Figure 6 shows the impacts of agricultural land management on the input of total nitrogen (TN) to the creek. Large decreases in the input of total nitrogen to the creek are most likely with nutrient management, inter-row ground covers and cover crops after clearing. Road design can also result in a moderate decrease while sediment control dams and clearing method – injection are only likely to result in a small decrease in total nitrogen input to the creek.

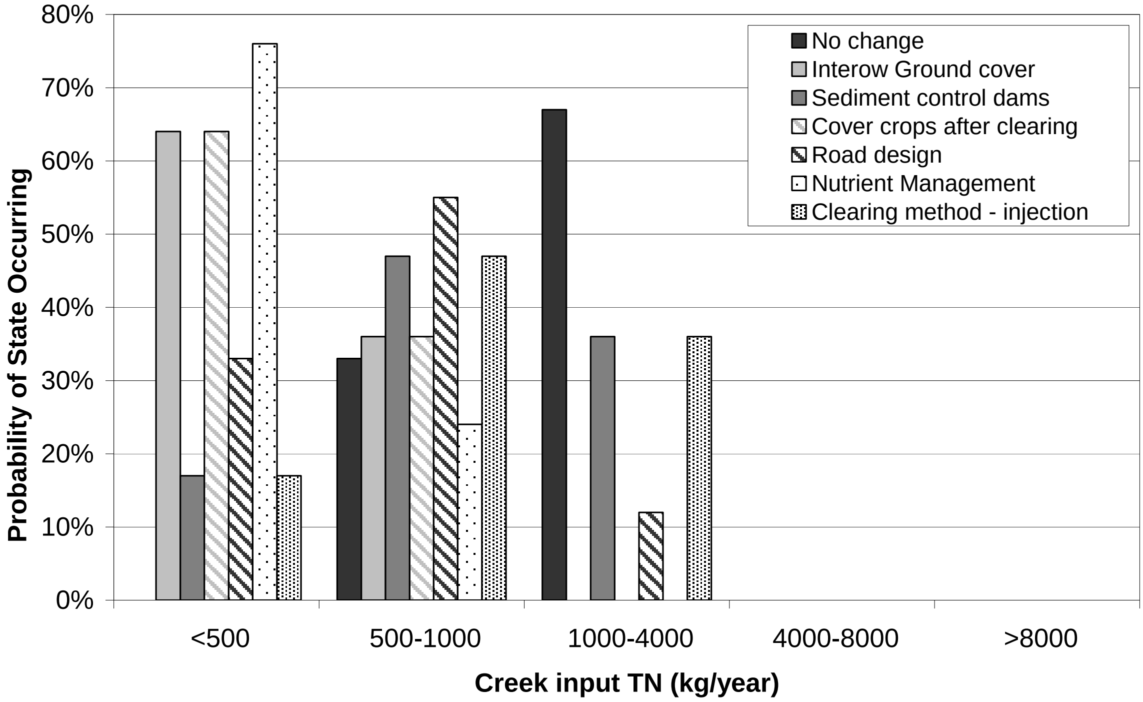

Figure 6. Probability of different levels of creek input total nitrogen in kg/year under agricultural land management scenarios

Interestingly, the large decreases likely in the input to the creek of TP, TN and TSS are only likely to result in very small changes, if any, to creek WQ. This could be explained by the small size of the Willis Creek catchment and its relatively short freshwater replacement time (see Creek Flushing on the Input Page CD for Willis Creek), meaning input loads are dissipated quickly as concentrations for creek water quality parameters. Alternatively, this may simply be indicative of inadequate threshold values used for creek WQ parameters that make the model insensitive to any subtle changes. In the case of creek water quality TN, the 'no change' scenario sees close to 100% probability that concentration level rests in the lowest output state of less than or equal to 250 g/m^3. Any agricultural management options that lead to a decrease in concentration of TN in Willis Creek relative to the 'no change' or 'base case' cannot be detected in this set-up.

Figure 7 shows the impact of agricultural land management on the input of total suspended solids (TSS) to the creek. Inter-row ground covers and covering crops after clearing are both likely to lead to large decreases in input TSS. However, the resulting concentration of creek water quality TSS differs for the two agricultural management options: no change in creek TSS with inter-row ground covers, and a very small decrease in creek TSS with covering crops after clearing. This disparity is generated by the likely slight decrease in creek flushing with implementation of inter-row ground covers (as shown in figure 8). The slight decrease in creek flushing equates to longer residence time, and so a decrease in input TSS that would normally lead to a small decrease in water quality TSS instead sees no change in water quality TSS due to the reduced flushing of the system and accumulation of TSS. [Note: the data used and anticipated impact of creek flushing on Willis Creek has not been reviewed by local experts and the consultant Robert McKenzie has questioned this result].

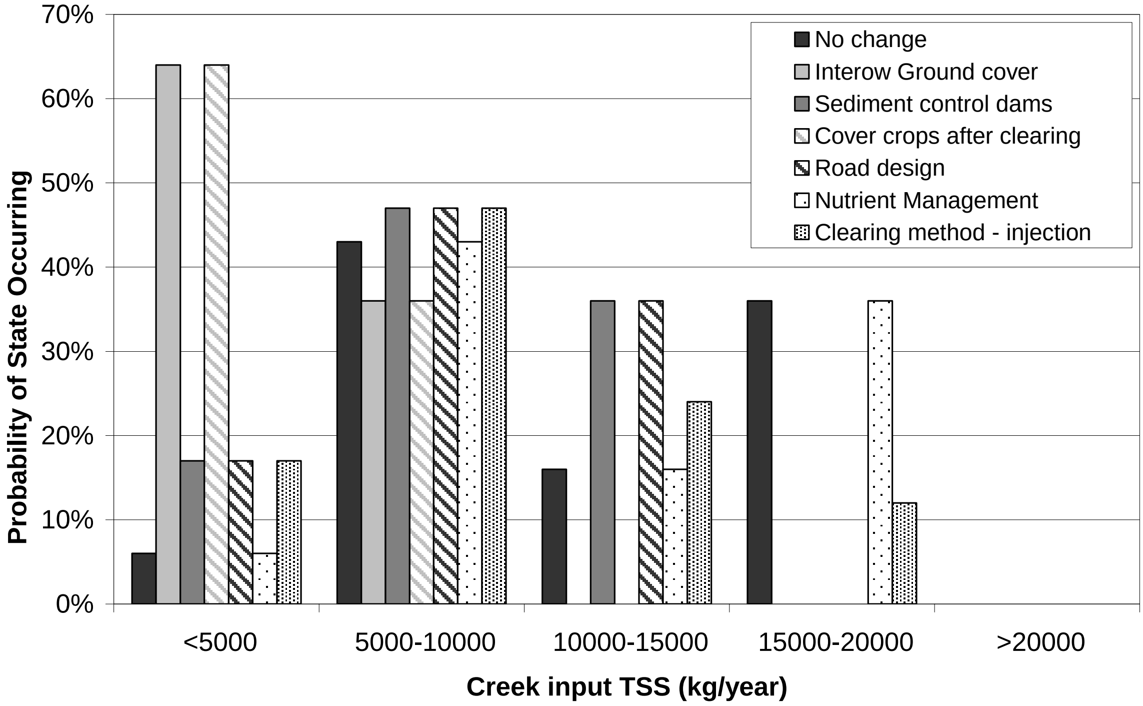

Figure 7. Probability of different levels of input total suspended solids to the creek under agricultural land management

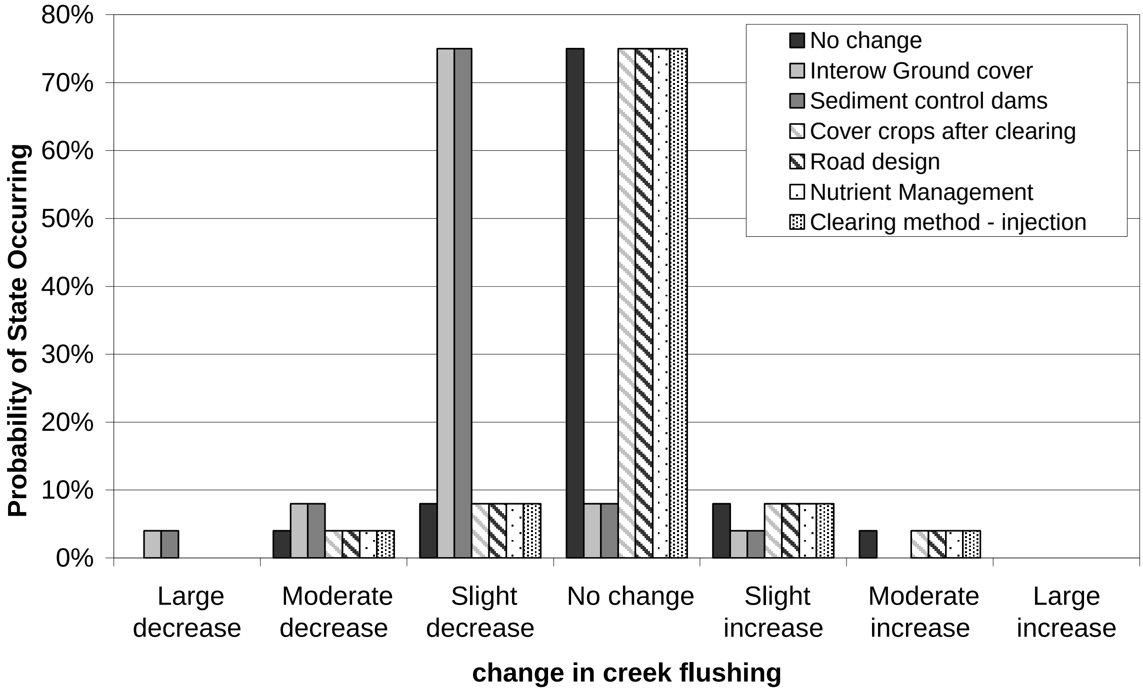

Figure 8. Probability of the change in creek flushing under agricultural land management scenarios

5.3 Existing stormwater management

Four options for existing stormwater management have been considered, including the 'no change' scenario. Table 5 provides a summary of the impacts of stormwater management on impacted nodes. 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 5. Impacts of existing stormwater management on likely state values for impacted nodes

	Stormwater Wetland	Drain restoration for treatment	Rainwater Tanks
Creek flushing	small decrease	no change	small decrease
Creek Input Pathogens	very small decrease	no change	very small decrease
Creek Input TN	no change	small decrease	no change
Creek Input TSS	no change	small decrease	no change
Creek Water Quality Pathogens	very small decrease	no change	very small decrease
Creek Water Quality TN	very small increase	no change	very small increase
Creek Water Quality TSS	small increase	very small decrease	small increase
Implementation costs - council	$260,000	$125,920	$235,000
Recreational use value	very small decrease	no change	very small decrease
Willis Creek WQ objectives	very small decrease	very small increase	very small decrease

These existing stormwater management options have no impact on the following nodes: creek input TP; creek water quality TP; creek input acidity; creek water quality acidity; Coffs Harbour Regional Park & SEPP14 wetland; habitat diversity; shorebird recovery program; mangrove area; community survey; saltmarsh area; implementation cost - landfill restoration; Solitary Island Marine Park water quality objectives.

These results show:

- the overall impact of existing stormwater management on Willis Creek nodes is very small to small. The consultant, Robert McKenzie, has questioned this trend as perhaps representative of data quality rather than system processes – further study / review of data is required to clarify / confirm these results;
- creek flushing is likely to experience a small decrease under the scenarios of stormwater wetland and rainwater tanks, which in turn is likely to lead to a very small and small increase in the creek water quality parameters of TN and TSS respectively. [Note that the data and assumptions used for creek flushing and the resulting impacts have not been reviewed, and the consultant Robert McKenzie has questioned this result];
- the small increase in creek water quality TSS under the management options of stormwater wetlands and rainwater tanks is likely to lead to a very small decrease in the Willis Creek WQ objectives. However, when viewed in the CLAM results, this trend is negligible (only 2% shift in probability between the two output states of either slightly or greatly meeting the objectives) and overall there remains a 98% probability of meeting the Willis Creek WQ objectives under all three management options;
- the largest impact is on creek water quality TSS, which is likely to have a small increase under the stormwater wetland and rainwater tank options with the associated decrease in

creek flushing, despite no change to the input TSS under these scenario options (see figures 10 and 11).

Figure 9 shows the impact of existing stormwater management on creek flushing in more detail. It is likely that stormwater wetland or rainwater tanks will result in a slight decrease in creek flushing. These options are unlikely to change the input of TSS to the creek, but drain restoration is likely to result in a small decrease of input TSS to the creek as shown in Figure 10.

Note that the data and assumptions used for populating the creek flushing node and the resulting impacts in the Willis Creek CLAM have not been reviewed, and the consultant Robert McKenzie has questioned the accuracy of the trends here as perhaps representative of the data quality and model sensitivity rather than system processes – further study / review of data is required to clarify / confirm these results.

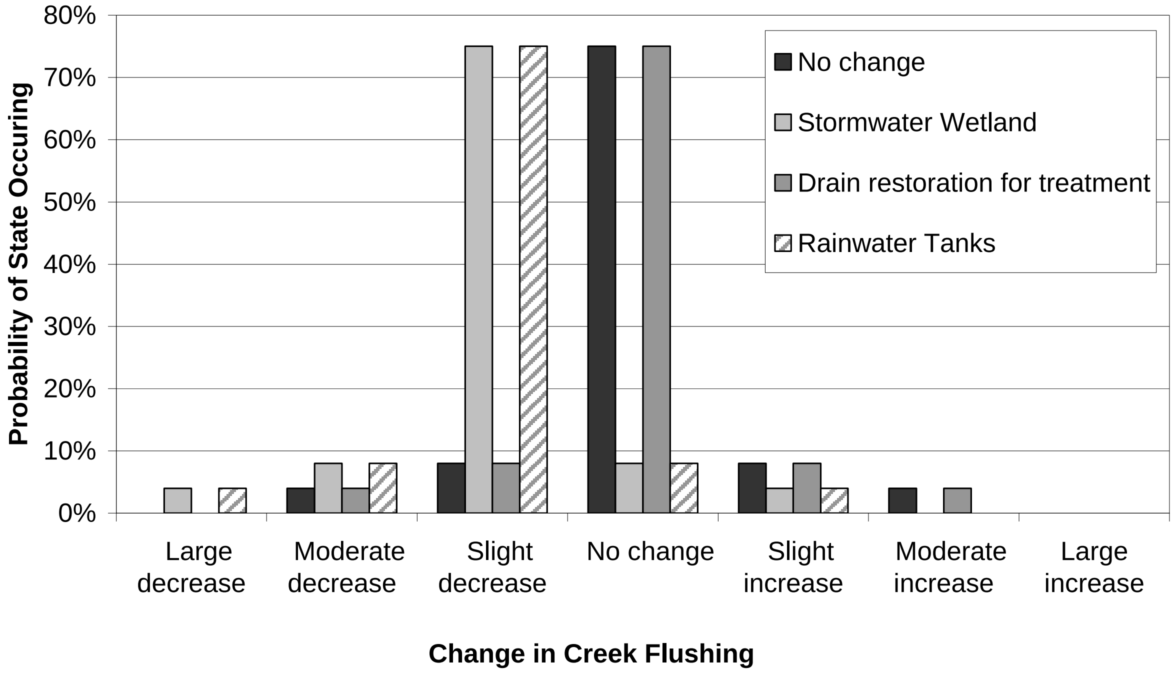

Figure 9. Probability of different levels of change in creek flushing under existing stormwater management scenarios

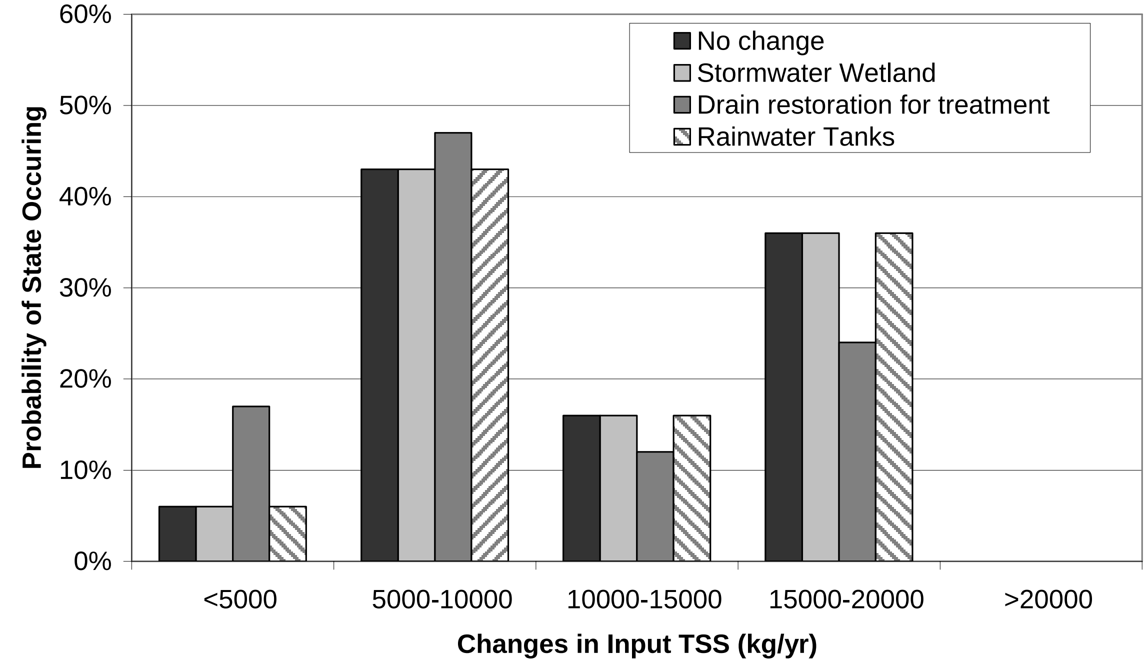

Figure 10. Probability of different levels of input of TSS to the creek under existing stormwater management scenarios

The combination of likely changes to creek flushing and to the input of TSS to the creek results in a range of impacts from a very small decrease to a small increase in creek water quality TSS as shown in Figure 11.

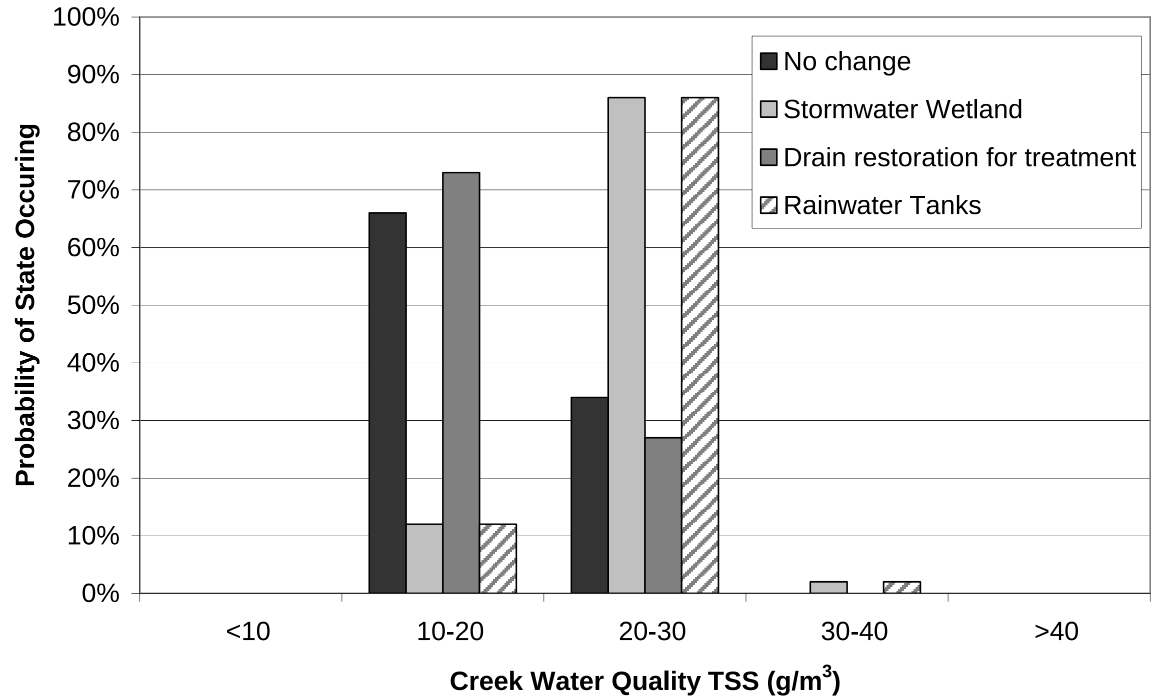

Figure 11. Probability of different levels of creek water quantity TSS under existing stormwater management scenarios

5.4 Special release area

Five options were considered in the special release area including the 'no change' option. Table 6 provides a summary of impacts of special release area options on impacted nodes. 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 6. Impacts of special release area options on likely state values for impacted nodes

	Stormwater wetland	Rainwater tanks	Grass swales	All of the above WSD technology combined
Creek Input TN	small decrease	small decrease	small decrease	small decrease
Creek Input TP	moderate decrease	moderate decrease	moderate decrease	moderate decrease
Creek Input TSS	moderate decrease	moderate decrease	moderate decrease	moderate decrease
Creek Water Quality TN	no change	no change	no change	no change
Creek Water Quality TP	no change	no change	no change	no change
Creek Water Quality TSS	very small decrease	very small decrease	very small decrease	very small decrease

Overall the following nodes experienced no impact: creek flushing; creek water quality TN; creek water quality TP; creek input pathogens; creek water quality pathogens; creek input acidity; creek water quality acidity; implementation costs – stormwater; implementation cost - landfill restoration; Willis Creek water quality objectives; Solitary Islands Marine Park water quality objectives; Coffs Harbour Regional Park & SEPP14 wetland; habitat diversity; shorebird recovery program; mangrove area; saltmarsh area; recreational use value; and community survey.

The table shows:

- overall there was likely to be a small to moderate decrease of nutrients and sediments to Willis Creek (input TN, TP and TSS);
- moderate decreases in creek input TP and TSS and a small decrease in creek input TN result in no change to creek water quality TN and TP and a very small decrease in the creek water quality TSS – as per the results for Existing Stormwater Management, the consultant Robert McKenzie has queried whether this result is representative of data quality or sensitivity of output states, rather than system processes and further study / review is required to clarify / confirm these trends;
- financial costs have not been calculated in this model on the implementation of these WSUD technology options.

Note: there appears to be no benefit to combining the technologies over any single option. This is result may be due to the sensitivity of the model itself and warrants further investigation.

In the case of creek water quality TN, the lack of any change in concentrations despite reduced loads entering Willis Creek, could well be indicative of the output states selected and in particular that the 'no change' scenario sees 100% probability in the lowest range output state of <250 g / m^3. This means that any reduction in concentration would not be recognised. A revision of the CLAM should consider amendment of these output states such that both decreases and increases in concentration can be recognised.

The impacts of special release area options on the input of TSS to the creek are shown in Figure 12. From the Willis Creek CLAM outputs it appears that any of the options are equally likely to reduce TSS input to the creek. This is difficult to interpret given that that the combination of technologies does not appear to provide any additional reduction in TSS input as compared to any of the individual technologies. Further review of this scenario and node is warranted before the results are used.

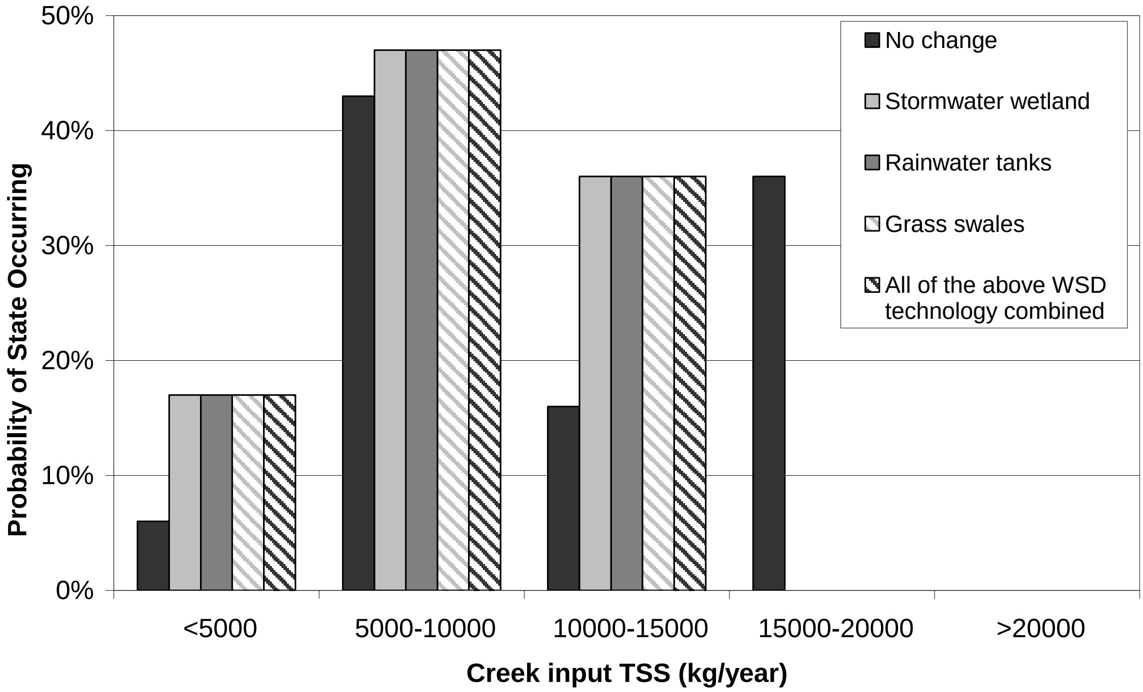

Figure 12. Probability of different levels of creek input TSS under special release scenarios

6 DISCUSSION OF THE RESULTS

This sustainability assessment report has provided a sample of results for management of recreational use of the ICOLL, agricultural land management, existing stormwater management and special release areas. These options are a small subset of the total number of scenarios which can be considered by the Willis 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 that for recreational use of the ICOLL:

- the largest benefits to the shorebird recovery program are likely to occur with implementation of all conservation measures;
- there is likely to be a moderate to large increase in shorebird recovery program with no 4WD access;
- seasonal fencing or permanent fencing with signage, is likely to result in a moderate increase in shorebird recovery, as is the prohibiting of dogs from proposed shorebird areas;
- education and awareness alone (without physical restrictions of fencing, prohibiting dogs or limiting 4WD access) are likely to lead to a small to moderate increase in the shorebird recovery; and,
- all measures that lead to an increase in the shorebird recovery program also result in a increase, albeit 'very small', to habitat diversity and recreational use value of the Willis Creek area.

Within the agricultural management options, inter-row ground cover, the covering of crops after clearing and nutrient management options are likely to result in moderate to large decreases in the input of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) to the creek. However, creek water quality parameters are only likely to experience a small decrease or even experience a small increase in the level of TN, TP, TSS. This disparity between reduced loads from the catchment and increased concentrations within the creek may be due to the existing creek flushing regime, and impacts of some of the agricultural land management options in reducing creek flushing thereby increasing residence time. It should be noted that the creek flushing data used and the resulting anticipated impact of creek flushing on Willis Creek water quality parameters has not been reviewed by local experts and the consultant Robert McKenzie has questioned the trends and identified this as a significant knowledge gap. Further study or review is required, and until this time, usage of the water quality concentration results in decision-support should be cautioned.

Changes to existing stormwater management have a small overall impact on Willis Creek, the greatest impact was on creek flushing and creek water quality TSS which are likely to decrease and increase respectively under the stormwater wetland or rainwater tanks options (see discussion above re creek flushing and water quality concentrations). In the special release areas there is likely to be very small to moderate decreases in some input and creek water quality nodes. However, there appears to be no benefit in combining the technologies over any single option. This is may be due to the sensitivity of the model itself and warrants further investigation.

These results regarding the water quality of Willis Creek do not necessarily indicate negligible impact where no impact is shown, only that the impact is not noticeable given the coarseness of output values in the CLAM model (e.g., creek water quality TN, where the 'no change' scenario sees the highest probability already in the lowest output state such that any decrease in TN does not show a change the output table). A finer resolution of output states may allow any changes to be seen more clearly. If the output states reflect the level of sensitivity of these pollutants that is of concern to the community then this is indicative that the system may not respond significantly to these management options. Otherwise a finer resolution may be necessary to ensure this is the case.

Similarly, future community consultation should test output states to quantify changes in community expectations and values from previous surveys (Ewers 2006) and make them available for better informed management of the Willis Creek catchment.

When using this CLAM, decision-makers should assess the quality of the data used in the CLAM as documented in the input pages for each variable, and from this determine their level of confidence. In some cases, the CLAM can be an indicator of where future investment / research is required to fill knowledge gaps and build confidence in decision making.

Overall the agricultural, stormwater and special release area scenarios evaluated in this report, as recommended by a workshop held at Coffs Harbour City Council in May 2007, had only a small impact on creek water quality parameters. However, options for recreational use of the ICOLL can increase shorebird protection and is likely to have a small flow-on benefit to habitat diversity in the Willis Creek area.

7 ACKNOWLEDGEMENTS

This project has been funded by the Northern Rivers Catchment Management Authority. The authors would particularly like to acknowledge the efforts of Roger Stanley of the Northern Rivers CMA who has managed the project and provided considerable time and knowledge to this work. In addition the time and efforts of the project Reference Group need to be acknowledged. This group consisted of John Schmidt, Department of Natural Resources, Brian Hughes of Coastcare (initially), David Greenhalgh of the Solitary Islands Marine Park Authority, Marcus Riches of the Department of Primary Industries and Steve Jensen of the Department for Planning. Finally this CLAM and subsequent results would not have been possible without the efforts Coffs Harbour City Council.

We would also like to acknowledge all stakeholders who provided the consultant, Robert McKenzie, with input and feedback on the CLAM scenarios, framework and data (see Section 3.2). In particular thanks are given to Glen Ewers, Russell Glover, Geoff Unwin and Peter Newley for all their assistance.

The CLAM model presented in this report has been developed by the consultant Robert McKenzie and the text describing the catchment and scenarios are authored by Robert McKenzie.

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

Node	Description	Output States	Units
Coffs Harbour Regional Park and SEPP14 wetland	This node assesses the increase or decrease in ecosystem biodiversity based on weed management within the Coffs Harbour Regional Park and SEPP14 wetland.	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Community survey	This node provides the results from the community survey undertaken as part of the Willis Creek CLAM.		
Creek Flushing	Flushing of the creek, which may be varied according to the frequency of breakouts of the entrance, and as such, is impacted by climate change, sea level rise, agricultural land management and existing stormwater management.	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Creek input acidity	Inputs of total acidity to Willis Creek	Large decrease, small decrease, no change, small increase, large increase	
Creek input pathogens	Delivery of pathogens to creek of faecal coliforms from runoff and direct delivery of manure to stream.	<14, 14-75, 75-150, 150-300, 300-500, 500-1000, 1000-2000, >2000	CFU/100 mL
Creek input TN	Inputs of total nitrogen to Willis Creek	<500, 5000-1000, 1000-4000, 4000-8000, >8000	kg/year
Creek inputs TP	Inputs of total phosphorus to Willis Creek	<250, 250-500, 500-1000, 1000-2000, >2000	kg/year
Creek inputs TSS	Inputs of total suspended solids to Willis Creek	<5000, 5000-10 000, 10 000-15 000, 15 000-20 000, >20 000	kg/year
Creek water quality acidity	Changes to total acidity of Willis Creek based on ASS management in the catchment.	Large decrease, small decrease, no change, small increase, large increase	
Creek water quality pathogens	The concentration of faecal coliforms in Willis Creek	<14, 14-150, 150-1000, >1000	cfu/100mL
Creek water quality TN	Total nitrogen in Willis Creek.	<250, 250-500, 500-750, 750-1000, >1000	µg/L
Creek water quality TP	Total phosphorus in Willis Creek.	<50, 50-100, 100-150, 150-200, >200	µg/L

Creek water quality TSS	Total Suspended Solids in Willis Creek	<10, 10-20, 20-30, 30-40, >40	g/m^3
Habitat diversity	A node to address considerable community concerns of changes in biodiversity and ecosystem health	Large decrease, small decrease, no change, small increase, large increase	
Implementation cost - landfill	This node estimates the costs of an environmental planting at the decommissioned landfill site.	No change, Landfill restoration - environmental planting	
Implementation costs – to council	This node estimates the costs of selected scenario options for existing stormwater management (stormwater wetland, drain restoration (industrial estate) and 100 rainwater tanks retrofitted to the existing residential area).	No change, Wetland - $260000, Drain restoration - $125920, Rainwater tanks - $235000	$
Mangrove area	This node assesses the increase or decrease in the area covered by mangroves.	Large decrease, small decrease, no change, small increase, large increase	
Recreational use value	This node assesses changes to recreational use value based on other nodes that have been incorporated into the Willis Creek CLAM such a shorebird recovery program, water quality objectives and Coffs Harbour Regional Park etc.	Large decrease, small decrease, no change, small increase, large increase	
Saltmarsh area	Assesses the increase or decrease in the area covered by saltmarsh area as a result of various scenario options.	Large decrease, small decrease, no change, small increase, large increase	
Shorebird recovery program	This node assesses the advantages-disadvantages of a variety of different conservation measures for shorebirds. In particular, targeting the endangered Little Tern that has been observed at the site in February, 2007.	Large decrease, moderate decrease, small decrease, no change, small increase, moderate increase, large increase	
Solitary Islands Marine Park Water Quality Objectives – Flat Top Head	This node has been included to assess the impact of selected management issues (decision variables) and associated scenario options on Water Quality objectives developed by MHL (1997)	Greatly exceed objectives, slightly exceed objectives, meets Water Quality objectives, slightly meet objectives, greatly meet objectives	

Willis Creek Water Quality Objectives	This node has been included to assess the impact of selected management issues (decision variables) and associated scenario options on Water Quality objectives developed by Jelliffe (1997)	Greatly exceed objectives, slightly exceed objectives, meets Water Quality objectives, slightly meet objectives, greatly meet objectives	

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

1. Acid sulfate soil management
2. Climate change
3. Decommissioned landfill site
4. Sea level rise
5. Terrestrial weed management
6. Water reclamation facility
7. Woolgoolga highway bypass

Acid sulfate soil management

Acid Sulfate Soils (ASS) occur mainly over low-lying coastal areas, predominantly below 5 metres above Australian Height Datum (AHD). These soils may be found close to the natural ground level but may also be found at depth in the soil profile. ASS is particularly found in coastal wetlands.

Under anaerobic conditions maintained by permanent groundwater, iron sulfides are stable and the pH is often weakly acid to alkaline. ASS only becomes a problem when they are disturbed and exposed to air. When iron sulfides are oxidised, sulfuric acid forms and the soil becomes strongly acidic. Typically, excavating or otherwise removing soils or sediments, manipulating water levels or filling land, causes disturbance of ASS.

The exposure of ASS to oxygen (e.g. by drainage, excavation or filling) usually results in production of sulfuric acid and toxic quantities of iron, aluminum and other heavy metals, in forms that can be released into waterways. These ASS products exert a very high oxygen demand in the water bodies.

The acid is corrosive to concrete and steel infrastructure combining with heavy metals to result in fish kills or damage. This also relates to other aquatic organisms and native vegetation resulting in considerable negative impacts on ecological processes in waterways (Dear *et al*., 2002).

"Any disturbances to the groundwater hydrology or surface drainage patterns in coastal areas below 5 metres AHD, including the subsoil or sediments below 5m AHD where the natural ground level of the land exceeds 5m AHD, should be investigated, and where justified should be designed and managed to avoid potential adverse effects on the natural and built environment (including infrastructure) and human health from ASS" (Stone *et al*., 1998).

The Willis Creek CLAM has qualitatively assessed the impact of disturbance of ASS from the identified area. Any future development within the catchment requires an ASS expert to investigate the possible impacts and provide appropriate recommendations. The NSW ASS Manual is the guiding document for ASS management in NSW.

Rationale for inclusion in CLAM

In assessing the Willis Creek catchment for disturbance of Acid Sulfate Soils it was identified that the highest risk is the high probability area west of the Pacific Highway as shown in the ASS map (see interface tool maps). This area may be subject to disturbance from future developments such as the proposed highway bypass and the possible industrial development within the special investigation area.

Scenario management options

1. No change
2. Disturbance of ASS high priority area with no management
3. Disturbance of ASS high priority area with management

Assumptions

- Future developments may affect the area identified as ASS high priority area under NSW ASS risk maps located west of the Pacific Highway as shown in the ASS map.

References:

Dear SE, Moore NG, Dobos SK, Watling KM and Ahern CR (2002). Soil Management Guidelines. In Queensland Acid Sulfate Soil Technical Manual. Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

Stone, Y., Ahern, C., and Blunden, B. (1998) Acid Sulfate Soils Manual. Acid Sulfate Soils management Advisory Committee, Wollongbar, NSW, Australia.

Climate change

While there is little accuracy in predicting localised impacts of climate change on weather patterns in the Coffs Harbour area, there are general expectations of sea level rise, increased daily temperatures and increase storm severity that will most likely apply at this local scale. This scenario allows the user to view the impact of such predictions upon Willis Creek, and accounts for the inherent uncertainty in the predictions

A CSIRO / Bureau of Meteorology Technical Report: *Climate Change in Australia* (2007) suggest that temperatures in Australia are likely to increase by 1^{0}C by 2030, and depending on the amount of greenhouse gases emitted globally in coming years, an increase between 1 and 5^{0}C by 2070. An associated decrease in rainfall is predicted, and when rain falls, an increase in intensity.

A key climate change threat for the Australian coast is that of storm surges with sea level rise and intense rainfall events. CSIRO and the Bureau of Meteorology warn that "storm surges occurring on higher mean sea levels will enable inundation and damaging waves to penetrate further inland increasing flooding, erosion and damage to build infrastructure and natural ecosystems" (CSIRO/BOM 2007:93).

Drought and higher daily temperatures may lead to increase creek water temperatures, greater evaporation, and in turn may cause higher salinity in Willis creek.

Scenario options:

1. No change;
2. Increased storm severity; and
3. Reduction in annual rainfall by 25%.

References:

CSIRO, Australian Bureau of Meteorology. 2007. *Climate change in Australia: technical report 2007.* CSIRO. 148 pp

Decommissioned landfill site

The standard approach for landfill sites of capping and grass cover in the past means that it is commonly believed that they cannot escape being i) unattractive and ii) sources of environmental problems. Landfill sites do have problems, however they present unique opportunities. Due to the nature of the waste landfill sites contain, especially its high organic matter content, they are unstable, produce gas and leachate, and show settlement over the long-term. A number of landuses such as housing and farming are not feasible based on the nature of these sites. Instead, these areas provide the possibility of creating desirable landforms for public benefit and biodiversity (Wong and Bradshaw, 2002).

Decommissioned landfill sites are potential sites for ecological restoration of native ecosystems. Grassland is the most common after-use for landfill sites, which is the case for the Woolgoolga landfill site. Opportunities for increasing biodiversity can be taken whenever possible and landfill restoration can assist in this objective if the correct techniques are used. The key factors that affect the feasibility of planting on a contaminated system include the characteristics of the landfill surface (such as soil depth and soil quality), the desired plant habitat, and the physical setting of the site (for example, topography and climate). Research and a growing body of experience indicate that a properly designed and implemented restoration project can increase biodiversity, maintain integrity of the landfill surface and support a variety of plants (Wong and Bradshaw, 2002).

In the Woolgoolga landfill, household waste, building material, dead trees and miscellaneous wastes were tipped into trenches estimated at 6m wide by 3m deep by an average 30m long (pers. comm. Arnold Austin). It is unknown from records and anecdotal evidence the magnitude and complete composition of waste material deposited but it is assumed that some chemical material was deposited at the site. These trenches were scavenged by local community members for materials and regularly burnt to reduce the volume of material in the trenches. In addition, anecdotal evidence was provided that the predominant soil type was sand and a relatively high water table was observed in the trenches.

The Woolgoolga landfill site was decommissioned in April of 1989. At this stage, it is unknown whether or not the landfill site was capped during decommissioning.

Based on the fact that over 15 years have passed since the decommissioning of the Woolgoolga landfill site, it is considered that the threat of pollution from the site is negligible and the cost of hydrogeological investigations and remediation precludes this option. Therefore environmental plantings on the landfill site for amenity, aesthetics and biodiversity are considered in the Willis Creek CLAM.

It is considered that the adjacent ecosystem type should be the model for environmental plantings on the landfill site.

Rationale for inclusion in CLAM

During CLAM consultation a member of the Coasts and Estuary Advisory Group, Senior Park Officer from NSW NP&WS and local landholders identified the decommissioned landfill site within the Coffs Harbour Regional Park as a management issue to be included in the Willis Creek CLAM tool. Possible groundwater contamination from the site was identified. In addition, a National Parks and Wildlife Service field officer identified the site for possible landfill restoration works.

Scenario management options

1. No change
2. Landfill restoration for biodiversity

Assumptions

- It is considered feasible to restore the landfill site with environmental plantings managed over a five-year period.
- Estimated restoration costs are provided in the Willis Creek CLAM (see utility variable – landfill restoration costs).

References:

Robinson, G., and Handel, S. (1995) Woody Plant Roots Fail to Penetrate a Clay-Lined Landfill: Management Implications, Environmental Management. Volume **19**, Number 1, Pg.57-64.

Wong, M. and Bradshaw, A. (2002) The restoration and management of derelict land – modern approaches, World Scientific, London.

Sea level rise

The following excerpts are taken from Haines and Thom, 2007:

> "Future climate change is expected to modify a number of climate variables that define the physical and chemical structure and ecological behaviour of the NSW coastal lagoons. These climate variables include mean sea level, wave climate, and rainfall behaviour (total depth and storm intensity)."
>
> "Entrance morphodynamic processes are particularly vulnerable to climate change. These processes, which describe the opening and closing cycle of these lagoons, are controlled by dominant coastal (wave and sea level) conditions, and episodic catchment runoff events."
>
> "An increase in mean sea level is likely to move the entrance sand berm upward and landward. An increase in south-easterly waves will cause minor rotations in beach planform alignments, with expected net erosion from the southern ends of the beaches and net accretion at northern ends. For lagoon entrances at the southern end of beaches, this will result in a net loss of sand from the entrance…[and] at the northern end of beaches this will result in a net growth of the entrance berm".
>
> "Increased typical lagoon water levels behind the berm are expected. A decrease in total rainfall depth is likely to retard the cycle of filling and draining, and reducing the frequency of entrance breakout for mostly closed lagoons"

[Note: the Willis Creek mouth is predominately located at the northern end of the southern beach so it is presumed this will result in a net gain of sand.]

Sea level rise is the most accepted of the predictions associated with climate change. However, predictions as to the extent of this rise vary greatly due to the uncertainty of greenhouse gas concentrations in the future and disagreement on the effect of various levels of such gases.

Greenhouse gases within the atmosphere, enhanced by past, current and future human activities across the globe, are expected to cause an increase in global atmospheric temperatures of between 1.4 and 5.8 ^{0}C between 1990 and 2100 (IPCC 2001), and will represent the most significant global temperature variation in the last

10,000 years. More recent assessments undertaken by IPCC in preparation for their next major report (due 2007) suggest that temperatures by the year 2100 are more likely to be at the higher end of the predicted range.

Some likely consequences for coastal NSW are:

Temperature increases
For coastal NSW, predicted increases in temperature range between 0.2 and 1.6 °C by 2030, and 0.7 and 4.8 °C by 2070. This will lead to more hot days over 35°C and generally warmer spring conditions.

Sea Water Level Rise
The predicted sea level rise (m) from values in the year 2004 used here were:

Rate of sea level rise	Low	Medium	High
2030	0.018	0.094	0.17
2050	0.031	0.17	0.30
2100	0.066	0.35	0.66

Changes to El Nino
Sea level rise in Australia is also likely to be affected by the El Nino Southern Oscillation (ENSO), a decadal cycle characterised by periods of drought and dryer weather during the El Nino phase of the cycle, and relatively high rainfall and wetter weather during the La Nina phase. The likely effects of a warmer climate on the ENSO are not currently well understood.

Berm Erosion
An increase in mean sea level would result in a net landward and upward shift in the beach berm height.

Scenario options:
1. Present sea level 2007
2. Predicted sea level 2030
3. Predicted sea level 2080
4. Predicted sea level 2100

References

Haines, P., & Thom, B. (2007) Climate Change Impacts on Entrance Processes of Intermittently Open / Closed Coastal Lagoons in New South Wales, Australia. *Journal of Coastal Research* SI50:242-246

Terrestrial weed management
Weeds are among the most serious threats to Australia's natural environment. They displace native species and contribute significantly to land degradation.

A considerable amount of bush regeneration has been undertaken by the NSW NP&WS and the local Coast Care Group to combat the impacts of weeds in the Willis Creek area with the primary area of management undertaken on the dune area.

This scenario assesses the benefits of future weed management works in the context of resources required, ecosystem value, and benefits to biodiversity and amenity. A study undertaken by Ewers (2006) identified ecosystem biodiversity and amenity as a high priority issues for the local community. In addition, site investigations identified weeds as a considerable management issue in particular in the *Eucalyptus robusta* (EEC) and SEPP14 wetland.

Scenario management options for terrestrial weed management in the Willis Creek CLAM are:

1. No change;
2. Dune ecosystem;
3. *Eucalyptas robusta* overstorey (EEC);
4. Grassland community (EEC); and
5. Melaleuca overstorey.

References:

Ewers, G. (2006) Baseline Community Values and Subsequent Management Options of an Intermittently Closed Estuary in New South Wales, Southern Cross University.

Water reclamation facility

The Woolgoolga sewerage system was constructed in 1973. The Water Reclamation Facility (WRF) discharged to Willis Creek, which normally flows across the beach to the ocean adjacent to Flat Top Head. In 1990, the former State Pollution Control Commission (now NSW EPA) told Council to cease discharge to Willis Creek by December 1991.

The Woolgoolga treatment plant constituted a major discharge to Willis Creek. The daily flow averages 1.7 ML/d. The nitrogen load from the treatment plant from 1996 to 1998 averaged 8.2 t/a while the phosphorus load averaged 0.21 t/a. Although the residence time in Willis Creek between the discharge location and the ocean is relatively short, large increases in nutrient loads stimulated algal blooms within Willis Creek.

A major upgrade of the Woolgoolga Reclamation Plant (WRP) to ensure a higher standard of wastewater treatment and additional capacity to deal with extra sewerage flows from Mullaway and Arrawarra was completed in 2005. The completion of the upgrade meant that the outfall to Willis Creek at Woolgoolga adjacent to Flat Top Rock could be decommissioned.

This scenario option was requested by Council (pers. Comm. Martin Rose) to enable assessment of the cessation of wastewater into Willis Creek within the CLAM.

Scenario management options:

1. No change; and
2. Discharge of 1.7Ml/day into Willis Creek.

References:

CHCC (2007) What's Council Doing - Woolgoolga Water Reclamation Plant, http://www.coffsharbour.nsw.gov.au/www/html/987-woolgoolga-water-reclamation-plant.asp, accessed 12/4/2007.

Woolgoolga highway bypass

On 7 December 2004, the RTA announced that the preferred routes for the Pacific Highway will be Inner South 1 and Inner North 2 in the west. The Highway between Sapphire and Woolgoolga will be upgraded and Option E adopted around Woolgoolga.

Predicted sediment transport with associated nutrients from the highway construction site poses a considerable problem to stormwater management and associated water quality in Willis Creek.

The Willis Creek CLAM has assessed the impact of a proposed highway bypass to determine the need for management controls or not before more robust studies are undertaken under Part 5 of the Environment Planning and Assessment Act, 1979.

Scenario management options:

1. No change;
2. Highway bypass with no controls; and
3. Highway bypass with controls.