CRC Freshwater Ecology

SCOPING STUDY

Groundwater Nutrient Concentrations in Riparian Zones of Agricultural Catchments

Final Report

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Aim:

To provide preliminary data for a proposed joint CRC project on "*Transport and transformation of nitrogen in riparian zones*."

Context:

Increased stream loadings of nitrogen are now recognised as a significant impact of upstream land use in many catchments, both in Australia and overseas (see Burt *et al.* 1993; Hunter and Walton 1997). Nitrogen (rather than phosphorus) has been identified as the major problem nutrient in coastal systems in eastern Australia (e.g. Moreton Bay – Dennison and Abal 1999; Port Phillip Bay – Murray and Parslow 1999). Furthermore, recent Australian research suggests that algal growth in some Australian river systems is also limited by nitrogen supply (Mosisch *et al.* 1999; in press). That is, an increased delivery of nitrogen to these systems is likely to boost algal growth, to the detriment of ecosystem health (Bunn *et al.* 1999). This is particularly the case for bioavailable forms of nitrogen such as ammonia and nitrate, which can constitute a significant proportion of the total nitrogen flux.

The presence of riparian zone buffers is considered to be the most important factor controlling entry of non-point source nitrate to surface waters (Burt and Haycock 1996). Fluxes of nitrate through the riparian zone are intrinsically linked to water movement (both over and through the soil) and are also strongly influenced by biological processes occurring in that zone. Nitrogen and organic carbon dynamics in riparian zones are closely interrelated. Nitrogen loss to the atmosphere through the process of denitrification, and its uptake by riparian vegetation are two important means by which nitrate loads can be reduced (Haycock and Pinay 1993). While many of the factors that can potentially influence nitrogen and carbon fluxes through riparian zones are broadly known, there is presently no quantitative information on the relative importance of these various processes, and their interactions, in the variety of climatic and physiographic settings typical of Australian catchments.

This project was designed to provide a preliminary assessment of nutrient concentrations in the groundwater in the riparian zone to identify if nitrate was attenuated along sub-surface water pathways in riparian zones. We also planned to identify likely processes that could be occurring in the riparian zone that would contribute to observed changes in nutrient concentration. For example, if a decrease in groundwater nitrate concentrations were detected along a gradient from the riparian zone to the river, stable isotope analysis of the nitrate might indicate denitrification as a possible mechanism for this gradient.

The specific activities of the proposed scoping study were:

- install piezometers and water table wells at up to 4 study sites
- collect hydrologic and geochemical data
- collect additional samples for isotopic analysis where warranted by geochemical data

Methods:

The study was conducted in five subcatchments of the Brisbane River: Buaraba, Lockyer, Kilcoy, and Monsildale Creeks, and Stanley River (Figure 1).

Piezometer installation

To collect groundwater samples from different depths and distances from each stream, multiple piezometers were installed at each site. The planned configuration included a transect of piezometers perpendicular to the direction of stream flow (shown in Figure 2) with multiple piezometers installed at different depths at each point along the transect. Additionally, short transects of piezometers were installed longitudinally along sandbars at 3 of the streams to examine hyporheic water (Figure 2). Piezometers were inserted through the riparian soil by coring until the water table was reached and then hammering each piezometer to the desired depth with a sledgehammer. The piezometers were constructed from PVC pipe (OD 19 mm) with holes drilled in the bottom 20 cm and covered with 100μm mesh screening. This allowed water to enter the piezometer, but reduced the amount of sediment entering. After installation, the water was continuously removed from inside the piezometers until it flowed clean. Once the groundwater entering the piezometer was relatively clear of sediment, water samples were collected.

A total of 29 groundwater piezometers were installed among the five streams. However, it was only possible to achieve a complete transect perpendicular to the stream at one site, Buaraba Creek, as most streams had very steep banks. A total of 27 piezometers were installed in sandbars among three of the streams (9 per sandbar, 1 sandbar per stream).

Water sample collection and analysis

All samples were collected in February 2000. Surface water and groundwater samples were collected in pre-rinsed 50 ml syringes and filtered through Whatman GF/F (0.7 μm) and Satorius minisart (0.45μm) filters. Samples were stored frozen in acid-washed polyethylene bottles and analysed for ammonium (NH_4-N) oxidized N (nitrate plus nitrite, NO_x-N)and orthophosphate (PO_4-P) by the water analysis laboratories of the Queensland Department of Natural Resources, using automated continuous flow methods that broadly followed those described in APHA-AWWA-WEF (1998). The sum of NO_x-N and NH_4-N was reported as total dissolved inorganic nitrogen (DIN, mg/l).

Hydraulic head and other physical variables

Hydraulic head was quantified by lowering a small tube down the side of the piezometer and measuring the distance between the top of the piezometer and the water level. The height of the piezometer above the ground was then subtracted to give an estimate of the depth of the water table below ground surface. The contributions of groundwater inputs were measured by placing seepage meters in the centre of each stream (Lee and Cherry 1978).

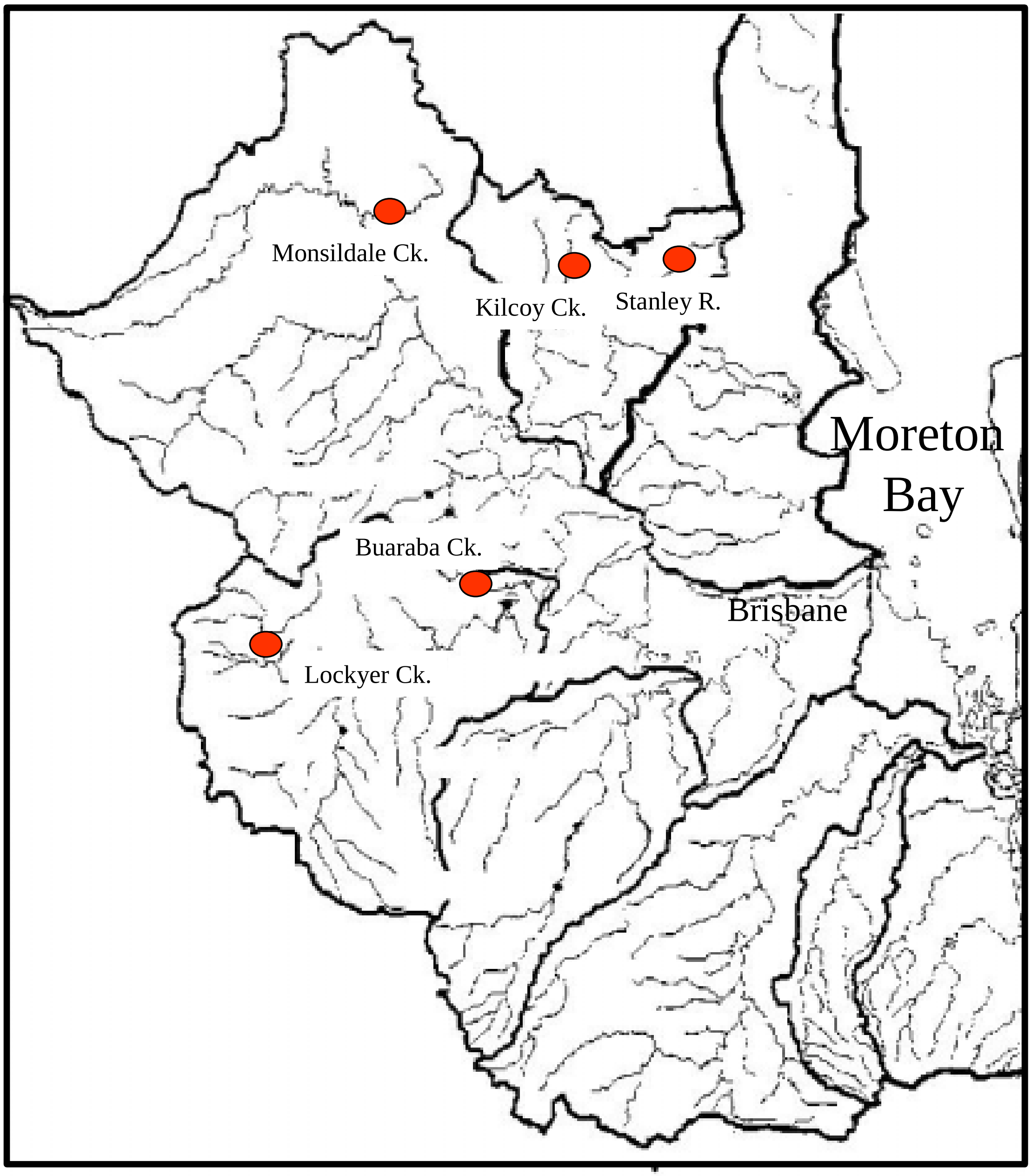

Figure 1: *Map of Brisbane River Catchment showing the location of the five study sites.*

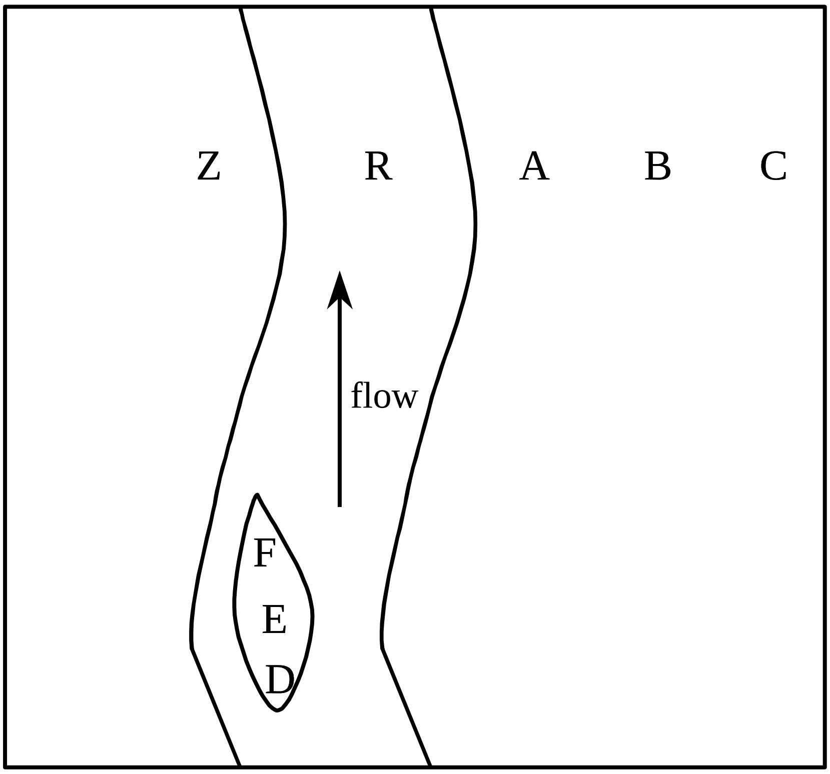

Figure 2: *Schematic map view of the general spatial lay out of piezometer installation locations within a site. Groundwater piezometers: R = within river and A, B, C, and Z are locations along a transect perpendicular to the direction of flow. Hyporheic zone piezometers: D, E, and F are at the head, middle, and tail of a sandbar, respectively.*

Results:

Groundwater Nutrient concentrations

The results from the four streams instrumented with groundwater piezometers demonstrate that ammonium is the dominant form of N in groundwater, with oxidized N concentrations at most sites ranging between 1 and 2 orders of magnitude lower than the corresponding ammonium values (Table 1). An exception to this generalization occurred at Buaraba Creek approximately 150 cm below the water table where there was a decrease in the ammonium concentration and an equivalent increase in the proportion of oxidized N (Figures 3 and 4).

None of the four sites exhibited a clear gradient in oxidized N concentrations perpendicular to the stream (Table 1 and Figure 3). As a result, stable nitrogen isotope analyses were not performed.

Phosphate concentrations were generally low relative to ammonium and oxidized N and did not show any clear trends relating to either the sampling depth or proximity to the stream (Figure 5).

Hyporheic Zone Nutrient Concentrations

Similar to groundwater nutrient concentrations, hyporheic zones typically had greater concentrations of ammonium and lower concentrations of oxidized N than surface water (Table 2). At Kilcoy Creek, piezometers at location D had nutrient concentrations which were very similar to stream water, with ammonium increasing

Table 1: Comparison of in-stream and riparian groundwater nutrient concentrations at 3 streams in the Brisbane River Catchment. Piezometers are identified by a letter and number. See Figure 2 for a description of the position of the letters relative to the stream. The number represents the depth below ground surface at which the piezometer is located.

Site and piezometer	NH_4-N (mg/l)	NO_X-N (mg/l)	Total DIN (mg/l)	PO_4-P (mg/l)
Lockyer Creek	0.003	0.002	0.005	0.003
A -120	1.9	0.029	1.929	0.005
B -185	0.73	0.056	0.786	0.007
B -210	1.7	0.019	1.719	0.003
C -275	0.33	0.019	0.349	0.02
Kilcoy Creek	0.002	0.149	0.151	0.017
R -50	0.13	0.013	0.143	0.01
R -100	0.15	0.018	0.168	0.01
A -125	0.21	0.021	0.234	0.004
A -175	0.06	0.01	0.07	0.002
Stanley River	0.017	0.118	0.135	0.010
R -50	0.044	0.009	0.053	0.025
R -100	0.022	0.014	0.036	0.009
A -125	0.078	0.011	0.089	0.003
A -175	0.47	0.008	0.478	0.005

and nitrate decreasing from location D to F. This suggests that there may be microbial transformations of nitrogen along a flowpath through the sand bar, including denitrification. At Stanley River, most hyporheic zone nutrient concentrations more closely resembled groundwater concentrations than stream concentrations, suggesting hydrology influence hyporheic nutrient concentrations more than microbial activity.

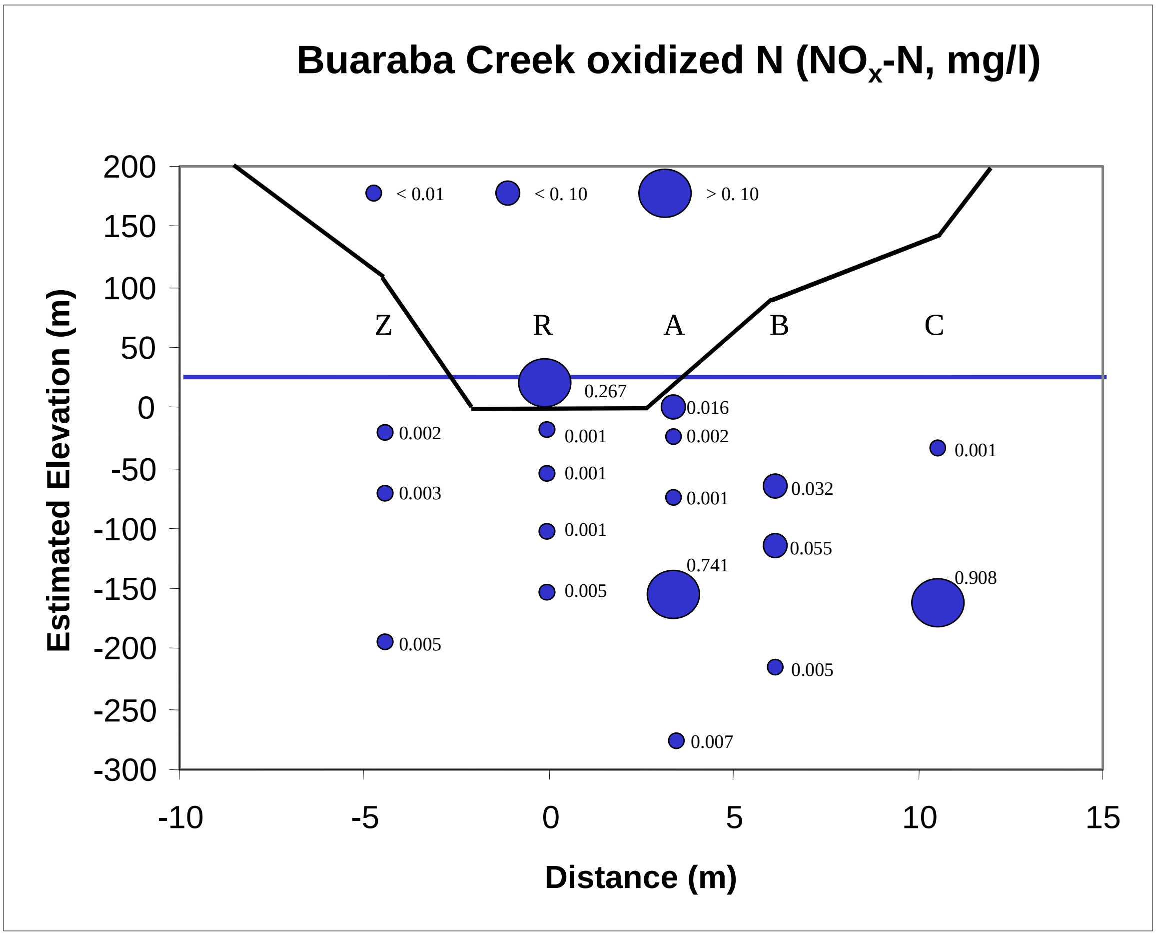

Figure 3: *Buaraba Creek oxidized N profiles (February 2000).* Concentrations are present in a vertical cross section, perpendicular to the stream. The black line represents the ground surface elevation and the blue line represents the water table. Distance 0 is the center of the stream. Each circle represents the concentration of a water sample taken from surface water or groundwater, with the size of the circle proportional to the concentration of oxidized N. Except for the surface water sample, the locations of the circles reflect the position of the piezometer along a transect perpendicular to the stream (letters as in Figure 2) as well as the depth of the piezometer.

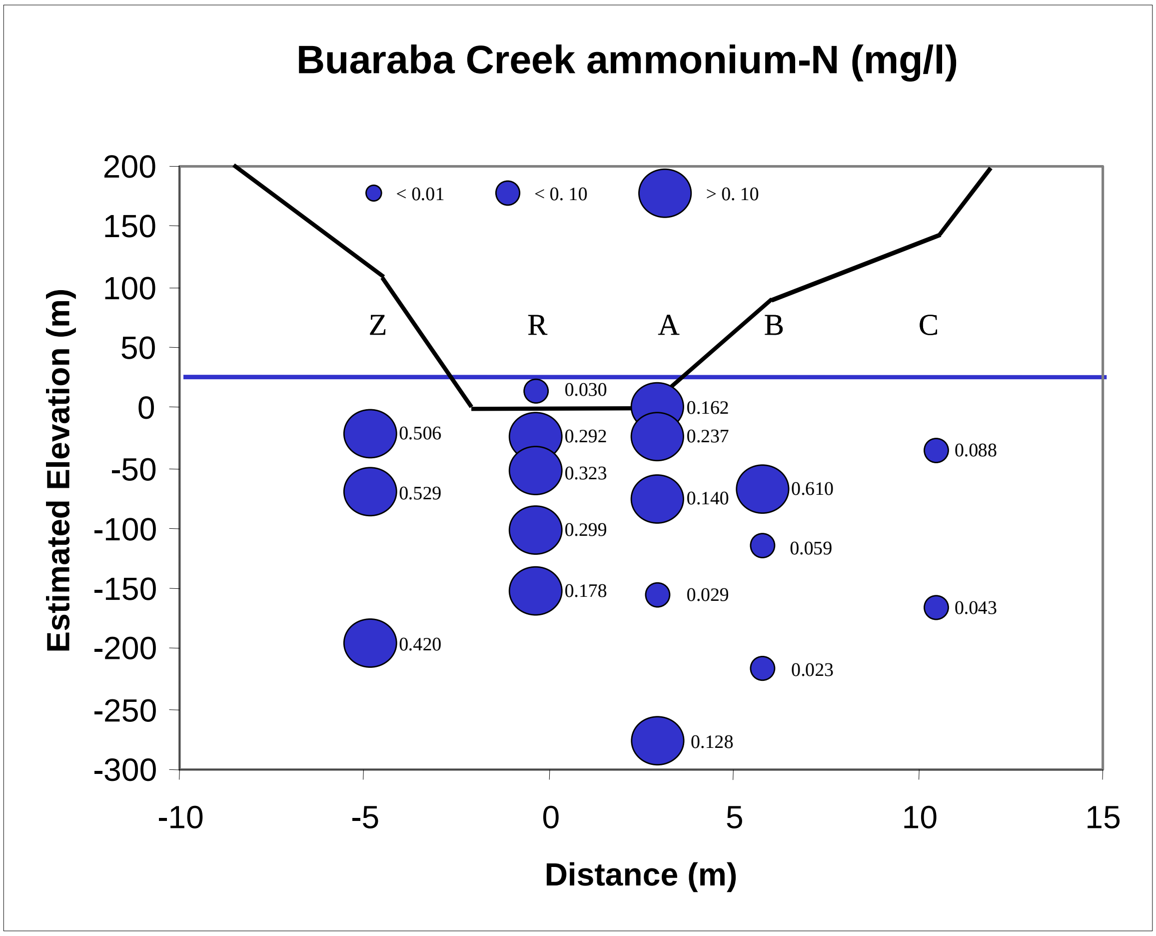

Figure 4: *Buaraba Creek ammonium-N profiles.* Details as in Figure 3.

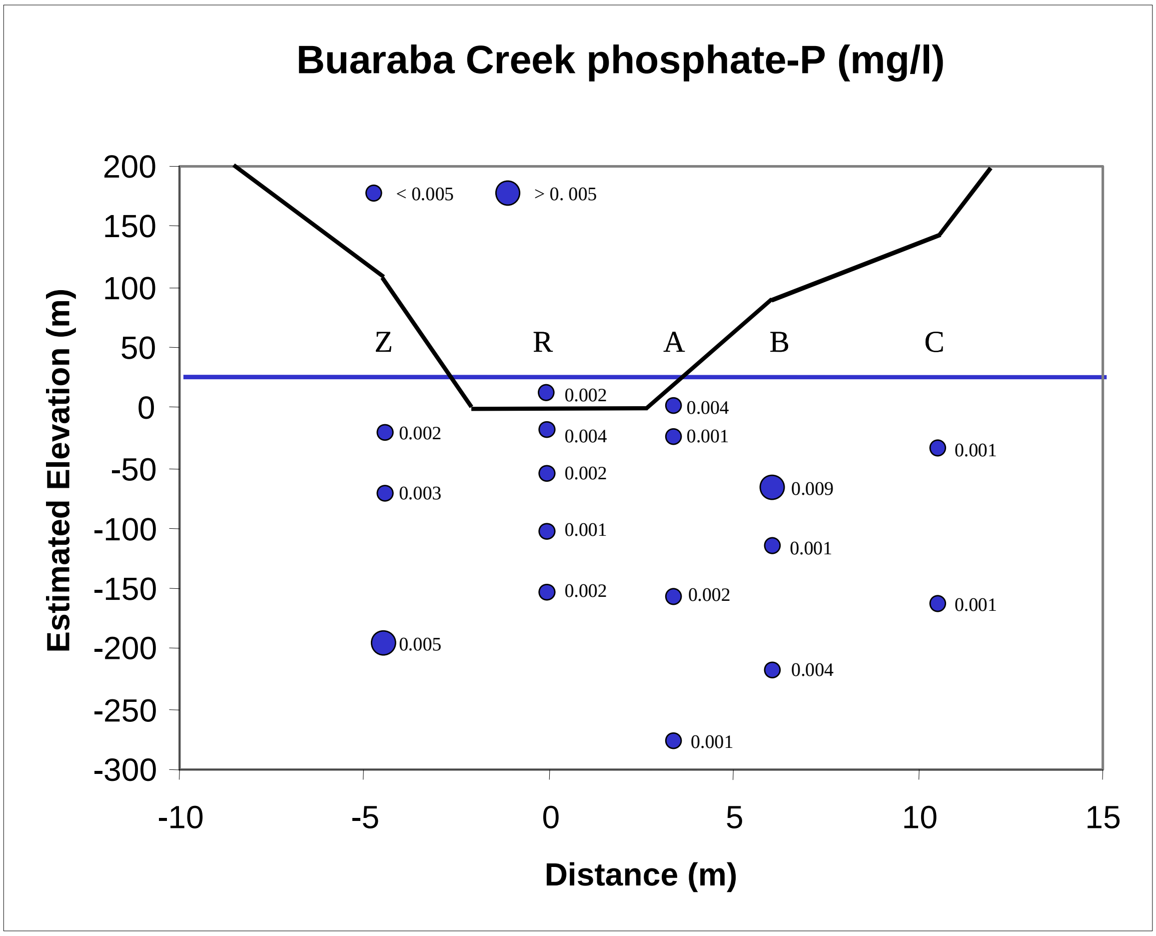

Figure 5: *Buaraba Creek orthophosphate-P profiles*. Details as in Figure 3.

Table 2: Nutrient concentrations of water samples taken from piezometers installed in the sandbars of 3 streams in the Brisbane River Catchment. Piezometers are identified by a letter and number. The letter defines the location of the piezometer in the sandbar (see Figure 2) and the number represents the depth of the piezometer below the ground surface (cm).

Site and piezometer	NH_4-N (mg/l)	NO_X-N (mg/l)	Total DIN (mg/l)	PO_4-P (mg/l)
Kilcoy Creek	0.002	0.149	0.151	0.017
D-10	0.011	0.148	0.159	0.016
D-20	0.003	0.053	0.056	0.013
D-30	0.001	0.104	0.105	0.012
E-10	0.003	0.035	0.038	0.017
E-20	0.008	0.01	0.018	0.013
E-30	0.01	0.022	0.032	0.02
F-10	0.24	0.012	0.252	0.037
F-20	0.48	0.012	0.492	0.044
F-30	0.64	0.011	0.651	0.06
Stanley River	0.017	0.118	0.135	0.010
D-10	0.083	0.024	0.107	0.003
D-20	0.19	0.01	0.2	0.005
D-30	1.4	0.011	1.411	0.005
E-10	0.31	0.012	0.322	0.004
E-20	0.24	0.009	0.249	0.015
E-30	0.23	0.008	0.238	0.006
F-10	0.27	0.013	0.283	0.01
F-20	0.38	0.009	0.389	0.003
F-30	0.49	0.008	0.498	0.003
Monsildale Creek	0.003	0.003	0.006	0.003
D-10	0.009	0.058	0.067	0.014
D-20	0.019	0.048	0.067	0.015
D-30	0.002	0.052	0.054	0.008
E-10	0.002	0.097	0.099	0.015
E-20	0.002	0.089	0.091	0.015
E-30	0.003	0.035	0.038	0.025
F-10	0.005	0.058	0.063	0.022
F-20	0.003	0.166	0.169	0.026
F-30	0.021	0.078	0.099	0.037

Groundwater Discharge

Groundwater discharge ranged from 10.4 ± 2.2 $L\ m^{-2}d^{-1}$ at Kilcoy Ck to 115 ± 35 $L\ m^{-2}d^{-1}$ at Stanley River (Table 3). The 3 streams with the lowest rates had sandy banks and streambed. However, Stanley River with the highest rate of discharge, had relatively impermeable clay banks with a sandy streambed suggesting that groundwater discharge may be more focused at this site. Low groundwater discharge at Kilcoy Creek and high discharge at Stanley River are consistent with hyporheic zone nutrient data in that the sandbar at Stanley River had nutrient concentrations similar to groundwater while the upstream end of the sandbar at Kilcoy Creek had concentrations which were very similar to stream water.

Table 3: Groundwater discharge from the streambed of 4 streams in the Brisbane River catchment; mean (SD) of 2 to 5 replicates.

Site	Discharge ($L\ m^{-2}d^{-1}$)
Kilcoy Creek	10.4 (2.2)
Buaraba Creek	18.4 (4.1)
Monsildale Creek	39.0 (2.5)
Stanley River	115 (35.4)

Conclusions:

This study has demonstrated that relative to in-stream concentrations, there were high concentrations of ammonium in the groundwater immediately adjacent to the stream and that ammonium was the dominant form of N in groundwater. Conversely, oxidized N concentrations were generally higher in the stream than in the adjacent groundwater. This suggests that either ammonium in groundwater was oxidized to nitrite and nitrate on entering the stream, or that groundwater inflows at these sites were insufficient to significantly affect stream concentrations. Our results also indicated differences in the groundwater inflow rates to streams at the four sites where inflow was measured. We did not identify any regions of apparent denitrification at Buaraba Creek, the one site where we were able to sample a complete transect.

Implications of our findings for future research are:

(i) Alternative coring techniques (e.g. drilling rigs) will need to be used at most sites if we hope to sample the groundwater at significant distances from the streams.

(ii) Installation of multiple transects of piezometers perpendicular to the stream to delineate a grid would enable estimates of groundwater flux through the riparian zone to be made. From these fluxes, nutrient fluxes could then be calculated from measured concentrations.

(iii) Additional description of groundwater flow is needed prior to choosing samples for stable isotope analysis. Once specific flowpaths are delineated, differences in nutrient concentrations along these flowpaths may suggest specific processes to investigate.

(iv) Patterns in nutrient concentrations should also be investigated over time and include transient events such as rainstorms. The influence of the riparian zone may be more important during and after rain events, when the water table is elevated and inflows of shallow groundwater from hillslopes are likely to occur.

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