Spot sampling of nutrient concentrations in the Puarenga catchment, Rotorua

CBER Report 122

Prepared for Tūhourangi Tribal Authority

By Jonathan M. Abell and David P. Hamilton

Centre for Biodiversity and Ecology Research,
The University of Waikato, Private Bag 3105,
Hamilton 3240, New Zealand

September 2011

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

CBER University of Waikato
Centre for Biodiversity and Ecology Research

Table of contents

List of Figures

List of Tables

Reviewed by:
Deniz Özkundakci

University of Waikato
Affiliation

Approved for release by:
Joanne Faber

University of Waikato
Affiliation

Introduction

The Centre for Biodiversity and Ecology Research was approached by Tūhourangi Tribal Authority for assistance with measuring water quality in streams in the Puarenga Stream catchment. Water sampling was subsequently undertaken on 18 July 2011 and samples were analysed to determine concentrations of total and dissolved fractions of nitrogen and phosphorus.

Nitrogen and phosphorus are both essential plant nutrients which, when present in excess, can cause eutrophication and associated water quality decline of freshwaters. High concentrations of dissolved forms of nitrogen can also be toxic to aquatic organisms. Excessive nitrogen and phosphorus concentrations are typically the result of pollution due to human activities, although groundwater in the Central Volcanic Plateau region can have elevated concentrations of phosphorus arising from natural geological sources (Timperley 1983).

This report summarises the methods used, presents the results and places measured concentrations in context by drawing comparisons with both guideline and regional mean values.

1. Methods

1.1. Study site

2.1.1 Overview

The Puarenga Stream flows into the southern end of Lake Rotorua and drains a catchment of approximately 77 km^2 in area (Figure 1). The stream has a mean discharge of approximately 2.03 m^3 s^{-1} and is the second largest inflow to Lake Rotorua (Hoare 1980; NIWA 2008). There are significant geothermal inputs to the stream at the Whakarewarewa geothermal area located approximately 2.5 km upstream of the mouth. Downstream, the Puarenga Stream is geothermal-influenced and has warm acidic waters with a temperature of 14 – 22 °C (Kusabs and Shaw 2008). Major tributaries of the Puarenga Stream include: the Waipa, Tureporepo, Kauaka and Waihuahuakakahi streams.

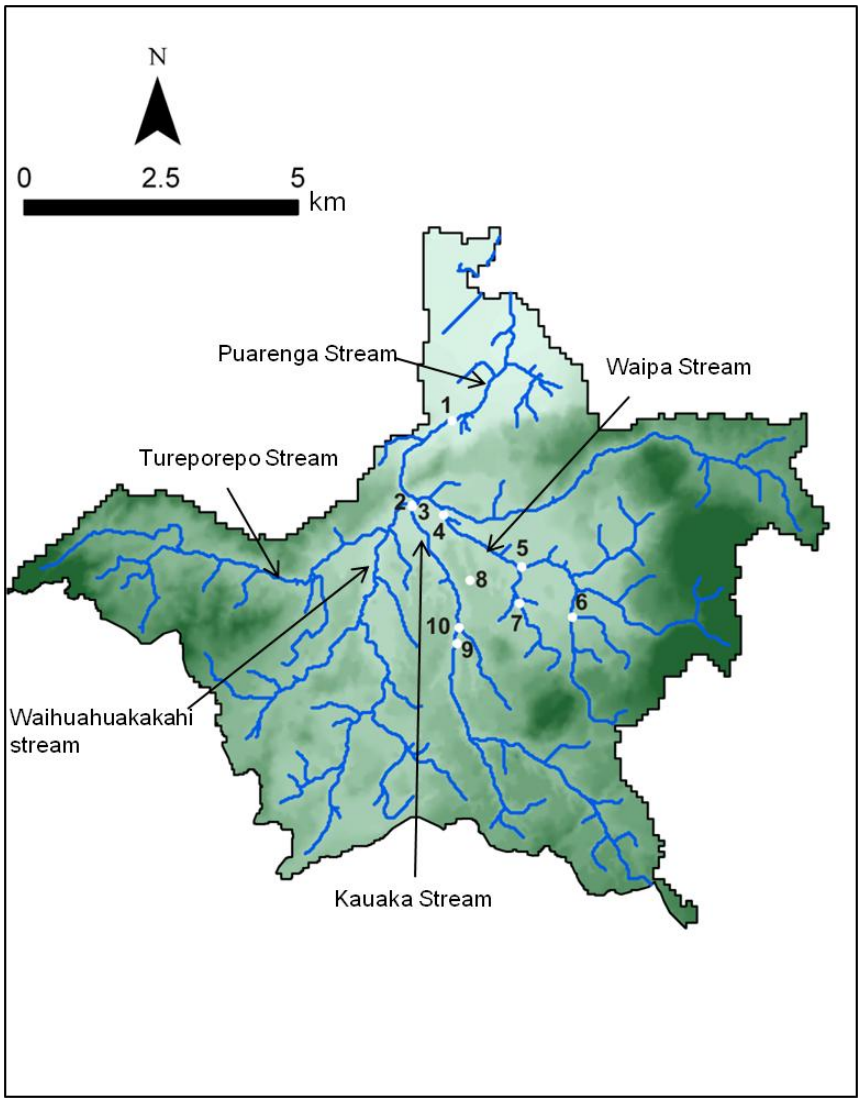

Figure 1*:* The Puarenga Stream catchment and location of main tributaries. Numbers denote sampling locations.

2.1.2 Nutrient sources

The predominant land use in the catchment is exotic coniferous forestry which is managed on a commercial basis. This land use covers approximately 46% of the catchment while approximately 33% of the catchment comprises pasture (LCDB2 2003). Other land uses include native forest and residential buildings in the lower catchment. Since 1991, treated wastewater has been pumped from the Rotorua Wastewater Treatment Plant and spray-irrigated over an area of 191 ha in the Whakarewarewa Forest situated in the eastern part of the catchment (Tomer *et al*. 2000). Rotorua District Council holds a Resource Consent for this operation. This consent requires that a stream water quality monitoring programme be undertaken and imposes limits to the permissible loads of nitrogen and phosphorus measured in the Waipa Stream, downstream of the irrigated area (Bay of Plenty Regional Council 2009).

2.2 Sampling methods

Weather conditions were dry at the time of sampling and no rainfall was recorded at the Whakarewarewa rain gauge in the catchment in the preceding 24 hours (BOPRC 2011a). Puarenga Stream discharge measured at the State Highway 30 gauge was elevated (3.02 – 3.10 $m^3 s^{-1}$; BOPRC 2011b) above winter base flow and the stream water level was receding following high rainfall in the week prior to sampling.

The ten sampling sites were selected by Tūhourangi Tribal Authority who provided access to sampling locations (see Appendix for photographs of all sites). Grab samples (~40 mL) were collected in acid-washed (10% HCl) polypropylene tubes. Two unfiltered samples and one filtered sample were collected at each site. Filtering was undertaken in the field immediately after sample collection using acid-washed syringes and 0.5 μm Advantec GC filters. Samples were stored on ice until return to the laboratory where they were frozen until analysis.

2.3 Analytical methods

Dissolved nutrients (NO_2-N, NO_3-N, NH_4-N, PO_4-P) were measured with an Aquakem 200 discrete analyser (Thermo Fisher) using standard colorimetric methods (APHA 1998). Limits of detection were 0.001 mg N L^{-1} for NO_2, NO_3, 0.002 mg N L^{-1} for NH_4 and 0.001 mg P L^{-1} for PO_4. Total nitrogen (TN) and total phosphorus (TP) concentrations were determined following alkaline persulphate digestion (APHA 1998) of an unfiltered sample and subsequent colorimetric analysis for NO_3 and PO_4 respectively, using a Lachat QuickChem flow injection analyser (Zellweger Analytics Inc.). Limits of detection were 0.001 mg N L^{-1} for TN and 0.001 mg P L^{-1} for TP. Particulate nitrogen (PN) and particulate phosphorus (PP) were calculated by subtraction and these fractions also included dissolved organic nitrogen and dissolved organic phosphorus, respectively. Dissolved inorganic nitrogen (DIN) is the sum of NO_2-N, NO_3-N and NH_4-N. Oxides of nitrogen (NO_x-N) are NO_2-N and NO_3-N.

One unfiltered sample from each site will be kept frozen for one year following sampling should further analyses be required.

2. Results and discussion

There are currently no statutory water quality standards for the protection of freshwater ecosystems in New Zealand. To provide context, measured data have therefore been compared with values from the following three sources (Table 1):

i. Mean nutrient concentrations for Bay of Plenty river and stream sampling sites during the period 1996 – 2007, calculated by McDowell *et al*. (2009).
ii. Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000)
iii. Recommended guideline to avoid chronic (long term) nitrate (NO_3) toxicity to aquatic organisms. This guideline was specifically developed for the Canterbury region and relates to slightly to moderately disturbed systems subjected to a range of disturbances from human activity (NIWA 2009). Note that measured NO_x-N is considered equal to NO_3-N in this report as NO_2-N concentrations were below detection limits (Table 2).

Table 1: Mean and guideline values compared with measured data

Reference	Source	TN (mg L^{-1})	TP (mg L^{-1})	NOx-N (mg L^{-1})	NO_3-N (mg L^{-1})	NH4-N (mg L^{-1})	DIN (mg L^{-1})	PO_4-P (mg L^{-1})
Mean concentrations for Bay of Plenty (BOP) river and stream sampling sites, 1996 – 2007.	McDowell *et al*. (2009)	1.307	0.047	-	-	-	0.501	0.033
Australian and New Zealand Guidelines for Marine and Freshwater Quality	ANZECC & ARMCANZ (2000)	0.614	0.033	0.444	-	0.021	-	0.010
Guideline for chronic nitrate toxicity in slightly to moderately disturbed systems.	NIWA (2009)	-	-	-	1.7	-	-	-

All sites exceeded one or more of the Australian and New Zealand Guidelines for Marine and Freshwater Quality (Table 2; Figure 2). Such exceedances are common in New Zealand streams and rivers in non-alpine areas (Larned *et al*. 2004). Nitrogen concentrations were generally highest at Site 7, likely reflecting the location of this site in the wastewater spray-irrigation area. This is the only site where measured NO_3 exceeded the recommended chronic toxicity guideline applicable to slightly to moderately disturbed systems. This guideline is based on the results of tests conducted on three fish species belonging to the family *Salmonidae*. These species are known to be particularly sensitive to NO_3 pollution and include rainbow trout (*Oncorhynchus mykiss*). Other organisms such as invertebrates are likely to be less sensitive, however, few toxicity data have been collected for native species

(NIWA 2009). Phosphorus concentrations were highest at Site 8 which was a groundwater seep from disturbed ground understood to be a waste disposal site (Walton Lee, personal communication). The high phosphorus concentrations may therefore reflect local mineralisation of organic waste material. Ammonium concentrations were greatly elevated at Sites 6 and 8 as measured concentrations were over six times greater than the ANZECC & ARMCANZ (2000) guideline. Comparison with the guideline value for lowland rivers, however, is not necessarily appropriate for these sites as Site 6 is an outflow from a wetland and Site 8 is a groundwater seep. High ammonium concentrations likely reflect the low oxygen environments upstream which create suitable conditions for the reduction of nitrate and prevent ammonium being oxidised to NO_x species. With the exception of three sites, DIN concentrations were high relative to mean values for streams in the Bay of Plenty reported by McDowell *et al*. (2009).

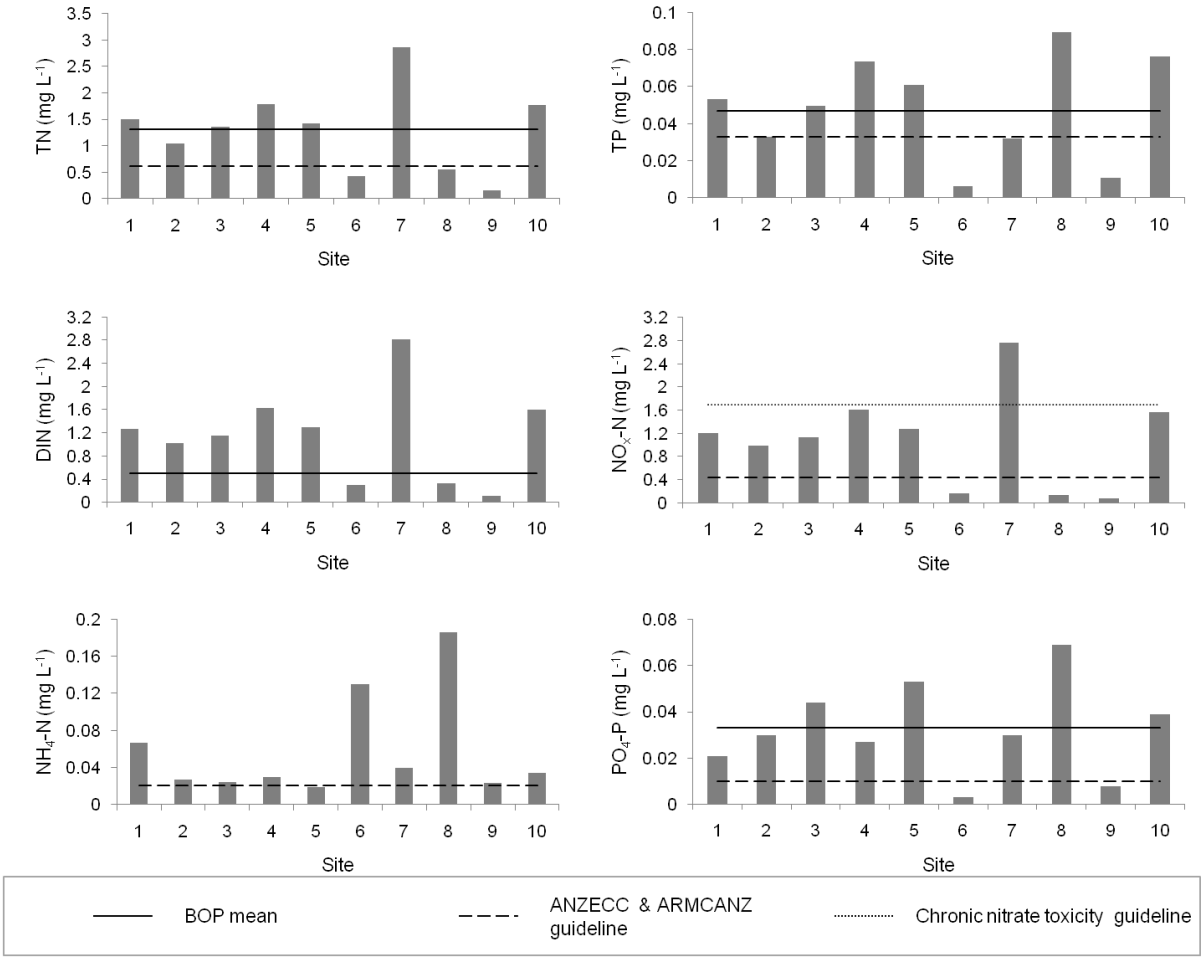

Figure 2*:* Measured nutrient concentrations at ten sites sampled in the Puarenga Stream catchment on 18 July 2011. Site locations are shown in Figure 1. Details of the mean and guideline values used for comparison (horizontal lines) are presented in Table 1.

Table 2: Site descriptions and nutrient concentrations on 18 July 2011. Map coordinates relate to New Zealand Map Grid projection.

Site # (Fig. 1)	Site name	Easting (m)	Northing (m)	TN (mg L^{-1})	TP (mg L^{-1})	PN (mg L^{-1})	PP (mg L^{-1})	NH_4-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	PO_4-P (mg L^{-1})
1	Penny Diving Pool, Puarenga Stream	2795469	6332753	1.507	0.053	0.243	0.032	0.067	1.198	< 0.001	0.021
2	Kauaka Stream U/S of confluence with Tureporepo Stream	2794743	6331189	1.038	0.033	0.018	0.003	0.027	0.993	< 0.001	0.03
3	Tureporepo Stream U/S of confluence with Kauaka Stream	2794740	6331208	1.363	0.050	0.212	0.006	0.025	1.126	< 0.001	0.044
4	Waipa Stream D/S of Waipa Saw Mill	2795316	6331030	1.792	0.074	0.160	0.047	0.030	1.603	< 0.001	0.027
5	Waipa stream U/S of Waipa Saw Mill	2796743	6330081	1.419	0.061	0.117	0.008	0.019	1.283	< 0.001	0.053
6	Wetland outlet, spray irrigation area	2797669	6329165	0.421	0.006	0.121	0.003	0.130	0.170	< 0.001	0.003
7	Lake outlet, spray irrigation area	2796707	6329414	2.860	0.032	0.051	0.002	0.040	2.770	< 0.001	0.030
8	Groundwater seepage from hill side, Taeda Road hill top	2795796	6329839	2.023	0.089	0.229	0.020	0.190	0.140	< 0.001	0.069
9	Tributary of the Kauaka Stream at inlet to Culvert 17 under SH 5	2795561	6328684	0.834	0.011	0.056	0.003	0.024	0.082	< 0.001	0.008
10	Tributary of the Kauaka Stream by SH 5. Drains recently logged area.	2795595	6328973	0.409	0.076	0.161	0.037	0.034	1.570	< 0.001	0.039

3. Conclusion

Concentrations of nitrogen and phosphorus species were determined in grab samples collected from ten sites in the Puarenga Stream catchment. All sites exceeded guideline values for the protection of lowland river ecosystems for at least one determinand, although these guideline values may not necessarily be relevant to all sites. Nutrient concentrations at most sites were broadly comparable to regional mean values although dissolved inorganic nitrogen concentrations were relatively high at most sites, particularly at sites within or downstream of the wastewater irrigation area. Nitrate concentration at one site, located at the outflow of a lake in the wastewater irrigation area, exceeded a chronic toxicity guideline value based on the results of tests conducted using fish species belonging to the family *Salmonidae*.

The sampling programme undertaken was limited and only provides a 'snapshot' of nutrient concentrations at one time in a hydrologically variable system. The catchment is relatively well monitored and nutrient concentrations in both the Waipa and the Puarenga streams have been measured on a weekly or monthly basis by Rotorua District Council and Bay of Plenty Regional Council, respectively, for over ten years. A large amount of data has therefore been collected which could be used to undertake a more detailed assessment of water quality in the catchment.

4. Acknowledgments

Photographs in this report were provided by Wang Me.

5. References

APHA. 1998. Standard methods for the examination of water and wastewater, 20th edition. American Public Health Association.

Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ). 2000. Australian and New Zealand guidelines for fresh and marine water quality. Chapter 8.2, Physical and chemical stressors.

Bay of Plenty Regional Council. 2009. Rotorua District Council Spray Irrigation Compliance Report, p. 50. Environmental Publication 2009/13.

Bay of Plenty Regional Council. 2011a. 'Rotorua at Whakarewarewa' rainfall depth telemetry data. Available at: http://old.boprc.govt.nz/MonitoredSites/cgi-bin/hydwebserver.cgi/sites/details?site=228&treecatchment=21. Accessed 08/09/2011.

Bay of Plenty Regional Council. 2011b. 'Puarenga at SH 30 bridge' stream flow telemetry data. Available at: http://old.boprc.govt.nz/MonitoredSites/cgi-bin/hydwebserver.cgi/sites/details?site=302&treecatchment=22. Accessed 08/09/2011.

Hoare, R. A. 1980. Inflows to Lake Rotorua. Journal of Hydrology (New Zealand) **19:** 49-59.

Kusabs, I., and W. Shaw. 2008. An ecological overview of the Puarenga Stream with particular emphasis on cultural values, p. 42. Report prepared for Rotorua District Council and Bay of Plenty Regional Council.

Land Cover Database (LCDB) 2. 2003. GIS map layer. Available at: http://koordinates.com/. Accessed 08/09/11.

Larned, S. T., M. R. Scarsbrook, T. H. Snelder, N. J. Norton, and B. J. F. Biggs. 2004. Water quality in low-elevation streams and rivers of New Zealand: recent state and trends in contrasting land-cover classes. N. Z. J. Mar. Freshw. Res. **38:** 347-366.

McDowell, R. W., Larned, S. T., Houlbrooke, D. J. 2009. Nitrogen and phosphorus in New Zealand streams and rivers: control and impact of eutrophication and the influence of land management. N. Z. J. Mar. Freshw. Res. **43:** 985-995.

National Institute of Water and Atmospheric Research (NIWA). 2008. Water balance modelling in the Lake Rotorua catchment, p. 52. Client report for Bay of Plenty Regional Council

National Institute of Water and Atmospheric Research (NIWA). 2009. A review of nitrate toxicity to freshwater aquatic species, p. 56. Client report for Environment Canterbury.

Timperley, M. H. 1983. Phosphorus in spring waters of the Taupo Volcanic Zone, North Island, New Zealand. Chemical Geology **38:** 287-306.

Tomer, M., C. Smith, A. Thorn, G. Gielen, T. Chaleston, and L. Barton. 2000. Evaluation of treatment performance and processes after six years of wastewater application at Whakarewarewa Forest, New Zealand, p. 155-162. *In* C. Henry, R. Harrison and P. Bastian [eds.], The forest alternative: Principles and practice of residuals use. University of Washington.

Appendix: site photographs

Site 1: Penny Diving Pool, Puarenga Stream

Site 2: Kauaka Stream upstream of confluence with Tureporepo Stream

Site 3: Tureporepo Stream upstream of confluence with Kauaka Stream

Site 4: Waipa Stream downstream of Waipa Saw Mill

Site 5: Waipa Stream upstream of Waipa Saw Mill, by Waiariki Institute of Technology Waipa Campus

Site 6: Wetland outlet, spray irrigation area. Sample was taken from the outlet pipe (left), immediately downstream of the wetland area (right).


Site 7: Lake outlet, spray irrigation area. Sample was taken from the outlet (left) of the small lake (right).


Site 8: Groundwater seepage from hill side, Taeda Road hill top. Sample was taken from a small gully (left) where groundwater seeping from the north-facing slope (right) had ponded. Note oily sheen on the water surface.

Site 9: Tributary of the Kauaka Stream at inlet to Culvert 17 under SH 5

Site 10: Tributary of the Kauaka Stream by SH 5. Drains recently logged area.