State of the Estuarine Environment Report for the Burnett Mary NRM Region 2008

Burnett Mary
REGIONAL GROUP
Practical Solutions for Natural Resource Management

Queensland
Government

Australian Government

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Executive Summary

The Burnett Mary NRM Regional Group (BMRG) places a high priority on the protection and management of the coastal and marine resources in its region, including the estuaries of the region. Over the past several years, the BMRG, in partnership with the Queensland Environmental Protection Agency (EPA), has been collecting a wide range of data on the risks to and the condition of many of these estuaries. The aims of this were firstly to establish a baseline of information on the current status of estuaries and secondly to use the data to inform management priorities. This State of the Estuaries Environment (SoEE) report addresses these aims by providing an assessment of the risk to, and condition of, the region's estuaries and recommendations for management actions.

This study covered a total of 18 estuaries. It includes all the major estuary systems in the Burnett Mary NRM region and a number of the smaller ones. For resourcing reasons, many smaller estuaries in the region could not be included in the study. A list of the estuaries covered is given in Table 1.

Table 1. Estuaries covered by this report.

Estuary	**Description**
Eurimbula Creek	Small estuary with its catchment mostly in National Park
Baffle Creek	Extensive estuary with minimal disturbance and a medium sized catchment with low intensity agriculture
Littabella Creek	Small estuary with a moderately developed lower catchment
Kolan River	Medium sized estuary with extensive surrounding cane growing areas and a tidal barrage
Burnett River	Highly impacted mid-sized estuary with a tidal barrage and extensively surrounded by urban and cane growing areas
Elliott River	Small estuary in very good condition but with a highly developed agricultural catchment
Coonarr Creek	Very small estuary with a mostly undisturbed catchment but some adjacent residential and agricultural development
Theodolite Creek	Small estuary with a largely undisturbed catchment
Gregory River Isis River Burrum River	Medium sized estuaries with a common mouth (Burrum Heads). All have moderate catchment development and tidal barrages
Susan River Mary River	The Susan is a small tributary of the Mary whose estuary joins the Mary near its mouth (River Heads). The Mary is a long and highly turbid estuary with a large moderately developed catchment
Kauri Creek	Small near pristine estuary with a largely undisturbed catchment
Snapper Creek	Small near pristine estuary with little development in its catchment except for the township of Tin Can Bay at its mouth
Wathumba Creek Coongul Creek Bogimbah Creek	Three separate small creeks on the north/west coast of Fraser Island, all located in National Park. Estuaries and catchments are in pristine condition

Assessment of the estuaries was based on a framework developed by the Queensland EPA. This framework is described in the section "The Assessment Framework Use" of this report. Briefly, the framework is based around a set of 13 key stressors that are known to impact on estuary condition. These stressors are not limited to traditional water quality type issues but cover the whole range of factors that may impact estuaries. This allows a holistic assessment of the estuary. A list of the stressors considered is given below in Table 2 together with a brief description of each.

The framework examines both the level of threat or risk to the estuary from each stressor and the actual measured impact on estuary, i.e. condition, caused by each stressor. Risk and condition are quantified through measurement of a series of, respectively, pressure indicators and condition indicators. Undertaking these measurements made up the bulk of the work of this study. Given that 87 indicators were measured for each estuary, this was a very significant task. A list of the pressure and condition indicators for each stressor is given in Appendix 2.

Table 2. Stressors considered in the estuary assessment framework.

Stressor	Description
Aquatic Sediments	Sediments that cause siltation and reductions in light availability
Bacteria/Pathogens	Harmful bacteria or pathogens from sources such as sewage, septics, aquaculture operations, intensive animal production
Biota removal/disturbance	Direct removal of biota by humans, mainly fishing, crabbing and bait collection
Connectivity	Connectivity between the estuary and its catchment and the impact of this on the ability of migratory species to move along the estuary as well as between the estuary and freshwater riverine areas
Freshwater flow regime	The extent to which freshwater inflows to the estuary have been impacted by the construction of water storages in the catchment
Habitat removal/disturbance	Loss of habitat such as mangroves through direct human removal
Hydrodynamics	Changes in the estuary's hydrodynamic regime caused by engineering works such as canals, training walls and barrages
Litter (rubbish)	Rubbish entering the estuary from either terrestrial (e.g. urban areas) or aquatic (e.g. boating) sources
Nutrients	Nitrogen and phosphorus derived from point or catchment sources and the impact on algal growth in the estuary
Organic matter	Organic matter derived from point or catchment sources and its impact on dissolved oxygen levels
Pest (animal, plant) species	The occurrence of exotic pest species (aquatic and terrestrial, plant and animal)
pH	The occurrence of acid drainage from acid sulphate soils or mine drainage and its impact on biota
Toxicants	Toxicants (e.g. heavy metals, pesticides) derived from agricultural or industrial sources and the impacts on biota

Based on the measured indicator values, both risk and condition were rated into categories from 1 (negligible risk/excellent condition) to 5 (extreme risk or very poor condition). An example of an output is given below in Table 3.

Table 3. Example of the stressor risk and condition scores for an estuary.

Stressor	Risk	Condition
Aquatic Sediments	Extreme	Very Poor
Bacteria/Pathogens	Low	Excellent
Biota removal/disturbance	High	Fair
Connectivity	High	Poor
Freshwater flow regime	Extreme	Very Poor
Habitat removal/disturbance	Low	Fair
Hydrodynamics	High	Poor
Litter (rubbish)	Moderate	Poor
Nutrients	Low	Good
Organic matter	Moderate	Good
Pests	Negligible	Excellent
pH	Moderate	Fair
Toxicants	Negligible	Excellent

This clearly identifies which stressors have the highest risk and/or worst condition and this information can then be used to determine management actions and priorities. Generally the level of risk would be expected to correlate with condition rating but this is not always the case. This may be due to a number of factors, such as good management of the pressures (human activities) or factors to do with natural variability in response and resilience. However, where a mismatch between risk and condition is noted, this should be taken as an indication that further investigation may be required. It may also indicate the possibility that the high risk will be expressed as poor condition some time in the future.

For each result, information on the confidence of the supporting data and on the dependability of the data is available in individual estuary chapters. Similar outputs were produced for all estuaries and these can most readily be viewed in the individual estuary report cards.

Details of results for each estuary are provided in individual chapters of this report.

As could be expected, the 18 estuaries studied varied widely in terms of both risk and condition. However, there were a number of issues that were found to be regionally significant. The remainder of this executive summary describes these issues and potential management actions.

KEY REGIONAL ISSUES

Barriers

In seven of the 18 estuaries, connectivity between the estuary and freshwater reaches has been almost entirely lost due to construction of barriers, i.e. tidal barrages or downstream weirs. Some of these barriers have fishways but a proportion of these are largely ineffective while the effectiveness of others may be impacted by the way water flows are managed. In these estuaries, populations of diadromous fish (fish that migrate between freshwater and estuaries/sea) are greatly reduced or absent.

The management response to this issue would be the installation of effective fishways on all these barriers (see the Burnett Mary Regional Biopass Strategy (Stockwell *et al*., 2008)).

Fishing

Nearly all the estuaries included in this study experience moderate to high levels of both recreational and commercial fishing. Catch data indicates that fish stocks in some estuaries are decreasing, whilst in virtually all estuaries crab stocks appear to be declining, sometimes quite markedly. Because of the indirect nature of the fishing statistics and also the way they are collected, particularly in relation to recreational activities, confidence in these data is only moderate. Nevertheless, there is some cause for concern. It is certainly desirable that improved fisheries data be collected specifically for estuaries so that we can better assess changes in these habitats. With regard to crabs, the apparent decrease in populations across nearly all estuaries is sufficient reason to prompt some management response such as the introduction of green (no take) zones within estuaries.

An issue on which we have almost no condition data is bait collection. We know that some estuaries experience significant levels of bait collection but the effect of this on bait species populations is largely unknown. The initiation of some research on this issue is desirable.

Litter

Litter is a ubiquitous problem across all estuaries. Even some of the pristine estuaries, such as those on Fraser Island, can experience high levels of litter and ongoing littering. The constant littering of estuaries is a disappointing although not entirely unexpected finding. Clearly some management response is desirable. Policing littering in estuaries will always be difficult so therefore longer-term measures such as education or more anti-litter signage will need to be considered.

Catchment pollutant sources

Flow events introduce loads of catchment sourced materials into estuaries. This is a natural process but human disturbance of catchments increases the loads of many natural pollutants, such as fine sediments, nutrients and organic matter. These have short term but often quite significant impacts on estuaries.

In the Burnett Mary estuaries, catchment nutrients loads result in short-term bursts of phytoplankton growth which are sometimes picked up in monthly monitoring programs. To date, this process does not appear to have resulted in major algal blooms in any of the estuaries. Nevertheless, ongoing management of catchment nutrient loads is necessary to ensure that this issue is kept under control. Management of catchment nutrients is also very important for protection of coastal ecosystems although this is outside the scope of this report.

Catchment loads of organic material result in temporary decreases in estuary dissolved oxygen levels. In all estuaries in this study, the minimum dissolved oxygen level recorded was following catchment inflows, thus showing that catchment organic loads are clearly having an impact. However, to date, dissolved oxygen has never been recorded at levels likely to be critical to ecosystem health. Nevertheless, as with nutrients, ongoing management of catchment organic loads is necessary to ensure that this issue is kept under control.

Diffuse source loads of fine sediments cause large, but temporary, increases in estuary turbidity. However, sediment dispersion and settlement processes usually return turbidity to the much lower dry weather levels within a few weeks. What we do not know, due to lack of historical data, is the extent to which the increased fine sediment loads have impacted on residual dry weather turbidity levels. Nor do we have much quantitative information on the impacts of increased sediment deposition – these include impacts on benthic ecosystems and also increased risk of resuspension back into the water column. The loss of seagrass in many estuary systems does indicate that there have been long-term increases in turbidity in these systems. Management of catchment sediment loads is important for many reasons and the potential for impacts on estuaries is one among these.

Point sources of pollutants

There are relatively few point source discharges to the estuaries in this study. The only significant ones are treated sewage discharges to the Mary and Burnett estuaries. In the Mary this increases nutrient levels but due to high turbidity levels has little impact on algal growth. In the less turbid Burnett, increased nutrient levels do result in some increase in algal growth although no blooms have been recorded. Other potential impacts of these discharges, such as reductions in dissolved oxygen levels or increases in bacteria numbers, appear to be minor. In the Burnett there have been very significant reductions in point source pollutant loads over the years and in the long term it is desirable that these discharges are diverted to some alternate form of disposal.

The other main class of point discharges to these estuaries are aquaculture and industrial operations, although again there are relatively few of these. The main potential pollutants from these include nutrients and organic matter. Available data suggests that none of these operations is currently having large impacts on water quality, although in some of the affected estuaries the extent of monitoring data is very limited. As with all point discharges, the implementation of the reduce/re-use/recycle policy is strongly recommended, with discharges to waters reduced to an absolute minimum.

Seagrass loss

Of the estuaries in this study only three, Baffle Creek, Kauri Creek and Snapper Creek had extensive seagrass present. It seems no coincidence that these estuaries have some of the least disturbed catchments and lowest levels of general disturbance. On the other hand, there are some other undisturbed estuaries, such as Eurimbula Creek, that currently have no seagrass and probably never did. Clearly there are also natural factors that impact on seagrass presence in estuaries.

Nevertheless, there is evidence that estuaries such as the Kolan and Burnett did have seagrass. The loss of seagrass in these and probably other estuaries is symptomatic of a long term increase in stresses caused by human activities.

A long-term management aim for the region's estuaries should be, firstly, to retain the current level of seagrass and, secondly, try to restore seagrass to areas where it used to occur naturally. A study to determine the true historical extent of seagrass would be an important pre-cursor to this. Programs to reduce catchment sediment loads should in any case be implemented, as these have many benefits in addition to assisting in seagrass recovery.

Habitat loss

Mangrove and saltmarsh habitat in most estuaries is largely intact. Estuary foreshore riparian zones are also mostly in good condition. However, in some estuaries, a significant proportion of the

background vegetation has been lost. In part this is due to long standing agricultural activity but in some estuaries there is encroachment of rural residential blocks. This is likely to be an increasing trend in the future and, ideally, future subdivisions of this type should include a requirement for a buffer strip to protect estuarine habitat. Ideally, there should also be incentives for agricultural landholders to restore 'background' riparian and buffer vegetation.

In many of these estuaries there are localised issues impacting on habitat, such as cattle grazing in mangrove areas or 4WD vehicle use in saltmarshes. These issues are described in detail in Mackenzie and Duke (2009) and should be addressed as part of any habitat management plans.

Reduced freshwater inflows

Nearly all the larger systems examined have one or more impoundments in their catchment. In two systems (Burnett and Kolan) the impoundment volume exceeds 100% of median annual flow. In other systems a lower percentage of the annual median flow is impounded (e.g. 35% in the Burrum), however, even this level of water storage has a large impact on freshwater inflows to an estuary, particularly in drier years.

Freshwater inflows are essential for an estuarine environment and their loss means that what used to be an estuary becomes a more marine type of environment. There is also evidence that estuaries are experiencing ongoing build up of sediment because of the great reduction in flushing inflows that would normally wash this away. The detailed impacts of reduced freshwater inflows on estuarine biota are poorly understood but the overall effect is to change the essential nature of these unique systems.

Returning inflows to estuaries to natural levels is clearly an unrealistic proposition. However, it is important that the Water Resource Plans and related Resource Operation Plans that have been or are being developed should take proper account of the environmental flow needs of estuaries.

Herbicides

Herbicides were nearly always below detection limits in sediments but were commonly detected in the water column of most estuaries. Generally, the levels detected were below the most stringent guideline values.

Using our current guideline values, toxicants in general do not appear to present a major risk to these estuaries – though there are some serious knowledge gaps. The detection of herbicides in most estuaries is an indication of the widespread use of these chemicals. Additionally, their unexpected presence in some near-pristine systems illustrates the pervasive nature of these compounds and how with even relatively low levels of use they still manage to find their way into waterways. This is a warning against complacency.

Clearly, ongoing careful management of the application of these chemicals is essential.

Introduction

In 2005, the Burnett Mary Regional Group for NRM Inc. (BMRG) launched their regional NRM Plan, *Country to Coast – a healthy, sustainable future*. Under this plan, estuaries were identified as performing a critical role for both ecological and ecosystem services in the region.

Sadly, our knowledge of this ecosystem was identified as a key knowledge gap for the region with over 50 recognised estuaries and tidal streams occurring, but little information to support future investment. Therefore, over the past two years, the BMRG, in partnership with the Queensland EPA, has been collecting a wide range of data on the risks to, and the condition of, many of these estuaries. The aims of this were firstly, to establish a baseline of information on the current status of estuaries and, secondly, to use the data to inform management actions and priorities. The purpose of this report is to address both these aims. It provides an assessment of the current condition of the region's estuaries and the threats to their well-being. In addition, based on data, the report identifies a number of management actions.

This study covered a total of 18 estuaries – see Figure 1. It includes all the major estuary systems in the region and a number of the smaller ones. It also includes three estuaries on Fraser Island (within the Fraser Island World Heritage Area). These were included to ensure that the study covered pristine as well as impacted estuaries. For resourcing reasons, many smaller estuaries in the region could not be included in the study. A list of the estuaries covered is given in Table 1 in the executive summary.

The assessment of the risk to, and condition of, the estuaries in this study was undertaken based on a framework developed by the Queensland EPA (see Moss *et al.,* 2006; Scheltinga *et al*., 2004, Scheltinga and Moss, 2007, 2008). This framework is described in section "The Assessment Framework Use" of this report. Briefly, the framework is based around a set of 13 key stressors that are known to impact on estuary condition (see Table 2 in the executive summary). These stressors are not limited to traditional water quality type issues but cover the whole range of factors that may impact on estuaries, examples include nutrients, fishing and changes to connectivity. Consideration of this broad range of stressors allows a holistic assessment of the estuary.

The framework examines both the level of threat or risk to the estuary from each stressor and the actual measured impact on estuary, i.e. condition, caused by each stressor. Both risk and condition for each stressor are quantified through the measurement of a series of indicators that were identified in the studies referred to above. The measurement of these indicators (total of 87) in each of 18 estuaries was a significant task and comprised the bulk of work in this study.

The reason for basing the framework around specific stressors and linking pressure and condition indicators is that it allows management actions to be readily identified. Thus, if nutrients are found to impact on an estuary's condition, then management would need to target catchment or point sources of nutrients. Similarly, if connectivity is an issue then constructing more fishways might be a management response.

This study has a number of outputs.

Main report (this document)**:**

- An introduction to the study and report
- A description of the assessment framework and the indicators
- A summary of the results from all estuaries
- Chapters on each estuary that provide a detailed assessment for that estuary as well as identifying management actions. These individual estuary chapters also include the full results for each indicator for each stressor.

Summary A3 report for all estuaries:

- Brief description of the study and methods
- Overall assessment, risk and condition scores for all estuaries
- Brief comments on risk and condition for each estuary
- Summary of regional estuary issues

Report cards for each estuary:

- Brief comments on the nature of the estuary together with a satellite image showing some of the key features
- Overall assessment, risk and condition scores
- Risk and condition scores for each stressor
- Summary comments on each stressor
- Management suggestions for each stressor

Website:

- Access to all reports
- Access to all data associated with the reports
- Links to the OzCoasts website which reports the data in the national context

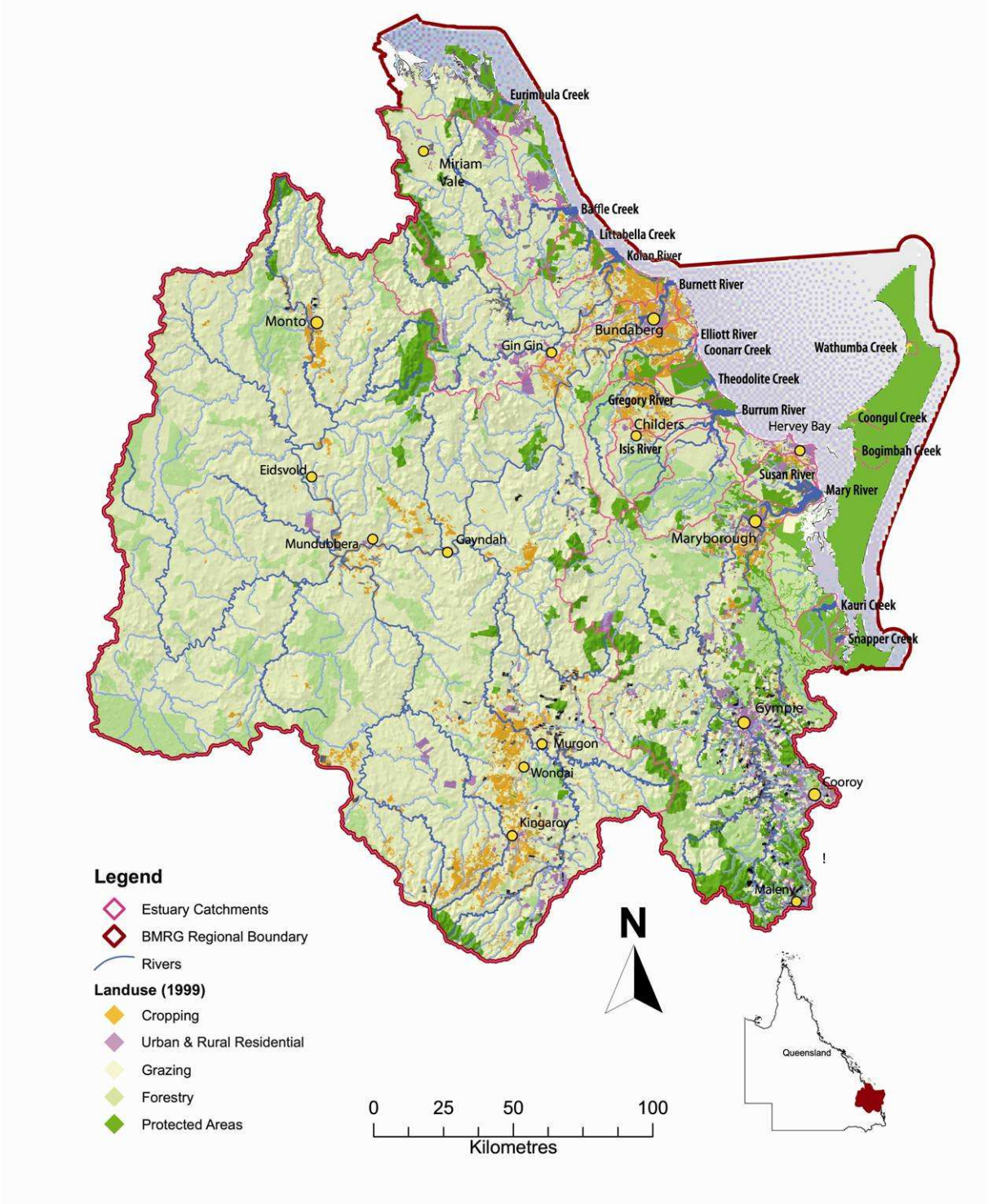


Figure 1. Map of the Burnett Mary NRM region with the estuaries examined as part of the SoEE study highlighted.

The Assessment Framework Used

The assessment framework used for this State of the Estuarine Environment (SoEE) Report is that produced by the Queensland EPA (Scheltinga and Moss, 2008). The framework explicitly links condition information directly back to pressures (i.e. human activities) and hence supports management decisions.

The basis of the framework is the identification of a set of 13 key stressors that can potentially impact on estuarine waterbodies (see also Table 2 in the executive summary). Stressors are defined as components of the environment that when changed can affect the condition of the ecosystem. These can be natural components such as nutrients or entirely anthropogenic components such as litter (rubbish) or biota removal/disturbance. Some stressors, such as toxicants, may have natural (e.g. particular metals) and anthropogenic (e.g. pesticides) aspects.

In Queensland, the following 'components of the environment' have been identified as major stressors, important in estuarine ecosystems:

- Aquatic sediments
- Bacteria/pathogens
- Biota removal/disturbance
- Connectivity
- Freshwater flow regime
- Habitat removal/disturbance
- Hydrodynamics
- Litter (rubbish)
- Nutrients
- Organic matter
- Pest (animal, plant) species
- pH
- Toxicants

For each stressor, the following linked elements were identified:

1. human activities that result in a change to the stressor;
2. the actual factor directly related to the stressor that is changing. For example, the actual nutrient load entering the estuary;
3. the change in physical-chemical state observed in response to a stressor; and,
4. the biological impact observed as a response to the change in physical-chemical state.

For each of the 13 stressors listed above, Scheltinga and Moss (2008) identified both pressure and condition indicators which are linked together and specifically relevant to that stressor which allows us to relate condition information obtained directly back to the causal human activities that ultimately need to be managed.

This SoEE monitoring program uses the indicators identified by Scheltinga and Moss (2008) to provide information about the risk to, and health of, 18 estuaries within the Burnett Mary NRM Region. Each indicator is reported using a five point scoring scale with a score of 1 being the 'best' and 5 the 'worst'. The assessment methodology used allows scores of individual indicators to be combined to give risk and condition score for each stressor as well as an overall assessment, overall risk, and overall health score for each estuary as a whole. These scores are provided from A+ through to D- with a score of F being the highest risk/worst health score possible.

The Scheltinga and Moss (2008) document also includes vulnerability and management practice indicators, however, they require further development and testing or lacked data and have not been used here.

Burnett Mary NRM Region

INTRODUCTION

The Burnett Mary Region covers approximately 56,000 square kilometres of land and includes another 40,000 square kilometres of marine area. It has a diversity of landscapes and communities and covers five major river basins: Baffle, Burnett, Burrum, Kolan and Mary and a series of smaller coastal creeks (such as Eurimbula, Kauri and Wathumba).

The region also contains major urban areas, including the cities of Bundaberg, Hervey Bay, Maryborough and Gympie. The Burnett Mary region is home for close to 250,000 people and there are five Local Government Authorities and parts of four more regional councils that fall within the planning boundaries.

All of Fraser Island World Heritage Area and part of the Great Barrier Reef World Heritage Area occur within the Burnett Mary region as does the Great Sandy Strait, a Ramsar listed wetland of international significance.

Graziers and farmers are the land managers for over 75% of the Burnett Mary region. Climatic influences have led to the development of intensive continuous crop systems in coastal areas with rainfall in excess of 1,000 mm and less intensive fallow-crop systems further inland with rainfall in the 700-800 mm range. On poorer soils or steeply sloping land, cattle production from native or sown pasture is the major enterprise. Overall, 69% of the region is devoted to extensive grazing of cattle, with intensive livestock and dairy production occupying 1% of the region. Dryland crop production (peanuts, maize, grain sorghum) with 1.5%, horticultural tree and annual cropping with <1%, and irrigated crops (sugarcane, soybeans, cotton) with 2.5%, are the remaining major agricultural land uses. The grazing industry as a percentage of land use is more significant in the Burnett, Baffle and Kolan catchments (>74%). Dryland crop production is significant in the south Burnett, while irrigated cropping and horticulture are more significant in the coastal (lower Mary, Burnett, Burrum and Kolan) parts of the catchments.

RESULTS

The framework used here to assess the estuaries is based on a series of defined stressors. By its nature, the framework is designed to identify the individual stressors that are having the greatest impact on an estuary and to use this information to identify priority management actions. Creation of an 'overall assessment' rating based on all stressors for each estuary is in a sense moving away from the main purpose of the framework, which is to identify specifics. However, overall ratings can provide a measure of which estuaries are in better health than others but leave unanswered the question of "what to do next?" In addition, overall ratings can be useful for some higher level reporting purposes. For this reason, two types of overall ratings are presented in this summary and are also presented in the report cards. These overall ratings are created by combining the scores from all the stressors – details of the method used are given in Scheltinga and Moss (2008). Table 4 provides a single overall assessment rating for each estuary. These ratings are based on combined scores for both overall risk and overall health for each estuary. The next table (Table 5), provides more detailed summary information, giving separate overall ratings for risk and health and includes some measure of the confidence in these ratings.

The overall ratings in Table 4 suggest that most estuaries are in fairly good health. For the estuaries with an 'A' rating this is largely true. These estuaries all have catchments that are entirely or very largely undisturbed. Similarly, they all have largely intact habitat and very good water quality. Nevertheless, even these estuaries have some issues, some appear to be overfished and nearly all suffer from significant levels of littering.

Estuaries with 'B' ratings are for the most part in good health. However, they often have a B rather than an A rating because they are significantly impacted by at least one stressor and generally have higher risk levels. For example, in the Burrum and Isis systems, connectivity between the estuary and freshwater reaches has been completely lost. Because the 'rolled up' rating takes account of all stressors, the effect of one poor score tends to be damped out. This is of course the main weakness of a rolled up score.

Estuaries with scores of less than a 'B' have significant issues with a number of stressors and are clearly in poorer health. However, even these are by no means hopeless cases, the Kolan for example scores a C but still has largely intact habitat.

Table 4. Overall assessment ratings for all estuaries.

Estuary	*Overall assessment rating*				
Baffle		B+			
Bogimbah	A+				
Burnett				D-	
Burrum		B			
Coonarr	A-				
Coongul	A+				
Elliott		B			
Eurimbula	A				
Gregory		B			
Isis		B-			
Kauri	A-				
Kolan			C		
Littabella		B			
Mary			C-		
Snapper		B+			
Susan		B+			
Theodolite	A				
Wathumba	A+				

Table 5 shows overall risk and health ratings separately. In a perfect system, the links between risk and condition would be quantified to the extent that risk could be used to precisely predict condition, and thus the two ratings would always be the same. However, our current knowledge is a long way from that ideal and therefore there are some discrepancies between risk and condition. In most cases the discrepancy has the level of risk overestimating the impact on condition. One example is the case of fine sediments. We know that catchments generate much larger loads of fine sediment now compared to pre-European times. However, while this has short-term impacts on turbidity, the longer term effects are less than expected because this excess sediment is quite rapidly removed by various estuarine processes. Occasionally, risk underestimates impact on condition as in the case of litter. Some estuaries appear to have a low level of risk but yet this is sufficient to cause high levels of littering. Sometimes the discrepancies may be due to natural anomalies such as natural variability in response, time lags and resilience. Thus for example, water quality in Kauri Creek is poorer than expected given its pristine catchment. This requires further examination but may be a natural feature of this system. Another factor that may cause a discrepancy between the risk score and condition score is the occurrence of good management of the pressures (human activities). The EPA's assessment framework does take management actions into account when determining risk scores, however, due to a lack of data on current management practices occurring in the region this could not be included.

Thus there are a number of reasons why these discrepancies occur. One is obviously that we do not fully understand the links between risk and condition. Another is that in relation to condition, we may not be measuring the most appropriate indicators. The ones we do measure may not be sensitive or responsive enough to the stressor in question. As our knowledge increases these discrepancies will be reduced. However, the ability of this framework to compare risk and condition will always remain (i) an important internal check on how well the system is performing and (ii) a means of highlighting natural anomalies.

Table 5. Overall risk and overall health ratings for each estuary.

Estuary	*Overall Risk*	*Confidence*	*Dependability (%)*	*Overall Health*	*Confidence*	*Dependability (%)*
Baffle	C+	High	99	A+	High	78
Bogimbah	A+	Very high	100	A+	High	86
Burnett	F	Very high	99	D	High	87
Burrum	B-	Very high	97	B+	High	77
Coonarr	B	Very high	94	A+	Moderate	69
Coongul	A+	Very high	100	A+	High	32
Elliott	C	Very high	99	A	High	88
Eurimbula	A	Very high	95	A+	High	73
Gregory	B-	Very high	97	B+	High	60
Isis	B-	Very high	97	B-	High	83
Kauri	A	Very high	94	B+	Moderate	91
Kolan	C-	Very high	99	C+	High	96
Littabella	C	Very high	97	A	Moderate	71
Mary	D+	High	97	C+	High	78
Snapper	C+	Very high	94	A+	High	73
Susan	B-	Very high	97	A	Moderate	74
Theodolite	A-	Very high	97	A+	Moderate	71
Wathumba	A+	Very high	100	A+	High	85

Confidence = confidence in the data used. Dependability = the % of all potential indicators that have been monitored.

Summary of Regional Issues and Management Responses

While each estuary has its own particular characteristics, it is clear from the results that a number of issues were common among many of the estuaries. This section summarises these regional issues and provides some suggested management responses.

Barriers

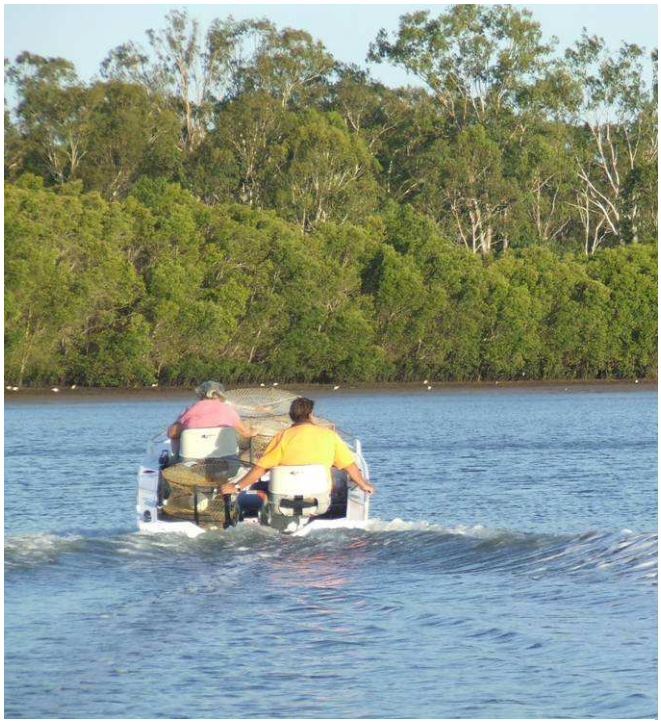
In seven of the 18 estuaries, connectivity between the estuary and the catchment has been almost entirely lost due to construction of barriers - barrages or downstream weirs. Some of these barriers have fishways but a proportion of these are largely ineffective while the effectiveness of others may be impacted by the way water flows are managed. In these estuaries, populations of diadromous fish (fish that migrate into freshwaters and spend part of their life cycle there) are greatly reduced or absent. The loss of connectivity, together with the effect other related factors such as the reduction in freshwater inflows, acts to significantly alter the essential estuarine nature of these systems.

Barriers without effective fishways prevent migratory fish from moving between freshwater reaches and the estuary/sea

The management response to this issue would be the installation of effective fishways on all these barriers (see the Burnett Mary Regional Biopass Strategy (Stockwell *et al*., 2008)). However, this has obvious implications for water resources which need to be taken into account. Nevertheless, the implementation of well designed fishways which are operated at critical times of year could have very beneficial effects for the estuary without causing major impacts on water resources.

Fishing

Nearly all the estuaries included in this study experience moderate to high levels of both recreational and commercial fishing. Catch data indicates that fish stocks in some estuaries are decreasing, whilst in virtually all estuaries crab stocks appear to be declining, sometimes quite markedly. Because of the indirect nature of the fishing statistics and also the way they are collected, particularly in relation to recreational activities, confidence in these data is only moderate. Nevertheless, there is some cause for concern. It is certainly desirable that improved fisheries data be collected specifically for estuaries so that we can better assess changes in these habitats. With regard to crabs, the apparent decrease in populations across nearly all estuaries is sufficient reason to prompt some management response such as the introduction of green (no take) zones within estuaries.



Fishing, crabbing and prawning are important commercial and recreational activities in the region

Protected marine zones have been demonstrated to have beneficial effects on fish and crab populations (Halpern and Warner, 2002; Williamson *et al*., 2004). Recent work in Moreton Bay (Pillans *et al*., 2005) has shown that there are large differences in crab populations between green zones and general use zones. This not only shows the impact that fishing pressures have, but also demonstrates the effectiveness of green zones in preserving stocks. There is every reason to suppose that fishing is having similar impacts on the estuaries in this study and that the introduction of green zones would be similarly beneficial. In late 2006 much of the region's marine and estuarine areas were declared a marine park (the Great Sandy Marine Park). This introduced restrictions to fisheries activities in many of the estuaries included in this report. Some, such as the Burrum, Isis and Gregory now have green 'no take' zones, while most others have conservation park zoning but some, such as the Burnett estuary, remain unchanged with no zoning. It is important to note that all of the fisheries data used in this estuarine assessment come from pre-marine park status.

An issue on which we have almost no condition data is bait collection. We know that some estuaries experience significant levels of bait collection but the effect of this on bait species populations is largely unknown. The initiation of some research on this issue is desirable.

Litter

Litter is a ubiquitous problem across all estuaries. Even some of the pristine estuaries, such as those on Fraser Island, can experience high levels of litter and ongoing littering. This result suggests that the great majority of litter in many estuaries is sourced directly from recreational or commercial users rather than being washed in from adjacent urban areas or from the catchment. The constant littering of estuaries is a disappointing although not entirely unexpected finding. Clearly some management response is desirable. Policing littering in estuaries will always be difficult so therefore longer-term measures such as education or more anti-litter signage will need to be considered.

Significant amounts of rubbish was found in all estuaries across the region

Investigations into the sources of litter and identification of the key risk factors would be beneficial for future management planning.

Catchment pollutant sources

Flow events introduce loads of catchment sourced materials into estuaries. This is a natural process but human disturbance of catchments increases the loads of many natural pollutants, such as fine sediments, nutrients and organic matter. These have short term but often quite significant impacts on estuaries.

In the Burnett Mary estuaries, catchment nutrients loads result in short-term bursts of phytoplankton growth which are sometimes picked up in monthly monitoring programs. To date, this process does not appear to have resulted in major algal blooms in any of the estuaries. Nevertheless, ongoing management of catchment nutrient loads is necessary to ensure that this issue is kept under control.

Cropping is an important land-use in the region, particularly within coastal areas

Management of catchment nutrients is also very important for protection of coastal ecosystems although this is outside the scope of this report.

Catchment loads of organic material result in temporary decreases in estuary dissolved oxygen levels. In all estuaries in this study, the minimum dissolved oxygen level recorded was following catchment inflows. Thus showing that catchment organic loads are clearly having an impact. However, to date, dissolved oxygen has never been recorded at levels likely to be critical to ecosystem health. Nevertheless, as with nutrients, ongoing management of catchment organic loads is necessary to ensure that this issue is kept under control.

Diffuse source loads of fine sediments are well known to have increased several-fold in many catchments since European settlement. These loads cause large, but temporary, increases in estuary turbidity. However, sediment dispersion and settlement processes usually return turbidity to the much lower dry weather levels within a few weeks. What we do not know, due to lack of historical data, is the extent to which the increased fine sediment loads have impacted on residual dry weather turbidity levels. Nor do we have much quantitative information on the impacts of increased sediment deposition – these include impacts on benthic ecosystems and also increased risk of resuspension back into the water column. The loss of seagrass in many estuary systems does indicate that there have been long term increases in turbidity in these systems. Management of catchment sediment loads is important for many reasons and the potential for impacts on estuaries is one among these.

Point sources of pollutants

There are relatively few point source discharges to the estuaries in this study. Treated sewage is discharged to the Mary and Burnett estuaries. In the Mary this increases nutrient levels but due to high turbidity levels has little impact on algal growth. In the less turbid Burnett, increased nutrient levels do result in some increase in algal growth although no blooms have been recorded. Other potential impacts of these discharges, such as reductions in dissolved oxygen levels or increases in bacteria numbers, appear to be minor. In the Burnett there have been very significant reductions in point source pollutant loads over the years and in the long term it is desirable that these discharges are diverted to some alternate form of disposal.

Point discharges are present in a few estuaries and generally contribute relatively small loads but they are continuous and their impacts tend to predominate in dry weather when dilution is the lowest

The other main class of point discharges to these estuaries are aquaculture and industrial operations, although again there are relatively few of these. The potential pollutants from these include nutrients and organic matter. Available data suggests that none of these operations is currently having large

impacts on water quality, although in some of the affected estuaries the extent of monitoring data is very limited. As with all point discharges, the implementation of the reduce/re-use/recycle policy is strongly recommended, with discharges to waters reduced to an absolute minimum.

Owing to overseas competition, development of estuary based aquaculture in Queensland has been slow. However, the introduction of new technology or new culture species has the potential to greatly increase pressure from this source and this needs be kept under constant surveillance.

Seagrass loss

Historical records of seagrass extent are mostly anecdotal and fragmented. However, seagrass was undoubtedly once much more extensive in many Queensland estuaries than it is now. A good example of this is the Maroochy estuary in southern Queensland. In the early settlement days this had extensive seagrass meadows and large populations of black swans (hence the name Maroochy being an aboriginal word for black swan) which grazed on the seagrass. Nowadays the Maroochy estuary has virtually no seagrass present. The exact reasons for this loss are not clear, an incremental increase in turbidity is probably one factor but there may well be others.

Anecdotal evidence is that seagrass has been lost, or greatly reduced, in several of the region's estuaries

Of the estuaries in this study only three, Baffle Creek, Kauri Creek and Snapper Creek had extensive seagrass present. It seems no coincidence that these estuaries have some of the least disturbed catchments and low levels of general disturbance. On the other hand, there are some other undisturbed estuaries, such as Eurimbula Creek, that currently have no seagrass and probably never did. Clearly there are also natural factors that influence seagrass presence in estuaries.

Nevertheless, there is evidence that estuaries such as the Kolan and Burnett did have. The loss of seagrass in these and probably other estuaries is symptomatic of a long term increase in stresses caused by human activities.

A long-term management aim for these estuaries should be to, firstly, retain the current level of seagrass and, secondly, try to restore seagrass to areas where it used to occur naturally. A first action should be to undertake a study to specifically gather together as much evidence as possible about the extent of seagrass in this region (including anecdotal historical information). This should include gathering information on when seagrass disappeared and any factors that may have been associated with this loss. Based on this, an expert assessment should be made on the most significant factors involved in seagrass loss. This would in turn help to direct future management actions. Programs to reduce catchment sediment loads should be implemented in any case, as these have many benefits in addition to assisting in seagrass recovery.

Habitat loss

Mangrove and saltmarsh habitat in most estuaries is largely intact. Estuary foreshore riparian zones are also mostly in good condition. However, in some estuaries, a significant proportion of the background vegetation has been lost. In part this is due to long standing agricultural activity but in some estuaries there is encroachment of rural residential blocks. This is likely to be an increasing trend in the future and, ideally, future subdivisions of this type should include a requirement for a buffer strip to protect estuarine habitat.

Vehicle access to estuarine areas is a significant issue resulting in habitat loss in some estuaries

In many of these estuaries there are localised issues impacting on habitat, such as cattle grazing in mangrove areas or 4WD vehicle use in saltmarshes. These issues are described in detail in Mackenzie and Duke (2009) and should be addressed as part of any habitat management plans.

Reduced freshwater inflows

Nearly all the larger systems examined have one or more impoundments in their catchment. In two systems (Burnett and Kolan) the impoundment volume exceeds 100% of median annual flow. This level of water storage has a large impact on freshwater inflows to an estuary. All but the largest flow events are unlikely to reach the estuary, which is thus starved of freshwater inflows. These intermittent inflows of freshwater are part of what makes up the essential nature of an estuarine environment and their loss means that what used to be an estuary becomes a more marine type of environment. Species that rely on inflows are disadvantaged and may disappear. While this does not have dramatically obvious effects, if we are concerned to maintain the diversity of our aquatic environments, we should aim to maintain some level of freshwater inflow into our estuaries.

Impoundments reduce the amount of freshwater reaching the estuary and can impact a variety of water quality parameters

The Burrum River has impoundment volumes that total about 35% of its annual median flow. While this is a lot less significant than 100%, it still has a major impact on inflows. Especially in the drier years, the low levels of storages may prevent any inflow at all from reaching the estuary. There is anecdotal evidence that the upper reaches of the Burrum estuary are experiencing ongoing build up of sediment because of the great reduction in flushing inflows that would normally wash this away.

In the other estuaries, storage volumes comprise a smaller proportion of annual median inflows. The impacts on inflows will clearly be less but not necessarily in proportion. As noted above, in dry years even small storages can have significant impacts on freshwater inflows. Unfortunately, the detailed impacts of reduced freshwater inflows on estuarine biota are poorly understood.

Returning inflows to estuaries to natural levels is clearly an unrealistic proposition. However, it is important that the Water Resource Plans and related Resource Operation Plans that have been or are being developed should take proper account of the environmental flow needs of estuaries. The problem with this is that it is extremely difficult to determine what level of inflow is the minimum requirement for an estuary. It may be that we need to quickly develop a guideline for estuary flow requirements based on best expert opinion and apply this until better knowledge is available.

The statistics on storage volume quoted above relate to what are termed referable storages. In virtually all catchments there are also a large number of smaller farm dams which are not usually accounted for in assessments of water resources. The impact of these on downstream flows has never been properly assessed. In some catchments it may be quite significant. It is therefore suggested that one or two catchments be selected for a pilot assessment of the impact of these smaller storages on overall water resources. The results of this would be used to direct further study or management action.

Herbicides

Levels of insecticides in both the sediment and water column in all estuaries were nearly always below detection limits. Herbicides were also nearly always below detection limits in sediments but were commonly detected in the water column of most estuaries. Generally, the levels detected were below the most stringent guideline values.

Cropping and horticultural activities are sources of toxicants in the region with contamination, usually herbicides, detected in every mainland estuary except Eurimbula

Using our current guideline values, toxicants in general do not appear to present a major risk to these estuaries. However, the detection of herbicides in a number of estuaries is an indication of the widespread use of these chemicals. Additionally, their unexpected presence in some near-pristine systems illustrates the pervasive nature of these compounds and how with even relatively low levels of use they still manage to find their way into waterways. In almost all cases the levels detected are thought to be too low to be of concern but their presence is a warning against complacency.

A cause for concern is that we do not know what the effect of combining these chemicals, even in very low concentrations, will be on estuarine species. In fact, the effect that the individual chemicals, at the concentrations detected, have on most estuarine species or their various life history stages is unknown.

Clearly, ongoing careful management of the application of these chemicals is essential.

SUMMARY OF REGIONAL MONITORING RECOMMENDATIONS

1. Implement more monitoring of seagrass within estuaries (where possible) or in the mouth/adjoining coastal areas influenced by estuarine waters – monitoring extent, % cover and epiphytic cover
2. Determine historical seagrass extent for all estuaries for future comparisons and management planning
3. Acquire baseline habitat mapping of Fraser Island estuaries for future reference/baseline and level of natural change comparisons
4. Improve processes for the monitoring and reporting of fish kills – including analysis of the cause of the kill
5. Develop/formalise processes for the monitoring and reporting of red-spot data
6. Acquire information on current management practices (and their level of implementation) within catchments. Due to a lack of this data information on management practices could not be assessed and included in the assessment
7. Implement ‘marine’ pest surveys – starting with estuaries at highest risk (Burnett, Mary and Snapper) but including some of the ‘negligible’ risk estuaries for comparison and confirmation
8. Acquire better information on the current level of pest infestation and locations – including information aquatic weed infestation of freshwater reaches
9. Acquire better information on estuary fisheries stocks and bait species (condition) and fisheries activities (pressures) (e.g. catch, usage, effort)
10. Acquire better information on the location of actual acid sulphate soils
11. Acquire better information on unsealed road density in region
12. Acquire information on septic density within catchments

Eurimbula Creek estuary

Overall assessment A

Overall risk	**A**	Very high confidence	95% dependability
Overall health	**A+**	High confidence	73% dependability

SUMMARY

The Eurimbula estuary is subject to a 'negligible' level of risk of damage due to human activities. As a result, the estuary's health is currently rated as 'excellent'. This suggests that under the current *status quo* the condition of the estuary will remain in this state of excellent health. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is also backed by high quality data but only 73% of the potential condition indicators were monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating results is still strongly supported.

All stressor were found to be at negligible or low risk levels. With the exception of 'litter' (poor condition) and 'aquatic sediments' (good condition) all stressor condition scores were reported as 'excellent' (Table 6).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 6. Summary of the stressor risk and condition scores for Eurimbula Creek estuary.

Stressor	Risk	Condition
Aquatic Sediments	Low	Good
Bacteria/Pathogens	Negligible	Excellent
Biota removal/ disturbance	Low	Excellent
Connectivity	Negligible	Excellent
Freshwater flow regime	Negligible	Excellent
Habitat removal/ disturbance	Negligible	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Low	Poor
Nutrients	Negligible	Excellent
Organic matter	Negligible	Excellent
Pests	Negligible	Excellent
pH	Negligible	Excellent
Toxicants	Low	Excellent

INTRODUCTION

Eurimbula Creek has a very small coastal catchment of only ~80 km^2. The predominant land use is conservation and natural environments (73%) with some grazing (25%). A small area of residential land (two houses) adjoins the estuary. The Eurimbula Creek system is relatively unmodified with only very limited areas of disturbed riparian vegetation (only ~6% of the estuary's shoreline is modified) and no artificial barriers to flow. A small camping site with facilities is located near the mouth of the estuary.

The estuary is short (~6 km long) with an average depth in the main channel of around 1 to 3 m. The actual spring tidal range near the mouth is unknown but would be around 2.5 m.

Satellite imagery of the Eurimbula Creek estuary

STRESSOR RESULTS

Aquatic sediments

Low risk	Very high confidence	90% dependability
Good condition	High confidence	75% dependability

Risk

Eurimbula Creek catchment has a very low level of development. Over 70% of it is in a conservation zone and only 4% has been cleared. Nearly all the creek system's riparian zone is intact and other sediment risk factors are also low. Thus the overall risk with respect to sediment loads is low. The fact that the catchment is very small and therefore has limited capacity to generate sediment further reduces the risk.

Much of the catchment is within National Park

Indicators of suspended sediment sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.77	Low	High
PI2: % of catchment cleared	4	Low	Very high
PI3: % length of river system with no riparian vegetation	2	Negligible	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Low	Very high
PI6: unsealed road density (m/km^2)	160-250	Low	Low
PI7: % of catchment with intensive agriculture on steep slopes	0.8	Low	High
PI8: % of catchment with less than 70% ground cover	0.55	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	No data		

Condition

Data for turbidity and Secchi depth clarity is limited to less than one year of results at two sites. Turbidity levels are higher than would be expected but Secchi depth values meet the guidelines. Seagrass is not present but anecdotal evidence is that it was not present in historical times either. This may be partly due to the dynamic nature of the bottom sediments in the creek.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI1: turbidity (% of sites exceed guidelines)	50	Fair	High
CI2: Secchi depth (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No change	Excellent	Moderate
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

There are no significant risk factors, such as sewage discharges or urban stormwater, for this stressor in Eurimbula Creek. Other risk factors, such as septic systems or intensive animal production, are also low or non-existent.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI14: density of septics within catchment (per km^2)	2 houses in catchment	Low	Very high
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤36 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems certain that this stressor is not an issue in the Eurimbula estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	29	Excellent	High
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Low risk	High confidence	100% dependability
Excellent condition	High confidence	17% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Due to its isolation, fishing pressure in the estuary is relatively low

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no

reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

Both recreational and commercial fishing pressure in Eurimbula Creek is low. Some trawling occurs within the adjoining coastal waters but not within the estuary itself. The resident population is negligible.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	None reported	Negligible	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	14	Low	High
PI21: 'estuary' population size (people/km^2)	2.852	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	None reported	Negligible	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	None reported	Negligible	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	6	Moderate	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	2487	Negligible	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

There is very limited data on fisheries catch in Eurimbula Creek. However, given the low level of pressure it is likely that fish stocks are in reasonable condition. Eurimbula Creek and all adjoining waterways are closed to the harvesting of mud crabs.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	No data		
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	High
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	No data		
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

Eurimbula Creek catchment contains no impoundments or other barriers to fish movement and is therefore in near natural situation with respect to this aspect of the stressor. The estuary's shoreline riparian vegetation is almost completely intact (6.1% modified – mostly in one section near the residential properties) and so there are minimal barriers to movement along the estuary foreshore.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	6.1	Low	High
PI32: % of estuarine 'background habitat' length modified	2.2	Negligible	Very high

Condition

As would be expected given the high level of connectivity, diadromous fish populations in the estuary are common and stable.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species common and population stable throughout system	Excellent	High

Freshwater flow regime

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There are no referable impoundments (larger storages that require a licence and which are accounted for in Water Resource Plans) in the Eurimbula Creek catchment and there are no farm dams either. Thus, risk to freshwater inflows is nil. However, owing to the small size of the catchment, inflows would always have been very limited anyway. Mackenzie and Duke (2009) suggest that groundwater inflows to the estuary are relatively important in this system.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	0	Negligible	High
PI34: % of catchment area covered by artificial waterbodies	0	Negligible	High
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of Eurimbula Creek, the negligible risk from reduced freshwater inflow suggests that impacts on the estuary are currently nil.

Habitat removal or disturbance

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

The estuary riparian zone has had little disturbance and is almost entirely intact. There are no significant human activities which would remove habitat, such as dredging, in this estuary. However, there are some issues, such as those associated with cattle grazing and vehicular tracks, that are causing localised damage (Mackenzie and Duke, 2009). A small percentage (6.1%) of the estuary's shoreline riparian vegetation has been modified – mostly in one section near the residential properties.

Shoreline and background vegetation is intact

Indicators of habitat removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	2.2	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	6.1	Low	High

Condition

There has been a slight increase in the extent of mangrove or saltmarsh habitat. Seagrass is absent (or maybe present at times but uncommon), but this appears to be the natural condition for Eurimbula Creek. Thus, overall habitat condition in Eurimbula Creek is very good. There are however, localised issues such as cattle grazing within upstream tidal wetlands, vehicle access and a small road may be restricting the movement of mangroves up the inter-tidal profile (Mackenzie and Duke, 2009).

Biological condition indicators	**Raw data**	**Condition score**	**Confidence**
CI3: change in seagrass extent (% change per year)	No change	Excellent	Moderate
CI14: change in mangrove extent (% change per year)	1.6% increase	Excellent	High
CI15: change in saltmarsh extent (% change per year)	1.8% increase	Excellent	High

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There has been only very minor anthropogenic physical modifications to Eurimbula Creek with two boat ramps and a small length of rock wall present. Therefore, the hydrodynamics of the estuary are close to natural.

Indicators of sources of changed hydrodynamic	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	1	Negligible	High
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the negligible risk for all pressure indicators in Eurimbula Creek it can be concluded that these impacts are currently nil.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

Litter risk factors in Eurimbula Creek are mostly low – local populations are small with no significant urban/residential areas. However, there is a moderate level of boating in the estuary and recreational usage (camp site present near the estuary mouth) which does present some risk.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	14	Low	High
PI21: 'estuary' population size (people/km^2)	2.852	Negligible	Very high
PI38: % of estuary adjoining urban area	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

Despite the low level of risk, Eurimbula Creek scored a 'poor condition' for the amount of litter present. All the litter sighted was removed and a follow up litter survey carried out three months later to assess accumulation rates. This scored only 'fair condition' indicating that significant amounts of littering had occurred in that period. Given the almost complete absence of a permanent population in the undisturbed catchment, the littering must be due to commercial and recreational boating activities and other visitors to the area.

Rubbish near Eurimbula estuary

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0105	Poor	High
CI17: litter accumulation rate (per m^2 per day)	0.000071	Fair	Moderate

Nutrients

Negligible risk	Very high confidence	80% dependability
Excellent condition	High confidence	88% dependability

Risk

The level of risk for all nutrient pressure indicators is low or negligible. This would be expected given the undisturbed nature of the catchment and the absence of any point discharges.

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.31	Negligible	High
PI3: % length of river system with no riparian vegetation	2	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.8	Low	High
PI8: % of catchment with less than 70% ground cover	0.55	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	No data		
PI42: % difference between pre-European total nitrogen load and current load	No data		

Condition

A limited data set is available for condition indicators – 19 samples in total over a 12 month period at two sites. However, the levels of both nutrients and chlorophyll-a were consistently low and met the guidelines. This is what would be expected given the low level of risk. Being a fairly short estuary, Eurimbula Creek is well flushed with clean ocean water and this predisposes the estuary to have good water quality.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	High
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	High
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	High
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Negligible risk	Very high confidence	83% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

All the catchment indicators monitored give a low or negligible level of risk for this stressor and there are no point sources. No data on the occurrence of aquatic weeds in the Eurimbula Creek system is available.

Indicators of organic matter sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.54	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.8	Low	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI43: % river system affected by aquatic weeds	No data		

Condition

Dry weather dissolved oxygen levels in Eurimbula Creek comply with guidelines at both sites. No significant wet weather events were captured but the minimum DO value detected over the 12 months was 61% saturation which indicates that catchment organic loads are not having significant impacts on condition, although the data set is small.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	61.1	Good	Low
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of Eurimbula estuary so the risk from these is negligible. There is a low risk from visiting non-trailerable boats, however this is minimal as the entrance is quite dangerous.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Small, non-trailerable, international/domestic vessels commonly visit estuary (generally just passing through)	Low	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in Eurimbula estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. However, it is quite possible that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Low confidence	100% dependability

Risk

No disturbance of potential acid sulphate soils have been recorded adjacent to Eurimbula Creek estuary so the potential risk of acid water entering the estuary from these is negligible.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	0	Negligible	Moderate

Condition

The minimum pH value detected over the 12 months was 6.9, which indicates that no acid run-off impacts are occurring.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6.9	Good	Low
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	None reported	Excellent	Low

Toxicants

Low risk	High confidence	100% dependability
Excellent condition	High confidence	67% dependability

Risk

Given the almost complete absence of agricultural activity or urban areas in the catchment, the current risk from toxicant is negligible from these sources. There is a small risk associated with the moderate level of boating occurring in the area.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.3	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.8	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that levels of all toxicants tested for were below detection limits, or in the case of metals, were below the most stringent guideline values. Given the overall low level of risk and the negligible risks associated with catchment land-use, this result is what would be expected.

Of interest is that in every other mainland system, some trace contamination, usually of herbicides, was detected. This illustrates the pervasive nature of these compounds and how with even relatively low levels of use they still manage to find their way into waterways. In almost all cases the levels are thought to be too low to be of concern but their presence is a warning against complacency.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	Not detected	Excellent	High
CI35c: toxicants in the water column (Diuron) (µg/L)	Not detected	Excellent	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	Not detected	Excellent	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	Not detected	Excellent	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	12	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.8	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	16	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	<6	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	<2	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	11	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	15	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		

Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Address litter issue – education initiatives, signage or other approaches

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species






Baffle Creek estuary

Overall assessment B+

Overall risk	C+	High confidence	99% dependability
Overall health	A+	High confidence	78% dependability

SUMMARY

The Baffle estuary is subject to a 'moderate' level of risk of damage due to human activities. However, the estuary's health is currently rated as 'excellent'. This suggests that unless management actions are taken to reduce this moderate risk then the condition of the estuary may remain in this state of excellent health or more likely deteriorate in the future. The overall risk rating reported is backed by a large amount of high quality data which provide strong support for the accuracy of this result. The overall health rating reported is also backed by high quality data but only 78% of the potential condition indicators were monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still strongly supported.

The only stressor reported with a negligible level of risk is 'hydrodynamics'. The majority are reported as low risk, however, 'nutrients', 'habitat removal/disturbance' and 'aquatic sediments' are reported as at moderate risk while 'biota removal/disturbance' is at high risk.

The majority of condition scores for stressors are reported as 'excellent', however, 'organic matter' and 'freshwater flow regime' were in good condition while 'litter' and 'biota removal/disturbance' were only in fair condition (Table 7).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 7. Summary of the stressor risk and condition scores for Baffle Creek estuary.

Stressor	Risk	Condition
Aquatic Sediments	Moderate	Excellent
Bacteria/Pathogens	Low	Excellent
Biota removal/ disturbance	High	Fair
Connectivity	Low	Excellent
Freshwater flow regime	Low	Good
Habitat removal/ disturbance	Moderate	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Low	Fair
Nutrients	Moderate	Excellent
Organic matter	Low	Good
Pests	Low	Excellent
pH	Low	Excellent
Toxicants	Low	Excellent

INTRODUCTION

Baffle Creek has a moderate sized coastal catchment (~2,500 km^2) which has been developed mainly for grazing (78%), with only 12% classified as 'conservation and natural environments. The stream system itself is hydrologically unmodified with no artificial barriers to stream flow, however, water

extractions do occur. Large areas of seagrass occur along the estuary (at least up to 16 km from the mouth).

The estuary is about 36 km long and has a spring tidal range of around 2.5m. Depths vary between 2 m and 4 m. There is one small aquaculture facility that discharges at approximately 8.5 km from the mouth.

A small town (Winfield) is located in the lower part of the estuary.

Satellite imagery of the Baffle Creek estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	75% dependability

Risk

Quite extensive areas of Baffle Creek catchment are under modified land-use (e.g. 78% is under grazing) with only a small proportion (12%) classified as 'conservation and natural environments' which gives it a high risk score for sediment. Similarly, SedNet model sediment loads for the Baffle indicate significant increases over natural. However, much of the grazing is on unmodified pasture so the risk may not be as high as the figures suggest. Also, only 0.1% of the catchment has ground cover of less than 70%, which may suggest a reduced risk for sediment run-off from catchment land-use activities. Moderate levels of clearing (26%) and riparian vegetation loss (16%) have occurred within the catchment.

26% of the catchment has been cleared

Indicators of suspended sediment sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.53	High	High
PI2: % of catchment cleared	26	Moderate	Very high
PI3: % length of river system with no riparian vegetation	16	Moderate	Very high
PI4: number of point sources per km estuary	0.03	Low	Very high
PI5: boating activity within the estuary	Recreational vessels only	Negligible	Very high
PI6: unsealed road density (m/km^2)	250-330	Moderate	Low
PI7: % of catchment with intensive agriculture on steep slopes	0.32	Low	High
PI8: % of catchment with less than 70% ground cover	0.1	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	3078	Moderate	Moderate

Condition

There is an extensive data set for both turbidity and Secchi depth clarity with all sites in the estuary meeting the guidelines. More importantly, Baffle Creek estuary is one of the few estuaries in central Queensland that has retained extensive seagrass beds. This is a strong indication that the effects of fine sediments have been limited up to this point. Whether this remains the case as the catchment develops remains to be seen. Ongoing monitoring of the seagrass extent would provide a good indication of this.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	Very high
CI2: Secchi depth (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	Good coverage to ≈16 km ATM and variety species	Excellent	Low
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Low risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges or urban stormwater for this stressor. Housing density in the catchment is low so that the risk from septics is probably not high, although there is no specific data on this. There is some intensive animal production which may create a small risk of bacteria entering the estuary. The risk of pathogens entering the estuary from aquaculture facilities is also relatively small.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	1.039	Moderate	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0.1	Low	High
PI17: boat moorings	Small craft mooring sites identified	Low	Very high
PI16: number of 'marine' aquaculture facilities present	3	Moderate	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤14 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but combined with the low level of risk, it seems unlikely that this stressor is a significant issue in the Baffle.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	13	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

High risk	High confidence	100% dependability
Fair condition	High confidence	100% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Recreational fishing and crabbing are important activities in the estuary

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

Baffle Creek has a small resident population but the number of recreational fishers is high and presents an extreme level of risk. Recreational fish take is also high. Associated with the high levels of recreational fishing are high levels of recreational bait collection. Levels of commercial fishing and crabbing in the estuary and adjoining coastal waters are also very significant.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	15.8	Extreme	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	Small craft mooring sites identified	Low	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	21	Moderate	High
PI21: 'estuary' population size (people/km^2)	1.395	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	13.1	Extreme	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	3.03	Extreme	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Low	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Low	High

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	156	High	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	119752	High	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Commercial and recreational CPUE of finfish and prawns appears to be increasing (only a slight decrease in recreational finfish CPUE) and indicates that fish and prawn stocks are reasonably stable. However, there are significant decreases in the commercial and recreational CPUE of crabs. These results indicate that crab stocks appear to be decreasing and that the level of crabbing effort may not be sustainable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	20.6% decrease	Poor	High
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	High
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	4.1% decrease	Good	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	11.3% decrease	Fair	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	Moderate

Connectivity

Low risk	Very high confidence	100% dependability
Excellent condition	Very high confidence	100% dependability

Risk

Baffle Creek has probably the best connectivity of any of the larger estuaries in central/SE Queensland. There are no significant weirs or barrages on the estuary or in the freshwater reaches of the system. There has been a moderate amount of clearing of background vegetation (i.e. vegetation behind the riparian zone) that may impact terrestrial fauna movement. Limited shoreline modifications have occurred and result in a low risk of connectivity impacts.

Some areas of estuarine foreshore and background vegetation have been removed

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	13.5	Low	High
PI32: % of estuarine 'background habitat' length modified	49.1	Moderate	High

Condition

As would be expected given the high level of connectivity, diadromous fish populations in the estuary are common and stable.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species common and population stable throughout system	Excellent	Very high

Freshwater flow regime

Low risk	Very high confidence	100% dependability
Good condition	Assumed condition from risk	

Risk

The Baffle Creek system has no artificial barriers to freshwater flow. The volume of referable impoundments (larger storages that require a licence and which are accounted for in Water Resource Plans) and water extractions is less than 20% of median annual flow and so has only a low risk score. There are a number of artificial waterbodies, such as farm dams, which cover only 0.15% of the catchment – also resulting in only a low risk score, though their impact remains to be quantified.

While there are no impoundments, some water is directly extracted from the river system

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	<20	Low	High
PI34: % of catchment area covered by artificial waterbodies	0.15	Low	High
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of Baffle Creek, the low risk from reduced freshwater inflow suggests that it is unlikely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Moderate risk	Very high confidence	100% dependability
Excellent condition	Low confidence	100% dependability

Risk

Only a small percentage (13.5%) of the estuary's shoreline has been lost although changes to the background vegetation are much more significant (49% modified). There are no significant human activities which would remove habitat, such as dredging, in this estuary. There are some significant issues, such as those associated with cattle grazing, that are causing localised damage (Mackenzie and Duke, 2009).

In some areas cattle are allowed to graze down to the waterline

Indicators of habitat removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	3	Moderate	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	49.1	High	High
PI31: % of estuarine 'shoreline' length modified (habitat)	13.5	Low	High

Condition

There has been very little, and only localised, loss of either mangrove or saltmarsh habitat in the Baffle Creek estuary (the overall extent of both habitats has increased). Similarly, seagrass appears to still be abundant with a variety of species found and extending to 16 km upstream from the mouth. Thus, overall habitat condition in Baffle estuary is excellent. There are however, some localised issues, particularly related to grazing within estuarine habitats, noted by Mackenzie and Duke (2009).

Biological condition indicators	**Raw data**	**Condition score**	**Confidence**
CI3: change in seagrass extent (% change per year)	Good coverage to ≈16 km ATM and variety species	Excellent	Low
CI14: change in mangrove extent (% change per year)	0.3% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	1.4% increase	Excellent	Moderate

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

With the exception of some shoreline modifications which affect hydrodynamics (in the form of a few jetties/pontoons and boat ramps, and small areas of rock, tyre or wood walls), there have been no significant physical modifications to Baffle Creek that would alter the hydrodynamics of the estuary.

Indicators of sources of changed hydrodynamic	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	11	Low	High
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Shoreline modifications such as wood or rock walls, boat ramps, pontoons and jetties can alter the natural hydrodynamics of the estuary

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall negligible risk in Baffle Creek it can be concluded that these impacts are likely to be insignificant.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

Litter risk factors in Baffle Creek are mostly low, local populations are small with no significant urban areas. However, there is a high level of recreational use of the estuary which does present some risk.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	21	Moderate	High
PI21: 'estuary' population size (people/km^2)	1.395	Negligible	Very high
PI38: % of estuary adjoining urban area	4.72	Low	High
PI15: number of stormwater inflows per km estuary	0.1	Low	High

Condition

Despite the small local populations, Baffle Creek exhibited moderate levels of litter and ongoing littering. The most likely cause of this is the recreational users of the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0033	Fair	High
CI17: litter accumulation rate (per m^2 per day)	0.000013	Fair	Moderate

Nutrients

Moderate risk	High confidence	100% dependability
Excellent condition	Very high confidence	88% dependability

Risk

The risk level for most indicators of catchment nutrient sources is low, although up to 16% of the riparian zone has been lost. SedNet model calculations do however indicate that there has been a significant increase in catchment nutrient loads compared to natural.

Freshwater wetlands and riparian vegetation in much of the upper catchment is intact

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.05	Low	High
PI3: % length of river system with no riparian vegetation	16	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.32	Low	High
PI8: % of catchment with less than 70% ground cover	0.1	Low	High
PI15: number of stormwater inflows per km estuary	0.1	Low	High
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	654	High	Moderate
PI42: % difference between pre-European total nitrogen load and current load	277	Moderate	Moderate

Condition

There is an extensive water quality data set for Baffle Creek. Levels of both nutrients and chlorophyll-a are low and meet guidelines at all times. Significant inflows from the catchment would introduce short-term high loads of nutrients but there is no indication in the extensive data set that this leads to unusually high algal growth. The presence of healthy seagrass beds also indicates that nutrients are not having a significant impact on Baffle Creek.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Low risk	High confidence	100% dependability
Good condition	High confidence	100% dependability

Risk

Most catchment indicators give a low to moderate level of risk for this stressor. The catchment is mostly under grazing land use and there are no particular risk factors apart from small areas of intensive animal production. There are no significant point discharges of organic matter to the estuary.

Loads from the small aquaculture facility would be minimal. Less than 2% of the Baffle Creek system is affected by aquatic weeds so any impact of these being flushed down after flow events would likely be minimal.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.88	Moderate	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.32	Low	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	1.039	Moderate	High
PI43: % river system affected by aquatic weeds	≤2	Low	Low

Condition

Dry weather dissolved oxygen levels in Baffle Creek comply with guidelines at all sites indicating that discharges are not having a significant impact on this indicator. The lowest levels of dissolved oxygen in the estuary occur following freshwater flow events and are associated with catchment organic matter loads. However, the minimum value recorded over ~15 years of EPA sampling in the estuary was 48% saturation which is not indicative of an abnormal catchment impact.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	48	Fair	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of Baffle estuary so the risk from these is negligible. There is some risk from visiting boats because there are some permanent moorings in the estuary with occasional visits from overseas boats. The aquaculture facility presents a minor risk of species escaping into the estuary and becoming a pest.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Moorings for small, non-trailerable, international/domestic vessels present (published in boating guides/well know by boaties)	Moderate	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	3 land based facilities present	Moderate	Very high

Condition

No surveys to detect pest species have been carried out in Baffle estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this time. However, it is quite possible that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There are only limited disturbance of potential acid sulphate soils adjacent to Baffle Creek estuary so the potential risk of acid water entering the estuary from this is low, particularly as the level of urbanisation is minor. However, given the growth of population in the area, there may be an increased risk of acid soils being disturbed in the future.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	3.5	Low	Moderate

Condition

There is an extensive data set for pH and there is no indication of the low levels associated with acid drainage. The minimum value detected in over ~15 years of EPA sampling in the estuary was 6.7.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6.7	Good	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Low risk	High confidence	100% dependability
Excellent condition	High confidence	67% dependability

Risk

Due to the low level of cropping/horticulture and mining activity in the catchment, the current risk from toxicants is relatively low.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.04	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.32	Low	High
PI15: number of stormwater inflows per km estuary	0.1	Low	High
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were always below the most stringent guideline values.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.0004	Good	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.0003	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0001	Good	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0053	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	0.001	Good	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	4	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	18	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	11	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	9	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	7.5	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	29	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Baffle Creek estuary is the least impacted of the larger estuaries in the Burnett Mary region. It is highly desirable that it is maintained in its current good condition as a representative of what natural condition in these estuaries should be. Baffle Creek has high ecological values that should be protected.

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse source pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Introduce initiatives to reduce pressure on crab populations, e.g. no take zones
3. Ensure that the Baffle Water Resource Plan affords a high level of priority to environmental flows to the estuary. In order to maintain this estuary in its near pristine state, there should be no construction of any large storages in the catchment

4. Construction of barriers in the catchment waterways should be discouraged and any that are built should have effective fishways.
5. Encourage revegetation of background 'buffer' vegetation along the estuary and target localised mangrove and saltmarsh habitat degradation/loss (as reported in Mackenzie and Duke, 2009)
6. Address litter issue – education initiatives, signage or other approaches
7. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation
8. Introduce/maintain catchment management initiatives aimed at reducing toxicant (pesticide) loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of mangrove and saltmarsh habitat extent
3. Regular (annual/biannual) monitoring seagrass areas (extent, % cover, % epiphyte cover) – via seagrass watch
4. In light of Baffle Creek being a high value aquatic ecosystem and our incomplete knowledge of toxicant effects on estuarine biota a detailed monitoring program for toxicants to fully assess future management actions seems prudent

Littabella Creek estuary

Overall assessment B

Overall risk	C	Very high confidence	97% dependability
Overall health	A	Moderate confidence	71% dependability

SUMMARY

The Littabella Creek estuary is subject to a 'moderate' level of risk of damage due to human activities. However, the estuary's health is currently rated as 'excellent'. This suggests that unless management actions are taken to reduce this moderate risk then the condition of the estuary may remain in this state of excellent health or more likely deteriorate in the future. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is backed by only moderate quality data with 71% of the potential condition indicators monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still supported though more data to improve the confidence level would be beneficial.

The only stressors reported with a negligible level of risk were 'hydrodynamics', 'litter' and 'pests'. Four others are reported as low risk, five as moderate risk and one at high risk ('freshwater flow regime').

The majority of condition scores for stressors are reported as 'excellent' with 'biota removal/disturbance' found to be in good condition. However, 'connectivity' was only in fair condition, 'freshwater flow regime' was in poor condition, and 'litter' was in very poor condition (Table 8).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 8. Summary of the stressor risk and condition scores for Littabella Creek estuary.

Stressor	Risk	Condition
Aquatic Sediments	Moderate	Excellent
Bacteria/Pathogens	Low	Excellent
Biota removal/ disturbance	Low	Good
Connectivity	Moderate	Fair
Freshwater flow regime	High	Poor
Habitat removal/ disturbance	Low	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Negligible	Very Poor
Nutrients	Moderate	Excellent
Organic matter	Moderate	Excellent
Pests	Negligible	Excellent
pH	Moderate	Excellent
Toxicants	Low	Excellent

INTRODUCTION

Littabella Creek has a small coastal catchment of only ~300 km^2. The predominant land use is grazing (52%) and 'conservation and natural environments' (33%). There is some forestry (7%) and cropping (6%) as well as intensive animal production (2%) is present. There is one point discharge to the

estuary from an aquaculture facility but no urbanised areas. A single impoundment is present on a tributary (Walsh Creek) of the river system. The estuary is relatively unmodified with limited areas of disturbed mangrove and saltmarsh vegetation (only ~9% is of the shoreline is modified).

The estuary is short (~12 km long). The actual spring tidal range near the mouth is unknown but would be around 2.5 m.

Satellite imagery of the Littabella Creek estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	25% dependability

Risk

Littabella Creek has moderate scores for most sediment pressure indicators. Around 21% of the catchment has been cleared of natural vegetation and there is some cropping, particularly adjacent to the upper reaches of the estuary and on the south side of the lower freshwater reaches of the Littabella Creek tributary. There has also been a significant loss (24%) of the systems riparian vegetation.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	3.03	Moderate	High
PI2: % of catchment cleared	21	Moderate	Very high
PI3: % length of river system with no riparian vegetation	24	High	Very high
PI4: number of point sources per km estuary	0.08	Moderate	Very high
PI5: boating activity within the estuary	Recreational vessels only	Negligible	Very high
PI6: unsealed road density (m/km^2)	250-330	Moderate	Low
PI7: % of catchment with intensive agriculture on steep slopes	1.56	Moderate	High
PI8: % of catchment with less than 70% ground cover	0.34	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	1300	Low	Moderate

Condition

The relatively limited amount of turbidity data available indicated that values were relatively low, at least during dry weather, with no exceedance of guidelines. However, no wet weather data is available. No data was available for seagrass.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	High
CI2: Secchi depth (% of sites exceed guidelines)	No data		
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data (none found during EPA 2008 survey)		
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Low risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges or urban stormwater for this stressor in Littabella Creek. There is a moderate risk from some limited areas of intensive animal production. Housing density in the catchment is low so that the risk from septics is probably not high, although there is no specific data on this.

Indicators of bacteria/pathogen sources	**Raw data**	**Risk score**	**Confidence**
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	2.129	Moderate	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤8 cfu/100 mL, which meets the primary contact guideline. However, only a few samples were collected.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	8	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Low risk	High confidence	100% dependability
Good condition	Moderate confidence	50% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

Littabella Creek has a small resident population and low levels of recreational use – small numbers of fishers, no permanent moorings, low levels of boating activity. Most indicators returned low or negligible scores. Commercial use is reported as more significant, particularly net fishing and crabbing which have a moderate risk score, however, these mostly these activities occur in the adjoining coastal waters.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	0.4	Negligible	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	12	Low	High
PI21: 'estuary' population size (people/km^2)	3.866	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	0.1	Negligible	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.07	Negligible	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	6	Moderate	Moderate
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	72	Moderate	Moderate
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	73859	Moderate	Moderate
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate level of confidence.

Commercial CPUE indicators show no evidence of any decline which suggests that populations in the estuary and adjoining coastal waters are reasonably stable. Conversely, recreational CPUE from within the estuary shows a small decline, despite the relatively low level of activity.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	Moderate
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	13.3% decrease	Fair	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Moderate risk	High confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

There is a barrage on the Walsh Creek tributary that completely blocks fish movement to the freshwater reaches above it. There are also some small impoundments on Landsborough Creek tributary that isolate the upper freshwater reaches of that system. However, overall, less than 20% of the total freshwater reaches are cut of from the estuary. The catchment has a high score for impoundment density but this is due to the creek system's small size. There are quite a number of small impoundments on gully lines rather than the main stems of the tributaries but the main impact of these is on freshwater inflow rather than connectivity. Estuary shoreline (9% modified) and background (21% modified) habitat is largely intact so connectivity along the riparian zone is still good.

Much of the estuary's shoreline remains intact

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	<20%	Low	High
PI29: impoundment density (per 500 km of river)	7.49	High	High
PI31: % of estuarine 'shoreline' length modified (habitat)	8.9	Low	High
PI32: % of estuarine 'background habitat' length modified	20.8	Low	Very high

Condition

Despite the relatively good connectivity between freshwater and estuarine reaches of the system, diadromous species have become rare but a few populations are still present. The reason for this decline is not known, but may be a natural attribute of this system.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species have become rare but a few populations are still present	Fair	High

Freshwater flow regime

High risk	High confidence	100% dependability
Poor condition	Assumed condition from risk	

Risk

The volume of referable impoundments (larger storages that require a licence and which are accounted for in Water Resource Plans) is less than 20% of median annual flow and so has only a low risk score. However, there are a number of artificial waterbodies such as farm dams present, which cover 0.57% of the catchment – resulting in a moderate risk score, though their impact remains to be quantified. The combined volumes of these would probably significantly increase the total impoundment volume. The catchment has a high score for impoundment density but this is due to the creek system's small size.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	<20	Low	High
PI34: % of catchment area covered by artificial waterbodies	0.57	Moderate	High
PI29: impoundment density (per 500 km of river)	7.49	High	High

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of Littabella Creek, the high risk from reduced freshwater inflow suggests that it is quite likely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Low risk	Very high confidence	100
Excellent condition	Moderate confidence	67% dependability

Risk

Only a small percentage of the estuary's shoreline (9%) has been lost although changes to the background vegetation are more significant (21% modified). There are no significant human activities which would remove habitat, such as dredging, in this estuary. There are some significant issues, such as those associated with cattle grazing, altered hydrology and reduced freshwater inflows, that are causing localised damage (Mackenzie and Duke, 2009).

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	20.8	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	8.9	Low	High

Condition

There has been very little, and only localised, loss of either mangrove or saltmarsh habitat in the Littabella Creek estuary (the overall extent of both habitats has increased). No seagrass was found in the estuary during June 2008 surveys but it is not known if seagrass was ever present or if it was then to what extent. With respect to shoreline habitat, the estuary is in reasonably good condition,

particularly in the lower reaches. Thus, overall habitat condition in Littabella estuary is excellent. There are however, some localised habitat issues as noted by Mackenzie and Duke (2009) and in relation to shoreline modification.

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	No data (none found during EPA 2008 survey)		
CI14: change in mangrove extent (% change per year)	2.9% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	12% increase	Excellent	Moderate

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

With the exception of some very minor shoreline modifications which affect hydrodynamics (in the form of a few jetties/pontoons and boat ramps, and small areas of rock, tyre or wood walls), there have been no significant physical modifications to Littabella Creek that would alter the hydrodynamics of the estuary. The most significant is the small rock training wall at the north side of the entrance. A barrage is present on Walsh Creek but this is above the tidal limit.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	25 m rock wall at mouth	Low	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	2	Negligible	High
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall negligible risk in Littabella Creek it can be concluded that these impacts are likely to be insignificant.

Litter (rubbish)

Negligible risk	Very high confidence	100% dependability
Very poor condition	High confidence	100% dependability

Risk

Given the low population adjacent to the estuary and in the catchment and also the low level of recreational use, the risk of litter is low.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	12	Low	High
PI21: 'estuary' population size (people/km^2)	3.866	Negligible	Very high
PI38: % of estuary adjoining urban area	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

Despite the low risk, a litter survey showed a very high level of litter in the estuary. The reason for this unexpected result is not known and probably deserves further investigation. A more complete analysis of litter might assist.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.1778	Very poor	High
CI17: litter accumulation rate (per m^2 per day)	0.000317	Poor	Moderate

Nutrients

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	88% dependability

Risk

Catchment indicators of nutrient risk range from low to high. There is a fairly low level of bare ground in the catchment but a large percentage of the creek system's riparian vegetation has been lost (24%). There is also some intensive agriculture on steep slopes. There are no major point discharges to the estuary although a aquaculture facility may contribute a small load. SedNet model calculations indicate that there has been a low to moderate increase in catchment nutrient loads compared to natural.

Aquaculture can be a source of nutrients, bacteria/pathogens and organic matter to the estuary

Indicators of nutrient sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.96	Low	High
PI3: % length of river system with no riparian vegetation	24	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	1.56	Moderate	High
PI8: % of catchment with less than 70% ground cover	0.34	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0.08	Moderate	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	178	Moderate	Moderate
PI42: % difference between pre-European total nitrogen load and current load	147	Low	Moderate

Condition

Levels of nutrients and chlorophyll-a in Littabella Creek were low and met guidelines at all times. The data set is fairly small but clearly nutrient enrichment in dry weather is not a significant issue. The effects of diffuse catchment loads following flow events is not known but given the moderate level of risk, they are probably not unusually large.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	High
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	High
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	High
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Moderate risk	Very high confidence	83% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

Most pressure indicators give a moderate level of risk for this stressor. This is due to agricultural activity in the catchment and the presence of the aquaculture operation. No data on the occurrence of aquatic weeds in the Littabella Creek system is available.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.59	Moderate	High
PI4: number of point sources per km estuary	0.08	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	1.56	Moderate	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	2.129	Moderate	High
PI43: % river system affected by aquatic weeds	No data		

Condition

Dissolved oxygen levels in Littabella Creek comply with guidelines at all sites in dry weather which indicates that discharges are not having a significant impact on this indicator. The lowest levels of dissolved oxygen measured occurred following a freshwater inflow and is associated with catchment organic loads. However, the minimum value of 68% is not indicative of any abnormal impact from the catchment. However, the data set is very small and so conclusions related to wet weather impacts are of low reliability.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	67.7	Good	Low
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators	0		
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of Littabella estuary so the risk from these is negligible. Boat usage in Littabella Creek is largely restricted to trailerable boats or local commercial operators. There are no permanent moorings and visitation from overseas yachts is unlikely. The aquaculture facility presents a minor risk of species escaping into the estuary and becoming a pest. Thus the overall risk of pest species being introduced is negligible.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	No port/harbour/marina or permanent moorings present. Non-trailerable, international/domestic vessels rarely visit estuary	Negligible	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	1 land based facility present	Low	Very high

Condition

No surveys to detect pest species have been carried out in Littabella estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. However, it is quite possible that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Moderate risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There is some disturbance of potential acid sulphate soils adjacent to Littabella Creek estuary so the potential risk of acid water entering the estuary is moderate. However, given the limited development in the area, apart from the aquaculture facility, the realised risk from these deposits is not great.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	5.2	Moderate	Moderate

Condition

The relatively small data set shows that pH levels in the estuary are within the normal range and there is no indication of any acid drainage. However, further measurements after significant flow events would be useful to confirm this.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6.6	Good	Low
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Low risk	High confidence	100% dependability
Excellent condition	High confidence	67% dependability

Risk

Due to the low level of cropping/horticulture and mining activity in the catchment, the current risk from toxicants is relatively low. There is however, potential for increased horticultural activity in the future which would measurably increase the risk.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.94	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI7: % of catchment with intensive agriculture on steep slopes	1.56	Moderate	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were always below the most stringent guideline values.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.0008	Good	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.0019	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	Not detected	Excellent	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0002	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	11	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	21	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	8	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	<1	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	8.8	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	30	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	0.0006	Good	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

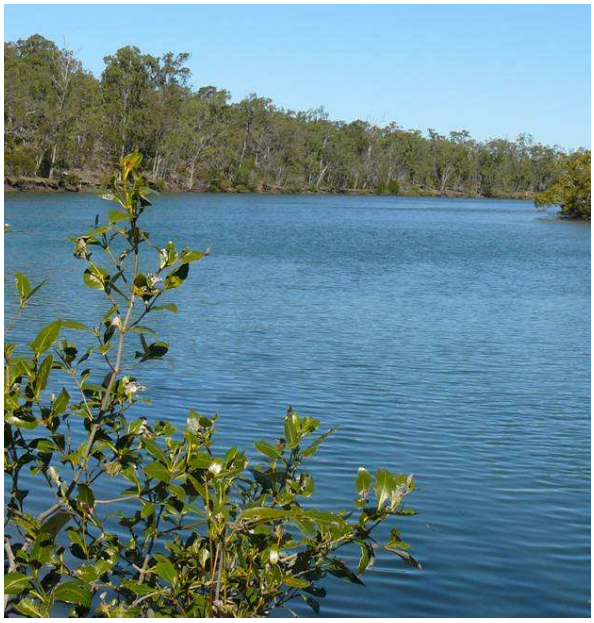
Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Construct effective fishway on Walsh Creek barrage
3. Investigate impact of farm dams on water resources in the catchment
4. Address litter issue – education initiatives, signage or other approaches
5. Investigate cause of high litter presence (a more complete analysis of litter might assist) to help determine management needs
6. Encourage revegetation of background ‘buffer’ vegetation along the estuary and target localised mangrove and saltmarsh habitat degradation/loss (as reported in Mackenzie and Duke, 2009)

7. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation

Monitoring

1. Four yearly assessment of habitat extent including riparian zones



Kolan River estuary

Overall assessment C

Overall risk	**C-**	Very high confidence	99% dependability
Overall health	**C+**	High confidence	96% dependability

SUMMARY

The Kolan estuary is subject to a 'moderate' level of risk of damage due to human activities. As a result, the estuary's health is currently rated as 'fair'. This suggests that under the current *status quo* the condition of the estuary will remain in this state of fair health. The overall risk and health ratings reported are backed by a large amount of very high and high quality data which provide strong support for the accuracy of these results.

The only stressors reported with a negligible level of risk are 'bacteria/pathogens' and 'pests', however, four others were found to have low risk. Two others are reported as moderate risk, while four are at high risk and one is at an extreme level of risk ('freshwater flow regime').

Only four of the condition scores for stressors are reported as 'excellent', with another two classified as in good condition. 'Biota removal/disturbance' and 'connectivity' are only in fair condition, 'habitat removal/disturbance', 'hydrodynamics' and 'litter' are in poor condition while 'aquatic sediments' and 'freshwater flow regime' are in very poor condition (Table 9).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 9. Summary of the stressor risk and condition scores for Kolan River estuary.

Stressor	Risk	Condition
Aquatic Sediments	High	Very Poor
Bacteria/Pathogens	Negligible	Excellent
Biota removal/ disturbance	High	Fair
Connectivity	High	Fair
Freshwater flow regime	Extreme	Very Poor
Habitat removal/ disturbance	Low	Poor
Hydrodynamics	High	Poor
Litter	Moderate	Poor
Nutrients	Moderate	Good
Organic matter	Low	Excellent
Pests	Negligible	Excellent
pH	Low	Good
Toxicants	Low	Excellent

INTRODUCTION

The Kolan River has a moderate sized modified catchment (~2,900 km^2) with some areas of cropping agriculture (6%), mainly sugar cane, in the lower catchment and extensive clearing for grazing (74%) in the mid and upper catchment. Forestry (8%) activities also occurs. Only 6% of the catchment is classified as 'conservation and natural environments'.

The estuary is about 15 km long and terminates at a tidal barrage which has shortened the estuary by approximately 50%. Depth varies between 2 m and 4 m and the spring tidal range is around 2.0 m.

Three impoundments occur along the river system with a large water storage (Fred Haigh Dam) located in the mid catchment area (approximately 80 km upstream) and which captures a significant proportion of catchment flows (the dam capacity is approximately 100% of median annual flow). Some of this water is transferred to the Burnett River catchment. The estuary receives no point discharges but a small amount of dredging does occurs.

Satellite imagery of the Kolan River estuary

STRESSOR RESULTS

Aquatic sediments

High risk	High confidence	100% dependability
Very poor condition	High confidence	100% dependability

Risk

Significant amounts of bank erosion occur along the estuary

The Kolan catchment is extensively modified, particularly in the rivers mid and lower reaches. Around 74% of the catchment is used for grazing while there are large areas of cropping in the lower catchment. Around 37% of the catchment has been cleared and 32% of the river system's riparian vegetation has been removed. Thus the level of risk for sediments is quite high. SedNet calculations estimate that sediment loads have increased by 3080% over natural (i.e. 31 times greater). There are some factors that act to reduce sediment loads. The Fred Haigh dam is large enough to trap all upstream sediment loads but this only accounts for a moderate proportion of the catchment. Further downstream, Bucca weir and the Kolan Barrage are much smaller but would trap some of the lower catchment sediment loads. Within the estuary there is a small amount of dredging that might also contribute resuspended sediment.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	3.73	High	High
PI2: % of catchment cleared	37	High	Very high
PI3: % length of river system with no riparian vegetation	32	High	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Low	Very high
PI6: unsealed road density (m/km^2)	160-250	Low	Low
PI7: % of catchment with intensive agriculture on steep slopes	0.66	Low	High
PI8: % of catchment with less than 70% ground cover	0.3	Low	High
PI9: dredging activity in river system (licensed amount)	<5,000t/a estuary	Low	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	3080	Moderate	Moderate

Condition

An extensive water quality data set is available for the Kolan. This shows that turbidity and Secchi depth clarity in the estuary meet guidelines at most sites, with only the most upstream site failing guidelines by a small margin. The reason that the potentially large catchment sediment loads are not having more impact on estuary condition relates to the fact that significant inflows to the estuary only occur occasionally. These impact turbidity for several weeks but, subsequently, the fine sediment is settled out in deposition areas or dispersed out of the estuary by tidal exchange. Following this, the estuary reverts to a typical dry weather pattern which is to some extent independent of flood event loads. This pattern is driven by tidal movement and exhibits a consistent neap/spring tidal cycle. The residual impact of catchment sediment loads on dry weather estuary water quality is not known. However, the limited available evidence suggests that the Kolan estuary did once have seagrass and this has now all but disappeared, which may be due to reductions in clarity compared to natural.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	20	Fair	Very high
CI2: Secchi depth (% of sites exceed guidelines)	20	Fair	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	100% lost	Very poor	Low
CI4: % cover of seagrass	100% lost	Very poor	Low

Bacteria/Pathogens

Negligible risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges or urban stormwater for this stressor in the Kolan estuary. There is only a limited amount of intensive animal production. Housing density in the catchment is low so that the risk from septics is probably not high, although there is no specific data on this. A camping/caravan site near the estuary mouth may present a low level of risk.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.12	Low	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤22 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems very probable that this stressor is not an issue in the Kolan estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	22	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

High risk	High confidence	100% dependability
Fair condition	High confidence	100% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Government regulations can help to reduce the pressure from human activities

Risk

The Kolan estuary and adjacent coastal waters experience quite a high level of both recreational and commercial fishing and both result in significant levels of catch. There is also recreational bait collecting but no commercial collection. The residential population is relatively small but there is a moderate level of recreational use of the estuary.

A small amount of dredging occurs in the estuary which may impact on benthic organisms although the significance of this impact is not known.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	<5,000t/a	Low	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	4.5	Moderate	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	19	Moderate	High
PI21: 'estuary' population size (people/km^2)	9.273	Low	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	5.8	High	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	2.57	High	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	21	High	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	18	High	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	174	High	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	143319	High	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Commercial and recreational CPUE of finfish and prawns appears to be increasing and indicates stable fish and prawn stocks. Commercial crab CPUE is also stable but there is evidence of a decline in the recreational CPUE of crabs – though this value has only a moderate level of confidence.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	Increase	Excellent	High
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	High
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	16.4% decrease	Poor	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	Moderate

Connectivity

High risk	Very high confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

The Kolan Barrage has a working fishway that allows access to some of the lowland riverine areas. However, Bucca Weir which is not much further upstream does not allow fish passage and as a result, 82% of the freshwater reaches cannot be accessed by migratory fish from the estuary.

Significant areas of estuary foreshore and background vegetation have been lost

The catchment has three major impoundments which give it a moderate score for impoundment density. Estuary shoreline (15% modified) and background (32% modified) habitat is somewhat disturbed so connectivity along the riparian zone will be affected.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	82.1	Extreme	Very high
PI29: impoundment density (per 500 km of river)	1.66	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	14.6	Low	Very high
PI32: % of estuarine 'background habitat' length modified	31.2	Moderate	Very high

Condition

As would be expected from the low level of connectivity, diadromous fish populations are rare. However, a few populations are still present, which may be due to the working fishway on the barrage. It should be noted that the efficacy of the fishway is to some extent dependent on the level of water behind the barrage and this in turn is dependent on the management of flows and draw down in the river system as a whole (A. McDougall, 2008, pers. comm., NRW).

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species have become rare but a few populations are still present	Fair	High

Freshwater flow regime

Extreme risk	Very high confidence	100% dependability
Very poor condition	Assumed condition from risk	

Risk

The water storage volume in the Kolan system is 127% of annual median flow and thus inflows to the estuary are very significantly altered compared to natural. There are also a number of artificial waterbodies such as farm dams present, which cover 2.28% of the catchment – resulting in a high risk score, though their impact remains to be quantified. The catchment has three major impoundments which give it a moderate score for impoundment density.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	127	Extreme	High
PI34: % of catchment area covered by artificial waterbodies	2.28	High	High
PI29: impoundment density (per 500 km of river)	1.66	Moderate	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the Kolan River, the extreme risk from reduced freshwater inflow suggests that it is highly likely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Low risk	Very high confidence	100% dependability
Poor condition	Low confidence	100% dependability

Risk

The Kolan estuary's shoreline has had only limited disturbance (15% modified) while the background vegetation has a higher level of disturbance (31% modified). These estimates are based on the current extent of the estuary. In fact, construction of the barrage reduced the estuary length by 53% so that more than half the estuary original habitat was lost in the past. There is also a limited amount of dredging in the estuary which will affect benthic habitats.

There are significant issues associated with cattle grazing, vehicle access, altered hydrology and reduce freshwater inflows that are causing localised or widespread damage to mangroves and saltmarsh habitats along the estuary (Mackenzie and Duke, 2009).

Government regulations can help to reduce the amount of habitat lost due to human activities

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	<5,000t/a	Low	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	31.2	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	14.6	Low	Very high

Condition

In terms of extent there has been no loss of either mangrove or saltmarsh habitat in the Kolan estuary. However, there is now little or no seagrass present. No seagrass was found in the estuary during June 2008 surveys but the historical extent of seagrass in the Kolan estuary is not known and can only be

assessed from anecdotal evidence (which suggests that seagrass was originally quite extensive in the Kolan). It would appear therefore that there has been a total loss of seagrass from the estuary. Again anecdotally, the introduction of beam trawling into the estuary has been suggested as the cause of the disappearance.

Tidal wetlands in the Kolan estuary were reported as being in poor condition by Mackenzie and Duke (2009). They found that "more than 60% of mangrove forest along the estuary was affected by some level of dieback and crown retreat was noticeable".

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	100% lost	Very poor	Low
CI14: change in mangrove extent (% change per year)	0.3% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	10.6% increase	Excellent	Moderate

Hydrodynamics

High risk	Very high confidence	100% dependability
Poor condition	Assumed condition from risk	

Risk

The main physical alteration to the Kolan estuary is the construction of the tidal barrage which has reduced the estuary length by 53% and would have greatly altered water movement patterns. There is also some dredging which has altered flows through the estuary mouth.

Shoreline modifications such as wood or rock walls, boat ramps and jetties can alter the natural hydrodynamics of the estuary

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	<5,000t/a	Low	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	2.6	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	53	Extreme	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall high risk in the Kolan River it can be concluded that these impacts are quite likely to be significant. The reduction of the estuary length by 53% must have resulted in some changes, but there is no quantitative 'condition' data on this.

Litter (rubbish)

Moderate risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

The Kolan has a low resident population but there are moderate levels of risk from boating and general recreation in the estuary.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	19	Moderate	High
PI21: 'estuary' population size (people/km^2)	9.273	Low	Very high
PI38: % of estuary adjoining urban area	1.94	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

The Kolan estuary scored a poor condition for the amount of litter present. All the litter sighted was removed and a follow up litter survey carried out three months later to assess accumulation rates. This scored only fair condition, indicating that significant amounts of littering had occurred in that period. Given the low density population in the catchment, the littering is most likely to be due to recreational users of the estuary.

Recreational use is a major source of rubbish

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0435	Poor	High
CI17: litter accumulation rate (per m^2 per day)	0.000094	Fair	Moderate

Nutrients

Moderate risk	High confidence	100% dependability
Good condition	Very high confidence	88% dependability

Risk

The level of risk for catchment sources of nutrients is low, although the loss of 32% of the river system's riparian vegetation is a high risk factor. The Kolan receives no point discharges of nutrients so dry weather nutrient loading would be low. SedNet model calculations do however, indicate that there has been a significant increase in catchment nutrient loads compared to natural.

Riparian vegetation has been lost from 32% of the river system

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.28	Low	High
PI3: % length of river system with no riparian vegetation	32	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.66	Low	High
PI8: % of catchment with less than 70% ground cover	0.3	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	646	High	Moderate
PI42: % difference between pre-European total nitrogen load and current load	247	Moderate	Moderate

Condition

An extensive water quality data set is available. Nitrogen indicators meet guidelines at all sites but phosphorus guidelines are exceeded at a number of sites. The cause of this is not known but may be related to the extensive areas of cane cultivation adjacent to the estuary. Despite the increased levels of phosphorus, chlorophyll-a levels in the estuary meet guidelines at all sites.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	50	Fair	Very high
CI23: total phosphorus (% of sites exceed guidelines)	50	Fair	Very high
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Low risk	High confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

Catchment indicators give a moderate or low level of risk for this stressor and there are no point sources. Approximately 5% of the river system is affected by aquatic weeds which provides a moderate level of risk to the estuary as these weeds can be washed downstream during flow events.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.11	Moderate	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.66	Low	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.12	Low	High
PI43: % river system affected by aquatic weeds	≈5	Moderate	Low

Condition

Dry weather dissolved oxygen levels in the Kolan estuary comply with guidelines at all sites which indicates an absence of any ongoing organic matter loads. Minimum oxygen levels detected over a 10 year period was 67% which indicates that catchment organic matter loads are not having significant impacts on the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	67	Good	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Kolan estuary so the risk from these is negligible. There are no permanent moorings in the estuary so the likelihood of visitation from overseas boats is also a very low.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	No port/harbour/marina or permanent moorings present. Non-trailerable, international/domestic vessels rarely visit estuary	Negligible	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Kolan estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. However, it is quite possible that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Good condition	Moderate confidence	100% dependability

Risk

Limited disturbance of potential acid sulphate soils (ASS) have been recorded adjacent to the Kolan estuary so the potential risk of acid water entering the estuary from this is low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	3.4	Low	Moderate

Condition

The minimum pH value detected over ~15 years of EPA sampling in the estuary was 6.6, which indicates that no acid run-off impacts are occurring. Red-spot disease of fish has been anecdotally reported in this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6.6	Good	Moderate
CI32: ambient pH (% of sites exceed guidelines)	40	Fair	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	Red-spot 'anecdotally' (rarely) reported in estuary	Good	Moderate

Toxicants

Low risk	High confidence	100% dependability
Excellent condition	High confidence	95% dependability

Risk

Due to the low level of cropping/horticulture and mining activity in the catchment, the current risk from catchment sources is scored as low. However, there are significant areas of cane adjacent to the estuary which, due to their proximity, must present some level of risk for pesticides. The risk for metal contamination is very low. There is a moderate risk associated with the level of boating occurring in the area.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.28	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.66	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were always below the most stringent guideline values.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI35a: toxicants in the water column (Ametryn) (µg/L)	0.0033	Good	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.0094	Good	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.077	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0057	Good	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	Not detected	Excellent	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	Not detected	Excellent	High
CI35j: toxicants in the water column (Chlordane) (µg/L)	Not detected	Excellent	High
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	Not detected	Excellent	High
CI35l: toxicants in the water column (Dieldrin) (µg/L)	Not detected	Excellent	High
CI35m: toxicants in the water column (Endrin) (µg/L)	Not detected	Excellent	High
CI35n: toxicants in the water column (Endosulfan) (µg/L)	Not detected	Excellent	High
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	Not detected	Excellent	High
CI35p: toxicants in the water column (Lindane) (µg/L)	Not detected	Excellent	High
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	Not detected	Excellent	High
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	Not detected	Excellent	High
CI35s: toxicants in the water column (Total DDT) (µg/L)	Not detected	Excellent	High
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	Not detected	Excellent	High
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	11	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.8	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	29	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	10	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	14	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	14	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	40	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	0.0033	Good	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Construct effective fishway on Bucca weir and ensure that water management practices facilitate fish passage
3. Introduce initiatives to reduce pressure on crab populations, e.g. no take zones
4. Ensure estuary has an adequate environmental flow allocation under the Burnett Basin Water Resource Plan
5. Investigate impact of farm dams on water resources in the catchment
6. Encourage revegetation of background 'buffer' vegetation along the estuary and target localised mangrove and saltmarsh habitat degradation/loss (as reported in Mackenzie and Duke, 2009)
7. Address litter issue – education initiatives, signage or other approaches
8. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas
3. Investigate reasons for seagrass loss and historical extent

Burnett River estuary

Overall assessment D-

Overall risk	**F**	Very high confidence	99% dependability
Overall health	**D**	High confidence	87% dependability

SUMMARY

The Burnett estuary is subject to an 'extreme' level of risk of impact due to human activities. As a result, the estuary's health is currently rated as 'poor'. This suggests that unless management actions are taken to reduce this extreme risk then the condition of the estuary will at best remain in this state of poor health or more likely deteriorate in the future. The overall risk and health ratings reported are backed by a large amount of very high and high quality data which provide strong support for the accuracy of these results.

Except for the stressor 'pH' (at moderate risk level), all stressors are at high or extreme risk levels. Condition scores for stressors range from 'excellent' for the stressor 'pests', (which has only a moderate confidence level as no pest surveys have been completed in the estuary), to 'very poor' for four stressors ('aquatic sediments', 'freshwater flow regime', 'habitat removal/disturbance' and 'hydrodynamics'). The majority of stressor condition scores are 'poor' or 'very poor' (Table 10).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 10. Summary of the stressor risk and condition scores for Burnett River estuary.

Stressor	Risk	Condition
Aquatic Sediments	High	Very Poor
Bacteria/Pathogens	High	Good
Biota removal/ disturbance	Extreme	Fair
Connectivity	Extreme	Poor
Freshwater flow regime	Extreme	Very Poor
Habitat removal/ disturbance	Extreme	Very Poor
Hydrodynamics	Extreme	Very Poor
Litter	Extreme	Poor
Nutrients	Extreme	Poor
Organic matter	High	Fair
Pests	High	Excellent
pH	Moderate	Good
Toxicants	High	Good

INTRODUCTION

The Burnett River has a large catchment (~33,300 km^2) with a wide range of land uses, including cropping agriculture (4%) mainly on the coastal plain and grazing (78%) mainly in upstream sub-catchments. Forestry (12%) land use is also present. Only 3% of the catchment is classified as 'conservation and natural environments'. The estuary reach runs through both sugar cane areas and the Bundaberg urban area. It is heavily modified with only limited areas of undisturbed riparian vegetation remaining along the river system.

The estuary ends at a tidal barrage about 25 km from the mouth. Prior to construction of the barrage, the estuary extended approximately 40 km upstream from the mouth, close to the current location of Bingera Weir. Training walls and the Port of Bundaberg occur at the mouth of the estuary and there is extensive dredging to keep the main channel navigable.

Average estuary depth in the main channel varies from around 9 m at the mouth adjacent to the port to <2 m in the upper reaches near the barrage, while spring tidal range is around 2.6 m.

There are many impoundments (many lacking fishways) on the Burnett and the whole system is heavily regulated. As a result, the estuary receives far less freshwater inflows than formerly. The Burnett Basin Water Resource Plan (2007) may address this to an extent but inflows to the estuary will never return to anywhere near natural. The estuary receives several discharges of treated sewage and also a hot water discharge from a sugar mill. However, discharges of pollutants to the estuary have been greatly reduced compared to the 1980s. Some discharges have been diverted to land disposal and the sewage treatment plant discharges have been considerably upgraded.

Satellite imagery of the Burnett River estuary

STRESSOR RESULTS

Aquatic sediments

High risk	High confidence	100% dependability
Very poor condition	High confidence	100% dependability

Risk

Due to the developed nature of its catchment, the Burnett estuary is subject to a high level of risk with respect to sediment inputs. Land use in approximately 97% of the catchment has been changed from natural and there are areas of more intensive agriculture, particularly surrounding the estuary. There is also the Bundaberg urban area adjacent to the estuary. A large portion of the catchment has been cleared (47%) and has relatively poor ground cover. Along the river system, 45% of the riparian vegetation has been lost. Many of these factors have high risk scores and they all contribute to a greater or lesser extent to an increase in fine sediment loads entering the estuary compared to natural. SedNet calculations estimate that sediment loads have increased by 3173% over natural (i.e. 32 times greater). There is also a relatively large amount of dredging in the port area that would contribute resuspended sediment.

The highly regulated nature of the river system may actually act to reduce sediment loads as a large proportion of freshwater flows and much of the associated sediment load is captured in water storages.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	3.74	High	High
PI2: % of catchment cleared	47	High	Very high
PI3: % length of river system with no riparian vegetation	45	High	Very high
PI4: number of point sources per km estuary	0.31	High	Very high
PI5: boating activity within the estuary	International port facilities present	Moderate	Very high
PI6: unsealed road density (m/km^2)	250-330	Moderate	Low
PI7: % of catchment with intensive agriculture on steep slopes	2.04	Moderate	High
PI8: % of catchment with less than 70% ground cover	3.6	High	High
PI9: dredging activity in river system (licensed amount)	<5,000t/a f/w plus >100,000 t/a estuary	High	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	3173	Moderate	Moderate

Condition

Physico-chemical condition indicators – turbidity and Secchi depth clarity – suggest that fine sediments are only having a moderate impact on the estuary. One reason for this is that significant inflows to the estuary only occur occasionally. These impact turbidity for several weeks but, subsequently, the fine sediment is settled out in deposition areas or dispersed out of the estuary by tidal exchange. Following this, the estuary reverts to a typical dry weather pattern which is to some extent independent of flood event loads. This pattern is driven by tidal movement and exhibits a consistent neap/spring tidal cycle. However, as we have no data on historical dry weather levels of turbidity in the Burnett estuary, it is difficult to know what the residual effect the increased wet weather sediment loads have had on current dry weather turbidity.

Biological indicators of condition – relating to seagrass – suggest that over time, the increase in sediment loads has had an impact. The very poor scores are an indication of the total loss of seagrass from the estuary. This may be due to a range of factors, but the reduction in light availability due to increased fine sediment loads and smothering by pulse sediment bed loads are very likely to be the main cause. This has certainly been the case in other estuary or coastal systems.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	20	Fair	Very high
CI2: Secchi depth (% of sites exceed guidelines)	10	Good	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	100% lost	Very poor	Low
CI4: % cover of seagrass	100% lost	Very poor	Low

Bacteria/Pathogens

High risk	Very high confidence	86% dependability
Good condition	High confidence	100% dependability

Risk

Several local factors potentially contribute bacterial loads to the estuary. These include treated waste water from sewage treatment plants (STP), occasional sewage overflows and stormwater from the Bundaberg urban area. Of these, the STP effluent is disinfected via chlorination only and therefore in practice does not have a large impact during normal operations. The frequency of reported sewage overflows in the Bundaberg area is generally around two per year and of moderate risk. Stormwater inflows from urban areas invariably contribute significant loads of bacteria to adjacent waters. This will certainly be true for the Bundaberg area but no actual measurements of wet weather levels of intestinal enterococci bacteria in the Burnett estuary have been undertaken. However, this is an intermittent source and its effects are usually short lived in estuarine waters – a few days.

Sewage treatment plants discharge into the estuary

Large catchment inflows to the estuary are also likely to contribute loads of intestinal enterococci bacteria, some of which will come from livestock and some from natural sources. The significance of these for human health is the subject of some debate with no clear resolution at this stage. At present we have no reliable measurements of the impacts of catchment inflows on bacteria numbers.

Many boats moor in the estuary and marina, sometimes for extended periods, which does pose a significant risk of sewage release into the water.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	Chlorination	High	Very high
PI12: frequency of sewage overflow events (per year)	2	Moderate	Moderate
PI13: % of catchment under intensive animal production	0.876	Low	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0.67	Moderate	Very high
PI17: boat moorings	Marina AND permanent mooring/anchorage sites present (live aboard)	Extreme	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high

Condition

A limited number of measurements of intestinal enterococci bacteria were undertaken in the estuary in 2007-08 under generally 'dry' weather conditions. The good score for this indicator results from the low levels detected – all measurements gave values ≤62 cfu/100 mL. The estuary met the criteria for primary contact recreation at the time of sampling. This suggests that disinfection at the STPs is effective.

We have no wet weather (i.e. event) measurements of intestinal enterococci bacteria so it is not possible to judge the impact of wet weather sources on condition. There is however, no reason to suppose that these impacts would be unusually large.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	57	Good	High
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Extreme risk	High confidence	100% dependability
Fair condition	High confidence	100% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

In the Burnett, most pressure measures had a high to extreme level of risk, a reflection of the high level of fishing and general recreational activities occurring in and around the estuary. This in turn is a reflection of the large local population. Dredging would also have some impact on benthic biota near the estuary mouth although the significance of this impact is not known.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	>100,000 t/a	High	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	19	Extreme	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	Marina AND permanent mooring/anchorage sites present (live aboard)	Extreme	Very high
PI5: boating activity within the estuary	International port facilities present	High	Very high
PI20: recreational usage index (value between 8 and 40)	34	Extreme	High
PI21: 'estuary' population size (people/km^2)	54.085	Moderate	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	25.1	Extreme	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	13.48	Extreme	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	61	Extreme	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	18	High	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	324	Extreme	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	292646	Extreme	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Moderate	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Despite the extreme level of overall risk recorded, many condition indicators suggest that biota in the Burnett estuary are only moderately impacted. Commercial CPUE of finfish, crabs and prawns appear to be sustainable at this stage. Recreational CPUE of finfish is probably being maintained. However, recreational CPUE of both crabs and prawns are declining.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	Increase	Excellent	High
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	High
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	0.7% decrease	Good	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	9.2% decrease	Fair	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	19.8% decrease	Poor	Moderate

Connectivity

Extreme risk	Very high confidence	100% dependability
Poor condition	Very high confidence	100% dependability

Risk

The Burnett has a large number of water storages. Some of the newer structures do have fishways (not all are functional) but the great majority of the older ones do not. Fish from the estuary are able to enter the lower freshwater reaches due to a fishway on the Ben Anderson Barrage at the head of the estuary. The next barrier upstream, Bingera Weir, also has a fishway but this is ineffective. A small tributary (Splitters Creek) enters the estuary below the barrage and allows some freshwater connectivity but overall fish access to the rest (98%) of the river's freshwater reaches is prevented.

Approximately half of the estuary shoreline vegetation and three quarters of the background vegetation has been lost

Estuary shoreline (52% modified) and background (74% modified) habitat is significantly disturbed so connectivity along the riparian zone and with the catchment will be greatly affected. The estuary is therefore at extreme risk of impacts due to this loss of connectivity.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	98.1	Extreme	Very high
PI29: impoundment density (per 500 km of river)	1.84	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	52.2	Extreme	Very high
PI32: % of estuarine 'background habitat' length modified	73.8	High	Very high

Condition

The Burnett estuary has a very low population of diadromous fish which indicates that the presence of the many barriers to migration is having a real impact.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species have become rare and are only seen occasionally	Poor	Very high

Freshwater flow regime

Extreme risk	Very high confidence	100% dependability
Very poor condition	Assumed condition from risk	

Risk

The water storage capacity in the Burnett system is 106% of the median annual flow, giving a very poor score for this indicator. This amount of storage will clearly impact significantly on inflows to the estuary, including both base flows and flushing flood inflows.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	106	Extreme	High
PI34: % of catchment area covered by artificial waterbodies	0.13	Low	High
PI29: impoundment density (per 500 km of river)	1.84	Moderate	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the Burnett River, the extreme risk from reduced freshwater inflow suggests that it is highly likely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Extreme risk	Very high confidence	100% dependability
Very poor condition	Low confidence	100% dependability

Risk

Surveys of the vegetation along the Burnett estuary show that 52% of the natural shoreline habitat has been modified and 74% of the background vegetation has also been modified. The construction of the Ben Anderson Barrage shortened the estuary by about 30 km, so that around 54% of estuarine length

Much of the estuary's shoreline habitat has been replaced by rock walls

(and associated habitat) was completely lost. Dredging at the mouth of the estuary would impact on the benthic habitat there but there are no quantitative measures of this.

There are significant localised issues relating to mangroves and saltmarshes throughout the estuary. Mackenzie and Duke (2009) found that "the overall mangrove biomass was low" with "almost 60% of mangrove in the river occur as sparse populations of individuals rather than dense stands". They also reported that "recruitment of mangrove seedlings in the estuary was also surprisingly low." Some areas of saltmarsh (such as near the ferry crossing) were also found to be in poor health by Mackenzie and Duke (2009).

Indicators of habitat removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	>100,000 t/a	High	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	73.8	Extreme	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	52.2	Extreme	Very high

Condition

There has been very little, and only localised, loss of saltmarsh habitat in the Burnett River estuary (the overall extent of saltmarsh habitats has increased over the last decade). However, both seagrass and mangrove extent have been significantly reduced from natural. Seagrass appears to have been completely lost from the estuary although information on its original extent does not have a high reliability. The loss has probably been due to reduced clarity or other in-stream disturbance.

A large area of mangrove near the mouth of the estuary (northern side) has lost all connectivity with the estuary due to the presence of the training wall.

Mackenzie and Duke (2009) reported that (of the mangroves left) "overall mangrove health in the Burnett river is good with only 30% of mangrove forest experiencing some level of dieback. However some level of mangrove dieback was recorded in much of the estuary." There are therefore, various localised habitat issues occurring along the length of the estuary, such as altered hydrology, as noted by Mackenzie and Duke (2009) and in relation to shoreline modification.

Biological condition indicators	**Raw data**	**Condition score**	**Confidence**
CI3: change in seagrass extent (% change per year)	100% lost	Very poor	Low
CI14: change in mangrove extent (% change per year)	14.6% decrease	Very poor	Moderate
CI15: change in saltmarsh extent (% change per year)	7.8% increase	Excellent	Moderate

Hydrodynamics

Extreme risk	Very high confidence	100% dependability
Very poor condition	Assumed condition from risk	

Risk

Training walls are present at the estuary mouth

The Burnett estuary has experienced extensive physical modifications that would have resulted in changes to the hydrodynamics. The construction of the town barrage has reduced the estuary length by 54%. This would have reduced the tidal prism considerably. It also creates a poorly flushed zone just downstream of the barrage which is particularly vulnerable to pollutants such as nutrients. This effect may have been counteracted to some extent by dredging at the mouth which acts to increase tidal flows and hence increase the tidal prism. The construction of training walls in the Burnett also acts to increase tidal velocities in the mid channel.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	>100,000 t/a	High	Very high
PI35: presence of entrance modifications	Training wall and port facility and dredging	Extreme	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	46.9	High	Very high
PI37: % of original estuary length lost due to a tidal barrage	54	Extreme	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall extreme risk in the Burnett River it can be concluded that these impacts are highly likely to be significant. The combination of a reduction of the estuary length by 54%, the high level of shoreline modification, dredging and a training wall must have resulted in some changes, but there is no quantitative 'condition' data on this.

Litter (rubbish)

Extreme risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

Being adjacent to a large urban area and having a high level of human use, the litter pressures on the Burnett estuary are extreme. Urban stormwater and the various commercial and recreational users of the estuary would most likely be the main contributors.

Stormwater drains are a source of rubbish to the estuary

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	International port facilities present	Extreme	Very high
PI20: recreational usage index (value between 8 and 40)	34	Extreme	High
PI21: 'estuary' population size (people/km^2)	54.085	Moderate	Very high
PI38: % of estuary adjoining urban area	20.2	High	High
PI15: number of stormwater inflows per km estuary	0.67	Moderate	Very high

Condition

An initial litter survey indicated that the extreme level of risk is reflected in high litter levels in the estuary. Litter was removed during the first survey. A subsequent survey three months later showed that litter levels were again high which indicates high levels of ongoing littering.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0136	Poor	High
CI17: litter accumulation rate (per m^2 per day)	0.000158	Poor	Moderate

Nutrients

Extreme risk	High confidence	100% dependability
Poor condition	Very high confidence	88% dependability

Risk

Nutrient loads to the estuary from catchment sources are estimated by SedNet modelling to have increased by between 245 and 688% compared to natural. Loads from the catchment only impact on the estuary for short periods after an inflow event has occurred. However, in the past few years, there

have been very few significant flow events. The many storages on the Burnett would act to significantly reduce catchment loads of nutrients reaching the estuary.

Irrigated cropping occurs in the lower catchment and along the estuary

The estuary also receives treated effluent from sewage treatment plants operated by the Bundaberg Regional Council. The nutrient loads from this source have an impact on the estuary during low flow periods, which is >90% of the time. In comparison, nutrient loads contributed by factors such as loss of riparian vegetation or sewerage system overflows would be relatively minor.

Indicators of nutrient sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	2.15	Low	High
PI3: % length of river system with no riparian vegetation	45	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	2.04	Moderate	High
PI8: % of catchment with less than 70% ground cover	3.6	High	High
PI15: number of stormwater inflows per km estuary	0.67	Moderate	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	STP wastewater containing >10 mg/L N and >3 mg/L P	Extreme	Very high
PI12: frequency of sewage overflow events (per year)	2	Moderate	Moderate
PI40: number of point sources per km estuary (excluding STPs)	0.08	Moderate	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	688	High	Moderate
PI42: % difference between pre-European total nitrogen load and current load	245	Moderate	Moderate

Condition

The treated sewage effluent causes phosphorus, and to a lesser extent nitrogen, concentrations to exceed guidelines in the water column. This in turn results in exceedance of the chlorophyll-a guideline at some sites. However, maximum dry weather chlorophyll-a levels are not particularly high (~30 µg/L) so the increased nutrients are having only a small impact. The highest chlorophyll-a levels recorded in the Burnett occurred soon after a freshwater inflow event and were presumably related to the influx of catchment sourced nutrients.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	29	Fair	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	29	Fair	Very high
CI21: total nitrogen (% of sites exceed guidelines)	29	Fair	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	100	Very poor	Very high
CI23: total phosphorus (% of sites exceed guidelines)	100	Very poor	Very high
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	43	Fair	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

High risk	High confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

Most of the pressure indicators for this stressor show only a moderate risk. The highest risk is from the sewage treatment plant discharges. Historically, the Burnett received some very significant organic waste discharges from the Bundaberg distillery, which caused very low dissolved oxygen levels on occasion. However, this discharge has now been diverted to land disposal. Approximately 5% of the river system is affected by aquatic weeds which provides a moderate level of risk to the estuary as these weeds can be washed downstream during flow events.

Catchment sourced organic matter enters the estuary during flow events and has the potential to cause short term, but highly significant, reductions in dissolved oxygen.

Indicators of organic matter sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	3.1	Moderate	High
PI4: number of point sources per km estuary	0.2	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	2.04	Moderate	High
PI12: frequency of sewage overflow events (per year)	2	Moderate	Moderate
PI13: % of catchment under intensive animal production	0.876	Low	High
PI43: % river system affected by aquatic weeds	≈5	Moderate	Low

Condition

Ambient dissolved oxygen (DO) levels in the Burnett are within guidelines at all but two sites in dry weather. However, all sites are above the minimum DO guideline which indicates that the point source discharges are not having a significant impact on this indicator. The lowest levels of dissolved oxygen occurred following a small flow event and were presumably related to diffuse catchment organic loads. However, these levels (42% saturation) are not sufficiently low to cause large impacts on the estuary such as fish kills.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	42	Fair	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	20	Fair	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

High risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Burnett estuary so the risk from these is negligible. However, the presence of a port and marinas in the Burnett estuary is a significant risk factor for the introduction of marine pest species. Particularly in light of Bundaberg Port being one of the major, and often first, receiving ports for small craft from overseas in Australia.

Indicators of pest species sources	**Raw data**	**Risk score**	**Confidence**
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Port present	Extreme	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	1 land based facility present	Low	Very high

The presence of international port facilities and marinas within the estuary are significant risk factors for pest introduction

Condition

No surveys to detect pest species have been carried out in the Burnett estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. However, it is quite possible that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Moderate risk	Moderate confidence	100% dependability
Good condition	Moderate confidence	100% dependability

Risk

There is considerable disturbance of potential acid sulphate soils adjacent to the Burnett estuary so the potential risk of acid water entering the estuary is moderate. The extent to which this is realised will be dependant on the level of development in these zones and also how well such developments are managed.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	11.9	Moderate	Moderate

Condition

Long term (~15 years) measurements of pH by the EPA have never detected levels of pH below 6 in the main channel of the estuary. This level is not indicative of significant acid run-off. However, the possibility remains that acid run-off could occur into small creeks entering the estuary. The past incidence of red-spot disease or “Bundaberg” fish disease suggests that acid run-off may have occurred at some time. Red-spot is rarely observed today.

Ambient pH levels in the estuary were within the guideline range at all sites.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6	Fair	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	Red-spot rarely observed (≤3% fish)	Fair	Moderate

Toxicants

High risk	Very high confidence	100% dependability
Good condition	Very high confidence	79% dependability

Risk

Given the large areas of cropping surrounding, and just upstream, of the estuary, there is clearly some risk of agricultural chemicals entering the estuary. The adjacent urban area also poses some level of risk for both pesticides and some heavy metals. The high level of boating activity in the estuary is also a significant risk factor for some specific chemicals. A small number of oil spills/slicks were reported in the estuary.

Boating activity can be a source of toxicants to the estuary

Indicators of toxicant sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	2.16	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	International port facilities present	Extreme	Very high
PI7: % of catchment with intensive agriculture on steep slopes	2.04	Moderate	High
PI15: number of stormwater inflows per km estuary	0.67	Moderate	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	Small number reported	Moderate	High

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were, with the exception of Diazinon, always below the most stringent guideline values. Diazinon, a broad spectrum insecticide, was detected in the water at below the ANZECC 95% level of protection guideline values.

Traces of DDT and Dieldrin have been detected in mud crabs in studies by the Great Barrier Reef Marine Park Authority which suggests that toxicant are at the least accumulating in the tissues of the estuary's biota but the specific 'impact' on them is unknown.

Using our current guideline values, toxicants in general appear to present a small risk to this estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI35a: toxicants in the water column (Ametryn) (µg/L)	0.0005	Good	Very high
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.039	Good	Very high
CI35c: toxicants in the water column (Diuron) (µg/L)	0.027	Good	Very high
CI35d: toxicants in the water column (Fluometuron) (µg/L)	0.001	Good	Very high
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0025	Good	Very high
CI35f: toxicants in the water column (Prometryn) (µg/L)	0.001	Good	Very high

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0007	Good	Very high
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	0.003	Good	Very high
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	0.00003	Good	High
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	Not detected	Excellent	High
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	Diazinon was detected at 0.0002	Fair	High
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	14	Excellent	Very high
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.8	Excellent	Very high
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	38	Excellent	Very high
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	42	Excellent	Very high
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	12	Excellent	Very high
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	17	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	78	Excellent	Very high
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	0.0067	Good	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	Traces	Good	High
CI37b: toxicants in biota (Dieldrin) (mg/kg)	Traces	Good	High
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Introduce/maintain stormwater management initiatives aimed at reducing pollutant loads
3. Modify fishway on Bingera weir to make it more effective and construct functional fishways further upstream
4. Introduce initiatives to reduce pressure on crab populations, e.g. no take zones
5. Ensure estuary has an adequate environmental flow allocation under the Burnett Basin Water Resource Plan

6. Encourage revegetation of background 'buffer' vegetation along the estuary and target localised mangrove and saltmarsh habitat degradation/loss (as reported in Mackenzie and Duke, 2009)
7. Maintain existing mangrove and saltmarsh habitat (no further loss)
8. Examine option for returning connectivity between the estuary and mangroves north of the mouth which are effectively isolated by the training wall
9. Address litter issue – education initiatives, signage or other approaches
10. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation
11. Strongly encourage implementation of point discharge/effluent re-use schemes in medium to long term

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas
3. Monitor for marine pest species to assess future management action needs
4. Acquire better information on the location and disturbance of actual acid sulphate soils to assess future management action needs
5. Monitor pH during and after significant flow events to determine if acid run-off is occurring (particularly within some of the smaller tributaries)





Elliott River estuary

Overall assessment B

Overall risk	C	Very high confidence	99% dependability
Overall health	A	High confidence	88% dependability

SUMMARY

The Elliott estuary is subject to a 'moderate' level of risk of impact due to human activities. However, the estuary's health is currently rated as 'excellent'. Although the moderate level of risk has does not appear to have impacted greatly on the estuary at this stage, it has the potential to do so in the future. For this reason some action to reduce the level of risk should be undertaken. The overall risk and health ratings reported are backed by a large amount of very high and high quality data which provide strong support for the accuracy of these results.

The only stressor reported with a negligible level of risk is 'hydrodynamics'. Four others are reported as low risk, five as moderate risk and three at high risk ('aquatic sediments', 'connectivity' and 'freshwater flow regime').

The majority of condition scores for stressors are reported as 'excellent' with 'aquatic sediments' found to be in good condition. However, 'biota removal/disturbance' and 'litter' were only in fair condition, and 'connectivity' and 'freshwater flow regime' were in poor condition (Table 11).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 11. Summary of the stressor risk and condition scores for Elliott River estuary.

Stressor	Risk	Condition
Aquatic Sediments	High	Good
Bacteria/Pathogens	Low	Excellent
Biota removal/ disturbance	Moderate	Fair
Connectivity	High	Poor
Freshwater flow regime	High	Poor
Habitat removal/ disturbance	Low	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Moderate	Fair
Nutrients	Moderate	Excellent
Organic matter	Moderate	Excellent
Pests	Low	Excellent
pH	Low	Excellent
Toxicants	Moderate	Excellent

INTRODUCTION

The Elliott River has a small coastal catchment (~390 km^2) which has been extensively developed for cropping (40%), mostly sugar cane, grazing (27%) and forestry (12%) with only 16% classified as 'conservation and natural environments'. In contrast, the estuary is relatively undisturbed (only ~4% of the estuary riparian length has been modified).

The estuary is quite short (approximately 10 km) and has a spring tidal range of around 2.5 m – as a result it is well flushed throughout. Depths range from 2 m to 4 m. It has significant groundwater inputs.

There are two aquaculture discharges to the estuary and two artificial barriers to flow (both of which lack fishways). The first barrier is located at the approximate natural tidal limit of the estuary. The town of Elliott Heads is located along the north side of the estuary mouth.

Satellite imagery of the Elliott River estuary

STRESSOR RESULTS

Aquatic sediments

High risk	High confidence	100% dependability
Good condition	Very high confidence	50% dependability

Risk

The Elliott catchment is extensively cleared (58%), mainly for cultivation with 40% of the catchment used for irrigated cropping, mostly in the lower catchment just upstream of the estuary. The river system has lost 32% of its riparian vegetation, there is a high density of unsealed roads and a relatively large percentage of the catchment (6.6%) with less than 70% ground cover. All these factors result in a high overall risk for sediment loads to the estuary.

SedNet calculations estimate that sediment loads have increased by 4900% over natural (i.e. 49 times greater). There is no dredging in the estuary.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	4.11	High	High
PI2: % of catchment cleared	58	High	Very high
PI3: % length of river system with no riparian vegetation	32	High	Very high
PI4: number of point sources per km estuary	0.2	High	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Low	Very high
PI6: unsealed road density (m/km^2)	330-460	High	Low
PI7: % of catchment with intensive agriculture on steep slopes	0.65	Low	High
PI8: % of catchment with less than 70% ground cover	6.58	High	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	4900	High	Moderate

Condition

An extensive water quality data set is available for the Elliott. This shows that turbidity in the estuary meet guidelines at all sites while Secchi depth clarity only just failed at one lower estuary site. The reason that the potentially large catchment sediment loads are not having more impact on estuary condition relates to the fact that significant inflows to the estuary occur only occasionally. In longer estuaries these might impact turbidity for several weeks. However, in the Elliott estuary, because it is very short (10 km), and because the rate of flushing with clean coastal water is so high, much of the incoming sediment load is either flushed straight out of the estuary during the flow event or is soon after removed by tidal flushing. Thus, the impacts of sediment loads are likely to last for only a few days or a week or two at most. Following this, the estuary reverts to a typical dry weather pattern which is to some extent independent of flood event loads. The dry weather pattern is driven by tidal movement and exhibits a consistent neap/spring tidal cycle. The residual impact of catchment sediment loads on dry weather estuary water quality is not known. However, with such a short estuary this is likely to be small. A survey of current seagrass extent in the Elliott showed only one or two small patches present (approximately 3 m^2). However, there is no reliable information on the historical extent of seagrass in this estuary so it is not possible to determine if seagrass has been lost or if it was always sparse.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	Very high
CI2: Secchi depth (% of sites exceed guidelines)	33	Fair	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data (3 m^2 found in 2008 EPA survey)		
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Low risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no high risk factors, such as treated sewage discharges or urban stormwater, for this stressor in the Elliott estuary. Resident populations are low, boat moorings are minimal and there is only a limited amount of intensive animal production. There are two aquaculture facilities on the estuary and these may present some risk for the release of pathogens. Housing density in the

catchment is low so that the risk from septics is probably not high, although there is no specific data on this.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.157	Low	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	Small craft mooring sites identified	Low	Very high
PI16: number of 'marine' aquaculture facilities present	3	Moderate	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤15 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems very probable that this stressor is not an issue in the Elliott estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	13	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Moderate risk	High confidence	100% dependability
Fair condition	Moderate confidence	67% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

The Elliott estuary is an important site for recreational activities in the region

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

The Elliott estuary and adjacent coastal waters experience relatively low levels of commercial fishing while there is quite a high level of recreational fishing in the estuary, with recreational fisheries catch quite significant. There is also some recreational bait collecting but no commercial collection. In

addition, there are moderate population densities close to the estuary as well as boating and recreational activities occurring in and around the estuary.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	2	Low	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI17: boat moorings	Small craft mooring sites identified	Low	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	19	Moderate	High
PI21: 'estuary' population size (people/km^2)	72.16	Moderate	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	3.9	High	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	1.16	Moderate	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	19	Moderate	Moderate
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	6278	Low	Moderate
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate level of confidence.

Commercial CPUE of finfish shows evidence of a significant level (21%) of decline which suggests that stock are not stable and at the least, some further investigation of the sustainability of populations would be desirable. Recreational finfish and prawn CPUE appears to be stable but, as with many other estuaries in the region, recreational CPUE of crabs is declining. There are no data for commercial crab catch.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	20.6% decrease	Poor	Moderate
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	28.6% decrease	Poor	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	Moderate

Connectivity

High risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

Two weirs are located on the Elliott River with the first located just upstream of the estuary tidal limit. The weir has no fishway so the Elliott estuary has essentially no connectivity to any of the system's freshwater reaches. The estuary's shoreline (4% modified) and background (7% modified) habitat is largely intact so there is good connectivity along the estuary riparian zone. The catchment has a high score for impoundment density but this is due to the creek system's small size.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	100	Extreme	Very high
PI29: impoundment density (per 500 km of river)	9.72	High	High
PI31: % of estuarine 'shoreline' length modified (habitat)	3.9	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	7.2	Low	Very high

Condition

As would be expected from the poor connectivity between the estuary and freshwater reaches, diadromous fish populations have become rare.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species have become rare and are only seen occasionally	Poor	High

Freshwater flow regime

High risk	High confidence	100% dependability
Poor condition	Assumed condition from risk	

Risk

The storage volume of referable dams (larger storages that require a licence and which are accounted for in Water Resource Plans) in the Elliott is less than 20% of annual median flow and thus inflows to the estuary are probably only altered to a small degree. There are also a number of artificial waterbodies such as farm dams present, which cover 1.53% of the catchment – resulting in a high risk score, though their impact remains to be quantified. The catchment has a high score for impoundment density which is related to the river system's small size.

The risk to the freshwater flow regime of the system is compounded by surface water-groundwater interactions along the river. This means that licensed groundwater extractions (i.e. bores) adjacent to the river are in fact taking from the 'same water body' as licensed surface water extractions from the river (T. Espinoza, 2009, pers. comm., NRW). This is in essence a double-allocation of the same water. In addition, surface water extractions from the river are largely unregulated except for a couple licences with water harvesting conditions set in them (e.g. 1 cumec passing flow before take) (T. Espinoza, 2009, pers. comm., NRW).

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	<20	Low	High
PI34: % of catchment area covered by artificial waterbodies	1.53	High	High
PI29: impoundment density (per 500 km of river)	9.72	High	High

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the

upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

There is only a relatively small reduction in freshwater inflows (as a % of median annual flow) to the Elliott estuary but the high level of clearing in the catchment and other flow modifications means that inflows are probably very peaky compared to natural and base flows are probably lower. In the case of the Elliott River, the high risk from reduced freshwater inflow suggests that it is quite likely that the types of effects listed above are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Low risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	67% dependability

Risk

Only a small percentage of the estuary's shoreline (4%) or background (7%) vegetation has been lost. However, there is one large aquaculture operation present and a second smaller one. There is no dredging in the estuary. There are some significant issues, such as those associated with altered hydrology, vehicle damage and erosion, that are causing localised damage (Mackenzie and Duke, 2009).

The estuary's habitat is largely intact

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	3	Moderate	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	7.2	Low	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	3.9	Negligible	Very high

Condition

There has been very little, and only localised, loss of either mangrove or saltmarsh habitat in the Elliott River estuary (the overall extent of both habitats has increased). Two very small patches of seagrass (~3 m^2) were found in the estuary during June 2008 surveys but the natural (historic) seagrass extent within the estuary is not known. As such, it is not possible to determine what loss, if any, has occurred. Thus, overall habitat condition in the Elliott estuary is excellent. There are however, some localised habitat issues as noted by Mackenzie and Duke (2009).

Mackenzie and Duke (2009) reported that "tidal wetlands in the Elliott river estuary are in good condition, are extensive, have high recruitment rates and are of moderate biomass throughout the estuary". However, "more than 50% of tidal wetlands in the estuary exhibited signs of dieback and tree death".

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	No data (3 m^2 found in 2008 EPA survey)		
CI14: change in mangrove extent (% change per year)	0.1% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	2.9% increase	Excellent	Moderate

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There have been no significant physical alterations to the estuary so the hydrodynamic regime is close to natural.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	3.9	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	Tidal barrage at upper limit	Low	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall negligible risk in the Elliott River it can be concluded that these impacts are likely to be insignificant.

Litter (rubbish)

Moderate risk	Very high confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

The Elliott estuary has a moderate level of recreational use and boating activity. The resident population close to the estuary is substantial with moderate portion of the estuary adjoining urban areas (but with no stormwater inputs). These factors indicate a moderate level of risk to the estuary.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	19	Moderate	High
PI21: 'estuary' population size (people/km^2)	72.16	Moderate	Very high
PI38: % of estuary adjoining urban area	8.36	Moderate	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

An initial survey found moderate amounts litter (rubbish) present in the estuary. This litter was collected and disposed of and another survey carried out three months later. This follow up survey showed that a moderate level of litter had been deposited in that period. The most likely cause of this appears to be the recreational users of the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0013	Fair	High
CI17: litter accumulation rate (per m^2 per day)	0.000013	Fair	Moderate

Nutrients

Moderate risk	High confidence	100% dependability
Excellent condition	Very high confidence	88% dependability

Risk

Because of the highly developed nature of the catchment and the extensive cropping, catchment nutrient loads are potentially very large. Nutrient loads to the estuary from catchment sources are estimated by SedNet modelling to have increased by between 221 and 289% compared to natural. Point discharge of nutrients are present in the form of two aquaculture operations but these contribute relatively small loads.

Aquaculture facilities are a potential source of nutrients, bacteria/pathogens, organic matter and/or pests to the estuary

Indicators of nutrient sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	3.75	High	High
PI3: % length of river system with no riparian vegetation	32	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.65	Low	High
PI8: % of catchment with less than 70% ground cover	6.58	High	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0.2	High	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	289	Moderate	Moderate
PI42: % difference between pre-European total nitrogen load and current load	221	Moderate	Moderate

Condition

An extensive water quality data set is available. Nitrogen, phosphorus and chlorophyll-a indicators meet guidelines at all sites. This indicates that nutrient enrichment is not a significant problem. The lack of any impact related to the potentially large catchment loads is because these occur infrequently and much of the load passes straight through this short estuary during flow events or is soon after dispersed out of the estuary by tidal flushing.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

Most of the pressure indicators for this stressor show only a low or negligible risk. However, owing to the developed nature of the Elliott catchment, there is a high risk for catchment sources of organic matter. There are point discharges from the aquaculture operations but these are relatively small in terms of organic matter. Less than 2% of the Elliott River system is affected by aquatic weeds so any impact of these being flushed down after flow events would likely be minimal.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	4.24	High	High
PI4: number of point sources per km estuary	0.098	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.65	Low	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.157	Low	High
PI43: % river system affected by aquatic weeds	≤2	Low	Low

Condition

Dry weather dissolved oxygen levels in the Elliott estuary comply with guidelines at all sites which indicates an absence of any ongoing organic loads. Minimum oxygen levels detected over the ~15 years of EPA sampling in the estuary was 56% which is not unusual for estuaries in post event periods and indicates that catchment organic loads are not having significant impacts on the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	56	Good	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Elliott estuary so the risk from these is negligible. However, there are permanent moorings in the estuary with the potential for occasional visitation from overseas boats which could introduce exotic pest species. The aquaculture facilities present a minor risk of species escaping into the estuary and becoming a pest.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Moorings for small, non-trailerable, international/domestic vessels present (published in boating guides/well know by boaties)	Moderate	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	2 land based facilities present	Moderate	Very high

Condition

No surveys to detect pest species have been carried out in the Elliott estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. However, it is quite possible that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There is only limited disturbance of potential acid sulphate soils (ASS) adjacent to the Elliott estuary so the potential risk of acid water entering the estuary from this is low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	3.3	Low	Moderate

Condition

The minimum pH value detected over the ~15 years of EPA sampling in the estuary was 6.7, which indicates that no acid run-off impacts are occurring. Ambient pH levels in the estuary were within the guideline range at all sites.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6.7	Good	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	95% dependability

Risk

Given the high level of cropping in the lower catchment, the risk of pesticide contamination is high. There is a moderate level of risk associated with boating activities but this is probably insignificant relative to catchment sources. All other pressure indicators returned low or negligible risk scores.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.87	High	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.65	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were always below the most stringent guideline values. This is unexpected given the high level of cropping in the catchment and the high catchment land-use risk score.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	0.001	Good	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.011	Good	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.014	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0014	Good	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0005	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	Not detected	Excellent	High
CI35j: toxicants in the water column (Chlordane) (µg/L)	Not detected	Excellent	High
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	Not detected	Excellent	High
CI35l: toxicants in the water column (Dieldrin) (µg/L)	Not detected	Excellent	High
CI35m: toxicants in the water column (Endrin) (µg/L)	Not detected	Excellent	High
CI35n: toxicants in the water column (Endosulfan) (µg/L)	Not detected	Excellent	High
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	Not detected	Excellent	High
CI35p: toxicants in the water column (Lindane) (µg/L)	Not detected	Excellent	High
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	Not detected	Excellent	High
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	Not detected	Excellent	High
CI35s: toxicants in the water column (Total DDT) (µg/L)	Not detected	Excellent	High
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	Not detected	Excellent	High
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	10	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	20	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	4	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	5	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	8.2	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	17	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	0.0006	Good	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Construct fishway on the Elliott weirs

3. Introduce initiatives to reduce pressure on crab populations, e.g. no take zones
4. Ensure estuary has an adequate environmental flow allocation under the Burnett Basin Water Resource Plan
5. Investigate impact of farm dams on water resources in the catchment
6. Address litter issue – education initiatives, signage or other approaches
7. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas






Coonarr Creek estuary

Overall assessment A-

Overall risk	B	Very high confidence	94% dependability
Overall health	A+	Moderate confidence	69% dependability

SUMMARY

The Coonarr estuary is subject to a 'low' level of risk of impact due to human activities and the estuary's health is currently rated as 'excellent'. Provided any future developments are well managed the estuary should remain in good condition – however litter issues need to be addressed. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is backed by only moderate quality data with 69% of the potential condition indicators monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still supported though more data to improve the confidence level would be beneficial.

With the exception of 'aquatic sediments', 'biota removal/disturbance', 'nutrients' and 'pH' (at moderate risk) all stressor were found to be at low (two stressors) or negligible (seven stressors) risk levels.

The majority of condition scores for stressors are reported as 'excellent', however, 'freshwater flow regime' and 'toxicants' were in good condition while 'biota removal/disturbance' and 'litter' were in poor condition (Table 12).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 12. Summary of the stressor risk and condition scores for Coonarr Creek estuary.

Stressor	Risk	Condition
Aquatic Sediments	Moderate	Excellent
Bacteria/Pathogens	Negligible	Excellent
Biota removal/ disturbance	Moderate	Poor
Connectivity	Negligible	Excellent
Freshwater flow regime	Low	Good
Habitat removal/ disturbance	Negligible	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Low	Poor
Nutrients	Moderate	Excellent
Organic matter	Negligible	Excellent
Pests	Negligible	Excellent
pH	Moderate	Excellent
Toxicants	Negligible	Good

INTRODUCTION

Coonarr Creek has a very small coastal catchment of only ~40 km^2. The predominant land use is conservation and natural environments (62%) with significant grazing (24%) and irrigated cropping (13%). A small area of residential land adjoins the mid estuary. The Coonarr Creek estuary is largely unmodified with undisturbed shoreline vegetation (only 0.1% modified) and no artificial barriers to flow or point source discharges.

The estuary is short (~3.5 km long) and shallow. The spring tidal range is unknown.

Satellite imagery of the Coonarr Creek estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	Very high confidence	90% dependability
Excellent condition	High confidence	25% dependability

Risk

The Coonarr catchment has experienced a moderate degree of clearing (25%) and has a high loss (22%) of riparian vegetation from the creek system. However, 62% of the catchment is classified as 'conservation and natural environments' with no disturbance of natural vegetation. The catchment is extremely small and therefore has limited capacity to generate large diffuse pollutant loads, including sediment. It does have a high density of unsealed roads and a significant portion (4.5%) has less than 70% ground cover. No dredging occurs in the estuary.

Indicators of suspended sediment sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.42	Low	High
PI2: % of catchment cleared	25	Moderate	Very high
PI3: % length of river system with no riparian vegetation	22	High	Very high

Indicators of suspended sediment sources	Raw data	Risk score	Confidence
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Negligible	Very high
PI6: unsealed road density (m/km^2)	330-460	High	Low
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	4.45	High	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	No data		

Condition

A limited water quality data set (10 months at one site) is available for Coonarr Creek. This shows that turbidity (no Secchi depth clarity data is available) in the estuary meets guidelines at this site. This would be expected given the relatively minor risk from the catchment. Also, given the very short length of the estuary, any sediment that enters the estuary is likely to be rapidly flushed out again by tidal exchange. Thus, any impacts from sediment loads will be short lived.

A survey of current seagrass extent in Coonarr showed only one or two small (0.25 m^2 in total) patches present near the mouth. Both *Halophila ovalis* and *Zostrea capricorni* were found. However, there is no reliable information on the historical extent of seagrass in this estuary so it is not possible to determine if seagrass has been lost or if it was always sparse.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	High
CI2: Secchi depth (% of sites exceed guidelines)	No data		
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data (0.25 m^2 found in 2008 EPA survey)		
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Negligible risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges or urban stormwater for this stressor in the Coonarr estuary catchment. There is only a limited amount of intensive animal production and no boat mooring or aquaculture. Housing density in the catchment is low so that the risk from septics is probably not high, although there is no specific data on this.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.166	Low	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤14 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems very probable that this stressor is not an issue in the Coonarr estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	13	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Moderate risk	High confidence	100% dependability
Poor condition	Moderate confidence	33% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

The Coonarr estuary and adjacent coastal waters experience low to moderate levels of both commercial and recreational fishing and crabbing. Catch similarly ranges from low to moderate. There are also quite high levels of recreational bait collection but no commercial collection in the estuary. In addition, there are low population densities close to the estuary as well as very limited boating and recreational activities occurring in and around the estuary. No dredging occurs in the estuary.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	9.3	High	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	12	Low	High
PI21: 'estuary' population size (people/km^2)	75.229	Moderate	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	3.1	Moderate	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.83	Moderate	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	19	Moderate	Moderate
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	6278	Low	Moderate
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate level of confidence.

Both commercial and recreational finfish catches are experiencing significant declines in CPUE – though these values have only a moderate level of confidence. This indicates that fish populations may be declining. There are no data for trends in crab or prawn catch.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	20.6% decrease	Poor	Moderate
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	15.9% decrease	Poor	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

There are no weirs or other barriers to fish migration on the Coonarr system so connectivity is unimpeded, albeit to a small freshwater reach. The estuary's shoreline (0.1% modified) and background (11% modified) habitat is largely intact so there is good connectivity along the estuary riparian zone and with the catchment.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.1	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	10.8	Low	Very high

Condition

As would be expected from the high level of connectivity between the estuary and freshwater reaches, diadromous fish populations are common with stable populations.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species common and population stable throughout system	Excellent	High

Freshwater flow regime

Low risk	Very high confidence	100% dependability
Good condition	Assumed condition from risk	

Risk

There are no significant water storages in the Coonarr catchment. There are some artificial waterbodies such as farm dams in the catchment, which cover 0.83% of the catchment – resulting in a moderate risk score, though their impact remains to be quantified. Thus, it appears that freshwater flows are little altered from natural. However, given the very small size of the catchment, freshwater inflows would have been very limited even under natural conditions. The system is partly dependent on groundwater inflows (Mackenzie and Duke, 2009).

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	0	Negligible	High
PI34: % of catchment area covered by artificial waterbodies	0.82	Moderate	High
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of Coonarr Creek, the low risk from reduced freshwater inflow suggests that it is unlikely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Negligible risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	67% dependability

Risk

Virtually none of the estuary's shoreline (0.1%) has been modified although changes to the background vegetation along the western side are more significant (11% modified). There are no significant human activities which would remove habitat, such as dredging, in this estuary. There are some significant issues, such as those associated with vehicle access, that are causing localised damage (Mackenzie and Duke, 2009).

Much of the estuary's habitat is intact

Indicators of habitat removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	10.8	Low	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.1	Negligible	Very high

Condition

There has been very little, and only very localised, loss of either mangrove or saltmarsh habitat in the Coonarr Creek estuary (the overall extent of both habitats has increased). However, there is now only little or virtually no seagrass present. As the natural extent of seagrass in the estuary is unknown it is not possible to determine what loss, if any, has occurred. Thus, overall habitat condition in Coonarr Creek is excellent. There are however, some localised habitat issues as noted by Mackenzie and Duke (2009).

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	No data (0.25 m^2 found in 2008 EPA survey)		
CI14: change in mangrove extent (% change per year)	4.1% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	3.3% increase	Excellent	Moderate

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There have been no significant physical alterations to the estuary so the hydrodynamic regime is natural.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	0.1	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the negligible risk for all pressure indicators in Coonarr Creek it can be concluded that these impacts are currently nil.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

The Coonarr estuary has a minor level of recreational use and boating activity. There is a significant population living within 20 km of the estuary, however, road access to the estuary is probably a deterrent for many people. A very small residential population adjoins the estuary. Combining all these factors indicate a only a low level of risk to the estuary.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	12	Low	High
PI21: 'estuary' population size (people/km^2)	75.3	Moderate	Very high
PI38: % of estuary adjoining urban area	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

An initial survey showed a substantial amount of litter was present in the estuary. This litter was collected and disposed of and another survey carried out three months later. This follow up survey showed that significant amounts of additional litter had been deposited in that period. The most likely source of this litter is related to recreational use.

Rubbish among mangrove roots

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.023	Poor	High
CI17: litter accumulation rate (per m^2 per day)	0.000511	Poor	Moderate

Nutrients

Moderate risk	Very high confidence	80% dependability
Excellent condition	High confidence	88% dependability

Risk

Much of the Coonarr catchment is uncleared and natural but there are also some completely cleared areas. A relatively large percentage of the catchment (4.5%) has less than 70% ground cover and 22% of the system's riparian vegetation has been lost which results in a high risk of nutrients (particular those associated with sediments) entering the estuary. The overall risk of catchment nutrient loads is moderate given the nature of land use in the catchment and its small size. There are no point discharges or urban stormwater inflows to the Coonarr estuary.

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.91	Low	High
PI3: % length of river system with no riparian vegetation	22	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	4.45	High	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	No data		
PI42: % difference between pre-European total nitrogen load and current load	No data		

Condition

A limited water quality data set is available (10 months at one site). Nitrogen, phosphorus and chlorophyll-a indicators all met guidelines, indicating that nutrient enrichment is not a significant problem.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	High
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	High
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	High
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Negligible risk	Very high confidence	83% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

Much of the Coonarr catchment is uncleared ('conservation and natural environments' (62%)) but there are also grazing (24%) and irrigated cropping (13%) areas, as well as limited intensive animal production. The overall risk of catchment organic loads is low given the significant proportion of natural land use and the catchment's small size. There are no point discharges to the Coonarr estuary. No data on the occurrence of aquatic weeds in the Coonarr Creek system is available.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.15	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.166	Low	High
PI43: % river system affected by aquatic weeds	No data		

Condition

Dry weather dissolved oxygen levels in the Coonarr estuary comply with guidelines at all sites which indicates an absence of any ongoing organic loads. Dry weather values lie within the range of 90 to 100% saturation while post-event dissolved oxygen values fell to a minimum of 61% saturation. This is a clear indication of the impact of diffuse organic loads. However, this is well within the normal range of post-event dissolved oxygen values for estuaries and does not indicate any unusual impact.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	61.5	Good	Low
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Coonarr estuary so the risk from these is negligible. There are also no permanent moorings in the estuary and the entrance is quite dangerous so visitation from overseas boats is very unlikely. There are also no aquaculture operations.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	No port/harbour/marina or permanent moorings present. Non-trailerable, international/domestic vessels rarely visit estuary	Negligible	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Coonarr estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Moderate risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There considerable disturbance of potential acid sulphate soils adjacent to the Coonarr estuary so the potential risk of acid water entering the estuary is significant. The extent to which this is realised will be dependant on the level of development in these zones and also how well such developments are managed.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	10.6	Moderate	Moderate

Condition

The minimum pH value detected over the 10 months of sampling was 7.2, which indicates that no acid run-off impacts are occurring. However, the data set is small with only one post event data point so the confidence in the data is low. Nevertheless, the likelihood of acid run-off effects in Coonarr estuary is low. The occurrence of red-spot disease in fish is unknown.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	7.2	Excellent	Low
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Negligible risk	High confidence	100% dependability
Good condition	High confidence	67% dependability

Risk

There is some cropping in the catchment and very limited mining however, the risk of toxicants from catchment land use affecting the estuary is low. There may be a small risk from the rural residential properties on the western side of the estuary and the limited boating that does occur. There are no toxicant point sources or stormwater inflows.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.94	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were, with the exception of Atrazine and Diuron, always below the most stringent guideline values. The levels of Diuron and Atrazine detected were higher than expected given the nature of catchment land-use and low risk level. However, the levels detected were below the ANZECC 95% level of protection guideline values. The source of these herbicides is not known although it may be from the rural residential areas.

Using our current guideline values, toxicants in general appear to present a small risk to this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	1.9	Fair	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.75	Fair	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0092	Good	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0049	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	5	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	15	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	3	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	<1	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	8.9	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	10	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg	Not detected	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
dry weight)			
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Investigate impact of farm dams on water resources in the catchment
2. Address litter issue – education initiatives, signage or other approaches
3. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas
3. Acquire better information on the location and disturbance of actual acid sulphate soils to assess future management action needs
4. Monitor pH during and after significant flow events to determine if acid run-off is occurring




Theodolite Creek estuary

Overall assessment A

Overall risk	**A-**	Very high confidence	97% dependability
Overall health	**A+**	Moderate confidence	71% dependability

SUMMARY

The Theodolite estuary is subject to a 'negligible' level of risk of impact due to human activities. As a result, the estuary's health is currently rated as 'excellent'. This suggests that under the current *status quo* the condition of the estuary will remain in this state of excellent health. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is backed by only moderate quality data with only 71% of the potential condition indicators monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still supported though more data to improve the confidence level would be beneficial.

With the exception of 'aquatic sediments' and 'biota removal/disturbance' (both moderate risk) all stressor were found to be at negligible or low risk levels. With the exception of 'litter' (fair condition) and 'biota removal/disturbance' (poor condition) all stressor condition scores were reported as 'excellent' (Table 13).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

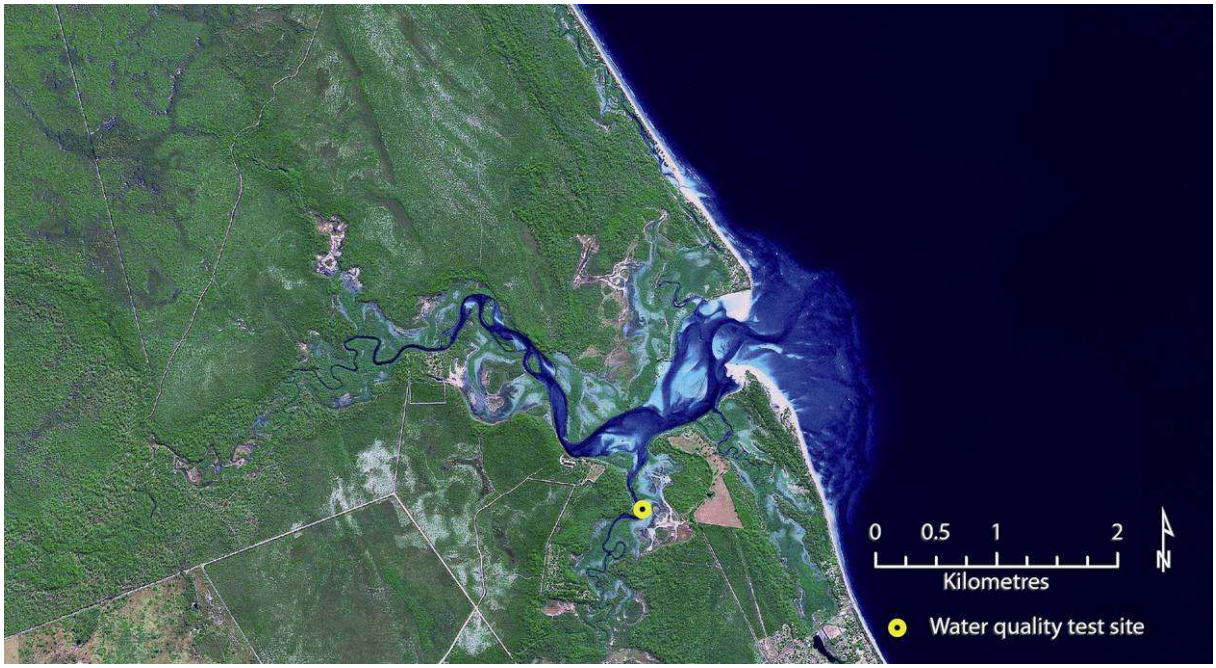
Table 13. Summary of the stressor risk and condition scores for Theodolite Creek estuary.

Stressor	Risk	Condition
Aquatic Sediments	Moderate	Excellent
Bacteria/Pathogens	Negligible	Excellent
Biota removal/ disturbance	Moderate	Poor
Connectivity	Negligible	Excellent
Freshwater flow regime	Negligible	Excellent
Habitat removal/ disturbance	Negligible	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Low	Fair
Nutrients	Low	Excellent
Organic matter	Negligible	Excellent
Pests	Negligible	Excellent
pH	Low	Excellent
Toxicants	Negligible	Excellent

INTRODUCTION

Theodolite Creek (here including Lagoon Creek) has a small coastal catchment of only ~220 km^2. The predominant land use is conservation and natural environments (64%) with significant grazing (30%) and some irrigated cropping (5%). The town of Woodgate extends south from the lower estuary. The stream system is largely unmodified with only very limited areas of disturbed riparian vegetation (only ~3% of the estuarine shoreline is modified) and no artificial barriers to flow or point source discharges.

The estuary is short (~7.5 km), shallow and has a spring tidal range of around 2.5 m – as a result it is well flushed throughout.



Satellite imagery of the Theodolite Creek estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	25% dependability

Risk

Much of the catchment of Theodolite Creek is in national park and therefore largely undisturbed (64% classified as 'conservation and natural environments'). Most of the remainder is grazing (30%) land with a very small amount of cropping (5%). 23% of the catchment has been cleared, 2.6% has less than 70% ground cover and only 12% of the system's riparian vegetation has been lost. It does have a high density of unsealed roads. The catchment therefore has a moderate risk for generating sediment loads. The catchment is however quite small which limits its capacity to generate loads.

SedNet calculations estimate that sediment loads have increased by only 1300% over natural (i.e. 13 times greater). There is no dredging in the estuary.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	2.19	Low	High
PI2: % of catchment cleared	23	Moderate	Very high
PI3: % length of river system with no riparian vegetation	12	Moderate	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Negligible	Very high
PI6: unsealed road density (m/km^2)	330-460	High	Low
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	2.6	Moderate	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	1300	Low	Moderate

Condition

A limited water quality data set (12 months at one site) is available for Theodolite Creek. This shows that turbidity (no Secchi depth clarity data is available) in the estuary met the guideline value. This would be expected given the moderate risk from the catchment. Also, given the very short length of

the estuary, any sediment that enters the estuary is likely to be rapidly flushed out again by tidal exchange. Thus, any impacts from sediment loads will be short lived.

A survey of current seagrass extent in Theodolite Creek estuary failed to find any seagrass beds (a small piece of *Zostrea capricorni* was attached to the boat after the survey). However, there is no reliable information on the historical extent of seagrass in this estuary so it is not possible to determine if seagrass has been lost or if it was always sparse.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	High
CI2: Secchi depth (% of sites exceed guidelines)	No data		
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data (none found during EPA 2008 survey)		
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Negligible risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges or urban stormwater for this stressor in the Theodolite estuary catchment. There is no intensive animal production, aquaculture or boat moorings. Housing density in the catchment is low so that the risk from septics is probably not high, although there is no specific data on this.

Indicators of bacteria/pathogen sources	**Raw data**	**Risk score**	**Confidence**
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high

Condition

Limited measurements of intestinal enterococci bacteria all gave values ≤4 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems very probable that this stressor is not an issue in the Theodolite estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI5: intestinal enterococci counts (95^{th} percentile value of counts per 100 mL)	4	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Moderate risk	High confidence	100% dependability
Poor condition	Moderate confidence	50% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

Theodolite Creek estuary experiences a moderate level of commercial fishing and quite a high level of recreational fishing. There is also a moderate amount of recreational bait collection but no commercial collection. Both commercial and recreational fishing have a moderate level of catch. Boating and other recreational activities are relatively low with a small local resident population.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	4.9	Moderate	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	13	Low	High
PI21: 'estuary' population size (people/km^2)	7.342	Low	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	7.7	High	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.85	Moderate	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Low	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	63	Moderate	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	32024	Moderate	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Both commercial and recreational finfish catches are experiencing declines in CPUE which suggests that populations are declining – although some of these values have only a moderate level of confidence. Recreational CPUE of crabs is also decreasing. These results indicate that finfish and crab stocks appear to be decreasing and that the level of fishing and crabbing effort may not be sustainable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	10.9% decrease	Fair	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	19.3% decrease	Poor	Moderate

Biological condition indicators	Raw data	Condition score	Confidence
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	10.7% decrease	Fair	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

There are no weirs or other barriers to migration on the Theodolite system so connectivity is good, albeit to a fairly limited freshwater reach. The estuary's shoreline (3% modified) and background (3% modified) habitat is largely intact so there is good connectivity along the estuary riparian zone and with the catchment.

Almost all of the estuary's shoreline and background vegetation is unmodified

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	3.1	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	3.4	Negligible	Very high

Condition

As would be expected from the high level of connectivity between the estuary and freshwater reaches, diadromous fish populations are common with stable populations.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species common and population stable throughout system	Excellent	High

Freshwater flow regime

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There are no significant storages in the Theodolite catchment and very few artificial waterbodies such as farm dams. Thus, freshwater flows are little altered from natural. However, given the very small size

of the catchment, freshwater inflows would have been very limited even under natural conditions. The freshwater wetlands backing the estuary are dependent on groundwater inflows (Mackenzie and Duke, 2009).

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	0	Negligible	High
PI34: % of catchment area covered by artificial waterbodies	0.02	Low	High
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of Theodolite Creek, the negligible risk from reduced freshwater inflow suggests that impacts on the estuary are currently nil.

Habitat removal or disturbance

Negligible risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	67% dependability

Risk

Only a small percentage of the estuary's shoreline (3%) or background (3%) vegetation has been modified. There are no significant human activities which would remove habitat, such as dredging, in this estuary. There are some significant issues associated with vehicle access that are causing localised, but significant, damage (Mackenzie and Duke, 2009).

Vehicle access to saltmarsh areas removes important habitat

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	3.4	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	3.1	Negligible	Very high

Condition

There has been very little, and only localised, loss of either mangrove or saltmarsh habitat in the Theodolite estuary (the overall extent of both habitats has increased). No seagrass was found in the estuary during June 2008 surveys but it is not known if seagrass was ever present or if it was then to what extent. Thus, overall habitat condition in the estuary is excellent. There are however, some localised habitat issues as noted by Mackenzie and Duke (2009), particularly in relation to vehicle access.

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	No data (none found during EPA 2008 survey)		
CI14: change in mangrove extent (% change per year)	2.5% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	2.5% increase	Excellent	Moderate

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There have been no significant physical alterations to the estuary so the hydrodynamic regime is close to natural.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	0.7	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the negligible risk for all pressure indicators in Theodolite Creek it can be concluded that these impacts are currently nil.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

The Theodolite estuary has a relatively low level of boating and recreational use. There is a small resident population to the south of the estuary in the Woodgate township – no stormwater enters the estuary from this small urbanised area. These factors indicate a low level of risk to the estuary for litter.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	13	Low	High
PI21: 'estuary' population size (people/km^2)	7.342	Low	Very high
PI38: % of estuary adjoining urban area	3.78	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

An initial survey showed moderate amounts of litter were present in the estuary. This litter was collected and disposed of and another survey carried out three months later. This follow up survey showed that a substantial amount of additional litter had been deposited in that period. The most likely source of this litter is related to recreational use.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0015	Fair	High
CI17: litter accumulation rate (per m^2 per day)	0.000039	Fair	Moderate

Nutrients

Low risk	High confidence	100% dependability
Excellent condition	High confidence	88% dependability

Risk

Much of the Theodolite catchment is conservation area with some grazing and very limited cropping. A moderate percentage of the catchment (2.6%) has less than 70% ground cover and 12% of the system's riparian vegetation has been lost which results in a moderate risk of nutrients (particular those associated with sediments) entering the estuary. The overall risk of catchment nutrient loads is negligible given the nature of land use in the catchment and its small size. There are no point discharges to the Theodolite estuary.

SedNet model calculations indicate that there has been a very minor increase in catchment nutrient loads compared to natural.

Indicators of nutrient sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.59	Negligible	High
PI3: % length of river system with no riparian vegetation	12	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	2.6	Moderate	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	56	Low	Moderate
PI42: % difference between pre-European total nitrogen load and current load	147	Low	Moderate

Condition

A limited water quality data set is available (12 months at one sites). Nitrogen, phosphorus and chlorophyll-a indicators all met guidelines. This indicates that nutrient enrichment is not a significant problem.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	High
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	High
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	High
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Negligible risk	Very high confidence	83% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

Much of the Theodolite catchment is conservation area with some grazing and very limited cropping. Thus the risk of catchment organic loads is low given the nature of land use in the catchment and its small size. There are no point discharges to the Theodolite estuary. No data on the occurrence of aquatic weeds in the Theodolite Creek system is available.

Indicators of organic matter sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.89	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI43: % river system affected by aquatic weeds	No data		

Condition

A limited data set is available for dissolved oxygen (12 months at one site). Dry weather dissolved oxygen levels in the Theodolite estuary complied with guidelines, which indicates an absence of any ongoing organic loads. The minimum oxygen levels detected over the 12 month period was 69% saturation which is not unusual for estuaries in post event periods. This value is however, substantially lower than dry weather values which are in the range 90 to 100% saturation and indicates that catchment organic loads do have a minor effect on the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	69.5	Good	Low
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Theodolite estuary so the risk from these is negligible. There are also no permanent moorings in the estuary and navigation is hazardous so visitation from overseas boats is very unlikely. There are also no aquaculture operations.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	No port/harbour/marina or permanent moorings present. Non-trailerable, international/domestic vessels rarely visit estuary	Negligible	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Theodolite estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There is only limited disturbance of potential acid sulphate soils (ASS) adjacent to the Theodolite estuary so the risk of acid water entering the estuary from these is quite low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	2.9	Low	Moderate

Condition

The minimum pH value detected over the 12 months of sampling was 7.1, which indicates that no acid run-off impacts are occurring. However, the data set is small with only one post event data point so the confidence in the data is low. Nevertheless, the likelihood of acid run-off effects in Theodolite estuary is very low. Ambient pH was within the guideline range.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI31: minimum sustained pH values during the days following an inflow event	7.1	Excellent	Low
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Negligible risk	High confidence	100% dependability
Excellent condition	High confidence	67% dependability

Risk

There is very little cropping in the lower catchment so the risk of pesticide contamination from this source is very low. Overall, catchment land use activities results in negligible risk of toxicants affecting the estuary. There may be a small risk from the rural residential properties and the limited boating that does occur. There are no toxicant point sources or stormwater inflows.

Indicators of toxicant sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.6	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that, with the exception of Simazine and metals, levels of all toxicants tested for were below detection limits. Metals and traces of Simazine were detected but these where below the most stringent guideline values.

The detection of Simazine in the waters of Theodolite Creek is somewhat unexpected given the nature of the catchment land use – negligible risk scores in relation to land-use activities. This illustrates the pervasive nature of these compounds and how with even relatively low levels of use they still manage to find their way into waterways.

Using our current guideline values, Simazine does not appear to present a major risk to this estuary. However, the effect that it has, at the concentrations detected, on most estuarine species or their various life history stages is unknown.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	Not detected	Excellent	High
CI35c: toxicants in the water column (Diuron) (µg/L)	Not detected	Excellent	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	Not detected	Excellent	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0001	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	<4	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	3.7	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	<3	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	<1	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	1.4	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	1.8	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce initiatives to reduce pressure on crab populations, e.g. no take zones
2. Address litter issue – education initiatives, signage or other approaches
3. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation
4. Reduce the level of vehicle access to mangrove and saltmarsh habitat (see Mackenzie and Duke, 2009)
5. Determine/target for management the source of Simazine (herbicide) to the estuary

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas

Gregory River estuary

Overall assessment B

Overall risk	**B-**	Very high confidence	97% dependability
Overall health	**B+**	High confidence	60% dependability

SUMMARY

The Gregory estuary is subject to a 'low' level of risk of impact due to human activities. As a result, the estuary's health is currently rated as 'good'. This suggests that under the current *status quo* the condition of the estuary will remain in this state of good health. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is also backed by high quality data but only 60% of the potential condition indicators were monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still strongly supported.

Approximately half of the stressors were found to have a negligible or low level of risk. Four are reported as at moderate risk and two at high risk ('aquatic sediments' and 'connectivity').

Six of the condition scores for stressors are reported as 'excellent', with 'nutrients' considered to be in good condition. However, 'aquatic sediments', 'biota removal/disturbance', 'freshwater flow regime' and 'organic matter' are only in fair condition, while 'connectivity' is in very poor condition. No condition indicators were monitored for the stressor 'litter' (Table 14).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 14. Summary of the stressor risk and condition scores for Gregory River estuary.

Stressor	Risk	Condition
Aquatic Sediments	High	Fair
Bacteria/Pathogens	Negligible	Excellent
Biota removal/ disturbance	Low	Fair
Connectivity	Moderate	Very Poor
Freshwater flow regime	Moderate	Fair
Habitat removal/ disturbance	Negligible	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Low	no data
Nutrients	Moderate	Good
Organic matter	Moderate	Fair
Pests	Negligible	Excellent
pH	Low	Excellent
Toxicants	Moderate	Excellent

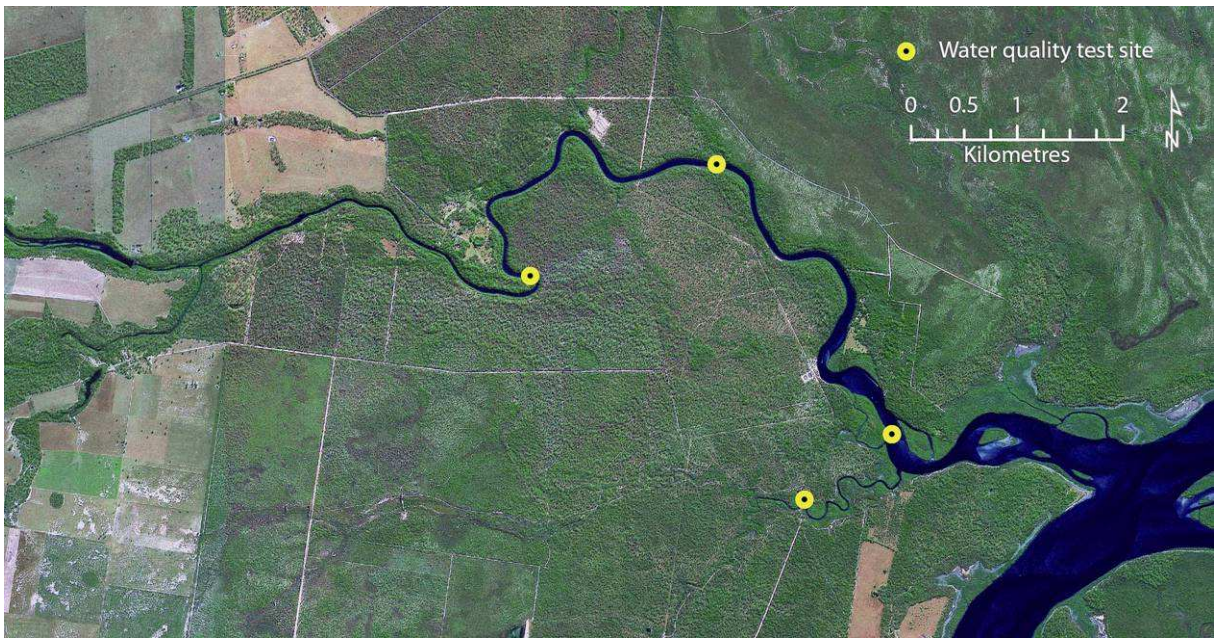
INTRODUCTION

The Gregory, Isis and Burrum rivers are branches of the same system which enter the ocean at Burrum Heads. A fourth branch, the Cherwell, was not included in this program.

The Gregory River has a small coastal catchment (~880 km^2) which has been extensively developed for grazing (63%), cropping (15%, mostly sugar cane) and forestry (15%) with only 6% classified as 'conservation and natural environments'. In contrast, the estuary is relatively undisturbed (only 1% of the estuary shoreline has been modified).

There are no point discharges to, or major towns along, the estuary.

The Gregory estuary is approximately 14 km long and ends at a weir at approximately the natural tidal limit. The weir reduces freshwater (particularly base flow) inflows to the estuary and lacks a functional fishway. The spring tidal range is around 2.5 m.



Satellite imagery of the Gregory River estuary

STRESSOR RESULTS

Aquatic sediments

High risk	High confidence	100% dependability
Fair condition	Very high confidence	50% dependability

Risk

Land use in the Gregory catchment is highly modified (93% is used for grazing, cropping and forestry). The risk from land use activities is therefore rated as high. Other high risk factors are the density of unsealed roads, the loss of 20% of the river system's riparian zone and the large proportion of the catchment (4.5%) with intensive agriculture on steep slopes. 32% of the catchment has been cleared. There are no point source sediment discharges, no dredging and boating activity is minimal.

Bank erosion can be an important source of sediments

SedNet calculations estimate that sediment loads have increased by 2825% over natural (i.e. 28 times greater). (Note that this SedNet modelling is performed for the entire Burrum/Gregory/Isis/Cherwell catchment as one catchment and hence when using the data 'for one estuary' it has been given only a moderate confidence here).

All these factors result in a high overall risk for sediment loads to the estuary.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	3.83	High	High
PI2: % of catchment cleared	32	Moderate	Very high
PI3: % length of river system with no riparian vegetation	20	High	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Negligible	Very high
PI6: unsealed road density (m/km^2)	330-460	High	Low
PI7: % of catchment with intensive agriculture on steep slopes	4.45	High	High
PI8: % of catchment with less than 70% ground cover	0.9	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	2825	Moderate	Moderate

Condition

There is an extensive water quality data set available for the Gregory estuary. Turbidity and Secchi depth clarity meet guidelines at mid and lower estuary sites but fail at the most upstream site. Like most estuaries, turbidity in the Gregory is high immediately after large inflow events but within a few weeks the fine particulates settle out or are dispersed out of the estuary and it reverts to its dry weather pattern, which is mainly driven by the neap/spring tidal cycle. Thus, even though the risk from the catchment is quite high, this may not be reflected in the dry weather turbidity. The degree to which wet weather catchment loads of fine particulates residually impact on dry weather turbidity is not known.

There is no information on seagrass extent or % cover in the Gregory estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	33	Fair	Very high
CI2: Secchi depth (% of sites exceed guidelines)	33	Fair	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data		
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Negligible risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges or urban stormwater for this stressor in the Gregory estuary catchment, while there is only a limited amount of intensive animal production. There is one aquaculture facilities on the estuary which may present some risk of the release of pathogens. Housing density in the catchment is low so that the risk from septics is probably not high, although there is no specific data on this.

Indicators of bacteria/pathogen sources	**Raw data**	**Risk score**	**Confidence**
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.078	Low	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤30 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems very probable that this stressor is not an issue in the Gregory estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	27	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Low risk	High confidence	100% dependability
Fair condition	Moderate confidence	67% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Relatively limited recreational activities occur in the estuary

Risk

The Gregory estuary experiences a moderate to low level of both commercial and recreational fishing pressure, including both finfish and crabs. There are moderate levels of commercial fish catch in the estuary and adjacent waters. There is no significant bait collection but this may simply reflect the absence of suitable habitat. In addition, there are low population densities close to the estuary as well as minor levels of boating and recreational activities occurring in and around the estuary.

Indicators of biota removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	0.4	Negligible	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	13	Low	High
PI21: 'estuary' population size (people/km^2)	6.82	Low	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	0.5	Low	Moderate

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.08	Negligible	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	6	Moderate	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	57	Moderate	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	38766	Moderate	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Commercial fishers are experiencing quite large declines in finfish catch per unit effort, however, recreational fish CPUE appears to be stable – though these values have only a moderate level of confidence. There is also a large decline in recreational crab CPUE and to a lesser extent prawn CPUE. These results indicate that fish, crab and prawn stocks appear to be decreasing and that the level of fishing effort may not be sustainable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	18.4% decrease	Poor	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	29.5% decrease	Poor	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	2.6% decrease	Good	Moderate

Connectivity

Moderate risk	Very high confidence	100% dependability
Very poor condition	High confidence	100% dependability

Risk

The Gregory River weir, which is located close to the tidal limit, has no fishway and effectively cuts off connectivity to all freshwater reaches above it. However, there is still connectivity to the freshwater reaches of the much smaller Stockyard Creek system which connects to the Gregory slightly below the weir. Thus, 67% of the entire system's freshwater reaches are effectively lost to diadromous fish in the estuary. Within the estuary connectivity is good as there has been virtually no modification of the shoreline (0.9%) or background (0.6%) vegetation. This results in an overall moderate risk to the estuary from lost connectivity.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	67.1	High	Very high
PI29: impoundment density (per 500 km of river)	1.81	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.9	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	0.6	Negligible	Very high

Condition

It would be expected that given the loss of connectivity to freshwater reaches in the Gregory system reported that there would be some impacts seen on diadromous populations in the estuary. The reported impact of "diadromous fish populations being absent from the estuary" though is worse than expected from the level of risk and level of connectivity still present in relation to Stockyard Creek.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species lost from a system they previously inhabited	Very poor	High

Freshwater flow regime

Moderate risk	Very high confidence	100% dependability
Fair condition	Assumed condition from risk	

Risk

The major storage in the Gregory catchment is the weir. This holds less than 20% of the median annual flow and thus has limited impacts on freshwater flows. However, it may have disproportionate impacts on flows in dry weather. There are also a number of artificial waterbodies such as farm dams present, which cover 0.79% of the catchment – resulting in a moderate risk score, though their impact remains to be quantified. The catchment has a moderate score for impoundment density.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	<20	Low	High
PI34: % of catchment area covered by artificial waterbodies	0.79	Moderate	High
PI29: impoundment density (per 500 km of river)	1.81	Moderate	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the Gregory River, the moderate risk from reduced freshwater inflow suggests that it is likely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Negligible risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	67% dependability

Risk

The Gregory estuary riparian zone is almost completely intact with no virtually no loss of either shoreline (0.9% modified) or background (0.6% modified) vegetation. There are no significant human activities which would remove habitat, such as dredging, in this estuary but an aquaculture facility is present.

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	0.6	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.9	Negligible	Very high

Both shoreline and background habitat are intact

Condition

There has been no loss of either mangrove or saltmarsh habitat in the Gregory estuary, in terms of overall extent. There is no information on seagrass extent in the Gregory estuary.

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	No data		
CI14: change in mangrove extent (% change per year)	No change	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	No change	Excellent	Moderate

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There have been no significant physical alterations to the Gregory estuary so the hydrodynamic regime is close to natural. The weir is close to the original tidal limit so has had very limited, if any, effect on estuary hydrodynamics.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	0.9	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	Tidal barrage at upper limit	Low	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall negligible risk in the Gregory River it can be concluded that these impacts are likely to be insignificant.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
No data		

Risk

The Gregory estuary has a low level of recreational use and boating activity. The resident population close to the estuary is small with no adjoining urban areas and no stormwater inflows. These factors indicate a low level of risk to the estuary.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	13	Low	High
PI21: 'estuary' population size (people/km^2)	6.82	Low	Very high
PI38: % of estuary adjoining urban area	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

There were no litter surveys performed in the Gregory estuary so no definite conclusions can be drawn. As is clear from the results in other estuaries, the fact that the risk appears to be low does necessarily mean that littering is minimal. Results for the adjacent Burrum estuary showed that litter levels were moderate and that litter was accumulating at a moderate rate. It seems likely that litter conditions in the Gregory may be similar.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	No data		
CI17: litter accumulation rate (per m^2 per day)	No data		

Nutrients

Moderate risk	High confidence	100% dependability
Good condition	Very high confidence	88% dependability

Risk

Because of the highly developed nature of the catchment, catchment nutrient loads are potentially large and give a moderate risk score. Other catchment indicators such as the 20% loss of riparian vegetation and high level of intensive agriculture on steep slopes give high risk scores. Nutrient loads to the estuary from catchment sources are estimated by SedNet modelling to have increased by between 160 and 295% compared to natural. Point discharge of nutrients are absent as are stormwater inflows.

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.6	Moderate	High
PI3: % length of river system with no riparian vegetation	20	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	4.45	High	High
PI8: % of catchment with less than 70% ground cover	0.9	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	295	Moderate	Moderate
PI42: % difference between pre-European total nitrogen load and current load	160	Moderate	Moderate

Condition

An extensive water quality data set is available. Nitrogen and phosphorus indicators meet guidelines at all sites. Chlorophyll-a meets guidelines at two of three sites but just fails at the most upstream site. Thus nutrient enrichment does not appear to be a major problem overall but there is some limited evidence of enrichment of the upper estuary reaches.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	Very high

Biological condition indicators	Raw data	Condition score	Confidence
CI24: chlorophyll-a (% of sites exceed guidelines)	33	Fair	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Moderate risk	Very high confidence	83% dependability
Fair condition	High confidence	100% dependability

Risk

Most pressure indicators for catchment organic loading give a moderate to low risk, the only exception being intensive agriculture on steep slopes which has high risk rating. There are no point discharges of organic matter. No data on the occurrence of aquatic weeds in the Gregory River system is available.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.39	Moderate	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	4.45	High	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0.078	Low	High
PI43: % river system affected by aquatic weeds	No data		

Condition

An extensive water quality data set is available. Dry weather dissolved oxygen levels in the Gregory estuary comply with guidelines at all but the upstream site. The minimum oxygen levels detected occurred after large inflow events, which indicates that catchment organic loads are having some impact. However, the lowest value detected over ~15 years of EPA sampling in the estuary was 38% saturation which is lower than normal for a post event period. This suggests there may be some larger than normal anthropogenic source of organic matter entering the estuary during flow events.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	38	Fair	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	33	Fair	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Gregory estuary so the risk from these is negligible. There are no permanent moorings in the estuary so visitation from overseas boats is unlikely, however, some overseas visitation occurs in the downstream reaches of the Burrum/Isis/Gregory system (e.g. around Burrum Heads). There is a small aquaculture operation which presents a minor risk of species escaping into the estuary and becoming a pest.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	No port/harbour/marina or permanent moorings present. Non-trailerable, international/domestic vessels rarely visit estuary	Negligible	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	1 land based facility present	Low	Very high

Condition

No surveys to detect pest species have been carried out in the Gregory estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There is only limited disturbance of potential acid sulphate soils (ASS) adjacent to the Gregory estuary so the risk of acid water entering the estuary from these is quite low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	2.6	Low	Moderate

Condition

The minimum pH value detected over ~15 years of EPA sampling in the estuary was 6.3, which indicates that no acid run-off impacts are occurring. Ambient pH levels in the estuary were within the guideline range at all sites.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6.3	Good	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	49% dependability

Risk

Overall, catchment land use activities results in moderate risk of toxicants affecting the estuary, owing mainly to the cropping areas in the mid catchment. Intensive agriculture of steep slopes is a high risk factor. There may be a small risk from the rural residential properties adjoining the estuary and the limited boating that does occur. There are no toxicant point sources or stormwater inflows.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.61	Moderate	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI7: % of catchment with intensive agriculture on steep slopes	4.45	High	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Due to the loss (theft?) of three passive samplers the Gregory was the only mainland estuaries in which no water column toxicant sampling was carried out. Surveys of toxicants in sediments showed that, with the exception of Diuron and metals, levels of all toxicants tested for were below detection

limits. Metals and traces of Diuron were detected but these were below the most stringent guideline values.

Using our current guideline values, Diuron does not appear to present a major risk to this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	No data		
CI35b: toxicants in the water column (Atrazine) (µg/L)	No data		
CI35c: toxicants in the water column (Diuron) (µg/L)	No data		
CI35d: toxicants in the water column (Fluometuron) (µg/L)	No data		
CI35e: toxicants in the water column (Hexazinone) (µg/L)	No data		
CI35f: toxicants in the water column (Prometryn) (µg/L)	No data		
CI35g: toxicants in the water column (Simazine) (µg/L)	No data		
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	No data		
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	12	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	26	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	5	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	8	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	9.4	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	24	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	0.001	Good	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Education initiatives around the location and benefit of green zones as well as the enforcement of these 'no take' zones
3. Construct effective fishway on Gregory weir
4. Construction of barriers in the Cherwell River and Stockyard Creek should be discouraged
5. Ensure estuary has an adequate environmental flow allocation under the Burrum Water Resource Plan
6. Investigate impact of farm dams on water resources in the catchment
7. Address litter issue – education initiatives, signage or other approaches
8. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Acquire better information on diadromous fish stocks
3. Four yearly assessment of habitat extent including riparian zones and seagrass areas (if present)
4. Collect data for litter condition to assess future management action needs
5. Collect data for toxicants in the water column to fully assess future management actions
6. Investigate current and historic status of seagrass





Isis River estuary

Overall assessment B-

Overall risk	**B-**	Very high confidence	97% dependability
Overall health	**B-**	High confidence	83% dependability

SUMMARY

The Isis estuary is subject to a 'low' level of risk of impact due to human activities. As a result, the estuary's health is currently rated as 'good'. This suggests that under the current *status quo* the condition of the estuary will remain in this state of good health. The overall risk and health ratings reported are backed by a large amount of very high and high quality data which provide strong support for the accuracy of these results.

The only stressor reported with a high level of risk is 'connectivity', with three others ('aquatic sediments', 'freshwater flow regime' and 'hydrodynamics') reported as at moderate risk. All other stressors were found to be at low (eight stressors) or negligible ('pests') risk.

Only four of the condition scores for stressors are reported as 'excellent', with another two classified as in good condition. 'Connectivity', 'freshwater flow regime', 'hydrodynamics' and 'organic matter' are only in fair condition, while 'aquatic sediments' and 'nutrients' are in very poor condition. No condition indicators were monitored for the stressor 'litter' (Table 15).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 15. Summary of the stressor risk and condition scores for Isis River estuary.

Stressor	Risk	Condition
Aquatic Sediments	Moderate	Very Poor
Bacteria/Pathogens	Low	Excellent
Biota removal/ disturbance	Low	Good
Connectivity	High	Fair
Freshwater flow regime	Moderate	Fair
Habitat removal/ disturbance	Low	Excellent
Hydrodynamics	Moderate	Fair
Litter	Low	no data
Nutrients	Low	Very Poor
Organic matter	Low	Fair
Pests	Negligible	Excellent
pH	Low	Good
Toxicants	Low	Excellent

INTRODUCTION

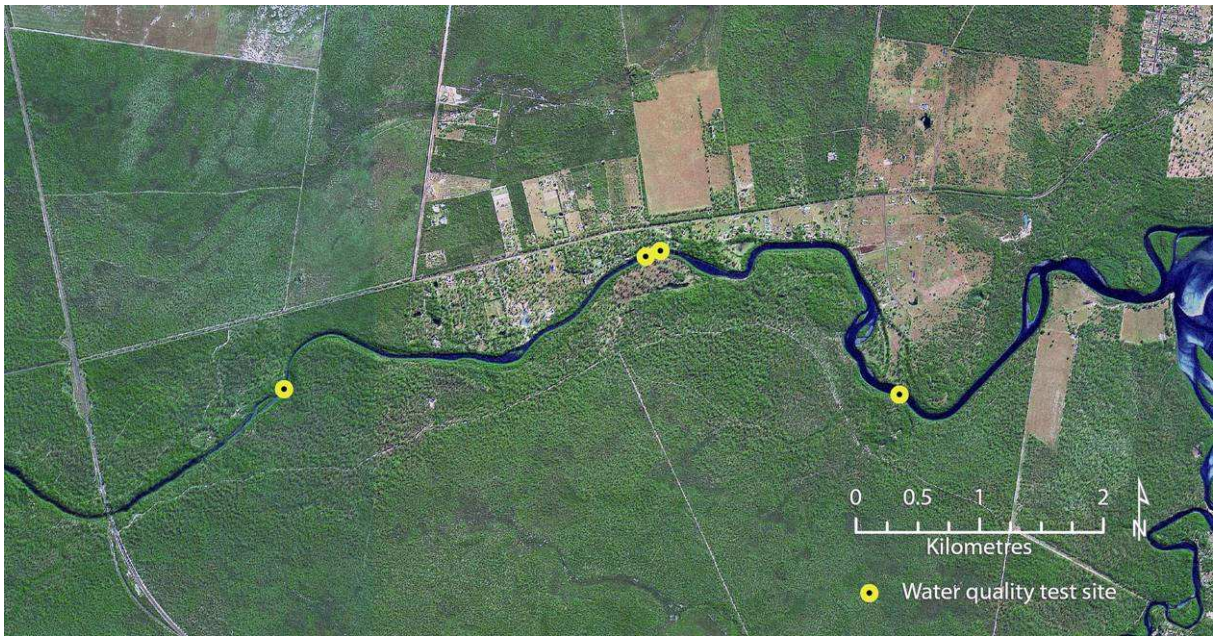
The Gregory, Isis and Burrum rivers are branches of the same system which enter the ocean at Burrum Heads. A fourth branch, the Cherwell, is present but was not included in this program.

The Isis River has a small coastal catchment (~520 km^2) which has been extensively developed for grazing (54%), forestry (41%) and cropping (3%), mostly sugar cane with less than 1% classified as

'conservation and natural environments'. In contrast, the estuary is relatively undisturbed (only ~4% of the estuary shoreline has been modified).

There are no point discharges to, or major towns along, the estuary.

The Isis estuary is approximately 12 km long and ends at a weir which has reduced the natural estuary length by approximately 19%. The weir reduces freshwater (particularly base flow) inflows to the estuary and lacks a functional fishway. The spring tidal range is around 2.5 m.



Satellite imagery of the Isis River estuary

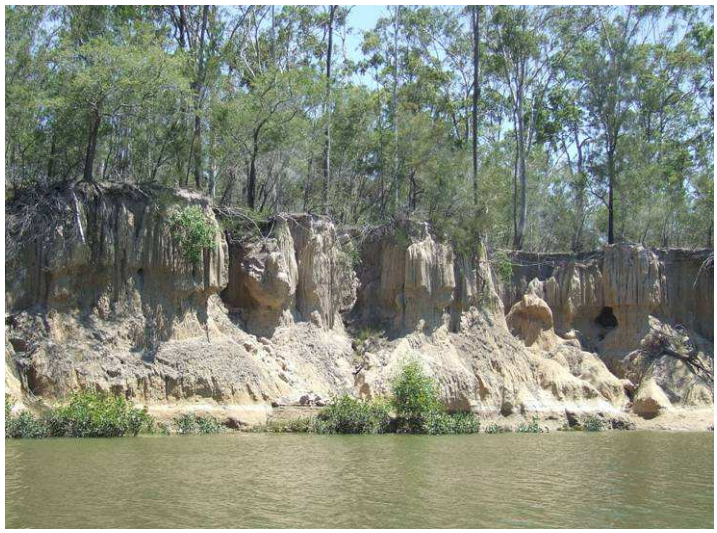
STRESSOR RESULTS

Aquatic sediments

Moderate risk	High confidence	100% dependability
Very poor condition	Very high confidence	50% dependability

Risk

Land use in the Isis catchment is highly modified (95% is used for grazing and forestry) but there is relatively little cropping (3%). The risk from these low intensity land use activities is therefore rated as moderate. The only high risk factor is the density of unsealed roads. Catchment clearing and the presence of intensive agriculture on steep slopes both have moderate risk scores. There are no point source sediment discharges, no dredging and boating activity is minimal. Good levels of ground cover and riverine riparian vegetation occur in the catchment.



Bank erosion can be an important source of sediments

SedNet calculations estimate that sediment loads have increased by 2825% over natural (i.e. 28 times greater). (Note that this SedNet modelling is performed for the entire Burrum/Gregory/Isis/Cherwell catchment as one catchment and hence when using the data 'for one estuary' it has been given only a moderate confidence here).

All these factors result in a moderate overall risk for sediment loads to the estuary.

Indicators of suspended sediment sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.22	Moderate	High
PI2: % of catchment cleared	20	Moderate	Very high
PI3: % length of river system with no riparian vegetation	10	Low	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Negligible	Very high
PI6: unsealed road density (m/km^2)	330-460	High	Low
PI7: % of catchment with intensive agriculture on steep slopes	1.83	Moderate	High
PI8: % of catchment with less than 70% ground cover	0.21	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	2825	Moderate	Moderate

Condition

There is an extensive water quality data set available for the Isis estuary. Despite the moderate level of risk, turbidity levels fail guidelines at all sites while Secchi depth clarity fails guidelines at two of three sites. Like most estuaries, turbidity in the Isis is high immediately after large inflow events but within a few weeks the fine particulates settle out or are dispersed out of the estuary and it reverts to its dry weather pattern, which is mainly driven by the neap/spring tidal cycle. Thus, even though the risk from the catchment is quite high, this may not be reflected in the dry weather turbidity levels. However, in the Isis, dry weather turbidity does seem to be unusually high compared to the other tributaries of the Burrum system. There is no obvious reason for this though land use is slightly more modified than in the Gregory. There may be some in-estuary factor involved but this needs further investigation.

There is no information on seagrass extent or % cover in the Isis estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI1: turbidity (% of sites exceed guidelines)	100	Very poor	Very high
CI2: Secchi depth (% of sites exceed guidelines)	67	Poor	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data		
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Low risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges or urban stormwater for this stressor in the Isis estuary or its catchment. Resident populations are low and there is no intensive animal production. Aquaculture facilities in the catchment may present some potential for the release of pathogens, however, the likelihood of this is minimal. Housing density in the catchment is low so that the risk from septics is probably minimal, although there is no specific data on this. However, there are quite a number of rural residential blocks adjoining the estuary which could present some risk.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	2	Moderate	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤14 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems very probable that this stressor is not an issue in the Isis estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	14	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Low risk	High confidence	100% dependability
Good condition	High confidence	33% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Green (no take) zone are one form of management that reduce the risk of biota removal impacting the estuary

Risk

The Isis estuary experiences a low level of both commercial and recreational fishing pressure, including both finfish and crabs. There are low levels of fisheries catch in the estuary and adjacent waters. There is no significant bait collection but this may simply reflect the absence of suitable habitat. In addition, there are low population densities close to the estuary as well as minor levels of boating and recreational activities occurring in and around the estuary.

Indicators of biota removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	None reported	Negligible	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	15	Low	High
PI21: 'estuary' population size (people/km^2)	7.278	Low	Very high

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	0.1	Negligible	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.01	Negligible	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Low	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	23	Moderate	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	7104	Low	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Commercial fishers are experiencing an increase in finfish catch per unit effort, however, recreational fish CPUE is decreasing slightly – though these values have only a moderate level of confidence. There is no information for the Isis on crab CPUE, which in most estuaries is decreasing.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	9.5% decrease	Fair	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

High risk	Very high confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

The Isis River weir, which is located close to the tidal limit, has no fishway and effectively cuts off connectivity to all freshwater reaches above it. Within the estuary connectivity is good as there has been minimal loss of shoreline vegetation (4% modified) and only limited loss of background vegetation (10% modified).

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	100	Extreme	Very high
PI29: impoundment density (per 500 km of river)	2.55	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	4.3	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	10.3	Low	Very high

Condition

Although there has been a complete loss of connectivity to freshwater reaches in the Isis system, diadromous fish populations are still present, albeit in very reduced numbers. This better than

expected result may be related to the Cherwell River system which is free of barriers and connects to the Burrum just upstream of the Isis connection.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species have become rare but a few populations are still present	Fair	High

Freshwater flow regime

Moderate risk	Very high confidence	100% dependability
Fair condition	Assumed condition from risk	

Risk

The major storage in the Isis catchment is the weir. This holds less than 20% of the median annual flow and thus has limited impacts on freshwater flows. However, it may have a disproportionate effect in dry years. There are also a number of artificial waterbodies such as farm dams present, which cover only 0.14% of the catchment – resulting in a low risk score, though their impact remains to be quantified. The catchment has a moderate score for impoundment density.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	<20	Low	High
PI34: % of catchment area covered by artificial waterbodies	0.14	Low	High
PI29: impoundment density (per 500 km of river)	2.55	Moderate	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the Isis River, the moderate risk from reduced freshwater inflow suggests that it is likely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Low risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	67% dependability

Risk

The construction of the weir has reduced the estuary length by 19% so that around a fifth of the estuary's original habitat was lost in the past. Measurements based on the current extent of the estuary show only a small percentage of the estuary's shoreline (4%) has been lost although changes to the background vegetation are slightly more (10% modified). The Isis estuary riparian zone is thus almost completely intact. There are no significant human activities which would remove habitat, such as dredging, in this estuary.

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	2	Moderate	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	10.3	Low	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	4.3	Negligible	Very high

Both shoreline and background habitat are largely intact

Condition

There has been no loss of either mangrove or saltmarsh habitat in the Isis estuary, in terms of overall extent. However, this system has never had much saltmarsh. There is no information on seagrass extent.

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	No data		
CI14: change in mangrove extent (% change per year)	No change	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	No change	Excellent	Moderate

Hydrodynamics

Moderate risk	Very high confidence	100% dependability
Fair condition	Assumed condition from risk	

Risk

The main physical alteration to the Isis estuary is the construction of the weir which has reduced the estuary length by 19% and would have altered water movement patterns. There have been no other significant physical alterations, such as dredging or training wall, to the Isis estuary.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	1.7	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	19	High	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall moderate risk in the Isis River it can be concluded that these impacts are likely to be important. The reduction of the estuary length by 19% must have resulted in some changes, but there is no quantitative 'condition' data on this.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
No data		

Risk

The level of risk to the Isis estuary is low, resident populations are low and recreational use and boating is limited. The rural residential development adjacent to the estuary may present a moderate risk. There are no stormwater inflows to the estuary.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	15	Low	High
PI21: 'estuary' population size (people/km^2)	7.278	Low	Very high
PI38: % of estuary adjoining urban area	11.13	Moderate	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

There were no litter surveys in the Isis so no definite conclusions can be drawn. As is clear from the results in other estuaries, the fact that the risk appears to be low does necessarily mean that littering is minimal. Results for the adjacent Burrum estuary showed that litter levels were moderate and that litter was accumulating at a moderate rate. It seems likely that litter conditions in the Isis may be similar.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	No data		
CI17: litter accumulation rate (per m^2 per day)	No data		

Nutrients

Low risk	High confidence	100% dependability
Very poor condition	Very high confidence	88% dependability

Risk

Despite the highly developed nature of the catchment, land use activities are relatively low intensity and catchment nutrient loads are small and give a low risk score. Intensive agriculture on steep slopes gives a moderate risk scores but other catchment indicators, such as the small (10%) loss of riparian vegetation and good levels of ground cover give low risk scores. Nutrient loads to the estuary from catchment sources are estimated by SedNet modelling to have increased by between 160 and 295% compared to natural. Point discharge of nutrients are absent as are stormwater inflows.

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.18	Low	High
PI3: % length of river system with no riparian vegetation	10	Low	Very high
PI7: % of catchment with intensive agriculture on steep slopes	1.83	Moderate	High
PI8: % of catchment with less than 70% ground cover	0.21	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	295	Moderate	Moderate
PI42: % difference between pre-European total nitrogen load and current load	160	Moderate	Moderate

Condition

An extensive water quality data set is available. Generally, nitrogen and phosphorus indicators meet guidelines at the mid estuary site but fail at the upper estuary site (total phosphorus fails at both sites). Chlorophyll-a fails the guidelines at both sites. The Isis estuary is clearly experiencing abnormal levels of algal production. However, the reason for this is not known. Compared to the Gregory, catchment factors present a lower risk in the Isis and there are no point discharges.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	50	Fair	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	50	Fair	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	50	Fair	Very high
CI21: total nitrogen (% of sites exceed guidelines)	50	Fair	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	50	Fair	Very high
CI23: total phosphorus (% of sites exceed guidelines)	100	Very poor	Very high
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	100	Very poor	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Low risk	Very high confidence	83% dependability
Fair condition	High confidence	100% dependability

Risk

Most pressure indicators for catchment organic loading give a moderate risk, the only exception being intensive agriculture on steep slopes which has negligible risk rating. There are no point discharges of organic matter. No data on the occurrence of aquatic weeds in the Isis River system is available.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.15	Moderate	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	1.83	Moderate	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI43: % river system affected by aquatic weeds	No data		

Condition

An extensive water quality data set is available. Dry weather dissolved oxygen levels in the Isis estuary comply with guidelines at two out of three sites and the third site only fails by a very small margin. These levels indicate an absence of any ongoing dry weather organic loads. The minimum oxygen levels detected occurred after large inflow events, which indicates that catchment organic loads are having some impact. The lowest value detected over ~15 years of EPA sampling in the estuary was 32% saturation. This is unusually low for estuaries in post event periods and indicates that organic loads to the Isis are higher than expected. This is surprising given the low risk from catchment sources and the cause is not known at this stage.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	32	Poor	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	33	Fair	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Isis estuary so the risk from these is negligible. There are no permanent moorings in the estuary so visitation from overseas boats is unlikely, however, some overseas visitation occurs in the downstream reaches of the Burrum/Isis/Gregory system (e.g. around Burrum Heads).

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	No port/harbour/marina or permanent moorings present. Non-trailerable, international/domestic vessels rarely visit estuary	Negligible	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Isis estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Good condition	Moderate confidence	75% dependability

Risk

There is only limited disturbance of potential acid sulphate soils (ASS) adjacent to the Isis estuary so the risk of acid water entering the estuary from these is quite low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	4.98	Low	Moderate

Condition

The minimum pH value detected over ~15 years of EPA sampling in the estuary was 5.9, which is not indicative of the presence of acid run-off. Ambient pH levels in the estuary were within the guideline range at all sites.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	5.9	Fair	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Low risk	High confidence	100% dependability
Excellent condition	High confidence	95% dependability

Risk

The Isis has a low level of risk owing to the absence of significant cropping areas in the catchment. There are also no significant urban areas in the catchment although the rural residential development adjacent to the estuary may present a small risk. There are no stormwater inflows and boating activities are minimal. The main risk factor appears to be associated with intensive agriculture on steep slopes and this only provides a moderate risk at most. No oil spills or slicks were reported.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.2	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI7: % of catchment with intensive agriculture on steep slopes	1.83	Moderate	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that levels of all toxicants tested for, with the exception of phosphate tri-n-butyl and metals, were below detection limits. Metals and traces of phosphate tri-n-butyl were detected but these were below the most stringent guideline values.

Phosphate tri-n-butyl is a plasticizer than leaches out of plastic into waterways. Using our current guideline values, phosphate tri-n-butyl does not appear to present a major risk to this estuary. However, the effect that it has, at the concentrations detected, on most estuarine species or their various life history stages is unknown.

Given the overall low level of risk, the absence of even traces of pesticides is not unexpected.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	Not detected	Excellent	High
CI35c: toxicants in the water column (Diuron) (µg/L)	Not detected	Excellent	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	Not detected	Excellent	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	Not detected	Excellent	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	Not detected	Excellent	High
CI35j: toxicants in the water column (Chlordane) (µg/L)	Not detected	Excellent	High
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	Not detected	Excellent	High
CI35l: toxicants in the water column (Dieldrin) (µg/L)	Not detected	Excellent	High
CI35m: toxicants in the water column (Endrin) (µg/L)	Not detected	Excellent	High
CI35n: toxicants in the water column (Endosulfan) (µg/L)	Not detected	Excellent	High
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	Not detected	Excellent	High
CI35p: toxicants in the water column (Lindane) (µg/L)	Not detected	Excellent	High
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	0.001	Good	High
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	Not detected	Excellent	High
CI35s: toxicants in the water column (Total DDT) (µg/L)	Not detected	Excellent	High
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	Not detected	Excellent	High
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	11	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	26	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	6	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	8	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	10	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	27	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Education initiatives around the location and benefit of green zones as well as the enforcement of these 'no take' zones
3. Examine the option of removing the Isis Weir. The weir is not 'owned' by anyone, has no licensed water extractions and may not be structurally sound. If this is not possible then construct a functional fishway
4. Construction of barriers in the Cherwell River and Stockyard Creek should be discouraged
5. Ensure estuary has an adequate environmental flow allocation under the Burrum Water Resource Plan
6. Address litter issue – education initiatives, signage or other approaches
7. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation
8. Investigate the reason for the unusually high turbidity and poor Secchi depth results
9. Investigate cause of high nutrient and chlorophyll-a levels
10. Investigate cause of low post-event dissolved oxygen levels

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas (if present)
3. Collect data for litter condition to assess future management action needs
4. Investigate current and historic status of seagrass

Burrum River estuary

Overall assessment B

Overall risk	**B-**	Very high confidence	97% dependability
Overall health	**B+**	High confidence	77% dependability

SUMMARY

The Burrum estuary is subject to a 'low' level of risk of impact due to human activities. As a result, the estuary's health is currently rated as 'good'. This suggests that under the current *status quo* the condition of the estuary will remain in this state of good health. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is also backed by high quality data but only 77% of the potential condition indicators were monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still strongly supported.

No stressors were found to have a negligible level of risk. The majority are reported as low risk with three reported as moderate risk and two at high risk ('biota removal/disturbance' and 'connectivity').

The majority of condition scores for stressors are reported as 'excellent' or 'good', however, 'freshwater flow regime', 'litter' and 'organic matter' are only in fair condition, while 'biota removal/disturbance' and 'connectivity' are in poor condition (Table 16).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 16. Summary of the stressor risk and condition scores for Burrum River estuary.

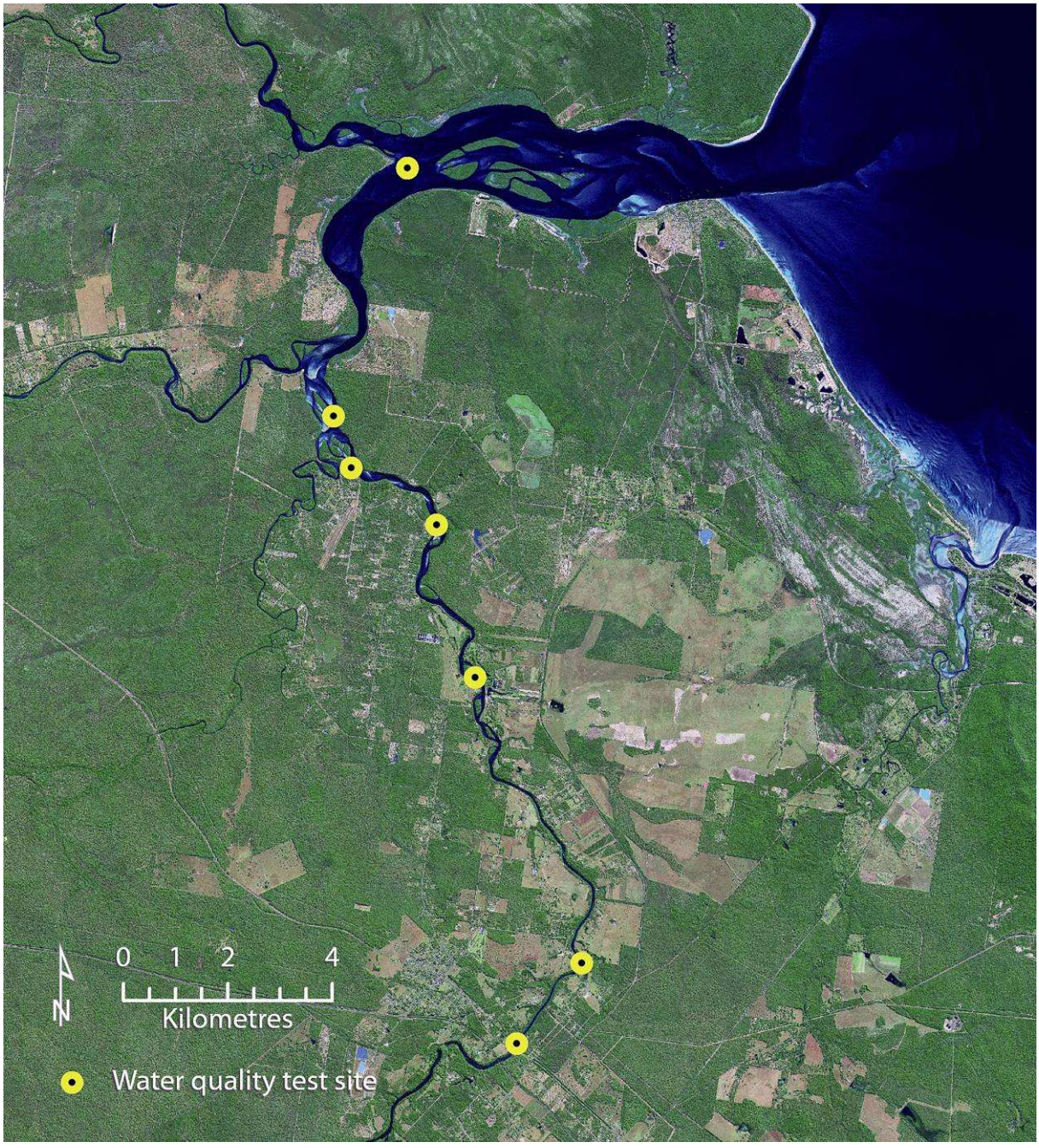
Stressor	Risk	Condition
Aquatic Sediments	Moderate	Good
Bacteria/Pathogens	Low	Good
Biota removal/ disturbance	High	Poor
Connectivity	High	Poor
Freshwater flow regime	Moderate	Fair
Habitat removal/ disturbance	Low	Excellent
Hydrodynamics	Low	Good
Litter	Moderate	Fair
Nutrients	Low	Good
Organic matter	Low	Fair
Pests	Low	Excellent
pH	Low	Good
Toxicants	Low	Excellent

INTRODUCTION

The Gregory, Isis and Burrum rivers are branches of the same system which enter the ocean at Burrum Heads. A fourth branch, the Cherwell, was not included in this program. The Burrum estuary is here (and by convention) taken to include the lower reaches of the Isis/Gregory/Burrum estuary system.

The Burrum River has a small coastal catchment (~910 km^2) which has been extensively developed for grazing (52%) and forestry (40%) with only 5% classified as 'conservation and natural environments'. Three small towns occur along the 'Burrum' estuary, town of Howard occurs at the upper end of the estuary, Buxton occurs between the junctions with the Isis and Gregory, while Burrum Heads occurs at the mouth. Freshwater inflows to the Burrum have been greatly reduced from their natural state due to the presence of Lenthalls Dam (and two other impoundments). This has recently been raised which will further reduce inflows to the estuary. There are no point discharges to the estuary.

The Burrum estuary is approximately 23 km long and terminates at a tidal barrage which has shortened the estuary by approximately 11%. The tidal barrage lacks a functional fishway. The spring tidal range is around 2.5 m.



Satellite imagery of the Burrum River estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	High confidence	100% dependability
Good condition	Very high confidence	75% dependability

Risk

Land use in the Burrum catchment is highly modified (92% is used for grazing and forestry) there is almost no cropping. The risk from these low intensity land use activities is therefore rated as moderate. In fact, all pressure indicators recorded a moderate or lower risk rating. The catchment having a moderate level of catchment clearing (13%), unsealed road density, and riverine riparian vegetation loss (17%). There are no point source sediment discharges, no dredging and boating activity is minimal. Intensive agriculture on steep slopes is minimal and ground cover in the catchment is good.

Bank erosion can be an important source of sediments

SedNet calculations estimate that sediment loads have increased by 2825% over natural (i.e. 28 times greater). (Note that this SedNet modelling is performed for the entire Burrum/Gregory/Isis/Cherwell catchment as one catchment and hence when using the data 'for one estuary' it has been given only a moderate confidence here).

All these factors result in a moderate overall risk for sediment loads to the estuary.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	3.03	Moderate	High
PI2: % of catchment cleared	13	Moderate	Very high
PI3: % length of river system with no riparian vegetation	17	Moderate	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Negligible	Very high
PI6: unsealed road density (m/km^2)	250-330	Moderate	Low
PI7: % of catchment with intensive agriculture on steep slopes	0.01	Low	High
PI8: % of catchment with less than 70% ground cover	0.07	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	2825	Moderate	Moderate

Condition

There is an extensive water quality data set available for the Burrum estuary. As would be expected given the moderate level of risk, both turbidity and Secchi depth clarity meet guidelines at all sites except one mid estuary site which marginally failed a turbidity guideline. Like most estuaries, turbidity in the Burrum is high immediately after large inflow events but within a few weeks the fine particulates settle out or are dispersed out of the estuary and it reverts to its dry weather pattern, which is mainly driven by the neap/spring tidal cycle. Thus, even though the risk from the catchment is significant, this may not be reflected in the dry weather turbidity.

A 2008 survey of seagrass extent in the Burrum found significant patches to be present, some with dugong feeding trails. However, there is no reliable information on the historical extent of seagrass in this estuary so it is not possible to determine if seagrass extent within the estuary has changed. However, there is Seagrass Watch data for seagrass beds just outside the mouth off Burrum Heads. This data showed that the % cover of seagrass was increasing between 2002 and 2006. This suggests that sediment loads coming out the Burrum system are not impacting seagrass beds just outside the mouth. No seagrass extent data was available.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI1: turbidity (% of sites exceed guidelines)	25	Fair	Very high
CI2: Secchi depth (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data	Significant areas present	
CI4: % cover of seagrass	Increase	Excellent	High

Bacteria/Pathogens

Low risk	Very high confidence	86% dependability
Good condition	High confidence	100% dependability

Risk

There are a number of low level risks in the Burrum catchment. Sewage treatment plants are present but they treat the wastewater to an A- recycle standard and then dispose to land, thus, resulting in minimal risk of bacteria release to the estuary. The presence of the Howard and Buxton towns result in some risk from stormwater as well as the potential for sewage overflow events to occur. Housing density in the catchment is low so that the risk from septics is probably minimal, although there is no specific data on this. However, there are quite a number of rural residential blocks adjoining the estuary which could present some risk. Some boat mooring occurs in the estuary, particularly around Buxton and Burrum Heads. An aquaculture facility in the catchment may present some potential for the release of pathogens, however, the likelihood of this is minimal.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	Treat to 'A-' recycled standard	Low	Very high
PI12: frequency of sewage overflow events (per year)	Sewerage infrastructure present but no reported overflows	Low	Moderate
PI13: % of catchment under intensive animal production	0.011	Low	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0.07	Low	Very high
PI17: boat moorings	Small craft mooring sites identified	Low	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high

Condition

Levels of intestinal enterococci bacteria values were ≤30 cfu/100 mL, which meets the primary contact guideline of 40 cfu/100 mL, except on one occasion when a level of 72 cfu/100 mL was recorded which is only a small exceedance. The data indicates that condition is generally good and in line with the level of risk.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95^{th} percentile value of counts per 100 mL)	53	Good	High
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

High risk	High confidence	100% dependability
Poor condition	Moderate confidence	67% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available

A moderate level of recreational activities, such as sailing and fishing, occur within the estuary

measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

The Burrum estuary experiences generally high levels of recreational and commercial fisheries activity and bait collection. Commercial recreational catch is also high. In addition, there are low population densities close to the estuary as well as minor levels of boating but moderate levels of recreational activities occurring in and around the estuary. There is no dredging in the Burrum.

Indicators of biota removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	10.1	High	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Moderate	High
PI17: boat moorings	Small craft mooring sites identified	Low	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	24	Moderate	High
PI21: 'estuary' population size (people/km^2)	8.324	Low	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	18.1	Extreme	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	3.63	Extreme	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	11	Moderate	High

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Low	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	180	High	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	76248	High	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Recreational CPUE of finfish appears to be increasing and indicates stable fish stocks but there are significant decreases in the recreational CPUE of both crabs and prawns – though these values have only a moderate level of confidence. Commercial CPUE of finfish is also decreasing but there is no information on commercial CPUE of crabs or prawns. These results indicate that crab and prawn stocks, and possibly fish stocks, appear to be decreasing and that the level of fishing effort may not be sustainable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	9.4% decrease	Fair	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	17.3% decrease	Poor	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	19.7% decrease	Poor	Moderate

Connectivity

High risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

The Burrum estuary is effectively cut from all the freshwater reaches of the river system by the Burrum River barrage. The barrage, which is located just below the tidal limit, does have a fishway but this is ineffective. Two other barriers occur in the Burrum but neither have a fishway. Along the estuary connectivity is fairly good as there has been only a 10% loss of shoreline vegetation and an 18% loss of background vegetation. The impoundment density for the system is moderate.

Burrum River Barrage 1 does not have an effective fishway and blocks connectivity to the freshwater reaches of the river system

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	100	Extreme	Very high
PI29: impoundment density (per 500 km of river)	3.51	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	10	Low	Very high
PI32: % of estuarine 'background habitat' length modified	17.8	Low	Very high

Condition

As a result of the complete loss of connectivity to freshwater reaches, diadromous fish populations are rare and they are occasionally seen. The Cherwell River system which connects to the Burrum just upstream of the Isis connection is free of barriers and may help support the limited number of diadromous fish found in the Burrum.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species have become rare and are only seen occasionally	Poor	High

Freshwater flow regime

Moderate risk	Very high confidence	100% dependability
Fair condition	Assumed condition from risk	

Risk

With the recent completion of the upgrade to Lenthalls Dam, storage capacity on the Burrum is now 35% of annual median flow, which is quite a high value. While this has only moderate effects on large flood events it is likely to dramatically reduce the number of medium and smaller freshwater inflows to the estuary, especially in dry years. There are also a number of artificial waterbodies such as farm dams present, which cover 0.59% of the catchment – resulting in a moderate risk score, though their impact remains to be quantified. The catchment has a moderate score for impoundment density.

Impoundments stop, or at least reduce, much of the freshwater flows into the estuary

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	35	Moderate	High
PI34: % of catchment area covered by artificial waterbodies	0.59	Moderate	High
PI29: impoundment density (per 500 km of river)	3.51	Moderate	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the Burrum estuary, the moderate risk from reduced freshwater inflow suggests that it is likely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this. However, there is anecdotal evidence that the upper reaches of the Burrum estuary have indeed silted up since the construction of Lenthalls Dam.

Habitat removal or disturbance

Low risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	67% dependability

Risk

Estuarine habitat is largely intact although some shoreline and background vegetation has been lost

The construction of the barrage has reduced the estuary length by 11% so that around a tenth of the estuary's original habitat was lost in the past. Measurements based on the current extent of the estuary show that only a small percentage of the estuary's shoreline (10%) has been lost although changes to the background vegetation are slightly more (18% modified). Some of the background vegetation loss is due to the increasing rural subdivision along the banks of the estuary. There are no significant human activities which would remove habitat, such as dredging, in this estuary. There are some issues, such as those associated with cattle grazing, vehicle access and altered hydrology, that are causing localised damage (Mackenzie and Duke, 2009).

Indicators of habitat removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	17.8	Low	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	10	Low	Very high

Condition

Since the construction of the barrage there has been very little, and only localised, loss of either mangrove or saltmarsh habitat in the Burrum River estuary (the overall extent of both habitats has remained unchanged). A 2008 survey of seagrass extent in the Burrum found significant patches to be present, some with dugong feeding trails. However, there is no reliable information on the historical extent of seagrass in this estuary so it is not possible to determine if seagrass extent within the estuary has changed due to human activities. Seagrass beds are also present just outside the mouth near Burrum Heads. Thus, overall habitat condition in the Burrum estuary is excellent. There are however, some localised habitat issues as noted by Mackenzie and Duke (2009) and in relation to shoreline and background vegetation modification.

Biological condition indicators	**Raw data**	**Condition score**	**Confidence**
CI3: change in seagrass extent (% change per year)	No data		
CI14: change in mangrove extent (% change per year)	No change	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	No change	Excellent	Moderate

Hydrodynamics

Low risk	Very high confidence	100% dependability
Good condition	Assumed condition from risk	

Risk

The main physical alteration to the Burrum estuary is the construction of the barrage which has reduced the estuary length by 11% and would have reduced the tidal prism and therefore altered water movement patterns. There has also been some shoreline modifications which effects hydrodynamics (in the form of a numerous jetties/pontoons and boat ramps, and significant area of rock wall along the southern bank near Burrum Heads). No dredging occurs in the Burrum estuary.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	0.77 km rock wall near mouth	Low	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	7.5	Low	Very high
PI37: % of original estuary length lost due to a tidal barrage	11	Moderate	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall low risk in the Burrum River it can be concluded that these impacts are likely to be minimal. The reduction of the estuary length by 11% and the presence of a 770 m long rock wall near the mouth must have resulted in some, if only minor, changes, but there is no quantitative 'condition' data on this.

Litter (rubbish)

Moderate risk	Very high confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

There is a moderate level of risk to the Burrum estuary from litter. Resident populations and boating activity are low but recreational use is moderate. The rural residential development adjacent to the estuary and the Howard and Buxton urban areas may also pose some risks in relation to littering and stormwater run-off into the estuary.

The town of Buxton adjoins the estuary and may be a source of litter

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	24	Moderate	High
PI21: 'estuary' population size (people/km^2)	8.324	Low	Very high
PI38: % of estuary adjoining urban area	10.61	Moderate	High
PI15: number of stormwater inflows per km estuary	0.07	Low	Very high

Condition

An initial litter survey in the Burrum estuary showed that litter levels were moderate. The litter was removed and a further survey carried out three months later. This showed that litter was continuing to accumulate at a moderate rate. Recreational use and catchment (e.g. stormwater inflows) sources are the most likely source of this litter, though a more complete analysis of litter might assist in determining the main source.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0018	Fair	High
CI17: litter accumulation rate (per m^2 per day)	0.000016	Fair	Moderate

Nutrients

Low risk	High confidence	100% dependability
Good condition	Very high confidence	100% dependability

Risk

A moderate amount of the river's riparian vegetation has been removed

The relatively low intensity of land use in the Burrum means that the risk from catchment nutrient loads is low. There are no point discharges except for a small aquaculture operation.

Despite the highly developed nature of the catchment, land use activities are relatively low intensity and catchment nutrient loads are small and give a low risk score. Intensive agriculture on steep slopes and good levels of ground cover give low risk scores but other catchment indicators, such as the 17% loss of riparian vegetation give a moderate risk score. Nutrient loads to the estuary from catchment sources are estimated by SedNet modelling to have increased by between 160 and 295% compared to natural. Point discharge of nutrients are absent. Risks associated with stormwater inflows and the potential for sewage overflows is low.

Indicators of nutrient sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	2.14	Low	High
PI3: % length of river system with no riparian vegetation	17	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.01	Low	High
PI8: % of catchment with less than 70% ground cover	0.07	Low	High
PI15: number of stormwater inflows per km estuary	0.07	Low	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	Sewerage infrastructure present but no reported overflows	Low	Moderate
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	295	Moderate	Moderate
PI42: % difference between pre-European total nitrogen load and current load	160	Moderate	Moderate

Condition

An extensive water quality data set is available. Virtually all nitrogen and phosphorus indicators meet guidelines at all sites. The two exceptions being organic nitrogen and total phosphorus at the upper estuary site. Chlorophyll-a meets guidelines at all sites. As would be expected from the low level of risk, nutrient enrichment does not appear to be a significant issue in the Burrum.

There is no information on epiphytic cover of seagrass in the Burrum estuary itself but there is Seagrass Watch data for seagrass beds just outside the mouth off Burrum Heads. Data showed that the % epiphyte cover of seagrass was decreasing between 2002 and 2006. This suggests that nutrient loads coming out the Burrum system are not impacting seagrass beds just outside the mouth.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	25	Fair	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
CI23: total phosphorus (% of sites exceed guidelines)	25	Fair	Very high

Biological condition indicators	Raw data	Condition score	Confidence
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	Very high
CI25: % epiphytic cover on seagrass	Decrease trend	Excellent	High

Organic matter

Low risk	High confidence	83% dependability
Fair condition	High confidence	100% dependability

Risk

Pressure indicators for organic loading in the Burrum mostly give a moderate to low risk. Land use activities in the catchment are relatively low intensity but catchment organic loads are significant and give a moderate risk score. Levels of intensive agriculture and animal production are both low in the catchment. There are no point discharges of organic matter but sewerage infrastructure is present and overflow events are possible though highly unlikely. No data on the occurrence of aquatic weeds in the Burrum River system is available.

Grazing is a major land-use activity in the catchment and along the estuary, where in some places they graze down to the waterline

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.14	Moderate	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.01	Low	High
PI12: frequency of sewage overflow events (per year)	Sewerage infrastructure present but no reported overflows	Low	Moderate
PI13: % of catchment under intensive animal production	0.011	Low	High
PI43: % river system affected by aquatic weeds	No data		

Condition

An extensive water quality data set is available. Dry weather dissolved oxygen levels in the Burrum estuary comply with guidelines at all sites. These levels indicate an absence of any ongoing dry weather organic loads. The minimum oxygen levels detected occurred after large inflow events, which indicates that catchment organic loads are having some impact. The lowest value detected over ~15 years of EPA sampling in the estuary was 26% saturation. This is unusually low for estuaries in post event periods and indicates that organic loads to the Burrum may be higher than expected. This is surprising given the low risk from catchment sources and the cause is not known at this stage. It could however, relate to low levels of dissolved oxygen in the hypolimnetic layers of the upstream water storages.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	26.5	Poor	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Burrum estuary so the risk from these is negligible. There are some permanent moorings in the estuary so low level visitation from overseas boats may occur, presenting a small risk of introducing marine pest species.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Moorings for small, non-trailerable, international/domestic vessels present (published in boating guides/well know by boaties)	Moderate	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Burrum estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Good condition	Moderate confidence	100% dependability

Risk

There is only limited disturbance of potential acid sulphate soils (ASS) adjacent to the Burrum estuary so the risk of acid water entering the estuary from these is quite low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	2.5	Low	Moderate

Condition

The minimum pH value detected over ~15 years of EPA sampling in the estuary was 6.0, which is not indicative of the presence of acid run-off. Red spot disease has been reported in the past for the Burrum and suggests that acid run-off may have occurred at some time. Red-spot is rarely observed today.

Ambient pH levels in the estuary were within the guideline range at all sites.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	6	Fair	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	Red-spot rarely observed (≤3% fish)	Fair	Moderate

Toxicants

Low risk	High confidence	100% dependability
Excellent condition	High confidence	67% dependability

Risk

The Burrum has a low level of risk owing the absence of significant cropping areas or other intensive agriculture in the catchment. There are however, small urban areas (stormwater inflows) in the catchment and some rural residential development adjacent to the estuary, both of which may present a small risk. Boating activities are minimal, point source discharges are absent and no oil spills or slicks were reported.

Indicators of toxicant sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	2.21	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.01	Low	High
PI15: number of stormwater inflows per km estuary	0.07	Low	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were always below the most stringent guideline values.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.0004	Good	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.0021	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0006	Good	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0004	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	0.001	Good	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	5	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	14	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	<3	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	4	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	4.8	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	14	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Construct effective fishways on Burrum barrage, Burrum No 2 Weir and Lenthalls dam
3. Education initiatives around the location and benefit of green zones as well as the enforcement of these 'no take' zones
4. Construction of barriers in the Cherwell River and Stockyard Creek should be discouraged
5. Ensure estuary has an adequate environmental flow allocation under the Burrum Water Resource Plan
6. Encourage revegetation of background 'buffer' vegetation along the estuary and target localised mangrove and saltmarsh habitat degradation/loss (as reported in Mackenzie and Duke, 2009)
7. Address litter issue – education initiatives, signage or other approaches
8. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas
3. Investigate cause of low post-event dissolved oxygen levels
4. Acquire better information on the location and disturbance of actual acid sulphate soils to assess future management action needs
5. Monitor pH during and after significant flow events to determine if acid run-off is occurring

Susan River estuary

Overall assessment B+

Overall risk	**B-**	Very high confidence	97% dependability
Overall health	**A**	Moderate confidence	74% dependability

SUMMARY

The Susan estuary is subject to a 'low' level of risk of impact due to human activities. However, the estuary's health is currently rated as 'excellent'. Under the current situation, the estuary condition is likely to remain good. However, the rapid development in the Hervey Bay region may increasingly impact on the Susan catchment in the future leading to greater impacts on the estuary. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is backed by only moderate quality data with 74% of the potential condition indicators monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still supported though more data to improve the confidence level would be beneficial.

With the exception of 'aquatic sediments', 'biota removal/disturbance' and 'nutrients' (at moderate risk) all stressors were found to be at low (eight stressors) or negligible ('connectivity' and 'hydrodynamics') risk levels.

The majority of condition scores for stressors are reported as 'excellent', however, 'connectivity', 'freshwater flow regime' and 'toxicants' were in good condition while 'biota removal/disturbance' was only in fair condition. No condition indicators were monitored for the stressor 'litter' (Table 17).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 17. Summary of the stressor risk and condition scores for Susan River estuary.

Stressor	Risk	Condition
Aquatic Sediments	Moderate	Excellent
Bacteria/Pathogens	Low	Excellent
Biota removal/ disturbance	Moderate	Fair
Connectivity	Negligible	Good
Freshwater flow regime	Low	Good
Habitat removal/ disturbance	Low	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Low	no data
Nutrients	Moderate	Excellent
Organic matter	Low	Excellent
Pests	Low	Excellent
pH	Low	Excellent
Toxicants	Low	Good

INTRODUCTION

The Susan River is a branch of the main Mary River system which drains the north side of the Mary River east of Maryborough.

The Susan River has a small coastal catchment (~360 km^2) which has been developed for grazing (53%) and cropping (8%) with 29% classified as 'conservation and natural environments'. The estuary itself is relatively undisturbed (less than 1% of the estuary shoreline has been modified).

The exact length of the estuary is not exactly known but is approximately 20 km and has a spring tidal range of around 3.1 m. It joins the Mary estuary at the mouth.

There are no point source discharges to the estuary or artificial barriers to flow. The rural township of River Heads occurs along the east side of the estuary mouth.

Satellite imagery of the Susan River estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	High confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

Land use in the Susan catchment is moderately modified (68% is used for grazing, cropping and residential activities) with 29% being listed as 'conservation and natural environments'. The risk from these low intensity land use activities is therefore rated as moderate. In fact, most pressure indicators recorded a moderate or lower risk rating. The exception being the large lost (32%) of the river systems riparian vegetation which scores a high. The catchment haves a moderate level of catchment clearing (34%) and unsealed road density. There are no point source sediment discharges, no dredging and boating activity is minimal. Intensive agriculture on steep slopes is minimal and ground cover in the catchment is good.

Unsealed roads can be a major source of sediments

SedNet calculations estimate that sediment loads have increased by 1919% over natural (i.e. 19 times greater). (Note that this SedNet modelling is performed for the entire Mary/Susan catchment as one catchment and hence when using the data 'for one estuary' it has been given only a moderate confidence here).

All these factors result in a moderate overall risk for sediment loads to the estuary.

Indicators of suspended sediment sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.19	Moderate	High
PI2: % of catchment cleared	34	Moderate	Very high
PI3: % length of river system with no riparian vegetation	32	High	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Low	Very high
PI6: unsealed road density (m/km^2)	250-330	Moderate	Low
PI7: % of catchment with intensive agriculture on steep slopes	0.77	Low	High
PI8: % of catchment with less than 70% ground cover	0.6	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	1919	Moderate	Moderate

Condition

Only a limited water quality data set (12 months at one site) is available for the Susan estuary. Turbidity and Secchi depth values meet guidelines at the one site sampled. However, it is evident from the data that significant catchment inflows cause large spikes in turbidity levels, so clearly the catchment does contribute quite large sediment loads. Like most estuaries, the pulse of fine sediments either settles out or is flushed out of the estuary within a few weeks and the estuary reverts to its dry weather pattern, which is mainly driven by the neap/spring tidal cycle. Thus, even though the risk from the catchment is quite high, this may not be reflected in the dry weather turbidity. The main impact of the increased sediments is most likely on seagrass beds in the Great Sandy Straits.
A survey of current seagrass extent in the Susan estuary showed none present. However, anecdotal reports suggest that seagrass has always been absent from the Susan River and was only ever rare and uncommon in the Mary River. It is therefore concluded that there has probably been no change with respect to seagrass extent in the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	High
CI2: Secchi depth (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No change	Good	Low
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Low risk	Very high confidence	86% dependability
Excellent condition	Low confidence	100% dependability

Risk

There are no significant risk factors such as treated sewage discharges, intensive animal production or urban stormwater for this stressor in the Susan estuary or its catchment. An aquaculture facility in the catchment may present some potential for the release of pathogens, however, the likelihood of this is minimal. Housing density in the catchment is low so that the risk from septics is probably minimal, although there is no specific data on this. A number of boats moor in the estuary, sometimes for extended periods, which does pose some risk of sewage release into the water.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	Anchorage sites identified	Moderate	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high

Condition

Only a single intestinal enterococci sample was collected in the Susan estuary. This gave a low reading (9 cfu/100 mL) but a single result is insufficient to draw any conclusions. However, give the low risk and the results from other estuaries in the region it seems highly unlikely that there would be significant levels of bacteria in the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	9	Excellent	Low
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Moderate risk	High confidence	100% dependability
Fair condition	Moderate confidence	83% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Recreational fishing and crabbing are important activities in the estuary

Risk

The Susan estuary has a large local (i.e. within 20 km) population and it experiences moderate to high levels of both recreational and commercial activity. The numbers of recreational fishers are high, there is a high level of bait collection and a significant recreational catch. There is similarly a high level of commercial fishing and catch. The estuary has mooring facilities and a moderate level of boating activity but in generally relatively low recreational use. There are no dredging activities in the Susan estuary which would impact on benthic biota.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	5.7	High	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI17: boat moorings	Anchorage sites identified	Moderate	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	13	Low	High
PI21: 'estuary' population size (people/km^2)	74.19	Moderate	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	3.2	Moderate	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	1.55	High	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	8	Moderate	Moderate
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	102	High	Moderate
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	116030	High	Moderate
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	Moderate

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate level of confidence.

Recreational and commercial CPUE of finfish appears to be increasing, however, there are significant decreases in the recreational and commercial CPUE of crabs. Commercial prawn CPUE is increasing. These results indicate that fish and prawn stocks appear to be stable. In contrast, crab stocks appear to be declining, indicating that the level of crabbing effort may not be sustainable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	8.1% decrease	Fair	Moderate
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	Moderate
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	23.9% decrease	Poor	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Negligible risk	Very high confidence	100% dependability
Good condition	High confidence	100% dependability

Risk

There are no impoundments on the Susan system so the estuary has good connectivity with its freshwater reaches. Estuary shoreline is virtually unmodified so connectivity along the estuarine riparian zone is still natural. A more significant portion (21%) of the background vegetation has been modified so connectivity with the catchment may be slightly impacted.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.2	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	20.7	Low	Very high

Condition

As would be expected from the good connectivity between the estuary and the freshwater reaches, populations of diadromous fish are still common in the system.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species lost/reduced in some reaches but common and population stable in most of the system	Good	High

Freshwater flow regime

Low risk	Very high confidence	100% dependability
Good condition	Assumed condition from risk	

Risk

Currently, there are no significant storages on the Susan system. There are however, a number of artificial waterbodies such as farm dams present, which cover 0.45% of the catchment – resulting in a moderate risk score, though their impact remains to be quantified. This means that the overall risk of impact of altered freshwater inflow regime on the estuary is low.

Artificial waterbodies, such as farm dams, cover a moderate amount of the catchment

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	0	Negligible	High
PI34: % of catchment area covered by artificial waterbodies	0.45	Moderate	High
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the Susan River, the low risk from reduced freshwater inflow suggests that it is unlikely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

Low risk	Very high confidence	100% dependability
Excellent condition	Low confidence	100% dependability

Risk

The estuary's shoreline vegetation is virtually fully intact (only 0.2% modified). However, changes to the background vegetation are more significant (21% modified). There are no significant human activities which would remove habitat, such as dredging, in this estuary. There are some significant issues, such as those associated with cattle grazing, that are causing localised damage (Mackenzie and Duke, 2009).

Indicators of habitat removal/disturbance sources	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	20.7	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.2	Negligible	Very high

Condition

There has been very little, and only localised, loss of either mangrove or saltmarsh habitat in the Susan River estuary (the overall extent of both habitats has increased). No seagrass was found in the estuary during June 2008 surveys but this is thought to be the natural condition of the estuary. Thus, overall habitat condition in the Susan estuary is excellent. There are however, some localised habitat issues as noted by Mackenzie and Duke (2009) and in relation to background habitat modification.

Biological condition indicators	**Raw data**	**Condition score**	**Confidence**
CI3: change in seagrass extent (% change per year)	No change	Good	Low
CI14: change in mangrove extent (% change per year)	1.3% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	6.9% increase	Excellent	Moderate

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There have been no significant physical alterations to the Susan estuary that would affect its hydrodynamic regime.

Indicators of sources of changed hydrodynamic	**Raw data**	**Risk score**	**Confidence**
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	0.2	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the negligible risk for all pressure indicators in the Susan River it can be concluded that these impacts are currently nil.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
No data		

Risk

There is an overall low level of risk of litter entering the Susan estuary. Resident populations and boating activity are moderate but recreational use is low. The rural residential areas adjacent to the estuary may also pose some risks in relation to littering.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	13	Low	High
PI21: 'estuary' population size (people/km^2)	74.19	Moderate	Very high
PI38: % of estuary adjoining urban area	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

No litter surveys were carried out on the Susan estuary. A litter survey is needed to determine the actual level of litter present and its accumulation rate as it has been shown in other estuaries in the region that condition can be significantly different from the level of risk.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	No data		
CI17: litter accumulation rate (per m^2 per day)	No data		

Nutrients

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	88% dependability

Risk

Despite the moderate level of catchment development, most land use activities are relatively low intensity and catchment nutrient loads are small and give a low risk score. Low levels of Intensive agriculture on steep slopes and good ground cover give low risk scores but other catchment indicators, such as the 32% loss of riverine riparian vegetation gives a high risk score. Nutrient loads to the estuary from catchment sources are estimated by SedNet modelling to have increased by between 238 and 531% compared to natural – though this result has only a moderate level of confidence as the SedNet calculations include the entire Mary River catchment. Point discharge of nutrients and stormwater inflows are absent.

Two-thirds of the catchment is covered by woody vegetation

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.19	Low	High
PI3: % length of river system with no riparian vegetation	32	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.77	Low	High
PI8: % of catchment with less than 70% ground cover	0.6	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	531	High	Moderate
PI42: % difference between pre-European total nitrogen load and current load	238	Moderate	Moderate

Condition

A limited water quality data set is available (12 months at one site). Levels of all nitrogen and phosphorus indicators as well as chlorophyll-a meet guidelines at the one site sampled so the impact of nutrients is minimal.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	High
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	High
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	High
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Low risk	Very high confidence	83% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

Pressure indicators for organic loading in the Susan mostly give a low to negligible risk. Most land use activities in the catchment are relatively low intensity but some cropping does occur so catchment organic loads are significant and give a moderate risk score. Levels of intensive agriculture on steep slopes is low in the catchment. There are no point discharges of organic matter or intensive animal production sites. No data on the occurrence of aquatic weeds in the Susan River system is available.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.73	Moderate	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.77	Low	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI43: % river system affected by aquatic weeds	No data		

Condition

A limited water quality data set is available (12 months at one site). Dry weather dissolved oxygen levels in the Susan estuary were consistently high and complied with guidelines.

Minimum DO values occurred following significant catchment inflows, which is clear evidence of the presence of catchment generated organic loads. However, the minimum levels were above 70% saturation so that the current catchment loads are not having major impacts.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	70.5	Excellent	Low
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Susan estuary so the risk from these is negligible. There are some permanent moorings in the estuary

so low level visitation from overseas boats may occur, presenting a small risk of introducing marine pest species.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Moorings for small, non-trailerable, international/domestic vessels present (published in boating guides/well know by boaties)	Moderate	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Susan estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There is only limited disturbance of potential acid sulphate soils (ASS) adjacent to the Susan estuary so the risk of acid water entering the estuary from these is quite low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	4.6	Low	Moderate

Condition

The minimum pH value detected over the one year of sampling was 7.1, which indicates that no acid run-off impacts are occurring. However, the data set is small with only two post event data points so the confidence in the data is low. Ambient pH levels in the estuary were within the guideline range.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	7.1	Excellent	Low
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Low risk	High confidence	100% dependability
Good condition	High confidence	67% dependability

Risk

The Susan has a low level of risk owing the small amount of urban area, mining and intensive agriculture in the catchment. There are however, some rural residential development adjacent to the estuary which may present a small risk. There is also some risk associated with the moderate level of boating that occurs in the estuary. Point source discharges or stormwater inflows are absent and no oil spills or slicks were reported.

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.24	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0.77	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were, with the exception of nickel, always below the most stringent guideline values. As there are no sources of nickel in the catchment, this is almost certainly related to local geology, as is the case with the adjoining Mary estuary.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.0026	Good	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.0036	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0006	Good	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.0046	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	14	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	53	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	9	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	10	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	25	Fair	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	34	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg	Not detected	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
dry weight)			
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Introduce initiatives to reduce pressure on crab populations, e.g. no take zones
3. Investigate impact of farm dams on water resources in the catchment
4. Encourage revegetation of background 'buffer' vegetation along the estuary and target localised mangrove and saltmarsh habitat degradation/loss (as reported in Mackenzie and Duke, 2009)
5. Address litter issue – education initiatives, signage or other approaches
6. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation
7. Encourage revegetation of the river system's riparian zone

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones (and seagrass areas if present)
3. Collect data for litter condition to assess future management action needs

Mary River estuary

Overall assessment C-

Overall risk	**D+**	High confidence	99% dependability
Overall health	**C+**	High confidence	78% dependability

SUMMARY

The Mary estuary is subject to an 'high' level of risk of impact due to human activities. The estuary's health is currently rated as 'fair'. This suggests that unless management actions are taken to reduce this high risk then the condition of the estuary will at best remain in this state of fair health or may deteriorate in the future. The overall risk rating reported is backed by a large amount of high quality data which provide strong support for the accuracy of this result. The overall health rating reported is also backed by high quality data but only 78% of the potential condition indicators were monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still strongly supported.

Except for the stressor 'pH' (at low risk level), all stressors are at moderate (four stressors), high (six stressors) or extreme ('bacteria/pathogens' and 'biota removal/disturbance') risk levels. Condition scores for stressors are evenly spread throughout the range from 'excellent' for the stressors 'habitat removal/disturbance', 'pH' and 'pests' (which has only a moderate confidence level as no pest surveys have been completed in the estuary), to 'very poor' for two stressors ('bacteria/pathogens' and 'nutrients') (Table 18).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 18. Summary of the stressor risk and condition scores for Mary River estuary.

Stressor	Risk	Condition
Aquatic Sediments	High	Good
Bacteria/Pathogens	Extreme	Very Poor
Biota removal/ disturbance	Extreme	Fair
Connectivity	Moderate	Good
Freshwater flow regime	Moderate	Fair
Habitat removal/ disturbance	High	Excellent
Hydrodynamics	High	Poor
Litter	High	Poor
Nutrients	High	Very Poor
Organic matter	High	Fair
Pests	Moderate	Excellent
pH	Low	Excellent
Toxicants	Moderate	Good

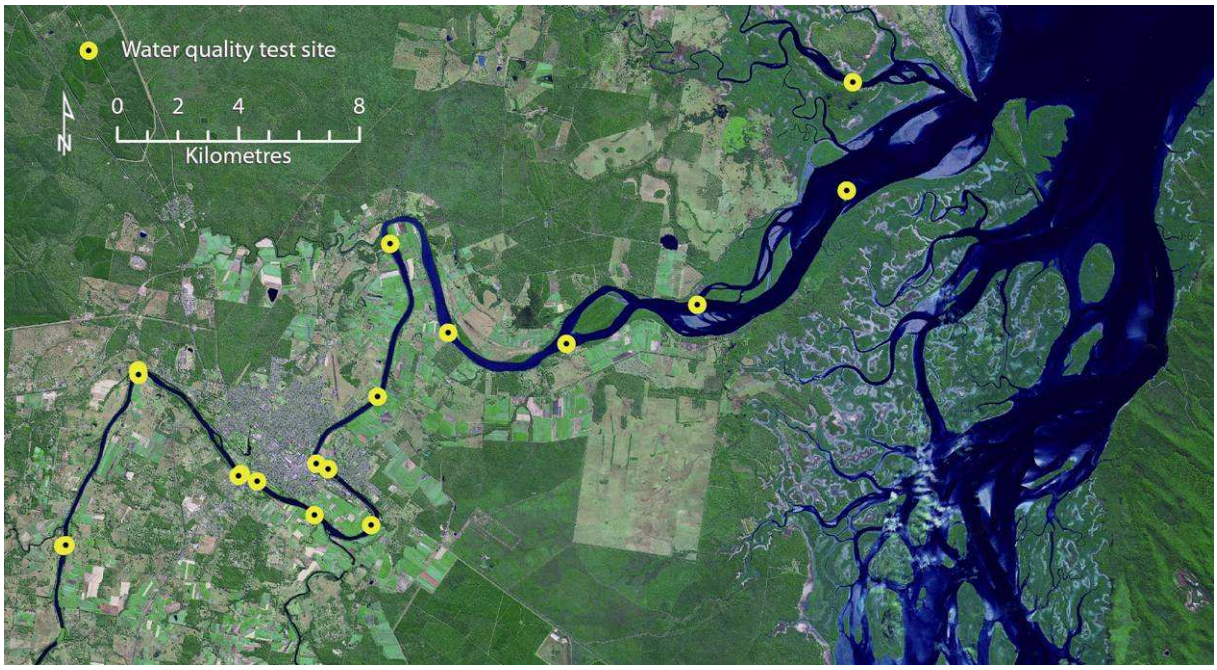
INTRODUCTION

The Mary River has a medium sized catchment (~9,100 km^2) which has been extensively developed for grazing (46%) and forestry (20%). Irrigated cropping (2%), mostly sugar cane in the lower catchment, and intensive animal production (3%), mostly dairying in the mid to upper catchment, is also present. Approximately 20% of the catchment is classified as 'conservation and natural

environments'. In contrast, the estuary is relatively undisturbed (only ~6% of the estuary shoreline has been modified). A major marina and other boating facilities are present.

Major centres along the system are Gympie, in the mid catchment, and Maryborough which is situated in the mid estuary region. There is a discharge of treated sewage from the Maryborough sewage treatment plant just downstream of Maryborough. Four other point source discharges occur to the estuary. Significant dredging activities occur in the estuary. There are several impoundments along the river system (mainly on the Mary River's tributaries) which impede freshwater flow to the estuary. In addition, many of them lack functional fishways.

The estuary is approximately 57 km long and terminates at the barrage near Tiaro which has shortened the estuary by approximately 29%. There is also a tidal barrage on Tinana Creek, a major coastal tributary, which appears to have further reduced the estuary length of the system. The spring tidal range is around 3.1 m.



Satellite imagery of the Mary River estuary

STRESSOR RESULTS

Aquatic sediments

High risk	High confidence	100% dependability
Good condition	High confidence	75% dependability

Risk

Land use in the Mary catchment is principally grazing (46%) and production forestry (20%). Total cropping (3%) area is low but much of this is in areas just upstream and around the estuary so that it is more likely to contribute sediment. There is also a substantial amount of conservation and natural environments (20%). Overall his gives only a moderate risk for sediment loads from catchment land use although these would still be much higher than natural. There has however, been a very significant loss of riverine riparian area (48%) which creates a high risk of bank erosion and slumping, something the Mary catchment is well known for. Large areas of the catchment have been cleared (36%) and there is a significant amount of intensive agriculture of steep slopes, however, ground cover in the catchment is good. SedNet calculations estimate that sediment loads have increased by 1919% over natural (i.e. 19 times greater).

The Mary is a large catchment and has good rainfall in some areas which means that sediment loads to the estuary are always going to be quite large. Storages in the Mary are only likely to capture a small proportion of the catchment generated sediment load.

Within the estuary there is significant dredging that contributes to increased suspended sediment. Point sources are also present.

All these factors result in a high overall risk for sediment loads to the estuary.

Indicators of suspended sediment sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.02	Moderate	High
PI2: % of catchment cleared	36	High	Very high
PI3: % length of river system with no riparian vegetation	48	High	Very high
PI4: number of point sources per km estuary	0.09	Moderate	Very high
PI5: boating activity within the estuary	Marina facilities present	Low	Very high
PI6: unsealed road density (m/km^2)	250-330	Moderate	Low
PI7: % of catchment with intensive agriculture on steep slopes	3.26	High	High
PI8: % of catchment with less than 70% ground cover	0.24	Low	High
PI9: dredging activity in river system (licensed amount)	>5,000 but <100,000 t/a plus >100,000 t/a	Extreme	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	1919	Moderate	Moderate

Condition

There is an extensive water quality data set available for the Mary estuary. Turbidity levels in the Mary estuary, particularly the mid reaches are very high and clarity correspondingly low. However, this is in part at least a natural occurrence. While the fine sediments are supplied by the catchment, the ongoing high levels of turbidity in the estuary are mainly a result of the physical characteristics of the estuary. The Mary estuary is long (56 km) and has strong tidal currents. The length of the estuary acts to trap incoming particulates in the estuary for long periods whilst the strong currents continually resuspend sediments resulting in high turbidity levels. This is typical of all long estuaries with strong tidal currents.

The Mary estuary is a naturally turbid system

Like most estuaries, turbidity in the Mary is substantially higher immediately after large inflow events but within a few weeks the fine particulates settle out or are dispersed out of the estuary and it reverts to its dry weather pattern, which is mainly driven by the neap/spring tidal cycle. However, as described above, this dry weather pattern is characterised by high levels of turbidity compared to many of the shorter estuaries in this report. Nevertheless, the increased sediment load to the estuary is likely to have had some residual impact on dry weather turbidity, but we have no long term data to verify this.

The Mary River estuary is greater than 40 km long and as such the Queensland Water Quality Guidelines can not be used as a threshold for scoring, however, EPA sampling over 13 years has shown a slight increasing trend in turbidity in the Mary River so it has therefore been scored as ‘good’ for turbidity and Secchi depth indicators.

A survey of current seagrass extent in the Mary estuary showed only small areas present in the lower estuary. However, anecdotal reports suggest that seagrass has always been rare/uncommon in the Mary River. It is therefore concluded that there has probably been no change with respect to seagrass extent in the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI1: turbidity (% of sites exceed guidelines)	The Mary River estuary is greater than 40 km long and as such the QLD WQ guidelines can not be used, however, EPA WQ sampling over 13 years has shown a slight increasing trend in turbidity in the Mary River	Good	Very high
CI2: Secchi depth (% of sites exceed guidelines)	The Mary River estuary is greater than 40 km long and as such the QLD WQ guidelines can not be used, however, EPA WQ sampling over 13 years has shown a slight decreasing trend in Secchi depth in the Mary River	Good	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	Present at times although uncommon	Good	Low
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Extreme risk	Very high confidence	86% dependability
Very poor condition	High confidence	100% dependability

Risk

Several local factors potentially contribute bacterial loads to the estuary. These include treated waste water from sewage treatment plants (STP), occasional sewage overflows and stormwater from the Maryborough urban area. Of these, the STP effluent is disinfected via chlorination only and therefore in practice does not have a large impact during normal operations. The frequency of reported sewage overflows in the Maryborough area is around three per year and of high risk. Stormwater inflows from urban areas invariably contribute significant loads of bacteria to adjacent waters. This will certainly be true for the Maryborough area but no actual measurements of wet weather levels of intestinal enterococci bacteria in the estuary have been undertaken. However, this is an intermittent source and its effects are usually short lived in estuarine waters – a few days.

Large catchment inflows to the estuary are also likely to contribute loads of intestinal enterococci bacteria, some of which will come from livestock and some from natural sources. The significance of these for human health is the subject of some debate with no clear resolution at this stage. At present we have no reliable measurements of the impacts of catchment inflows on bacteria numbers.

Many boats moor in the estuary and marina, sometimes for extended periods, which does pose a significant risk of sewage release into the water.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	Chlorination	High	Very high
PI12: frequency of sewage overflow events (per year)	3	High	Moderate
PI13: % of catchment under intensive animal production	3.424	High	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0.16	Low	High
PI17: boat moorings	Marina AND permanent mooring/anchorage sites present (live aboard)	Extreme	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high

Condition

Of the eight measurements of intestinal enterococci bacteria taken half gave values ≤33 cfu/100 mL, which meets the primary contact guideline. However, the other samples ranged from 54 to ~1900 cfu/100 mL, well above the highest guideline values. The exact cause of these higher values cannot be determined from the available data but clearly the generally higher level of risk compared to most other estuaries is resulting in an increased frequency of high bacteria counts.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95^{th} percentile value of counts per 100 mL)	1351	Very poor	High
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Extreme risk	High confidence	100% dependability
Fair condition	High confidence	100% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

Boating, fishing and crabbing are important activities in the estuary

The Mary estuary has a large local resident population and it experiences moderate to high levels of both recreational and commercial activity. The numbers of recreational fishers are high, there is a high level of bait collection and a large recreational catch. Within the estuary and adjacent coastal waters there is similarly a high level of commercial fishing and commercial fish catch. There is also some commercial bait collection. Boating activity in the estuary is high with both marina and fixed mooring facilities present. Recreational usage of the estuary and adjoining areas is high.

There is significant dredging activity in the Mary which would impact on benthic biota.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	>5,000 but <100,000 t/a plus >100,000 t/a	Extreme	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	22.3	Extreme	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Moderate	High
PI17: boat moorings	Marina AND permanent mooring/anchorage sites present (live aboard)	Extreme	Very high
PI5: boating activity within the estuary	Marina facilities present	High	Very high
PI20: recreational usage index (value between 8 and 40)	25	High	High
PI21: 'estuary' population size (people/km^2)	38.235	Moderate	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	14.5	Extreme	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	4.61	Extreme	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	11	Moderate	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	296	Extreme	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	213926	Extreme	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate level of confidence.

Recreational and commercial CPUE of finfish and prawns appears to be increasing, however, there are significant decreases in the recreational and commercial CPUE of crabs. These results indicate that fish and prawn stocks appear to be stable. In contrast, crab stocks appear to be declining, indicating that the level of crabbing effort may not be sustainable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	8.0% decrease	Fair	High
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	High
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	24.5% decrease	Poor	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	Increase	Excellent	Moderate

Connectivity

Moderate risk	Very high confidence	100% dependability
Good condition	High confidence	100% dependability

Risk

The Mary estuary has good connectivity with its freshwater reaches. There is a tidal barrage on the estuary but this has an effective fishway. Access to the freshwater reaches of Tinana Creek is blocked by Teddington weir. However, barriers (mainly water storages) prevent access to only ~15% of the freshwater reaches of the entire river system. Within the estuary, only ~5% of the shoreline vegetation has been modified but 58% of the background vegetation has been lost. Thus connectivity along the estuary and with the catchment is likely to be impacted to some degree. The impoundment density for the system is moderate.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	15.5	Low	Very high
PI29: impoundment density (per 500 km of river)	2.14	Moderate	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	5.5	Low	High
PI32: % of estuarine 'background habitat' length modified	58.4	High	High

Condition

As would be expected from the relatively good connectivity between the estuary and its freshwater reaches, populations of diadromous fish are still common in the system.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species lost/reduced in some reaches but common and population stable in most of the system	Good	High

Freshwater flow regime

Moderate risk	Very high confidence	100% dependability
Fair condition	Assumed condition from risk	

Risk

Currently, the storage capacity of referable impoundments (larger storages that require a licence and which are accounted for in Water Resource Plans) on the Mary system is only 8% of the annual median flow. This means that the impact on large inflows to the estuary is quite small although the impact on medium and small inflows may be more significant. There are a number of artificial waterbodies such as farm dams present, which cover only 0.08% of the catchment – resulting in a low risk score, though their impact remains to be quantified. The impoundment density for the system is moderate.

This means that the overall risk of impact of altered freshwater inflow regime on the estuary is moderate.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	8	Low	High
PI34: % of catchment area covered by artificial waterbodies	0.08	Low	High
PI29: impoundment density (per 500 km of river)	2.14	Moderate	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the Mary River, the moderate risk from reduced freshwater inflow suggests that it is likely that these types of effects are occurring in this estuary, but there is no quantitative 'condition' data on this.

Habitat removal or disturbance

High risk	Very high confidence	100% dependability
Excellent condition	Low confidence	100% dependability

Risk

The construction of the Mary barrage has reduced the estuary length by 29% so that around a third of the estuary's original habitat was lost in the past. Measurements based on the current extent of the estuary show that the shoreline component of the estuarine riparian zone is largely intact with only around 5% modified. However, the background component has been significantly altered with 58% lost. A significant part of this loss is due to cultivation along the banks of the estuary and there are also losses in the Maryborough urban area.

Although much of the shoreline vegetation is intact a large percentage of the background vegetation have been lost

There is significant dredging activity in the Mary which would impact on benthic habitats.

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	>5,000 but <100,000 t/a plus >100,000 t/a	Extreme	Very high
PI16: number of 'marine' aquaculture facilities present	1	Low	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	58.4	High	High
PI31: % of estuarine 'shoreline' length modified (habitat)	5.5	Low	High

Condition

There has been no loss of either mangrove or saltmarsh habitat in the Mary estuary since the construction of the barrage. In recent times the overall extent of both habitats has increased. Small patches of seagrass are present in the lower estuary but anecdotal reports suggest that seagrass has always been rare/uncommon in the Mary River. It is therefore concluded that there has probably been no change with respect to seagrass extent in the estuary.

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	Present at times although uncommon	Good	Low
CI14: change in mangrove extent (% change per year)	1.3% increase	Excellent	Moderate
CI15: change in saltmarsh extent (% change per year)	6.9% increase	Excellent	Moderate

Hydrodynamics

High risk	Very high confidence	100% dependability
Poor condition	Assumed condition from risk	

Risk

Apart from the barrage and dredging activities, there have been no significant physical alterations to the Mary estuary. The barrage was constructed within the tidal zone and has reduce the length of the estuary by 29%. A tidal barrage is also present on Tinana Creek, a tributary of the Mary, which is also located within the original tidal zone but it is not know by how much it has reduce that portion of the estuary's length. The barrages would have thus reduced the tidal prism in the estuary, while dredging in the mid estuary may have increased tidal flows although the bar area at the mouth is still intact.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	>5,000 but <100,000 t/a plus >100,000 t/a	Extreme	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	5.4	Low	High
PI37: % of original estuary length lost due to a tidal barrage	29	High	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall high risk in the Mary estuary it can be concluded that these impacts are quite likely to be significant. The reduction of the estuary length by 29% and regular dredging must have resulted in some changes, but there is no quantitative 'condition' data on this.

Litter (rubbish)

High risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

Given the population adjacent to the estuary, the presence of a significant urban area and the high level of commercial and recreational boating activity and other recreational activities within and around the estuary, the risk for litter is quite high.

Urban stormwater is a major source of litter

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Marina facilities present	High	Very high
PI20: recreational usage index (value between 8 and 40)	25	High	High
PI21: 'estuary' population size (people/km^2)	38.235	Moderate	Very high
PI38: % of estuary adjoining urban area	13.34	Moderate	High
PI15: number of stormwater inflows per km estuary	0.16	Low	High

Condition

An initial litter survey in the Mary estuary showed that litter levels were moderate. The litter was removed and a further survey carried out three months later. This showed that litter was being replenished quite rapidly and there was more present at the subsequent survey than on the original survey. Whether the principal source is the urban area or recreational use is not known.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0067	Fair	High
CI17: litter accumulation rate (per m^2 per day)	0.000185	Poor	Moderate

Nutrients

High risk	High confidence	100% dependability
Very poor condition	Very high confidence	88% dependability

Risk

Although cropping is only a small percentage of land use in the Mary catchment, much of it is in the vicinity of the estuary so that it may be having a disproportionate effect relative to its size with respect to catchment nutrient loads. The size of the catchment alone ensures that it would generate significant nutrient loads. This would be further exacerbated by the extensive loss of the river system's riparian vegetation (48%). There is a significant amount of intensive agriculture of steep slopes, however, ground cover in the catchment is good.

Irrigated cropping is an important land-use in the lower catchment, particularly around the estuary

Nutrient loads to the estuary from catchment sources are estimated by SedNet modelling to have increased by between 238 and 531% compared to natural. Loads from the catchment only impact on the estuary for short periods after an inflow event has occurred. Point source loads are smaller than catchment loads but are continuous and their impacts tend to predominate in dry weather when dilution is the lowest.

There is a significant point discharge of nutrient to the Mary estuary from the Maryborough sewage treatment plant. There may also be a significant risk from overflows from the Maryborough sewerage system with on average 3 overflow report per year. Stormwater from the urban area also discharges directly to the estuary.

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	2.31	Low	High
PI3: % length of river system with no riparian vegetation	48	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	3.26	High	High
PI8: % of catchment with less than 70% ground cover	0.24	Low	High
PI15: number of stormwater inflows per km estuary	0.16	Low	High
PI39: nutrient concentration of sewage treatment plant wastewater	STP wastewater containing >10 mg/L N and >3 mg/L P	Extreme	Very high
PI12: frequency of sewage overflow events (per year)	3	High	Moderate
PI40: number of point sources per km estuary (excluding STPs)	0.02	Low	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	531	High	Moderate
PI42: % difference between pre-European total nitrogen load and current load	238	Moderate	Moderate

Condition

An extensive water quality data set is available. Levels of both nitrogen and phosphorus indicators exceed guidelines at most sites. This is partly due to the treated sewage discharge but in the upper estuary is more likely to be related to catchment influences. Nutrients associated with freshwater inflows do cause spikes in nutrient levels although these tend to be transient. Chlorophyll-a meets guidelines at most sites except those in the upper estuary. The reason that the elevated nutrient levels do not have a greater impact on algal growth is that much of the estuary is too turbid to allow growth to occur. Only in the upper estuary is the water clarity sufficient to allow significant growth.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	40	Fair	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	100	Very poor	Very high
CI21: total nitrogen (% of sites exceed guidelines)	80	Poor	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	60	Poor	Very high
CI23: total phosphorus (% of sites exceed guidelines)	80	Poor	Very high
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	29	Fair	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

High risk	High confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

Catchment land use indicators give a moderate level of risk for catchment organic loading. The presence of the Maryborough sewage treatment plant discharge in the mid estuary is also a moderate risk factor. Approximately 7% of the river system is affected by aquatic weeds which provides a high level of risk to the estuary as these weeds can be washed downstream during flow events. Additionally, there are high levels of intensive agriculture on steep slopes and intensive animal production in the catchment and a high number of sewage overflows entering the estuary.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	3.07	Moderate	High
PI4: number of point sources per km estuary	0.07	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	3.26	High	High
PI12: frequency of sewage overflow events (per year)	3	High	Moderate
PI13: % of catchment under intensive animal production	3.424	High	High
PI43: % river system affected by aquatic weeds	7.2	High	Moderate

Condition

An extensive water quality data set is available. Dry weather dissolved oxygen levels in the Mary estuary comply with guidelines at upper and lower estuary sites but fail at mid estuary sites. This is due to the presence of the treated sewage discharge in this reach. The extent of non-compliance is not great but clearly the organic load from the Maryborough STP is having some impact.

In many estuaries, minimum dissolved oxygen values tend to occur soon after large inflow events as a result of organic loading from the catchment. Such decreases do occur in the Mary estuary. The lowest value recorded was 36% saturation, which is indicative of significant organic loading, which could be expected given the large size of the catchment and the high overall risk level.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	**36**	Fair	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	42	Fair	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Moderate risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Mary estuary so the risk from these is negligible. There are permanent moorings and a marina in the estuary so visitation from overseas boats is likely, presenting a significant risk of introducing marine pest species.

Indicators of pest species sources	**Raw data**	**Risk score**	**Confidence**
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Harbour/marina present	High	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Mary estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	75% dependability

Risk

There is only limited disturbance of potential acid sulphate soils (ASS) adjacent to the Mary estuary so the risk of acid water entering the estuary from these is quite low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	**Raw data**	**Risk score**	**Confidence**
PI48: % of estuary length adjoining disturbed acid sulphate soils	3.3	Low	Moderate

Condition

The minimum pH value detected over ~15 years of EPA sampling in the estuary was 6.4, which indicates that no acid run-off impacts are occurring. There is no data on the occurrence of red-spot disease in the estuary but given the high levels of fishing activity in the estuary it seems unlikely that it does occur and has not been reported.

Ambient pH levels in the estuary were within the guideline range at all sites.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI31: minimum sustained pH values during the days following an inflow event	6.4	Good	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	No data		

Toxicants

Moderate risk	Very high confidence	100% dependability
Good condition	High confidence	67% dependability

Risk

The Mary has a low level of risk in relation to catchment land use activities owing to the small amount of cropping, mining and urban areas in the catchment. However, the fact that these cropping areas are close to the estuary may increase this risk in real terms. The Maryborough urban area also presents some level of risk via stormwater inflows. With respect to oil, there were a large number of slicks reported in recent years, mostly from urban sources and appear to have now been fixed. The large amount of boating in the estuary has risks associated with oil/fuel spills and anti-biofouling chemicals.

There are no point source discharges to the estuary.

Indicators of toxicant sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	2.34	Low	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Marina facilities present	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	3.26	High	High
PI15: number of stormwater inflows per km estuary	0.16	Low	High
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	2006 lots small spills reported	High	High

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were, with the exception of nickel and chromium, always below the most stringent guideline values. Given the absence of any known sources of nickel in the catchment it is fairly certain that the higher levels of nickel and chromium are related to local geology.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	0.011	Good	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.035	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	0.0049	Good	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.042	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	0.0005	Good	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	13	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.8	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	74	Good	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	21	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	13	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	50	Fair	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	63	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	0.0083	Good	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Introduce/maintain catchment management initiatives aimed at reducing diffuse pollutant loads (e.g. ongoing implementation of best management practices through industry codes of practice and incentive programs such as Reef Rescue)
2. Point discharges to the estuary to be diverted to other disposal options (e.g. strongly encourage implementation of STP effluent re-use schemes) in medium to long term
3. Introduce initiatives to reduce pressure on crab populations, e.g. no take zones
4. Ensure estuary has an adequate environmental flow allocation under the Mary Water Resource Plan
5. Encourage revegetation of background 'buffer' vegetation along the estuary
6. Introduce/maintain stormwater management initiatives aimed at reducing pollutant loads
7. Address litter issue – education initiatives, signage or other approaches
8. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation

9. Encourage revegetation of the Mary River's riparian zone

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones (and seagrass areas if present)
3. Monitor for marine pest species to assess future management action needs

Kauri Creek estuary

Overall assessment A-

Overall risk	A	Very high confidence	94% dependability
Overall health	B+	Moderate confidence	91% dependability

SUMMARY

The Kauri estuary is subject to a 'negligible' level of risk of damage due to human activities. However, the estuary's health is currently rated as only 'good' This suggests that under the current *status quo* the condition of the estuary will remain in this state of good health. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is backed by only moderate quality data but with 91% of the potential condition indicators monitored. Although, this overall health rating results is therefore still supported more data to improve the confidence level would be beneficial and may even result in an upgrade of the overall health rating to excellent.

With the exception of 'aquatic sediments' and 'biota removal/disturbance' (at moderate risk) all stressor were found to be at low (four stressors) or negligible (seven stressors) risk levels.

The majority of condition scores for stressors are reported as 'excellent', however, 'aquatic sediments' were in good condition while 'nutrients' were only in fair condition and 'litter' and 'organic matter' were found to be in poor condition (Table 19).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 19. Summary of the stressor risk and condition scores for Kauri Creek estuary.

Stressor	Risk	Condition
Aquatic Sediments	Moderate	Good
Bacteria/Pathogens	Low	Excellent
Biota removal/ disturbance	Moderate	Excellent
Connectivity	Negligible	Excellent
Freshwater flow regime	Negligible	Excellent
Habitat removal/ disturbance	Negligible	Excellent
Hydrodynamics	Negligible	Excellent
Litter	Low	Poor
Nutrients	Negligible	Fair
Organic matter	Negligible	Poor
Pests	Low	Excellent
pH	Negligible	Excellent
Toxicants	Low	Excellent

INTRODUCTION

Kauri Creek has a small coastal catchment of only ~190 km^2. The predominant land use is conservation and natural environments (94% – note that this includes the Wide Bay Military Training Area which covers 75% of the catchment), with the remainder being forestry (6%). The Kauri Creek system is relatively unmodified with only very limited areas of disturbed riparian vegetation (only ~0.5% of the estuarine riparian area is modified) and no artificial barriers to flow. Two camping sites (one with facilities) are located along the estuary.

The estuary is around 16 km long. The actual spring tidal range is unknown.

Satellite imagery of the Kauri Creek estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	Very high confidence	90% dependability
Good condition	Moderate confidence	75% dependability

Risk

A large part of the Kauri Creek catchment lies within a Defence Department area (Wide Bay Military Training Area) and is in close to natural condition. 94% of the catchment is classified as 'conservation and natural environments' and most of the remainder is forestry and results in a negligible risk is relation to catchment sediment loads. However, there is a high density of unsealed roads in the catchment which has a risk of sediment loading associated with it. All other pressures have low to negligible risks associated with them.

Unsealed roads can be a major source of sediments

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.07	Negligible	High
PI2: % of catchment cleared	5	Low	Very high
PI3: % length of river system with no riparian vegetation	4	Negligible	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Low	Very high
PI6: unsealed road density (m/km^2)	330-460	High	Low
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	0.37	Low	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	No data		

Condition

Only a limited water quality data set (12 samples over 11 months at one site) is available for the Kauri estuary. Turbidity values are low and meet guidelines at the one site sampled. (No Secchi depth readings were taken). Increased turbidity was recorded after an inflow event but the increase was relatively small owing to the largely undisturbed nature of the catchment.

A survey of the Kauri estuary showed extensive areas of seagrass present up to 7 km from the mouth, and including three different species. As there is no reliable information on the historical extent of seagrass in this estuary it is not possible to determine if seagrass extent has changed. Nevertheless, Kauri Creek clearly has a healthy seagrass population at present, which would be expected given the undisturbed catchment. Seagrass Watch data for one seagrass site in Kauri Creek showed that the % cover of seagrass at this site was decreasing between 2003 and 2007. This suggests that sediment loads coming out the Kauri system may be impacting seagrass but further data would be useful to confirm this as seagrass % cover is highly variable. Further data on Secchi depth and turbidity would also be useful for examining any correlation with changes in seagrass % cover.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	High
CI2: Secchi depth (% of sites exceed guidelines)	No data		
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	Good coverage to ≈7 km and variety species	Excellent	Low
CI4: % cover of seagrass	17% decrease	Fair	High

Bacteria/Pathogens

Low risk	Very high confidence	86% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There is very little human activity in the catchment and thus the risk for bacteria or pathogens is negligible. A number of boats moor in the estuary, sometimes for extended periods, which does pose some risk of sewage release into the water.

Indicators of bacteria/pathogen sources	**Raw data**	**Risk score**	**Confidence**
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	Anchorage sites identified	Moderate	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high

Condition

Measurements of intestinal enterococci bacteria all gave values ≤6 cfu/100 mL, which meets the primary contact guideline. Only a relatively small number of samples were collected but, combined with the low level of risk, it seems very probable that this stressor is not an issue in the Kauri estuary.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI5: intestinal enterococci counts (95^{th} percentile value of counts per 100 mL)	6	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

Moderate risk	High confidence	100% dependability
Excellent condition	High confidence	67% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available

measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Risk

Kauri Creek has almost no resident population. However, it experiences moderate to high levels of both recreational and commercial fisher activity. There are moderate numbers of recreational fishers and a high recreational fish catch. There is also a moderate amount of recreational bait collection. There is a moderate to high level of commercial fishing and commercial fish catch. The estuary has a number of identified anchorage/mooring sites but has a low level of general recreational use (two camp sites occur on the estuary).

Boating, fishing and crabbing are important activities in the estuary

There are no dredging activities in the Kauri that would impact on benthic biota.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	2.4	Moderate	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	Anchorage sites identified	Moderate	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	12	Low	High
PI21: 'estuary' population size (people/km^2)	3.473	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	2.6	Moderate	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	1.52	High	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	54	Moderate	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	21049	Moderate	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate level of confidence.

Kauri Creek is one of the few estuaries in which both recreational and commercial CPUE of finfish and crabs appears to be increasing which suggests that current catch levels are sustainable and stocks are stable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	Increase	Excellent	High
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	Increase	Excellent	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

There are no impoundments on the Kauri Creek system and so the estuary has good connectivity with freshwater reaches. Estuary shoreline is virtually unmodified as is the background vegetation so connectivity along the estuarine riparian zone and with the rest of the catchment is still natural.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.5	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	2.1	Negligible	Very high

Condition

As would be expected from the natural level of connectivity between the estuary and freshwater reaches, diadromous fish species are common with stable populations.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species common and population stable throughout system	Excellent	High

Freshwater flow regime

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

Currently, there are no water storages on the Kauri system. Also, there are no artificial waterbodies such as farm dams within the catchment. The absence of storages and the undisturbed nature of the vegetation mean that there is almost no change to the freshwater flow regime compared to natural.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	0	Negligible	High
PI34: % of catchment area covered by artificial waterbodies	0	Negligible	High
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of Kauri Creek, the negligible risk from reduced freshwater inflow suggests that impacts on the estuary are currently nil.

Habitat removal or disturbance

Negligible risk	Very high confidence	100% dependability
Excellent condition	Low confidence	33% dependability

Government regulation is one management practice used to protect habitat

Risk

Both the shoreline and background vegetation of the Kauri estuary is virtually completely intact. There are no significant human activities which would remove habitat, such as dredging, in this estuary. There is some localised damage to mangrove and saltmarsh vegetation but these are all associated with natural process, such as storm damage, natural erosion and deposition, and ecotone shift (Mackenzie and Duke, 2009).

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	2.1	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0.5	Negligible	Very high

Condition

It seems certain that there has been no loss of either mangrove or saltmarsh habitat in the Kauri estuary. However, no historical data is available for comparison with recent extent surveys. A seagrass survey of estuary showed significant areas were present from the mouth to around 7 km upstream. However, as there is no reliable information on the previous extent of seagrass it is not possible to determine if there have been significant losses but current populations appear healthy.

Both shoreline and background habitat are intact

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	Good coverage to ≈7 km and variety species	Excellent	Low
CI14: change in mangrove extent (% change per year)	No data		
CI15: change in saltmarsh extent (% change per year)	No data		

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There have been no significant physical alterations to the Kauri estuary that would affect its hydrodynamic regime.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	0.4	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the negligible risk for all pressure indicators in Kauri Creek it can be concluded that these impacts are currently nil.

Litter (rubbish)

Low risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Risk

While resident populations are negligible, there is significant boating activity in Kauri Creek and some recreational use along the estuary which presents some level of risk for litter.

Recreational activities are the major source of rubbish to the estuary

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	12	Low	High
PI21: 'estuary' population size (people/km^2)	3.473	Negligible	Very high
PI38: % of estuary adjoining urban area	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

An initial survey of litter in Kauri Creek estuary showed high levels present. This was removed and a second survey carried out in three months time. This also recorded high levels which is indicative of ongoing high levels of littering. As there are is no significant resident population or catchment modification, this litter can only have come from recreational users of the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0594	Poor	High
CI17: litter accumulation rate (per m^2 per day)	0.000187	Poor	Moderate

Nutrients

Negligible risk	Very high confidence	80% dependability
Fair condition	High confidence	100% dependability

Risk

The undisturbed nature of the catchment means that the risk of increased catchment nutrient loads associated with changes to land use is negligible. There are no point sources of nutrients present. With the exception of the low risk associated with the small amount (0.37%) of the catchment with less the 70% ground cover, all other pressures have negligible risks associated with them.

The majority of the catchment is relatively undisturbed with the Wide Bay Military Training Area covering 75% of the catchment

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.18	Negligible	High
PI3: % length of river system with no riparian vegetation	4	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	0.37	Low	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	No data		
PI42: % difference between pre-European total nitrogen load and current load	No data		

Condition

A limited water quality data set is available (12 samples over 11 months at one site). All but one nutrient indicators met guidelines, and while ammonia failed it was by a very small margin. This was probably a natural occurrence although the reason for this is not known. Levels of chlorophyll-a were very low and easily met guidelines.

Thus as expected, there is no evidence of any nutrient impact and the 'fair' overall condition score for this stressor is an underestimate of the actual condition (an artefact of the small water quality data set).

Epiphyte cover of seagrass within Kauri Creek was decreasing between 2002 and 2006. This suggests that nutrient loads coming out the Kauri system are not impacting seagrass beds within the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	100	Very poor	High
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	High
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	High
CI25: % epiphytic cover on seagrass	Decrease trend	Excellent	High

Organic matter

Negligible risk	Very high confidence	83% dependability
Poor condition	Moderate confidence	100% dependability

Risk

The undisturbed nature of the catchment means that the risk of increased catchment organic loads is negligible. There are no point sources of organic material present. No data on the occurrence of aquatic weeds in the Kauri Creek system is available.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.29	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI43: % river system affected by aquatic weeds	No data		

Condition

A limited water quality data set is available (12 samples over 11 months at one site). Given the pristine nature of the catchment and estuary, the dissolved oxygen levels in the Kauri estuary were a little lower than expected and failed the guideline, albeit by a very small margin. The reason for these slightly lower than expected values is not known. It is most likely a natural occurrence but some further investigation would be worthwhile.

DO values did not record any significant falls following significant catchment inflows which indicates that as expected, catchment generated organic loads are small.

Thus as expected, there is no evidence of any organic matter impact and the ‘poor’ overall condition score for this stressor is an underestimate of the actual condition (an artefact of the small water quality data set).

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	80.6	Excellent	Low
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	100	Very poor	High
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Kauri estuary so the risk from these is negligible. There are some anchorage sites in the estuary but

the likelihood of visitation from overseas boats is probability very low, particularly in light of Kauri's proximity to Snapper Creek marina.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Moorings for small, non-trailerable, international/domestic vessels present (published in boating guides/well know by boaties)	Moderate	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Kauri estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Low confidence	100% dependability

Risk

There is no disturbance of potential acid sulphate soils adjacent to the Kauri estuary so the risk of acid water entering the estuary is negligible.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	0	Negligible	Moderate

Condition

The minimum pH value detected over the one year of sampling was 7.4, which indicates that no acid run-off impacts are occurring. Red spot disease has not been reported in the estuary.

Ambient pH levels in the estuary were within the guideline range.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	7.4	Excellent	Low
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	None reported	Excellent	Low

Toxicants

Low risk	High confidence	100% dependability
Excellent condition	High confidence	95% dependability

Risk

The undisturbed Kauri Creek catchment presents a negligible risk for toxicants from catchment sources. There is however, some risk associated with the moderate level of boating that occurs in the estuary. Point source discharges or stormwater inflows are absent and no oil spills or slicks were reported.

Forestry may be a source of toxicants

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.24	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were always below the most stringent guideline values.

The detection of two herbicides in the waters of Kauri Creek is unexpected given the pristine nature of the catchment. This illustrates the pervasive nature of these compounds and how with even relatively low levels of use they still manage to find their way into waterways.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	Not detected	Excellent	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.0006	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	Not detected	Excellent	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.021	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	Not detected	Excellent	High
CI35j: toxicants in the water column (Chlordane) (µg/L)	Not detected	Excellent	High
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	Not detected	Excellent	High
CI35l: toxicants in the water column (Dieldrin) (µg/L)	Not detected	Excellent	High
CI35m: toxicants in the water column (Endrin) (µg/L)	Not detected	Excellent	High
CI35n: toxicants in the water column (Endosulfan) (µg/L)	Not detected	Excellent	High
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	Not detected	Excellent	High
CI35p: toxicants in the water column (Lindane) (µg/L)	Not detected	Excellent	High
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	Not detected	Excellent	High
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	Not detected	Excellent	High
CI35s: toxicants in the water column (Total DDT) (µg/L)	Not detected	Excellent	High
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	Not detected	Excellent	High
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	7	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	19	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	5	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	<1	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	8.1	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	12	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Address litter issue – education initiatives, signage or other approaches
2. Investigate the significance of the decrease in seagrass density observed
3. Investigate the sources of toxicants in the estuary and ensure appropriate management occurring

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas
3. Investigate causes of anomalies in dissolved oxygen and ammonia levels
4. Maintain current Seagrass Watch monitoring within the estuary (encourage expansion to further sites within the estuary)




Snapper Creek estuary

Overall assessment B+

Overall risk	**C+**	Very high confidence	94% dependability
Overall health	**A+**	High confidence	73% dependability

SUMMARY

The Snapper estuary is subject to a 'moderate' level of risk of impact due to human activities. However, the estuary's health is currently rated as 'excellent'. This suggests that unless management actions are taken to reduce this moderate risk then the condition of the estuary may remain in this state of excellent health or more likely deteriorate in the future. The overall risk rating reported is backed by a large amount of very high quality data which provide strong support for the accuracy of this result. The overall health rating reported is also backed by high quality data but only 73% of the potential condition indicators were monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still strongly supported.

The only stressors reported with a negligible level of risk were 'connectivity' and 'freshwater flow regime'. Three others are reported as low risk, five as moderate risk and three at high risk ('bacteria/pathogens', 'biota removal/disturbance' and 'nutrients').

With the exception of 'hydrodynamics' (good condition) and 'litter' (fair condition) all other condition scores for stressors are reported as 'excellent' (Table 20).

Note that no condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

Table 20. Summary of the stressor risk and condition scores for Snapper Creek estuary.

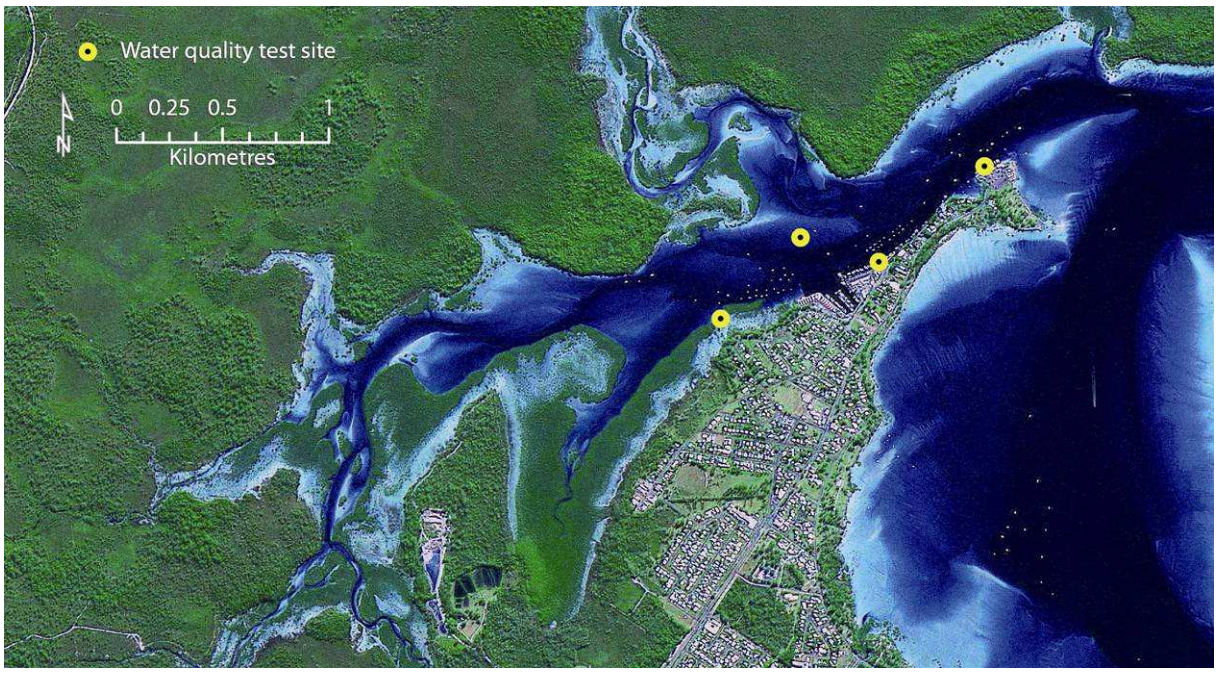
Stressor	Risk	Condition
Aquatic Sediments	Moderate	Excellent
Bacteria/Pathogens	High	Excellent
Biota removal/ disturbance	High	Excellent
Connectivity	Negligible	Excellent
Freshwater flow regime	Negligible	Excellent
Habitat removal/ disturbance	Low	Excellent
Hydrodynamics	Low	Good
Litter	Moderate	Fair
Nutrients	High	Excellent
Organic matter	Moderate	Excellent
Pests	Moderate	Excellent
pH	Low	Excellent
Toxicants	Moderate	Excellent

INTRODUCTION

Snapper Creek has a very small coastal catchment of only ~35 km^2. The predominant land use is conservation and natural environments (91% – note that this includes the Wide Bay Military Training Area which covers 55% of the catchment), with remainder made up of a proportion of the Tin Can Bay township which occurs at the mouth of the estuary. Approximately 10% of the estuary's shoreline has been modified with a major marina and other boating facilities present. There are no artificial barriers

to flow. A STP discharges treated effluent to Snapper Creek via an artificial wetland. Dredging occurs within the estuary.

The estuary is short (~6.5 km long) with a spring tidal range around 1.9 m.



Satellite imagery of the Snapper Creek estuary

STRESSOR RESULTS

Aquatic sediments

Moderate risk	Very high confidence	90% dependability
Excellent condition	High confidence	75% dependability

Risk

A large part of the Snapper Creek catchment lies within a Defence Department area (Wide Bay Military Training Area) and is in close to natural condition. A large proportion (91%) of the catchment is classified as 'conservation and natural environments' and most of the remainder is largely urbanised, therefore, the estuary has a negligible risk is relation to catchment sediment loads. In addition, the catchment is quite small which limits its capacity to generate loads. However, the catchments has a moderately high level of catchment clearing, unsealed roads and loss of riparian vegetation. It also has a significant area of ground with less than 70% ground cover.

There is some dredging in the estuary so this factor may contribute to increased suspended sediment.

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.19	Negligible	High
PI2: % of catchment cleared	16	Moderate	Very high
PI3: % length of river system with no riparian vegetation	16	Moderate	Very high
PI4: number of point sources per km estuary	0.15	High	Very high
PI5: boating activity within the estuary	Marina facilities present	Low	Very high
PI6: unsealed road density (m/km^2)	250-330	Moderate	Low
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	2.36	Moderate	High
PI9: dredging activity in river system (licensed amount)	<5,000t/a estuary plus >5,000 but <100,000 t/a estuary	Moderate	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	No data		

Condition

An extensive water quality data set is available for the Snapper estuary. Both turbidity and Secchi depth clarity values easily meet guidelines at the one site sampled. The dredging appears to be having no persistent impact although localised effects may occur during dredging operations.

The data shows little evidence of increased turbidity following inflow events which indicates that, as could be expected, the catchment is not contributing large sediment loads.

A survey of the Snapper estuary showed extensive areas of one species (*Halophila ovalis*) of seagrass present. As there is no reliable information on the historical extent of seagrass in this estuary it is not possible to determine if seagrass extent has changed. Nevertheless, Snapper Creek clearly has a healthy seagrass population at present, which would be expected, given its largely undisturbed catchment.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	Very high
CI2: Secchi depth (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	Moderate coverage and one species	Excellent	Low
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

High risk	Very high confidence	86% dependability
Excellent condition	High confidence	100% dependability

Risk

There are three main local factors which potentially contribute bacterial loads to the estuary. These are treated waste water from sewage treatment plant (STP), sewage overflows and stormwater from the Tin Can Bay urban area. Of these, the STP effluent is disinfected via chlorination and passes through a wetland before reaching the creek and therefore in practice does not have a large impact during normal operations. There have been no reported sewage overflows in the area so risk associated with this is low. Stormwater inflows from urban areas invariably contribute significant loads of bacteria to adjacent waters, however, only a small portion of the Tin Can Bay urban area drains into Snapper Creek.

Boating is a potential source of bacteria to the estuary

Many boats moor in the estuary and marina, sometimes for extended periods, which does pose a significant risk of sewage release into the water.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	Chlorination	High	Very high
PI12: frequency of sewage overflow events (per year)	Sewerage infrastructure present but no reported overflows	Low	Moderate
PI13: % of catchment under intensive animal production	0	Negligible	High
PI14: density of septics within catchment (per km^2)	No data		
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	Marina AND permanent mooring/anchorage sites present (live aboard)	Extreme	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high

Condition

Levels of intestinal enterococci bacteria values were ≤42 cfu/100 mL and resulted in a 95th percentile value of 40 cfu/100 mL which just meets the primary contact guideline of ≤40 cfu/100 mL. The data indicates that condition is generally good and better than what is expected under the current level of risk. However, on the final sampling occasion the three samples taken were mistakenly analysed for *E. coli* instead of intestinal enterococci. One of these samples gave an extremely high *E. coli* count of ~2,400 cfu/100 mL which indicates that there appears to be an issue with bacteria entering the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	40	Excellent	High
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

Biota removal or disturbance

High risk	High confidence	100% dependability
Excellent condition	Moderate confidence	50% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Fishing and crabbing are important activities in the estuary

Risk

Snapper Creek has a small resident population. There are relatively low numbers of recreational fishers, low recreational catch and bait collection. Although there is no commercial trawling in the estuary there is moderate levels of commercial crabbing and commercial catch. The estuary has a

high level of boating with a marina and numerous anchorage sites present. General recreational use of the estuarine area is moderate.

There are some dredging activities in the Snapper estuary that would have a localised impact on benthic biota.

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	<5,000t/a plus >5,000 but <100,000 t/a	Moderate	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	2	Low	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Moderate	High
PI17: boat moorings	Marina AND permanent mooring/anchorage sites present (live aboard)	Extreme	Very high
PI5: boating activity within the estuary	Marina facilities present	High	Very high
PI20: recreational usage index (value between 8 and 40)	23	Moderate	High
PI21: 'estuary' population size (people/km^2)	1.967	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	1.5	Low	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.72	Low	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Low	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	54	Moderate	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	32728	Moderate	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence.

Snapper Creek is one of the few estuaries in which the CPUE of both finfish and crabs appears to be increasing which suggests that current catch levels are sustainable and stocks are stable, although better data is required to verify this.

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	Increase	Excellent	Moderate
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

There are no impoundments on the Snapper Creek system and so the estuary has good connectivity with its freshwater reaches. The estuary's shoreline is slightly modified, almost entirely near the south bank around the mouth, so connectivity along the estuarine riparian zone is good. A similar portion (10%) of the background vegetation has been modified, again along the southern side associated with the town, so connectivity with most of the catchment is also good.

Much of the shoreline adjoining the town has been modified

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	8.5	Low	Very high
PI32: % of estuarine 'background habitat' length modified	9.8	Low	Very high

Condition

As would be expected from the good connectivity between the estuary and its freshwater reaches, diadromous fish species are common with stable populations.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species common and population stable throughout system	Excellent	High

Freshwater flow regime

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

Currently, there are no water storages on the Snapper system. Also, there are virtually no artificial waterbodies such as farm dams present, covering only 0.07% of the catchment – resulting in a low risk score, though their impact remains to be quantified. The absence of storages and the undisturbed nature of the vegetation mean that there is almost no change to the freshwater regime compared to natural.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	0	Negligible	High
PI34: % of catchment area covered by artificial waterbodies	0.07	Low	High
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of Snapper Creek, the negligible risk from reduced freshwater inflow suggests that impacts on the estuary are currently nil.

Habitat removal or disturbance

Low risk	Very high confidence	100% dependability
Excellent condition	Low confidence	33% dependability

Risk

There has been some limited loss of the estuary's shoreline (9%) and background (10%) vegetation. This loss is generally localised along the south bank around the town reach of the estuary. Dredging near the mouth of the estuary would impact on the benthic habitat there but there are no quantitative measures of this. There are some significant issues, such as those associated with vehicles, direct damage and oil spills, that are causing localised damage (Mackenzie and Duke, 2009).

Vehicle access has caused localised damage to estuarine habitat such as this saltmarsh

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	<5,000t/a plus >5,000 but <100,000 t/a	Moderate	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	9.8	Low	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	8.5	Low	Very high

Condition

There appears to have been very little, and only localised, loss of either mangrove or saltmarsh habitat in the Snapper Creek estuary. However, no historical data is available for comparison with recent mangrove and saltmarsh extent surveys. A survey of the estuary showed significant areas of seagrass present. However, as there is no reliable information on the previous extent of seagrass it is not possible to determine if there has been any losses. Nevertheless, current populations appear to be in good condition. Thus, overall habitat condition in Snapper Creek is excellent. There are however, some localised habitat issues as noted by Mackenzie and Duke (2009).

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	Moderate coverage and one species	Excellent	Low
CI14: change in mangrove extent (% change per year)	No data		
CI15: change in saltmarsh extent (% change per year)	No data		

Hydrodynamics

Low risk	Very high confidence	100% dependability
Good condition	Assumed condition from risk	

Shoreline modifications such as wood or rock walls, boat ramps, pontoons and jetties can alter the natural hydrodynamics of the estuary

Risk

With the exception of dredging and some shoreline modifications which affect hydrodynamics (in the form of jetties/pontoons, boat ramps and rock walls along the southern side of the estuary along the town reach), there have been no significant physical modifications to Snapper Creek that would alter the hydrodynamics of the estuary.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	<5,000t/a plus >5,000 but <100,000 t/a	Moderate	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	8.5	Low	Very high
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the overall low risk in Snapper Creek it can be concluded that these impacts are likely to be minimal.

Litter (rubbish)

Moderate risk	Very high confidence	100% dependability
Fair condition	High confidence	100% dependability

Risk

The township of Tin Can Bay adjoins the southern bank of Snapper Creek and presents some risk of litter. There is also significant boating and other recreational activity the creek and along its foreshore which likewise presents a moderate to high level of risk for litter.

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary	Marina facilities present	High	Very high
PI20: recreational usage index (value between 8 and 40)	23	Moderate	High
PI21: 'estuary' population size (people/km^2)	1.967	Negligible	Very high
PI38: % of estuary adjoining urban area	6.55	Moderate	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

Condition

An initial survey of litter in Snapper Creek estuary showed moderate levels present. This was removed and a second survey carried out in three months time. This also recorded moderate levels which is indicative of ongoing moderate levels of littering.

While plastic bags are commonly discussed in public forums as important litter entering estuarine and marine areas, plastic drink bottle are by far the more commonly found litter item

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0053	Fair	High
CI17: litter accumulation rate (per m^2 per day)	0.000019	Fair	Moderate

Nutrients

High risk	Very high confidence	80% dependability
Excellent condition	Very high confidence	88% dependability

Risk

The undisturbed nature of the catchment means that the risk of increased catchment nutrient loads from land use activities is negligible. However, there is a moderate risk associated sediment bound nutrients entering the estuary due to erosion associated with the loss of riparian vegetation and the 2.36% of the catchment with less than 70% ground cover.

The STP effluent is relatively high in nutrients, however, it passes through a wetland before reaching the creek and therefore in practice is probably a lower risk than that given it here (extreme risk). There have been no reported sewage overflows in the area so risk associated with this is low. Stormwater inflows from urban areas invariably contribute loads of nutrients to adjacent waters, however, only a small portion of the urban area drains into Snapper Creek.

Indicators of nutrient sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1.19	Negligible	High
PI3: % length of river system with no riparian vegetation	16	Moderate	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	2.36	Moderate	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	STP wastewater containing >10 mg/L N and >3 mg/L P	Extreme	Very high
PI12: frequency of sewage overflow events (per year)	Sewerage infrastructure present but no reported overflows	Low	Moderate
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	No data		
PI42: % difference between pre-European total nitrogen load and current load	No data		

Condition

A reasonable nutrient water quality data set is available (15 samples over 14 months at one site). Levels of all nitrogen and phosphorus indicators as well as chlorophyll-a meet guidelines at the one site sampled so the impact of nutrients is minimal.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	Very high
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	Very high
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	Very high
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Moderate risk	High confidence	83% dependability
Excellent condition	High confidence	100% dependability

Risk

The undisturbed nature of the catchment means that the risk of increased catchment organic loads due to land use activity is negligible. There is one point sources of organic material present and while sewerage infrastructure is present there were no sewage overflow events reported. No data on the occurrence of aquatic weeds in the Snapper Creek system is available.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.17	Negligible	High
PI4: number of point sources per km estuary	0.15	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI12: frequency of sewage overflow events (per year)	Sewerage infrastructure present but no reported overflows	Low	Moderate
PI13: % of catchment under intensive animal production	0	Negligible	High
PI43: % river system affected by aquatic weeds	No data		

Condition

An extensive water quality data set is available. Dry weather dissolved oxygen levels in the Snapper estuary easily comply with guidelines. These levels indicate an absence of any ongoing dry weather organic loads. Also, dissolved oxygen values did not record any significant falls following significant catchment inflows which indicates that, as expected, catchment generated organic loads are small. The lowest value detected over ~15 years of EPA sampling in the estuary was 76% saturation which indicates that catchment organic matter loads are not having significant impacts on the estuary.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	76	Excellent	Moderate
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

Pest (animal, plant) species

Moderate risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of the Snapper estuary so the risk from these is negligible. There are some anchorage sites and a significant marina present in the estuary so the likelihood of visitation from overseas boats is significant. No aquaculture facilities are present.

Indicators of pest species sources	Raw data	Risk score	Confidence

Visitation by small non-trailerable yachts is a potential source of marine pest species to the estuary

PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low

PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity	Harbour/marina present	High	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in the Snapper estuary. However, there is no evidence of the presence of any large scale nuisance pest species populations in the estuary at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There is only very limited disturbance of potential acid sulphate soils (ASS) adjacent to the Snapper estuary so the risk of acid water entering the estuary from these is quite low. This will remain the case unless there are future large developments on ASS close to the estuary.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	0.004	Low	Moderate

Condition

The minimum pH value detected over the approximately 15 years of sampling was 7.6, which indicates that no acid run-off impacts are occurring. Red spot disease has not been reported in the estuary.

Ambient pH levels in the estuary were within the guideline range.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	7.6	Excellent	Moderate
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	Very high
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	None reported	Excellent	Low

Toxicants

Moderate risk	Very high confidence	100% dependability
Excellent condition	High confidence	67% dependability

Risk

The undisturbed Snapper Creek catchment presents a negligible risk from land use activities for toxicants. There is however, some risk associated with the high level of boating that occurs in the estuary. Point source discharges are absent. Stormwater inflows from urban areas may contribute significant loads of toxicants to adjacent waters, however, only a small portion of the Tin Can Bay urban area drains into Snapper Creek. A small number of oil spills were reported.

Boating is a potential source of toxicants

Indicators of toxicant sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1.28	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary	Marina facilities present	High	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	Small number reported	Moderate	High

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) showed that while traces of a number of toxicants, particularly herbicides, were detected these were always below the most stringent guideline values.

Using our current guideline values, toxicants in general do not appear to present a major risk to this estuary. Some damage to mangrove habitat was caused by oil at two locations within the estuary (Mackenzie and Duke, 2009).

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	Not detected	Excellent	High
CI35c: toxicants in the water column (Diuron) (µg/L)	0.04	Good	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	Not detected	Excellent	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	0.002	Good	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	<4	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	2.2	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	<3	Excellent	High
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	2	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	1	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	4.4	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	0.0008	Good	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Address litter issue – education initiatives, signage or other approaches
2. All future developments adjacent to the estuary should be required to maintain a reasonable buffer of natural vegetation
3. Introduce/maintain management initiatives aimed at reducing toxicant spills/released from boating activities
4. Develop/implement an urban stormwater management plan
5. Investigate/manage boating sewage disposal practices
6. Investigate sources of toxicants and manage appropriately

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Four yearly assessment of habitat extent including riparian zones and seagrass areas
3. Monitor for marine pest species to assess future management action needs
4. Regular (annual/biannual) monitoring seagrass areas (extent, % cover, % epiphyte cover) – via seagrass watch





Fraser Island estuaries – Wathumba Creek, Coongul Creek and Bogimbah Creek

These three creeks are very similar. They are all on the 'Hervey Bay side' of Fraser Island and have similar biogeographical features. Also, they are all in national park settings and therefore have a very low level of risk for almost all stressors. They are therefore treated together in this report and the scores provided are for all three estuaries unless otherwise stated.

Overall assessment A+

Overall risk	A+	Very high confidence	100% dependability
Overall health	A+	High confidence	85%†, 32%‡, 86%# dependability

†Wathumba; ‡Coongul; #Bogimbah

SUMMARY

The three Fraser Island estuaries examined are subject to a 'negligible' level of risk of impact due to human activities. As a result, the health of all three estuaries is currently rated as 'excellent'. This suggests that under the current *status quo* the condition of the estuaries will remain in this state of excellent health. The overall risk and health ratings reported are backed by a large amount of very high quality data which provide strong support for the accuracy of these results. (Note that the overall health rating reported for Coongul is also backed by high quality data but only 32% of the potential condition indicators were monitored. However, as many of the 'missing' indicators are to do with toxicant 'sub-samples' the accuracy of this overall health rating result is still strongly supported.)

With the exception of 'biota removal/disturbance' (high risk in Wathumba or moderate risk in Coongul and Bogimbah) all stressor were found to be at negligible or low risk levels.

With the exception of 'litter' (poor condition in Wathumba or good condition in Coongul and Bogimbah) and 'biota removal/disturbance' (fair condition in Coongul or good condition in Bogimbah) all stressor condition scores were reported as 'excellent'. No condition indicators of 'habitat removal/disturbance' were monitored in any of the three creeks, however, due to the protected status of the creeks it is certain that habitat is in excellent condition (Table 21).

No condition indicators are available for 'freshwater flow regime' and 'hydrodynamics' so condition scores are assumed from the level of risk and are not included in the overall health rating calculation.

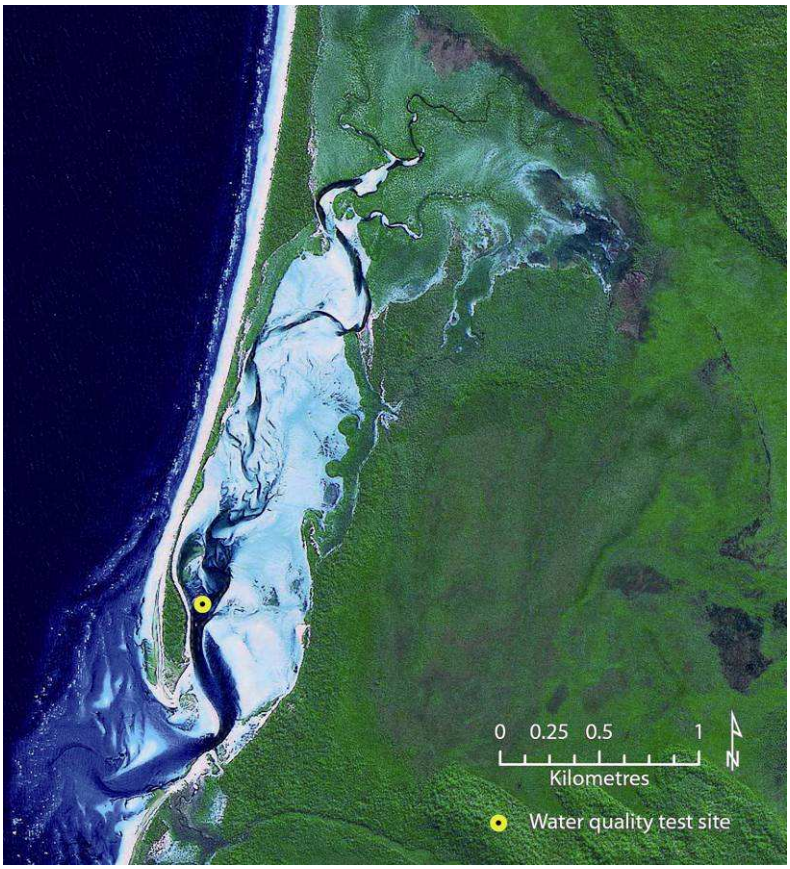
INTRODUCTION

All three creeks examined have small catchments (Wathumba (16.2 km^2), Coongul (48.9 km^2) and Bogimbah (45.7 km^2)) within the Great Sandy National Park. The main activities occurring in the systems are recreation orientated (i.e. boating, fishing and camping) – over 100,000 people camp on Fraser Island each year with visitation about 3 to 4 times that number. As such, any increases in risk are related to these activities.

Coongul Creek estuary

Table 21. Summary of the stressor risk and condition scores for Wathumba, Coongul and Bogimbah creek estuaries.

Stressor	Estuary	Risk	Condition
Aquatic Sediments	All	Negligible	Excellent
Bacteria/Pathogens	All	Negligible	Excellent
Biota removal/ disturbance	Wathumba	High	Excellent
	Coongul	Moderate	Fair
	Bogimbah	Moderate	Good
Connectivity	All	Negligible	Excellent
Freshwater flow regime	All	Negligible	Excellent
Habitat removal/ disturbance	All	Negligible	no data
Hydrodynamics	All	Negligible	Excellent
Litter	Wathumba	Low	Poor
	Coongul and Bogimbah	Negligible	Good
Nutrients	All	Negligible	Excellent
Organic matter	All	Negligible	Excellent
Pests	Wathumba	Low	Excellent
	Coongul and Bogimbah	Negligible	Excellent
pH	All	Negligible	Excellent
Toxicants	Wathumba	Low	Excellent
	Coongul and Bogimbah	Negligible	Excellent



Satellite imagery of the Wathumba Creek estuary

Satellite imagery of the Coongul Creek estuary

Satellite imagery of the Bogimbah Creek estuary

STRESSOR RESULTS

Aquatic sediments

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	50% dependability

Risk

All three creeks have catchments that are almost completely undisturbed and so the risk of increased sediment loads is negligible. Wathumba Creek has a lot more boat traffic than the others so this may be a small risk factor in terms of erosion from boat wash and the resuspension of sediments, but is unlikely to be very significant. The only other pressure indicator to have a risk above a negligible level was unsealed road density. However, due to the sandy soil on the island even this would not cause any real risk to the estuary in terms of sediment load.

Catchments and creek systems are intact and natural

Indicators of suspended sediment sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1	Negligible	High
PI2: % of catchment cleared	1	Negligible	Very high
PI3: % length of river system with no riparian vegetation	0	Negligible	Very high
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary **(Wathumba)**	Commercial vessels or 'anchorage' sites identified	Low	Very high
PI5: boating activity within the estuary **(Coongul : Bogimbah)**	Recreational vessels only : Limited/none	Negligible	Very high
PI6: unsealed road density (m/km^2)	160-250	Low	Low
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	0	Negligible	High
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
Indicators of direct pressure			
PI10: % difference between pre-European sediment load and current load	0	Negligible	Very high

Condition

All three estuaries were sampled on seven occasions at a single site. Both turbidity and Secchi depth met guidelines in all three estuaries. The data shows little evidence of increased turbidity following inflow events which indicates that, as could be expected, the undisturbed catchments are not contributing large sediment loads.

No surveys of seagrass extent have been completed in any of the three estuaries. However, seagrass has been observed in both Wathumba and Coongul though the exact extent and location was not recorded. It is unknown if seagrass is present in Bogimbah.

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI1: turbidity (% of sites exceed guidelines)	0	Excellent	High
CI2: Secchi depth (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI3: change in seagrass extent (% change per year)	No data		
CI4: % cover of seagrass	No data		

Bacteria/Pathogens

Negligible risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no significant risk factors for bacteria in any of these estuaries. The only potential risk factor is the release of sewage from visiting boats.

Indicators of bacteria/pathogen sources	Raw data	Risk score	Confidence
PI11: level of sewage treatment plant wastewater disinfection	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI14: density of septics within catchment (per km^2)	0	Negligible	Very high
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high

Condition

Four samples for faecal enterococci were collected in each estuary. Values in all three were very low with the highest value of 13 cfu/100 mL, which meets the primary contact guideline, recorded in Bogimbah Creek.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI5: intestinal enterococci counts (95th percentile value of counts per 100 mL)	2†, 3‡, 13$^{\#}$	Excellent	Moderate
Biological condition indicators			
CI6: number of mass mortality events caused by pathogens	0	Excellent	Moderate

†Wathumba; ‡Coongul; $^{\#}$Bogimbah

Biota removal or disturbance

Wathumba Creek

High risk	High confidence	100% dependability
Excellent condition	High confidence	33% dependability

Coongul Creek

Moderate risk	High confidence	100% dependability
Fair condition	High confidence	17% dependability

Bogimbah Creek

Moderate risk	High confidence	100% dependability
Good condition	High confidence	50% dependability

This is a difficult stressor to quantify. This is because there are no precise data on within-estuary fishing effort or on estuary fish, crab, prawn or bait species populations. Many of the available measures of pressure or condition are either indirect or imprecise. Commercial fishing statistics usually cover an area larger than just the estuary. Recreational fishing data has only a moderate level of confidence. Nevertheless, the available indicators do provide a semi-quantitative indication of the relative levels of fishing effort and whether fisheries stocks are declining.

Initial data from current studies in Moreton Bay are showing large differences in both fish and crab populations between green zones (i.e. no take zones) and general use zones. Studies of protected areas in the Great Barrier Reef (Williamson *et al*., 2004) and overseas (Halpern and Warner, 2002) show similar differences. The effects of fishing can undoubtedly be very significant and there is no reason to suppose that similar impacts are not occurring in some of the estuaries within the Burnett Mary NRM region.

Recreational fishing is a popular activity

Risk

None of these estuaries has any resident population. However, they all experience both recreational and commercial fisheries activity in the estuary and the adjoining coastal waters. Recreational use is moderate to low. There is some recreational catch in both Wathumba and Coongul but very little in Bogimbah which is small and difficult to access. Commercial use is much more significant. There are high levels of commercial line fishing, netting and crabbing in and around all three estuaries and there are corresponding high levels of fish catch. There is also commercial bait collection in and around the Bogimbah estuary.

Boating is highest in Wathumba and occurs less in Coongul and is almost absent from Bogimbah. Recreational activities also follows this trend. There are no dredging activities in any of the estuaries.

Wathumba

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	0.4	Negligible	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI20: recreational usage index (value between 8 and 40)	13	Low	High
PI21: 'estuary' population size (people/km^2)	0	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	0.4	Low	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.12	Low	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Low	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	28	Extreme	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	116	High	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	175488	High	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Coongul

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	0.8	Low	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Recreational vessels only	Low	Very high
PI20: recreational usage index (value between 8 and 40)	10	Low	High
PI21: 'estuary' population size (people/km^2)	0	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	0.2	Negligible	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.28	Low	Moderate

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	17	High	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	118	High	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	139602	High	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Bogimbah

Indicators of biota removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary (as a % of total reported recreational bait collector usage for the region)	None reported	Negligible	Moderate
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters (total number of boats per year)	<5	Moderate	High
PI17: boat moorings	No anchorage or mooring sites identified in estuary	Negligible	Very high
PI5: boating activity within the estuary	Limited/none	Negligible	Very high
PI20: recreational usage index (value between 8 and 40)	9	Low	High
PI21: 'estuary' population size (people/km^2)	0	Negligible	Very high
PI22: number of recreational fishers using an estuary (as a % of total reported recreational fisher usage for the region)	0.1	Negligible	Moderate
PI23: total recreational fisher catch from an estuary (as a % of total reported recreational fisher "raw kept" for the region)	0.02	Negligible	Moderate
PI24: commercial trawl usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI25: commercial line fishing usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters (total number of boats per year)	188	High	High
PI27: total commercial fisher catch from an estuary and adjoining coastal waters (total catch weight (kg) per year)	110263	High	High
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters (total number of boats per year)	None	Negligible	High

Condition

Indicators of biota populations are all indirect and related to fisheries species, i.e. using fisheries catch per unit effort (CPUE) data as an indication of abundance, and have only a moderate to high level of confidence. Data for these three estuaries is very limited.

Fish CPUE is in general being maintained, though a slight decrease was observed in Coongul, so the fish stocks appears to be stable. The only estuary for which there is information on crab CPUE is in Bogimbah, where there has been a decrease in CPUE observed. This suggests that crab stocks may be in decline in this estuary, although better data is required to verify this.

Wathumba

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Biological condition indicators	Raw data	Condition score	Confidence
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Coongul

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	6.2% decrease	Fair	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	No data		
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Bogimbah

Biological condition indicators	Raw data	Condition score	Confidence
CI7: commercial finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	High
CI8: commercial crab catch per unit effort (estimate of crab abundance) (% change per year)	11.5% decrease	Fair	High
CI9: commercial prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		
CI10: recreational finfish catch per unit effort (estimate of fish abundance) (% change per year)	Increase	Excellent	Moderate
CI11: recreational crab catch per unit effort (estimate of crab abundance) (% change per year)	No data		
CI12: recreational prawn catch per unit effort (estimate of prawn abundance) (% change per year)	No data		

Connectivity

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	100% dependability

Risk

There are no impoundments on any of these systems and so the estuaries have a natural level of connectivity with their freshwater reaches. The estuary shoreline and background vegetation is also completely intact in all three systems so that connectivity along the estuaries and between the estuary and its catchment are also at natural levels.

Indicators of altered connectivity source	Raw data	Risk score	Confidence
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	No impoundments	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0	Negligible	Very high
PI32: % of estuarine 'background habitat' length modified	0	Negligible	Very high

Condition

As would be expected from the high levels of connectivity, diadromous fish species are common with stable populations in all three estuaries.

Biological condition indicators	Raw data	Condition score	Confidence
CI13: abundance of diadromous species	Diadromous species common and population stable throughout system	Excellent	High

Freshwater flow regime

Negligible risk Very high confidence 100% dependability
Excellent condition Assumed condition from risk

Risk

There are no significant storages or small dams on any of these systems and the vegetation is entirely natural. Thus there would be no changes to the quantity or characteristics of freshwater inflows compared to natural.

Indicators of altered freshwater flow regime sources	Raw data	Risk score	Confidence
PI33: % of median annual flow impounded and extracted	0	Negligible	Very high
PI34: % of catchment area covered by artificial waterbodies	0	Negligible	Very high
PI29: impoundment density (per 500 km of river)	No impoundments	Negligible	Very high

Condition

Because of the lack of information on the impacts of reduced freshwater inflow to estuaries, no suitable condition indicators have been defined. Broadly speaking, reduced inflows change the nature of an estuary so that it becomes more akin to a marine inlet. Species abundance may remain similar but marine species start to replace true estuarine species. As a result, our diverse and unique estuary systems are gradually being lost. The reduction in inflows can also lead to increased siltation in the upper reaches of the estuary. This happens because the frequency and magnitude of flushing inflows is reduced. However, this is difficult to measure and information is generally lacking.

In the case of the three Fraser Island creeks examined, the negligible risk from reduced freshwater inflow suggests that impacts on these estuaries are currently nil.

Habitat removal or disturbance

Negligible risk Very high confidence 100% dependability
No data

Risk

Both the shoreline and the background vegetation components of the estuary is completely intact in all three systems. There are no significant human activities which would remove habitat, such as dredging, in these estuaries.

Indicators of habitat removal/disturbance sources	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI16: number of 'marine' aquaculture facilities present	0	Negligible	Very high
Indicators of direct pressure			
PI32: % of estuarine 'background habitat' length modified	0	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (habitat)	0	Negligible	Very high

Condition

There have been no formal surveys of mangrove, saltmarsh or seagrass habitat in these systems but given that they are all in a national park it is reasonable to assume that any changes would have been minimal or been caused by natural processes.

Biological condition indicators	Raw data	Condition score	Confidence
CI3: change in seagrass extent (% change per year)	No data		
CI14: change in mangrove extent (% change per year)	No data		
CI15: change in saltmarsh extent (% change per year)	No data		

Hydrodynamics

Negligible risk	Very high confidence	100% dependability
Excellent condition	Assumed condition from risk	

Risk

There have been no significant physical alterations to any of these systems that would affect their hydrodynamic regimes.

Indicators of sources of changed hydrodynamic	Raw data	Risk score	Confidence
PI9: dredging activity in river system (licensed amount)	None	Negligible	Very high
PI35: presence of entrance modifications	None	Negligible	Very high
PI36: presence of canals	None	Negligible	Very high
PI31: % of estuarine 'shoreline' length modified (hydrodynamics)	0	Negligible	Very high
PI37: % of original estuary length lost due to a tidal barrage	No tidal barrage present	Negligible	Very high

Condition

The effects of changes to hydrodynamics on water quality or ecosystem health are difficult to assess but given the negligible risk for all pressure indicators in the estuaries of Fraser Island it can be concluded that these impacts are currently nil.

Litter (rubbish)

Wathumba Creek

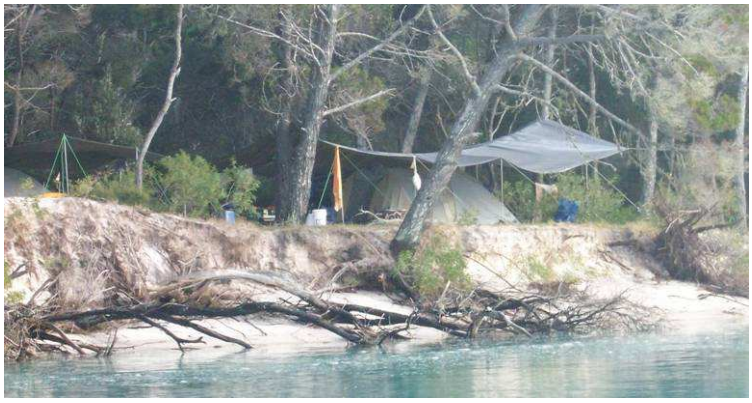
Low risk	Very high confidence	100% dependability
Poor condition	High confidence	100% dependability

Coongul and Bogimbah creeks

Negligible risk	Very high confidence	100% dependability
Good condition	High confidence	100% dependability

Risk

While there are no resident populations near these systems, they all experience recreational and commercial use. Wathumba Creek in particular is often used as a safe port for boats. Both Wathumba and Coongul have camp sites located near the estuary. Bogimbah experiences the least amount of commercial and recreational activity of all three estuaries.



Campers and visitors are the main sources of rubbish

Indicators of litter sources	Raw data	Risk score	Confidence
PI5: boating activity within the estuary **(Wathumba)**	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI5: boating activity within the estuary **(Coongul)**	Recreational vessels only	Low	Very high
PI5: boating activity within the estuary **(Bogimbah)**	Limited/none	Negligible	Very high
PI20: recreational usage index (value between 8 and 40)	13†, 10‡, 9#	Low	High
PI21: 'estuary' population size (people/km^2)	0	Negligible	Very high
PI38: % of estuary adjoining urban area	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high

†Wathumba; ‡Coongul; #Bogimbah

Condition

Initial litter surveys in these systems showed high levels in Wathumba, low levels in Coongul and moderate levels in Bogimbah. The litter was removed and a second survey carried out after approximately three months time. This repeat visit litter survey recorded no litter in Bogimbah so that

accumulation rates here are obviously very low which accords with the difficulty of access to this system. Low accumulation rates were recorded in Coongul. Wathumba, the system with the highest levels of use again recorded high levels of litter, which is indicative of ongoing high levels of littering (i.e. high accumulation rates). A more complete analysis of litter might assist in determining the actual litter source, for example is it from boating vs. camping vs. day use activities.

Wathumba

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.02	Poor	High
CI17: litter accumulation rate (per m^2 per day)	0.000282	Poor	Moderate

Coongul

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0007	Good	High
CI17: litter accumulation rate (per m^2 per day)	0.0000007	Good	Moderate

Bogimbah

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI16: presence (standing crop) of litter (per m^2)	0.0045	Fair	High
CI17: litter accumulation rate (per m^2 per day)	0	Excellent	Moderate

Nutrients

Negligible risk	Very high confidence	100% dependability
Excellent condition	High confidence	88% dependability

Risk

The undisturbed nature of the catchments of these three systems means that the risk of increased catchment nutrient loads is negligible. There are no point sources of nutrients present.

Indicators of nutrient sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1	Negligible	High
PI3: % length of river system with no riparian vegetation	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI8: % of catchment with less than 70% ground cover	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
PI39: nutrient concentration of sewage treatment plant wastewater	No STP	Negligible	Very high
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI40: number of point sources per km estuary (excluding STPs)	0	Negligible	Very high
Indicators of direct pressure			
PI41:% difference between pre-European total phosphorus load and current load	0	Negligible	Very high
PI42: % difference between pre-European total nitrogen load and current load	0	Negligible	Very high

Condition

A limited water quality data set is available (7 samples over 9 months at one site) for each estuary. Nutrient indicators and chlorophyll-a all met guidelines. Thus as expected, there is no evidence of any nutrient impact.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI18: ammonia (% of sites exceed guidelines)	0	Excellent	High
CI19: organic nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI20: oxidised nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI21: total nitrogen (% of sites exceed guidelines)	0	Excellent	High
CI22: filterable reactive phosphorus (% of sites exceed guidelines)	0	Excellent	High
CI23: total phosphorus (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI24: chlorophyll-a (% of sites exceed guidelines)	0	Excellent	High
CI25: % epiphytic cover on seagrass	No data		

Organic matter

Negligible risk	Very high confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

The undisturbed nature of the catchment of these three systems means that the risk of increased catchment organic loads is negligible. There are no point sources of organic material present.

Indicators of organic matter sources	Raw data	Risk score	Confidence
PI1: catchment land-use (index value between 1 and 6)	1	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI12: frequency of sewage overflow events (per year)	No sewerage infrastructure	Negligible	Very high
PI13: % of catchment under intensive animal production	0	Negligible	High
PI43: % river system affected by aquatic weeds	0	Negligible	High

Condition

A limited water quality data set is available (7 samples over 9 months at one site) for each estuary. Dissolved oxygen met guidelines at all sites.

DO values did not record any significant falls following significant catchment inflows which indicates that as expected, catchment generated organic loads are small.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI26: minimum sustained dissolved oxygen values during the days following an inflow event (% saturation)	96.2[†], 96.1[‡], 93.3[#]	Excellent	Low
CI27: ambient dissolved oxygen (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI28: number of mass mortality events caused by low dissolved oxygen	0	Excellent	Moderate

[†]Wathumba; [‡]Coongul; [#]Bogimbah

Pest (animal, plant) species

Wathumba Creek

Low risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Coongul and Bogimbah creeks

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Moderate confidence	100% dependability

Risk

There are no known infestations of significant marine or terrestrial pest species in the vicinity of any of these systems so the risk from these is negligible. There are some mooring sites in Wathumba Creek and a small likelihood of visitation from overseas boats. Of the other two estuaries the risk in relation to overseas boat visitation is low in Coongul and negligible in Bogimbah due to its limit/hazardous access.

Indicators of pest species sources	Raw data	Risk score	Confidence
PI44: presence of 'key' aquatic pest species in adjoining areas	No significant marine pest species within 200 km	Negligible	Low
PI45: presence of 'key' terrestrial pest species in adjoining areas	No significant terrestrial pest species within 100 km	Negligible	Low
PI46: presence of port/harbour/marina and related boating activity **(Wathumba)**	Moorings for small, non-trailerable, international/domestic vessels present (published in boating guides/well know by boaties)	Moderate	Very high
PI46: presence of port/harbour/marina and related boating activity **(Coongul)**	Small, non-trailerable, international/domestic vessels commonly visit estuary (generally just passing through)	Low	Very high

Indicators of pest species sources	Raw data	Risk score	Confidence
PI46: presence of port/harbour/marina and related boating activity **(Bogimbah)**	No port/harbour/marina or permanent moorings present. Non-trailerable, international/domestic vessels rarely visit estuary	Negligible	Very high
PI47: presence of aquaculture facilities using marine species non-native to the region	None present	Negligible	Very high

Condition

No surveys to detect pest species have been carried out in any of the three Fraser Island estuaries. However, there is no evidence of the presence of any large scale nuisance pest species populations in any of the estuaries at this stage. It is possible but unlikely that small populations of exotic species are present.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI29: occurrence of pest (animal, plant) species	No pests known to occur in estuary	Excellent	Moderate
CI30: % area impacted by pests	No pests known (0% area impacted)	Excellent	Moderate

pH

Negligible risk	Moderate confidence	100% dependability
Excellent condition	Low confidence	100% dependability

Risk

There are no recorded disturbance of potential acid sulphate soils adjacent to any of these three systems so the risk of acid water entering the estuary is negligible.

Indicators of pH sources	Raw data	Risk score	Confidence
PI48: % of estuary length adjoining disturbed acid sulphate soils	0	Negligible	Moderate

Condition

The minimum pH value detected in any of the estuaries was 7.3, which indicates that no acid run-off impacts are occurring. Red spot disease has not been reported in any of the estuaries.

Ambient pH levels in all estuaries were within the guideline range.

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI31: minimum sustained pH values during the days following an inflow event	7.9[†], 7.8[‡], 7.3[#]	Excellent	Low
CI32: ambient pH (% of sites exceed guidelines)	0	Excellent	High
Biological condition indicators			
CI33: number of mass mortality events caused by low pH	0	Excellent	Moderate
CI34: red-spot disease of fish	None reported	Excellent	Low

[†]Wathumba; [‡]Coongul; [#]Bogimbah

Toxicants

Wathumba Creek

Low risk	High confidence	100% dependability
Excellent condition	High confidence	95% dependability

Coongul Creek

Negligible risk	High confidence	100% dependability
Excellent condition	Moderate confidence	2% dependability

Bogimbah Creek

Negligible risk	High confidence	100% dependability
Excellent condition	High confidence	95% dependability

Risk

The undisturbed nature of the catchments of these systems presents a negligible risk for toxicants in terms of catchment activities. There is however, boating activity in all three estuaries (highest amount in Wathumba and least in Bogimbah) which posses some risk of toxicant release.

Indicators of toxicant sources	**Raw data**	**Risk score**	**Confidence**
PI1: catchment land-use (index value between 1 and 6)	1	Negligible	High
PI4: number of point sources per km estuary	0	Negligible	Very high
PI5: boating activity within the estuary **(Wathumba)**	Commercial vessels or 'anchorage' sites identified	Moderate	Very high
PI5: boating activity within the estuary **(Coongul)**	Recreational vessels only	Low	Very high
PI5: boating activity within the estuary **(Bogimbah)**	Limited/none	Negligible	Very high
PI7: % of catchment with intensive agriculture on steep slopes	0	Negligible	High
PI15: number of stormwater inflows per km estuary	0	Negligible	Very high
Indicators of direct pressure			
PI49: amount of oil spilled and number of oil slicks/spills reported	None reported	Negligible	Moderate

Condition

Surveys of toxicants in sediments and the water column (through the use of passive samplers) in Wathumba and Bogimbah creeks showed that levels of all toxicants tested for were below detection limits, or in the case of metals, were at natural levels (below the most stringent guideline values). Given the negligible/low level of risk, this result is what would be expected.

No toxicant sampling was done in Coongul Creek.

This is the expected result in these pristine systems but it is of some interest to note that in every other mainland system, with the exception of Eurimbula Creek, some trace contamination, usually of herbicides, was detected. This illustrates the pervasive nature of these compounds and how with even relatively low levels of use they still manage to find their way into waterways. In almost all cases the levels are thought to be too low to be of concern but their presence is a warning against complacency.

Wathumba and Bogimbah

Physical-chemical condition indicators	**Raw data**	**Condition score**	**Confidence**
CI35a: toxicants in the water column (Ametryn) (µg/L)	Not detected	Excellent	High
CI35b: toxicants in the water column (Atrazine) (µg/L)	Not detected	Excellent	High
CI35c: toxicants in the water column (Diuron) (µg/L)	Not detected	Excellent	High
CI35d: toxicants in the water column (Fluometuron) (µg/L)	Not detected	Excellent	High
CI35e: toxicants in the water column (Hexazinone) (µg/L)	Not detected	Excellent	High
CI35f: toxicants in the water column (Prometryn) (µg/L)	Not detected	Excellent	High
CI35g: toxicants in the water column (Simazine) (µg/L)	Not detected	Excellent	High
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	Not detected	Excellent	High
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	Not detected	Excellent	High
CI35j: toxicants in the water column (Chlordane) (µg/L)	Not detected	Excellent	High
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	Not detected	Excellent	High
CI35l: toxicants in the water column (Dieldrin) (µg/L)	Not detected	Excellent	High
CI35m: toxicants in the water column (Endrin) (µg/L)	Not detected	Excellent	High
CI35n: toxicants in the water column (Endosulfan) (µg/L)	Not detected	Excellent	High
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	Not detected	Excellent	High
CI35p: toxicants in the water column (Lindane) (µg/L)	Not detected	Excellent	High
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	Not detected	Excellent	High
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	Not detected	Excellent	High
CI35s: toxicants in the water column (Total DDT) (µg/L)	Not detected	Excellent	High
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	Not detected	Excellent	High
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	<4	Excellent	High
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	<0.4	Excellent	High
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	4.9[†], 18[#]	Excellent	High
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	<3	Excellent	High

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	<1[†], 2[#]	Excellent	High
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	1.6[†], 6.1[#]	Excellent	High
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	2.4[†], 7.7[#]	Excellent	High
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	Not detected	Excellent	High
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	Not detected	Excellent	High
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	Not detected	Excellent	High
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	Not detected	Excellent	High
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	Not detected	Excellent	High
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	Not detected	Excellent	High
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	Not detected	Excellent	High
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	Not detected	Excellent	High
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	Not detected	Excellent	High
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	Not detected	Excellent	High
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	Not detected	Excellent	High
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	Not detected	Excellent	High
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

[†]Wathumba; [#]Bogimbah

Coongul

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI35a: toxicants in the water column (Ametryn) (µg/L)	No data		
CI35b: toxicants in the water column (Atrazine) (µg/L)	No data		
CI35c: toxicants in the water column (Diuron) (µg/L)	No data		
CI35d: toxicants in the water column (Fluometuron) (µg/L)	No data		
CI35e: toxicants in the water column (Hexazinone) (µg/L)	No data		
CI35f: toxicants in the water column (Prometryn) (µg/L)	No data		
CI35g: toxicants in the water column (Simazine) (µg/L)	No data		
CI35h: toxicants in the water column (Tebuthiuron) (µg/L)	No data		
CI35i: toxicants in the water column (Bifenthrin) (µg/L)	No data		
CI35j: toxicants in the water column (Chlordane) (µg/L)	No data		
CI35k: toxicants in the water column (Chlorpyrifos) (µg/L)	No data		
CI35l: toxicants in the water column (Dieldrin) (µg/L)	No data		
CI35m: toxicants in the water column (Endrin) (µg/L)	No data		
CI35n: toxicants in the water column (Endosulfan) (µg/L)	No data		
CI35o: toxicants in the water column (Hexachlorobenzene (HCB)) (µg/L)	No data		
CI35p: toxicants in the water column (Lindane) (µg/L)	No data		
CI35q: toxicants in the water column (Phosphate tri-n-butyl) (µg/L)	No data		
CI35r: toxicants in the water column (Piperonyl butoxide) (µg/L)	No data		
CI35s: toxicants in the water column (Total DDT) (µg/L)	No data		
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column) (µg/L)	No data		
CI36a: toxicants in the sediments (Arsenic (As)) (mg/kg dry weight)	No data		
CI36b: toxicants in the sediments (Cadmium (Cd)) (mg/kg dry weight)	No data		
CI36c: toxicants in the sediments (Chromium (Cr)) (mg/kg dry weight)	No data		
CI36d: toxicants in the sediments (Copper (Cu)) (mg/kg dry weight)	No data		
CI36e: toxicants in the sediments (Lead (Pb)) (mg/kg dry weight)	No data		
CI36f: toxicants in the sediments (Nickel (Ni)) (mg/kg dry weight)	No data		
CI36g: toxicants in the sediments (Zinc (Zn)) (mg/kg dry weight)	No data		
CI36h: toxicants in the sediments (Atrazine) (mg/kg dry weight)	No data		

Physical-chemical condition indicators	Raw data	Condition score	Confidence
CI36i: toxicants in the sediments (Chlordane) (mg/kg dry weight)	No data		
CI36j: toxicants in the sediments (Chlorpyrifos) (mg/kg dry weight)	No data		
CI36k: toxicants in the sediments (Dieldrin) (mg/kg dry weight)	No data		
CI36l: toxicants in the sediments (Diuron) (mg/kg dry weight)	No data		
CI36m: toxicants in the sediments (Endosulfan) (mg/kg dry weight)	No data		
CI36n: toxicants in the sediments (Endrin) (mg/kg dry weight)	No data		
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB)) (mg/kg dry weight)	No data		
CI36p: toxicants in the sediments (Piperonyl butoxide) (mg/kg dry weight)	No data		
CI36q: toxicants in the sediments (Prometryn) (mg/kg dry weight)	No data		
CI36r: toxicants in the sediments (Lindane) (mg/kg dry weight)	No data		
CI36s: toxicants in the sediments (Total DDT) (mg/kg dry weight)	No data		
CI36t: toxicants in the sediments (any other pesticide detected in sediments) (mg/kg dry weight)	No data		
CI37a: toxicants in biota (DDT) (mg/kg)	No data		
CI37b: toxicants in biota (Dieldrin) (mg/kg)	No data		
Biological condition indicators			
CI38: number of mass mortality events caused by toxicants	0	Excellent	Moderate

MANAGEMENT AND MONITORING RECOMMENDATIONS

Management

1. Address litter issue – education initiatives, signage or other approaches

Monitoring

1. Acquire better information on estuary fisheries stocks and bait species
2. Monitor mangrove, saltmarsh and seagrass extent for baseline information from which future changes at these and other estuaries can be assessed. (Regular (annual/biannual) monitoring of seagrass areas (extent, % cover, % epiphyte cover))

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Appendix 1: Data sources

Pressure indicator 1: catchment land-use
Data source: Queensland Landuse Mapping Project (Qld Government, 1999).

Pressure indicator 2: % of catchment cleared
Data source: 2005 SLATS Foliage Projective Cover Data (≥ 12% cover as indicator of Woody Vegetation) as percentage of Catchment area. Calculated based from 25 x 25 m grid squares.

Pressure indicator 3: % length of river system with no riparian vegetation
Data source: 2005 SLATS Foliage Projective Cover Data (≥ 12% cover as indicator of Woody Vegetation) as percentage of 50 m Streams Buffer. Calculated based from 25 x 25 m grid squares.

Pressure indicator 4: number of point sources per km estuary
Data source: EPA, 2007 point source licence data.

Pressure indicator 5: boating activity within the estuary
Data source: Sue Sargent, Jenna Hill and 'locals', BMRG, pers. comm., 2008; Beacon to Beacon, 2007. Matt Davies, EPA, pers. comm., 2008.

Pressure indicator 6: unsealed road density
Data source: 'Eye balled' Catchment Condition Online Maps (http://www.brs.gov.au/mapserv/catchment/), from 1994 data.

Pressure indicator 7: % of catchment with intensive agriculture on steep slopes
Data source: SEQ DEM 25 m - Slope % > 3% and Intensive land-uses from Queensland Landuse Mapping Project (Qld Government, 1999).

Pressure indicator 8: % of catchment with less than 70% ground cover
Data source: Statewide Landcover and Trees Study (SLATS) 2008 Ground Cover Index (GCI) Ver. 1 April 2008, Landsat SLATS Scene Series (NRW, 2008).

Pressure indicator 9: dredging activity in river system
Data source: EPA, 2007.

Pressure indicator 10: % difference between pre-European sediment load and current load
Data source: SedNet data from OzEstuaries, 2006. Burrum/Gregory/Isis and Mary/Susan are each considered as one system in the SedNet modelling.

Pressure indicator 11: level of sewage treatment plant wastewater disinfection
Data source: EPA, 2008 (Listing of major point source inputs for Wide Bay Burnett district, Point Source Database). Currently STPs near the Burrum release to land but there is potential for waste to have to be released to the Burrum.

Pressure indicator 12: frequency of sewage overflow events
Data source: John McDougall (Bundaberg City Council). Maryborough City Council has bypass system at STP that operates occasionally during very heavy rain and this results in discharge to a section of the river that is tidal (at Aubinville Maryborough)(also EPA received reports of noticeable sewage sludge on banks/in water of the Mary river from Aubinville Treatment Plant on Lennox Street, Maryborough during September 2006). EPA, 2008 (reports of sewage overflows – 3 September 2007 and 25 October 2007 overflows reported in Burnett estuary; 8 October 2007 (100,000 L released), 28 August 2007 and 31 August 2007 overflows reported in Mary estuary).

Pressure indicator 13: % of catchment under intensive animal production
Data source: Queensland Landuse Mapping Project (Qld Government, 1999).

Pressure indicator 14: density of septics within catchment
Data source: Local knowledge.

Pressure indicator 15: number of stormwater inflows per km estuary
Data source: EPA, 2008 'Riparian Assessment' field survey. Note only 65% of Mary River and 42% of Baffle Creek surveyed.

Pressure indicator 16: number of 'marine' aquaculture facilities present
Data source: DPI&F, 2007.

Pressure indicator 17: boat moorings
Data source: Beacon to Beacon, 2007. Pers. comm., 2008, with Mary, Burnett and Snapper marina operators.

Pressure indicator 18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary and adjoining coastal waters
Data source: DPI&F, 2005 recreational fisher survey data.

Pressure indicator 19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters
Data source: DPI&F, 2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Pressure indicator 20: recreational usage index
Data source: Various – including: road maps, satellite images, local knowledge, phone book, EPA 'Riparian Assessment' field survey (2008), site visits.

Pressure indicator 21: 'estuary' population size
Data source: ABS, 2006.

Pressure indicator 22: number of recreational fishers using an estuary
Data source: DPI&F, 2005 recreational fisher survey data.

Pressure indicator 23: total recreational fisher catch from an estuary
Data source: DPI&F, 2005 recreational fisher survey data.

Pressure indicator 24: commercial trawl usage of an estuary and adjoining coastal waters
Data source: DPI&F, 2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Pressure indicator 25: commercial line fishing usage of an estuary and adjoining coastal waters
Data source: DPI&F, 2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Pressure indicator 26: commercial net and crab fisher usage of an estuary and adjoining coastal waters
Data source: DPI&F, 2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Pressure indicator 27: total commercial fisher catch from an estuary and adjoining coastal waters
Data source: DPI&F, 2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Pressure indicator 28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters
Data source: DPI&F, 2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Pressure indicator 29: impoundment density
Data source: Andrew Berghuis, DPI&F, pers. comm., 2007. GIS river and stream layers.

Pressure indicator 30: % of freshwater reaches without access to the sea due to impoundments without effective fish ladders
Data source: Andrew Berghuis, DPI&F, pers. comm., 2007. GIS data. A barrage is located on Walsh Ck on the Littabella system but it does not come up on the GIS stream layer available but it is estimated to be a less than 20% loss of access to the sea.

Pressure indicator 31: % of estuarine 'shoreline' length modified
Data source: EPA, 2008 ('Riparian Assessment' field survey).

Pressure indicator 32: % of estuarine 'background habitat' length modified
Data source: EPA, 2008 ('Riparian Assessment' field survey). Note only approx. half of Mary River and Baffle Creek surveyed – additional length estimated from Google Earth.

Pressure indicator 33: % of median annual flow impounded and extracted
Data source: NRW, 2008. (Note no extraction data available for use in calculations).

Pressure indicator 34: % catchment area covered by artificial waterbodies
Data source: EPA 2007, Wetlands Mapping Programme (WetlandInfo).

Pressure indicator 35: presence of entrance modifications
Data source: BMRG, local knowledge. EPA, 2008 ('Riparian Assessment' field survey and dredging licence database).

Pressure indicator 36: presence of canals
Data source: BMRG, local knowledge, EPA, 2008.

Pressure indicator 37: percentage of original estuary length lost due to a tidal barrage
Data source: Andrew McDougall, NRW, pers. comm., 2008.

Pressure indicator 38: % of estuary adjoining urban area
Data source: Queensland Landuse Mapping Project (Qld Government, 1999).

Pressure indicator 39: nutrient concentration of sewage treatment plant wastewater
Data source: EPA, 2008 (listing of major point source inputs for Wide Bay Burnett district, Point Source Database). Burnett average release for April 2007 to March 2008 was Bundaberg East STP = TN 17.79 / TP 8.25 mg/L; Millbank STP = TN 3.6 / TP 3.27 mg/L. Maximum limits for Snapper Creek (Tin Can Bay STP) are TN 40 / TP 12 mg/L. No maximum limits for Mary River (Aubinville STP) for TN and TP, however, in the future a maximum limit of TN 10 / TP 2 mg/L will occur.

Pressure indicator 40: number of point sources per km estuary (excluding STPs)
Data source: EPA, 2007 point source licence data.

Pressure indicator 41: % difference between pre-European total phosphorus load and current load
Data source: SedNet data from OzEstuaries, 2006. Burrum/Gregory/Isis and Mary/Susan are each considered as one system in the SedNet modelling.

Pressure indicator 42: % difference between pre-European total nitrogen load and current load
Data source: SedNet data from OzEstuaries, 2006. Burrum/Gregory/Isis and Mary/Susan are each considered as one system in the SedNet modelling.

Pressure indicator 43: % river system affected by aquatic weeds
Data source: Stacey Bratby, pers. comm., 2007. No known aquatic weeds on Fraser Island.

Pressure indicator 44: presence of 'key' aquatic pest species in adjoining areas
Data source: Port pest surveys (Gladstone and Brisbane), 2000. Expert knowledge.

Pressure indicator 45: presence of 'key' terrestrial pest species in adjoining areas
Data source: Current knowledge is that there are no significant 'terrestrial' pest species currently within 100 km of any estuary in the region.

Pressure indicator 46: presence of port/harbour/marina and related boating activity
Data source: Beacon to Beacon, 2007. Barry Thiele, pers. comm., 2007. Matt Davies, EPA, pers. comm., 2008 (boats (generally domestic/interstate) commonly moor for few days in Wathumba).

Pressure indicator 47: presence of aquaculture facilities using marine species non-native to the region
Data source: DPI&F, 2007.

Pressure indicator 48: % of estuary adjoining disturbed acid sulphate soils
Data source: BMRG, 2007 Acid Sulphate Soil Risk dataset.

Pressure indicator 49: amount of oil spilled and number of oil slicks/spills reported
Data source: Neville Ford, 2007. pers. comm. – Mary River Marina (mainly complaints of diesel spills from that washed in through the stormwater. Spill source was identified and fixed therefore the full year 2007 should see fewer slicks). John Wright, 2007 pers. comm. – Pollution Response Manager, Maritime Safety Qld (none reported for any estuaries over the last 5 years though small number spills (<5 litres) likely to occur in Snapper and Burnett estuaries.

Condition indicator 1: turbidity
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08. The Mary River estuary is greater than 40 km long and as such the QLD WQ guidelines can not be used, however, EPA WQ sampling over 13 years has shown a slight increasing trend in turbidity in the Mary River.

Condition indicator 2: Secchi depth
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08. The Mary River estuary is greater than 40 km long and as such the QLD WQ guidelines can not be used, however, EPA WQ sampling over 13 years has shown a slight decreasing trend in Secchi depth in the Mary River.

Condition indicator 3: change in seagrass extent
Data source: Sue Sargent, BMRG, pers. comm., 2007, of anecdotal evidence that seagrass existed before 1940s but was lost after Ben Anderson flooded and released water and sediment slug (Burnett River). OzEstuaries, 2006 (from Australian Estuarine Database (Digby) Survey 1998; Olsen, 1980 and EPA survey 2008.

Condition indicator 4: % cover of seagrass
Data source: DPI&F, 2003-2007 seagrass watch data for Kauri Creek site. DPI&F, 2002-2006 seagrass watch data for Burrum Heads sites (monitoring sites near the mouth of the Burrum River). Sue Sargent, BMRG, pers. comm., 2007, of anecdotal evidence that seagrass existed before 1940s but was lost after Ben Anderson flooded and released water and sediment slug (Burnett River). EPA survey 2008.

Condition indicator 5: intestinal enterococci counts
Data source: BMRG and EPA sampling, 2008. WBW analysis.

Condition indicator 6: number of mass mortality events caused by pathogens
Data source: EPA, 2007 – reports received of fish kills. Fish kill reported in the Elliott river estuary on 31 October 2006, hundreds of dead fish and some crustaceans – unknown cause. Fish kill reported in the Elliot river estuary on 8 October 2006 – most likely was trawler by-catch dumping. Several hundred fish killed in Mary estuary on 17 September 2007 – unknown cause. Small number of fish killed in Burnett estuary on 24 July 2007 – unknown cause. Fish kills in Gregory and Isis estuaries estuary on 21 July 2007 – thought to be natural.

Condition indicator 7: commercial finfish catch per unit effort (estimate of fish abundance)
Data source: DPI&F, 2002-2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Condition indicator 8: commercial crab catch per unit effort (estimate of crab abundance)
Data source: Data source: DPI&F, 2002-2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Condition indicator 9: commercial prawn catch per unit effort (estimate of prawn abundance)
Data source: DPI&F, 2002-2006 (catch data). Grid and site numbers used for each estuary: Eurimbula Creek: T31.9; Baffle Creek: U32.1, T32.4, T32.5; Littabella Creek: U32.2, U32.7; Kolan River: U32.7, U32.8, U32.12; Burnett River: U32.14, U32.15, U32.18, U32.19; Elliott Creek: U32.25; Coonarr Creek: U32.25; Theodolite Creek: V33.1; Gregory River: V33.6, V33.10; Isis River: V33.11, U33.15; Burrum River: V33.6, V33.7, V33.11, V33.16; Mary River: V33.23, V33.24, V33.25, V34.2, V34.3; Susan River: V33.24; Kauri Creek: V34.20; Snapper Creek: V34.25, W34.21; Wathumba Creek: W32.23; Coongul Creek: W33.6; Bogimbah Creek: W33.11.

Condition indicator 10: recreational finfish catch per unit effort (estimate of fish abundance)
Data source: DPI&F, 2002, 2005 recreational fisher survey data.

Condition indicator 11: recreational crab catch per unit effort (estimate of crab abundance)
Data source: DPI&F, 2002, 2005 recreational fisher survey data.

Condition indicator 12: recreational prawn catch per unit effort (estimate of prawn abundance)
Data source: DPI&F, 2002, 2005 recreational fisher survey data.

Condition indicator 13: abundance of diadromous species
Data source: Hutchison *et al*., 2002; Low number of diadromous species found in the main Burnett River body but large number found in the unregulated tributary (Splitters Ck), Heidenreich and Lupton, 1999. Chris Lupton and Andrew Berghuis, DPI&F, pers. comm., 2008. John Platten, EPA, pers. comm., 2008. Appendix I Fish species distribution abundance and trends by catchment (http://www.bmrg.org.au/downloads/General_Reports/AquaticBiodiversityAppen_i_vii.pdf). Considering all diadromous species.

Condition indicator 14: change in mangrove extent
Data source: OzEstuaries, 2006 (Digby, 1998; NLWRA, 2001 data); Mackenzie and Duke, 2009; Olsen, 1980; Andrew McDougall, NRW data, 2008.

Condition indicator 15: change in saltmarsh extent
Data source: OzEstuaries, 2006 (Digby, 1998; NLWRA, 2001 data); Mackenzie and Duke, 2009; Olsen, 1980.

Condition indicator 16: presence (standing crop) of litter (rubbish)
Data source: BMRG surveys, 2008.

Condition indicator 17: litter (rubbish) accumulation rate
Data source: BMRG surveys, 2008.

Condition indicator 18: ammonia
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 19: organic nitrogen
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 20: oxidised nitrogen
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 21: total nitrogen
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 22: filterable reactive phosphorus
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 23: total phosphorus
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 24: chlorophyll-a
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 25: % epiphytic cover on seagrass
Data source: DPI&F, 2003-2007 seagrass watch data for Kauri Creek site. DPI&F, 2002-2006 seagrass watch data for Burrum Heads sites (monitoring sites near the mouth of the Burrum River).

Condition indicator 26: minimum sustained dissolved oxygen values during the days following an inflow event
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08. EPA, 1993-2008 (Ambient WQ data). All relate to minimum 'ambient' DO recorded.

Condition indicator 27: ambient dissolved oxygen
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 28: number of mass mortality events caused by low dissolved oxygen
Data source: EPA, 2007 – reports received of fish kills. Fish kill reported in the Elliott river estuary on 31 October 2006, hundreds of dead fish and some crustaceans – unknown cause. Fish kill reported in the Elliot river estuary on 8 October 2006 – most likely was trawler by-catch dumping. Several hundred fish killed in Mary estuary on 17 September 2007 – unknown cause. Small number of fish killed in Burnett estuary on 24 July 2007 – unknown cause. Fish kills in Gregory and Isis estuaries estuary on 21 July 2007 – thought to be natural.

Condition indicator 29: occurrence of pest (animal, plant) species
Data source: Expert knowledge.

Condition indicator 30: % area impacted by pests
Data source: Expert knowledge.

Condition indicator 31: minimum sustained pH values during the days following an inflow event
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08. EPA, 1993-2008 (Ambient WQ data). All data relate to minimum 'ambient' pH recorded.

Condition indicator 32: ambient pH
Data source: EPA, 2006-08 (Ambient WQ data); BMRG, 2007-08.

Condition indicator 33: number of mass mortality events caused by low pH

Data source: EPA, 2007 – reports received of fish kills. Fish kill reported in the Elliott river estuary on 31 October 2006, hundreds of dead fish and some crustaceans – unknown cause. Fish kill reported in the Elliot river estuary on 8 October 2006 – most likely was trawler by-catch dumping. Several hundred fish killed in Mary estuary on 17 September 2007 – unknown cause. Small number of fish killed in Burnett estuary on 24 July 2007 – unknown cause. Fish kills in Gregory and Isis estuaries estuary on 21 July 2007 – thought to be natural.

Condition indicator 34: red-spot disease of fish
Data source: Chris Lupton, DPI&F, pers. comm., 2008. Jan-Olaf Meynecke, Griffith Uni, pers. comm., 2007. Andrew Berghuis, DPI&F, pers. comm., 2008. EPA, 2008 (reports received of fish kills – 3 December 2007 fish kill on Burrum River near weir (fish had red patches on them and mostly juvenile); 8 October 2008 fish kill in Burrum, 100s dead, fish have red sores and bleeding (like red-spot) but no rain in the area for a while).

Condition indicator 35: toxicants in the water column
Data source: EPA and BMRG sampling 2007/08 and QHSS analysis. Supported by GBRMPA 2005-06 passive sampler data from the Burnett Estuary (provided by GBRMPA).

Condition indicator 36: toxicants in the sediments
Data source: EPA and BMRG sampling 2007 and QHSS analysis. Includes data from EPA, 2007 report on Burnett estuary to Bundaberg City Council.

Condition indicator 37: toxicants in biota
Data source: GBRMPA 2006 (Reef Water Quality Protection Plan Marine Monitoring Programme) data from the Burnett Estuary.

Condition indicator 38: number of mass mortality events caused by toxicants
Data source: EPA, 2007 – reports received of fish kills. Fish kill reported in the Elliott river estuary on 31 October 2006, hundreds of dead fish and some crustaceans – unknown cause. Fish kill reported in the Elliot river estuary on 8 October 2006 – most likely was trawler by-catch dumping. Several hundred fish killed in Mary estuary on 17 September 2007 – unknown cause. Small number of fish killed in Burnett estuary on 24 July 2007 – unknown cause. Fish kills in Gregory and Isis estuaries estuary on 21 July 2007 – thought to be natural.

Appendix 2: Indicator weightings

Indicators	Weighting
Aquatic sediments	
PI1: catchment land-use	8.3
PI2: % of catchment cleared	8.7
PI3: % length of river system with no riparian vegetation	9.3
PI4: number of point sources per km estuary	2.3
PI5: boating activity within the estuary	4.0
PI6: unsealed road density	5.7
PI7: % of catchment with intensive agriculture on steep slopes	8.3
PI8: % of catchment with less than 70% ground cover	9.0
PI9: dredging activity in river system	7.0
PI10: % difference between pre-European sediment load and current load	10.0
CI1: turbidity	9.3
CI2: Secchi depth	9.3
CI3: change in seagrass extent	9.0
CI4: % cover of seagrass	9.0
Bacteria/pathogens	
PI11: level of sewage treatment plant wastewater disinfection	9.0
PI12: frequency of sewage overflow events	8.0
PI13: % of catchment under intensive animal production	7.3
PI14: density of septics within catchment	7.7
PI15: number of stormwater inflows per km estuary	7.0
PI17: boat moorings	4.0
PI16: number of 'marine' aquaculture facilities present	6.0
CI5: intestinal enterococci counts	9.7
CI6: number of mass mortality events caused by pathogens	6.3
Biota removal/disturbance	
PI9: dredging activity in river system	6.0
PI18: recreational bait (beachworm, bloodworm, bait fish, yabby, etc.) collector usage of an estuary	8.7
PI19: commercial bait (beachworm, bloodworm and yabby) collector usage of an estuary and adjoining coastal waters	8.7
PI17: boat moorings	5.7
PI5: boating activity within the estuary	6.3
PI20: recreational usage index	7.3
PI21: 'estuary' population size	7.7
PI22: number of recreational fishers using an estuary	9.0
PI23: total recreational fisher catch from an estuary	10.0
PI24: commercial trawl usage of an estuary and adjoining coastal waters	8.7
PI25: commercial line fishing usage of an estuary and adjoining coastal waters	8.7
PI26: commercial net and crab fisher usage of an estuary and adjoining coastal waters	9.0
PI27: total commercial fisher catch from an estuary and adjoining coastal waters	9.0
PI28: commercial licensed collector (of aquarium fish, shell, coral, etc.) usage of an estuary and adjoining coastal waters	9.0
CI7: commercial finfish catch per unit effort (estimate of fish abundance)	10.0
CI8: commercial crab catch per unit effort (estimate of crab abundance)	9.3
CI9: commercial prawn catch per unit effort (estimate of prawn abundance)	8.0
CI10: recreational finfish catch per unit effort (estimate of fish abundance)	10.0
CI11: recreational crab catch per unit effort (estimate of crab abundance)	9.3
CI12: recreational prawn catch per unit effort (estimate of prawn abundance)	7.3

Connectivity	
PI30: % of freshwater reaches without access to the sea due to impoundments without an effective fish ladder	10.0
PI29: impoundment density	5.0
PI31: % of estuarine 'shoreline' length modified	8.0
PI32: % of estuarine 'background habitat' length modified	7.0
CI13: abundance of diadromous species	10.0
Freshwater flow regime	
PI33: % of median annual flow impounded and extracted	10.0
PI34: % of catchment area covered by artificial waterbodies	8.0
PI29: impoundment density	6.3
Habitat removal/disturbance	
PI9: dredging activity in river system	6.3
PI16: number of 'marine' aquaculture facilities present	4.0
PI32: % of estuarine 'background habitat' length modified	9.0
PI31: % of estuarine 'shoreline' length modified	10.0
CI3: change in seagrass extent	10.0
CI14: change in mangrove extent	8.0
CI15: change in saltmarsh extent	9.3
Hydrodynamics	
PI9: dredging activity in river system	8.3
PI35: presence of entrance modifications	9.3
PI36: presence of canals	9.3
PI31: % of estuarine 'shoreline' length modified	6.3
PI37: % of original estuary length lost due to a tidal barrage	10.0
Litter	
PI5: boating activity within the estuary	8.3
PI20: recreational usage index	8.7
PI21: 'estuary' population size	9.0
PI38: % of estuary adjoining urban area	8.7
PI15: number of stormwater inflows per km estuary	6.7
CI16: presence (standing crop) of litter	9.3
CI17: litter accumulation rate	8.3
Nutrients	
PI1: catchment land-use	9.0
PI3: % length of river system with no riparian vegetation	8.0
PI7: % of catchment with intensive agriculture on steep slopes	7.3
PI8: % of catchment with less than 70% ground cover	8.0
PI15: number of stormwater inflows per km estuary	6.0
PI39: nutrient concentration of sewage treatment plant wastewater	8.7
PI12: frequency of sewage overflow events	7.0
PI40: number of point sources per km estuary (excluding STPs)	8.0
PI41:% difference between pre-European total phosphorus load and current load	10.0
PI42: % difference between pre-European total nitrogen load and current load	10.0
CI18: ammonia	6.7
CI19: organic nitrogen	5.7
CI20: oxidised nitrogen	8.3
CI21: total nitrogen	6.7
CI22: filterable reactive phosphorus	8.3
CI23: total phosphorus	6.7
CI24: chlorophyll-a	10.0
CI25: % epiphytic cover on seagrass	8.0

Organic matter	
PI1: catchment land-use	9.0
PI4: number of point sources per km estuary	9.0
PI7: % of catchment with intensive agriculture on steep slopes	7.7
PI12: frequency of sewage overflow events	7.0
PI13: % of catchment under intensive animal production	7.7
PI43: % river system affected by aquatic weeds	6.7
CI26: minimum sustained dissolved oxygen values during the days following an inflow event	9.3
CI27: ambient dissolved oxygen	6.7
CI28: number of mass mortality events caused by low dissolved oxygen	8.7
Pests	
PI44: presence of 'key' aquatic pest species in adjoining areas	9.7
PI45: presence of 'key' terrestrial pest species in adjoining areas	7.7
PI46: presence of port/harbour/marina and related boating activity	8.7
PI47: presence of aquaculture facilities using marine species non-native to the region	8.3
CI29: occurrence of pest (animal, plant) species	10.0
CI30: % area impacted by pests	10.0
pH	
PI48: % of estuary length adjoining disturbed acid sulphate soils	10.0
CI31: minimum sustained pH values during the days following an inflow event	9.3
CI32: ambient pH	6.0
CI33: number of mass mortality events caused by low pH	9.3
CI34: red-spot disease of fish	6.3
Toxicants	
PI1: catchment land-use	9.0
PI4: number of point sources per km estuary	6.3
PI5: boating activity within the estuary	5.3
PI7: % of catchment with intensive agriculture on steep slopes	6.3
PI15: number of stormwater inflows per km estuary	7.3
PI49: amount of oil spilled and number of oil slicks/spills reported	8.7
CI35a: toxicants in the water column (Ametryn)	7.0
CI35b: toxicants in the water column (Atrazine)	7.0
CI35c: toxicants in the water column (Diuron)	7.0
CI35d: toxicants in the water column (Fluometuron)	7.0
CI35e: toxicants in the water column (Hexazinone)	7.0
CI35f: toxicants in the water column (Prometryn)	7.0
CI35g: toxicants in the water column (Simazine)	7.0
CI35h: toxicants in the water column (Tebuthiuron)	7.0
CI35i: toxicants in the water column (Bifenthrin)	7.0
CI35j: toxicants in the water column (Chlordane)	7.0
CI35k: toxicants in the water column (Chlorpyrifos)	7.0
CI35l: toxicants in the water column (Dieldrin)	7.0
CI35m: toxicants in the water column (Endrin)	7.0
CI35n: toxicants in the water column (Endosulfan)	7.0
CI35o: toxicants in the water column (Hexachlorobenzene (HCB))	7.0
CI35p: toxicants in the water column (Lindane)	7.0
CI35q: toxicants in the water column (Phosphate tri-n-butyl)	7.0
CI35r: toxicants in the water column (Piperonyl butoxide)	7.0
CI35s: toxicants in the water column (Total DDT)	7.0
CI35t: toxicants in the water column (Any other non-polar pesticide detected in the water column)	7.0
CI36a: toxicants in the sediments (Arsenic (As))	9.3
CI36b: toxicants in the sediments (Cadmium (Cd))	9.3

CI36c: toxicants in the sediments (Chromium (Cr))	9.3
CI36d: toxicants in the sediments (Copper (Cu))	9.3
CI36e: toxicants in the sediments (Lead (Pb))	9.3
CI36f: toxicants in the sediments (Nickel (Ni))	9.3
CI36g: toxicants in the sediments (Zinc (Zn))	9.3
CI36h: toxicants in the sediments (Atrazine)	9.3
CI36i: toxicants in the sediments (Chlordane)	9.3
CI36j: toxicants in the sediments (Chlorpyrifos)	9.3
CI36k: toxicants in the sediments (Dieldrin)	9.3
CI36l: toxicants in the sediments (Diuron)	9.3
CI36m: toxicants in the sediments (Endosulfan)	9.3
CI36n: toxicants in the sediments (Endrin)	9.3
CI36o: toxicants in the sediments (Hexachlorobenzene (HCB))	9.3
CI36p: toxicants in the sediments (Piperonyl butoxide)	9.3
CI36q: toxicants in the sediments (Prometryn)	9.3
CI36r: toxicants in the sediments (Lindane)	9.3
CI36s: toxicants in the sediments (Total DDT)	9.3
CI36t: toxicants in the sediments (any other pesticide detected in sediments)	9.3
CI37a: toxicants in biota (DDT)	9.3
CI37b: toxicants in biota (Dieldrin)	9.3
CI38: number of mass mortality events caused by toxicants	8.0

Appendix 3: Stressor rankings

Stressor	Rank
Aquatic sediments	2
Bacteria/pathogens	4
Biota removal/disturbance	2
Connectivity	2
Freshwater flow regime	1
Habitat removal/disturbance	1
Hydrodynamics	3
Litter	4
Nutrients	1
Organic matter	2
Pest species	2
pH	3
Toxicants	2