# A Characterisation of Sediment Nutrient Transport and Depositional Dynamics in the Lake Cootharaba Catchment Post European Settlement

**Krystina Lamb, Peter Davies, Vanessa Moscato, Peter Brooks and Neil Tindale**

## Abstract

The Noosa River and catchment, including the Upper Noosa River and Kin Kin Creek which drain into Lake Cootharaba, is a valuable and relatively pristine ecosystem that is often used as a benchmark for healthy coastal waterways in South East Queensland. A combination of sediment analytical techniques were used to characterise sediment and nutrient dynamics in Lake Cootharaba, including particle size analysis by laser diffraction, element and nutrient analysis using ICP-OES and radioisotope analyses incorporating Lead-210 tracing. Combinations of these analyses were used to determine changes to sediment profile and deposition since human settlement in the Kin Kin and Cooloothin Creek catchment areas.

The data suggest that Kin Kin Creek contributes higher sediment load than the larger Upper Noosa River, particularly after heavy rain events. Major and minor elemental analysis of suspended sediments show that there is little variation in the geological profile across the catchment, though final results from elemental analysis of bottom sediments are still pending. Preliminary analysis also shows that the suspended sediments are the main contributor of nutrients to the Noosa River, rather than dissolved nutrients. This study is part of a larger study of the Noosa River Catchment area to help determine better land and water management practices.

## Introduction

Over the past 30 years, the detrimental effects that increases in sediment load and turbidity can have on the health of an aquatic ecosystem have been increasingly recognised (Douglas, et al., 2006; Henley, et al., 2000; Ryan, 1991). Much of these increases in sedimentation and nutrients inflow can be attributed to anthropogenic land use changes, such as increased urbanisation, development and deforestation (Bhaduri, et al., 2000; Kondolf, et al., 2002; Walling, 1999).

## Background

The Noosa River and catchment is a valuable and relatively pristine ecosystem that is often used as a benchmark for healthy water ways in South East Queensland (Noosa and District Landcare Group Inc., 2010). Lake Cootharaba is approximately 10km north of Noosa, and is the main lake in the upper part of the catchment. The two main tributaries into Lake Cootharaba are the larger Upper Noosa River, which drains the Cooloola Great Sandy National Park, and Kin Kin Creek, which drains primarily rural agricultural lands to the west of the lake (see Figure 1). Lake Cootharaba and the Lower Noosa River previously had a Ecosystem Health Monitoring Program (EHMP) report card grade of A, which fell to A- in 2006, continued to fall to a B+ in 2009, and the most recent report card grade is a B- in 2010 (Ecosystem Health Monitoring Program, 2011). This drop in grade has been largely due to increases in Dissolved Inorganic Nitrogen (DIN) in the lake and the Lower Noosa River, and is a cause of concern for the community and regional council.

Recent studies of the lake demonstrated that increases in DIN were primarily from the conversion of in-sediment total organic nitrogen (N) to DIN within Lake Cootharaba (Rissik, et al., 2008; Brooks, et al., 2008; Noosa and District Landcare Group Inc., 2010). This highlighted the question of whether the nutrient flux into the lake was natural or impacted by anthropogenic sources, and ultimately of whether it was of concern?

## Methods

Sediment samples were collected from the lake and surrounding catchment, together with suspended sediments in order to measure sediment fluxes and deposition rates in the lake. Lake sediment cores, sediment grab samples and suspended sediment samples were analysed for elemental content, nutrients, and lead-210 dating of core samples. Sediment cores from Lake Cootharaba that showed good structure were selected for lead-210 dating and ICP-OES geochemical analysis. Sediment grab samples from the major tributaries of Kin Kin Creek and the Upper Noosa River were collected and analysed for elemental composition. The focus of this study was on the sediment geochemical and nutrient load 'fingerprints'. Changes to this elemental 'fingerprint' over time will be quantified in regards to the age of the cores to obtain deposition rates and relative sources of the sediments in Lake Cootharaba.

### Sediment coring for dating

The sediment cores for dating and analysis were collected using a 1.5 meter long, 120 mm diameter down-hole piston corer. Cores were taken from fifteen sites within Lake Cootharaba, and four cores were selected for geochemical and nutrient 'fingerprinting' and lead dating. Two cores from each of the upper and the lower parts of the lake were selected. See Figure 1 for the core sample locations.

Sediment grab samples from the creeks were collected using a 1 metre sediment auger sampler, where the down-hole piston corer could not be used due to high sand content in sediments. See Figure 1 for suspended sediment and sediment grab samples sites of Kin Kin creek catchment and the Upper Noosa River catchment.

### Lead dating methods

The concentration of lead-210 from in-lake sediment samples were used to obtain the age profile of the four sediment cores. Samples from the cores were not filtered, dried at 60˚for 72 hours, and analysed at the Institute of Environmental Research at Australian Nuclear Science and Technology Organisation (ANSTO). Samples were digested in Nitric acid, followed by polonium plating and radium re-crystallisation (Madsen, et al., 1979; Appleby, et al., 1978; Zawadzki, 2011). The date of deposition was calculated two ways, using both a constant rate of sediment deposition, and a variable rate of sedimentation (Appleby, et al., 1978).

### Suspended sediment sampling

Suspended sediment samples were collected during three high flow events from 13 sample sites across the Kin Kin Creek and Upper Noosa River Catchment. See Figure 1 for suspended sediment water sample collection sites, red stars indicate sample collection sites.

### Suspended sediment analysis

The Total Suspended Solids (TSS) in the water samples were determined using a glass fibre filter method as outlined in Chanin, *et. al* (1958). Data from ICP-OES were used to create a 'fingerprint' of total suspended solids by analysing and comparing the difference between a filtered and unfiltered sample. This analysis technique is recommended for TSS analysis by Australian and New Zealand Environment Conservation and Council (ANZECC), and is outlined in Tighe, *et. al.* (2004).


Figure 1: Suspended sediment and grab sample sediment sites from Kin Kin Creek catchment and Upper Noosa River catchment. Red stars represent water and sediment grab sample sites, while blue stars represent sediment core collection sites (Map from Bureau of Meteorology's river and flood monitoring sites for South-East Queensland, 2011).

## Results

Table 1 shows the estimated age based on the preliminary sediment lead dating in a core collected from lower Lake Cootharaba. The sediment layer at 30cm below the surface corresponded to an age of 26±3 years using the variable rate of sedimentation model, or 30±6 using the constant rate of sedimentation model. Figures 2 and 3 show the relative contribution of suspended sediment bound nitrogen, compared to the total nitrogen, of water samples collected in fortnightly sampling from May 2011 to July 2011. Average Total Suspended Solids (TSS) in the Upper Noosa River during baseline (average low flow) conditions was 4.7mg/L (Range >1-12mg/L, n=10), while Kin Kin Creek's mean TSS load was 25.6mg/L (Range 3-53mg/L, n=10).

| Depth of sample (cm) | Preliminary age (CIC) | Preliminary age (CRS) | Rate of deposition (CRS) |
|---|---|---|---|
| 2.5 | 2.2±2.2 | 2.5±0.4 | 1.0±0.2 |
| 7.5 | 6.6±2.3 | 7.5±1.3 | 1.0±0.2 |
| 12.5 | 10.9±2.5 | 12.3±2.1 | 1.1±0.2 |
| 30 | 26.1±3.5 | 29.8±5.8 | 0.9±0.2 |

Table 1: Prelimanary age of sediment layer core from lower Lake Cootharaba.

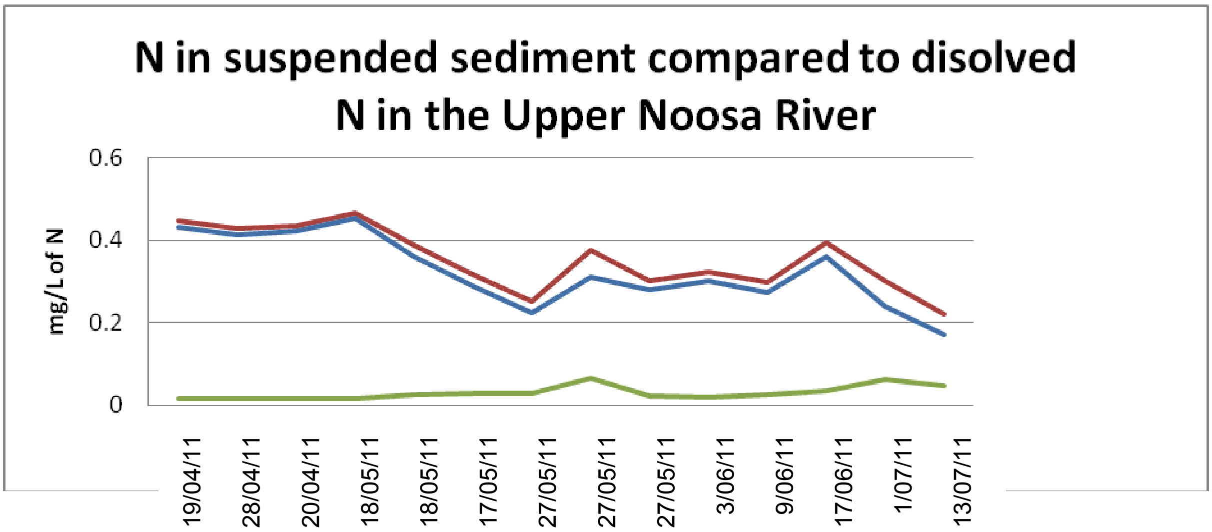


Figure 2: Nitrogen load in suspended sediment in the Upper Noosa River. Dissolved Nitrogen is taken from a filtered sample and the amount is then removed from Total nitrogen taken from an unfiltered sample to get suspended nitrogen.

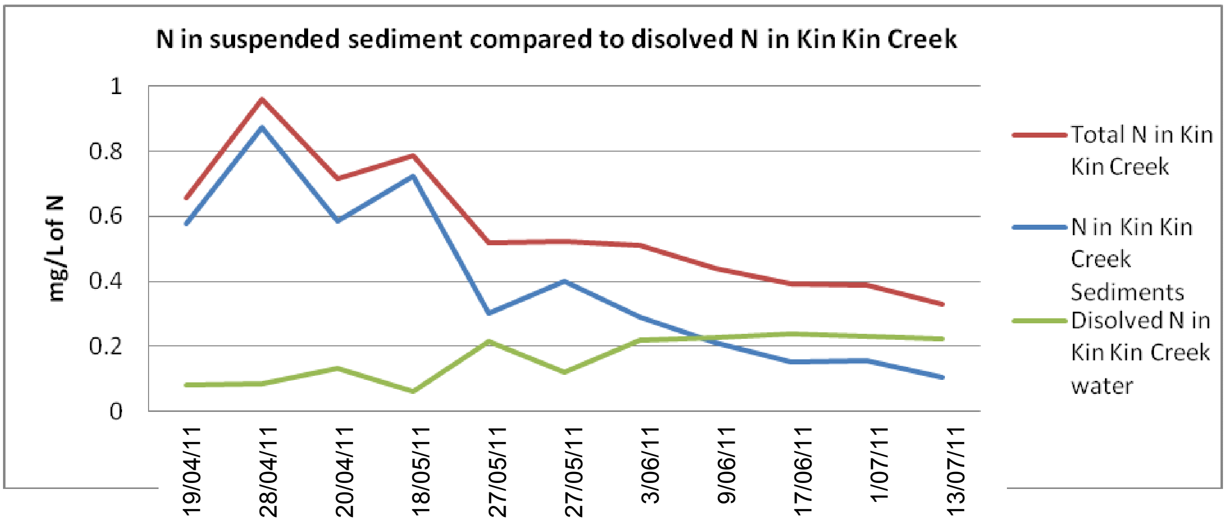


Figure 3: Nitrogen load in suspended sediment in Kin Kin Creek. Dissolved Nitrogen is taken from a filtered sample and the amount is then removed from Total nitrogen taken from an unfiltered sample to get suspended nitrogen.

**Discussion**

As the results in Table 1 show, both of the sediment deposition models give similar dates that provide a sedimentation rate of approximately 1g/cm$^2$/year, which equates to a deposition rate of approximately 1cm/year. This deposition rate is similar to studies in China, where the rates were between 1.98cm/year and 0.28cm/year since 1968 (Xiang, et al., 2002). However, comparison to Lake Alexandrina in South Australia, which had a sedimentation rate of 0.063 g/cm$^2$/year demonstrates that the sedimentation rate in Lake Cootharaba may be high compared to similar coastal lakes in Australia (Barnett, 1994).

Barnett's Lake Alexandrina study also showed an increase in the mean sedimentation rate of approximately three times (0.023 g/cm$^2$/year to 0.063 g/cm$^2$/year) since European settlement of the catchment area (Barnett, 1994). Preliminary results from this Lake Cootharaba study do not go back to pre-European settlement in the Noosa River area, but the possibility of anthropogenic acceleration of sediment deposition in Lake Cootharaba cannot be excluded. Further study on deeper cores from the lake may help resolve this.

The results shown in Figures 2 and 3 confirm that the suspended sediments carry most of the nitrogen into Lake Cootharaba, and this could explain the high nitrogen levels in the sediments in Lake Cootharaba that were found in previous studies. A study by Mitchell, Bramley and Johnson (1997) found that both suspended sediment load and suspended sediment nitrogen concentrations peaked during a flood event. During high flow (samples from 27/05/11 in Figures 2 and 3) in Kin Kin Creek, TSS were higher than the same samples from the Upper Noosa River. One potential reason for this is European settlement and land-use change in the Kin Kin Creek catchment compared to the relatively undisturbed Great Sandy National Park and Upper Noosa River catchment.

## Conclusions

Lead dating of sediment cores from Lake Cootharaba shows that Lake Cootharaba has a high sediment deposition rate compared to other similar shallow coastal Lakes. Kin Kin Creek has higher total suspended sediment loads than the larger Upper Noosa River. European settlement and associated land-use changes in the Kin Kin Creek catchment may contribute to increasing the transport and deposition of nutrient laden sediment to the lake. This also indicates that the high nitrogen levels in Lake Cootharaba sediments are due to the nitrogen laden suspended sediments coming from both the Upper Noosa River and Kin Kin Creek catchments. At present, the primary source appears to be the Kin Kin Creek, though the study is still ongoing.

## Take Home Messages

- Lake Cootharaba has a high sediment deposition rate, of approximately 1cm/year.
- The total suspended solids in Kin Kin Creek are higher than the Upper Noosa River.
- The suspended sediment from both the Upper Noosa River and Kin Kin Creek carry the majority of the nitrogen from these sources into Lake Cootharaba.

## Acknowledgments

Funding for this project was provided by the Sunshine Coast Regional Council and Federal Government Caring for our Country-Community action grants, through the Noosa and District Landcare and Waterwatch. The University of the Sunshine Coast, University of Queensland, Australian Institute of Nuclear Science and Engineering (AINSE), Australian Nuclear Science and Technology Organisation (ANSTO), the Department for Environment and Resource Management (DERM) Elandra Point Rangers, SEQ Catchments and the USC NATA accredited Analytical Services laboratory and staff have devoted many hours and in-kind support to this project.

## References

**Appleby P. G. and Oldfield F.** The Calculation of lead-210 dates assuming a constant rate of suppy of unsupported 210Pb to the sediment [Journal] // Catena. - 1978. - 1 : Vol. 5. - pp. 1-8.

**Barnett E. J.** A Holocene Paleoenvironmental history of Lake Alexandria, South Australia [Journal] // Journal of Paleolimnology. - 1994. - 3 : Vol. 12. - pp. 259-268.

**Bhaduri Budhendra [et al.]** Assessing watershed-scale, long-term hydrolic impacts of land-use change using a GIS-NPS model [Journal] // Environmental Management. - 2000. - 6 : Vol. 26. - pp. 643-658.

**Brooks Peter, Sullivan Daryle and Tindale Neil** Lake Cootharaba Nitrogen Project Study [Report] : Final report. - Sippy Downs, QLD : The University of the Sunshine Coast, 2008.

**Chanin G. [et al.]** Use of glass fibre filter mediums in the suspended solid determination [Journal] // Sewage Industry Wastes. - 1958. - Vol. 30. - p. 1062.

**Douglas G B [et al.]** Fitzroy River, Queensland, Australia. II. Identification of Sources of Estuary Bottom Sediments [Journal] // Environmental Chemistry. - 2006. - Vol. 3. - pp. 377-385.

**Douglas G, Caitcheon G and Palmer M** Sediment source identification and residence times in the Maroochy River estuary, southeast Queensland, Australia [Journal] // Environmental Geology. - 2009. - 3 : Vol. 57. - pp. 629-639.

**Ecosystem Health Monitoring Program** Ecosystem Health Monitoring Program [Online]. - 2011. - 15 March 2011. - http://www.healthywaterways.org/ehmphome.aspx.

**Elrick K A [et al.]** The use of sediment-trace element geochemical models for the identification of local fluvial baseline concerntrations [Conference] // Sediment and Stream Water Quality in a Changing Environment: Trends and Explanations. - Vienna : [s.n.], 1991. - pp. 339-348.

**Henley W. F. [et al.]** Effect of sedimentation and turbidity on lotic food webs: A concise review for natural resource managers [Journal] // Reviews in Fisheries Science. - 2000. - 2 : Vol. 8. - pp. 125-139.

**Jolliffe I. T.** Principal Component Analysis, Second edition [Book]. - New York : Springer-Verlag New York, Inc., 2002.

**Koinig Karin A [et al.]** 9000 years of geochemical evolution of lithogenic major and trace elements in the sediment of an alpine lake – the role of climate, vegetation, and land-use history [Journal] // Journal of Paleolimnology. - 2003. - Vol. 30. - pp. 307-320.

**Kondolf G M, Piegay H and Landon N** Channel response to increased and decreased bedload supply from land use change: contrasts between two catchments [Journal] // Geomorphology. - 2002. - Vol. 45. - pp. 35-51.

**Madsen P and Sorensen J** Validation of the lead-210 dating method [Journal] // Journal of Radionanalytical and Nuclear Chemistry. - 1979. - 1-2 : Vol. 54. - pp. 39-48.

**Mitchell A., Bramley R. and Johnson A.** Export of nutrients and suspended sediment during a cyclone-mediated flood event in the Herbert River catchment, Australia [Journal] // Marine and Freshwater Research. - 1997. - Vol. 48. - pp. 79-88.

**Noosa and District Landcare Group Inc.** Project proposal: A sediment and nutrient model to determine resilience of Upper Noosa River system [Report] : Project Proposal. - Pomona, QLD : [s.n.], 2010.

**Rissik Dave, Grinham Alistair and Constanzo Simon** Identifying causes for intermittent elevated dissolved inorganic nitrogen levels in Lake Cootharaba, Noosa [Report] : Progress report. - Brisbane : EPA and University of Queensland, 2008.

**Ryan Paddy A.** Envrionmental effects of sediment on New Zealand streams: A review [Journal] // New Zealand Journal of Marine and Freshwater Research. - 1991. - Vol. 25. - pp. 207-221.

**Tighe M. [et al.]** Comparison of digestion methods for ICP-OES analysis of a wide range of analytes in heavy metal contaminated soil samples with specific reference to Arsenic and Antimony [Journal] // Communication in Soil Science and Plant Analysis. - 2004. - 9-10 : Vol. 35. - pp. 1369-1385.

**Walling D. E.** Linking land use, erosion and sediment yields in river basins [Journal] // Hydrobiologia. - 1999. - Vol. 410. - pp. 223-240.

**Xiang L. [et al.]** Recent lake sedimentation in the middle and lower Yangtze basin from 137Cs and 210Pb measurements [Journal] // Journal of Asian Earth Sciences. - 2002. - Vol. 21. - pp. 77-86.

**Zawadzki A.** VI 3330: ERMC Radium Chemical Isolation. - Sydney : [s.n.], 3 June 2011.