

# A mouthful of mud: the fate of contaminants from the Fitzroy River, Queensland, Australia and implications for reef water policy

Robert Packett<sup>1,2</sup>

1 National Action Plan for Salinity and Water Quality, 209 Bolsover St Rockhampton, Qld, 4702, [www.wqonline.info/index.html](http://www.wqonline.info/index.html), [robert.packett@nrw.qld.gov.au](mailto:robert.packett@nrw.qld.gov.au)

2 Queensland Department of Natural Resources and Water (postal and email address as above)

## Abstract:

It is widely accepted that contaminants in storm runoff and flood waters can cause a decline in the health of coral reef ecosystems. The Fitzroy River catchment in Central Queensland, Australia is thought to contribute substantial amounts of contaminants to the Great Barrier Reef (GBR) lagoon. Just how much of this material actually reach the GBR lagoon is not well understood. To help address this knowledge gap a moderate flood in the Fitzroy River was intensively sampled 60km upstream of the river mouth, and at the river mouth and along the flood plume at near peak discharge. The upstream sampling site proved to be a poor indicator of the actual suspended sediment load delivered to the GBR lagoon. About 90% of the suspended sediment was being deposited close to the river mouth, in comparison, a high percentage of dissolved nutrients were transported into the GBR lagoon. Reef water quality policy may need to take the sediment trapping efficiency of estuaries into account. These findings will be useful in validating catchment and receiving waters models and for informing target setting mechanisms aimed at meeting reef water quality policy.

## Key Words:

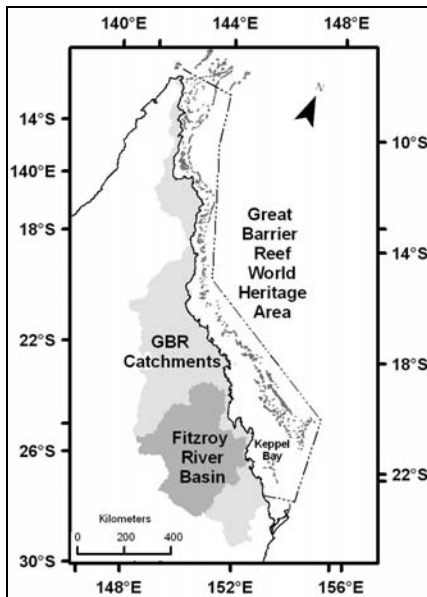
Load monitoring, flood plumes, estuary sediments, target setting, coastal rivers, catchment management

## Introduction:

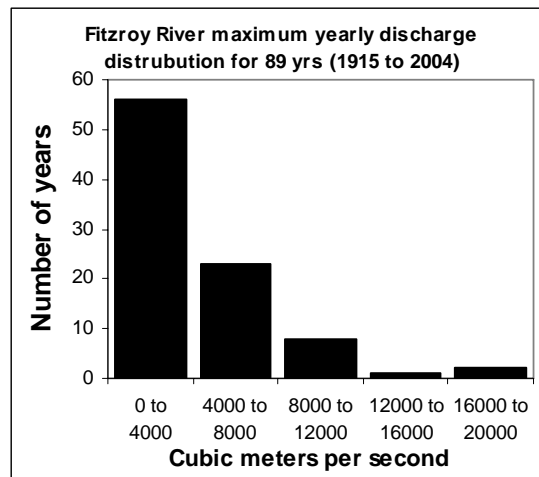
It is well documented that coral reef systems can be adversely affected by contaminants in flood waters from catchments which have undergone significant development. In recent years there have been changes in both state and federal government policy towards improving water quality from GBR catchments (The State of Queensland and Commonwealth of Australia, 2003). Natural Resource Management organisations are now required to demonstrate how funds spent on improving catchment management and condition will result in halting the decline in the quality of water delivered to the GBR lagoon. Water quality targets for certain contaminants are required to be developed based on historical data and monitoring for end of catchment loads. Future trends in water quality are then to be compared to these targets so that the success of changes in catchment management can be assessed. Water quality monitoring of GBR catchments is usually carried out near the most downstream gauging station on the freshwater system. These sampling locations are often well upstream of the mouth of the river and load calculations based on these sites may not take the contaminant trapping capacity of the lower flood plains and estuaries into account. Reef water quality policies regarding the setting of targets for flood contaminants may have to allow for the sediment trapping capacity of estuaries. If the delivery of contaminants to the GBR lagoon is the primary objective, monitoring at the most downstream gauge site may be a poor indicator of the true load delivered to the lagoon.

## *The study area*

The Fitzroy basin is a large sub-tropical catchment (~ 142,000 km<sup>2</sup>) that drains to the of east coast of Queensland, Australia (Figure 1). Dominant land use is cattle grazing (~80%). Total annual discharge is highly variable and most floods from the catchment usually occur during summer in one or two events. The maximum recorded discharge rate (n = 89 yrs) is around 20,000 cubic metres per second (m<sup>3</sup>/s), however, the majority of maximum yearly discharge rates are usually below 4,000 m<sup>3</sup>/s (Figure 2). A barrage constructed at Rockhampton in 1971 now forms the head of the estuary, with freshwater upstream and saltwater downstream of the barrage, except in flood conditions. During floods, gates on the barrage are raised allowing high flow into the estuary. A recent modelled estimate of the long term average annual export of fine sediments from the Fitzroy catchment is around 4.5 million tonnes per year (Dougall *et al.*, 2006).



**Figure 1. Great Barrier Reef Catchments and the Fitzroy River Basin**



**Figure 2. Fitzroy River long term maximum yearly discharge grouped into 4000 m<sup>3</sup>/s increments**

### *Previous studies*

A recent study has suggested that ignoring the contaminant trapping capacity of estuaries can lead to the gross over estimation of sediment yields from large Northern American coastal catchments. It was also found that there is a lack of direct monitoring studies regarding large coastal catchments and sediment delivery to the ocean (Phillips and Slattery, 2006). A study which compared a suspended sediment budget for the Brisbane River to a number of the northern hemisphere estuaries found that the Brisbane River estuary trapped on average around 68% of the suspended sediments delivered from the catchment. In comparison, American and west European estuaries trapped between 80 to 90% of the fluvial load (Eyre *et al.*, 1998).

Studies of flood plumes from coastal catchments in northern Queensland found that a large proportion of sediments were deposited close to river mouths and that dissolved nutrients were found to be mostly conserved in the flood plume (Devlin and Brodie, 2005). More recently, a study in the Fitzroy River estuary found that a large store of fine sediments is situated near the mouth of the river and in the southern regions of Keppel Bay. A 10m thick fan of fine sediments covers substantial parts of the southern bay originating from the river mouth and there appears to be sediments collecting in the lower estuary and in the extensive tidal creek network (Brooke *et al.*, 2006).

The Reef Water Quality Protection Plan (The State of Queensland and Commonwealth of Australia, 2003) has identified the Fitzroy River as a major contributor of suspended sediments and nutrients to the GBR lagoon based on water quality monitoring of floods at the end of the freshwater system. It could be assumed, based on the hydrological characteristics of the basin and the previous studies mentioned above that the lower Fitzroy River estuary would trap a substantial percentage of suspended sediments delivered in flood waters from the catchment. However, there have been few studies that have directly monitored a flood plume from the Fitzroy River and there is a lack of information regarding the trapping efficiency of the estuary.

This study was conducted to assess the contaminant trapping capacity of the lower Fitzroy estuary by (1) intensive sampling of a representative flood at Rockhampton (a site commonly used for monitoring at the end of the freshwater system), (2) sampling of the flood plume from the estuary into Keppel Bay and (3) comparing the concentration of contaminants from the sampling sites. It was found that the results from water quality sampling of the flow at Rockhampton, some 60km upstream of the mouth, were a poor indicator of the actual load of contaminants that were transported into the GBR lagoon.

## Methods:

In February 2003 a moderate flood with a maximum discharge rate of 4,200 m<sup>3</sup>/s was sampled for contaminants across the hydrograph (time series) at Rockhampton, the most downstream site commonly used for water quality sampling and load monitoring. It can be seen in Figure 2 that out of the last 89 years of record there have been just over 55 years when maximum discharge was 4,000 m<sup>3</sup>/s or lower. This flood is therefore considered to be fairly representative of flows encountered in the Fitzroy catchment. Flood plume sampling was conducted on 12 February just after peak discharge (4,000 m<sup>3</sup>/s) in the lower estuary and in Keppel Bay (GBR lagoon). Water column physical parameters and concentrations of suspended sediments and dissolved nutrients were then compared for the monitoring sites.

### *Hydrology*

Flow discharge data were obtained from the Queensland Department of Natural Resources and Water's hydrographic group in Rockhampton. Discharge data were then used to estimate total event volumes, and travel times for flood water through the system and to calculate loads of suspended sediments and nutrients.

### *Contaminant sampling and analysis*

Upper water column samples for suspended sediments and nutrients were collected 20cm below the water surface. Lower water column samples were collected when salinity reached ~ 15 to 20 parts per thousand (ppt), or ~ 1 to 2m from the river bottom (estuary samples). Analyses of water samples were performed by Queensland Health Scientific Services, Brisbane. Loads were calculated via the National Action Plan for Salinity and Water Quality "Loads Tool", via linear interpolation (<http://www.wqonline.info/products/tools.html>, 01/11/2006).

### *Plume monitoring*

The plume sampling was conducted on 12 February 2003 on a run out tide onboard "The Pearl" a 10 metre vessel operated by Queensland Parks and Wildlife Service out of Roslyn Bay, Yeppoon. Water column profile data for the flood plume into Keppel Bay were obtained via deployment of a Hydrolab Sonde 3™ with an attached 12-volt pump to allow for samples to be collected at known depths through the fresh/salt water transition zone. The plume sampling transect followed the official navigation channel, the deepest section from the river mouth out into Keppel Bay. Sites 6 and 7 (Figure 3) were at either side of the leading edge of the observed flood plume. Near real time satellite images (MODIS 250m) were used to gauge the extent of the plume and plan for water quality sampling (<http://rapidfire.sci.gsfc.nasa.gov>, 11/02/2003).

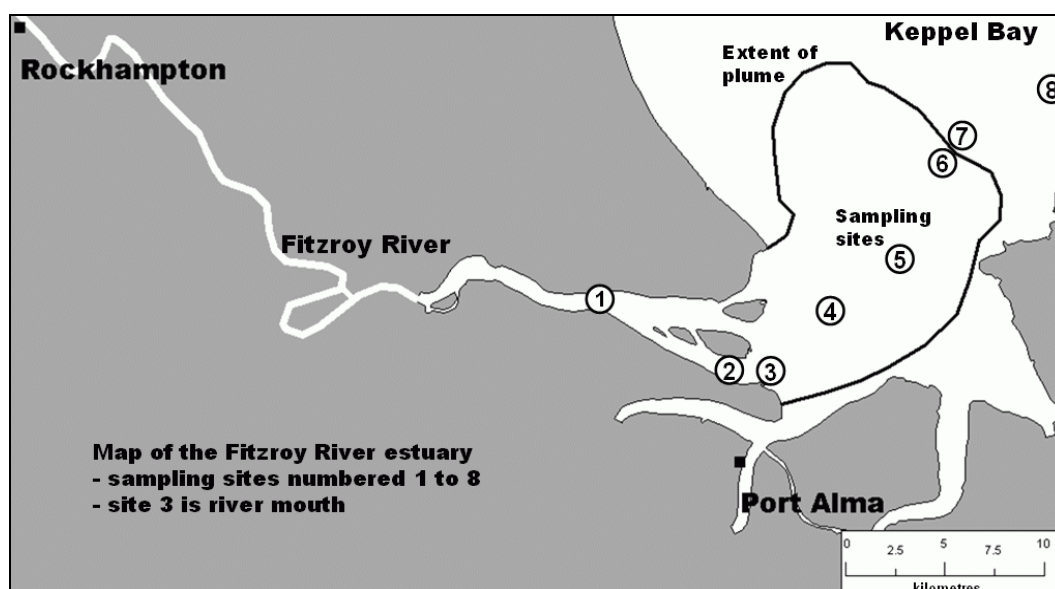


Figure 3. River, estuary and plume sampling sites for the February 2003 Fitzroy River flood

**Results:**

Heavy rains fell in the eastern parts of the Fitzroy catchment on 5, 6 and 7 February 2003 as ex-tropical Cyclone Beni moved close to the Central Queensland coast. Runoff produced a moderate flood with a recurrence interval of around four years at Rockhampton. Discharge at Rockhampton peaked about 5pm on 11 February at approximately 4200 m<sup>3</sup>/s. The event mean concentration (total event load divided by total event volume) for Total Suspended Solids (TSS) was just over 1000 mg/L (8 samples over the hydrograph). A mean concentration for TSS and dissolved nutrients was calculated for 3 samples taken at Rockhampton over peak flow. These data were then used to represent concentrations over peak discharge at Rockhampton and compared to concentrations near the river mouth and in the flood plume. The travel time for the flood peak to travel 60km downstream to the river mouth was calculated at around 10 hours and the plume sampling was conducted on 12 February (starting around 11am at site 1) just after peak flow ~ 4000 m<sup>3</sup>/s (Figure 3). The extent of the plume is shown in Figure 3. Salinity measurements through the plume profile are shown in cross section in Figure 4 (using a Kriging linear interpolation).

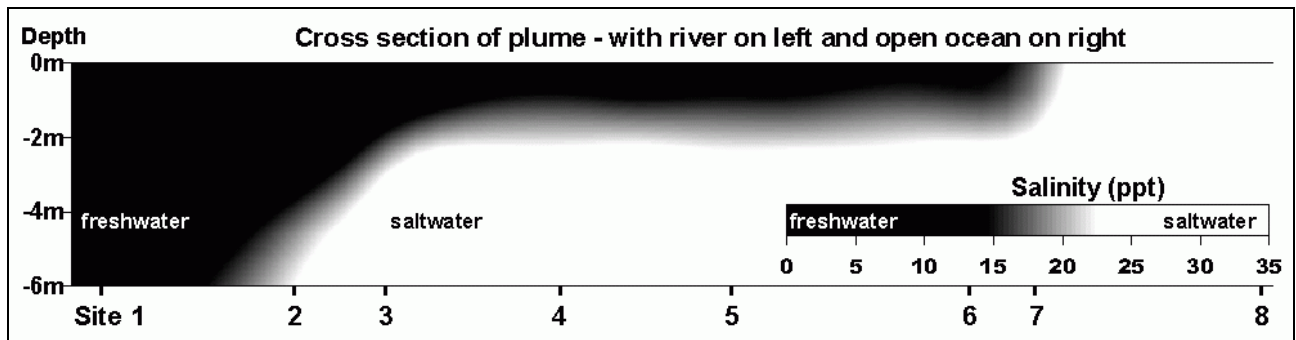


Figure 4. Map of flood plume (not to scale, Y axis [depth] is exaggerated) site 3 is river mouth

Results of surface and depth samples for TSS and for salinity are given in Figure 5. Results of surface samples for Filterable Reactive Phosphorus and Total Dissolved Nitrogen are given in Figure 6.

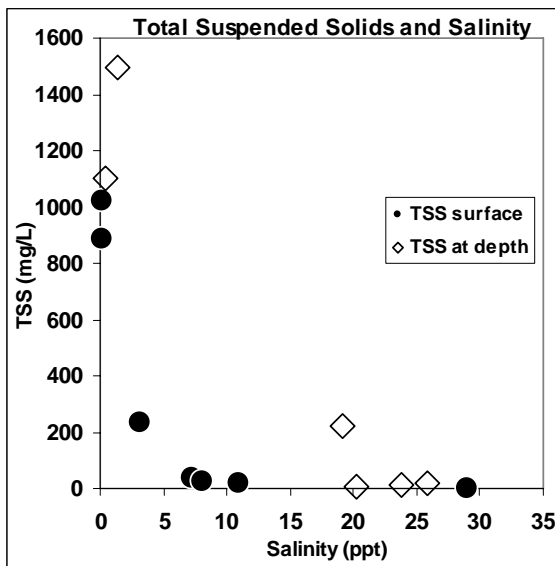


Figure 5. TSS concentrations for surface and depth (below plume) samples, and salinity (salinity increasing from sites 1 to site 7)

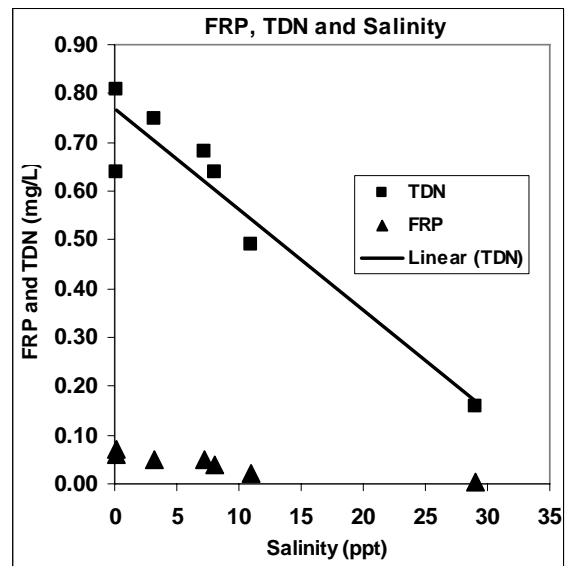


Figure 6. Filterable Reactive Phosphorus (FRP) and Total Dissolved Nitrogen (TDN) concentrations (surface only), and salinity

An important observation from Figure 5 is that TSS concentrations decrease substantially with increasing salinity, indicating deposition. In comparison, dissolved nutrient concentrations (Figure 6) remain relatively constant with increasing salinity, indicating dilution rather than deposition.

## Discussion:

The results suggest that the estuary acts as a pipe from Rockhampton (end of fresh water system) to the river mouth under these flow conditions. However, once the flood waters start to mix with marine waters of high salinity, substantial deposition occurs, with around 90% of the suspended sediments delivered to the lower estuary deposited within 5km of the river mouth. It can be seen from Figure 4 that a saltwater wedge extended into the estuary and that the plume was floating on the marine waters out into Keppel bay. Figure 5 illustrates that the concentration of suspended sediments declines rapidly from site 1 (10km upstream of river mouth) to site 3 at the river mouth.

Just upstream of the river mouth at site 2 (Figure 4), near the front of the saltwater wedge, sediments appear to be concentrating at depth (Figure 5). This region may be a zone of substantial deposition for flood flows of this magnitude. At around 10 km out into Keppel Bay (site 5) the concentration of TSS near the surface is 25 mg/L and 14 mg/L at depth, representing less than 5% of the concentrations found upstream of the river mouth. Recent studies by the Coastal CRC have found that suspended sediments deposited near the river mouth can, over time, be re-suspended in high velocity tidal currents and transported back up into the estuary and the extensive tidal creek system (Margvelashvili *et al.*, 2006; Bostock, *et al.*, 2006).

Dissolved nutrient concentrations tend to be maintained along the plume compared to TSS concentrations (Figure 6). At site 5 around 20km from the river mouth, surface concentrations for Filterable Reactive Phosphorus (FRP) and Total Dissolved Nitrogen (TDN) were 70% and 80% (respectively) of the concentrations measured at site 1 (10km upstream of the mouth). However, at site 6 the concentrations had decreased to 30% and 60% respectively. At site 7 FRP was below the limits of detection and TDN was only 19% of the site 1 concentration. Devlin and Brodie (2005) concluded that dissolved nutrients in northern GBR catchment floods may be conserved in plume waters and that diminishing concentrations along a plume profile may be due to dilution rather than loss via uptake by phytoplankton or deposition. The results from this plume sampling would tend to agree with those observations. However, the rate of suspended sediment deposition near the Fitzroy River mouth appears to be higher than rates for the rivers of northern Queensland, perhaps owing to the more extensive, sheltered estuarine areas of the lower Fitzroy River.

The findings of this study suggest that there could be similar suspended sediment deposition rates for Fitzroy River floods around the same peak discharge. Floods with a lower maximum discharge rate would result in greater sediment deposition further upstream in the estuary rather than near the mouth. There have been 57 out of the last 89 years when maximum discharge was at or below the peak discharge for the event reported here (Figure 2). The implication is that in most years a high percentage of suspended sediments will be trapped in and around the Fitzroy river estuary and river mouth. Higher discharge flows may transport suspended sediments further out into Keppel Bay, however, there would still be substantial deposition and only very fine suspended particles may be carried further into the GBR lagoon.

Dissolved nutrients appear to be carried in the plume for some distance and these contaminants (particularly those from intensive agriculture) may be of more concern than suspended sediments in regards to GBR lagoon water quality. The Fitzroy catchment has substantial areas under intensive use including dry-land and irrigated agriculture, and coal mining. Flood plumes from high discharge events ( $>10,000 \text{ m}^3/\text{s}$ ) could carry dissolved nutrients, pesticides and other agricultural and industrial chemicals well out into the GBR lagoon.

## Conclusions:

Most of suspended sediments (~ 90%) monitored at near peak discharge for this event (a representative flood based on historical discharge data) were being deposited close to the mouth of the river (within ~ 5km). Dissolved nutrients, in comparison, were transported at diluted concentrations to the leading edge of the flood plume some 20km out into Keppel Bay. The findings of this study constitute a first report of the direct measurement of substantial suspended sediment deposition in a flood plume from the Fitzroy River estuary. These results will be useful in helping to validate catchment and receiving waters simulation models.

The monitoring site at Rockhampton proved to be a poor indicator of the amount of suspended sediments actually delivered to the GBR lagoon. Natural resource management policies that require the monitoring of floods for water quality targets may need to take the trapping efficiency of estuaries into account for the

Fitzroy and other GBR catchments. Water quality policies may be misguided if load calculations based on monitoring at the most downstream gauging station is used as an indicator for catchment condition improvement and for the actual load of contaminants delivered to the GBR lagoon.

There is high variability in climate, flood event discharge and contaminant delivery to the coast from large dry tropical catchments. Also, it is often very difficult to work out what proportion of contaminants are man made compared to natural (pre-development) contributions in the total load delivered from flood events. These factors may make the end of catchment load monitoring for suspended sediments and nutrients far too insensitive to assess changes in landscape condition via improved catchment management.

Monitoring and target setting for agrochemicals such as pesticides and inorganic fertilisers may offer a more realistic approach as these contaminants “are” man made. In the case of pesticides for example there are no background levels occurring naturally. Alternatively, monitoring targets based on the direct assessment of catchment condition (eg. ground cover, riparian restoration and reduced agrochemical use) may provide a better overall indicator for improving river, estuary, inshore and GBR lagoon water quality.

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