Motupipi Estuary

Vulnerability Assessment & Monitoring Recommendations

Prepared
for

**Tasman
District
Council**

March 2008

Cover Photo: Motupipi Estuary glasswort beds and tidal flats. Inside Cover: Motupipi Estuary, eastern arm.

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Tasman District Council

By

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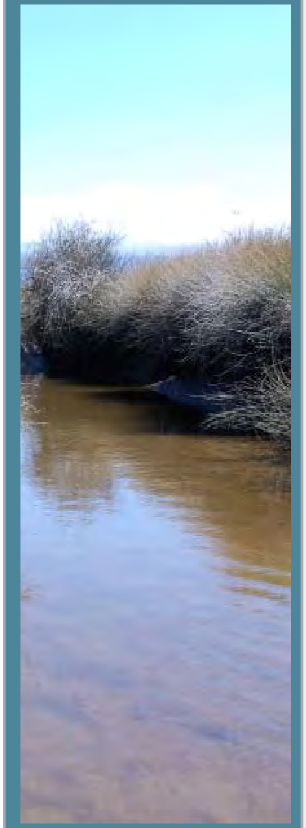
EXECUTIVE REPORT

BACKGROUND



Since 2000, Tasman District Council (TDC) has been developing a long-term monitoring programme to assess the condition of key estuaries in its region using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002). To date this has included the Ruataniwha, Waimea and Moutere Inlets and the Motueka Estuary.

More recently, the EMP approach has been extended to include an Ecological Vulnerability Assessment (Robertson and Stevens 2007a,b) to provide Councils with a better understanding of how estuary condition relates to monitoring and management requirements. The Ecological Vulnerability Assessment is a tool for identifying the vulnerability of an estuary to problems, and priorities for monitoring and management.

In 2007, TDC added the Motupipi Estuary in Golden Bay, to the estuary programme. The Motupipi Estuary has been identified as having a potential for algal blooms, areas of excessive sedimentation, elevated faecal coliforms, and habitat loss problems. In order to address the extent of these issues, a programme was developed which includes the following three steps.

1. Ecological Vulnerability Assessment of the Motupipi Estuary to major issues and appropriate monitoring design with particular emphasis on:
    - upper estuary areas (including phytoplankton blooms) and,
    - nutrient and pathogen distributions throughout the estuary.

   This component, which is the focus of this current report, has been undertaken by Wriggle Coastal Management in collaboration with Landcare NZ, with funding provided from two sources; TDC and a Foundation for Research Science and Technology (FRST), Envirolink medium advice grant.

2. Broad scale habitat mapping, including historical comparisons (EMP approach). This component, which documents the key habitats within the estuary and changes to these habitats over time, is reported separately in Stevens and Robertson (2008).

3. Fine scale physical, chemical and biological monitoring, including sedimentation plate deployment (EMP approach). This component, which provides detailed information on estuary condition, is reported separately in Robertson and Stevens (2008).

The approach used for the Ecological Vulnerability Assessment includes a review of existing information, as well as field data collected during two synoptic surveys in the estuary in November and December 2007.

This assessment is a tool adapted from a UNESCO methodology that is designed to be used by experts to represent how an estuary ecosystem is likely to react to the effects of potential “stressors” and to identify monitoring priorities.

EXECUTIVE REPORT (CONTINUED)

RESULTS OF VULNERABILITY ASSESSMENT

HUMAN USES AND ECOLOGICAL VALUES

The Motupipi Estuary was found to be highly valued with the major human uses being natural character, walking, fishing (e.g. for whitebait, flounder, kahawai), boating, swimming, shellfish collection and bird watching. Ecologically it was valued for its remaining saltmarsh and seagrass habitat, extensive shellfish beds, adjoining duneland, and its bird and fish-life.

SUSCEPTIBILITY TO ESTUARY PROBLEMS

In terms of susceptibility to problems, the Motupipi has two main issues.

1. **Limited Dilution**: The Motupipi Estuary is a "tidal lagoon type" estuary. Such estuaries are shallow and generally well flushed by tidal water and consequently have moderate to low susceptibility to water quality problems. However, because the Motupipi is a relatively small tidal lagoon estuary, dilution of incoming freshwater is limited, which makes it more susceptible to water and sediment quality problems, particularly in the western arm (i.e. close to the main Motupipi River input).
2. **Salt Wedge In Upper Estuary:** The upper estuary experiences salinity stratification during stable baseflows (i.e. salt wedge effect). The resulting high salinity bottom layer is generally more stable (less well-flushed) and is therefore susceptible to nuisance phytoplankton blooms if nutrient inputs are elevated.

STRESSORS (OR CAUSES OF ESTUARY PROBLEMS)

The major threats or stressors to these existing values were identified as follows:

- Excessive catchment inputs of nutrients, pathogens and, to a lesser extent, sediment.
- Climate change.
- Less importantly; drainage of margin areas, invasive weeds and pests, and fire.

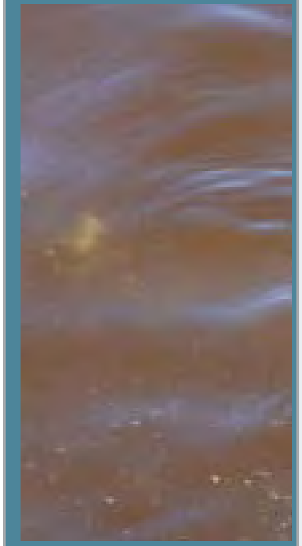
Based on available landuse information, catchment loadings of nutrients, sediment and pathogens are elevated to levels that would cause problems. In particular, nutrient loads (total nitrogen (TN) and dissolved reactive phosphorus (DRP)) and pathogen indicators (*Escherichia coli* (*E. coli*)) from intensive farming in the catchment are estimated to be extremely high (e.g. 30kgN/ha/year from the 2,000 cows on 700ha, i.e. 3 cows/ha). As a consequence, mean TN, DRP and *E. coli* concentrations in Motupipi River are high, exceeding quality guidelines for NZ low elevation rivers.

Motupipi Stream:	TN mean 1.5-2mg/l, DRP mean 0.03mg/l, E. coli 300-400 per 100ml
NZ Low elevation rivers (ANZECC 2000)	TN: 0.61mg/l, DRP: 0.01mg/l, E. coli <126 per 100ml

In the future, climate change stressors (including accelerated sea level rise, increased temperature, altered precipitation, and UV radiation) are predicted to have a major influence on the estuary because of its shallow nature and low volume compared with adjacent coastal seas. Other stressors included historical land development around the margins of the estuary, invasion of weeds and pests, and the presence of flapgates restricting tidal access in some areas.

EXISTING CONDITION

Although, much of the Motupipi Estuary was found to be in good condition (particularly the eastern arm), the combination of the susceptibility of the estuary to problems and the presence of high nutrient, pathogen and sediment inputs via the Motupipi River, has resulted in areas of poor condition in certain "at-risk" parts of the estuary. In particular:



- **Phytoplankton Blooms (Upper Estuary).** High phytoplankton growth (>10ug/l chlorophyll-*a*) is common in microtidal estuaries when the annual average dissolved inorganic N (DIN) concentrations exceed 200 ug/l, or 2,000 ug/l in macrotidal estuaries (Monbet 1992). However, if water residence time is < 3days, like in most of the Motupipi Estuary, then bloom concentrations are unlikely. Unfortunately, in the upper estuary the residence time is much greater (due to a salt wedge effect) and the risk of phytoplankton blooms is high. As a consequence, of the very high Motupipi River nutrient concentrations (1,500-2,000 ug/l DIN), and the low dilution potential of the upper estuary, the guideline of around 200 ug/l DIN is exceeded. Therefore, not surprisingly, the upper estuary has regular annual blooms of a non-toxic phytoplankton (a cryptomonad), which cause the waters to turn a dark brown colour, and dissolved oxygen levels to be depleted in the sediments and water column. These conditions are likely to be causing adverse effects to fish and macroinvertebrates, as well as possible impacts to seagrass through shading. In addition to excessive nutrients and a stable salt wedge, such blooms are likely favoured by warm temperatures, stable baseflows, and the absence of turbulent mixing. In Nov. 2007 the bloom was spread throughout the upper estuary from just upstream of the Abel Tasman Drive Bridge to approximately midway down the middle estuary (western arm) at low tide. At high tide it was restricted to the salt wedge area, which extended over much of the upper estuary.

- **Macroalgal Blooms (Upper, Mid and Lower Estuary).** Where primary production is dominated by large macroalgae, such as sea lettuce, most of the production is not grazed and accumulates in the sediment where it rots and cause oxygen depletion. Nuisance growths of macroalgae are common in estuaries where mean DIN concentrations exceed 200 ug/l (Pederson and Borum (1997). In the Motupipi Estuary, such concentrations are only likely throughout the estuary during high flows. For the rest of the time, such concentrations are only exceeded in the upper and middle (western arm) estuary areas, particularly in and close to the low tide channels. As a consequence, these areas experience regular macroalgal blooms (*Enteromorpha* sp., sea lettuce and *Gracilaria* sp.). Macroalgal blooms can deprive seagrass areas of light, causing their eventual decline. Decaying macroalgae can accumulate on shorelines causing depletion of sediment dissolved oxygen and an odorous nuisance to local residents and to the coastal tourism industry.

- **Sedimentation (Mid Estuary).** Excessive muddiness in New Zealand estuaries is common where catchment inputs are elevated and can lead to a shift in habitat type and adverse impacts on the existing ecology and human uses. These adverse impacts result from a lowering in water clarity, and a change in sediment type. In the Motupipi, the middle estuary (western arm) experiences excessive muddiness which manifest mainly as extensive areas of deep soft (and often anoxic) muds, particularly near the main channel. In addition, there is a significant mud component in the upper eastern arm. These muddy areas in the estuary are likely to be the result of the limited ability of the estuary to spread and dilute incoming sediment as well as elevated input loads during rain events.

- **Shellfish Health Risk (Mid Estuary).** A risk to human consumers of shellfish arises in estuaries where the shellfish guideline is exceeded (i.e. the median faecal coliform content not to exceed 14/100 ml, and not more than 10% of samples should exceed 43/100 ml - Ministry for Environment 2003). Based on estimates of bacterial concentrations in the Motupipi Estuary arising from catchment runoff, it is likely that the shellfish guideline is exceeded throughout the estuary at most times. However, a risk to shellfish consumers only occurs in the mid-lower estuary (i.e. where edible shellfish (pipis, cockles, oysters and mussels) are present). The risk in the upper estuary is low simply because no shellfish are present there.

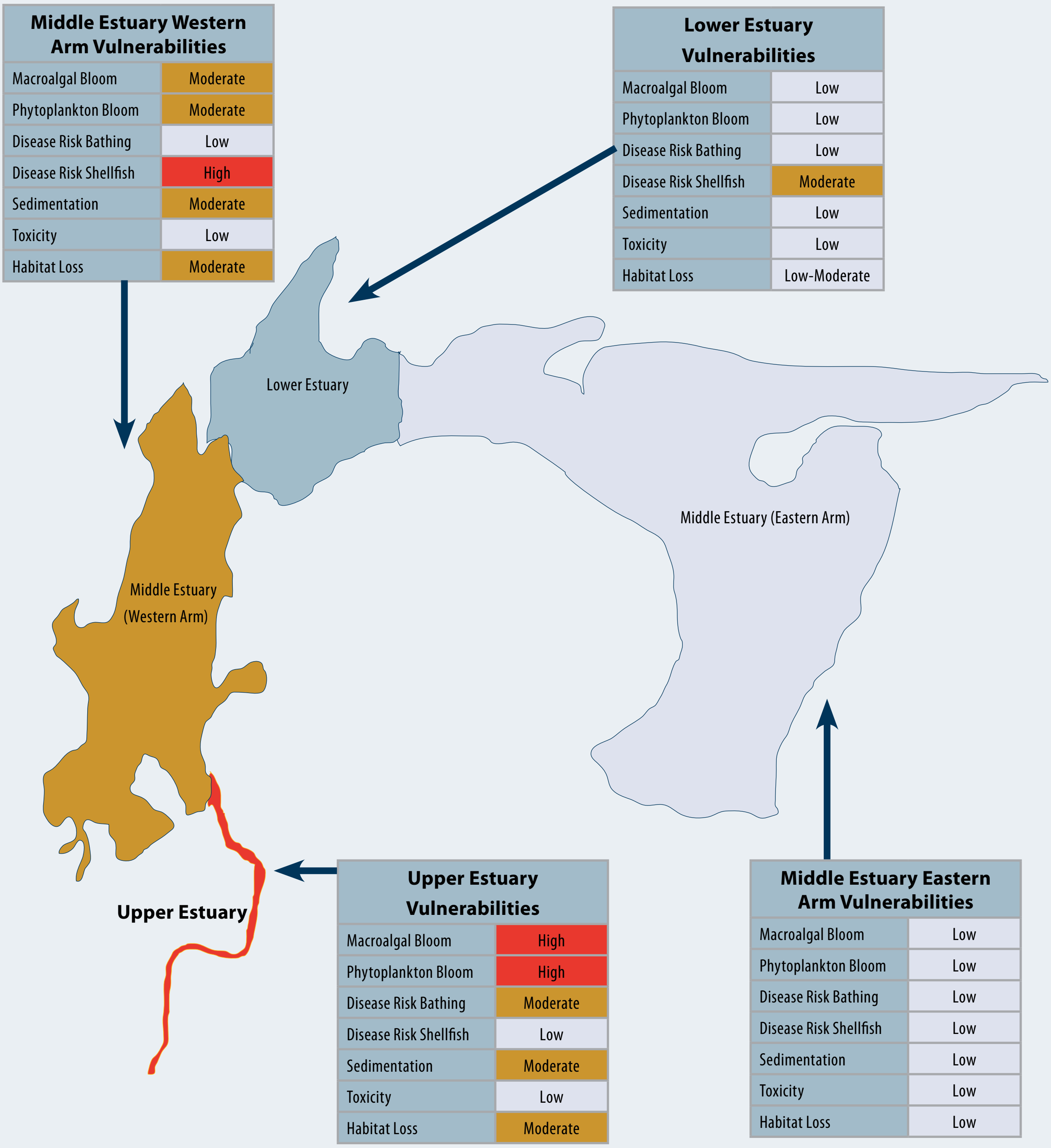
- **Loss of Natural Vegetated Margin (Upper, Mid and Lower Estuary).** A risk to human and ecological values arises when estuaries have lost their natural vegetated buffer zone (i.e. the area of land between the estuary saltmarsh vegetation and developed terrestrial land). Estuary buffer zones provide habitat for native plants and animals, protect water quality, protect scenic and aesthetic values, and erosion and flood control. In the case of the Motupipi Estuary, the majority of the estuary margins have no natural vegetated buffer and consequently have reduced human and ecological values.

- **Loss of Saltmarsh (Upper and Mid Estuary).** Saltmarsh is one of the most productive environments on earth, and serve as important nursery grounds and wildlife habitat. They provide nutrients to surrounding areas, fuelling other marine food webs. These dynamic ecosystems provide tremendous additional benefits for humans including flood and erosion control, water quality improvements, opportunities for recreation and for atmospheric gas regulation - estuaries tend to be "carbon sinks," since carbon dioxide is absorbed in the photosynthesis carried out by the prolific plant growth. If saltmarsh habitat is lost or it's condition deteriorates (through such actions as drainage and reclamation, sea level rise, change in sediment or nutrient supply or inundation through flooding), then such benefits are diminished. In the Motupipi Estuary, saltmarsh beds have in the past (and also to a small extent in the present) been modified through drainage and reclamation activities as well as through nutrient and sediment enrichment. The extent of this modification is currently being explored in an historical broad scale mapping investigation (Stevens and Robertson 2008). In the future, climate change variables (e.g. accelerated sea level rise) are likely to cause major changes to existing beds.

- **Weed and Pest Invasion.** The invasion of exotic plants and animals to estuaries is a common occurrence in New Zealand as a result of increased exposure to introduced species through such factors as the growth in global transport and the loss of estuary buffer margins. Once present, such species can cause damage to existing ecosystems and human uses. The Motupipi Estuary proved to be no exception with the lower estuary being invaded by an exotic bivalve, the Pacific oyster (*Crassostrea gigas*), in the 1980s. It is now well established in the estuary and the resulting oyster beds and shell banks have led to localised pockets of sediment enrichment, and represent a significant departure from the natural character. Additionally, extensive areas of the introduced iceplant (*Carpobrotus edulis*) have invaded the estuary margins and are competing with natural saltmarsh succulent herbs (e.g. glasswort).

Therefore, based on the combination of poor existing condition in certain at-risk areas, the moderate susceptibility and the moderate risk of the stressors causing issues, Motupipi Estuary was given a "moderate" overall ecological vulnerability rating. The figure on the following page summarises ratings in different sections of the estuary.

Vulnerability ratings for key estuary issues - Motupipi Estuary



Middle Estuary Western Arm Vulnerabilities	
Macroalgal Bloom	Moderate
Phytoplankton Bloom	Moderate
Disease Risk Bathing	Low
Disease Risk Shellfish	High
Sedimentation	Moderate
Toxicity	Low
Habitat Loss	Moderate

Lower Estuary Vulnerabilities	
Macroalgal Bloom	Low
Phytoplankton Bloom	Low
Disease Risk Bathing	Low
Disease Risk Shellfish	Moderate
Sedimentation	Low
Toxicity	Low
Habitat Loss	Low-Moderate

Upper Estuary Vulnerabilities	
Macroalgal Bloom	High
Phytoplankton Bloom	High
Disease Risk Bathing	Moderate
Disease Risk Shellfish	Low
Sedimentation	Moderate
Toxicity	Low
Habitat Loss	Moderate

Middle Estuary Eastern Arm Vulnerabilities	
Macroalgal Bloom	Low
Phytoplankton Bloom	Low
Disease Risk Bathing	Low
Disease Risk Shellfish	Low
Sedimentation	Low
Toxicity	Low
Habitat Loss	Low

MONITORING RECOMMENDATIONS

Because of the moderate-high overall susceptibility of the estuary to eutrophication, sedimentation, disease risk and habitat loss, as well as the very-limited extent of relevant monitoring data, a targeted monitoring programme is recommended. It should include:

- Mapping of estuary habitats so that any changes can be determined, particularly presence of macroalgal blooms, and areas of muddy sediments, saltmarsh and natural buffer vegetation.
- Determination of estuary condition through sediment monitoring.
- Determination of upper estuary water quality and presence of nuisance phytoplankton.
- Determination of water quality in the Motupipi River as it is the major determinant of estuary quality.
- Determination of the areas that are likely "hotspots" for contributing nutrients, sediment and pathogens to the estuary as the characteristics of the surrounding catchment (and the landuse undertaken within it) are major determinants of downstream conditions.

The detailed recommendations are outlined below:

1. Upper Estuary

Broad Scale Mapping	EMP Protocol broad scale mapping of upper estuary macroalgal % cover, seagrass % cover (including subtidal), saltmarsh % cover, RPD layer and unvegetated substrate type % cover (including subtidal areas).	Every 5 years (except macroalgae which is mapped annually).
Fine Scale Sediment Monitoring	EMP Protocol fine scale sediment monitoring at road bridge (i.e. site of phytoplankton blooms) of subtidal sediments for; total nitrogen, total phosphorus, organic carbon, indicator metals (Cd, Cr, Cu, Ni, Pb, Zn), grain size, (one composite sample of 3 replicates); as well as RPD layer, and macrofauna (3 replicates).	Annually for first 3 years to establish baseline then every 5 years.
Fine Scale Water Column Monitoring	Fine scale water column monitoring at one site (road bridge), for salinity, dissolved oxygen, total N, total P, chlorophyll-*a* and temperature at surface and near bottom of water column - also water clarity with secchi disc. In addition, if bloom conditions are visible, then identify dominant phytoplankton.	Monthly from September to April each year (target bloom periods by liaising with local observers).

2. Middle and Lower Estuary

Broad Scale Mapping	EMP Protocol broad scale annual mapping of estuary macroalgal % cover, seagrass % cover, saltmarsh % cover, RPD layer and unvegetated substrate type % cover (including subtidal areas).	Every 5 years (except macroalgae which is mapped annually).
Fine Scale Sediment Monitoring	EMP Protocol fine scale sediment monitoring at 2 sites (intertidal sites at western arm and eastern arm) for; total nitrogen, total phosphorus, organic carbon, indicator metals (Cd, Cr, Cu, Ni, Pb, Zn), grain size, as well as RPD layer, and macrofauna.	Annually for first 3 years to establish baseline then every 5 years.
Sedimentation Rate	Sedimentation rate monitoring at 2 representative mid-estuary sites using sedimentation plate methods.	Measure annually.
Old Landfill Monitoring	On one occasion monitor potential toxicants (metals and semi-volatile organic compounds) in sediments and shellfish adjacent to landfill.	One occasion.

TDC initiated broad scale monitoring of the entire estuary (including establishment of sedimentation plates) in September 2007, with the first year of the fine scale baseline monitoring of the middle estuary undertaken in February 2008.

MONITORING RECOMMENDATIONS (CONTINUED)

3. Catchment and River Monitoring

Identify Catchment "Hotspots"	Identify areas where a combination of different factors (e.g. landuse, land cover, slope, area, soil type, geology, rainfall, etc) highlight a high potential for immediate or potential inputs of nutrients, faecal bacteria and sediment. Use existing catchment data to identify "hotspots" such as erosion prone areas, easily mobilised sediment reserves etc. and target these for specific management.
Motupipi River Monitoring	Monitor suspended sediment, total N, total P and *E. coli* concentrations in the Motupipi River on at least three occasions during low flows, three during medium flows and hourly throughout three high flow events each year to better characterise likely loadings.

MANAGEMENT RECOMMENDATIONS

To limit the impact of stressors on the estuary, a number of management actions are recommended as follows:

Identify and Implement Catchment BMPs

- Catchment runoff was identified as one of the major stressors in Motupipi Estuary. To prevent avoidable inputs, best management practices should be identified and implemented to reduce runoff of sediment, nutrients and pathogens from catchment "hotspots".

TDC and Landcare Research, with Foundation for Research Science and Technology Envirolink funding, are currently working with farmers in the catchment to identify catchment nutrient sources and "hotspots", and to implement BMPs for reducing nutrient mobilisation and runoff to surface and groundwater.

Set Limits on Nutrient Inputs

- Because nutrient input was both high and strongly related to the eutrophication symptoms, it is recommended that catchment nutrient inputs be reduced. Currently the nitrogen input (as estuary areal load) is likely to be in the range 60-100 $mg.m^{-2}.d^{-1}$ which is elevated when compared with the 50 $mg.m^{-2}.d^{-1}$ upper limit suggested by Heggie (2006) for ensuring no eutrophication of temperate Australian estuaries. A Total Daily Maximum Load to the estuary of about 50 kgN/day (as opposed to the current input of 60-100 kg/day) is suggested as a preliminary guideline.

Establish Estuary Condition Ratings

- Estuary condition ratings for key indicators (e.g. area of macroalgae, area of soft mud, chlorophyll-*a* concentration, sediment toxicant concentrations) should be developed and used to facilitate reporting. Recommended condition ratings are presented in Technical Addendum 5.

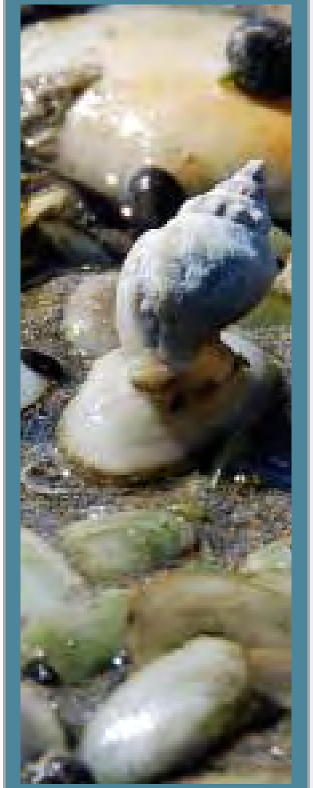
Re-instate Margin Buffer

- Because of the importance of a natural vegetated margin around the estuary, it is recommended that a management plan be developed to encourage its re-establishment.

Fencing and replanting of parts of the upper estuary margin has recently begun.

1.0 INTRODUCTION

1.1 SCOPE


Shellfish lower estuary

Developing an understanding of the distribution and risks to coastal and estuarine habitats is critical to the management of biological resources. Since 2000, Tasman District Council (TDC) has been developing a long-term monitoring programme to assess the condition of key estuaries in its region using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002). To date this has included the Ruataniwha, Waimea and Moutere Inlets and the Motueka Estuary.

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1. Ecological Vulnerability Assessment of the Motupipi Estuary to major issues and appropriate monitoring design with particular emphasis on:
   - upper estuary areas (including phytoplankton blooms) and,
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The approach used for the Ecological Vulnerability Assessment includes a review of existing information, as well as field data collected during two synoptic surveys in the estuary in November and December 2007.

1.2 STRUCTURE


Whitebait (inanga)

The report is structured as follows:

- Section 1 introduces the Ecological Vulnerability Assessment approach.
- Section 2 provides an overview of the relevant characteristics of "tidal lagoon" type estuaries (of which the Motupipi Estuary is an example), and the key issues facing estuaries. It provides background information on the types of habitat present in the Motupipi Estuary, and describes the results of the synoptic surveys. The background information underlies the choice of ratings assigned in Section 3.
- Section 3 presents a summary of the Ecological Vulnerability Assessments, and the ratings assigned to the key estuary issues (eutrophication, sedimentation, disease risk, toxicants, habitat loss).
- Sections 4, 5 and 6 present monitoring and management recommendations, and conclusions respectively.
- A series of Technical Addenda supporting the main report are also included.

1.0 INTRODUCTION (CONTINUED)

1.3 APPROACH

Oystercatcher feeding on lower estuary shellfish beds.

Sedimentation plate deployment.

An Estuary Ecological Vulnerability Assessment tool, adapted from a UNESCO methodology (UNESCO 2000), was used to determine the vulnerability of the Motupipi Estuary to major issues, and identify priorities for monitoring and management (with emphasis on upper estuary phytoplankton blooms and nutrient and pathogen distributions throughout the whole estuary) .

The Ecological Vulnerability Assessment is designed to be used by experts to represent how an estuary ecosystem is likely to react to the effects of potential "stressors" (the causes of estuary issues - often human activities) and to identify monitoring priorities. The approach uses various assessment techniques (e.g. Bricker et al. 1999) to produce an overall "vulnerability" rating of the extent to which potential stressors may affect the uses and values of an area. This is then combined with how susceptible the uses and values are to the identified stressors to identify the priority issues that need addressing.

The assessment has five key components that need to be completed (details on the assessment criteria for each are provided in Technical Addendum 1):

1. **Human Uses and Values**
2. **Ecological Values or Richness**
3. **Presence of Stressors or Likely Causes of Estuary Issues**
4. **Existing Condition and Susceptibility to Stressors**
5. **An Estuary Vulnerability Matrix**

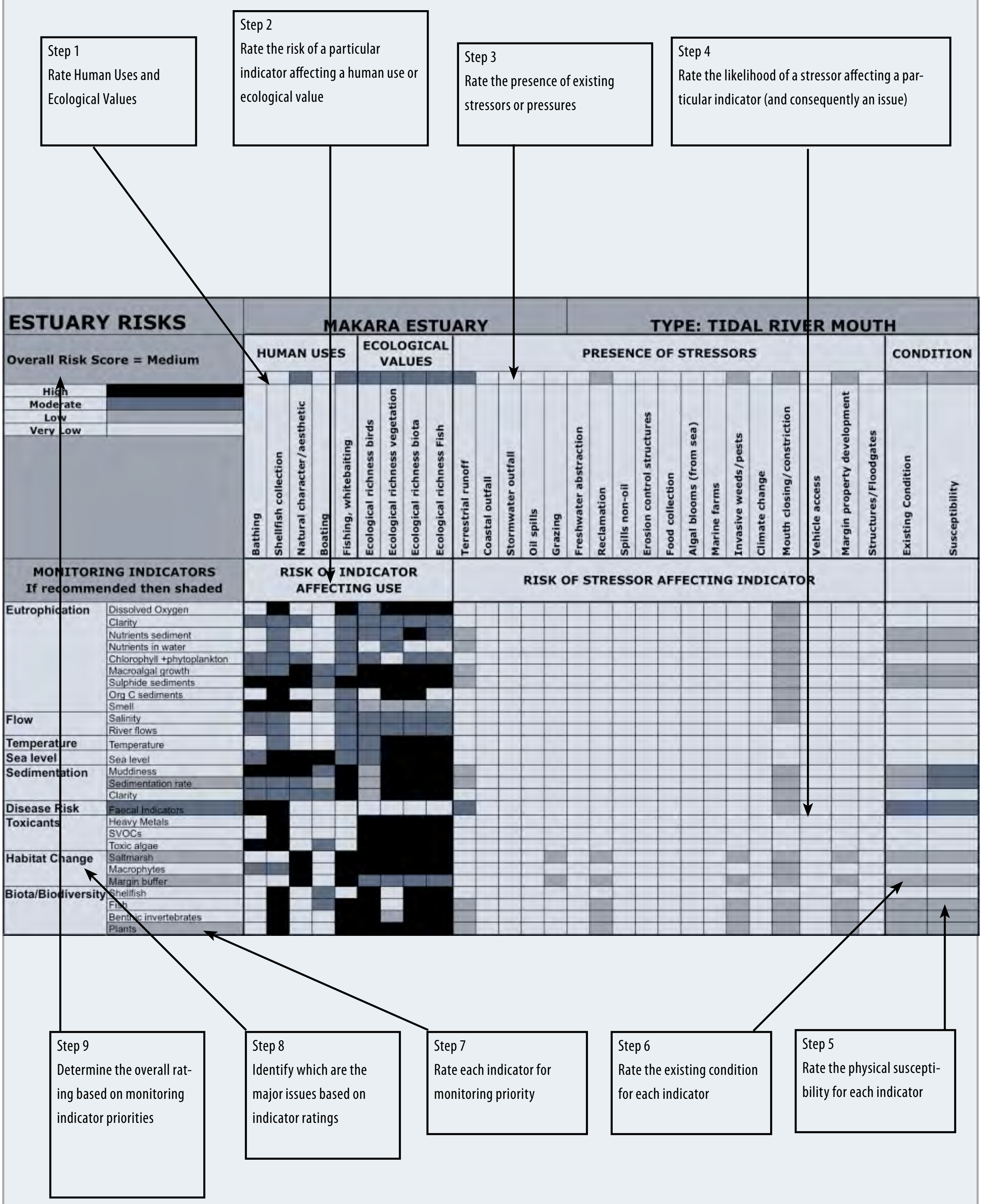
Components 1-4 are tables that provide background information used to assign "high", "medium", "low" or "very low" ratings. These are detailed in Technical Addendum 3. Component 5 is a pre-developed Estuary Vulnerability Matrix which summarises the ratings, and is used to identify the key issues and their monitoring and management priorities. An example of a completed matrix, and the steps required to fill it in, is presented on the following page - also see Robertson & Stevens (2007b).

Based on the overall ratings provided by the vulnerability assessments, a monitoring programme is then designed for the priority monitoring indicators (as identified in the matrix) using the monitoring tools provided in the EMP (Robertson et al. 2002), plus recent extensions developed by Wriggle Coastal Management (e.g. Robertson & Stevens 2007c). The monitoring tools include the elements in the table below.

National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002)	• **Broad scale habitat mapping using GIS**. Broad scale habitat mapping records the location and type of vegetation (e.g. saltmarsh, seagrass, macroalgae) and substrate (e.g. mud, sand, gravel, etc); and is used to provide information primarily on the issues of habitat and margin loss, sedimentation (through the mapping of substrate type), and eutrophication (by mapping macroalgae percent cover). • **Fine scale (i.e. detailed) monitoring of dominant intertidal habitat**. Fine scale monitoring focuses primarily on the physical, chemical, and biological characteristics of estuary sediments as these tend to be the most sensitive to degradation (Church 1975). Fine scale monitoring includes various indicators of estuary condition to provide information on sedimentation, eutrophication, and toxins (i.e. sediment particle size, organic matter, nutrients, heavy metals, and macrofauna).
Recent Extensions (Robertson & Stevens 2007a, Robertson & Stevens 2007b, Robertson & Stevens 2007c)	• Establishment of sedimentation rate measures (using plates buried in sediment). • Estimation of historical sedimentation rates (using radio-isotope ageing of cores). • Assessment of the percent cover of macroalgae and macrophytes (separate GIS layers). • Broad scale mapping of the 200m terrestrial margin surrounding the estuary. • Development of regional condition ratings for key indicators. • Provision of geo-referenced digital photos (as a GIS layer). • Development of a cost effective estuary and river plume modelling approach for determining nutrient, sediment and pathogen distributions.

1. INTRODUCTION (CONTINUED)

STEPS IN FILLING OUT THE VULNERABILITY MATRIX



Step 1
Rate Human Uses and Ecological Values

Step 2
Rate the risk of a particular indicator affecting a human use or ecological value

Step 3
Rate the presence of existing stressors or pressures

Step 4
Rate the likelihood of a stressor affecting a particular indicator (and consequently an issue)

Step 5
Rate the physical susceptibility for each indicator

Step 6
Rate the existing condition for each indicator

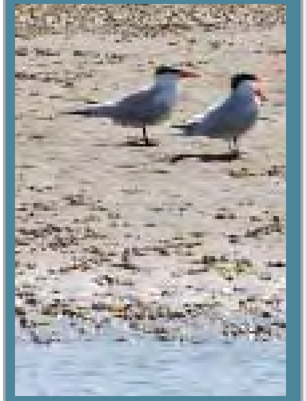
Step 7
Rate each indicator for monitoring priority

Step 8
Identify which are the major issues based on indicator ratings

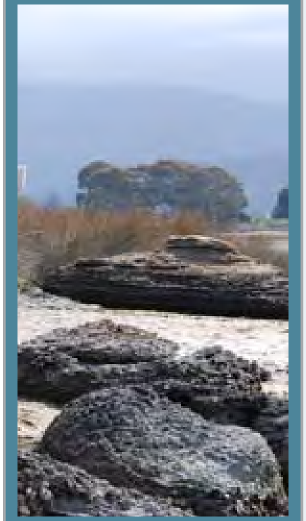
Step 9
Determine the overall rating based on monitoring indicator priorities

2.0 BACKGROUND

2.1 TIDAL LAGOON CHARACTERISTICS



Sandflats and Caspian Terns.



Rock habitat.

Pipi bed lower estuary.

Motupipi Estuary (Figure 1) is an example of a "tidal lagoon" type estuary, as are many others throughout New Zealand. Such estuaries have the following general characteristics (McLay 1976, Kirk & Lauder 2000, Hume et al. in press):

- Broad shallow basins, narrow mouths and are usually enclosed by a sand spit (hence sometimes called "barrier enclosed lagoons").
- Simple or complex shorelines - some have more than one arm (Motupipi Estuary has a complex shoreline with two main arms and numerous smaller ones).
- Their entrance to the sea is always open.
- Extensive intertidal areas which are cut by channels draining the arms.
- Funnel-shaped entrance (if alongshore movement of sand due to waves breaking at a angle to the shoreline is small - as is the case for the Motupipi).
- Tidal prism (i.e. the difference in the volume of water in the estuary between low and high tides) is large compared with the volume at low tide (most of the Motupipi Estuary is drained at low tide).
- Salinities tend to be high and close to that of seawater.
- Wind re-suspension of sediment can be high if arms are broad and exposure to wind fetch is elevated (Motupipi Estuary has moderate wind exposure).
- Main bodies are well flushed and dominated by sandy sediments with a shift to muds in the sheltered upper arms where flushing is less active as well as in the upper estuary area where freshwater inputs enter, often with elevated sediment loads. The Motupipi River is the main source of freshwater to the Motupipi Estuary. Where it enters in the upper estuary, muds are common.
- A well-mixed water column due to strong tidal flushing, wind mixing and shallow depths. In the Motupipi Estuary, the only likely area that isn't always well-mixed is in the upper estuary during low and moderate flows (freshwater likely to be floating on top of tidal salt water).
- High habitat diversity and ecological richness (in their natural state).

In terms of ecology, the major habitats of tidal lagoon estuaries include saltmarsh vegetation, seagrass beds, mud and sand intertidal flats, shellfish beds, water column, subtidal sand/mud and kelp beds. Technical Addendum 2 provides detailed descriptions of each of these habitats, their importance, and the major threats to their health.

In terms of potential estuary problems, there are five key issues that "tidal lagoon" type estuaries are vulnerable to, as follows:

Key Estuary Issues	
Excessive Sedimentation	Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived. This changes the types of plants and animals found in the estuary and degrades water quality. Because tidal lagoon estuaries are shallow, any muds are easily resuspended.
Excessive Nutrients	Increased nutrient richness of estuarine ecosystems stimulates the production and abundance of aquatic macrophytes (e.g. *Zostera*) and saltmarsh vegetation. If excessive, it stimulates fast-growing algae such as phytoplankton, and short-lived nuisance macroalgae (e.g. sea lettuce and *Enteromorpha*). It also detrimentally alters the community dynamics of saltmarsh ecosystems. Because estuarine systems are usually nitrogen limited, increased nitrogen delivery to pelagic habitats of estuaries produces the classic response of ecosystems to stress (altered primary producers and nutrient cycles and loss of secondary producer species and production; Nixon 1995, Rapport and Whitford 1999, Deegan et al. 2002).

2.0 BACKGROUND (CONTINUED)

Mullet in lower estuary.

Key Estuary Issues (continued)	
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the coastal lake environment, can survive for some time. Human contact with estuary water that has been contaminated with human and animal faeces, exposes them to these organisms and they risk getting sick.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), toxic heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, aquatic macrophyte beds, saltmarshes (rushlands, herbfields, reedlands, etc.), forested wetlands, beaches, river deltas, and hard shores. The major stressors causing habitat degradation or loss in estuaries are: drainage and reclamation of saltmarsh, sea level rise, population pressures on margins, pest and weed invasion, altered river input flows (damming, diversion and irrigation), over-fishing, polluted runoff and wastewater discharges.

Figure 1. Motupipi Estuary, location of Upper, Middle and Lower Estuary areas.

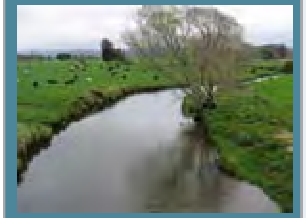
Photo: Google Earth

2.0 BACKGROUND (CONTINUED)

2.2 MOTUPIPI ESTUARY CHARACTERISTICS

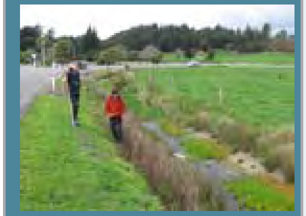
The Motupipi Estuary (Figure 1) is part of the coastal estuarine and embayment system of Golden Bay. The 2,700 ha catchment is predominantly grazed pasture and has moderate residential development. Approximately 1,000 ha of the catchment is flat, 1,200 ha is steep hill country, and 460 ha is rolling hills (James 2007).

In terms of the estuary itself, direct information on the physical characteristic, its ecology, and existing condition proved very limited - (confined to a small report given as evidence in a resource consent application for a proposed Motupipi Hill Residential Development in 1996). Therefore, in order to assess estuary vulnerabilities and identify monitoring priorities, it was firstly necessary to collect available data on estuary inputs, and to undertake synoptic field surveys to measure it's physical characteristics (e.g. area, volume, mean depth, salinity etc.) and to make observations on its habitats and condition. The sampling locations are shown in Figure 3 with results presented in the following subsections for three general zones defined based on salinity distribution and species composition: the lower, middle and upper estuary (see Figure 1).



Motupipi River.

Existing information on the Motupipi Estuary is summarised below. Motupipi Estuary is a small to medium-sized (100 ha), shallow (1m mean depth), well flushed estuary consisting of two arms, the eastern arm (60 ha) and the western arm (38 ha). The western arm receives the main river input from the Motupipi River, and consequently is the most affected by freshwater influences. Mean annual freshwater input from the Motupipi River is 0.5 $m^3.s^{-1}$, but during the summer is generally lower at 0.3 $m^3.s^{-1}$ (TDC monitoring data, Nov 2006-Nov 2007, Figure 2). Peak high flows, in the range of 8-10 $m^3.s^{-1}$, occur approximately twice per year and prolonged high flows (7 consecutive days) do not exceed 1 $m^3.s^{-1}$. Catchment runoff of nutrients, sediment and pathogens is expected to be elevated based on:



Old remnant saltmarsh near road.

- James (2007) classified the Motupipi River as having "consistently poor water quality", in particular high nutrient concentrations, moderately high concentrations of disease-causing organisms, and moderately high concentrations of fine sediment deposited on the river bed. The main causes being non-point source runoff from intensive landuse (primarily dairying at 2.7-3.4 cows/ha, 2,000 cows in catchment).
- Guideline values for clarity, faecal coliforms, dissolved nutrients were generally exceeded and fine sediment deposits on the stream bed were extensive.
- Summary water quality data for the Motupipi River (median, max, min) are as follows (James 2007): DIN (1.5, 0.5, 2.8); DRP (0.028, 0.025, 0.085); *E. coli* (379, 10, 1000).

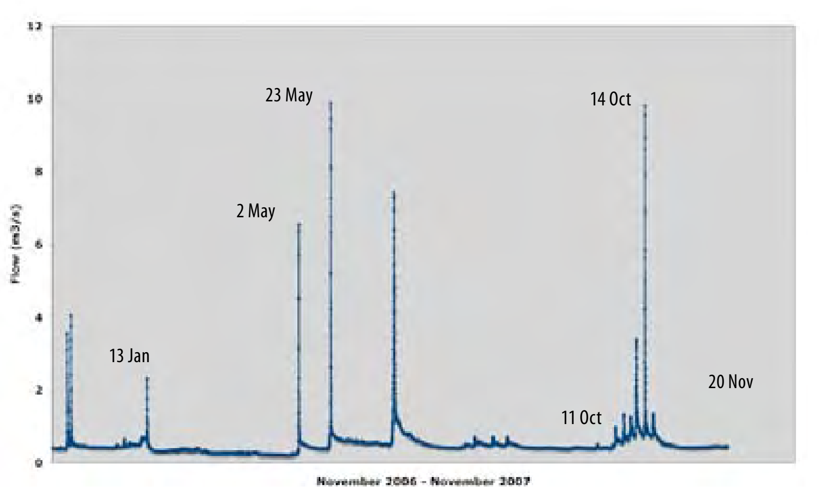
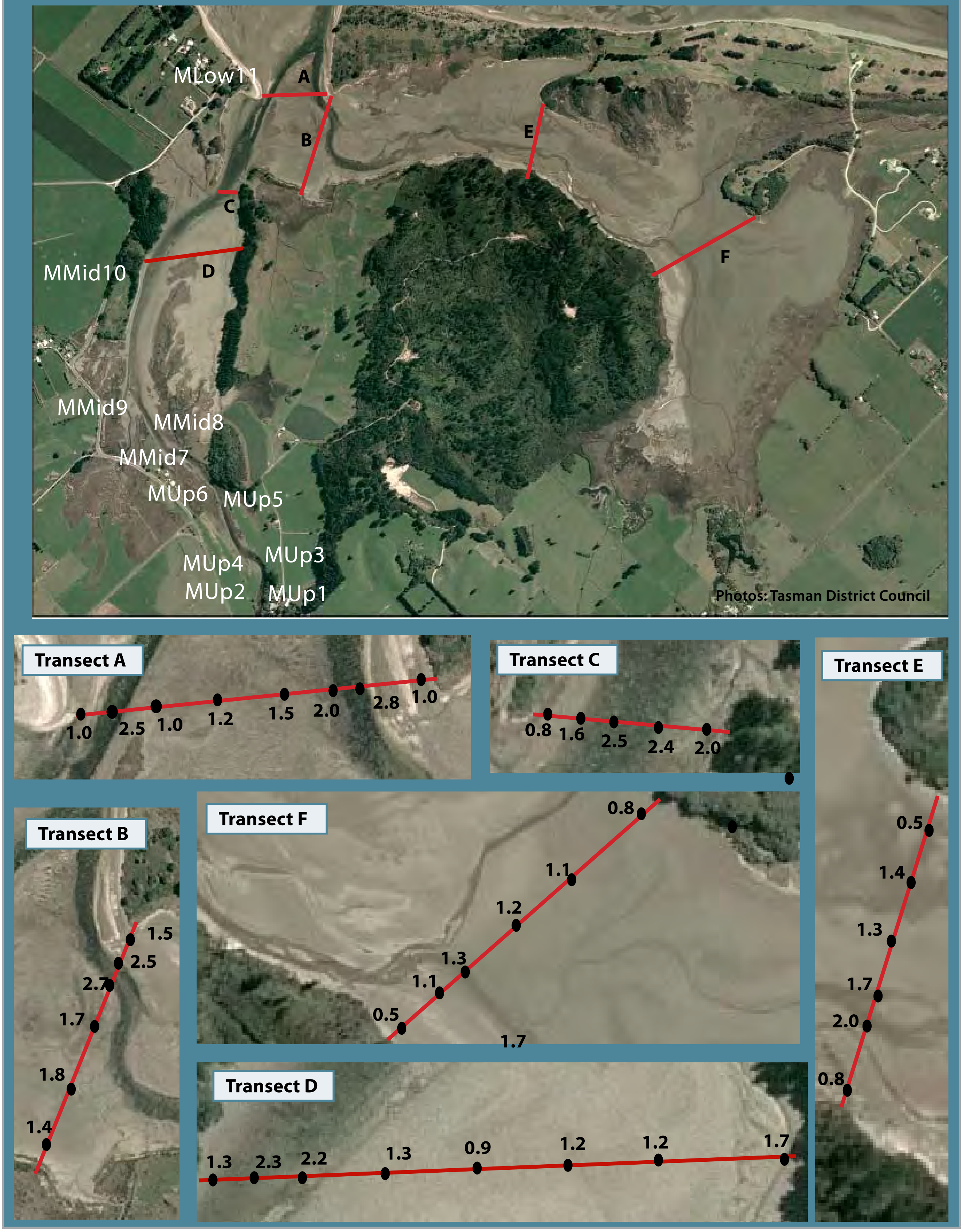


Figure 2. Flow data for Motupipi River at Reilly's Bridge November 2006 to November 2007 (provided by Trevor James, Tasman District Council).

Figure 3. Motupipi Estuary synoptic survey sample locations (top), and depth transects in metres (bottom) taken at high water, 25 November 2007.



Photos: Tasman District Council

2.0 BACKGROUND (CONTINUED)

2.2.1 Lower Estuary (High Salinity Zone)

Oyster bed in lower estuary.

The lower Motupipi Estuary covers the small section just up from and including the mouth that is well flushed each tide with incoming marine waters (mean depth approximately 1.5 m). Sampling details from a typical channel site (e.g. Transect A, Figure 3) are presented in Table 1.

This lower estuary includes deep tidal scour channels (2.5-3 m deep) bordered by steep shell and sand banks. Its habitats include; small areas of saltmarsh, duneland, extensive shellfish beds (pipi, cockles, mussels and Pacific oysters), macroalgal beds (sea lettuce and *Gracilaria*), unvegetated mud and sand bed deposits, rock, dunes and the water column (see Technical Addendum 2 for further detail on habitat types).

The most notable features of the lower estuary were: the extensive Pacific oyster beds in the central channel area, dense pipi beds, and the high incidence of nuisance macroalgal growth in the main channel and lower intertidal banks.

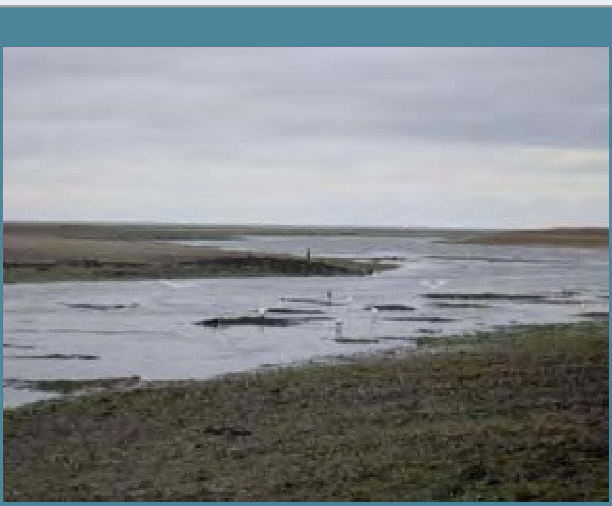
Symptoms of eutrophication were moderate (i.e. low incidence of anoxic sediments, extensive nuisance macroalgal mats and no phytoplankton blooms) and limited to around the channel areas. Excessive sedimentation of mud was limited to small localised areas and the sediments were all well-oxygenated with no significant blackening with sulphide deposits. Water clarity in this section was relatively high at high tide but was significantly reduced on the ebbing tide. Large numbers of surface deposit feeders were grazing the thin film of micro-algae on the sediment surface.

The lower banks and floor of the channels were composed of cobbles embedded in a sand/silt mix of sediment.

Table 1. Lower Motupipi Estuary (Western Arm) 26 November 2007 at low water

Station	Measure	Results	
MLow11	Depth	Pool 1-3m.	
	Sediment Type	Clean cobbles, gravel/sand. No sulphides. *Gracilaria* and *Ulva* common.	
	Water	Clear water. No salt wedge. Salinity 25ppt, temp. 21 degC surface, secchi disc >1.5m.	

Macroalgae and cobble habitat.



Mouth of the lower estuary.

2.2.2 Middle Estuary (Medium Salinity Zone)

Tidal flats and *Enteromorpha* bloom in middle estuary.

The middle estuary zone covers the majority of the length of most estuaries. It begins near the mouth of the estuary just up from the small lower estuary section that is well flushed each tide with incoming marine waters, and extends to the low salinity zone of the upper estuary. The middle estuary has a moderate amount of water movement and salt and fresh water mixing.

In the Motupipi, the middle estuary includes large areas of both the western and eastern arms (Figure 1) and has a mean depth at high water of approximately 1 m. Habitat mapping (Stevens and Robertson 2008) showed a wide diversity of habitats in both arms of the middle estuary which included; large areas of saltmarsh, subtidal and intertidal seagrass beds, macroalgal beds (primarily *Enteromorpha*), unvegetated mud and sand bed deposits, rock, shellfish beds (cockles and oysters) and the water column (see Technical Addendum 2 for further detail on habitat types).

Eastern Arm: This section of the estuary was dominated by large areas of saltmarsh and intertidal flats, and was relatively clean and in good condition. Symptoms of eutrophication (i.e. anoxic sediments, nuisance macroalgal and microalgal mats and phytoplankton blooms) were absent, and soft muds were only found in the shallow upper flats. Sediments of the middle and lower section were firm sands and silt with a low organic content likely. The sediments were all well-oxygenated with no significant blackening with sulphide deposits. Water clarity in this section was relatively high, but likely to be less during strong winds. Large numbers of surface deposit feeders were grazing the thin film of micro-algae on the sediment surface.

Western Arm: In comparison, the western arm of the middle estuary, which was also dominated by large areas of saltmarsh and some intertidal flats, was relatively dirty and in poor condition. Symptoms of eutrophication were present, particularly along the main channel and adjacent intertidal flat section. In this section, anoxic and sulphide-rich deep soft muds and macroalgal and microalgal mats were common and phytoplankton blooms (*Cryptomonas* sp.) occurred regularly in the upper section (close to the upper estuary and source of nutrients). Symptoms of excessive sedimentation were also present in the same section, with deep beds of very soft muds and low water clarity.

In the more isolated eastern section of the western arm, the sediments were firmer and more oxygenated. Sediments within the channel tended to be coarser, with less mud, and were often vegetated by seagrass beds and attached macroalgae. Cockles were also common in the channel sediments and along the lower intertidal margins. Results of sediment and water sampling in the muddier channel section of the western arm are presented in Table 2.

Additionally, a section of the western arm has been reclaimed in the past through its use as a landfill (Rototai Landfill), which operated for 40 years up until 1994. Some monitoring (sediment and shellfish) has been undertaken (James 2007) which suggests that significant contamination of the estuary from potentially toxic leachates is unlikely. However, because only a limited range of contaminants were analysed, the true situation can not yet be determined. This situation could be easily resolved through targeted monitoring of easily obtained biota for a full range of metals and semi-volatile organic compounds. Currently, large numbers of surface deposit feeders graze the sediment surface of the deep intertidal muds that border the landfill and similarly large numbers of filter feeding cockles live in the sediments of the adjacent middle estuary channel. Oyster beds are also present nearby in the main channel.

2.0 BACKGROUND (CONTINUED)

Table 2. Middle Motupipi Estuary (Western Arm) 26 November 2007 at low water

Station	Measure	Results	
MMid7	Depth	Pool 1-2m (below riffle section).	
	Sediment Type	Cobbles, gravel/silt/sand. Strong presence of sulphides. Seagrass present.	
	Water	All stained coffee brown. No salt wedge. Salinity 13.9 ppt at 0.2m and bottom, temp. 23 degC surface, secchi disc 20cm.	
MMid8	Depth	Pool 1m.	
	Sediment Type	Cobbles, gravel/silt/sand. Strong presence of sulphides. Seagrass present.	
	Water	All stained coffee brown. No salt wedge. Salinity 14 ppt at 0.2m and bottom, temp. 22 degC surface, secchi disc 25cm.	
MMid9	Depth	Pool 0.5-1m. Mudflats begin at this point.	
	Sediment Type	Silt/sand. Low sulphides. Seagrass present.	
	Water	All stained coffee brown. No salt wedge. Salinity 15.8 ppt at 0.2m and bottom, temp. 21 degC surface, secchi disc 25cm.	
MMid10	Depth	Pool 1-2.5. Mudflats present. Opposite old landfill.	
	Sediment Type	Silt/sand. Low sulphides. Seagrass present. Lots of large cockles in channel bed.	
	Water	No coffee stain. Water turbid. No salt wedge. Salinity 18 ppt, temp. 21 degC surface, secchi disc 85cm.	

Middle estuary showing saltmarsh, macroalgal blooms and tidal flats.

Middle estuary macroalgal blooms and tidal flats.

2.2.3 Upper Estuary (Low Salinity Zone)

Photo: Tasman District Council

Aerial view of the upper estuary.

The upper estuary or low salinity zone occupies the upper 1 km of the estuary where it meets the Motupipi River, consisting of a single main channel (15-20 m wide, less than 2 m deep and covering approximately 2 ha) that meandered through farmland initially in the upper reaches, and then broadened as it reached the middle estuary (western arm). The upper estuary can be defined as the section of the estuary where river input (rather than tidal seawater) dominates the water column and the water is generally less than 10 part per thousand (ppt) salinity. In addition, the biota include both typically freshwater organisms, as well as estuarine and marine species.

Tidal amplitude in the upper estuary was approximately 1.0-1.3 m and the channel was bounded by 1 m high banks. At low tide on 26-27 Nov. 2007 the upper estuary had a surface low salinity (freshwater) layer (salinity 1.2 ppt) and an underlying high salinity (seawater) layer (26-28 ppt) (i.e. a salt wedge effect). An algal bloom was also in progress at this time (see details later in this section and figures on following page). On 26 November the upper layer was 40 cm deep at high water (Table 3). On the following day, the salinity stratification broke down for a short period (8 ppt on surface, 18 ppt near bottom) during the rising tide, but re-established itself on the falling tide. Bed sediments (Table 3) in the upper estuary were found to be variable and included soft muds and sands, cobbles and gravels. In some locations, the sediments were anoxic, foul-smelling and blackened with sulphides (e.g. below the Abel Tasman Drive bridge).

Seagrass in the upper estuary.

Macroalgal bloom *(Enteromorpha)*.

Tidal flat.

In terms of habitats, the upper estuary had the following: subtidal and intertidal seagrass beds, macroalgal beds, unvegetated mud and sand bed deposits, cobble beds in riffle sections and the water column itself.

Seagrass Beds: A notable habitat feature of the upper estuary was the presence of thriving and extensive submerged beds of seagrass (*Zostera muelleri*) and their associated populations of invertebrates and small fish. Seagrass beds are usually absent from upper estuary areas in most New Zealand estuaries, which is probably a result of poor water clarity, scouring in high flows, and long periods of low salinity. The spring-fed Motupipi River provides relatively clear water to the upper estuary, flows are relatively even, and long periods of very low salinity are uncommon. However, in the last few years, algal blooms in the upper estuary during the warmer months have lowered water clarity to levels such that light doesn't reach the beds for long periods each day.

Macroalgal Beds: The green macroalga *Enteromorpha,* (a common inhabitant of nutrient-enriched, brackish areas in estuaries) was present in both the intertidal and subtidal areas. Most surfaces in the mid to low water zone were covered with these nuisance macroalgal growths. Growths were particularly prevalent on surfaces of rocks and cobbles in the riffle zones.

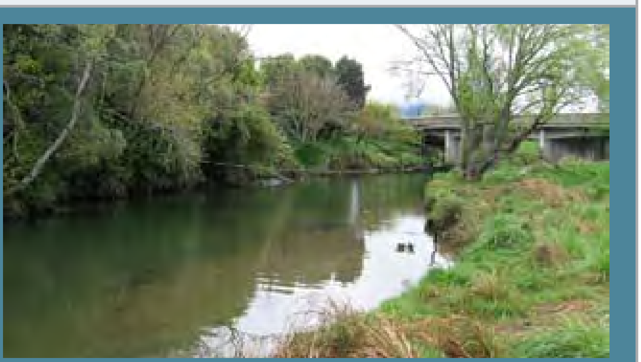
Unvegetated Sand/Mud Habitat The most abundant visible animals on the sediment surface were the mud crab (*Helice crassa*), and the snails *Potamopyrgus estuarinus* and *Amphibola crenata*. Common fish included inanga (*Galaxias maculatus*) and short-finned eels (*Anguilla australis*).

2.0 BACKGROUND (CONTINUED)

Table 3. Upper Motupipi Estuary 26 November 2007 at low water

Station	Measure	Results	
MUp1	Depth (low water)	Pool 1.5-3m (eastern side towards shore).	
	Sediment Type	Black muddy sand, strong sulphide smell, organic detritus, little sign of macroinvertebrates.	
	Water	Bottom layer stained coffee brown. Salinity 1.2 ppt at 0.2m, 27ppt below 0.4m, temp. 16 degC surface, 18 degC >0.4m, secchi disc 45cm.	
MUp2	Depth	Pool 1.0 -2m (western side of channel).	
	Sediment Type	Gravel/silt/sand. Moderate sulphide stain.	
	Water	Bottom layer stained coffee brown. Salinity 8.2 ppt at 0.2m, 27ppt below 0.4m, temp. 16 degC surface, 18 degC >0.4m, secchi disc 45cm.	
MUp3	Depth	0.8 -1.3m (western side of channel).	
	Sediment Type	Gravel/silt/sand. No sulphides. Seagrass present.	
	Water	Bottom layer stained coffee brown. Salinity 8.2 ppt at 0.2m, 27ppt below 0.4m, temp. 16 degC surface, 18 degC >0.4m, secchi disc 45cm.	
MUp4	Depth	20cm riffle.	
	Sediment Type	Cobbles/gravel. No sulphides. All cobbles in riffle coated with nuisance macroalgae (*Enteromorpha* sp).	
	Water	Water stained coffee brown. Salinity 9 ppt, temp. 18 degC, secchi disc 20-30cm.	
MUp5	Depth	Pool 1-2m (in pool below shallow riffle).	
	Sediment Type	Cobbles, gravel/silt/sand. No sulphides.	
	Water	Bottom layer stained coffee brown. Salinity 11.9 ppt at 0.2m, 26ppt below 0.3m, temp. 20 degC surface, 20 degC >0.4m, secchi disc 25cm.	
MUp6	Depth	Pool 1-2m.	
	Sediment Type	Cobbles, gravel/silt/sand. Some sulphides. Lots of *Enteromorpha* and *Zostera* present.	
	Water	Bottom layer stained coffee brown. Salinity 11.9 ppt at 0.2m, 26ppt below 0.3m, temp. 20 degC surface, 20 degC >0.4m, secchi disc 25cm.	

Eelgrass with macroalgal cover.



Upper estuary prior to cryptomonad bloom.

2.0 BACKGROUND (CONTINUED)

2.2.4 Upper Estuary Phytoplankton Blooms

Cryptomonad.

The key feature of the survey in the upper estuary was symptoms of eutrophication, in particular, phytoplankton and macroalgal blooms and anoxic black sediments.

Phytoplankton Blooms (Upper Estuary)

During the second field visit (26-27 November), a phytoplankton bloom (dominated by *Cryptomonas* sp.) occurred in the water column, which (according to local residents) began around 20 November and persisted until at least February 2008. The bloom was brown in colour and concentrated in the high salinity bottom water (see photos on following page). Similar blooms have been observed in the upper estuary since 2001 (Fred Winter pers. comm.), with the first sample being collected in early May 2007. This sample was dominated by various diatoms as well as a small unidentified flagellate (presumably *Cryptomonas* sp.).

Cryptomonas sp. is a unicellular, mobile and small flagellated algae. Their characteristics are as follows:

- They are known to provide high quality food for zooplankton (high nutrient quality) and are non-toxic.
- They have the ability to grow at low and high light levels (Reynolds and Reynolds 1985).
- They can show rapid growth and can tolerate high water temperatures (Lehman 1996).
- Under bloom conditions they cause water and sediment quality to deteriorate (e.g. low clarity and deoxygenation), and a lowering of ecological values.
- They are both heterotrophic and autotrophic. Their heterotrophic abilities mean they can utilize organic nutrients as an energy source under sub-saturating light levels. This ability to acclimate to available light levels allows cryptophyte algae to out-compete more traditional bloom forming phytoplankton under some conditions.
- They are stimulated by sediment release of iron and phosphorous in estuarine waters (Huan-Xin Wenga et al. 2007).
- Their small size makes them less susceptible to sinking in stable waters during dry conditions and their mobility allows them to avoid the high light and temperatures near the surface.
- Cryptomonad fluctuations are correlated with increases in nitrogenous content of the water in which they occur.

The other phytoplankton species which have been recorded in the upper estuary were various types of diatoms (including *Cymbella prostatum* and *Epithemia sorex*). Such species are common inhabitants of both estuaries, rivers and lakes. However, if waters are enriched, dominance can shift from small diatoms and green algae during the spring bloom, to cryptophyte flagellates, and later to filamentous blue-greens (cyanobacteria). The reason for the collapse of diatom blooms is that, unlike cryptophytes, diatoms favour low light, low water temperatures and require turbulent, well-mixed waters to keep their heavy silicate shells in suspension (Lehman 2000). Consequently, they are usually abundant in spring when river flows and vertical mixing is high, light is low and temperature is still depressed.

These characteristics, plus available monitoring data, enable a likely scenario for the development of the cryptophyte blooms in the Upper Motupipi Estuary in 2007. This is described in the following section.

2.0 BACKGROUND (CONTINUED)

PHOTOGRAPHS OF UPPER MOTUPIPI ESTUARY DURING ALGAL BLOOM


Algal bloom in deeper water below Abel Tasman Rd Bridge.


Algal bloom in deeper water below Abel Tasman Rd Bridge.


Close-up of algal bloom.


Sample of water with algal bloom.


Bloom the following day on incoming tide (mixed through water column).


Bloom in shallower water showing strands in high salinity patches.

2.2.5 Cryptophyte Bloom Scenario

A prolonged dry period preceded the cryptophyte bloom sampled early May (Figure 4), with flows in Motupipi River not exceeding 0.35 $m^3.s^{-1}$ for the 13 Jan - 2 May period. Observations by an adjacent landowner (Fred Winter) indicate that similar blooms occurred continuously over this period. Such blooms were likely favoured by the warm temperatures, low flows, absence of turbulent mixing and presence of a stable salt wedge.

From 2 May to mid July several high flow events ensured turbulent mixing and from mid July to late September the spring conditions of small flushing flows and rising water temperature likely favoured diatoms. Subsequently, as water temperatures became higher and river flows declined, a cryptophyte bloom was becoming more likely. However, before this could happen, a period of high river flows occurred in October which delayed the cryptophyte bloom by keeping the water turbulent and well-mixed. In late October, the dry period began, river flows declined, the salt wedge became more stable, and the diatoms likely began to sink. This made way for cryptophytes to bloom, probably utilizing their heterotrophic abilities to use organic nutrients at low light intensities (light disappeared in 10cm within the bloom on 27 November) as well as their motility and tolerance of elevated temperatures to out-compete the diatoms. Nutrients may also have been a controlling factor (high nutrients concentrations are common in the Motupipi River).

Once the November bloom began it spread throughout the upper estuary from just upstream of the Abel Tasman Drive Bridge to approximately midway down the middle estuary (western arm) at low tide. At high tide it was restricted to the salt wedge area, which extended over much of the length of the upper estuary. Dissolved oxygen levels in this high salinity bottom water were low (<1 mg/l). Such low concentrations were likely to be causing adverse effects to fish in the water column. In addition, possible impacts to seagrass may occur through shading effects.

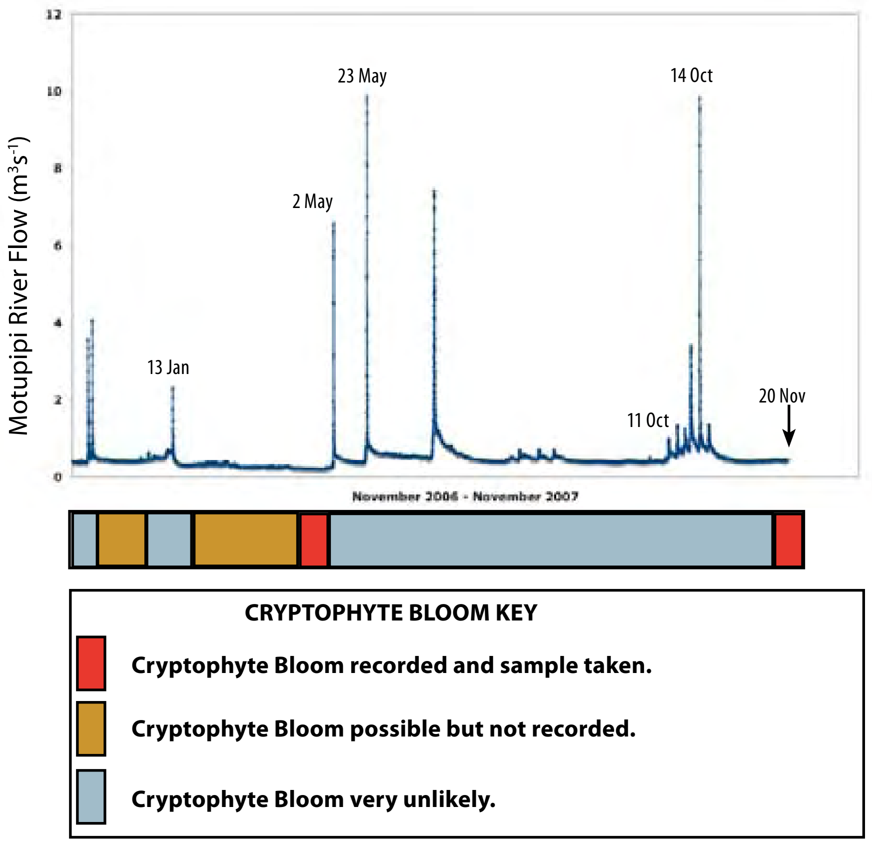
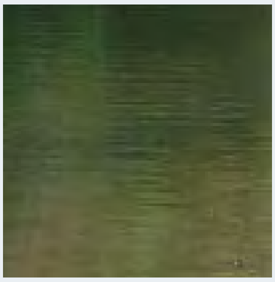
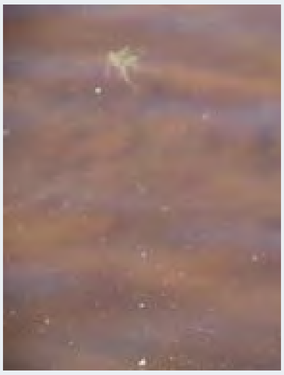


Figure 4. Motupipi river flow and predicted bloom sequence.



Before Bloom (early November).



During Bloom (26 November).

3.0 VULNERABILITY ASSESSMENT

3.1 INTRODUCTION

The collection of background information described in the previous section included the completion of detailed tables on the human uses and values, ecological richness, presence of stressors, existing condition, and susceptibility to stressors within the estuary. These tables, presented in Technical Addendum 3, underpin the Ecological Vulnerability Assessment and are used by experts to assign ratings to characterise the vulnerability of an estuary to problems, and based on this, priorities for monitoring and management.

As the process relies on an expert's evaluation and interpretation of the available information, the tables in Technical Addendum 3 provide a full record of the information upon which the judgements have been based, and the reason for each decision. This is to enable additional information to be added as it becomes available, and to provide a transparent process so that other experts can contribute to the assessment process.

However, because the decision-making process is complex, the reader is not expected to utilise the information in Technical Addendum 3 directly. Instead, a summary of the results of the Ecological Vulnerability Assessment is included in Figure 5 for each of the four sections of the estuary (upper estuary, middle estuary western arm, middle estuary eastern arm and lower estuary). This information is summarised in more detail in the accompanying Estuary Vulnerability Matrices (Figures 6 and 7) which provide the ratings, and identify the key issues and monitoring and management priorities. In addition, Sections 3.3 to 3.7 describe the findings of the Ecological Vulnerability Assessment for each of the key issues facing estuaries: eutrophication, sedimentation, disease risk, toxicants and habitat loss.

Flapgates in middle estuary.

3.2 OVERVIEW OF ECOLOGICAL VULNERABILITY FINDINGS

In brief, the Motupipi Estuary has high ecological values and is widely used by humans. However, the presence of stressors and a high susceptibility to certain issues or problems, means that in some areas the estuary is degraded and consequently has high vulnerability ratings (Figure 5).

The major issues affecting the existing condition were:

- eutrophication and, to a lesser extent,
- sedimentation,
- disease risk, and
- habitat loss.

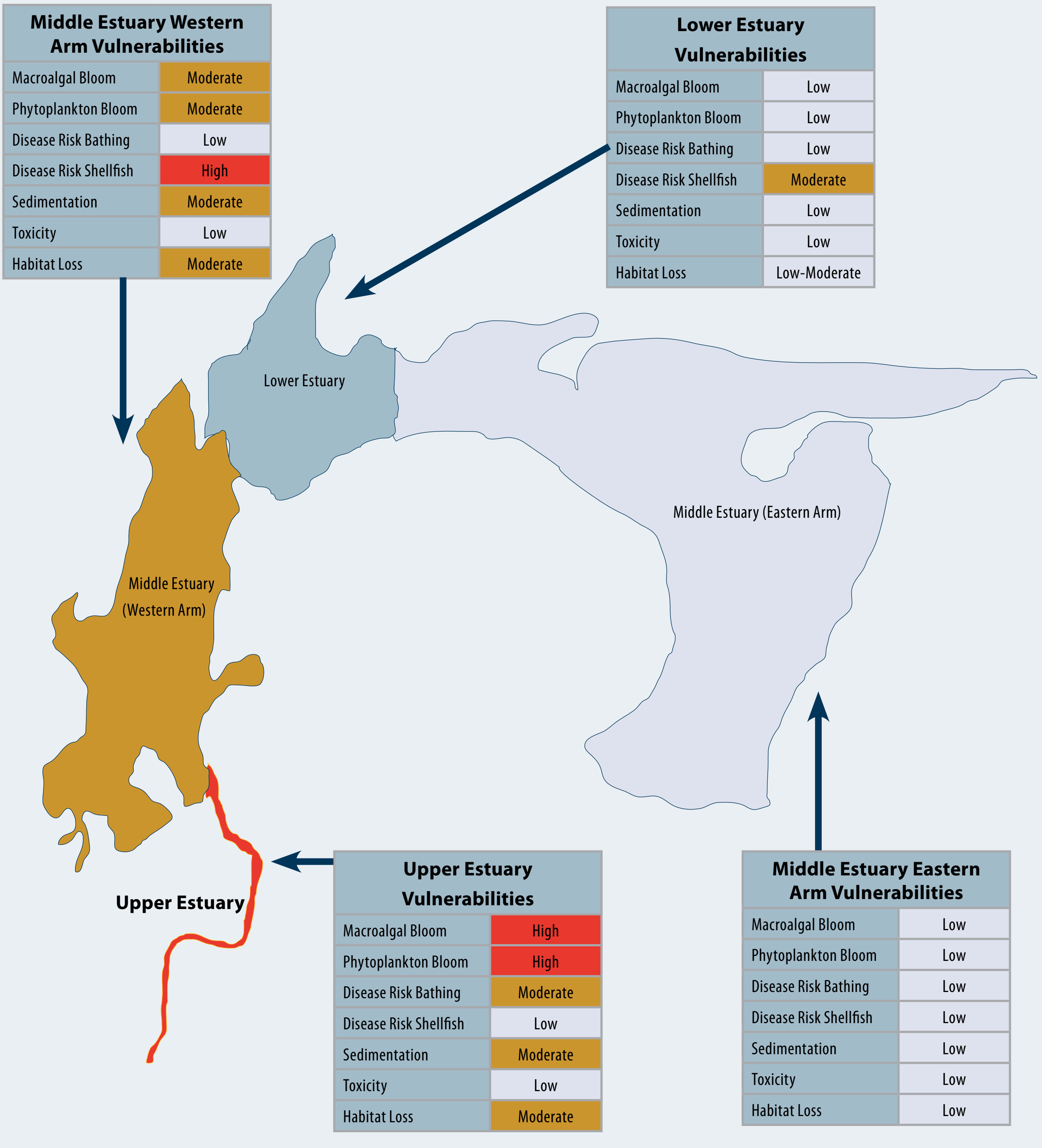
Contaminated runoff from a primarily dairying catchment (especially nutrients, sediment and faecal coliforms) and predicted accelerated sea level rise were identified as the major stressors. Other stressors included historical land development around the margins of the estuary and the presence of flapgates restricting tidal access in some areas.

3.3 EUTROPHICATION

The findings from the eutrophication assessment indicate that the Motupipi Estuary has "moderate" symptoms of eutrophication. These symptoms have a detrimental effect on fishing and aesthetic values and likely place stress on existing plant and animal communities.

3.0 VULNERABILITY ASSESSMENT (CONTINUED)

Figure 5. Vulnerability ratings for key estuary issues - Motupipi Estuary



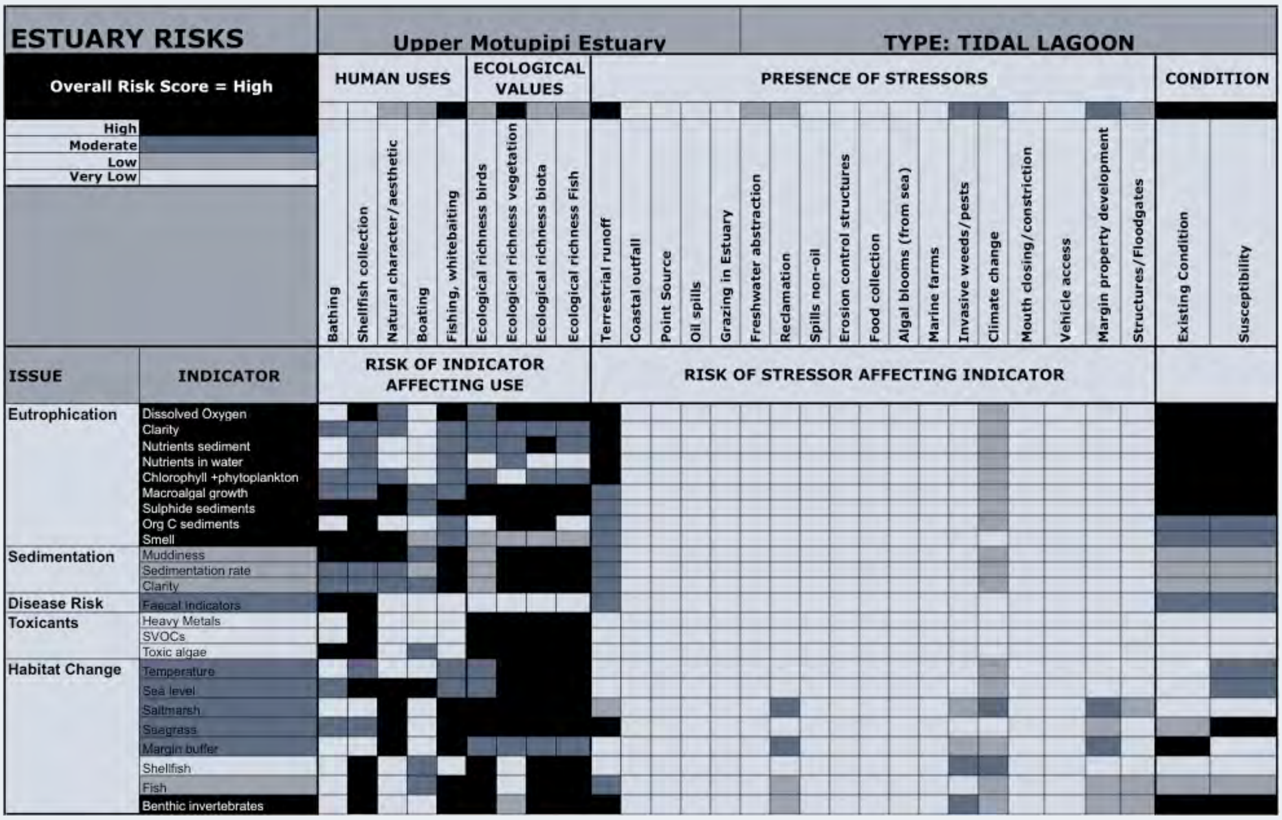
Middle Estuary Western Arm Vulnerabilities	
Macroalgal Bloom	Moderate
Phytoplankton Bloom	Moderate
Disease Risk Bathing	Low
Disease Risk Shellfish	High
Sedimentation	Moderate
Toxicity	Low
Habitat Loss	Moderate

Lower Estuary Vulnerabilities	
Macroalgal Bloom	Low
Phytoplankton Bloom	Low
Disease Risk Bathing	Low
Disease Risk Shellfish	Moderate
Sedimentation	Low
Toxicity	Low
Habitat Loss	Low-Moderate

Upper Estuary Vulnerabilities	
Macroalgal Bloom	High
Phytoplankton Bloom	High
Disease Risk Bathing	Moderate
Disease Risk Shellfish	Low
Sedimentation	Moderate
Toxicity	Low
Habitat Loss	Moderate

Middle Estuary Eastern Arm Vulnerabilities	
Macroalgal Bloom	Low
Phytoplankton Bloom	Low
Disease Risk Bathing	Low
Disease Risk Shellfish	Low
Sedimentation	Low
Toxicity	Low
Habitat Loss	Low

Figure 6. Vulnerability Matrices - Upper Estuary and Middle Estuary (Western Arm).



ESTUARY RISKS

Upper Motupipi Estuary

TYPE: TIDAL LAGOON

Overall Risk Score = High

High
Moderate
Low
Very Low

HUMAN USES: Bathing, Shellfish collection, Natural character/aesthetic, Boating, Fishing, whitebaiting

ECOLOGICAL VALUES: Ecological richness birds, Ecological richness vegetation, Ecological richness biota, Ecological richness Fish

PRESENCE OF STRESSORS: Terrestrial runoff, Coastal outfall, Point Source, Oil spills, Grazing in Estuary, Freshwater abstraction, Reclamation, Spills non-oil, Erosion control structures, Food collection, Algal blooms (from sea), Marine farms, Invasive weeds/pests, Climate change, Mouth closing/constriction, Vehicle access, Margin property development, Structures/Floodgates

CONDITION: Existing Condition, Susceptibility

ISSUE / INDICATOR / RISK OF INDICATOR AFFECTING USE / RISK OF STRESSOR AFFECTING INDICATOR

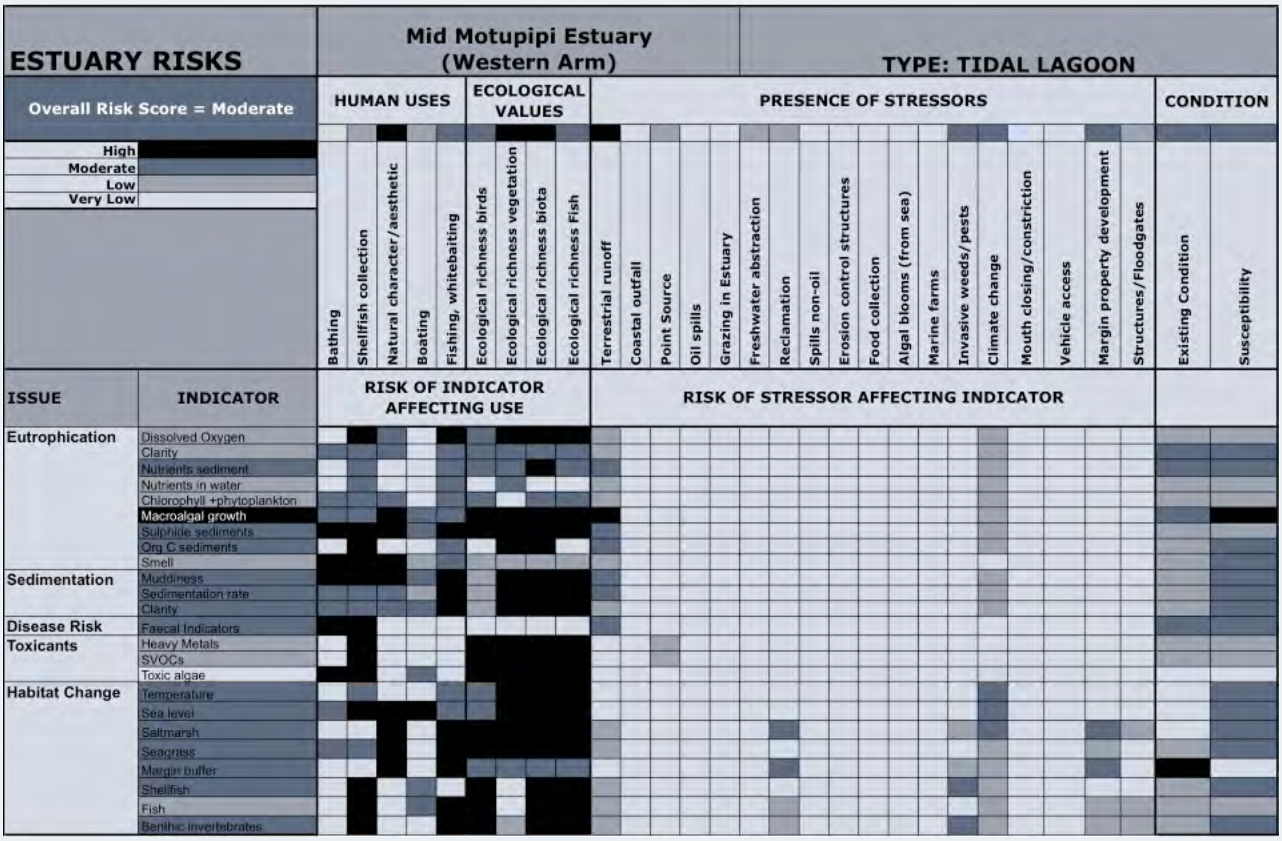
Eutrophication: Dissolved Oxygen, Clarity, Nutrients sediment, Nutrients in water, Chlorophyll +phytoplankton, Macroalgal growth, Sulphide sediments, Org C sediments, Smell

Sedimentation: Muddiness, Sedimentation rate, Clarity

Disease Risk: Faecal indicators

Toxicants: Heavy Metals, SVOCs, Toxic algae

Habitat Change: Temperature, Sea level, Saltmarsh, Seagrass, Margin buffer, Shellfish, Fish, Benthic invertebrates



ESTUARY RISKS

Mid Motupipi Estuary (Western Arm)

TYPE: TIDAL LAGOON

Overall Risk Score = Moderate

High
Moderate
Low
Very Low

HUMAN USES: Bathing, Shellfish collection, Natural character/aesthetic, Boating, Fishing, whitebaiting

ECOLOGICAL VALUES: Ecological richness birds, Ecological richness vegetation, Ecological richness biota, Ecological richness Fish

PRESENCE OF STRESSORS: Terrestrial runoff, Coastal outfall, Point Source, Oil spills, Grazing in Estuary, Freshwater abstraction, Reclamation, Spills non-oil, Erosion control structures, Food collection, Algal blooms (from sea), Marine farms, Invasive weeds/pests, Climate change, Mouth closing/constriction, Vehicle access, Margin property development, Structures/Floodgates

CONDITION: Existing Condition, Susceptibility

ISSUE / INDICATOR / RISK OF INDICATOR AFFECTING USE / RISK OF STRESSOR AFFECTING INDICATOR

Eutrophication: Dissolved Oxygen, Clarity, Nutrients sediment, Nutrients in water, Chlorophyll +phytoplankton, Macroalgal growth, Sulphide sediments, Org C sediments, Smell

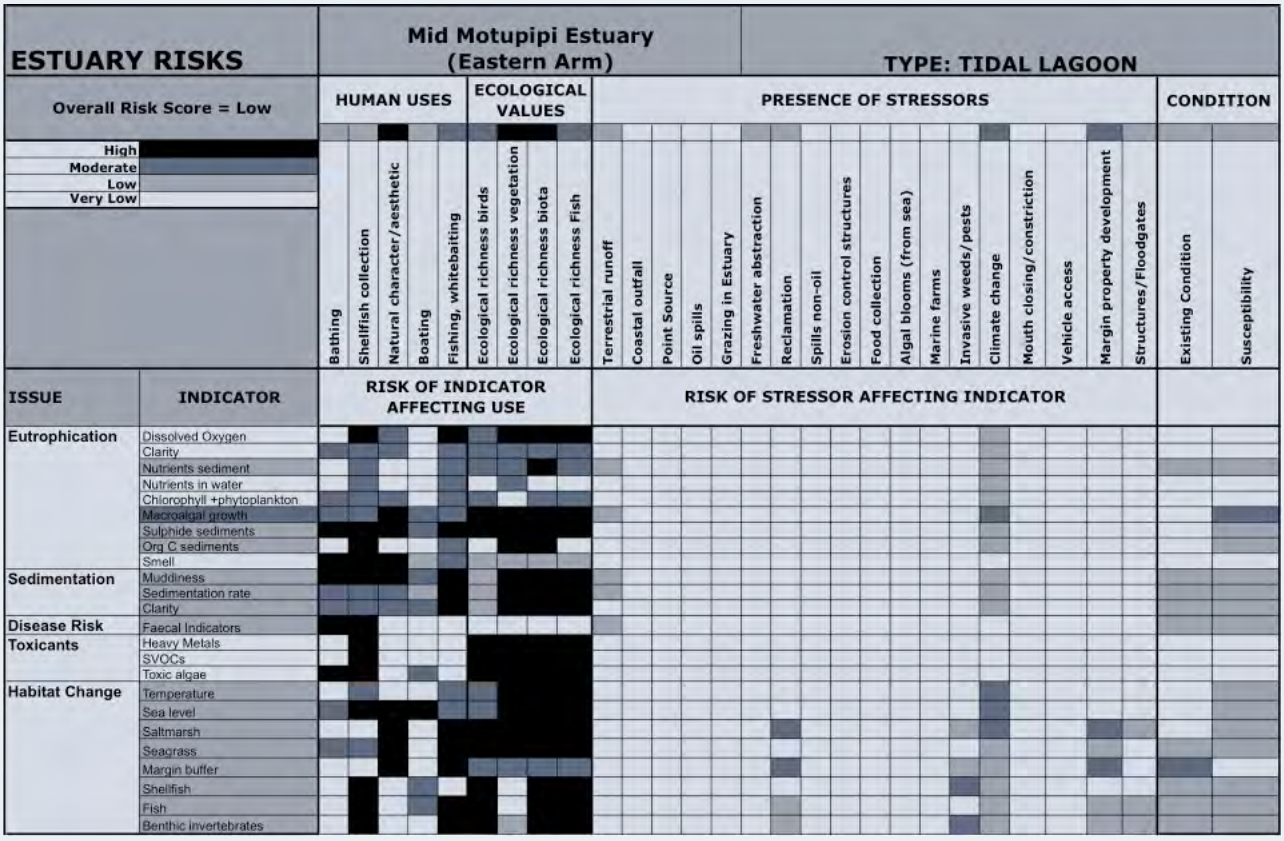
Sedimentation: Muddiness, Sedimentation rate, Clarity

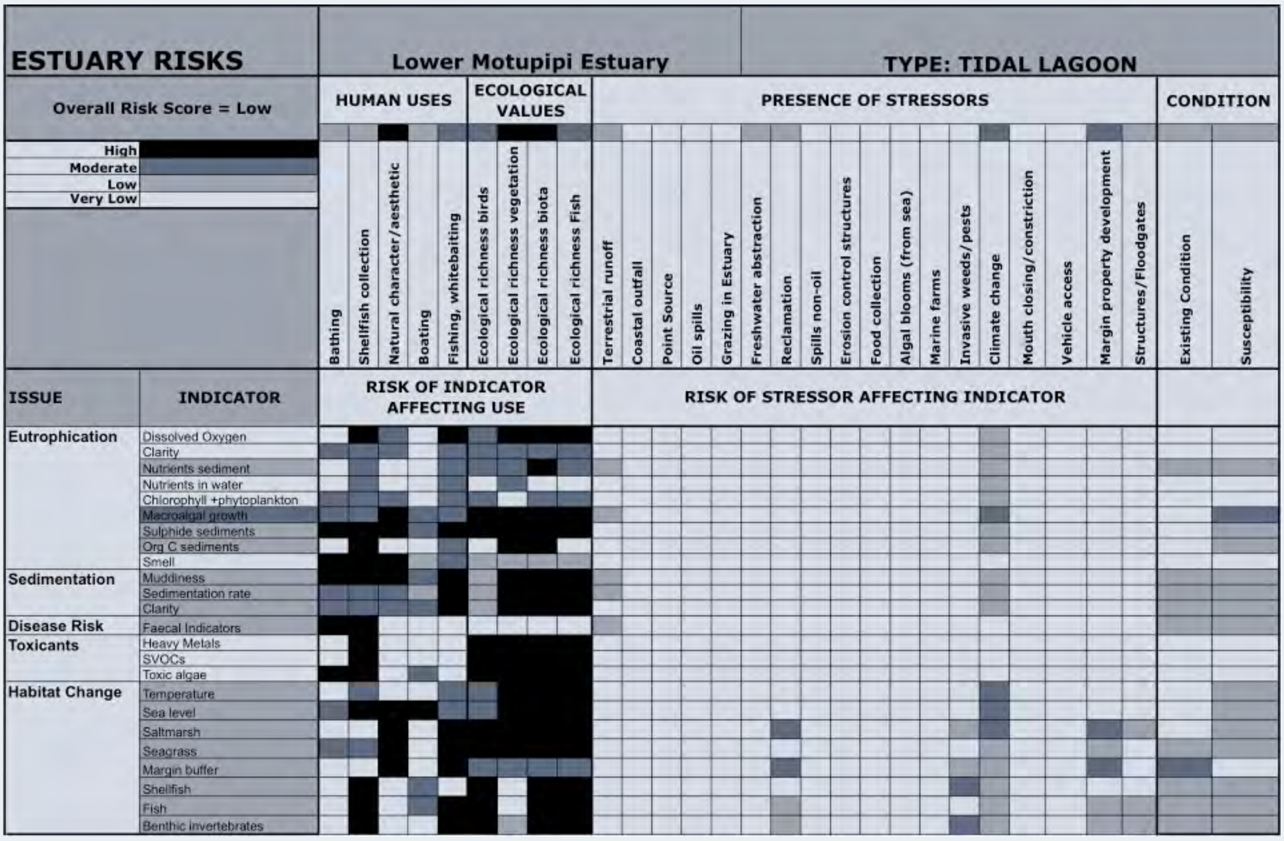
Disease Risk: Faecal indicators

Toxicants: Heavy Metals, SVOCs, Toxic algae

Habitat Change: Temperature, Sea level, Saltmarsh, Seagrass, Margin buffer, Shellfish, Fish, Benthic invertebrates

Figure 7. Vulnerability Matrices - Middle Estuary (Eastern Arm) and Lower Estuary.





3.3 EUTROPHICATION (CONTINUED)

In the middle and lower estuary, the symptoms were "moderate" and restricted to blooms of macroalgae and epiphytes along the edge of the main channels and phytoplankton blooms in the upper section of the middle estuary. Phytoplankton blooms in other sections of the middle and lower estuary are unlikely because of strong tidal mixing and a short residence time (<1 day). As a consequence, phytoplankton do not have the time to grow to bloom proportions despite adequate nutrient concentrations. Technical Addendum 4 provides a summary of the predicted nutrient concentrations in the upper, middle and lower estuary and recommended nutrient guideline criteria. In terms of susceptibility, the assessment shows that, although nutrient inputs from the catchment are high, their influence on plant growth in the mid and lower estuary is reduced through dilution and flushing actions to give an overall "moderate" susceptibility of the middle and lower estuary to eutrophication problems.

In the upper estuary, the symptoms were more severe and include nuisance phytoplankton blooms and associated low dissolved oxygen levels at times as well as macroalgal blooms. Phytoplankton blooms, and very low dissolved oxygen levels were present throughout the high salinity bottom water of the upper estuary during summer and autumn low flow periods. Such symptoms are rated "moderate to high". In terms of susceptibility, the upper estuary fits the "high" rating category, which results from the "high" nutrient input and the "moderate to high" dilution and flushing potential.

In terms of the overall distribution of nutrients in the estuary and the relationship with eutrophication symptoms, the findings suggest that currently the symptoms are restricted to areas where dilution of inputs is low and/or residence time elevated (i.e. in upper estuary or in main channel of mid and lower estuary, particularly in the western arm). Elevated nutrients and eutrophication symptoms in the eastern arm are unlikely, due to high tidal flushing and relative remoteness from the main nutrient input (the Motupipi River).

The major stressor or cause of these nutrient enrichment issues, was attributed to contaminated catchment runoff from the primarily dairying Motupipi catchment.

Based on available landuse information, catchment loadings of nutrients are elevated to levels that would cause problems. In particular, nutrient loads [total nitrogen (TN) and dissolved reactive phosphorus (DRP)] from intensive farming in the catchment are estimated to be extremely high (e.g. 30kgN/ha/year from the 2,000 cows on 700 ha, i.e. 3 cows/ha). As a consequence, mean TN and DRP concentrations in Motupipi River are high, exceeding quality guidelines for NZ low elevation rivers.

Motupipi Stream	TN mean 1.5-2mg/l, DRP mean 0.03mg/l
NZ Low elevation rivers (ANZECC 2000)	TN: 0.61mg/l, DRP: 0.01mg/l

In the future, climate change stressors (including accelerated sea level rise, increased temperature, altered precipitation, and UV radiation) are predicted to have a major influence on the estuary because of its shallow nature and low volume compared with adjacent coastal seas.

Such findings indicate that the issue of eutrophication of the Motupipi Estuary is a priority for further investigation and monitoring, as well as management.

3.4 SEDIMENTATION

The findings from the sedimentation assessment indicate that the Motupipi Estuary has "moderate" symptoms of sedimentation, primarily expanding areas of soft muds. These symptoms have a detrimental effect on human use values and place stress on existing plant and animal communities. In terms of susceptibility, the estuary was rated has having a moderate overall susceptibility to sedimentation based on its low-moderate sediment input and flushing and spreading potentials.

3.4 SEDIMENTATION (CONTINUED)

In the Upper Motupipi Estuary, the symptoms of excessive sedimentation were moderated by the relatively narrow channel and absence of tidal flats, which encouraged flushing during high flow events. However, in the middle estuary of both the eastern and particularly the western arms, sedimentation was encouraged in areas where flushing was not too elevated. In the lower estuary, tidal flushing and low proximity to the input source (the Motupipi River catchment), meant a low vulnerability to sedimentation.

Such findings indicate that the issue of sedimentation of the Motupipi Estuary is a priority for further investigation and monitoring, as well as management.

3.5 DISEASE RISK

The findings from the disease risk assessment indicate that the Motupipi Estuary has "moderate" symptoms of disease risk. These symptoms have a detrimental effect on shellfish collection and possibly bathing but are unlikely to place stress on existing plant and animal communities. In the middle and lower estuary, the symptoms were "moderate" and restricted to likely exceedance of shellfish bacterial guidelines and occasionally bathing guidelines. In the upper estuary, the symptoms were restricted to moderate exceedance of bathing criteria, and a low risk for shellfish collection (because no shellfish are present).

Like eutrophication, the major stressors or cause of these disease risk issues, was attributed to contaminated terrestrial runoff from the primarily dairying catchment. The Motupipi River bacterial concentrations exceed water quality guidelines for NZ low elevation rivers (ANZECC 2000).

Motupipi Stream	*E. coli* 300-400 per 100ml
NZ Low elevation rivers (ANZECC 2000)	*E. coli* <126 per 100ml

In terms of the overall distribution of faecal bacteria in the estuary and the relationship with disease risk symptoms, the findings suggest that currently the symptoms are restricted to areas where dilution of inputs is low and/or residence time elevated (i.e. in upper estuary or in main channel of mid and lower estuary, particularly in the western arm). Elevated faecal bacteria and disease risk symptoms in the eastern arm are unlikely, due to high tidal flushing and relative remoteness from the main bacterial input (the Motupipi River).

Such findings indicate that the issue of disease risk of the Motupipi Estuary is a priority for further investigation and monitoring, as well as management.

3.6 TOXICITY

The findings from the toxicity assessment indicate that the Motupipi Estuary has "low" symptoms of toxicity (e.g. contaminated sediments or biota), and in terms of susceptibility, the estuary was rated has having a low overall susceptibility to toxicity based on its low likely input and flushing and spreading potentials. One area however does need additional investigation and that relates to the possibility of contaminated leachate entering the estuary from the old Rototai Landfill. A targeted monitoring investigation is recommended.

3.7 HABITAT LOSS

The findings from the habitat loss assessment indicate that the Motupipi Estuary has "moderate" symptoms of habitat loss, primarily loss of saltmarsh through past drainage and reclamation work, invasion of tidal flats and channel areas with Pacific oysters, invasion of estuary margin with iceplant, presence of flapgates restricting tidal access, and loss of natural margin buffers through landuse development. In terms of susceptibility, the Motupipi Estuary was rated as being moderately susceptible to further loss of saltmarsh through sea level rise and highly susceptible to loss of seagrass habitat in the upper estuary.

Such findings indicate that the issue of habitat loss in the Motupipi Estuary is a priority for further investigation and monitoring, as well as management.

4.0 MONITORING RECOMMENDATIONS

Because of the moderate-high overall susceptibility of the estuary to eutrophication, sedimentation, disease risk and habitat loss, as well as the very-limited extent of relevant monitoring data, a targeted monitoring programme is recommended. It should include:

- Mapping of estuary habitats so that any changes can be determined, particularly presence of macroalgal blooms, and areas of muddy sediments, saltmarsh and natural buffer vegetation.
- Determination of estuary condition through sediment monitoring.
- Determination of upper estuary water quality and presence of nuisance phytoplankton.
- Determination of water quality in the Motupipi River as it is the major determinant of estuary quality.
- Determination of the areas that are likely "hotspots" for contributing nutrients, sediment and pathogens to the estuary as the characteristics of the surrounding catchment (and the landuse undertaken within it) are major determinants of downstream conditions.

The detailed recommendations are outlined below:

1. Upper Estuary

Broad Scale Mapping	EMP Protocol broad scale mapping of upper estuary macroalgal % cover, seagrass % cover (including subtidal), saltmarsh % cover, RPD layer and unvegetated substrate type % cover (including subtidal areas).	Every 5 years (except macroalgae which is mapped annually).
Fine Scale Sediment Monitoring	EMP Protocol fine scale sediment monitoring at road bridge (i.e. site of phytoplankton blooms) of subtidal sediments for; total nitrogen, total phosphorus, organic carbon, indicator metals (Cd, Cr, Cu, Ni, Pb, Zn), grain size, (one composite sample of 3 replicates); as well as RPD layer, and macrofauna (3 replicates).	Annually for first 3 years to establish baseline then every 5 years.
Fine Scale Water Column Monitoring	Fine scale water column monitoring at one site (road bridge), for salinity, dissolved oxygen, total N, total P, chlorophyll-*a* and temperature at surface and near bottom of water column - also water clarity with secchi disc. In addition, if bloom conditions are visible, then identify dominant phytoplankton.	Monthly from September to April each year (target bloom periods by liaising with local observers).

2. Middle and Lower Estuary

Broad Scale Mapping	EMP Protocol broad scale annual mapping of estuary macroalgal % cover, seagrass % cover, saltmarsh % cover, RPD layer and unvegetated substrate type % cover (including subtidal areas).	Every 5 years (except macroalgae which is mapped annually).
Fine Scale Sediment Monitoring	EMP Protocol fine scale sediment monitoring at 2 sites (intertidal sites at western arm and eastern arm) for; total nitrogen, total phosphorus, organic carbon, indicator metals (Cd, Cr, Cu, Ni, Pb, Zn), grain size, as well as RPD layer, and macrofauna.	Annually for first 3 years to establish baseline then every 5 years.
Sedimentation Rate	Sedimentation rate monitoring at 2 representative mid-estuary sites using sedimentation plate methods.	Measure annually.
Old Landfill Monitoring	On one occasion monitor potential toxicants (metals and semi-volatile organic compounds) in sediments and shellfish adjacent to landfill.	One occasion.

TDC initiated broad scale monitoring of the entire estuary (including establishment of sedimentation plates) in September 2007, with the first year of the fine scale baseline monitoring of the middle estuary undertaken in February 2008.

4.0 MONITORING RECOMMENDATIONS (CONTINUED)

3. Catchment and River Monitoring

Identify Catchment "Hotspots"	Identify areas where a combination of different factors (e.g. landuse, land cover, slope, area, soil type, geology, rainfall, etc) highlight a high potential for immediate or potential inputs of nutrients, faecal bacteria and sediment. Use existing catchment data to identify "hotspots" such as erosion prone areas, easily mobilised sediment reserves etc. and target these for specific management.
Motupipi River Monitoring	Monitor suspended sediment, total N, total P and *E. coli* concentrations in the Motupipi River on at least three occasions during low flows, three during medium flows and hourly throughout three high flow events each year to better characterise likely loadings.

5.0 MANAGEMENT RECOMMENDATIONS

To limit the impact of stressors on the estuary, a number of management actions are recommended as follows:

Identify and Implement Catchment BMPs

- Catchment runoff was identified as one of the major stressors in Motupipi Estuary. To prevent avoidable inputs, best management practices should be identified and implemented to reduce runoff of sediment, nutrients and pathogens from catchment "hotspots".

TDC and Landcare Research, with Foundation for Research Science and Technology Envirolink funding, are currently working with farmers in the catchment to identify catchment nutrient sources and "hotspots", and to implement BMPs for reducing nutrient mobilisation and runoff to surface and groundwater.

Set Limits on Nutrient Inputs

- Because nutrient input was both high and strongly related to the eutrophication symptoms, it is recommended that catchment nutrient inputs be reduced. Currently the nitrogen input (as estuary areal load) is likely to be in the range 60-100 $mg.m^{-2}.d^{-1}$ which is elevated when compared with the 50 $mg.m^{-2}.d^{-1}$ upper limit suggested by Heggie (2006) for ensuring no eutrophication of temperate Australian estuaries. A Total Daily Maximum Load to the estuary of about 50 kgN/day (as opposed to the current input of 60-100 kg/day) is suggested as a preliminary guideline.

Establish Estuary Condition Ratings

- Estuary condition ratings for key indicators (e.g. area of macroalgae, area of soft mud, chlorophyll-*a* concentration, sediment toxicant concentrations) should be developed and used to facilitate reporting. Recommended condition ratings are presented in Technical Addendum 5.

Re-instate Margin Buffer

- Because of the importance of a natural vegetated margin around the estuary, it is recommended that a management plan be developed to encourage its re-establishment.

Fencing and replanting of parts of the upper estuary margin has recently begun.

6.0 CONCLUSIONS

The ecological vulnerability assessment shows that the Motupipi Estuary has high ecological values and is widely used by humans. Because of its relatively small size, dilution of incoming freshwater is limited which makes it susceptible to water and sediment quality problems, while salinity stratification during stable baseflows in the upper estuary makes it susceptible to nuisance phytoplankton blooms if nutrient inputs are elevated.

Much of the Motupipi Estuary was found to be in good condition (particularly the eastern arm). In terms of the five key issues that are likely to affect tidal lagoon estuaries (i.e. sedimentation, eutrophication, disease risk, toxicity and habitat loss), the findings from the vulnerability assessments indicate that the Motupipi Estuary has problems with eutrophication, and to a lesser extent, disease risk and sedimentation, but only minor impacts from habitat loss and toxicity. Where there are problems however, they are generally restricted to certain “at risk” locations within the estuary as follows:

- Upper estuary phytoplankton blooms and dissolved oxygen depletion.
- Upper, mid and lower estuary macroalgal blooms (primarily in the western arm).
- Middle estuary sedimentation (western arm mainly but increasing soft mud in eastern arm).
- Mid and lower estuary shellfish health risk.
- Upper, mid and lower estuary loss of the vegetated margin.
- Saltmarsh and seagrass degradation through eutrophication and sedimentation effects, as well as sea level rise (a potential issue in the future).
- Invasion by Pacific oyster and ice plant.

Based on the combination of poor existing condition in certain at-risk areas, the moderate susceptibility, and the moderate risk of the stressors causing issues, Motupipi Estuary was given a “moderate” overall ecological vulnerability rating.

Monitoring and management is recommended in order to address these issues.

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This survey and report has been undertaken with help from various people to whom we are very grateful:

- Local farmers who provided access to the estuary,
- Residents who provided valuable local knowledge,
- Maz Robertson (Wriggle) for reviewing, editing and fieldwork assistance,
- Tasman District Council staff (particularly Trevor James) who provided valuable information, assorted sampling equipment and field assistance,
- Andrew Fenemor (Landcare Research) for feedback on the draft report, and
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REFERENCES

ANZECC 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 Volume 1. National Water Quality Management Strategy Paper No.4. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Bartholdy, J. 2000. Process controlling import of fine-grained sediment to tidal areas: a simulation model. Coastal and Estuarine Environments: sedimentology, geomorphology and geoarchaeology, Geological Society Special Publication, 175, 13-30.

Boorman, L.A., Garbutt, A. & Barratt, D. (1998). The role of vegetation in determining patterns of the accretion of salt marsh sediment. In Black, K.S., Paterson, D.M. & Cramp, A. (eds) Sedimentary Processes in the Intertidal Zone . Geological Society, London, Special Publications 139: 389-399.

Bricker S.B., C.G. Clement, D. E. Pirhalla, S.P. Orlando, and D.R.G. Farrow. 1999. National Estuarine Eutrophication Assessment. Effects of Nutrient Enrichment in the Nation's Estuaries. NOAA, National Ocean Service, Special Projects Office and National Centers for Coastal Ocean Science, Silver Spring.

Burns, N. M.; Hume, T. M.; Roper, D. S.; Smith, R. K. 1990: Estuaries. In: Climate change: impacts on New Zealand – implications for the environment, economy and society. Wellington, Ministry for the Environment. Pp. 81–84

Church, T. M. 1975. Ed. Marine Chemistry in the Coastal Environment. American Chemical Society, Symposium Series, Vol. 18.

Deegan, L. A., A. Wright, S. G. Ayvazian, J. T. Finn, H. Golden, R. Rand Merson, and J. Harrison. 2002. Nitrogen loading from upland areas alters seagrass support of higher trophic levels. Aquatic Conservation: Freshwater and Marine Ecosystems 12: 193-212.

Deegan, L.A. 2002. Lessons Learned: The Effects of Nutrient Enrichment on the Support of Nekton by Seagrass and Salt Marsh Ecosystems. Estuaries, Volume 25, Issue 4, p.727-742.

Eisma, D. and Dijkema, K.S. 1997. The influence of salt marsh vegetation on sedimentation. In: Eisma, D (ed.), Intertidal Deposits. Boca Raton: CRC Press, 403-414.

Friedrichs, C. T. & Perry, J. E. 2001. Tidal Salt Marsh Morphodynamics: A Synthesis. Journal of Coastal Research, 27, 7-37.

Heggie, D. 2006. Clean or green –Nitrogen in temperate estuaries. Aus Geo News. Issue 81 .

Hinga, K.R., Jeon, H. and Lewis, N.F. 1995. Marine eutrohication review I: Quantifying the effects of nitrogen enrichment on phytoplankton in coastal ecosystems. NOAA Coastal Ocean Office, Silver Spring, MD, 36p

Huan-Xin Wenga, Ya-Chao Qina, Xiang-Wei Suna, Hailiang Dongb and Xiang-Hua Chen. 2007. Iron and phosphorus effects on the growth of Cryptomonas sp. (Cryptophyceae) and their availability in sediments from the Pearl River Estuary, China. Estuarine, Coastal and Shelf Science, Volume 73, Issues 3-4, July 2007, Pages 501-509

Hume, T.M., Snelder, T., Weatherhead, M., and Liefting, R. (in press). A controlling factor approach to estuary classification. Ocean and Coastal Management.

James, T. 2007. Water quality and aquatic ecology of the Motupipi catchment. Tasman District Council Report (Interim Draft 07001) 42p.

Kirk, R.M., and Lauder, G.A. 2000. Significant coastal lagoon systems in the South Island, NZ - coastal processes and lagoon mouth closure. Published by Department of Conservation.

Kjerfve, B. (Ed.) 1994: Coastal lagoon processes. Elsevier Oceanography Series 60. Elsevier, Amsterdam. 577p.

Lehman, P. W. 1996. Changes in Chl a concentration and phytoplankton community composition with water-year type in the upper San Francisco Bay Estuary, p. 351–374. In J. T. Hollibaugh [ed.], San Francisco.

Lehman, P. W. 2000. The influence of climate on phytoplankton community biomass in San Francisco Bay Estuary. Limnol. Oceanogr., 45(3), 2000, 580–590.

McLay, C. L. 1976: An inventory of the status and origin of New Zealand estuarine systems. Proceedings of the New Zealand Ecological Society 23: 8-26.

Mills, C.E. 2001. Jellyfish blooms: are populations increasing globally in response to changing ocean conditions?. Hydrobiologia 451: 55-68.

Ministry for the Environment (2003). Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment, Wellington. Updated June 2003.

Monbet, Y. 1992. Control of phytoplankton biomass in estuaries: A comparative analysis of microtidal and macrotidal estuaries. Estuaries 15(4), 563-571.

Moore, P.J., Ogle, C. C., Moynihan, K. T. 1984: Habitat requirements of wetland birds in the Lake Wairarapa wetlands, Wellington. New Zealand Wildlife Service, Dept. of Internal Affairs. (Occasional publication/New Zealand Wildlife Service, No. 5).

Nixon, S. W. 1995. Coastal marine eutrophication: A definition, social causes and future concerns. Ophelia 41:199-219.

REFERENCES (CONTINUED)

Ogle, C.C., Moss, T., Druce, A. P. 1990: Vascular flora of Lake Wairarapa and its adjacent wetlands, Wellington. Head Office, Dept. of Conservation, (Science and Research series) No. 20.

Pedersen MF, Borum J (1996) Nutrient control of algal growth in estuarine waters. Nutrient limitation and the importance of nitrogen requirements and nitrogen storage among phytoplankton and species of macroalgae. Mar Ecol Prog Ser 142:261–272.

Pendleton, E.A., Williams, S.J., and Thieler, E.R. , 2004, Coastal Vulnerability and Assessment of Fire Island National Seashore to Sea-Level Rise, U.S. Geological Survey Open-File Report 03-439 http://pubs.usgs.gov/of/2003/of03-439/

Pennings, S.C., Stanton, L.E. and Brewer, J.S. 2002. Nutrient Effects on the Composition of Salt Marsh Plant Communities Along the Southern Atlantic and Gulf Coasts of the United States. Estuaries Vol. 25, No. 6A, p. 1164–1173.

Pethick, J., An Introduction to Coastal Geomorphology, London, 1984.

Rapport, D. J. and W. G. Whitford. 1999. How ecosystems respond to stress. Bioscience 49:193-203.

Reynolds, C. S., AND J. B. Reynolds. 1985. The atypical seasonality of phytoplankton in Crose Mere, 1972: An independent test of the hypothesis that variability in the physical environment regulates community dynamics and structure. Br. Phycol. J. 20: 227–242.

Robertson, B., and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Prepared for Environment Southland.

Robertson, B.M. and Stevens, L. 2007a. Wairarapa Coastal Habitats: Mapping, Risk Assessment and Monitoring. Prepared for Greater Wellington Regional Council. 120p.

Robertson, B.M. and Stevens, L. 2007b. Wellington Harbour, Kapiti, Southwest and South Coasts - Risks and Monitoring. Prepared for Greater Wellington Regional Council. 57p.

Robertson, B.M. and Stevens, L. 2007c. Waikawa Estuary 2007 Fine Scale Monitoring & Historical Sediment Coring. Prepared for Environment Southland. 29p.

Robertson, B.M. and Stevens, L. 2007d. Aorere Sustainable Farming Project Preliminary Assessment of Coastal Issues. Prepared for Landcare Trust.

Robertson, B.M. and Stevens, L. 2008. Motupipi Estuary 2008 Fine Scale Monitoring. Prepared for Tasman District Council.

Robertson, B.M., Gillespie, P.A., Asher, R.A., Frisk, S., Keeley, N.B., Hopkins, G.A., Thompson, S.J., Tuckey, B.J. 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

Stevens, L. and Robertson, B.M. 2008. Motupipi Estuary 2008 Broad Scale Habitat Mapping. Prepared for Tasman District Council.

Swedish Environmental Protection Agency (2000) Environmental Quality Criteria - Coasts and Seas. Report 5052, 138 pp.

Thayer, G.W., W.J. Kenworthy, and M.S. Fonseca. 1984. The ecology of eelgrass meadows of the Atlantic coast: A community profile. US Fish Wildl. Serv. FWS/OBS-84/02. 147 pp.

UNESCO 2000. Guidelines for Vulnerability Mapping of Coastal Zones in the Indian Ocean. IOC Manuals and Guides No. 38.

Wells, J.T. and Coleman, J.M. 1987. Wetland loss and the subdelta life cycle. Estuarine Coastal and Shelf Science, 25(1), 111-125.

TECHNICAL ADDENDUM 1: VULNERABILITY MATRIX DETAILS

The assessment criteria for key components of the vulnerability matrix are as follows:

1. Human Uses

Information on the human uses and values of the estuary and its margins were based on local knowledge and available information. However, as formal consultation with key users (including iwi and DoC), was not undertaken, the overall accuracy of this component is imprecise. The human use rating is based primarily on the estimated number of persons involved:

Low:	< 10 per year.
Medium:	10 to 50 per year (< 30 per day in summer).
High:	> 30 per day (maybe just in summer) but < 200 per day.
Very High:	> 200 per day.

2. Ecosystem Richness (Values)

Ecosystem richness defines an ecosystem's natural riches (generally interpreted as habitat diversity and biodiversity). It can be supposed that the more rich and diversified an ecosystem is, the greater the losses will be in the event of a disruption. The ecological richness component is divided into four subcategories; birds, vegetation, fish and other biota. The ecosystem richness of the Motupipi Estuary was assessed based on expert opinion, observations during the field visit, and available literature.

3. Presence of Stressors (Pressures)

The stressors (or pressures) are activities (often in the catchment) that affect the ecological condition of coastal habitat (e.g. terrestrial runoff, grazing, seawalls, reclamation). Because their harmful effects cause a variety of environmental deteriorations they are identified and their risk characterised according to their estimated effect on relevant condition indicators (e.g. loss of saltmarsh, macroalgal growth). The assignment of risk is based on existing data (e.g. landuse, sediment and nutrient areal loadings, rock type, erosion susceptibility), observation, and expert opinion.

4. Ecosystem Existing Condition and Susceptibility

The **"existing condition"** is a measure or estimate of the existing condition of the coastal habitats as assessed by relevant condition indicators (e.g. signs of eutrophication, sedimentation, habitat loss). The existing condition of the coastal area was primarily assessed based on expert opinion, supported by available information and monitoring data.

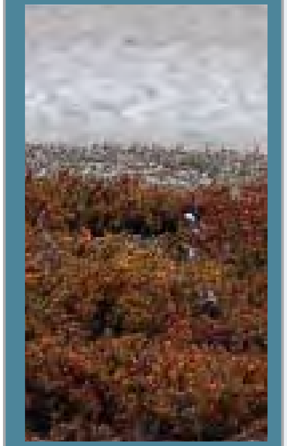
"Susceptibility" is assessed to provide an estimate of the susceptibility of the ecosystem to degradation. For example, an estuary where the mouth closes regularly and is poorly flushed, is physically susceptible to water and sediment quality degradation. Various tools were used to help determine the susceptibility of Motupipi Estuary, in particular flushing potential estimates and eutrophication susceptibility protocols (e.g. Bricker et al. 1999). Where uncertainty existed over the presence or potential impact of stressors, a conservative (protective) estimate was used.

5. Vulnerability Matrix and Monitoring Recommendations

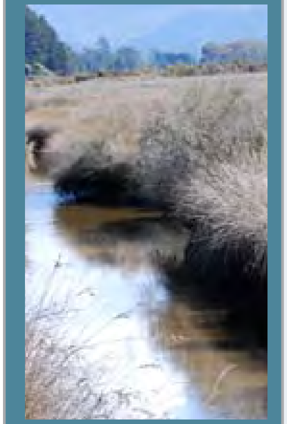
The combined information collected and assessed in components 1, 2, 3, and 4 is used to determine an overall "vulnerability" rating and identify the priority monitoring indicators. This information is then used to design a monitoring programme using various tools including those provided in the National Estuary Monitoring Protocol (Robertson et al. 2002) plus recent extensions developed by Wriggle (e.g. Robertson & Stevens 2007a, b). The risk assessment is designed as a framework to enable input by other parties and recalculation of risks, if required.

TECHNICAL ADDENDUM 2: HABITAT DETAILS

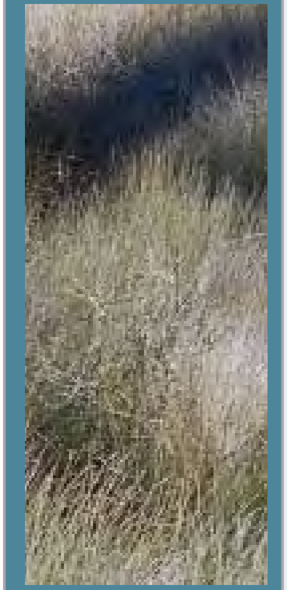
SALTMARSH HABITAT



Glasswort



Searush



Jointed wire rush

Description: A salt marsh is classified as being the intertidal area of fine sediment that has been transported by water and is stabilized by vegetation (Boorman et al., 1998). Extensive saltmarshes tend to be present if the coastal plain is gently sloping and wide (Freidrichs and Perry 2001), as in the Motupipi catchment. In general, marsh grasses cannot survive below mean tide level (the midway point between MLW and MHW) and are outcompeted by terrestrial plants above spring high tide (Pethick 1984). In Golden Bay, there are usually 4 distinct communities;

- a "rushland/sedge" community consisting of primarily searush (*Juncus kraussii*), oioi (*Apodasmia similis*) and three square (*Schoenoplectus pungens*);
- a "saltmarsh ribbonwood/rush" community consisting of a mix of saltmarsh ribbonwood (*Plagianthus divaricans*) and rushes;
- a "salt meadow" community consisting of small herb-like plants including, sea primrose (*Samolus repens*), remuremu (*Selliera radicans*), glasswort (*Sarcocornia quinqueflora*) and in more brackish areas batchelor's button (*Cotula coronapifolia*), leptinella (*Leptinella doica*), slender clubrush (*Isolepis cernua*) and arrow grass (*Triglochin striata*), and
- a "weed" community consisting of extensive patches of iceplant (*Carpobrotus edulis*), gorse and various introduced grasses.

Importance: Saltmarsh is one of the most productive environments on earth, and serve as important nursery grounds and wildlife habitat. They provide nutrients to surrounding areas, fuelling other marine food webs. These dynamic ecosystems provide tremendous additional benefits for humans including flood and erosion control, water quality improvements, opportunities for recreation and for atmospheric gas regulation - estuaries tend to be "carbon sinks," since carbon dioxide is absorbed in the photosynthesis carried out by the prolific plant growth.

Threats: Tidal salt marshes have the ability to respond rapidly to physical stressors, and their condition is often a dynamic balance between relative sea level rise, sediment supply and the frequency/duration of inundation (Freidrichs and Perry 2001). However, if sea level rises too much, or the sediment supply or inundation through flooding is excessive, then the balance can be upset and the saltmarsh is lost or its condition deteriorates. This balance varies between different types of estuaries but their response centres around how each reacts to sediment inputs and inundation (the latter is particularly important in face of predicted accelerated sea level rise through global warming).

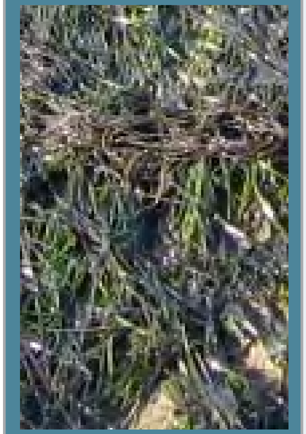
- **Sedimentation**: Sedimentation within saltmarshes is relatively high [approximately 5 times that of adjacent unvegetated flats (Eisma and Dijkema 1997)] with most of the sediment depositing close to the sediment source (e.g. tidal creek) or spread evenly if sourced from the main body of the estuary. Sedimentation rates increase with grass stem density and because most New Zealand saltmarsh plants tend to grow in dense stands [e.g. searush (*Juncus kraussii*) and oioi (*Apodasmia similis*)], sedimentation rates in NZ saltmarsh are expected to be relatively high. The increase in sedimentation and subsurface plant growth results in an elevation of bed level for most NZ estuaries.
- **Inundation**: The vulnerability to inundation of saltmarsh habitat in tidal lagoon estuaries of New Zealand is mainly from sea level rise. There are two processes by which sea level can increase relative to the marsh surface: (1) sea level rises because of increases in the volume of the oceans, and (2) the marsh surface sinks (subsides) because of soil compaction and other geologic processes [coastal fringe marshes with a thin layer of sediment deposits have low rates of sinking, whereas areas underlain with thick, unconsolidated sediments have higher subsidence rates (e.g. Mississippi delta)]. Under current conditions, we know that the majority of marsh environments tend to keep pace with sea level changes due to sedimentation and subsurface plant growth (Bartholdy, 2000). These environments are capable of responding very rapidly to changing conditions, be it sea level rise or alteration of current patterns. However, under an accelerated rate of sea-level rise it is expected that bed elevation through sedimentation will lag further behind relative sea-level rise and plant stress will increase until the plants die, the soil volume collapses, and the marsh becomes submerged. The vulnerability to saltmarsh decline is expected to vary between estuaries with different tidal ranges. The most vulnerable are the microtidal estuaries (those with a tidal range of less than 2 m) because a relatively small increase in sea level or decrease in sedimentation rate can submerge the marsh vegetation to a level that is too stressful for survival. Conversely, when sedimentation is high, microtidal marshes will expand seaward more quickly than systems in higher tidal ranges. This is because it takes relatively little upward growth to significantly reduce submersion, causing available suspended sediment to be deposited further seaward. The potential for massive marsh expansion in such systems in the presence of plentiful sediment is highlighted by historical mapping studies (Wells and Coleman 1987) which document horizontal marsh expansion rates of hundreds of meters per year on the Mississippi Delta, soon followed by equally remarkable marsh loss rates once the sediment supply decreased.

Saltmarsh is also vulnerable to increased nutrient inputs, particularly nitrogen. Added nutrients stimulate saltmarsh growth but, if excessive, may lower dissolved oxygen levels, change food web dynamics, alter community composition and stimulate the growth of algae and weeds (Deegan 2002, Pennings et al. 2002).

In addition, although the Water and Soil Conservation Act (1967) and the Resource Management Act (1991) introduced wide-ranging controls over the destruction of salt marshes and other wetlands, since 1967 the legacy of detrimental saltmarsh impacts remains visible in the undersized culverts below roads, railways and stopbanks that prevent adequate salt-water flow into these environments, and drainage and reclamation. The reduced salinity alters the plant community and facilitates the spread of the invasive species (e.g. reed *Phragmites australis*), which out-competes other salt marsh vegetation. Because of its lower habitat value for many species, biodiversity is reduced in areas where *Phragmites* becomes dominant. Docks and piers that span the width of the salt marsh shade the vegetation and can cause reduced growth rates or death of the plants.

TECHNICAL ADDENDUM 2: CONTINUED

SEAGRASS BEDS


Eelgrass.

Description: New Zealand has primarily one species of seagrass, *(Zostera muelleri),* called eelgrass. Apart from its common intertidal habitat, eelgrass can also grow as subtidal fringes in New Zealand estuaries if water clarity is high enough (i.e. there is sufficient light penetration). Eelgrass can grow in bottom sediments ranging from coarse sand to mud.

Importance: New Zealand eelgrass beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. They are one of the most productive marine habitat types and rival the productivity of intensively managed farmland (Thayer et al. 1984). They are also important for their role as a forerunner for the establishment of a saltmarsh on tidal mudflats. They promote sedimentation of muds and increasingly fertile underlying soils. When the soil becomes too fertile, the eelgrass can no longer grow, but salt marsh plants can (often beginning with salt meadow communities like glasswort, remuremu and sea primrose and/or searush communities).

Threats: These submerged plants need sunlight to survive. Decreased water clarity due to elevated sediment inputs and re-suspension are a direct threat as is direct smothering through excess sediment. Another widespread current threat comes from the excess input of nitrogen to estuaries which stimulate the growth of macroalgae and phytoplankton that shade out the seagrass. In terms of global warming impacts, it is predicted that eelgrass may be detrimentally affected by a rise in sea temperature (its tolerance to low salinities decreases as temperature increases - Burns et al. 1990). Sea level rise may also be detrimental in that plants become light limited as water depth increases. Seagrass beds are difficult to restore once they have become degraded.

MUD HABITAT

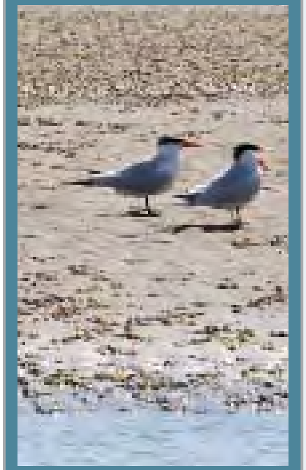

Intertidal mud flats.

Description: Mud flats are areas of unconsolidated fine-grained sediments that are either unvegetated or sparsely to densely vegetated by algae and/or diatoms. They are found in sheltered environments and support high biodiversity (snails, crabs, burrowing polychaete worms, shellfish and other macroinvertebrates). Most of the organisms inhabit the upper 10cm, because below that level, mud often becomes anoxic (low in oxygen or oxygen depleted). To adjust to these harsh physical conditions, many organisms build and maintain burrows or tubes to access oxygen in the air or water, or have adaptations such as siphons.

Importance: They provide a number of important ecosystem services including; primary and secondary production; habitat for polychaetes, crustaceans, flatfish and shellfish; refuge and nursery habitat for juvenile fish; and interception, uptake and processing of nutrients and contaminants from watershed drainage. Bacteria living in the sediments of estuaries can also help to break down certain pollutants.

Threats: The major threats are from agricultural and urban development and include: excessive sedimentation leading to infilling, contamination with toxicants and disease causing microbes, reclamation and drainage, building of structures, and spread of introduced species, e.g. Pacific oyster.

SAND HABITAT


Sandflats and Caspian Terns.

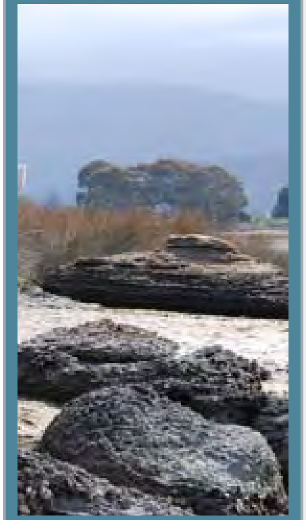
Description: This habitat includes both dune areas near the mouth and along the sand barrier spits, as well as extensive areas of sand flats in the main basin (which often include a mud or silt component and shell fragments) and sandy channel areas. In these highly dynamic environments, sand is moved by tides, winds, and storm surges, and this movement is responsible for shaping these habitats. Sand flats typically occur in higher energy areas than mud flats where the substrate is predominantly sand and is exposed to sorting from wave and current action.

Importance: Sand habitat tends to be the area most intensively used by humans for recreation. Shellfish, polychaetes, crustaceans and young fish are typical animals that inhabit sand flats. Sand channels generally occur in open, deeper areas where channels form. These open areas are typically inhabited by bivalve shellfish, polychaetes, young flat fish, and sand loving algae. They are also important for provision of refugia and food for anadromous, resident, and marine fishes, and transport of sediments.

Threats: Major threats are excessive sedimentation leading to muddy sediments and/or infilling, contamination with toxicants and disease causing microbes, reclamation and drainage, building of structures, and spread of introduced species. In addition, commercial and residential development on sand dunes, as well as by developing just landward of dunes, humans have prevented the natural movement of these landforms away from the sea. Trampling and grazing of dune vegetation can also lead to dune demise. Erosion can threaten sand beaches, especially when natural migration of sand is disrupted by jetties, groins, and seawalls. Off-road vehicles threaten sandy beach and sand flat inhabitants by compacting the sand, making burying and burrowing more difficult. These vehicles can also crush organisms that live just below the surface, and disturb crabs and nesting birds. Sand mining for beach nourishment poses a threat to communities inhabiting sandy bottoms, especially if large quantities of sand are continually removed from one area.

TECHNICAL ADDENDUM 2: CONTINUED

ROCK HABITAT


Rock habitat.

Description: Includes a range of larger material from solid rock ledges and boulders to cobble and gravel. This size regime strongly influences the composition of the biological community in the rocky habitat. A typical intertidal rock ledge community, for example, includes attached organisms with relatively long life spans (such as brown algae, anemones, barnacles, and mussels), while cobble beaches that are frequently disturbed by wave action tend to host small and ephemeral creatures, such as amphipods and isopods (e.g., beach hoppers and scuds). Rocky subtidal habitats commonly harbour seaweeds, crabs, sea urchins, and a variety of fish species. Some of the organisms found attached to rock ledges and boulders include mussels, oysters, limpets, chitons, and anemones. Finally, the biota of subtidal rocky habitats is distinct—many of the species found in these habitat types can only be found attached to rocky substrates.

Importance: The physical structure provided by both the rocks, and the plants and animals that adhere to them, provide valuable habitat for many other organisms, especially small invertebrates and juvenile fish. This structure is important for spawning and for providing protection from predation by larger organisms that cannot access the small spaces between rocks. Seaweed in the subtidal zone and the other algae in the intertidal zone are vitally important because they provide shelter and structure. Intertidal algae protect snails, mussels, barnacles, and crabs from exposure to sun, wind, rain, and predators when the tide is low. Because of their high productivity, algae in these rocky habitats also serve as important food source. The high abundance of animals that occur in subtidal rocky habitats also support larger species such as diving birds and large fish and humans that target these habitat types while fishing.

Threats: Coastal and catchment development can degrade rocky intertidal habitats, so that sediments accumulate on rocky shores. Human presence can damage habitat through trampling or excessive harvest. Rocky intertidal shores have been the subject of scientific scrutiny for decades and recent shifts in species distributions (i.e., declines in cold-tolerant species and increases in the relative abundance of warmer water species), which are potentially linked to climate change, have been documented.

SHELLFISH BEDS


Pipi bed lower estuary.

Description: In dense groupings, bivalve molluscs (e.g. mussels, cockles, oysters and pipi), form a habitat type known as shellfish beds. Small organisms, such as polychaete worms, juvenile crabs and snails find refuge in the spaces between the shells, while other organisms attach to the shells' hard surfaces, which provide an anchor unavailable in the surrounding soft sediments. Each species of bed-forming shellfish has different habitat requirements, which means that shellfish beds can be found in a range of depths, salinities, or substrates (surfaces, such as sand, rock, or mud).

Importance: Humans, crabs, fish, and seabirds all consume large quantities of shellfish. For coastal residents and tourists, collecting shellfish is an important pastime, while in some estuaries, shellfish beds support a significant commercial fishery. Through filter-feeding, shellfish improve water quality by removing suspended material and particulate pollutants from the water column. Shellfish beds also provide an important link between benthic (bottom) and pelagic (open water) habitats by capturing small food particles from the water column and transferring them to the benthos.

Threats: Intensification of landuse and excessive runoff of nutrients, sediment, pathogens and toxicants represent the largest threat to nearshore shellfish beds, through diminished water quality. Increased temperature through global warming is another significant threat. Overfishing of shellfish can also diminish their filtering function, potentially leading to increased turbidity (cloudiness due to sediments or other substances in the water) and diminished light penetration to the seafloor. Shellfish beds can be destroyed if they are dredged or if dredged material is deposited nearby or in upstream locations. Some introduced shellfish e.g. Pacific oyster can become nuisance organisms.

WATER COLUMN


Mullet in lower estuary.

Description: The water column is a dynamic environment subject to waves, currents, tides, and riverine influences. In New Zealand estuaries it is generally well supplied with sunlight and consequently phytoplankton (tiny plants suspended in the water column) are major primary producers. Phytoplankton include a wide range of species, but are generally dominated by diatoms in healthy waters. The water column also includes a variety of animal life including; zooplankton (tiny animals suspended in the water column), fish and jellyfish.

Importance:

Threats: Non-point source pollution is currently the greatest threat to estuary water quality. Harmful algal blooms (HABs) (which are caused by a superabundance of toxin-producing planktonic plants known as dinoflagellates) are also becoming increasingly prominent along the New Zealand coast. HABs can lead to shellfish closures through risk of shellfish poisoning in humans. Overfishing may also strongly influence the species found in the water column. For example, the dramatic increases in the abundance of jellyfish in coastal waters has been linked to the depletion of fish stocks. Many jellies eat similar food items as fish, and food that was formerly consumed by fish is now available for jellyfish (Mills 2001). Global climate change, and the associated change in weather and current patterns, pose another threat to water column habitats.

TECHNICAL ADDENDUM 3: VULNERABILITY ASSESSMENT

OVERVIEW

This addendum documents the information gathered on the Motupipi Estuary which has been used to apply the vulnerability ratings given to each of the following key components:

1. Human uses and values
2. Ecological richness
3. Presence of stressors (likely causes of estuary issues)
4. Existing condition and susceptibility to stressors

The rating scales used are based around three broad categories (Low, Moderate, High) designed to enable each issue to be evaluated and, based on the outcome, decisions made regarding what type and level of monitoring and management is appropriate. This is done by combining the information into a pre-developed Estuary Vulnerability Matrix (see Robertson & Stevens 2007) which summarises the ratings and includes the major issues and their monitoring indicators to identify monitoring and management priorities. Upper Estuary ratings are reported separately as this is a key focus of interest in the present study.

HUMAN USES AND VALUES (WHOLE ESTUARY AND UPPER ESTUARY)

Low	Moderate	High

Bathing	**Upper Estuary**	LOW or very little use.
	Whole Estuary	MODERATE use, near beach.
Shellfish collection	**Upper Estuary**	LOW. No known edible shellfish beds.
	Whole Estuary	HIGH potential use. Large numbers of edible shellfish present but likely to be contaminated.
Duckshooting/Fishing	**Upper Estuary**	MODERATE use. Popular for whitebaiting and some line fishing.
	Whole Estuary	MODERATE use. Fishing (especially with nets) is undertaken in the estuary mainly near the mouth and in tidal creeks for a variety of fish including, whitebait, mullet, kahawai, and flounder. The estuary is used for duck shooting.
Natural character and aesthetics	**Upper Estuary**	LOW-MODERATE natural character due to extensive past drainage and reclamation actions. Now highly modified but some bankside replanting being undertaken.
	Whole Estuary	HIGH natural character. A focal point locally. Water and surrounds important, pleasant odour.
Boating	**Upper Estuary**	LOW use by small canoes etc.
	Whole Estuary	MODERATE use.

ECOLOGICAL RICHNESS/VALUES (WHOLE ESTUARY AND UPPER ESTUARY)

Birdlife	**Upper Estuary**	Some use of saltmarsh and margin habitat by birds. Also waders use shallow margins as feeding habitat.
	Whole Estuary	Wide use. There's a wide variety of bird life in the area, especially waders, banded rail.
Vegetation	**Upper Estuary**	**Saltmarsh**: Low cover (Stevens & Robertson 2008). **Aquatic Macrophytes**: Extensive beds of seagrass (*Zostera muelleri*) growing subtidally and intertidally. **Phytoplankton**: Reported blooms of dinoflagellates. **Macroalgae**: Extensive green macroalgal blooms around margins and in channel.
	Whole Estuary	**Saltmarsh:** Extensive cover. **Aquatic Macrophytes**: Seagrass beds common. **Phytoplankton**: Likely to be low, dinoflagellate blooms near upper estuary at times. **Macroalgae**: Nuisance growths in western arm especially.
Biota (macro- invertebrates)	**Upper Estuary**	No data but expect wide diversity given broad range of habitats.
	Whole Estuary	Extensive, given broad range of habitats. Polychaetes, crabs, shellfish all common.
Fish	**Upper Estuary**	Fish (inanga, mullet), eels common.
	Whole Estuary	Wide range of fish species expected.

TECHNICAL ADDENDUM 3: CONTINUED

PRESENCE OF STRESSORS (WHOLE ESTUARY)

Issue	Indicators	Level of Expression ⬜ No problem 🟧 Moderate problem 🟥 Big problem
Terrestrial Runoff	🟥 **Nutrients, Sediment and Pathogens**	Catchment runoff of nutrients, sediment and pathogens is expected to be elevated based on the following: James (2007) classified the Motupipi River as having "consistently poor water quality", in particular high nutrient concentrations, moderately high concentrations of disease-causing organisms, and moderately high concentrations of fine sediment deposited on the river bed. The main causes being non-point source runoff from intensive landuse (primarily dairying at 2.7-3.4 cows/ha, 2000 cows in catchment). Guideline values for clarity, faecal coliforms, dissolved nutrients were generally exceeded and fine sediment deposits on the stream bed were extensive. Summary water quality data for the Motupipi River (median, max, min) are provided as follows (James 2007): DIN (1.5, 0.5, 2.8); DRP (0.028, 0.025, 0.085); *E. coli* (379, 10, 1000). NIWA (see maps on website) predict a high annual catchment N yield (>30 kg/ha/yr) and a moderate-low sediment yield (10-50 t/km^2/yr).
	⬜ **Heavy Metals**	No obvious sources in catchment. Except possibly the old Rototai Landfill.
	⬜ **SVOCs**	No obvious sources in catchment. Except possibly the old Rototai Landfill.
Point Source Discharges	⬜	Point source discharges are restricted to dairy effluent discharge and very occasional sewer overflows.
Margin Encroachment	🟥	HIGH - most estuary margins are developed for grazing and to a lesser extent forestry.
Reclamation, Drainage, Floodbanks, Floodgates	🟧	MODERATE reclamation and drainage of saltmarsh areas have been undertaken in the past (see Stevens and Robertson 2008). Flapgates on some culverts are also present but are usually left open. The major effects of these stressors are expected to be direct and indirect habitat loss.
Grazing in margins	⬜	Grazing amongst saltmarsh margins does not occur.
Man-made structures	⬜	Presence of seawalls, wharves and marinas is VERY LOW.
Spills	⬜	Low risk of spills.
Seafood Collection	🟧	Lots of edible shellfish in estuary but not sure how much is collected and consumed by humans - assume MODERATE.
Algal Blooms (sea)	⬜	LOW.
Aquaculture	⬜	LOW.
Invasive weeds/pests	⬜	LOW - but large uncertainty - some weeds growing in wetland areas, particularly gorse, also Pacific Oyster population is high.
Sea Level Rise	🟥	Barrier beach, estuary lagoon, salt marsh and tidal flats are all critical habitats that have HIGH or VERY HIGH vulnerability to sea level rise (Pendleton et al. 2004). Because all are present in the Motupipi Estuary and mean tidal range is also relatively low at around 1.5-1.8m in the lower estuary a VERY HIGH risk is assumed.
Fire	⬜	LOW.
Water Abstraction	⬜	LOW.
Vehicle Access	⬜	LOW.

SUSCEPTIBILITY AND EXISTING CONDITION (WHOLE ESTUARY)

This section assesses the susceptibility and condition of the estuary (whole estuary first and then upper estuary) to the key problems or issues that affect estuaries. The issues are as follows: Eutrophication, Sedimentation, Disease Risk, Toxicants and Habitat Loss. The approach adopted to assess the existing condition and susceptibility to the key estuarine issues uses a combination of expert opinion and available information to provide likely ratings (high, medium or low) for the following:

- Primary and Secondary Symptoms (existing condition symptoms, e.g. chlorophyll-*a* concentrations)
- Physical Susceptibility (physical susceptibility to stressors, e.g. potential to dilute and flush nutrients)
- Influence of Key Stressor (e.g. nutrients in the case of the eutrophication issue)
- Likely Future Outlook
- Likely Impact on Human Uses and Ecological Values

The results are summarised in Section 3 of the main report.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 1: Eutrophication: Whole Estuary

Issue	Indicators		Level of Expression
Issue 1: Eutrophication	**Issue 1. Eutrophication:** . The approach used to assess the existing condition and susceptibility to eutrophication follows the "Assessment of Estuarine Eutrophication Status" (ASSETS) methodology (Bricker et al. 1999), but with a strong emphasis on the use of primarily qualitative data and expert opinion. **Step 1:** Develop ratings for any existing eutrophication symptoms as follows:		
	Primary Symptoms	Chlorophyll-*a*	Chlorophyll-*a* concentration has not been measured but is likely to be "LOW" over middle and lower estuary. In the upper estuary, it is expected to be "HIGH" during periodic blooms of small flagellates and diatoms (often in spring after particularly high tides near the bridge at Abel Tasman Drive. The bloom manifests as a brown turbid layer, associated with high salinity bottom water. In May 2007, TDC collected a sample of this layer and found it to be dominated by unidentified small flagellates and the diatoms *Cymbella prostatum* and *Epithemia sorex*. This gives a "MODERATE" level of expression (Value = 0.5).
		Macroalgae	Nuisance macroalgal growth is present but at a relatively low spatial coverage (near main channels at the more saline end of the upper estuary). Frequency is periodic. This gives a "MODERATE" level of expression (Value = 0.5).
		Epiphytes	Benthic microalgal mats were not particularly visible in October 2007, but have not been measured. Assume moderate levels and episodic frequency. This gives a "MODERATE" level of expression (Value = 0.5).
		Primary Symptom Level of Expression	The level of expression of the primary symptoms for the upper estuary is determined by choosing the average of the three (taking likely area of cover into account). Primary symptom level of expression = 0.5 which rates as "MODERATE".
	Secondary Symptoms	Low Dissolved Oxygen	Water column DO has not been measured in the main or upper estuary. Outside of the upper estuary, DO levels are expected to be high. Low DO concentrations have been reported in the lower Motupipi River (Jan-Feb 2006 TDC monitoring data - James 2007). Taking a conservative stance, the upper estuary is expected to also have low oxygen levels at times and possibly anoxia and biological stress. In addition, sediment anoxia in this area is also possible. This gives an overall "LOW-MODERATE" level of expression (Value = 0.25).
		Seagrass Loss	Seagrass loss has not been measured. It is possibly low given the large beds in the upper estuary are thriving. A "LOW" level of expression is assumed (Value = 0.25).
		Nuisance and Toxic Blooms	No known toxic blooms but blooms of a phytoplankton species that causes nuisance conditions (persisting for days to weeks) for fishermen in the upper estuary do occur some years. This gives a "LOW-MODERATE" level of expression (Value = 0.25).
		Secondary Symptom Level of Expression	The level of expression of the secondary symptoms for the estuary is determined by choosing the highest of the three estuary level symptom expression values (depleted dissolved oxygen, seagrass loss, and nuisance/toxic blooms). Secondary symptom level of expression "MODERATE" (Value= 0.5)
	Overall Level of Expression of Eutrophic Conditions		MODERATE. Primary symptoms moderate and some secondary symptoms becoming expressed, indicating substantial eutrophication problems but may be localised to at-risk areas.
	Step 2: Rate the physical susceptibility of the estuary to eutrophication. This is achieved by considering firstly its ability to dilute nutrients (dilution potential) and secondly by its ability to flush nutrients (flushing potential) as follows;		
	Export Potential/Susceptibility	Dilution Potential	Dilution potential (DP) measures the potential for the estuary to dilute incoming nutrients based purely on its volume. The Motupipi Estuary is relatively small by New Zealand standards (100 ha in area and with a mean depth of around 1m gives it an estuary volume of approximately 1 million m^3). DP = 1/volume of upper estuary = 1/1,000,000 =1 x 10^{-6} which gives a "LOW" level of expression rating for dilution (i.e. the potential for the estuary to dilute incoming nutrients is low). For the upper estuary, the dilution potential is much less, and for the more isolated salt wedge component it is even lower.
		Flushing Potential	Flushing potential (FP) measures the ability of an estuary to flush nutrients and is based on the assumption that flushing increases with tidal range and/or freshwater flow. FP is given by the ratio of freshwater inflow (m^3/day)/estuary volume (m^3). Mean monthly freshwater inflows were approximately 0.5 m^3/s (i.e. 0.5 x 86400 = 43,200 m^3/d). Therefore FP = 43,200/1,000,000 = 0.043. For the macrotidal Motupipi Estuary, this high tidal range, and high ratio of freshwater inflow to upper estuary volume puts it in the "HIGH" Flushing Potential category (i.e. a high potential to flush nutrients and phytoplankton from the upper estuary) - although it is very close to being moderate. It must be remembered that this is just a physical measure of the ability to flush a load of nutrients out of the upper estuary. In the Motupipi Estuary such strong flushing means that phytoplankton are unlikely to spend enough time in the estuary to grow to bloom proportions (phytoplankton require >3 days to double size but nearly all of the estuary water leaves the estuary each tide), unless there are localised areas in the upper estuary where flushing is poor, e.g. in poorly mixed pools.
	Overall Export Potential and Susceptibility		The combination of low dilution and high flushing potential gives a "MODERATE" overall ability to dilute and flush nutrients. This means the Motupipi Estuary has the ability to flush nutrients but not to dilute them. In the upper estuary, the overall ability to dilute and flush nutrients is "LOW", because there are localised areas where flushing is poor (high salinity bottom water where a salt wedge develops). As a consequence, it may experience all three primary symptoms of eutrophication; phytoplankton blooms, and nuisance macroalgae and benthic microalgal conditions.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 1: Eutrophication: Whole Estuary (continued)

Issue	Indicators		Level of Expression
Issue 1: Eutrophication (continued)	**Step 3**: Rate the influence of nutrients on the estuary as follows:		
	Human or Nutrient Influence	Nutrient Influence	Nitrogen (N) is generally the limiting nutrient in estuaries. Levels of N measured in the Motupipi River are very high (James 2007). NIWAs website provides a map of likely nitrogen yields based on Sparrow Model outputs for New Zealand catchments. For the Motupipi catchment the estimate is VERY HIGH at >30 kgN/ha/yr. Two approaches are used below to assess the nutrient influence. **1. Calculations for the influence of nutrients on the estuary using the ASSETS approach (Bricker et al. 1999) are as follows:** • Assume 30 ‰ = Salinity of estuary (Se); 32 ‰ = Salinity of ocean (So). • Nitrogen concentration in inflow to the estuary (river input data from TDC - James 2007). (Nin) = 1.5 mg/L (but may be 2). • Nitrogen concentration of the ocean (Nsea) = 0.02 mg/L assumed • Background nitrogen concentration (Nb) = Nsea(Se/So) = 0.02x30/32 = 0.02 • Human derived nitrogen concentration (Nh) = Nin (So-Se)/So = 1.5 (32-30)/32 =0.09 • Expected total N concentration (Nc) = Nh + Nb = 0.09 + 0.02= 0.11 • INFLUENCING FACTORS (IF) Formula = Nh/(Nb + Nh) = 0.09/0.02+0.09 = 0.8 which corresponds to "Moderate-High" nutrient input score. If the Nin was 2 mg/l the score would be "High". For the upper estuary, IF = 1 which gives it a "High" score. **2. Comparing Estuary Concentration Estimates with Guideline Criteria.** • **Phytoplankton Criteria:** High phytoplankton growth (>10ug/l chlorophyll-*a*) is common in microtidal estuaries when the annual average dissolved inorganic N (DIN) concentrations exceed 200 ug/l (Monbet 1992). For macrotidal estuaries, the blooms are common when concentrations exceed 2,000ug/l. However, if water residence time is < 3days, then bloom concentrations are unlikely. Motupipi Estuary water residence time in the middle and lower estuary is <1 day, which means phytoplankton blooms are unlikely in these areas (either during low flows or high flows). However, in the upper estuary where residence time is much greater in the salt wedge area and such concentrations are almost certainly exceeded, there is a high risk of phytoplankton blooms in that location. • **Nuisance Macroalgal Criteria**: Nuisance growths of macroalgae are common in estuaries where mean DIN concentrations exceed 200 ug/l (Pederson and Borum (1997) found DIN at 200 ug/l to be growth saturating for sea lettuce). In the Motupipi Estuary, such concentrations are only likely throughout the estuary during high flows. For the rest of the time, such concentrations are only exceeded in the upper and middle (western arm) estuary areas, particularly in and close to the low tide channels.
	Overall Human or Nutrient Influence		Combining the "MODERATE" flushing and dilution potential with the "MODERATE - HIGH" nutrient influence equates to a "MODERATE" or "MODERATE - HIGH" overall susceptibility of the estuary to eutrophication problems. This means that the symptoms observed in the estuary are moderately to highly related to nutrient additions. For the upper estuary, the symptoms are "highly" related to nutrient inputs.
	Step 4: Estimate the likely future outlook for nutrient inputs as follows;		
	Future Nutrients	Future Nutrient Influence	The main source of nutrients to the estuary is currently from non-point catchment runoff and leachate (primarily dairying). Pressure to reduce catchment nutrient yields from dairying landuse is a national priority at present. But given the past inaction in this area, and ongoing population expansion, a conservative approach is recommended of assuming that the future nutrient load remains the same or increases.
	Step 5: Estimate the likely effect of the current eutrophication symptoms on human uses and ecological values of the upper estuary as follows;		
	Effect on Human Uses and Ecological Values	Effect on Human Uses	The major existing impact on human uses of the estuary from eutrophication symptoms is to fishermen, particularly whitebaiters, fishing in the upper estuary. Phytoplankton blooms make seeing the fish difficult and can clog nets. The resulting low water clarity and abnormal colour of the water also reduces aesthetic values. The presence of macroalgal blooms in the main channels and around the banks of the main estuary reduces aesthetic values.
		Effect on Ecological Values	The secondary symptoms of macroalgal blooms in the main channels and around the banks of the main estuary alters sediment chemistry (primarily nutrient enrichment and oxygen depletion) and consequently changes macrofaunal communities. The secondary symptoms of low dissolved oxygen (in water column and sediments) and reduced water clarity from phytoplankton blooms would place stress on existing plant and animal communities within the upper estuary. Such symptoms would be most severe in the summer periods when water temperatures are at their peak.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 2: Sedimentation: Whole Estuary

		Indicators	Level of Expression
Issue 2: Sedimentation	**Issue 2: Sedimentation:** The approach used to assess the existing condition and susceptibility to sedimentation is similar to that used for "eutrophication" but lacks the more rigorous foundation used to determine overall ratings of eutrophication. Instead, expert opinion and available information is used to provide likely ratings. **Step 1:** Develop ratings for any existing sedimentation symptoms as follows:		
	Primary Symptoms	Low Clarity	Water clarity has not been measured but observations suggest that it is likely to be in the medium category (1-3m). Water clarity in upper estuary is generally good at stable baseflows, (spring-fed catchment) with most of the estuary bed generally being visible at high water in most locations (except for low clarity associated with phytoplankton blooms). During high flows, clarity is reduced. Overall a "LOW" level of expression is attributed to sediment associated clarity symptoms.
		Excessive Sedimentation Rate	Sedimentation rates have not been measured but are likely to be elevated. Some localised areas of very soft muds are present where high levels of sedimentation are likely, particularly along the banks of the main channel near the old landfill. Overall a "MODERATE" rating is assumed.
		Area of Soft Mud	Areas of soft mud have been mapped in October 2007. Overall, soft muds occupied much of the upper estuary intertidal area which places it in a "MODERATE" category.
		Primary Symptom Rating	The level of expression of the primary symptoms of sedimentation for the upper estuary is determined by choosing the average of the three (taking likely area of cover into account). An overall primary symptom rating of "MODERATE" has been applied.
	Secondary Symptoms	Seagrass Loss	Seagrass loss is assumed to be low given the large beds in the upper estuary are thriving. This gives a "LOW" rating for the influence of sediment on these beds.
		Macro-invertebrate community change	Increased muddiness changes the types of animals found in the estuary sediments. No macro-invertebrate monitoring has yet been undertaken in the estuary. The first sampling will begin in February 2008. At this stage it is assumed that there has been a "MODERATE" change in community composition given the area of soft mud already present in the estuary.
		Secondary Symptom Rating	The level of expression of the secondary symptoms for the estuary is determined by choosing the highest of the two estuary level symptom expression values (seagrass loss, and macro-invertebrate community change). Secondary symptom rating is therefore "MODERATE."
	Overall Sedimentation		MODERATE. There is substantial evidence of existing sedimentation symptoms.
	Step 2: Rate the physical susceptibility of the estuary to sedimentation. This is achieved by considering firstly its ability to spread sediment and secondly by its ability to flush sediment as follows:		
	Export Potential/Susceptibility	Spreading (Dilution) Potential	Sediment dilution potential measures the potential for an estuary to dilute and spread incoming sediment - the larger the estuary area, the greater the potential for spreading. With an area of 100ha, which is relatively small, the ability to spread the input sediment in the estuary is therefore rated as low.
		Flushing Potential	Sediment flushing potential (FP) measures the ability of an estuary to flush sediment and is based on the assumption that flushing increases with tidal range and/or freshwater flow. Its flushing potential (FP) is given by the ratio of freshwater inflow(m^3/day)/estuary volume (m^3). Mean monthly freshwater inflows were approximately 0.5 m^3/s (i.e. 0.5 x 86400 = 43,200 m^3/d). Therefore FP = 43,200/1,000,000 = 0.043. For a macrotidal estuary like Motupipi, this small freshwater inflow in relation to estuary volume gives it a high ratio which puts it in the "HIGH" flushing potential category (i.e. a high potential to flush sediments from the estuary).
	Overall Export Potential and Susceptibility		The combination of low spreading and high flushing potential gives a "MODERATE" overall ability to spread and flush sediment. This means the Motupipi Estuary has a strong ability to flush sediment but not to spread it and also it may have localised areas where flushing is poor and sedimentation is elevated.
	Step 3: Rate the influence of human sourced sediment on the estuary as follows:		
	Sediment Influence	Sediment Influence	The major source of sediment to the estuary is assumed to be from the Motupipi River. Based on the low turbidity readings from the Motupipi River automatic recorder (TDC website) during stable baseflows and the predominantly spring-fed catchment, levels of suspended sediment are likely to be low during baseflows. However, because much of the catchment has been cleared of bush, sediment runoff during high rainfall events is expected to be moderate to high. As a consequence the sediment influence rating for the estuary is assumed to be "MODERATE".
	Overall Sediment Influence		Combining the "Moderate" flushing and spreading potential with the "MODERATE" sediment influence equates to a "MODERATE" overall susceptibility of the estuary to sedimentation problems. This means that the muddy areas in the estuary are likely to be the result of the limited ability of the estuary to spread and dilute incoming sediment as well as elevated input loads during rain events.

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 2: Sedimentation: Whole Estuary (continued)

		Indicators	Level of Expression
Issue 2: Sedimentation (cont.)	**Step 4:** Estimate the likely future outlook for sediment inputs as follows:		
	Future Sediment	Future Sediment Influence	The main source of sediment to the estuary is currently from non-point catchment runoff during rain events. Pressure to reduce catchment sediment yields from agricultural and urban landuse is a national priority at present. But given the past inaction in this area, and ongoing population expansion, a conservative approach is recommended of assuming that the future sediment load remains the same or increases.
	Step 5: Estimate the likely effect of the current sedimentation symptoms on human uses and ecological values of the estuary as follows;		
	Effect on Human & Ecological Values	Effect on Human Uses	The major existing impact on human uses of the estuary from sedimentation symptoms is to people walking in the estuary and being deterred by large areas of soft mud, and its effect on lowering water clarity.
		Effect on Ecological Values	The presence of large and increasing areas of muddy sediments are likely to lead to major and detrimental ecological changes (e.g. loss of seagrass beds, shift in macroinvertebrate community).

Issue 3: Disease Risk: Whole Estuary

Issue 3: Disease Risk	The approach adopted to assess the existing condition and susceptibility to disease risk symptoms uses a combination of expert opinion and available information to provide likely ratings. **Step 1:** Develop ratings for any existing sedimentation symptoms as follows:		
	Primary Symptoms	Faecal Bacteria Exceed Bathing Guidelines	The faecal indicator bacteria, *E. coli* (*Escherichia coli*) is commonly used to assess human disease risk. It can both cause disease and indicate the presence of other disease causing organisms (e.g. *Cryptosporidium* and *Campylobacter*). Ministry for Environment (2003) Guidelines for freshwater (and estuarine) contact recreation are 550/100ml (alarm level) and 260/100ml (alert level). ANZECC (2000) guideline is median should not exceed 150/100ml. Although monitoring has not been undertaken in the estuary, *E. coli* concentrations in the Motupipi River (2000 to 2005) range from 100-1000/100ml with 25% of baseflow samples exceeding alarm level guidelines. The median concentration in the river was 379/100ml which was double that of the ANZECC guideline. In terms of predicting *E. coli* concentrations in the estuary, some preliminary estimates based on tidal height can be made as follows (assuming "best case" dilution is 50-100 fold if river input is fully mixed with high water estuary volume and "worst case" dilution is 0-5 fold): Estimated *E. coli* concentrations are given in Technical Addendum 4. Overall a "MODERATE" level of expression is attributed to symptoms of exceedance of bathing guidelines.
		Faecal Bacteria Exceed Stockwater Guidelines	Stockwater drinking guidelines (1000 faecal coliforms/100mls, ANZECC 1992) were exceeded only during or following rainfall events in the Motupipi River. Because of its saltiness and poor accessibility, the estuary is unlikely to be used for stockwater except in the upper estuary. The upper estuary may on occasion exceed the stockwater guideline, particularly during rain events. Overall a "LOW" level of expression is attributed to symptoms of exceedance of stockwater guidelines.
		Faecal Bacteria Exceed Shellfish Guidelines	Edible shellfish (pipis, cockles, and mussels) are only present in the lower estuary, with oysters also present there and in the west arm of the middle estuary. The guideline for human consumption of shellfish is the median faecal coliform content not to exceed 14/100 ml, and not more than 10% of samples should exceed 43/100 ml (Ministry for Environment 2003). Based on the estimates of estuary bacterial concentrations made above in the bathing criteria section of this table and assuming *E. coli* and faecal coliform concentrations are similar, it is likely that shellfish criteria in the lower estuary will be exceeded often, (most of the time at low tide, and during high river flows at high tide). Overall a "HIGH" level of expression is attributed to symptoms of exceedance of shellfish guidelines.
		Primary Symptom Rating	The level of expression of the primary symptoms of sedimentation for the upper estuary is determined by choosing the average of the three (taking likely area of cover into account). An overall primary symptom rating of "MODERATE" has been applied.
	Secondary Symptoms	Reported Disease	No known reports of waterborne disease to humans through swimming or eating shellfish from the estuary or nearby coastal waters.
		Reported Stock Disease	No known reports of waterborne disease to stock through drinking from the estuary.
		Secondary Symptom Rating	The level of expression of the secondary symptoms for the estuary is determined by choosing the highest of the two secondary symptom expression values. Secondary symptom rating is therefore "LOW."
	Overall Disease Risk Condition Rating		MODERATE. There is substantial evidence to indicate disease risk symptoms.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 3: Disease Risk: Whole Estuary (continued)

	Indicators		Level of Expression
Issue 3: Disease Risk (continued)	**Step 2:** Rate the physical susceptibility of the estuary to disease risk. This is achieved by considering firstly its ability to dilute faecal bacteria and secondly by its ability to flush faecal bacteria as follows:		
	Export Potential Susceptibility	Dilution Potential	"LOW" (same as for eutrophication).
		Flushing Potential	"HIGH" (same as for eutrophication, but because shellfish filter feed they can concentrate faecal bacteria and pathogens from the water column).
	Overall Export Potential and Susceptibility		The combination of low dilution and high flushing potential gives a "MODERATE" overall ability to dilute and flush faecal bacteria. This means the Motupipi Estuary has a strong ability to flush faecal bacteria but not to dilute it, and also it may have localised areas where flushing is poor and faecal bacteria are elevated.
	Step 3: Rate the influence of faecal bacteria on the estuary as follows:		
	Faecal Bacteria Influence	Faecal Bacteria Influence	The major source of faecal bacteria to the estuary is assumed to be from the Motupipi River. Because of the absence of monitoring data, the influence of faecal bacteria on the estuary was estimated previously in the existing symptoms section of the Disease Risk table on the previous page. This estimate suggests that the faecal bacteria influence rating for the estuary is "MODERATE".
	Overall Faecal Bacteria Influence		Combining the "MODERATE" flushing and diluting potential with the "moderate" faecal bacteria influence equates to a "MODERATE" overall susceptibility of the estuary to disease risk problems. This means that the elevated faecal levels in the estuary are likely to be the result of the limited ability of the estuary to dilute incoming faecal bacteria as well as the elevated input loads.
	Step 4: Estimate the likely future outlook for faecal bacterial inputs as follows:		
	Future Faecal Bacteria	Future Faecal Bacteria Influence	The main source of faecal bacteria to the estuary is currently from non-point catchment runoff during rain events. Pressure to reduce catchment faecal bacteria yields from agricultural and urban landuse is a national priority at present. But given the past inaction in this area, and ongoing population expansion, a conservative approach is recommended of assuming that the future faecal bacterial load remains the same or increases.
	Step 5: Estimate the likely effect of the current faecal bacterial symptoms on human uses and ecological values of the estuary as follows;		
	Effect on Human Uses and Ecological Values	Effect on Human Uses	The major existing impact on human uses of the estuary from faecal bacterial symptoms is to people collecting shellfish for consumption, bathing near the beach, boating, playing in the sand and paddling.
		Effect on Ecological Values	The presence of faecal bacteria are not expected to influence ecological values.

Issue 4: Toxicants: Whole Estuary

		Indicators	Level of Expression
Issue 4: Toxicants		Heavy Metals and SVOCs	No measurements but also no obvious significant sources in catchment (except possibly the old Rototai landfill). Existing condition is therefore good and susceptibility is "LOW" based on low dilution potential, high flushing potential, low toxicant inputs and low future potential.
		Toxic algae	LOW-MODERATE risk of ocean sources of toxic algae. Existing condition is therefore GOOD and susceptibility is LOW based on low dilution potential, high flushing potential, low toxic algal inputs and low future potential.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 5: Habitat Loss and Biodiversity: Whole Estuary

	Indicators	Level of Expression
Issue 5: Habitat Loss & Biodiversity	Saltmarsh/Wetland	MODERATE past reclamations of saltmarsh habitat. Risk of further reclamations unknown. Existing condition of saltmarsh is "GOOD". Susceptibility of saltmarsh to stress is "MODERATE" based on moderate presence of stressors (sediment, nutrients, sea level rise) and low dilution potential and high flushing potential. Existing condition is therefore "MODERATE TO HIGH" (some saltmarsh present) and susceptibility to further change is "MODERATE".
	Aquatic Macrophytes Seagrass	Submersed aquatic macrophytes are present in both the upper and middle estuary. Existing condition is "GOOD". Susceptibility of seagrass beds to stress is "LOW-MODERATE" based on moderate presence of stressors (low clarity during upper estuary phytoplankton blooms, sedimentation, nutrient enrichment and anoxic sediments and sea level rise) and low dilution potential and high flushing potential.
	Tidal Flats	Symptoms "MODERATE"; invasion of tidal flats in middle and lower estuary with Pacific oysters and macroalgal blooms.
	Margin buffer	Most of 200m margin with the estuary and saltmarsh and dune areas is already highly modified (grassland and forest). Existing condition is therefore "POOR" but susceptibility to further change is "LOW".
	Shellfish (edible)	Existing condition of shellfish beds is expected to be "GOOD". Susceptibility of shellfish beds to stress is low-moderate based on moderate presence of stressors (anoxic sediments, sedimentation, macroalgal blooms and sea level rise) and low dilution potential and high flushing potential.
	Fish	Existing condition of fish populations is expected to be "GOOD" except for upper estuary. Susceptibility of fish populations to stress is "LOW-MODERATE" based on moderate presence of stressors (particularly anoxic sediments, sedimentation, macroalgal blooms, phytoplankton blooms in upper and mid estuary) and low dilution potential and high flushing potential.
	Benthic Invertebrates	Existing condition of benthic invertebrates is expected to be "GOOD" except for upper estuary. Susceptibility of macroinvertebrates to stress is "LOW-MODERATE" in the main estuary and moderate to high in the upper estuary.
	Invasive Species	No major invasive plant species have been identified. Pacific oysters are abundant in the lower and mid estuary. Existing condition is "MODERATE" and susceptibility to further change is "LOW-MODERATE".

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 1: Eutrophication: Upper Estuary

Issue	Indicators		Level of Expression
Issue 1: Eutrophication	**Issue 1. Eutrophication:** . The approach used to assess the existing condition and susceptibility to eutrophication follows the "Assessment of Estuarine Eutrophication Status" (ASSETS) methodology (Bricker et al. 1999), but with a strong emphasis on the use of primarily qualitative data and expert opinion. **Step 1:** Develop ratings for any existing eutrophication symptoms as follows:		
	Primary Symptoms	Chlorophyll-*a*	Chlorophyll-*a* concentration not measured but likely to be elevated during periodic blooms of small flagellates and diatoms (often in spring after particularly high tides). Near the bridge at Abel Tasman Drive, a brown turbid layer, associated with high salinity bottom water, often forms. In May 2007, TDC collected a sample of this layer and found it to be dominated by unidentified small flagellates and the diatoms *Cymbella prostatum* and *Epithemia sorex*. In November 2007, a similar bloom occurred again and was dominated by Cryptophyte flagellates. The bloom extends throughout the upper estuary area. Spatial coverage and frequency of blooms are therefore rated as high. This gives a "HIGH" level of expression (Value = 1.0).
		Macroalgae	Nuisance macroalgal growth is present but at a moderate spatial coverage (near main channels at the more saline end of the upper estuary). Frequency is periodic. This gives a "MODERATE" level of expression (Value = 0.5).
		Epiphytes	Benthic microalgal mats were not particularly visible in October 2007, but have not been measured. Assume moderate levels and episodic frequency. This gives a "MODERATE" level of expression (Value = 0.5).
		Primary Symptom Level of Expression	The level of expression of the primary symptoms for the upper estuary is determined by choosing the average of the three (taking likely area of cover into account). Primary symptom level of expression = 0.66 which rates as "HIGH".
	Secondary Symptoms	Low Dissolved Oxygen	Water column DO in the upper estuary was <1 mg/l on 4 December 2007 in bottom water (salinity 24-28ppt) during a Cryptophyte bloom. Low DO concentrations have been reported in the lower Motupipi River (Jan-Feb 2006 TDC monitoring data - James 2007). The upper estuary therefore has low oxygen levels at times and possibly anoxia and biological stress. In addition, sediment anoxia in this area is also present. This gives a "MODERATE" level of expression (Value = 0.5).
		Seagrass Loss	Seagrass loss has not been measured but is under threat due to shading from phytoplankton blooms and increasing anoxia in sediments and bottom water. As a result there may be some loss, so a conservative "MODERATE" level of expression is assumed (Value = 0.5).
		Nuisance and Toxic Blooms	No known toxic blooms but blooms of a phytoplankton species that causes nuisance conditions (persisting for days to weeks) for fishermen in the upper estuary do occur. This gives a "MODERATE" level of expression (Value = 0.5).
		Secondary Symptom Level of Expression	The level of expression of the secondary symptoms for the estuary is determined by choosing the highest of the three estuary level symptom expression values (depleted dissolved oxygen, seagrass loss, and nuisance/toxic blooms). Secondary symptom level of expression is "MODERATE" (Value= 0.5)
	Overall Level of Expression of Eutrophic Conditions		MODERATE - HIGH. Primary symptoms high and substantial secondary symptoms becoming more expressed, indicating potentially serious eutrophication problems.
	Step 2: Rate the physical susceptibility of the estuary to eutrophication. This is achieved by considering firstly its ability to dilute nutrients (dilution potential) and secondly by its ability to flush nutrients (flushing potential) as follows;		
	Export Potential/Susceptibility	Dilution Potential	Dilution potential (DP) measures the potential for the upper estuary to dilute incoming nutrients based purely on its volume. The Upper Motupipi Estuary is relatively small by New Zealand standards (2 ha in area and with an estimated mean depth of around 1m gives it an upper estuary volume of approximately 0.02 million m^3). DP = 1/volume of upper estuary = 1/20,000 = 5 x 10^{-5} which gives a "LOW" rating for dilution (i.e. the potential for the upper estuary to dilute incoming nutrients is low).
		Flushing Potential	Flushing potential (FP) measures the ability of an estuary to flush nutrients and is based on the assumption that flushing increases with tidal range and/or freshwater flow. FP is given by the ratio of freshwater inflow (m^3/day)/upper estuary volume (m^3). Mean monthly freshwater inflows were approximately 0.5 m^3/s (i.e. 0.5 x 86400 = 43,200 m^3/d). Therefore 43,200/20,000 = 2.16. For the Upper Motupipi Estuary, this high ratio of freshwater inflow to upper estuary volume puts it in the "HIGH" Flushing Potential category (i.e. a high potential to flush nutrients and phytoplankton from the upper estuary). However, because of the salt wedge effect in the upper estuary under stable baseflows, the bottom water is poorly flushed. An overall "MODERATE" rating is therefore given for flushing potential. This means that phytoplankton have localised areas where they are trapped and can grow to bloom proportions.
	Overall Export Potential and Susceptibility		In the upper estuary, the overall ability to dilute and flush nutrients is "LOW", because dilution potential is low and there are localised areas where flushing is poor (high salinity bottom water where a salt wedge develops). This means the Upper Motupipi Estuary has the ability to flush nutrients but not to dilute them and also it may have localised areas where flushing is poor and nutrients are elevated. As a consequence, it may experience all three primary symptoms of eutrophication; phytoplankton blooms, nuisance macroalgae, and benthic microalgal conditions.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 1: Eutrophication: Upper Estuary (continued)

Issue	Indicators		Level of Expression
Issue 1: Eutrophication (continued)	**Step 3**: Rate the influence of nutrients on the upper estuary as follows:		
	Human or Nutrient Influence	Nutrient Influence	Nitrogen is generally the limiting nutrient in estuaries but in upper estuary areas it may also be phosphorus. Levels of N and P measured in the Motupipi River are very high (James 2007). NIWAs website provides a map of likely nitrogen yields based on Sparrow Model outputs for New Zealand catchments. For Motupipi catchment the estimate is very high at >30 kgN/ha/yr. However, the nutrient influence in the upper estuary is difficult to determine. A likely scenario is the following: The surface low salinity layer will likely have high nutrient concentrations, similar to river inputs. Nitrogen concentration in inflow to the estuary (river input data from TDC - James 2007), (Nin) = 1.5 mg/L (but may be 2). Within the high salinity bottom water of the salt wedge (throughout most of upper estuary) the nutrient content will vary depending on exchange with surface water N and sediment nutrient release - but also could be elevated at times. However, because the primary source of the high salinity water is from the sea (which has a low N concentration), the nutrient content of this layer will tend to be lower. As such, the nutrient influence is rated as "HIGH".
	Overall Human or Nutrient Influence		Combining the "MODERATE" flushing and dilution potential with the "HIGH" nutrient influence equates to a "MODERATE to HIGH" overall susceptibility of the upper estuary to eutrophication problems. This means that the symptoms observed in the upper estuary are moderately to highly related to nutrient additions.
	Step 4: Estimate the likely future outlook for nutrient inputs as follows;		
	Future Nutrients	Future Nutrient Influence	The main source of nutrients to the upper estuary is currently from non-point catchment runoff and leachate (primarily dairying). Pressure to reduce catchment nutrient yields from dairying landuse is a national priority at present. But given the past inaction in this area, a conservative approach is recommended of assuming that the future nutrient load remains the same.
	Step 5: Estimate the likely effect of the current eutrophication symptoms on human uses and ecological values of the upper estuary as follows;		
	Effect on Human Uses and Ecological Values	Effect on Human Uses	The major existing impact on human uses of the upper estuary from eutrophication symptoms is to fishermen, particularly whitebaiters. Phytoplankton blooms make seeing the fish difficult and can clog nets. The resulting low water clarity and abnormal colour of the water also reduces aesthetic values.
		Effect on Ecological Values	The secondary symptoms of low dissolved oxygen (in water column and sediments) and reduced water clarity from phytoplankton blooms would place stress on existing plant and animal communities within the upper estuary. Such symptoms would be most severe in the summer periods when water temperatures are at their peak.

Issue 2: Sedimentation: Upper Estuary

Issue	Indicators		Level of Expression
Issue 2: Sedimentation	**Issue 2: Sedimentation:** The approach used to assess the existing condition and susceptibility to sedimentation is similar to that used for "eutrophication" but lacks the more rigorous foundation used to determine overall ratings of eutrophication. Instead, expert opinion and available information is used to provide likely ratings. **Step 1:** Develop ratings for any existing sedimentation symptoms as follows:		
	Primary Symptoms	Low Clarity	Water clarity in the upper estuary is generally good at stable baseflows, with most of the estuary bed generally being visible at high water in most locations (except for low clarity associated with phytoplankton blooms). During high flows, clarity is reduced. Overall a "LOW" level of expression is attributed to sediment associated clarity symptoms.
		Excessive Sedimentation Rate	Sedimentation rates have not been measured but are likely to be elevated. Some localised areas of very soft muds are present where high levels of sedimentation are likely, particularly along the banks of the main channel near the old landfill. Overall a "MODERATE" rating.
		Area of Soft Mud	Areas of soft mud have been mapped in October 2007. Overall, soft muds occupied much of the upper estuary area (particularly the shallow margins) which places it in a "MODERATE" category.
		Primary Symptom Rating	The level of expression of the primary symptoms of sedimentation for the upper estuary is determined by choosing the average of the three (taking likely area of cover into account). An overall primary symptom rating of "MODERATE" has been applied.
	Secondary Symptoms	Seagrass Loss	Seagrass loss is assumed to be low given the large beds in the upper estuary are thriving. This gives a "LOW" rating for the influence of sediment on these beds.
		Macro-invertebrate community change	Increased muddiness changes the types of animals found in the estuary sediments. No macro-invertebrate monitoring has yet been undertaken in the upper estuary. At this stage it is assumed that there has been a "MODERATE" change in community composition given the area of soft mud already present in the estuary.
		Secondary Symptom Rating	The level of expression of the secondary symptoms for the estuary is determined by choosing the highest of the two estuary level symptom expression values (seagrass loss, and macro-invertebrate community change). Secondary symptom rating is therefore "MODERATE".
	Overall Sedimentation		MODERATE. There is substantial evidence of existing sedimentation symptoms.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 2: Sedimentation: Upper Estuary (continued)

Issue	Indicators		Level of Expression
Issue 2: Sedimentation (continued)	**Step 2:** Rate the physical susceptibility of the estuary to sedimentation. This is achieved by considering firstly its ability to dilute nutrients (dilution potential) and secondly by its ability to flush nutrients (flushing potential) as follows:		
	Export Potential/ Susceptibility	Spreading (Dilution) Potential	Sediment spreading potential measures the potential for the upper estuary to spread incoming sediment - the larger the upper estuary area, the greater the potential for spreading. The Upper Motupipi Estuary is relatively small by New Zealand standards (2 ha in area). The ability to spread the input sediment in the upper estuary area is therefore rated as "LOW".
		Flushing Potential	"HIGH" Flushing Potential category (i.e. a high potential to flush sediment from the upper estuary).
	Overall Export Potential and Susceptibility		The combination of low spreading and high flushing potential gives a "MODERATE" overall ability to spread and flush sediment. This means the Upper Motupipi Estuary has the ability to flush sediment but not to spread them and also it may have localised areas where flushing is poor and sedimentation is elevated.
	Step 3: Rate the influence of human sourced sediment on the upper estuary as follows:		
	Sediment Influence	Sediment Influence	The major source of sediment to the upper estuary is assumed to be from the Motupipi River. Based on the low turbidity readings from the Motupipi River automatic recorder (TDC website), levels of suspended sediment are likely to also be low. As a consequence the sediment influence rating for the upper estuary is assumed to be "LOW".
	Overall Sediment Influence		Combining the "moderate" flushing and spreading potential with the "low" sediment influence equates to a "MODERATE to LOW" overall susceptibility of the upper estuary to sedimentation problems. This means that the muddy areas in the upper estuary are likely to be the result of the poor ability of the upper estuary to spread and dilute incoming sediment rather than elevated input loads.
	Step 4: Estimate the likely future outlook for sediment inputs as follows:		
	Future Sediment	Future Sediment Influence	The main source of sediment to the upper estuary is currently from non-point catchment runoff. Pressure to reduce catchment sediment yields from intensive landuse practices is a national priority at present. Extensive riparian planting is being undertaken to assist with sediment retention. A conservative approach is recommended of assuming that the future sediment load remains the same.
	Step 5: Estimate the likely effect of the current sedimentation symptoms on human uses and ecological values of the upper estuary as follows:		
	Effect on Human Ecological Values	Effect on Human Uses	The major existing impact on human uses of the upper estuary from sedimentation symptoms is to fishermen, particularly whitebaiters, who notice increased muddiness of the estuary banks and bed.
		Effect on Ecological Values	The secondary symptoms of increasing muddiness of estuary banks and subtidal areas alter the plant and animal communities within the upper estuary. Such symptoms are currently rated as having a moderate effect on ecological values.

Issue 3: Disease Risk: Upper Estuary

Issue	Indicators		Level of Expression
Issue 3: Disease Risk	The approach adopted to assess the existing condition and susceptibility to disease risk symptoms uses a combination of expert opinion and available information to provide likely ratings. **Step 1:** Develop ratings for any existing sedimentation symptoms as follows:		
	Primary Symptoms	Faecal Bacteria Exceed Bathing Guidelines	Bathing guidelines exceeded in river and upper estuary based on low levels of dilution available. Overall a "MODERATE" level of expression is attributed to symptoms of exceedance of bathing guidelines.
		Faecal Bacteria Exceed Stockwater Guidelines	The upper estuary may on occasion exceed the stockwater guideline, particularly during rain events. Overall a "LOW" level of expression is attributed to symptoms of exceedance of stockwater guidelines.
		Faecal Bacteria Exceed Shellfish Guidelines	No edible shellfish in upper estuary.
		Primary Symptom Rating	The level of expression of the primary symptoms of sedimentation for the upper estuary is determined by choosing the average of the three (taking likely area of cover into account). An overall primary symptom rating of "MODERATE" has been applied.
	Secondary Symptoms	Human Disease	No known reports of waterborne disease to humans through swimming or eating shellfish from the estuary or nearby coastal waters.
		Reported Stock Disease	No known reports of waterborne disease to stock through drinking from the estuary.
		Secondary Symptom Rating	The level of expression of the secondary symptoms for the estuary is determined by choosing the highest of the two secondary symptom expression values. Secondary symptom rating is therefore "LOW".
	Overall Disease Risk Condition Rating		MODERATE. There is substantial evidence to indicate disease risk symptoms.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 3: Disease Risk - Upper Estuary (continued)

	Indicators		Level of Expression
Issue 3: Disease Risk (continued)	**Step 2:** Rate the physical susceptibility of the upper estuary to disease risk. This is achieved by considering firstly its ability to dilute faecal bacteria and secondly by its ability to flush faecal bacteria as follows:		
	Export Potential Susceptibility	Dilution Potential	"LOW" (same as for eutrophication).
		Flushing Potential	"HIGH" (same as for eutrophication).
	Overall Export Potential and Susceptibility		The combination of low dilution and high flushing potential gives a "MODERATE" overall ability to dilute and flush faecal bacteria. This means the upper Motupipi Estuary has a strong ability to flush faecal bacteria but not to dilute them.
	Step 3: Rate the influence of faecal bacteria on the estuary as follows:		
	Faecal Bacteria Influence	Faecal Bacteria Influence	The major source of faecal bacteria to the estuary is assumed to be from the Motupipi River. Because of the absence of monitoring data in the upper estuary, the influence of faecal bacteria on the estuary has been estimated in Appendix 3. This estimate suggests that the faecal bacteria influence rating for the upper estuary is "moderate" (i.e. 5-400 FC/100ml during baseflows).
	Overall Faecal Bacteria Influence		Combining the "moderate" flushing and diluting potential with the "moderate" faecal bacteria influence equates to a "Moderate" overall susceptibility of the upper estuary to disease risk problems. This means that the elevated faecal levels in the upper estuary are likely to be the result of the limited ability of the estuary to dilute incoming faecal bacteria as well as the elevated input loads.
	Step 4: Estimate the likely future outlook for faecal bacterial inputs as follows:		
	Future Faecal Bacteria	Future Faecal Bacteria Influence	The main source of faecal bacteria to the upper estuary is currently from non-point catchment runoff during rain events. Pressure to reduce catchment faecal bacteria yields from agricultural and urban landuse is a national priority at present. But given the past inaction in this area, and ongoing population expansion, a conservative approach is recommended of assuming that the future faecal bacterial load remains the same or increases.
	Step 5: Estimate the likely effect of the current faecal bacterial symptoms on human uses and ecological values of the estuary as follows:		
	Effect on Human Uses and Ecological Values	Effect on Human Uses	The major existing impact on human uses of the upper estuary from faecal bacterial symptoms is to people fishing in the upper estuary, and to stock.
		Effect on Ecological Values	The presence of faecal bacteria are not expected to influence ecological values.

Issue 4: Toxicants - Upper Estuary

		Indicators	Level of Expression
Issue 4: Toxicants		Heavy Metals and SVOCs	No measurements but also no obvious significant sources in catchment (except possibly the old Rototai landfill). Existing condition is therefore good and susceptibility is low based on low dilution potential, high flushing potential, low toxicant inputs and low future potential.
		Toxic algae	Low-moderate risk of ocean sources of toxic algae. Existing condition is therefore GOOD and susceptibility is low based on low dilution potential, high flushing potential, low toxic algal inputs and low future potential. However, the possibility does exist for toxic flagellate blooms in the upper estuary.

TECHNICAL ADDENDUM 3: CONTINUED

SUSCEPTIBILITY AND EXISTING CONDITION (CONTINUED)

Issue 5: Habitat Loss and Biodiversity: Upper Estuary

	Indicators	Level of Expression
Issue 5. Habitat Loss and Biodiversity	Saltmarsh/Wetland	Past reclamations of wetland habitat likely. Presently small patches of saltmarsh at lower end of upper estuary only. Existing condition of saltmarsh/wetland is "MODERATE". Susceptibility of saltmarsh to stress is moderate based on moderate presence of stressors (sediment, nutrients, sea level rise) and low dilution potential and high flushing potential.
	Aquatic Macrophytes Seagrass	Submersed aquatic macrophytes are present in the upper estuary. Existing condition is "GOOD". Susceptibility of seagrass beds to stress is "HIGH" based on presence of stressors (low clarity during upper estuary phytoplankton blooms, sedimentation, nutrient enrichment and anoxic sediments and sea level rise) and low dilution potential and high flushing potential.
	Margin buffer	Most of 200m margin with the upper estuary is already highly modified (grassland). Existing condition is therefore "POOR" but susceptibility to further change is "LOW".
	Shellfish (edible)	No edible shellfish in upper estuary.
	Fish	Existing condition of fish populations is expected to be "POOR" at times in upper estuary. Susceptibility of fish populations to stress is "MODERATE" based on moderate presence of stressors (particularly anoxic sediments, sedimentation, macroalgal blooms, phytoplankton blooms in upper estuary) and low dilution potential and high flushing potential.
	Benthic Invertebrates	Existing condition of benthic invertebrates is expected to be "POOR" for upper estuary. Susceptibility of macroinvertebrates to stress is "HIGH" in the upper estuary.
	Invasive Species	No major invasive plant species have been identified in the upper estuary. Existing condition is "GOOD" and susceptibility to further change is "LOW-MODERATE".

TECHNICAL ADDENDUM 4: NUTRIENTS/BACTERIA DILUTION AND DISPERSION

In order to determine likely impacts of nutrients, and faecal bacteria on various parts of the estuary, it was necessary to firstly carry out desktop dilution calculations and to identify likely guideline criteria to minimize eutrophication and disease risk issues (see tables below).

The desktop dilution calculations were undertaken by measuring the salinity at high tide in various locations in the estuary to estimate the likely freshwater fraction (or dilution) at each location. The freshwater fraction was assumed to originate from the major freshwater input, i.e. the Motupipi River.

By combining this information with the likely residence time for various sections of the estuary, it was possible to estimate nutrient and faecal bacterial concentrations. These concentrations were then compared with relevant guideline criteria to determine susceptibilities to disease risk and eutrophication.

Upper Estuary		
	Baseflows	High flows
Residence time	> 1 week bottom <1 day surface	<1 day
Mean Salinity (HW) ppt Bottom Water	26 measured	<1 assumed
Mean Salinity (LW) ppt Bottom Water	26 measured	<1 assumed
% Freshwater HW Bottom Water	16%	99%
% Freshwater LW Bottom Water	16%	99%
Ocean Input N (mg/l)	0.04	0.1
River Input N (mg/l)	1.5	1.5
River Input *E. coli* /100mls	380 (100-1000)	3,000
Upper Estuary TN @HW (mg/l)	0.25 plus sediment release N - assume same as surface @ 0.8-1.0	1.5 mean
Upper Estuary TN @LW (mg/l)	0.25 plus sediment release N - assume same as surface @ 0.8-1.0	1.5 mean
Upper Estuary *E. coli* per 100mls @HW	50 mean	3,000 (but likely to be higher)
Upper Estuary *E. coli* per 100mls @LW	50 mean	3,000 (but likely to be higher)
Middle Estuary - Western Arm		
	Baseflows	High flows
Residence time	< 1 day	<1 day
Mean Salinity (HW) ppt	25 measured	10 assumed
Mean Salinity (LW) ppt	15 measured	<1 assumed
% Freshwater HW	19%	60%
% Freshwater LW	35%	85%
Ocean Input N (mg/l)	0.04	0.1
River Input N (mg/l)	1.5	1.5
River Input *E .coli* /100mls	380 (100-1000)	3,000
Middle Estuary Western Arm TN @HW (mg/l)	0.3 mean	0.9 mean
Middle Estuary Western Arm TN @LW (mg/l)	0.5 mean	1.3 mean
Middle Estuary Western Arm *E. coli* per 100mls @HW	76 mean	1,800
Middle Estuary Western Arm *E. coli* per 100mls @LW	125 mean	2,500

TECHNICAL ADDENDUM 4: CONTINUED

Middle Estuary - Eastern Arm		
	Baseflows	High flows
Residence time	< 1 day	<1 day
Mean Salinity (HW) ppt	27 measured	16 assumed
Mean Salinity (LW) ppt	23 measured	<1 assumed
% Freshwater HW	12%	50%
% Freshwater LW	25%	85%
Ocean Input N (mg/l)	0.04	0.1
River Input N (mg/l)	1.5	1.5
River Input *E. coli* /100mls	380 (100-1000)	3,000
Middle Eastern Arm TN @HW (mg/l)	0.2 mean	0.75 mean
Middle Eastern Arm TN @LW (mg/l)	0.4 mean	1.3 mean
Middle Eastern Arm *E. coli* per 100mls @HW	45 mean	1,500
Middle Eastern Arm *E. coli* per 100mls @LW	80 mean	2,500
Lower Estuary		
	Baseflows	High flows
Residence time	< 1 day	<1 day
Mean Salinity (HW) ppt	28 measured	16 assumed
Mean Salinity (LW) ppt	25 measured	<1 assumed
% Freshwater HW	10%	50%
% Freshwater LW	20%	85%
Ocean Input N (mg/l)	0.04	0.1
River Input N (mg/l)	1.5	1.5
River Input *E. coli* /100mls	380 (100-1000)	3,000
Lower Estuary TN @HW (mg/l)	0.18 mean	0.75 mean
Lower Estuary TN @LW (mg/l)	0.4 mean	1.3 mean
Lower estuary *E. coli* per 100mls @HW	38 mean	1,500
Lower estuary *E. coli* per 100mls @LW	80 mean	2,500

Detail	Proposed Guideline Limits
Nuisance macroalgal growths (sea lettuce)	Guideline = Nitrate and ammonia concentration in water column. The growth saturating concentration for sea lettuce is nitrate-N >0.18 mg/l, ammonia-N >0.09 mg/l (Pederson and Borum 1997). If these concentrations are present in the overlying water and other factors (i.e. temperature, availability of substrate, wind, light, grazing) are not limiting, then summer blooms are likely. A conservative assumption is made that nitrate-N and ammonia-N accounts for the majority of the TN in the Motupipi Estuary and River input.
Nuisance phytoplankton growths	Guideline = Nitrate or chlorophyll concentration in water column. ANZECC (2000) low risk trigger levels for nitrate-N is 0.01-0.1 mg/l and for chlorophyll-*a* 1.5-5 ug/l. USEPA guidelines for estuaries and coastal waters give low risk if chlorophyll-*a* <5ug/l. In Port Phillip Bay (Sth Australia), eutrophic conditions occurred when chlorophyll-*a* reached 15ug/l. Swedish estuary and marine water quality criteria (Swedish EPA 2000) indicate high risk if TN >0.36 mg/l.
Disease risk to bathers	Ministry for Environment (2003) *E. Coli*. Guidelines for freshwater (and estuarine) contact recreation are 550/100ml (alarm level) and 260/100ml (alert level). ANZECC (2000) guideline is median should not exceed 150/100ml.
Disease risk to shellfish consumers and aquaculturists	The median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a Most Probable Number (MPN) of 14/100 ml, and not more than 10% of samples should exceed an MPN of 43/100 ml (using a five-tube decimal dilution test). A conservative assumption is made that *E. coli*. and faecal coliform concentrations in the Motupipi Estuary and River input are the same.
Excessive sedimentation	Excessive sedimentation occurs when the area and/or depth of soft mud increases beyond natural or acceptable levels. These levels are generally set on a site specific basis.

TECHNICAL ADDENDUM 5:
EXAMPLE OF ESTUARY CONDITION RATINGS

OVERVIEW

RATING
Very Good
Good
Fair
Poor
Early Warning Trigger

At present, there are no formal criteria for rating the overall condition of estuaries in NZ, and development of scientifically robust and nationally applicable condition ratings requires a significant investment in research and is unlikely to produce immediate answers.

Robertson and Stevens (2006, 2007) have proposed a series of interim broad and fine scale estuary condition ratings to help Environment Southland interpret monitoring data collected on Southland's estuaries. The interim condition ratings (presented below) are based on a review of monitoring data, use of existing guideline criteria (e.g. ANZECC (2000) sediment guidelines), and expert opinion. They indicate whether monitoring results reflect poor, fair, good, or very good conditions, and also include an "early warning trigger" to indicate where rapid or unexpected change occurs.

For each of the condition ratings, a recommended monitoring frequency is proposed and a recommended management response is suggested. In most cases the management recommendation is simply to develop a plan to further evaluate an issue and consider what response actions may be appropriate.

At this stage, the interim condition ratings reflect the best guidance able to be provided based on the available information and budget. It is expected that the proposed ratings will continue to be revised and updated as better information becomes available, and new ratings developed for other indicators e.g. macroinvertebrate (infauna and epifauna). The proposed interim condition ratings for Motupipi Estuary based on the Southland ratings are presented below along with a brief rationale for their use.

Metals

Heavy metals provide a low cost preliminary assessment of toxic contamination in sediments and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for the presence of other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

METALS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established
Good	<ISQG-Low	Monitor at 5 year intervals after baseline established
Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source
Poor	>ISQG-High	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Nitrogen

In shallow estuaries like the Motupipi, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Good	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Fair	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Poor	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

TECHNICAL ADDENDUM 5: CONTINUED

Total Phosphorus

In shallow estuaries like the Motupipi, the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Good	200-500mg/kg	Monitor at 5 year intervals after baseline established
Fair	500-1000mg/kg	Monitor at 2 year intervals and manage source
Poor	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients, and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Good	1-2%	Monitor at 5 year intervals after baseline established
Fair	2-5%	Monitor at 2 year intervals and manage source
Poor	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Macroalgal Percent Cover

Certain types of macroalgae can grow to nuisance levels in nutrient-enriched estuaries causing sediment deterioration, oxygen depletion, bad odours and adverse impacts to biota.

MACROALGAE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	%cover <1%. No nuisance conditions	Monitor at 5 year intervals after baseline established
Good	%cover 1-10%. No nuisance conditions	Monitor at 5 year intervals after baseline established
Fair	%cover 10-50%. Isolated nuisance conditions	Monitor yearly. Initiate Evaluation & Response Plan
Poor	%cover >50%. Widespread nuisance conditions	Monitor yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Trend of % cover increasing	Initiate Evaluation and Response Plan

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	<1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-5mm/yr	Monitor at 5 year intervals after baseline established
Moderate	5-10mm/yr	Monitor at 5 year intervals after baseline established
High	10-20mm/yr	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>20mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan