State of the Environment Monitoring

Rivers & Streams Water Quality Data Report 2006

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Acknowledgments

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1 Background

There are approximately 10,000 km of permanently flowing waterways in the Auckland region, which if laid end to end would stretch from Cape Reinga to Bluff and back again. The Auckland region contains a wide variety of stream types covering four major geology types (hard rock, volcanic, sand, and clay) and four land use categories (bush, forestry, rural, and urban). Most streams in the Region are small, first and second order, of relatively short length when compared to some of the extensive river systems found in the rest of New Zealand. Major rivers in the Auckland Region include the Hoteo, Wairoa, Rangitopuni, Kaipara, Kaukapakapa and Kumeu.

Rivers and streams are receiving environments for a range of contaminants that flow directly or leach from the catchments in which they drain. These contaminants can adversely affect ecological and human health, and affect estuaries and marine resources downstream. The Rivers & Streams Water Quality Programme encompasses 27 individual sites that span a range of land uses and disturbance regimes.

Greater sampling intensity is undertaken in catchments adjoining the Tamaki Estuary, and Mahurangi Harbour, because of specific local issues. The Tamaki Estuary is one of the most highly impacted urban water bodies in the Auckland region, while the Mahurangi catchment, and its harbour is recognised for its high value and sensitivity to landuse activities.

Water quality data from this programme is also used in conjunction with freshwater macroinvertebrate and physical habitat data to provide an integrated overview of the physical, chemical, and biological condition of the region's streams.

The data collected is summarised and reported annually, and provides a basis for determining the relative state of freshwater resources in the Auckland Region and for informing water quality guidelines, standards and indicators. Analysis of trends is reported separately, typically at 5-yearly intervals.

2 Programme objectives

The water quality programme is designed to meet the following objectives:

- Satisfy the Auckland Regional Councils’ s35 Resource Management Act (1991) obligations with respect to state of the environment reporting.
- Contribute to community outcome monitoring required by the Local Government Act (2002).
- Help inform the efficiency and efficacy of policy initiatives and strategies.
- Assist with the identification of large scale and/or cumulative impacts of contaminants associated with varying land uses and disturbance regimes and link these to particular activities.
- Provide baseline, regionally representative data from which impacts of individual activities can be measured through compliance monitoring.
- Provide baseline, regionally representative data to support preparation of environmental effects assessments required through the resource consent process.
- Answer queries from the public, and promote awareness of water quality issues.

This water quality programme fits under the “Natural Environment and Heritage” component of the ARCs Long Term Community Consultation Plan 2004-14. A key issue for the region is to manage the effects of growth and development on our natural environment. This includes balancing the needs for sustainable environmental management with the community’s social, economic and cultural well being.

Specific objectives include managing and minimising the effects of present and future urban and rural development, growth, and intensification across the Region. The water quality parameters provide information on the condition of the region’s streams, and feedback on management actions. This is necessary to confirm that ARC’s management strategies are effective in sustaining stream functions and uses. By achieving this outcome we are working towards achieving the ARC mission:

- “Working in partnership with our regional community to achieve social, economic, cultural and environmental wellbeing”.

This is the 17th data report since the inception of the monitoring programme, although it is second time since 2000 that the data has been reported separately from the saline and lakes water quality monitoring programmes. Previous reports described in the list of references can be obtained by contacting the Auckland Regional Council (09) 366 2000, in electronic format where available from the ARC’s website: www.arc.govt.nz/publications or email: info@arc.govt.nz.

2.1 Report content

This report provides 12-months of summary data from the 2006 calendar year collected from 27 locations across the Auckland Region, and includes:

- Summary statistics tabulated by parameter, grouped by landuse class.
- Site specific time series graphs by parameter across the entire data record.

2.2 Programme Design

Water samples and site measurements are collected monthly by ARC technical officers. Sampling is divided into 5 geographically distinct runs (north, south, north-east, Tamaki and Mahurangi) and undertaken in the first two weeks of each month by the same group of technical staff. Temporal variation is avoided as much as possible by maintaining a consistent sampling time with each subsequent visit (± 1 hour). This avoids introducing diurnal variation to the dataset and improves the power of long term trend detection.

Routine water quality monitoring locations are summarised in Table 2 and illustrated in Figure 1. Two sites (Hoteo River and Rangitopuni River) also form part of the National Water Quality River Network (NWQRN) operated by the Crown Research Institute NIWA which is reported separately (Scarsbrook, 2006).

Sites were selected to provide broad geographic coverage, and to represent 4 major land use classes (bush, forestry, rural, urban) and two disturbance gradients (high and low). Reference sites with native forest catchments were selected to represent pre-human condition and the two major geology types in the region; hard-bottomed (hard rock) and soft-bottomed (clay). Site selection was assisted by evaluating catchment land use using the Land Cover Database version I and II and geology layers maintained by the ARC.

2.3 Water Quality Parameters

The water quality of the Region's rivers and streams is determined by measuring up to 25 parameters, 17 routinely. Some parameters are determined in the field but most are analysed in the laboratory. The number and type of parameters has varied since the programme's inception as new technology became more affordable, instrument sensitivity improved and the programme objectives were modified. Details of the laboratory analytes and field measurements are given in appendix I.

Table 1. WQ-stream sites by catchment land use, showing NZTM co-ordinates and start of sampling period.

Site	Land use	Disturbance	Easting	Northing	Start
Cascade Stream	Bush reference	Low	1735621	5916338	1986
WestHoe Stream	Bush reference	Low	1748201	5950704	2001
Ngakoroa Stream	Rural	High	1775151	5881625	1986
Hoteo River	Rural	High	1735254	5972546	1986
Kumeu River	Rural	High	1739247	5928774	1986
Matakana River	Rural	High	1753080	5977166	1986
Opanuku Stream	Rural	Low	1742139	5915566	1986
Rangitopuni River	Rural	High	1744433	5932282	1986
Waiwera River	Rural	High	1748752	5953672	1986
Papakura Stream	Rural	High	1771323	5900341	1986
Wairoa River	Rural	High	1782672	5901689	1986
Lucas Creek	Urban	High	1751401	5934549	1993
Oteha Stream	Urban	High	1751363	5933553	1986
Oakley Creek	Urban	High	1751980	5917698	1994
Puhinui Stream	Urban	High	1766465	5904304	1994
Awanohi Stream	Rural	Low	1751406	5938709	2003
Vaughan Stream	Rural	High	1756338	5939098	2001
Tamaki Streams					
Otara Creek, Kennell Hill	Urban	High	1768340	5908365	1992
Otara Creek, East Tamaki Rd	Urban	High	1767404	5907471	1985
Pakuranga Creek, Greenmount Drive	Urban	High	1769473	5910813	1985
Pakuranga Creek, Guys Rd	Urban	High	1770004	5910969	1985
Pakuranga Creek, Botany Rd	Urban	High	1770095	5913057	1985
Omaru Creek, Taniwha St	Urban	High	1766269	5916769	1985
Otaki Creek, Niddlemore Cres	Urban	High	1764290	5907217	1985
Mahurangi Streams					
Mahurangi River	Forestry	Low	1747633	5964891	1986
Mahurangi at Water Supply	Urban	High	1749099	5970577	1993
Mahurangi at Town Bridge	Urban	High	1748748	5970343	1993

Figure 1: Monitoring locations

2.4 Quality Control, Data Storage and Analysis

Quality control measures are undertaken in accordance with Auckland Regional Council's internal standards, including procedures for the collection, transport and storage of samples, and methods for data verification and quality assurance to ensure consistency across the monitoring programme. Samples are analysed under contract to the ARC by Watercare Laboratory Services Ltd, an IANZ accredited laboratory. Analytical methods follow the "Standard Methods for the Examination of Water and Wastewater" 18th Edition (APHA 1992). All field and laboratory data are stored in the ARCs water quality archiving database (HYDSTRA).

Data analysis is performed in HYDSTRA using specially designed scripts that interpret, collate and output pre-determined summary statistics. For the purposes of data analysis, non-detect results (results below instrument sensitivity and reported with 'less than' values) were assumed at face value.

2.5 Programme changes

The analytical programme was reviewed in June 2005. Key changes to water quality variables monitored are described in the 2005 Rivers and Streams Water Quality Data Report (ARC, 2007).

The monitoring of faecal contamination was increased from July 2006 to include *E.coli* at all monitored sites.

Metals analysis was included for Otara Creek at Kennell Hill, Vaughan Stream and Okura Creek where the proportion of urban landuse is currently low but where urban development is planned. Total and soluble cadmium was added to the metal analysis for a six month period from July to December 2006.

2.6 Reports

Comprehensive trend analysis is conducted approximately every 5 years, with the last report published in 2000 (Wilcock and Stroud 2000). A new trend analysis report is currently in preparation. Auckland Regional Council's State of the Environment Report 2004 briefly summaries water quality issues, including an assessment of the ecological health of the Region's freshwater resources and land use pressures (ARC, 2004).

The programme is reviewed approximately every 5 years. Recent reviews were conducted concurrently with the last trend analysis in 2000 (Wilcock and Stroud 2000), and in 2005 (internal ARC document).

Additional information can be found in "Summary of the Ecological Health of Auckland Streams based on State of the Environment Monitoring 2000-2004", which compares water quality data with other indices of ecosystem health including the macroinvertebrate community index and habitat quality index (Maxted, 2005).

The data contained in this report will also be used to populate relevant environmental indicators anticipated as a web-based reporting initiative currently in the early planning stages. When live this information can be accessed at the ARCs website www.arc.govt.nz.

Water quality data can be obtained from the ARC wbsite at http://maps.arc.govt.nz/website/maps/map_hydrotel.htm

3 Results

Table 2: Statistical summary of routine water quality variables obtained from each of the 27 monitoring sites for the 2006 calendar year plus the 02-06 median. NA= Parameter not analysed at that site.

		Dissolved oxygen (g.m^{-3})								Dissolved oxygen (% saturation)							
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Med	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Med
Cascade Stream	Native	12	9.7	9.7	7.9	10.6	0.6	-1.79	9.8	12	94.7	95.5	79.9	107.5	9.7	-0.35	95.3
WestHoe Stream	Native	10	8.7	9.3	5.5	10.5	1.8	-1.01	9.2	10	81.8	84.9	53.8	94.2	6.1	-1.53	85.6
Ngakoroa Stream	Rural	12	8.5	8.3	6.9	10.1	2.0	0.08	9.0	12	83.5	82.2	74.6	95.7	11.3	0.61	87.3
Hoteo River	Rural	12	8.4	8.1	7.3	10.4	0.9	1.27	8.6	12	84.9	85.9	76.7	90.9	8.1	-0.33	87.0
Kumeu River	Rural	12	8.6	8.5	6.1	10.1	1.2	-0.85	8.3	12	85.5	85.2	69.8	101.7	13.3	0.39	83.3
Matakana River	Rural	12	8.3	8.0	6.8	10.2	1.9	0.39	8.1	12	82.1	83.0	73.8	89.2	7.8	-0.12	83.2
Opanuku Stream	Rural	12	9.5	9.5	7.8	11.0	1.9	-0.15	9.7	12	91.7	89.2	84.4	100.8	10.4	0.46	92.5
Rangitopuni River	Rural	12	7.8	8.0	4.5	10.8	2.9	-0.15	8.0	12	76.0	80.6	49.5	91.7	21.2	-0.77	79.1
Waiwera River	Rural	12	9.1	9.1	7.5	10.6	1.6	-0.07	9.3	12	90.8	90.0	84.9	106.7	6.1	1.84	92.1
Papakura Stream	Rural	12	7.7	8.0	5.7	9.3	2.3	-0.39	7.7	12	76.7	77.0	65.2	90.6	14.3	0.00	78.0
Wairoa River	Rural	12	9.2	9.2	6.8	10.6	1.6	-0.67	9.5	12	91.7	91.7	79.2	100.7	6.8	-0.68	92.9
Okura Creek	Rural	10	8.4	8.6	3.2	11.7	3.2	-0.81	8.6	10	78.7	82.9	32.7	101.3	18.7	-1.47	80.5
Vaughan Stream	Rural	10	8.3	7.9	5.5	11.6	3.4	0.20	7.3	10	82.8	80.8	61.1	104.5	26.9	0.06	75.2
Lucas Creek	Urban	11	7.9	8.5	6.2	9.4	2.4	-0.20	8.2	11	77.8	81.1	63.5	90.0	14.4	-0.44	81.0
Oteha Stream	Urban	12	7.6	8.2	5.3	10.0	2.9	-0.21	7.7	12	74.5	79.7	56.8	86.2	21.4	-0.57	74.4
Oakley Creek	Urban	12	8.6	8.9	7.1	9.7	1.4	-0.44	8.6	12	86.1	86.0	79.0	93.4	10.2	0.04	84.8
Puhinui Stream	Urban	12	9.4	9.5	4.8	12.3	1.9	-1.15	9.2	12	98.9	100.5	52.5	137.7	20.9	-0.47	93.5
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	8.0	8.2	5.3	10.6	2.9	-0.24	7.3	12	79.8	79.3	61.0	103.5	20.8	0.09	76.7
Otara Ck East Tamaki	Urban	12	9.5	9.7	6.0	10.7	0.7	-2.48	9.7	12	96.1	97.3	61.0	110.4	8.0	-2.32	95.8
Pakuranga Ck Greenmt	Urban	12	7.8	7.5	6.3	9.7	2.3	0.30	7.7	12	80.0	75.8	67.8	103.4	18.7	0.83	79.9
Pakuranga Ck Guys Rd	Urban	12	8.0	8.5	0.9	16.9	3.0	0.46	6.5	12	81.5	81.8	10.0	196.2	22.4	1.30	66.6
Pakuranga Ck Botany	Urban	12	11.3	11.2	9.8	15.7	1.4	1.95	11.6	12	123.7	114.7	93.4	193.8	26.5	1.65	125.8
Omaru Creek	Urban	12	7.2	7.1	4.2	10.2	3.4	0.03	6.8	12	74.2	73.7	45.9	96.1	22.5	-0.30	73.1
Otaki Creek	Urban	12	6.9	7.3	3.2	10.9	3.5	-0.22	7.1	12	70.0	75.3	32.9	104.5	29.8	-0.49	74.6
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	12	9.1	8.9	7.5	10.6	1.5	0.03	9.2	12	87.5	87.1	81.2	94.1	5.0	0.01	89.8
Mahurangi River WS	Urban	12	9.6	9.6	8.0	11.1	1.6	-0.04	9.8	12	96.0	97.2	87.6	113.0	8.6	1.13	98.2
Mahurangi River Bdge	Urban	12	9.2	9.3	6.8	10.4	1.7	-0.95	9.4	12	92.1	93.0	75.8	107.5	6.5	-0.20	93.2

Site	Land use	Temperature (°C) Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Conductivity at 25°C (µS.cm^{-2}) Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	12	14.4	14.5	10.0	20.7	3.7	0.47	13.4	12	161.8	166.3	114.3	190.4	22.2	-1.07	166.3
WestHoe Stream	Native	12	13.0	13.4	8.5	18.5	3.9	0.26	13.3	12	176.9	179.4	145.7	200.2	18.7	-0.86	188.8
Ngakoroa Stream	Rural	12	14.7	14.7	9.6	21.3	3.6	0.20	14.6	12	160.5	155.3	141.2	194.0	27.4	0.77	155.6
Hoteo River	Rural	12	15.9	16.2	8.7	22.9	6.1	-0.08	15.8	12	186.0	192.9	121.5	201.9	14.2	-2.73	187.7
Kumeu River	Rural	12	15.6	15.2	9.9	22.3	6.0	0.28	15.2	12	168.0	167.0	116.2	202.5	28.9	-0.72	165.9
Matakana River	Rural	12	15.4	15.8	8.7	21.5	5.1	-0.17	15.2	12	179.0	183.0	131.7	210.5	21.7	-0.95	182.95
Opanuku Stream	Rural	12	13.8	13.5	9.2	21.0	4.5	0.62	13.5	12	137.0	137.6	117.2	156.1	18.1	-0.14	135.85
Rangitopuni River	Rural	12	15.4	15.7	7.9	22.0	6.4	-0.28	15.1	12	216.9	219.9	155.2	253.4	25.3	-1.36	219.7
Waiwera River	Rural	12	15.4	15.9	8.6	22.5	6.7	-0.07	15.2	12	198.4	202.0	164.4	214.4	16.6	-1.30	195.4
Papakura Stream	Rural	12	15.7	15.4	10.0	23.2	5.0	0.34	15.3	12	196.1	192.1	165.1	248.9	28.5	1.09	190.9
Wairoa River	Rural	12	15.6	15.0	9.5	23.1	5.7	0.10	14.9	12	115.7	112.4	96.0	142.1	22.3	0.54	108.8
Okura Creek	Rural	12	13.7	14.2	7.1	21.1	4.9	0.05	13.9	12	233.8	236.6	199.4	277.7	24.2	0.34	235.5
Vaughan Stream	Rural	12	16.1	15.8	10.2	21.9	5.1	-0.04	15.7	12	244.0	243.8	184.7	355.0	30.6	1.76	237.6
Lucas Creek	Urban	11	15.2	15.0	11.3	21.5	3.6	0.72	14.4	11	264.8	259.7	183.8	337.4	33.5	-0.45	258.0
Oteha Stream	Urban	12	15.1	15.2	8.9	21.2	4.8	0.04	14.7	12	215.0	201.8	127.9	316.4	107.2	0.26	229.4
Oakley Creek	Urban	12	15.7	15.5	12.2	21.0	3.5	0.52	15.0	12	228.3	241.9	113.3	266.5	48.1	-1.62	215.6
Puhinui Stream	Urban	12	18.1	18.0	11.7	24.0	5.3	-0.35	17.4	12	185.9	201.9	58.4	252.4	53.1	-1.52	202.3
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	16.0	15.8	8.7	24.0	4.8	0.03	15.2	12	239.6	233.4	195.1	370.4	34.6	2.16	222.7
Otara Ck East Tamaki	Urban	12	15.9	15.6	12.9	19.8	4.9	0.19	15.5	12	182.0	192.2	128.5	206.4	37.1	-1.13	194.0
Pakuranga Ck Greenmt	Urban	12	17.0	16.8	13.6	20.5	3.9	0.17	17.1	12	410.0	440.9	156.0	613.0	237.7	-0.44	427.7
Pakuranga Ck Guys Rd	Urban	12	17.3	18.1	12.5	22.7	6.1	-0.08	17.0	12	233.1	219.4	198.4	289.3	61.9	0.58	243.7
Pakuranga Ck Botany	Urban	12	19.1	18.4	12.9	25.8	6.6	0.31	18.3	12	262.9	278.8	119.8	327.8	39.9	-2.09	275.6
Omaru Creek	Urban	12	17.0	16.7	12.8	22.8	6.6	0.21	17.2	12	2770.3	817.5	199.5	14290.0	2303.8	2.12	821.0
Otaki Creek	Urban	12	16.7	15.7	13.6	20.3	4.8	0.29	16.1	12	684.2	350.6	204.4	2557.0	245.0	2.00	280.4
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	12	14.1	13.9	8.5	21.9	5.6	0.33	13.7	12	174.5	178.4	128.4	197.0	16.6	-1.72	179.3
Mahurangi River WS	Urban	12	15.4	16.0	7.6	20.8	6.2	-0.44	15.6	12	179.2	188.1	123.8	209.0	16.6	-1.54	181.8
Mahurangi River Bdge	Urban	12	15.5	15.9	7.7	20.9	6.4	-0.41	15.7	12	179.2	183.5	124.5	202.2	19.0	-1.89	174.1

		Salinity (ppt)								pH							
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.7	7.7	7.3	8.6	0.5	1.01	7.7
WestHoe Stream	Native	5	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.4	7.3	7.1	8.0	0.3	1.33	7.4
Ngakoroa Stream	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.3	7.3	7.1	7.6	0.1	0.12	7.4
Hoteo River	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.5	7.5	7.2	8.1	0.2	1.63	7.5
Kumeu River	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.4	7.3	7.0	8.2	0.4	1.73	7.4
Matakana River	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.5	7.4	7.3	8.2	0.2	2.24	7.5
Opanuku Stream	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.5	7.5	7.4	7.8	0.2	0.69	7.6
Rangitopuni River	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.4	7.4	7.1	8.1	0.1	2.30	7.4
Waiwera River	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.5	7.5	7.2	8.1	0.2	1.06	7.5
Papakura Stream	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.3	7.3	7.0	7.6	0.1	-0.06	7.3
Wairoa River	Rural	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.4	7.4	7.2	7.6	0.1	0.34	7.4
Okura Creek	Rural	5	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.4	7.4	7.1	8.1	0.2	1.83	7.4
Vaughan Stream	Rural	5	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.3	7.3	6.9	8.1	0.3	0.85	7.4
Lucas Creek	Urban	6	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.6	7.5	7.1	8.4	0.3	1.34	7.4
Oteha Stream	Urban	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.5	7.5	7.0	8.2	0.4	0.29	7.4
Oakley Creek	Urban	6	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.5	7.6	7.2	7.8	0.3	-0.59	7.6
Puhinui Stream	Urban	6	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.4	7.3	7.1	8.7	0.3	2.36	7.4
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	7	0.1	0.1	0.1	0.2	0.0	2.65	0.1	12	7.4	7.4	7.2	7.7	0.2	0.02	7.4
Otara Ck East Tamaki	Urban	8	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.6	7.6	7.0	8.0	0.6	-0.24	7.6
Pakuranga Ck Greenmt	Urban	8	0.2	0.2	0.1	0.3	0.2	-0.28	0.2	12	7.6	7.5	7.3	7.8	0.3	0.15	7.5
Pakuranga Ck Guys Rd	Urban	8	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.7	7.5	7.3	9.9	0.2	3.27	7.6
Pakuranga Ck Botany	Urban	8	0.1	0.1	0.1	0.2	0.0	2.83	0.1	12	7.6	7.5	7.3	8.8	0.3	2.18	7.5
Omaru Creek	Urban	8	1.1	0.4	0.1	5.2	1.2	2.24	0.4	12	7.5	7.5	7.2	7.7	0.2	-0.53	7.4
Otaki Creek	Urban	8	0.4	0.2	0.1	1.3	0.6	1.46	0.1	12	7.5	7.5	7.2	8.2	0.2	1.23	7.4
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	7	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.6	7.5	7.3	8.4	0.3	1.90	7.5
Mahurangi River WS	Urban	9	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.9	7.9	7.7	8.1	0.1	-0.68	7.9
Mahurangi River Bdge	Urban	9	0.1	0.1	0.1	0.1	0.0	0.00	0.1	12	7.8	7.8	7.5	8.2	0.3	0.42	7.7

Site	Land use	Suspended solid (g.m^{-3})								Turbity (NTU)							
		Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	12	2.2	1.6	0.6	7.5	2.2	1.83	1.0	12	7.0	2.5	1.3	28.9	6.4	1.92	3.1
WestHoe Stream	Native	12	4.1	3.1	0.4	11.0	3.1	1.44	4.6	12	9.3	7.2	5.1	30.9	2.5	3.14	9.0
Ngakoroa Stream	Rural	12	1.2	0.9	0.4	2.0	1.0	0.49	1.0	12	1.8	1.5	0.9	4.8	0.7	2.59	1.5
Hoteo River	Rural	12	19.8	10.9	2.6	125.0	8.1	3.35	7.8	12	17.2	8.6	4.0	90.7	7.8	3.01	10.1
Kumeu River	Rural	12	10.6	8.3	2.4	28.0	9.5	1.23	7.9	12	14.4	13.1	3.3	37.9	11.0	1.22	10.4
Matakana River	Rural	12	5.6	4.0	0.4	22.0	3.1	2.60	4.3	12	8.2	5.1	2.5	31.7	6.4	2.54	6.1
Opanuku Stream	Rural	12	4.9	3.4	1.6	20.0	2.2	3.05	3.5	12	8.4	5.4	1.1	25.3	9.8	1.35	6.0
Rangitopuni River	Rural	12	8.7	5.8	0.8	37.0	4.8	2.93	7.6	12	10.5	7.0	2.9	34.2	6.9	2.09	10.0
Waiwera River	Rural	12	10.3	7.2	2.2	39.0	6.2	2.36	6.7	12	12.5	7.7	3.5	47.9	9.7	2.42	9.9
Papakura Stream	Rural	12	12.8	4.1	1.4	110.0	4.6	3.44	4.4	12	6.1	5.8	0.6	13.9	6.0	0.65	6.0
Wairoa River	Rural	12	7.7	6.1	3.6	21.0	4.6	1.93	6.4	12	8.7	5.9	3.3	28.2	5.8	2.08	7.6
Okura Creek	Rural	12	14.7	13.3	5.4	26.0	5.9	0.63	14.0	12	20.0	17.3	12.5	34.9	9.6	1.03	22.5
Vaughan Stream	Rural	12	14.9	15.5	5.9	27.0	9.9	0.20	11.4	12	16.7	18.9	3.5	29.6	14.1	-0.21	15.8
Lucas Creek	Urban	12	14.4	10.8	2.0	69.0	13.8	2.71	12.0	12	29.1	18.1	4.4	111.0	34.5	1.87	29.2
Oteha Stream	Urban	12	11.7	6.8	1.4	38.0	13.5	1.34	7.1	12	19.6	7.2	1.9	63.9	33.1	1.15	11.0
Oakley Creek	Urban	12	6.0	4.8	2.4	18.0	3.6	2.34	3.4	12	6.4	4.8	0.8	23.2	5.9	2.04	3.9
Puhinui Stream	Urban	12	23.1	6.0	3.0	209.0	3.5	3.46	6.4	12	7.5	5.2	2.3	27.1	2.8	2.62	5.8
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	9.2	7.1	2.8	24.0	8.0	1.35	6.3	12	11.1	7.0	1.3	34.3	12.9	1.30	8.2
Otara Ck East Tamaki	Urban	12	11.4	4.6	2.4	54.6	9.7	2.25	3.5	12	7.8	4.5	1.5	28.5	5.3	2.01	3.8
Pakuranga Ck Greenmt	Urban	12	6.8	3.0	1.8	39.6	2.6	3.15	3.9	12	9.8	4.1	1.6	54.1	5.3	2.92	4.9
Pakuranga Ck Guys Rd	Urban	12	15.5	9.4	4.7	45.0	10.9	1.60	7.7	12	18.6	6.7	4.3	69.8	22.9	1.61	6.4
Pakuranga Ck Botany	Urban	12	7.3	5.8	3.4	24.2	2.1	3.03	5.8	12	8.9	8.3	3.1	23.8	3.3	2.37	8.0
Omaru Creek	Urban	12	8.5	7.2	3.6	15.2	4.8	0.89	11.0	12	8.4	6.8	3.7	24.5	5.6	2.27	8.5
Otaki Creek	Urban	12	6.2	4.8	1.7	21.2	3.7	2.59	4.0	12	7.9	6.8	4.8	19.6	2.6	2.74	7.1
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	12	4.0	3.0	1.2	15.0	2.6	2.71	3.4	12	9.1	5.0	3.1	32.8	7.5	2.22	7.0
Mahurangi River WS	Urban	12	8.4	3.8	1.5	33.4	11.2	1.82	4.2	12	7.0	4.6	1.6	29.8	5.6	2.52	5.7
Mahurangi River Bdge	Urban	12	4.7	3.0	1.0	14.0	4.2	1.52	4.3	12	5.7	2.0	0.6	30.8	4.9	2.79	5.5

Site	Land use	Ammoniacal Nitrogen (g.N.m^{-3})								Nitrate/Nitrite (g.N.m^{-3})							
		Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	12	0.01	0.01	0.00	0.04	0.00	2.99	0.01	12	0.05	0.02	0.01	0.39	0.02	3.34	0.02
WestHoe Stream	Native	12	0.01	0.01	0.00	0.05	0.01	3.17	0.01	12	0.02	0.01	0.01	0.05	0.02	1.22	0.01
Ngakoroa Stream	Rural	12	0.01	0.01	0.01	0.02	0.01	0.93	0.01	12	2.65	2.67	1.60	4.00	1.24	0.28	2.55
Hoteo River	Rural	12	0.04	0.04	0.01	0.09	0.02	0.91	0.04	12	0.31	0.37	0.03	0.52	0.24	-0.59	0.37
Kumeu River	Rural	12	0.04	0.04	0.01	0.07	0.02	-0.24	0.05	12	0.41	0.39	0.02	0.85	0.45	0.21	0.34
Matakana River	Rural	12	0.02	0.02	0.01	0.04	0.01	0.24	0.03	12	0.08	0.06	0.02	0.14	0.09	0.34	0.07
Opanuku Stream	Rural	12	0.02	0.02	0.01	0.04	0.01	1.27	0.03	12	0.14	0.14	0.01	0.33	0.13	0.34	0.16
Rangitopuni River	Rural	12	0.04	0.04	0.01	0.09	0.02	0.78	0.05	12	0.26	0.24	0.01	0.77	0.23	1.34	0.23
Waiwera River	Rural	12	0.03	0.03	0.01	0.06	0.03	-0.02	0.03	12	0.17	0.16	0.01	0.38	0.24	0.24	0.16
Papakura Stream	Rural	12	0.08	0.06	0.02	0.22	0.06	1.57	0.05	12	0.53	0.61	0.06	0.96	0.76	-0.23	0.57
Wairoa River	Rural	12	0.02	0.02	0.01	0.04	0.03	0.34	0.03	12	0.44	0.45	0.03	0.80	0.54	-0.01	0.45
Awanohi Stream	Rural	12	0.02	0.03	0.01	0.04	0.01	-0.74	0.03	12	0.16	0.18	0.08	0.19	0.05	-1.01	0.17
Vaughan Stream	Rural	12	0.02	0.02	0.01	0.04	0.02	-0.09	0.03	12	0.06	0.06	0.02	0.12	0.07	0.22	0.04
Lucas Creek	Urban	12	0.04	0.04	0.02	0.10	0.02	1.97	0.05	12	0.42	0.40	0.15	0.81	0.18	0.78	0.33
Oteha Stream	Urban	12	0.04	0.04	0.01	0.08	0.02	1.05	0.04	12	0.61	0.40	0.20	2.42	0.35	2.66	0.36
Oakley Creek	Urban	12	0.03	0.03	0.01	0.05	0.01	0.48	0.04	12	1.37	1.50	0.71	1.90	0.64	-0.44	1.50
Puhinui Stream	Urban	12	0.08	0.06	0.01	0.16	0.10	0.36	0.05	12	1.12	0.89	0.08	3.87	0.77	1.86	0.74
Tamaki Streams																	
Otara Ck, Kennell Hill	Urban	12	0.05	0.03	0.01	0.19	0.03	2.16	0.04	12	0.48	0.51	0.03	0.86	0.43	-0.26	0.35
Otara Ck, East Tamaki Rd	Urban	12	0.05	0.04	0.01	0.13	0.06	0.79	0.05	12	1.04	1.01	0.25	2.06	0.69	0.33	1.01
Pakuranga Ck, Greenmount Dr	Urban	12	0.14	0.15	0.06	0.22	0.11	-0.11	0.13	12	0.48	0.38	0.04	1.31	0.35	1.37	0.45
Pakuranga Ck, Guys Rd	Urban	12	0.07	0.07	0.01	0.21	0.07	1.31	0.04	12	0.34	0.27	0.02	0.93	0.52	0.60	0.33
Pakuranga Ck, Botany Rd	Urban	12	0.06	0.06	0.01	0.09	0.05	-0.14	0.06	12	0.68	0.60	0.15	1.51	0.66	0.59	0.62
Omaru Ck	Urban	12	0.09	0.08	0.04	0.17	0.04	1.20	0.10	12	0.54	0.39	0.05	1.86	0.60	1.59	0.37
Otaki Ck	Urban	12	0.08	0.05	0.03	0.27	0.05	2.30	0.05	12	1.06	0.97	0.45	2.42	0.51	1.39	1.00
Mahurangi Streams																	
Mahurangi River	Forestry	12	0.03	0.03	0.01	0.06	0.01	1.33	0.03	12	0.04	0.04	0.01	0.09	0.04	0.31	0.07
Mahurangi Water Suply	Urban	12	0.04	0.03	0.01	0.09	0.04	0.70	0.04	12	0.11	0.04	0.01	0.26	0.20	0.49	0.15
Mahurangi Town Bridge	Urban	12	0.03	0.03	0.00	0.11	0.04	1.44	0.04	12	0.11	0.03	0.01	0.28	0.20	0.57	0.15

Site	Land use	Total Kjedhal Nitrogen (g.N.m^{-3})								Total Nitrogen (g.m^{-3})							
		Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	12	0.27	0.20	0.10	0.50	0.20	0.77	0.20	12	0.32	0.25	0.11	0.59	0.20	0.57	0.23
WestHoe Stream	Native	12	0.30	0.20	0.20	0.60	0.18	1.40	0.20	12	0.32	0.24	0.21	0.61	0.14	1.38	0.27
Ngakoroa Stream	Rural	12	0.29	0.20	0.10	0.90	0.00	2.12	0.30	12	2.94	2.88	1.95	4.20	1.17	0.25	3.01
Hoteo River	Rural	12	0.40	0.20	0.10	1.00	0.41	1.07	0.36	12	0.71	0.62	0.23	1.31	0.38	0.50	0.71
Kumeu River	Rural	12	0.62	0.30	0.20	1.80	0.85	1.14	0.45	12	1.02	1.01	0.22	2.01	0.58	0.21	0.96
Matakana River	Rural	12	0.36	0.20	0.20	1.10	0.19	2.01	0.20	12	0.43	0.33	0.22	1.13	0.19	1.89	0.35
Opanuku Stream	Rural	12	0.35	0.20	0.20	1.50	0.10	3.16	0.30	12	0.50	0.40	0.21	1.83	0.08	3.07	0.49
Rangitopuni River	Rural	12	0.77	0.40	0.20	2.10	1.25	1.07	0.55	12	1.03	0.68	0.33	2.49	0.82	1.09	0.80
Waiwera River	Rural	12	0.49	0.20	0.13	1.70	0.45	1.70	0.33	12	0.66	0.50	0.21	2.08	0.44	1.90	0.80
Papakura Stream	Rural	12	0.29	0.20	0.10	0.86	0.05	2.16	0.60	12	0.82	0.96	0.26	1.23	0.55	-0.75	1.15
Wairoa River	Rural	12	0.25	0.20	0.16	0.80	0.00	3.26	0.31	12	0.70	0.71	0.23	1.00	0.49	-0.35	0.88
Okura Creek	Rural	12	0.88	0.57	0.20	3.30	1.15	1.81	0.50	12	1.03	0.71	0.30	3.41	1.08	1.75	0.71
Vaughan Stream	Rural	12	0.63	0.40	0.20	2.10	0.59	1.69	0.50	12	0.69	0.52	0.22	2.14	0.51	1.70	0.55
Lucas Creek	Urban	12	0.39	0.20	0.20	1.40	0.20	2.38	0.40	12	0.82	0.65	0.49	1.55	0.38	1.29	0.73
Oteha Stream	Urban	12	0.42	0.20	0.10	1.80	0.10	2.35	0.20	12	1.02	0.65	0.40	2.52	0.85	1.20	0.70
Oakley Creek	Urban	12	0.28	0.20	0.10	0.70	0.13	1.72	0.50	12	1.65	1.76	0.81	2.27	0.54	-0.66	2.05
Puhinui Stream	Urban	12	0.36	0.20	0.20	0.71	0.43	0.90	0.56	12	1.48	1.39	0.28	4.07	0.81	1.36	1.33
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	0.89	0.20	0.14	6.50	0.33	3.21	0.40	12	1.37	0.90	0.33	6.90	0.45	3.07	0.93
Otara Ck East Tamaki	Urban	12	0.44	0.45	0.20	0.88	0.44	0.43	0.45	12	1.49	1.38	1.04	2.46	0.53	1.22	1.59
Pakuranga Ck Greenmt	Urban	12	0.73	0.20	0.20	5.20	0.20	3.28	0.20	12	1.20	0.75	0.38	5.65	0.57	3.07	1.00
Pakuranga Ck Guys Rd	Urban	12	1.05	0.28	0.20	7.00	0.35	2.89	0.28	12	1.39	0.69	0.22	7.55	0.67	2.89	0.76
Pakuranga Ck Botany	Urban	12	2.05	0.30	0.18	18.80	0.90	3.42	0.30	12	2.73	1.32	0.35	19.19	1.16	3.39	1.44
Omaru Creek	Urban	12	0.71	0.20	0.20	5.10	0.28	3.35	0.20	12	1.25	0.71	0.25	5.42	0.62	2.70	1.05
Otaki Creek	Urban	12	1.14	0.20	0.20	9.70	0.23	3.37	0.20	12	2.20	1.37	0.65	10.45	1.26	3.08	1.48
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	12	0.38	0.20	0.10	1.10	0.30	1.63	0.20	12	0.42	0.26	0.13	1.17	0.23	1.68	0.38
Mahurangi River WS	Urban	12	0.53	0.29	0.20	2.60	0.27	3.07	0.29	12	0.63	0.44	0.21	2.64	0.27	2.83	0.44
Mahurangi River Bdge	Urban	12	0.41	0.25	0.20	0.83	0.45	0.68	0.20	12	0.52	0.48	0.22	0.98	0.46	0.46	0.44

		Dissolved Reactive Phosphorus (g.P.m^{-3})								Total Phosphorus (g.m^{-3})							
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	12	0.021	0.022	0.012	0.032	0.008	0.060	0.020	12	0.042	0.042	0.025	0.072	0.014	1.190	0.030
WestHoe Stream	Native	12	0.016	0.015	0.010	0.030	0.003	2.190	0.014	12	0.032	0.031	0.018	0.049	0.012	0.290	0.030
Ngakoroa Stream	Rural	12	0.013	0.014	0.005	0.019	0.006	-0.230	0.015	12	0.036	0.036	0.020	0.069	0.017	1.200	0.026
Hoteo River	Rural	12	0.033	0.030	0.019	0.059	0.011	1.250	0.030	12	0.088	0.069	0.047	0.276	0.033	2.850	0.060
Kumeu River	Rural	12	0.026	0.025	0.018	0.039	0.008	1.000	0.020	12	0.076	0.073	0.034	0.104	0.034	-0.420	0.068
Matakana River	Rural	12	0.018	0.017	0.012	0.031	0.004	1.600	0.019	12	0.051	0.049	0.030	0.101	0.017	1.810	0.040
Opanuku Stream	Rural	12	0.020	0.022	0.009	0.026	0.003	-1.320	0.020	12	0.047	0.044	0.028	0.086	0.015	1.420	0.040
Rangitopuni River	Rural	12	0.031	0.028	0.021	0.058	0.007	1.960	0.027	12	0.081	0.071	0.039	0.137	0.039	0.570	0.070
Waiwera River	Rural	12	0.019	0.019	0.012	0.025	0.004	0.030	0.018	12	0.056	0.051	0.036	0.123	0.012	2.700	0.046
Papakura Stream	Rural	12	0.038	0.037	0.017	0.055	0.026	-0.040	0.030	12	0.083	0.080	0.032	0.138	0.038	0.120	0.080
Wairoa River	Rural	12	0.020	0.022	0.001	0.027	0.007	-1.940	0.020	12	0.058	0.051	0.035	0.092	0.018	1.040	0.053
Okura Creek	Rural	12	0.023	0.021	0.015	0.050	0.009	2.240	0.019	12	0.061	0.064	0.030	0.081	0.023	-0.700	0.060
Vaughan Stream	Rural	12	0.024	0.023	0.019	0.034	0.005	1.290	0.020	12	0.065	0.058	0.040	0.109	0.029	1.020	0.057
Lucas Creek	Urban	12	0.019	0.020	0.014	0.025	0.004	0.190	0.020	12	0.079	0.053	0.038	0.305	0.021	3.090	0.070
Oteha Stream	Urban	12	0.021	0.020	0.016	0.029	0.007	0.600	0.020	12	0.071	0.051	0.037	0.193	0.041	1.860	0.050
Oakley Creek	Urban	12	0.038	0.038	0.021	0.075	0.016	1.380	0.030	12	0.075	0.073	0.050	0.108	0.028	0.470	0.070
Puhinui Stream	Urban	12	0.028	0.030	0.010	0.055	0.015	0.810	0.020	12	0.074	0.066	0.034	0.171	0.017	2.030	0.060
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	0.024	0.022	0.013	0.046	0.013	1.070	0.020	12	0.075	0.072	0.034	0.106	0.040	-0.240	0.077
Otara Ck East Tamaki	Urban	12	0.020	0.019	0.011	0.035	0.010	0.870	0.020	12	0.054	0.053	0.028	0.077	0.025	-0.130	0.046
Pakuranga Ck Greenmt	Urban	12	0.029	0.029	0.011	0.049	0.010	0.420	0.030	12	0.084	0.084	0.056	0.136	0.033	0.830	0.094
Pakuranga Ck Guys Rd	Urban	12	0.017	0.015	0.010	0.043	0.005	2.660	0.020	12	0.087	0.070	0.041	0.159	0.073	0.640	0.056
Pakuranga Ck Botany	Urban	12	0.021	0.017	0.014	0.037	0.009	1.370	0.020	12	0.076	0.069	0.046	0.147	0.040	1.340	0.080
Omaru Creek	Urban	12	0.027	0.025	0.014	0.049	0.005	1.230	0.025	12	0.083	0.084	0.042	0.119	0.024	-0.430	0.090
Otaki Creek	Urban	12	0.026	0.020	0.016	0.049	0.020	1.050	0.020	12	0.082	0.070	0.048	0.156	0.045	1.170	0.068
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	12	0.015	0.015	0.009	0.026	0.006	0.940	0.017	12	0.037	0.036	0.020	0.066	0.011	1.120	0.030
Mahurangi River WS	Urban	12	0.015	0.016	0.005	0.025	0.009	-0.120	0.020	12	0.048	0.044	0.031	0.088	0.017	1.760	0.044
Mahurangi River Bdge	Urban	12	0.013	0.014	0.005	0.023	0.010	-0.120	0.020	12	0.043	0.038	0.025	0.093	0.010	1.970	0.040

		Soluble Copper (g.m^{-3})								Total Copper (g.m^{-3})							
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	Na								Na							
WestHoe Stream	Native	Na								Na							
Ngakoroa Stream	Rural	Na								Na							
Hoteo River	Rural	Na								Na							
Kumeu River	Rural	Na								Na							
Matakana River	Rural	Na								Na							
Opanuku Stream	Rural	Na								Na							
Rangitopuni River	Rural	Na								Na							
Waiwera River	Rural	Na								Na							
Papakura Stream	Rural	Na								Na							
Wairoa River	Rural	Na								Na							
Okura Creek	Rural	12	0.001	0.001	0.001	0.003	0.001	1.480	0.001	12	0.002	0.001	0.001	0.004	0.001	0.950	0.002
Vaughan Stream	Rural	12	0.001	0.001	0.001	0.003	0.001	2.290	0.001	12	0.001	0.001	0.001	0.003	0.001	1.210	0.002
Lucas Creek	Urban	12	0.002	0.002	0.002	0.002	0.001	0.160	0.005	12	0.002	0.002	0.002	0.002	0.001	0.160	0.005
Oteha Stream	Urban	12	0.002	0.002	0.001	0.004	0.001	0.740	0.005	12	0.002	0.002	0.001	0.004	0.001	0.740	0.005
Oakley Creek	Urban	12	0.002	0.002	0.001	0.003	0.001	0.180	0.005	12	0.002	0.002	0.001	0.003	0.001	0.180	0.005
Puhinui Stream	Urban	12	0.002	0.002	0.001	0.004	0.001	0.770	0.005	12	0.002	0.002	0.001	0.004	0.001	0.770	0.005
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	0.002	0.001	0.001	0.005	0.001	2.870	0.001	12	0.003	0.002	0.001	0.012	0.002	2.480	0.002
Otara Ck East Tamaki	Urban	Na								Na							
Pakuranga Ck Greenmt	Urban	Na								Na							
Pakuranga Ck Guys Rd	Urban	Na								Na							
Pakuranga Ck Botany	Urban	Na								Na							
Omaru Creek	Urban	Na								Na							
Otaki Creek	Urban	Na								Na							
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	Na								Na							
Mahurangi River WS	Urban	Na								Na							
Mahurangi River Bdge	Urban	Na								Na							

Site	Land use	Soluble Zinc (g.m^{-3})								Total Zinc (g.m^{-3})							
		Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	Na								Na							
WestHoe Stream	Native	Na								Na							
Ngakoroa Stream	Rural	Na								Na							
Hoteo River	Rural	Na								Na							
Kumeu River	Rural	Na								Na							
Matakana River	Rural	Na								Na							
Opanuku Stream	Rural	Na								Na							
Rangitopuni River	Rural	Na								Na							
Waiwera River	Rural	Na								Na							
Papakura Stream	Rural	Na								Na							
Wairoa River	Rural	Na								Na							
Okura Creek	Rural	12	0.002	0.002	0.001	0.003	0.001	0.210	0.002	12	0.004	0.004	0.003	0.008	0.002	1.210	0.005
Vaughan Stream	Rural	12	0.003	0.002	0.000	0.009	0.001	2.180	0.002	12	0.006	0.005	0.003	0.010	0.004	0.330	0.006
Lucas Creek	Urban	12	0.005	0.004	0.001	0.013	0.004	1.230	0.006	12	0.011	0.010	0.004	0.026	0.007	1.350	0.015
Oteha Stream	Urban	12	0.027	0.028	0.002	0.058	0.014	0.210	0.029	12	0.044	0.045	0.011	0.077	0.030	-0.020	0.045
Oakley Creek	Urban	12	0.042	0.022	0.011	0.240	0.018	3.110	0.020	12	0.041	0.031	0.014	0.150	0.024	2.570	0.033
Puhinui Stream	Urban	12	0.046	0.026	0.010	0.200	0.022	2.550	0.033	12	0.074	0.050	0.018	0.340	0.032	2.950	0.050
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	0.021	0.013	0.003	0.085	0.018	1.960	0.013	12	0.045	0.020	0.010	0.160	0.053	1.570	0.023
Otara Ck East Tamaki	Urban	Na								Na							
Pakuranga Ck Greenmt	Urban	Na								Na							
Pakuranga Ck Guys Rd	Urban	Na								Na							
Pakuranga Ck Botany	Urban	Na								Na							
Omaru Creek	Urban	Na								Na							
Otaki Creek	Urban	Na								Na							
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	Na								Na							
Mahurangi River WS	Urban	Na								Na							
Mahurangi River Bdge	Urban	Na								Na							

		Soluble Lead (g.m^{-3})								Total Lead (g.m^{-3})							
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	Na								Na							
WestHoe Stream	Native	Na								Na							
Ngakoroa Stream	Rural	Na								Na							
Hoteo River	Rural	Na								Na							
Kumeu River	Rural	Na								Na							
Matakana River	Rural	Na								Na							
Opanuku Stream	Rural	Na								Na							
Rangitopuni River	Rural	Na								Na							
Waiwera River	Rural	Na								Na							
Papakura Stream	Rural	Na								Na							
Wairoa River	Rural	Na								Na							
Okura Creek	Rural	12	0.00009	0.0001	0.0000	0.0002	0.0001	0.0800	0.0001	12	0.0004	0.0003	0.0001	0.0006	0.0002	-0.010	0.0005
Vaughan Stream	Rural	12	0.00008	0.0001	0.0000	0.0002	0.0001	-0.010	0.0001	12	0.0003	0.0002	0.0001	0.0006	0.0003	0.3400	0.0004
Lucas Creek	Urban	12	0.0001	0.0001	0.0000	0.0003	0.0000	1.4800	0.0200	12	0.0007	0.0006	0.0001	0.0021	0.0006	1.3100	0.0200
Oteha Stream	Urban	12	0.0001	0.0001	0.0000	0.0002	0.0001	-0.090	0.0200	12	0.0006	0.0005	0.0001	0.0015	0.0009	0.6900	0.0200
Oakley Creek	Urban	12	0.0002	0.0002	0.0000	0.0004	0.0002	-0.290	0.0200	12	0.0012	0.0009	0.0004	0.0034	0.0006	2.0400	0.0200
Puhinui Stream	Urban	12	0.0002	0.0002	0.0001	0.0003	0.0001	0.0100	0.0200	12	0.0015	0.0007	0.0003	0.0110	0.0005	3.4100	0.0200
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	12	0.0001	0.0001	0.0000	0.0001	0.0001	-0.220	0.0001	12	0.0005	0.0004	0.0002	0.0012	0.0002	1.4800	0.0004
Otara Ck East Tamaki	Urban	Na								Na							
Pakuranga Ck Greenmt	Urban	Na								Na							
Pakuranga Ck Guys Rd	Urban	Na								Na							
Pakuranga Ck Botany	Urban	Na								Na							
Omaru Creek	Urban	Na								Na							
Otaki Creek	Urban	Na								Na							
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	Na								Na							
Mahurangi River WS	Urban	Na								Na							
Mahurangi River Bdge	Urban	Na								Na							

		Soluble Cadmium (g.m^{-3})								Total Cadmium (g.m^{-3})							
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	Na								Na							
WestHoe Stream	Native	Na								Na							
Ngakoroa Stream	Rural	Na								Na							
Hoteo River	Rural	Na								Na							
Kumeu River	Rural	Na								Na							
Matakana River	Rural	Na								Na							
Opanuku Stream	Rural	Na								Na							
Rangitopuni River	Rural	Na								Na							
Waiwera River	Rural	Na								Na							
Papakura Stream	Rural	Na								Na							
Wairoa River	Rural	Na								Na							
Okura Creek	Rural	6	0.00005	0.00005	0.00005	0.00007	0	2.45	0.00005	6	0.00005	0.00005	0.00005	0.00007	0	2.45	0.00005
Vaughan Stream	Rural	6	0.00005	0.00005	0.00005	0.00006	0	2.45	0.00005	6	0.00006	0.00005	0.00005	0.00009	0.00002	1.54	0.00005
Lucas Creek	Urban	6	0.00005	0.00005	0.00005	0.00006	0	2.45	0.00005	6	0.00006	0.00005	0.00005	0.00009	0	2.45	0.00005
Oteha Stream	Urban	6	0.00005	0.00005	0.00005	0.00005	0	0	0.00005	6	0.00005	0.00005	0.00005	0.00005	0	0	0.00005
Oakley Creek	Urban	6	0.00006	0.00005	0.00005	0.00009	0	2.45	0.00005	6	0.00008	0.00005	0.00005	0.00023	0	2.45	0.00005
Puhinui Stream	Urban	6	0.00005	0.00005	0.00005	0.00005	0	0	0.00005	6	0.00005	0.00005	0.00005	0.00005	0	0	0.00005
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	6	0.00005	0.00005	0.00005	0.00005	0	0	0.00005	6	0.00005	0.00005	0.00005	0.00005	0	0	0.00005
Otara Ck East Tamaki	Urban	Na								Na							
Pakuranga Ck Greenmt	Urban	Na								Na							
Pakuranga Ck Guys Rd	Urban	Na								Na							
Pakuranga Ck Botany	Urban	Na								Na							
Omaru Creek	Urban	Na								Na							
Otaki Creek	Urban	Na								Na							
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	Na								Na							
Mahurangi River WS	Urban	Na								Na							
Mahurangi River Bdge	Urban	Na								Na							

		Faecal Coliforms (MPN/100ml)								Escherichia coli (cfu/100ml)							
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	6	344	185	14	1100	420	1.65	50	6	325	168.5	12	1270	187	2.27	168
WestHoe Stream	Native	6	141	17	4	500	287	1.34	70	6	76	20	7	260	134	1.46	20
Ngakoroa Stream	Rural	6	510	500	230	1100	270	1.51	400	6	182	178	136	240	40	0.61	178
Hoteo River	Rural	6	8496	205	30	50000	460	2.45	250	6	4163	165	50	24000	480	2.45	165
Kumeu River	Rural	6	3650	3050	300	8000	6500	0.27	850	6	1320	1170	82	3300	1800	0.81	1170
Matakana River	Rural	6	2249	1100	27	8000	2730	1.80	300	6	955	450	127	3300	996	1.95	450
Opanuku Stream	Rural	6	934	600	28	3000	820	1.85	1200	6	721	735	310	1200	470	0.21	735
Rangitopuni River	Rural	6	5238	285	130	30000	270	2.45	500	6	1230	590	145	4700	840	2.19	590
Waiwera River	Rural	6	2100	1800	500	5000	2500	0.75	800	6	1407	855	136	4200	2000	1.30	855
Papakura Stream	Rural	6	14083	9000	500	50000	10000	2.03	3000	6	7833	3100	2	36000	2200	2.40	3100
Wairoa River	Rural	6	2155	950	230	5000	4200	0.90	500	6	745	168	55	2500	1437	1.34	168
Okura Creek	Rural	6	1093	1050	130	2400	1470	0.40	600	6	570	535	155	1090	490	0.40	535
Vaughan Stream	Rural	6	3105	3000	230	8000	1600	1.42	1400	6	1566	1215	370	4100	1700	1.16	1215
Lucas Creek	Urban	6	5038	965	70	17000	10770	1.23	750	6	1774	1280	90	4000	3809	0.39	1280
Oteha Stream	Urban	6	5805	1650	230	23000	7700	1.91	425	6	860	730	200	1700	1400	0.20	730
Oakley Creek	Urban	6	1504	1950	24	2400	1700	-0.85	1700	6	1352	865	55	3600	2473	0.82	865
Puhinui Stream	Urban	6	4750	2050	1100	17000	3700	2.18	2200	6	434	380	164	850	410	0.81	380
Tamaki Streams																	
Otara Ck Kennel Hill	Urban	6	917	650	72	2200	1470	0.77	800	6	515	415	340	950	170	1.90	415
Otara Ck East Tamaki	Urban	Na								12	9016	1795	127	72000	3750	3.12	1900
Pakuranga Ck Greenmt	Urban	Na								12	1096	520	127	5900	1030	2.55	220
Pakuranga Ck Guys Rd	Urban	Na								12	1470	305	10	6800	2346	1.85	118
Pakuranga Ck Botany	Urban	Na								12	1608	1045	210	4900	2015	1.16	2500
Omaru Creek	Urban	Na								12	4051	2050	440	17000	4125	2.33	3400
Otaki Creek	Urban	Na								12	3504	2500	340	9900	3650	1.15	2100
Mahurangi Streams																	
Mahurangi River FHQ	Forestry	6	1313	515	20	5000	1570	1.93	195	6	1132.2	270.0	72.0	5000.0	999.0	2.25	270.0
Mahurangi River WS	Urban	Na								12	414.0	150.0	2.0	2500.0	190.0	2.69	152.0
Mahurangi River Bdge	Urban	Na								12	500.8	153.0	2.0	3100.0	185.0	2.65	153.0

				Black disk (m)					
Site	Land use	Count	Mean	Median	Min	Max	IQR	Skew	02 -06 Median
Cascade Stream	Native	12	1.49	1.27	0.21	3.77	1.46	0.94	1.35
WestHoe Stream	Native	0							
Ngakoroa Stream	Rural	12	1.92	1.88	0.59	3.64	1.24	0.48	1.42
Hoteo River	Rural	12	0.37	0.44	0.06	0.58	0.16	-0.96	0.44
Kumeu River	Rural	12	0.32	0.34	0.12	0.47	0.25	-0.62	0.34
Matakana River	Rural	12	0.58	0.60	0.21	1.07	0.44	0.29	0.62
Opanuku Stream	Rural	12	0.57	0.61	0.11	0.87	0.26	-0.74	0.56
Rangitopuni River	Rural	12	0.36	0.36	0.12	0.62	0.14	0.18	0.37
Waiwera River	Rural	12	0.38	0.42	0.05	0.65	0.26	-0.28	0.44
Papakura Stream	Rural	12	0.54	0.55	0.27	0.95	0.32	0.48	0.41
Wairoa River	Rural	12	0.61	0.56	0.18	1.06	0.56	0.31	0.48
Okura Creek	Rural	Na							
Vaughan Stream	Rural	Na							
Lucas Creek	Urban	11	0.27	0.23	0.06	0.64	0.25	0.88	0.23
Oteha Stream	Urban	12	0.40	0.37	0.08	0.82	0.49	0.28	0.37
Oakley Creek	Urban	12	0.58	0.55	0.07	0.90	0.34	-0.58	0.53
Puhinui Stream	Urban	12	0.45	0.46	0.14	0.87	0.13	0.94	0.46
Tamaki Streams									
Otara Ck Kennel Hill	Urban	12	0.41	0.46	0.09	0.69	0.26	-0.41	0.38
Otara Ck East Tamaki	Urban	12	0.61	0.59	0.13	1.16	0.32	0.51	0.50
Pakuranga Ck Greenmt	Urban	12	0.47	0.43	0.18	0.80	0.44	0.19	0.40
Pakuranga Ck Guys Rd	Urban	12	0.26	0.28	0.08	0.45	0.24	-0.11	0.28
Pakuranga Ck Botany	Urban	12	0.42	0.45	0.06	0.71	0.18	-0.64	0.44
Omaru Creek	Urban	12	0.40	0.38	0.21	0.60	0.27	0.28	0.37
Otaki Creek	Urban	12	0.53	0.52	0.23	1.10	0.21	1.28	0.52
Mahurangi Streams									
Mahurangi River FHQ	Forestry	12	0.68	0.70	0.13	1.41	0.54	0.18	0.66
Mahurangi River WS	Urban	11	0.63	0.58	0.17	1.10	0.29	0.00	0.80
Mahurangi River Bdge	Urban	11	0.58	0.65	0.15	0.83	0.18	-1.22	0.71

3.2 Historic Variation

Figure 2: Northern streams – black disk (m)

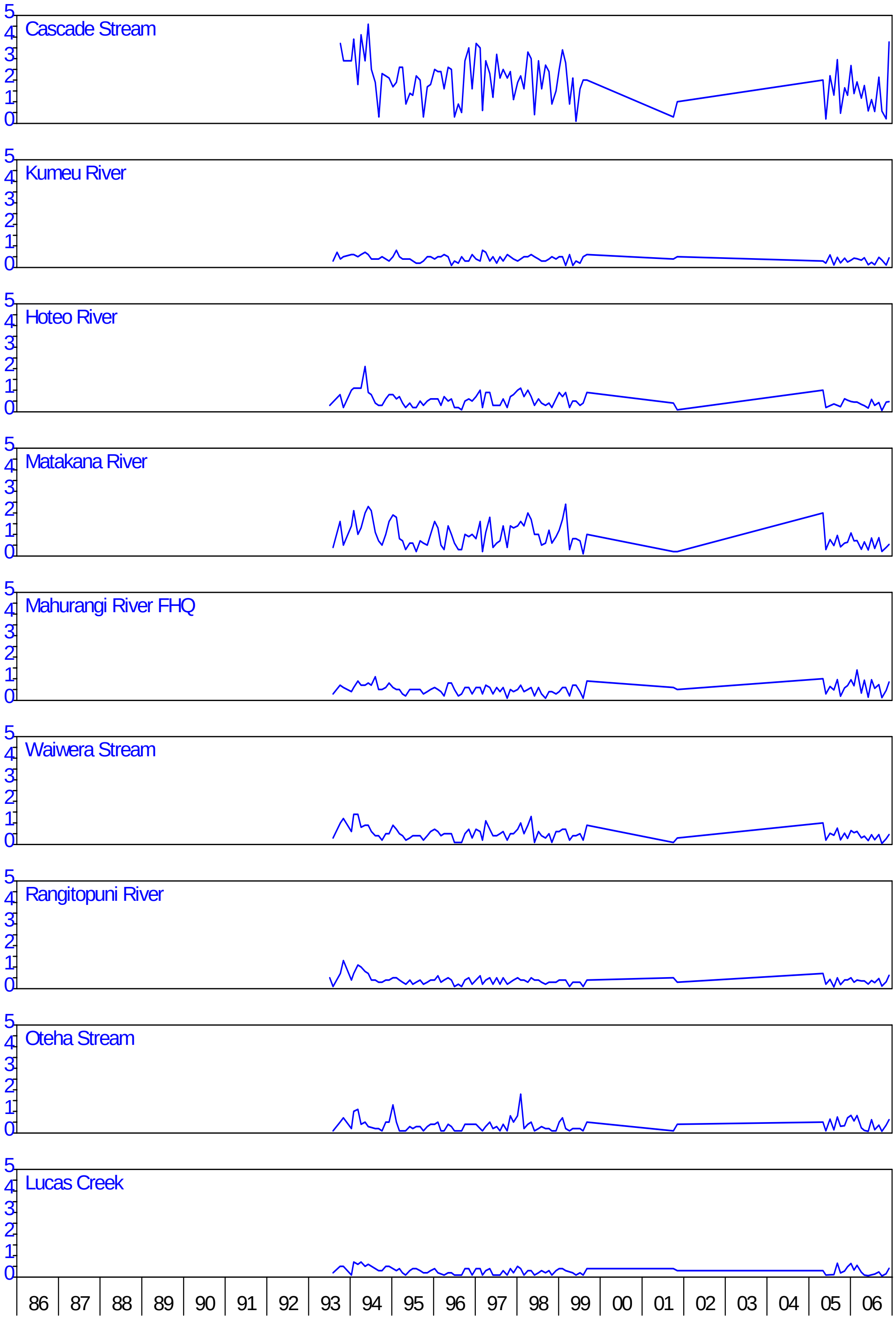


Figure 3: Northern streams – conductivity (μS.cm^{-2})

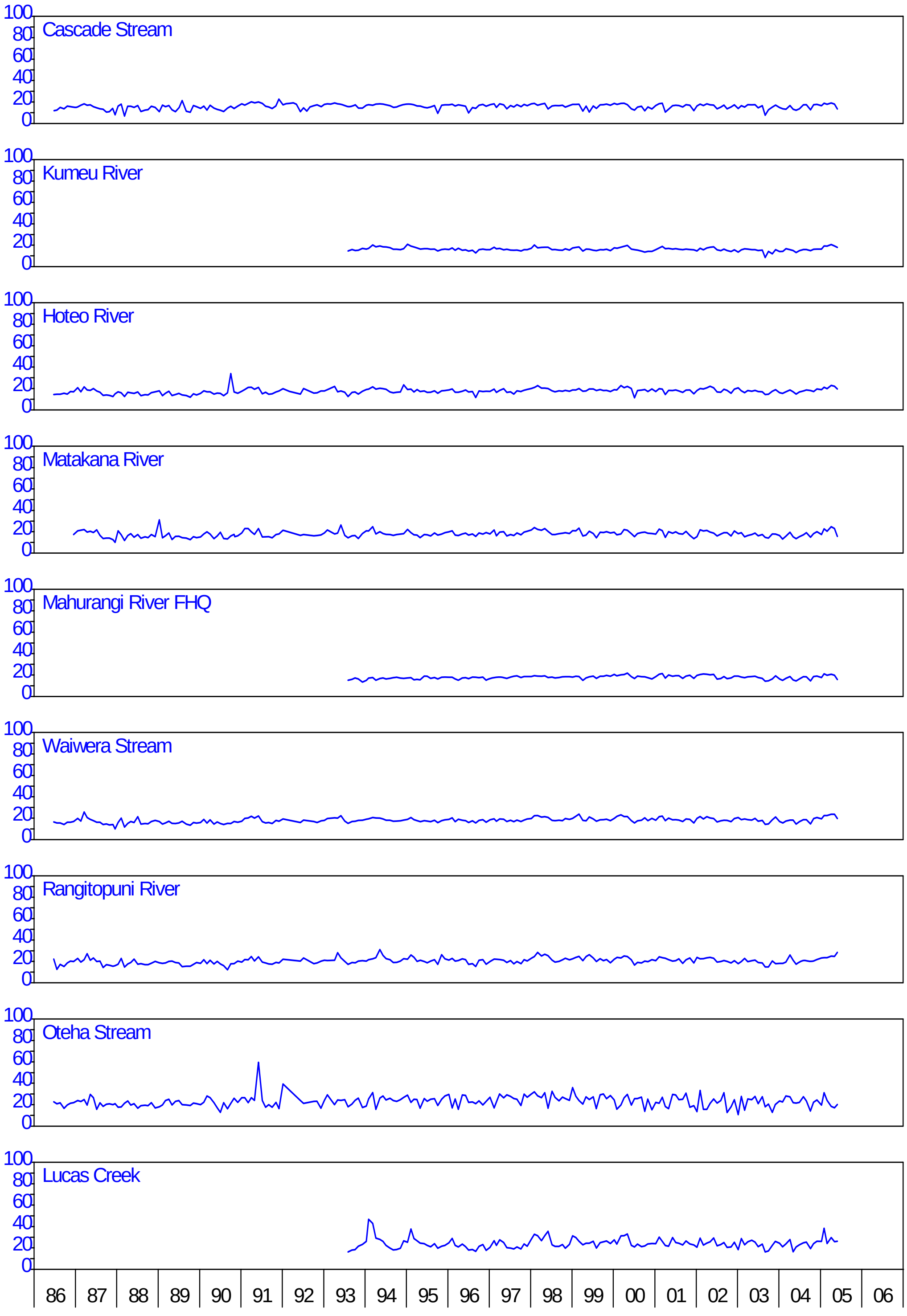


Figure 4: Northern streams – turbidity (NTU)

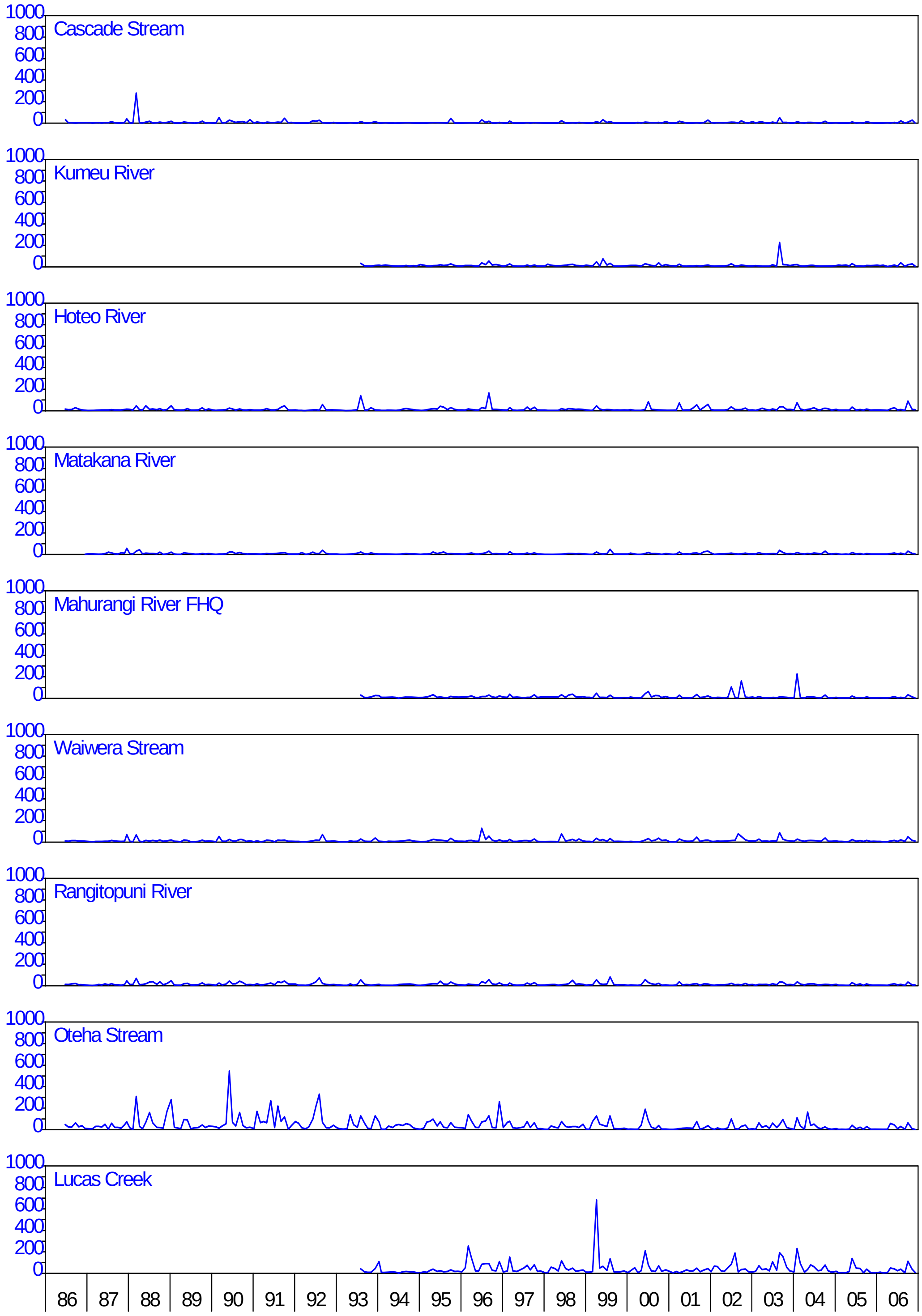


Figure 5: Northern streams – temperature (°C)

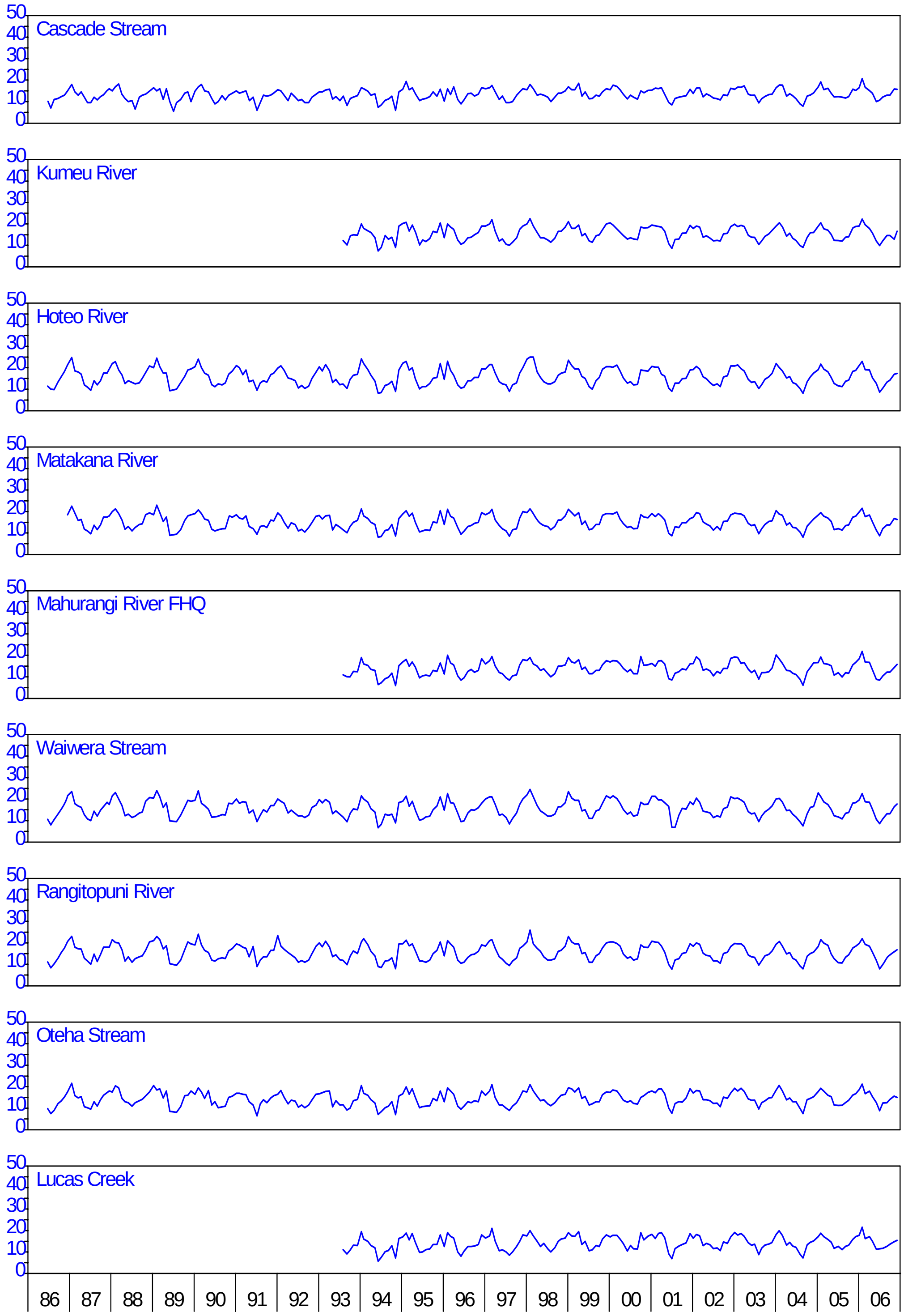


Figure 6: Northern streams - pH

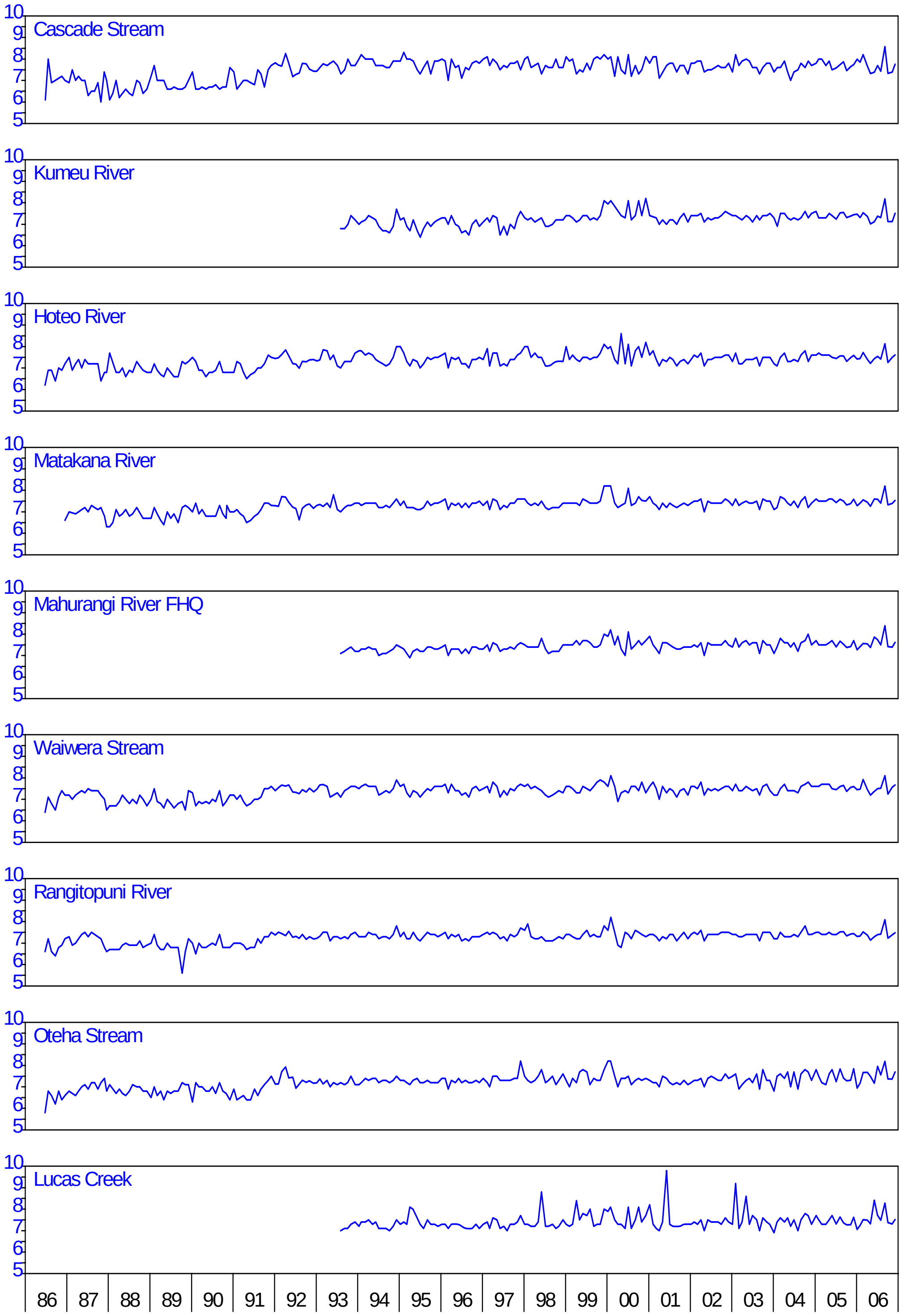


Figure 7: Northern streams – suspended solids (ppm)

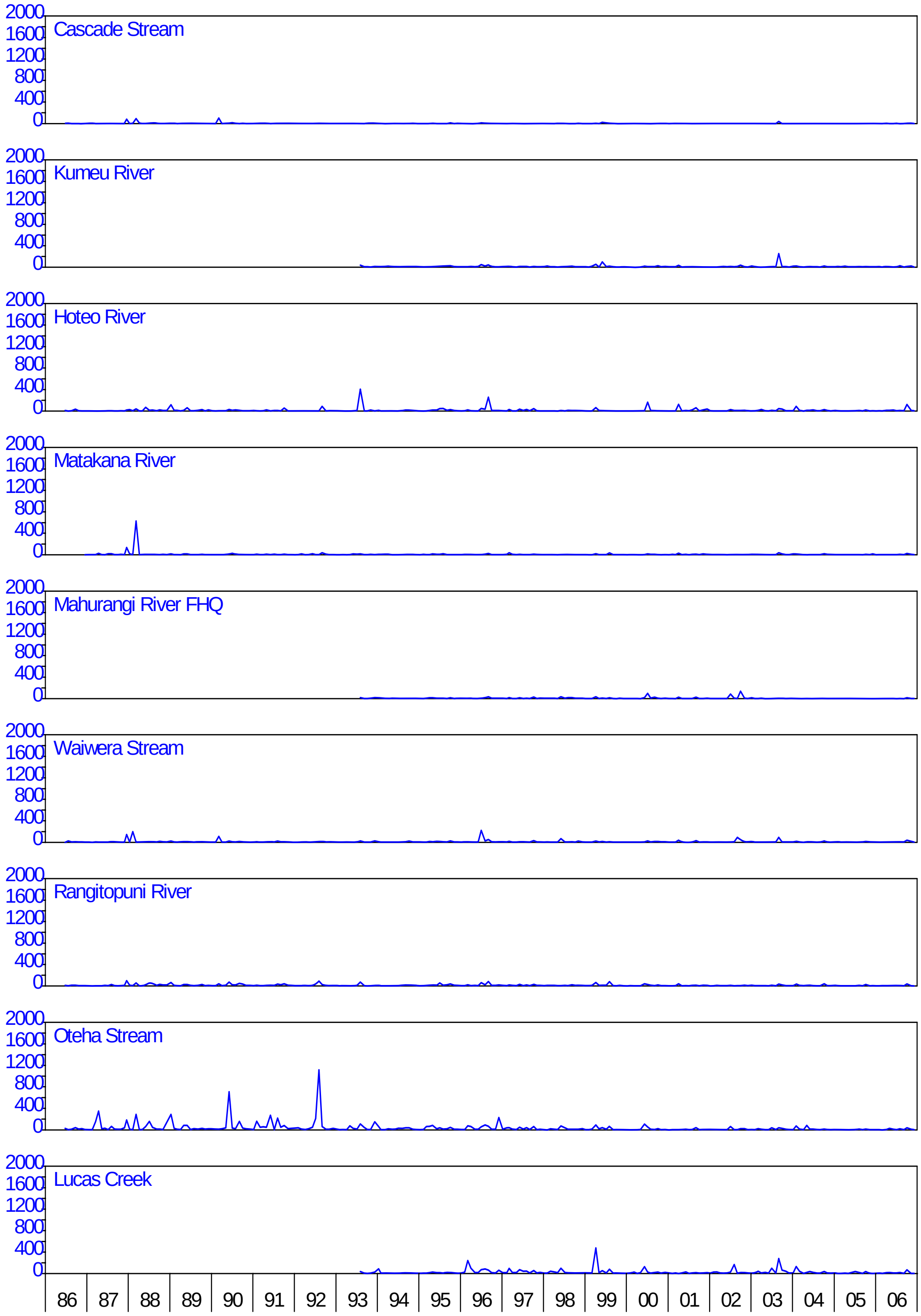


Figure 8: Northen streams – nitrate+nitrite ($gN.m^{-3}$)

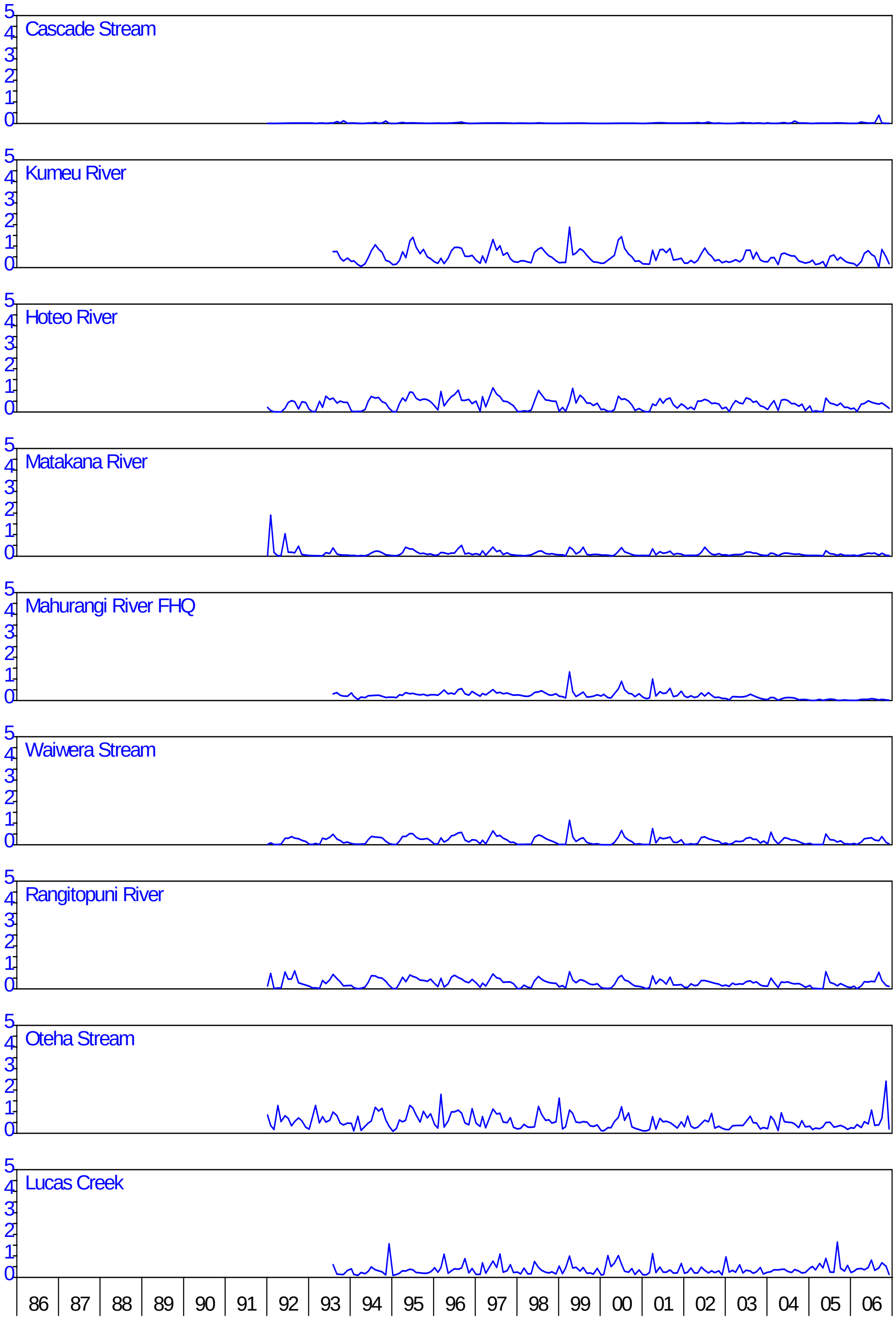


Figure 9: Northern streams – ammoniacal nitrogen (gN.m^{-3})

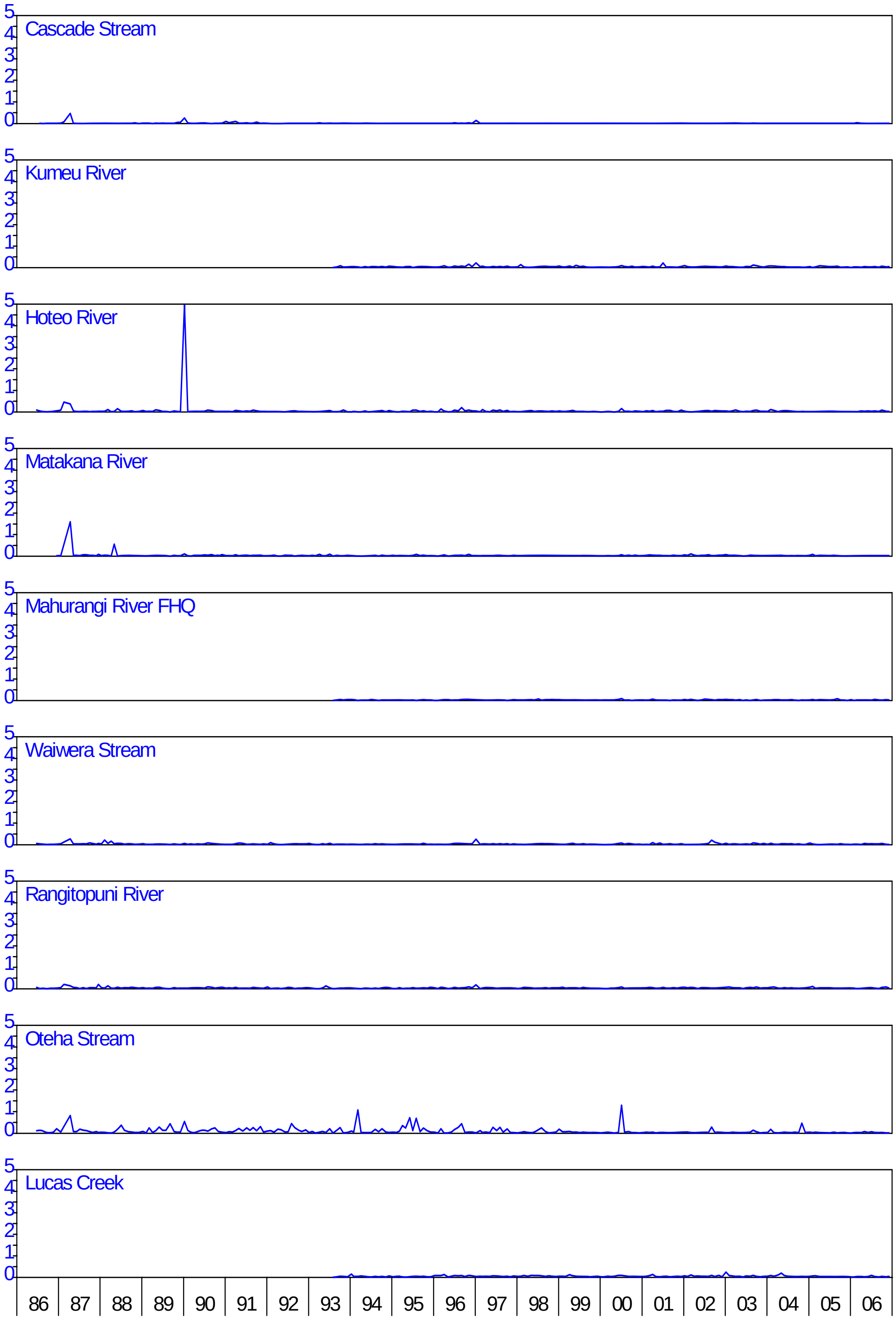


Figure 10: Northern streams – total kjedhal nitrogen (gN.m^{-3})

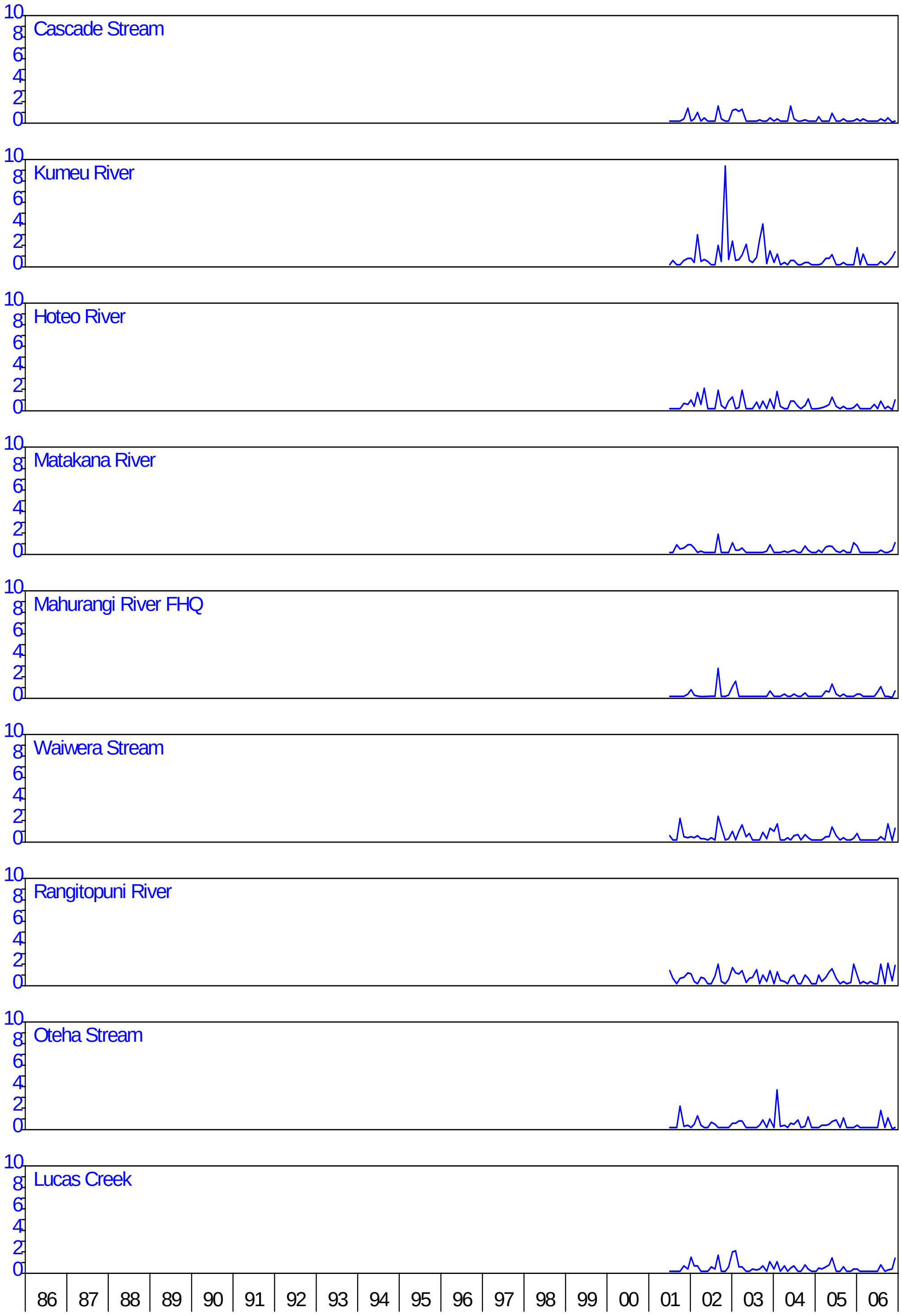


Figure 11: Northern streams – dissolved oxygen (% saturation)

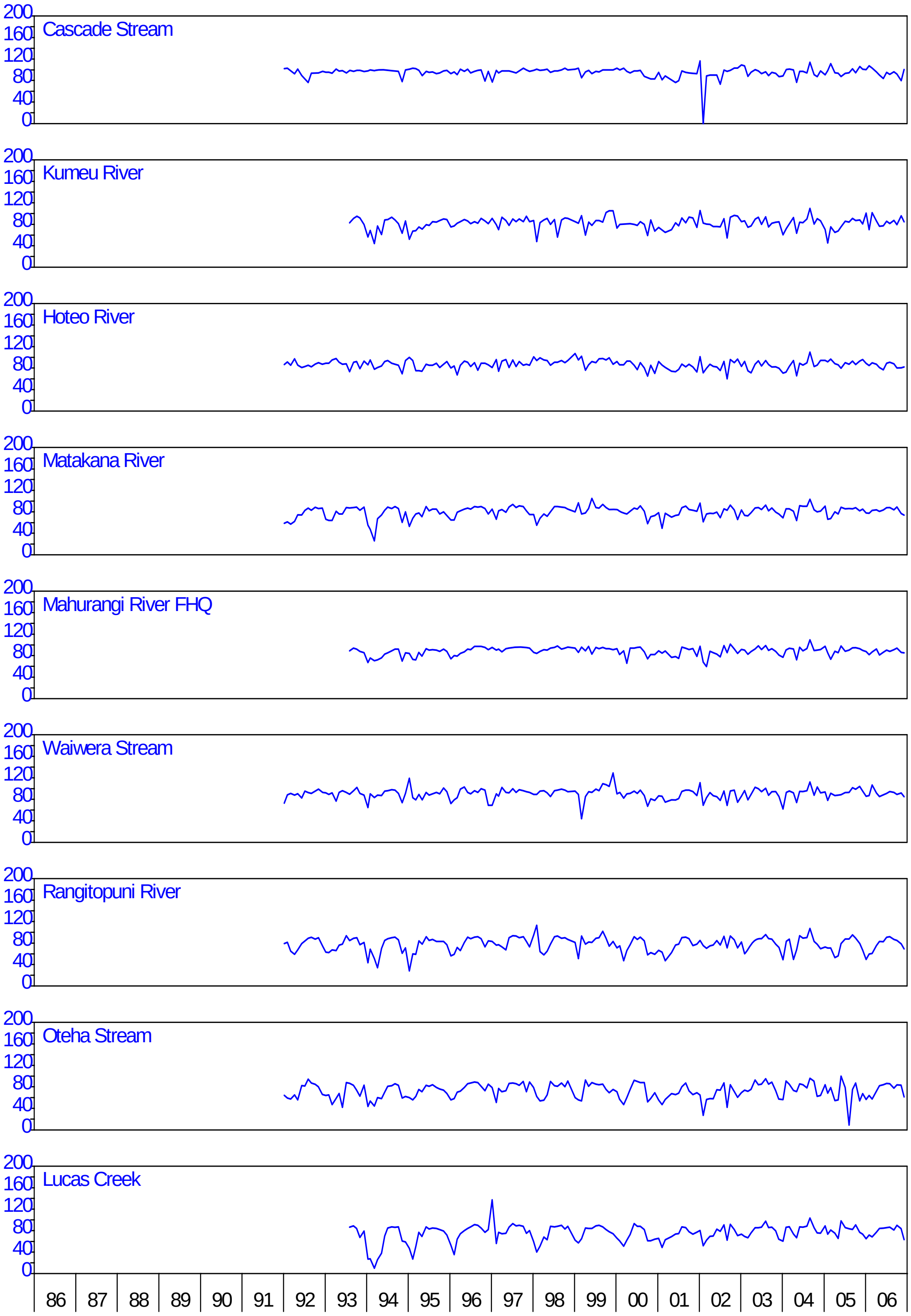


Figure 12: Northern streams – dissolved oxygen (ppm)

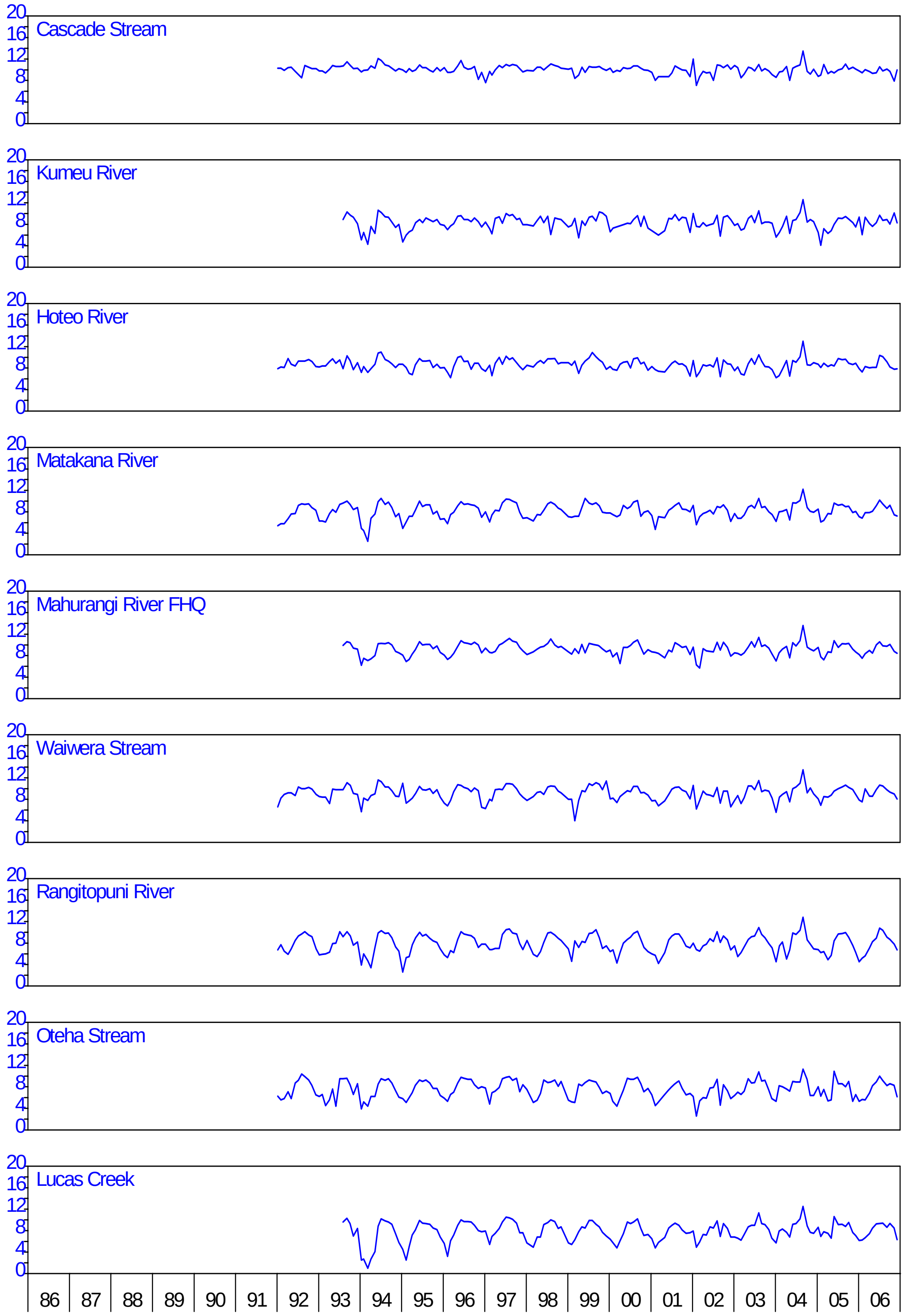


Figure 13: Northern streams – total phosphorus ($g.m^{-3}$)

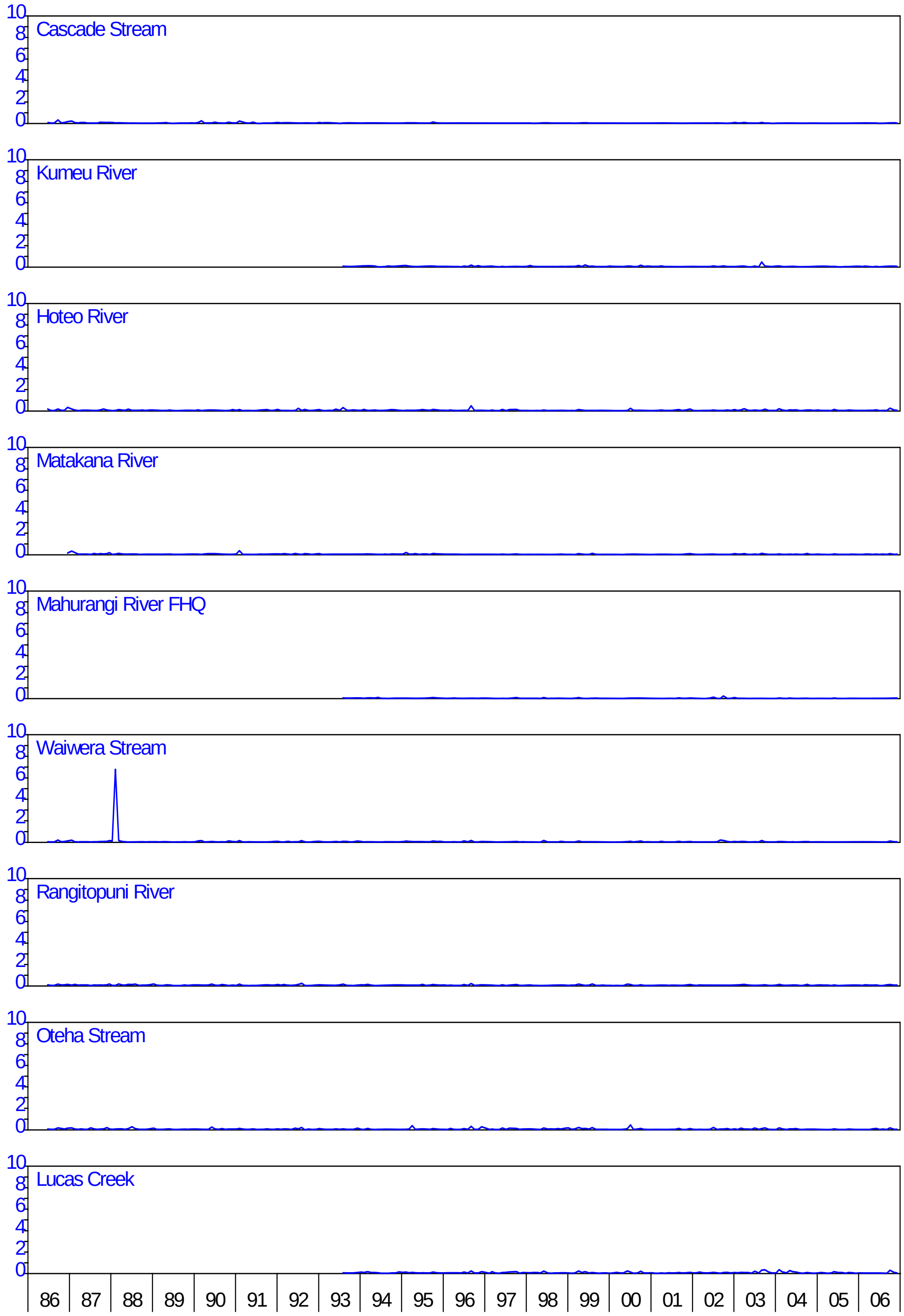


Figure 14: Northern streams – dissolved reactive phosphorus ($gP.m^{-3}$)

Figure 15: Northern streams – faecal coliforms (MPN/100ml)

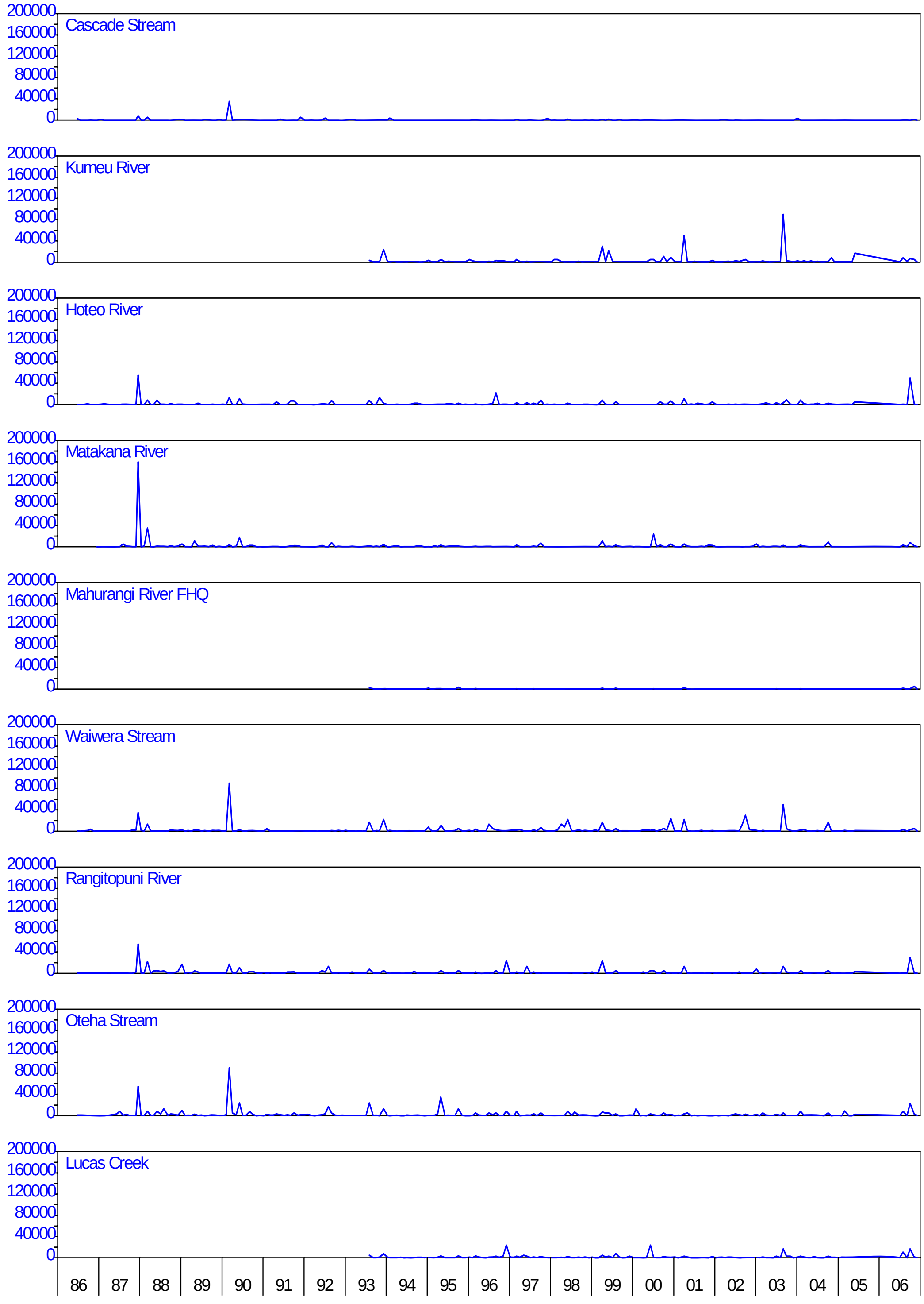


Figure 16: Southern streams – black disk (m)

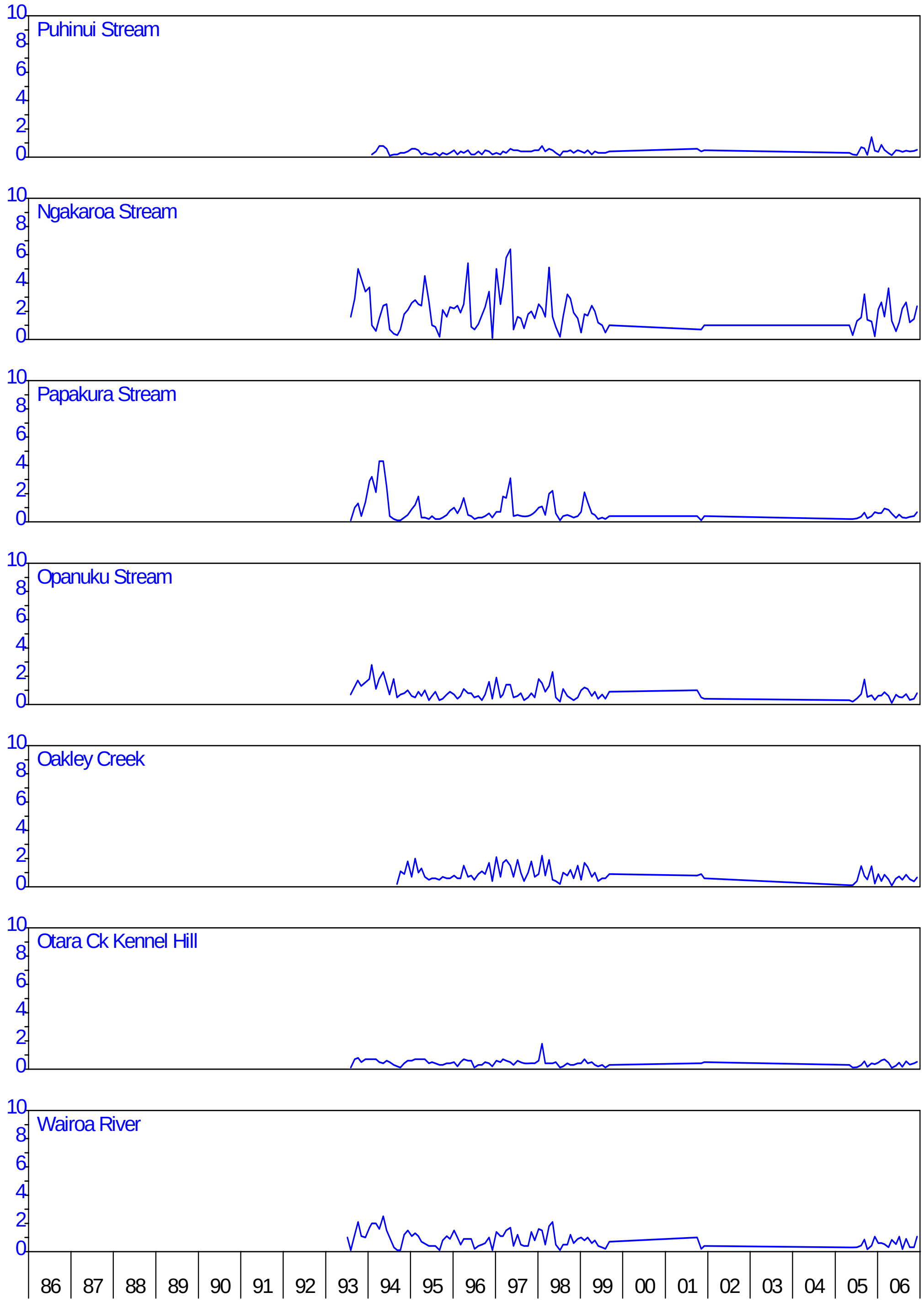


Figure 17: Southern streams – conductivity (μS.cm[-2])

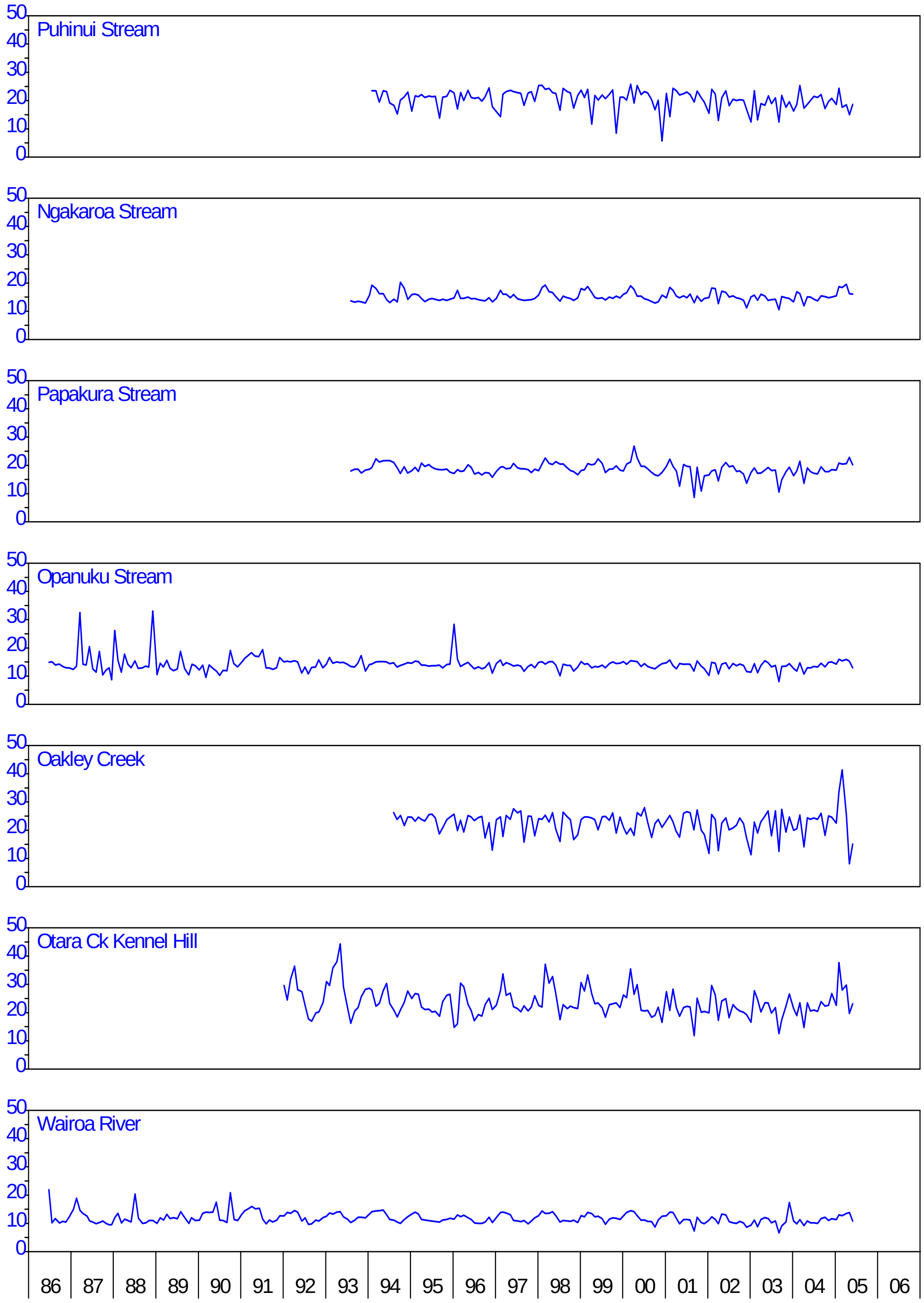


Figure 18: Southern streams – turbidity (NTU)

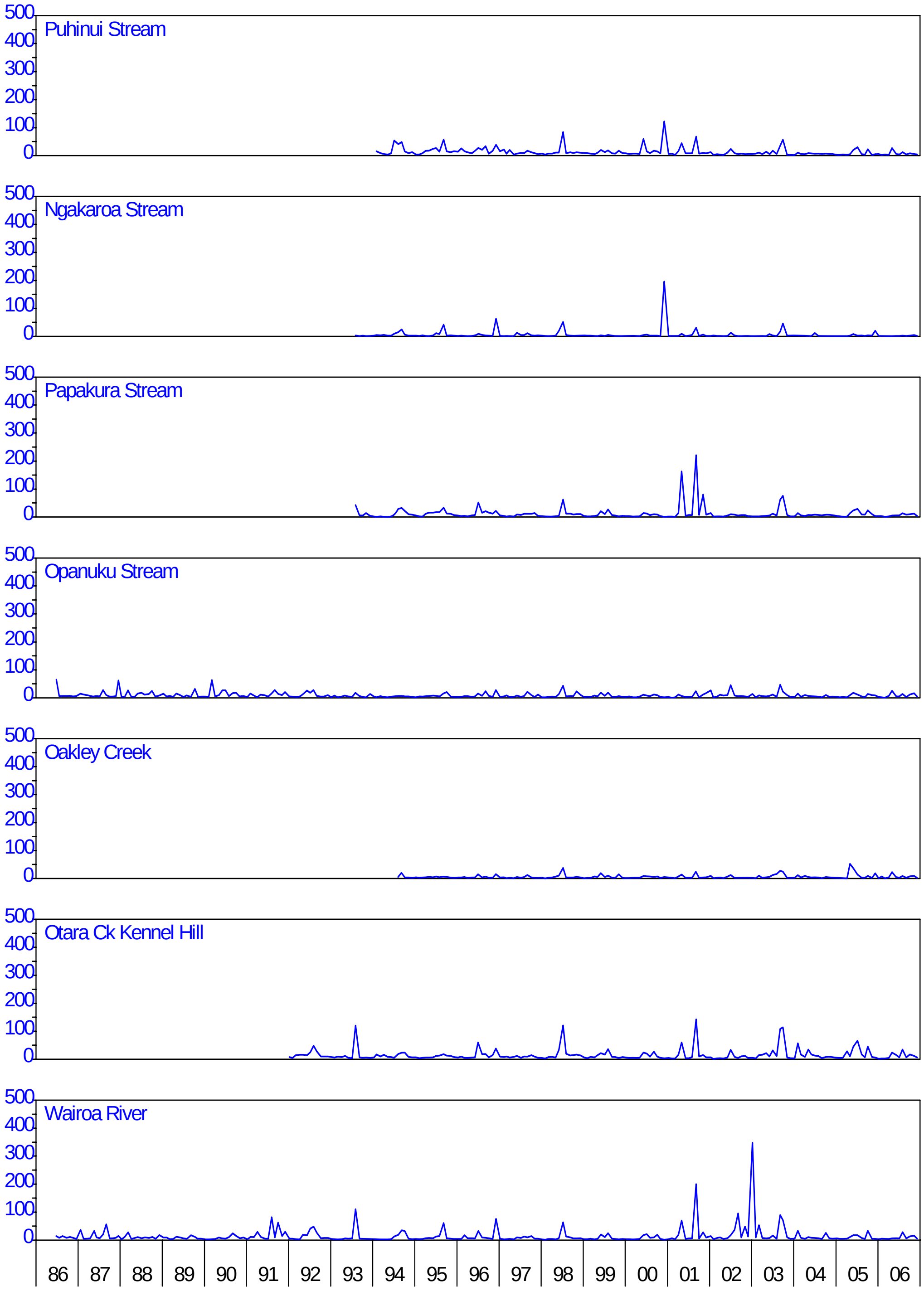


Figure 19: Southern streams – temperature (°C)

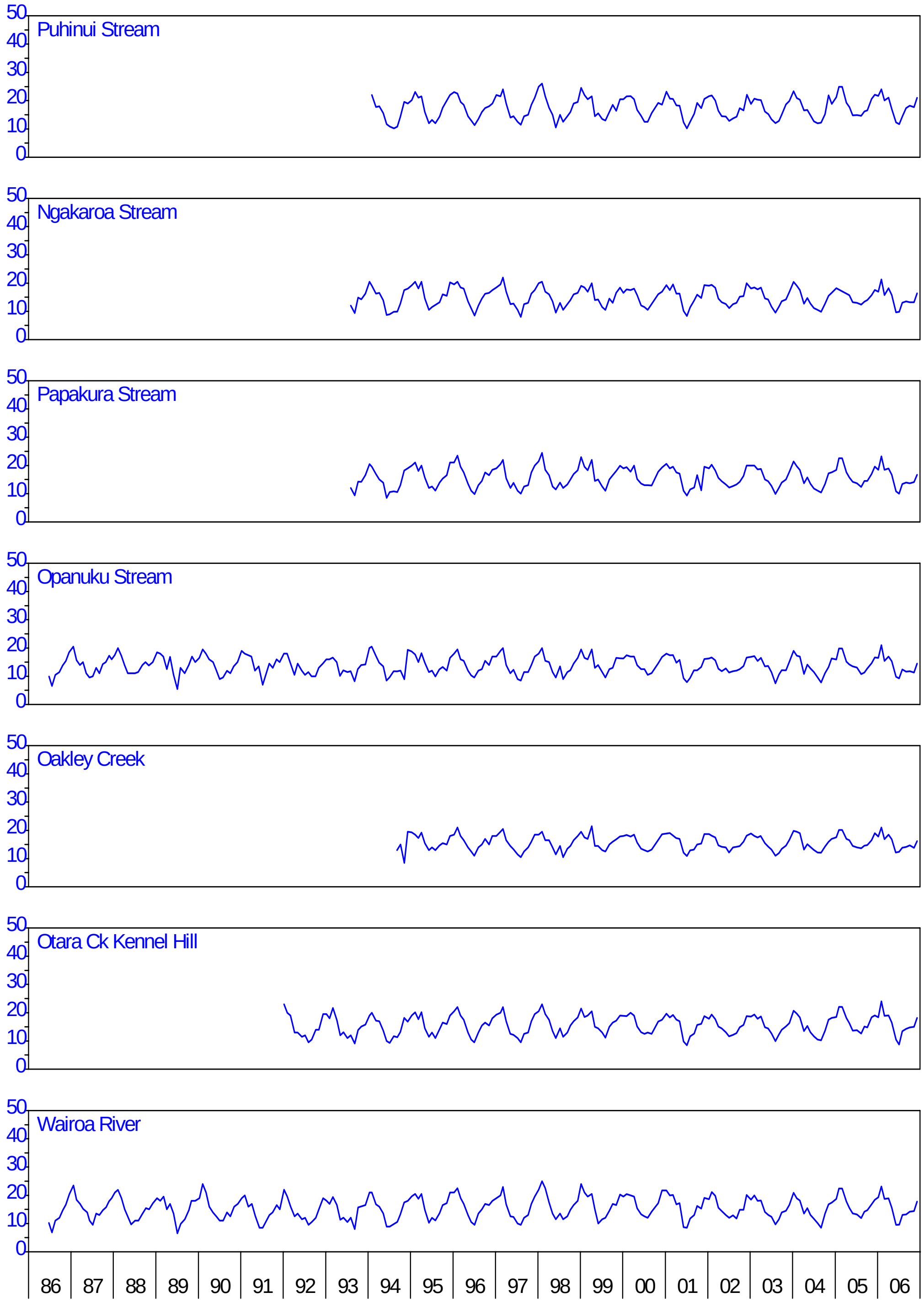


Figure 20: Southern streams - pH

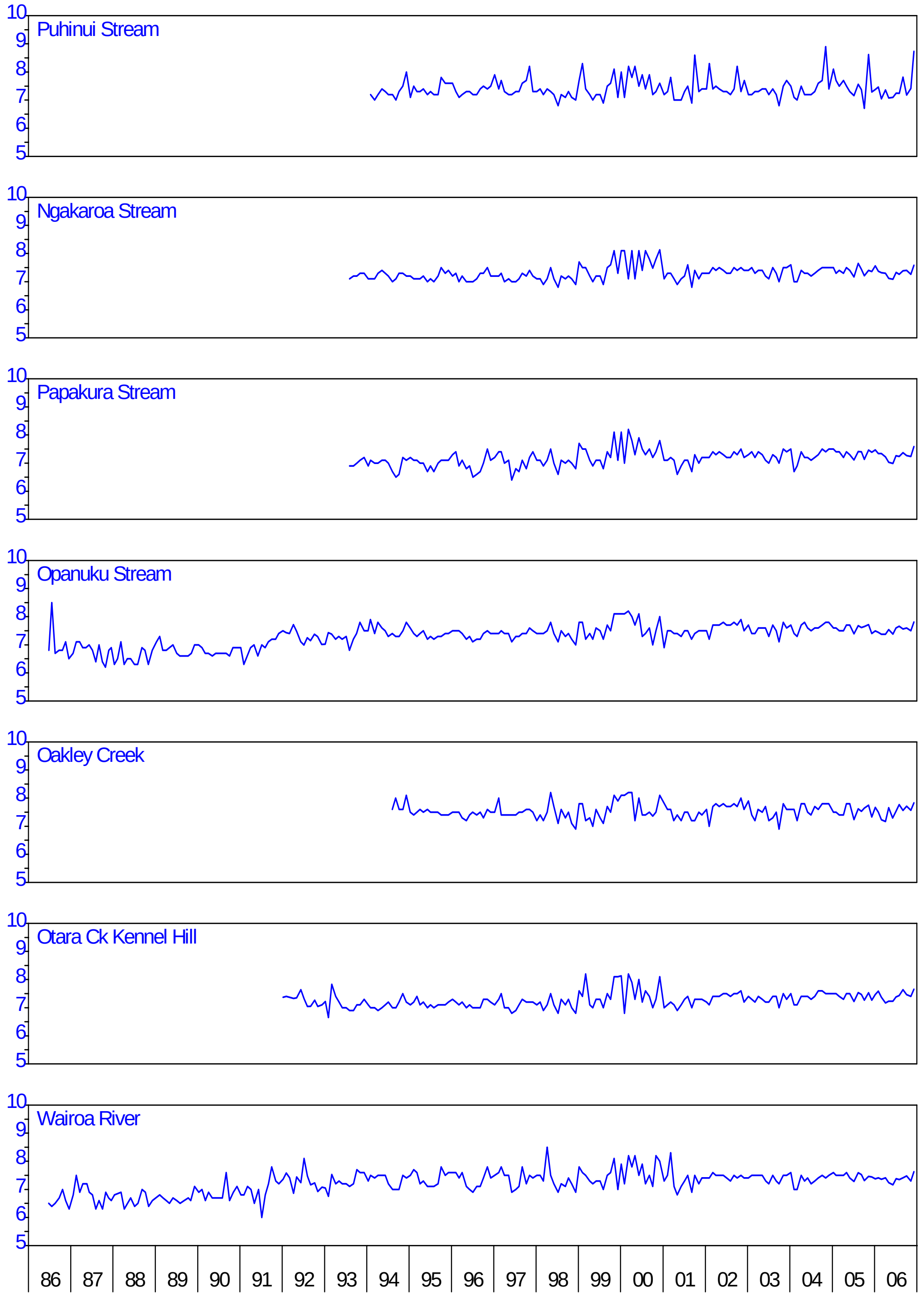


Figure 21: Southern streams – suspended solids (ppm)

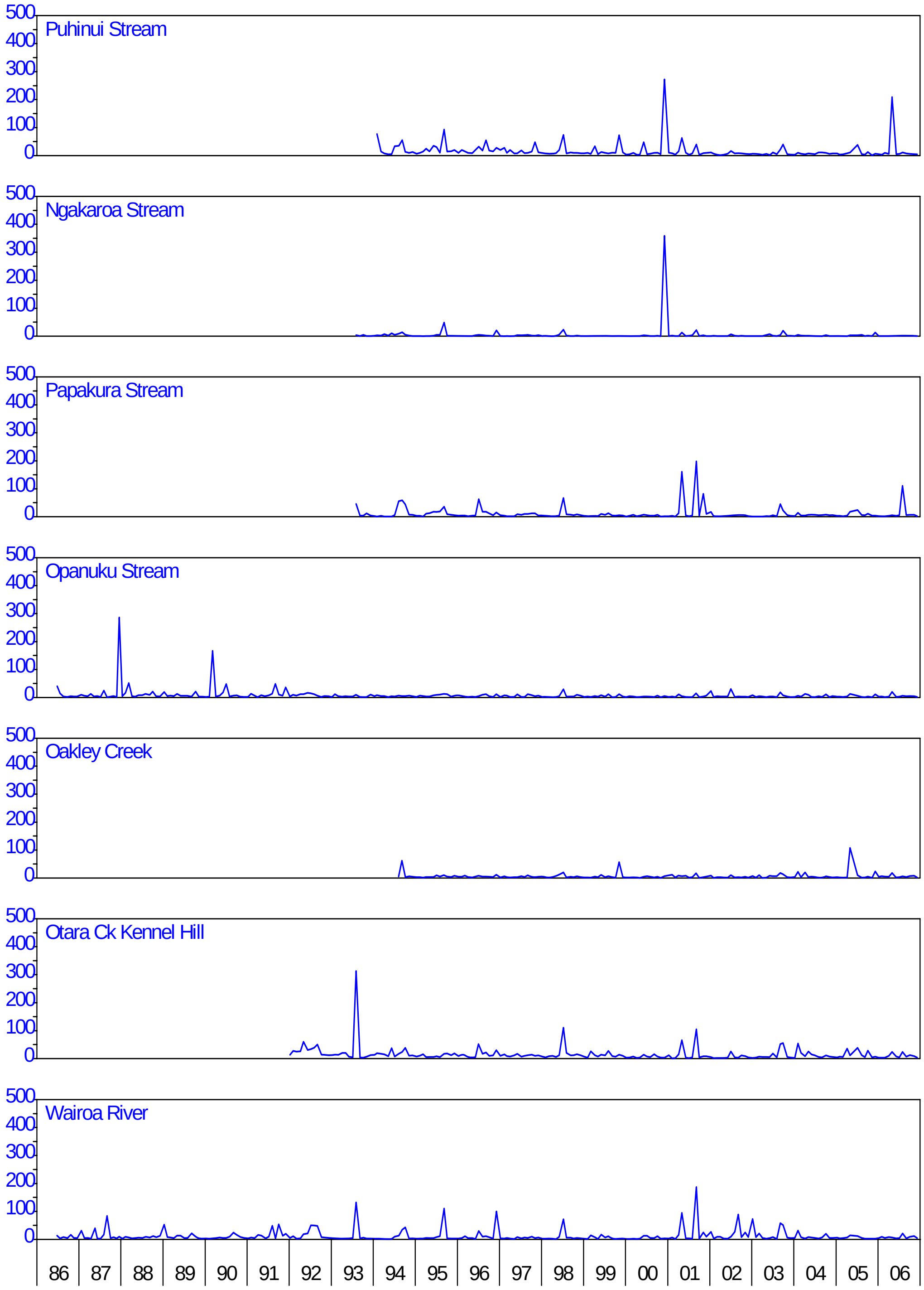


Figure 22: Southern streams – nitrate+nitrite (gN.m^{-3})

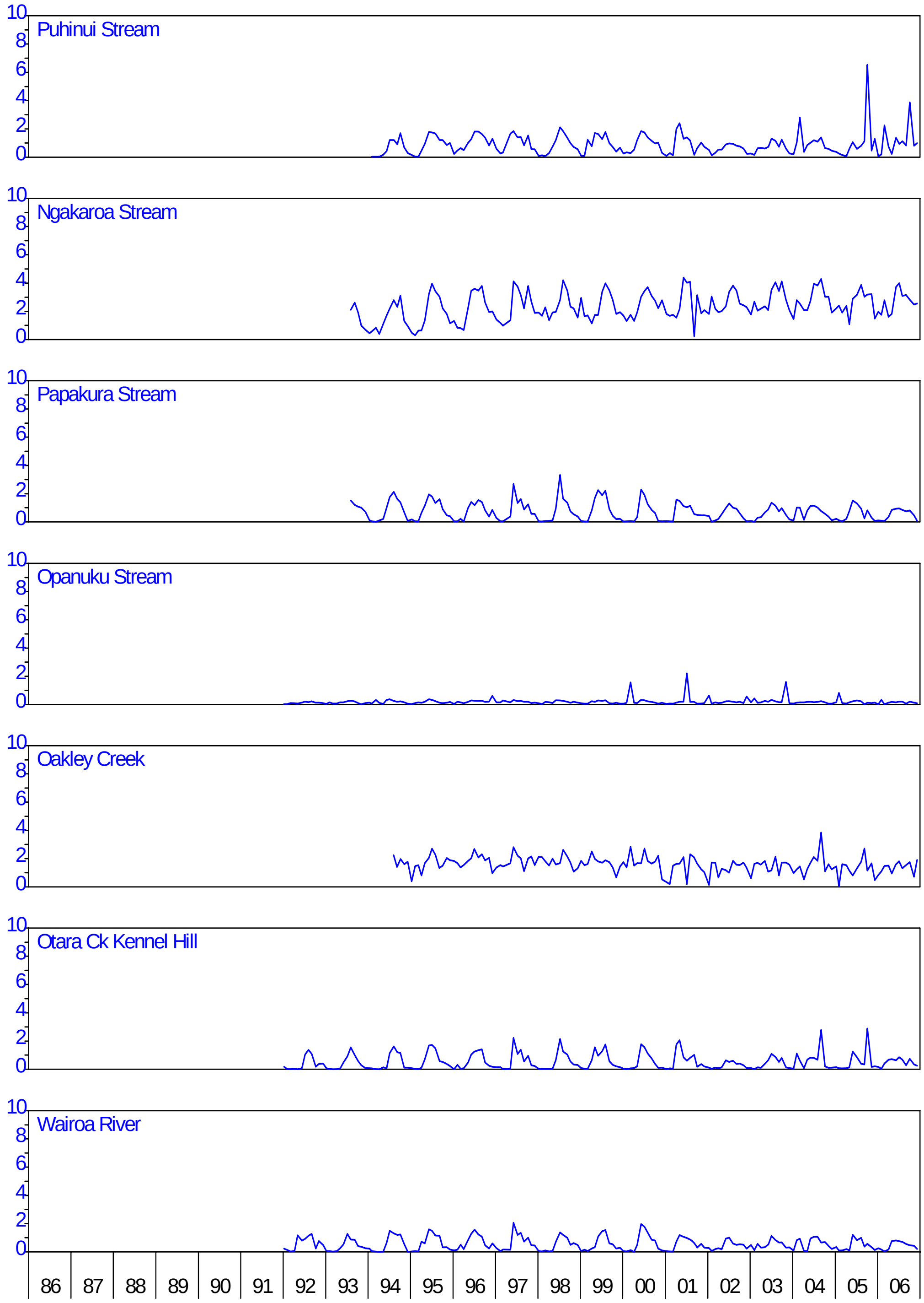


Figure 23: Southern streams – ammoniacal nitrogen (gN.m^{-3})

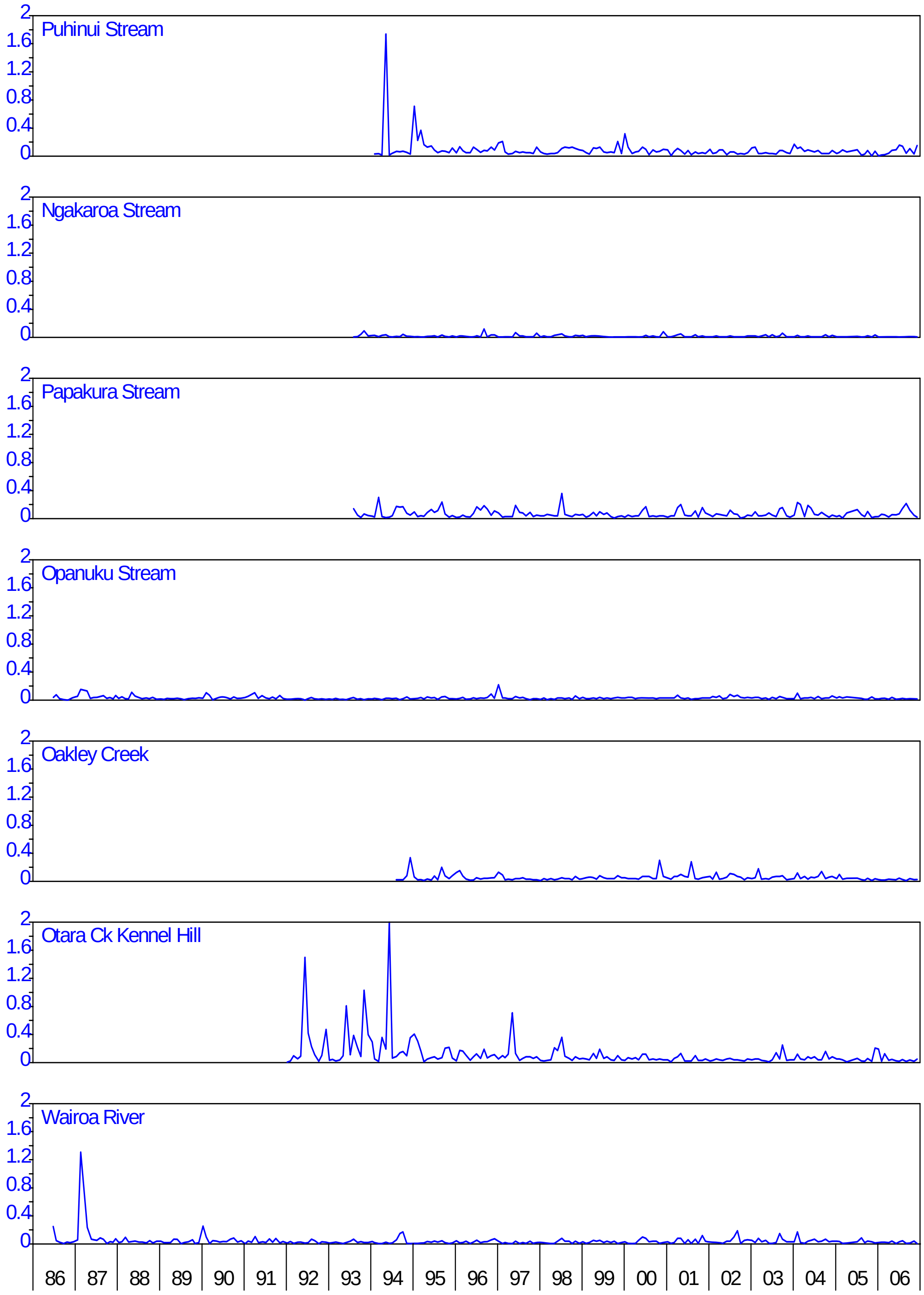


Figure 24: Southern streams - total kjedhal nitrogen (gN.m^{-3})

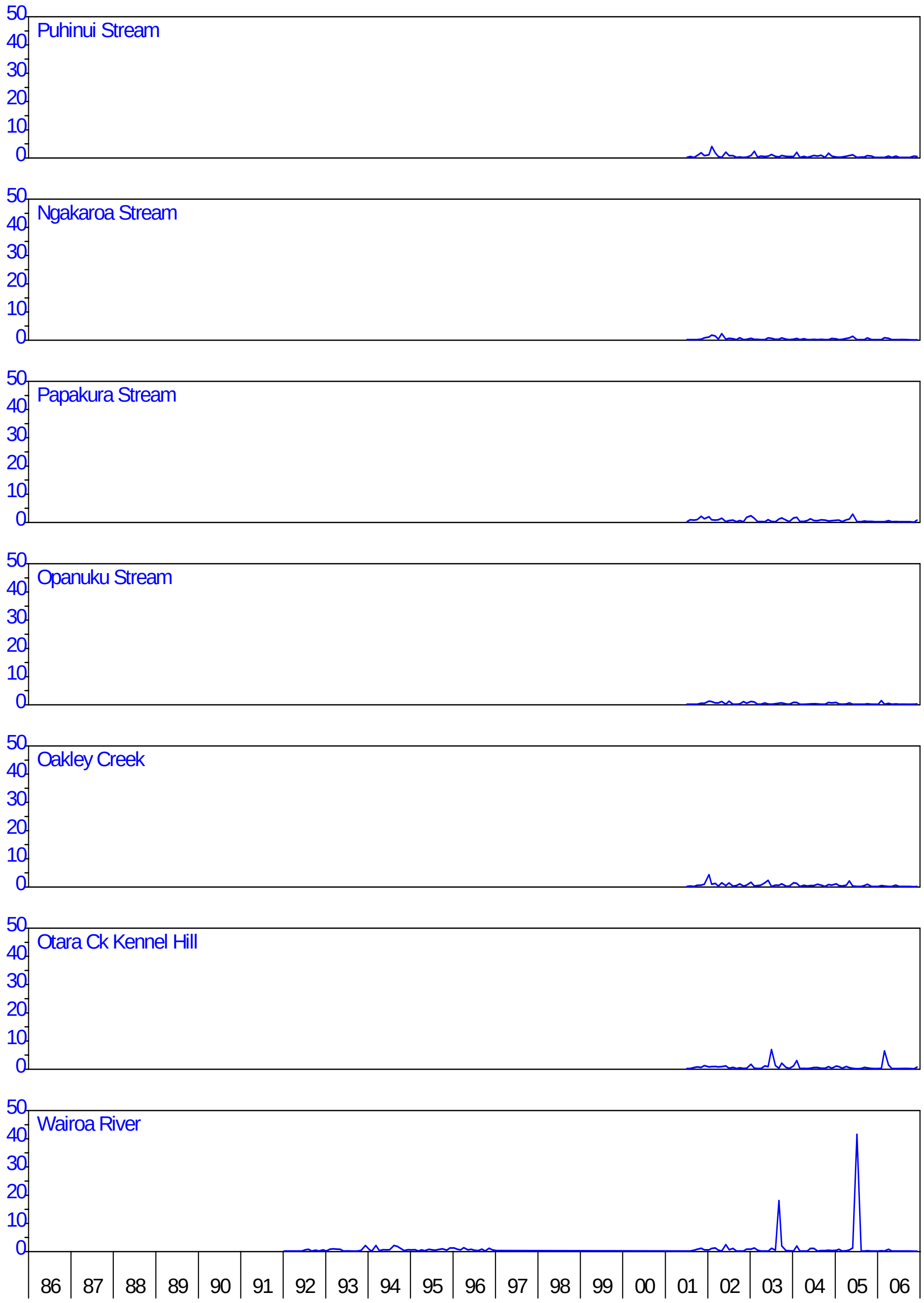


Figure 25: Southern streams - dissolved oxygen (% saturated)

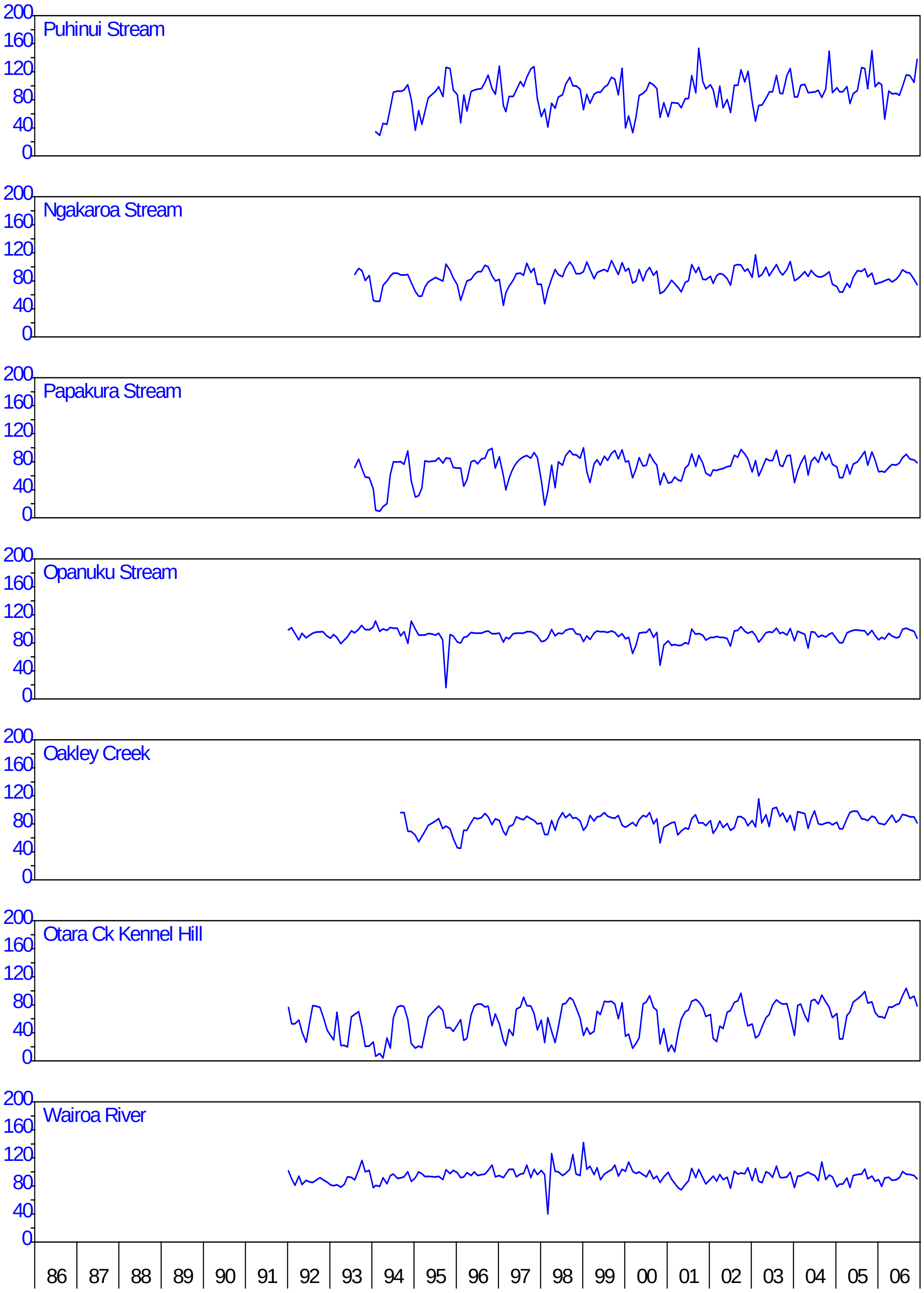


Figure 26: Southern streams – dissolved oxygen (ppm)

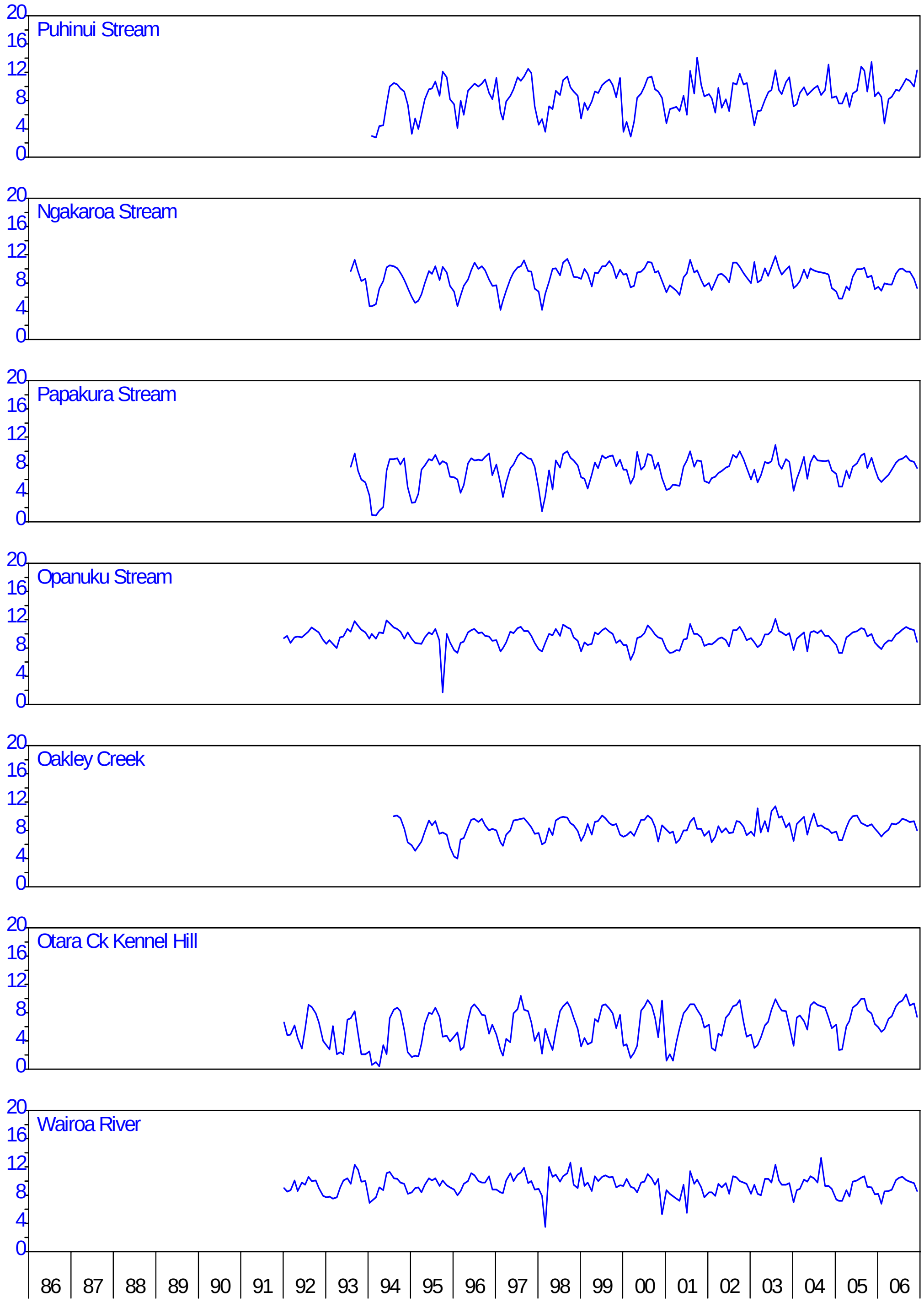


Figure 27: Southern streams – total phosphorus (g.m^{-3})

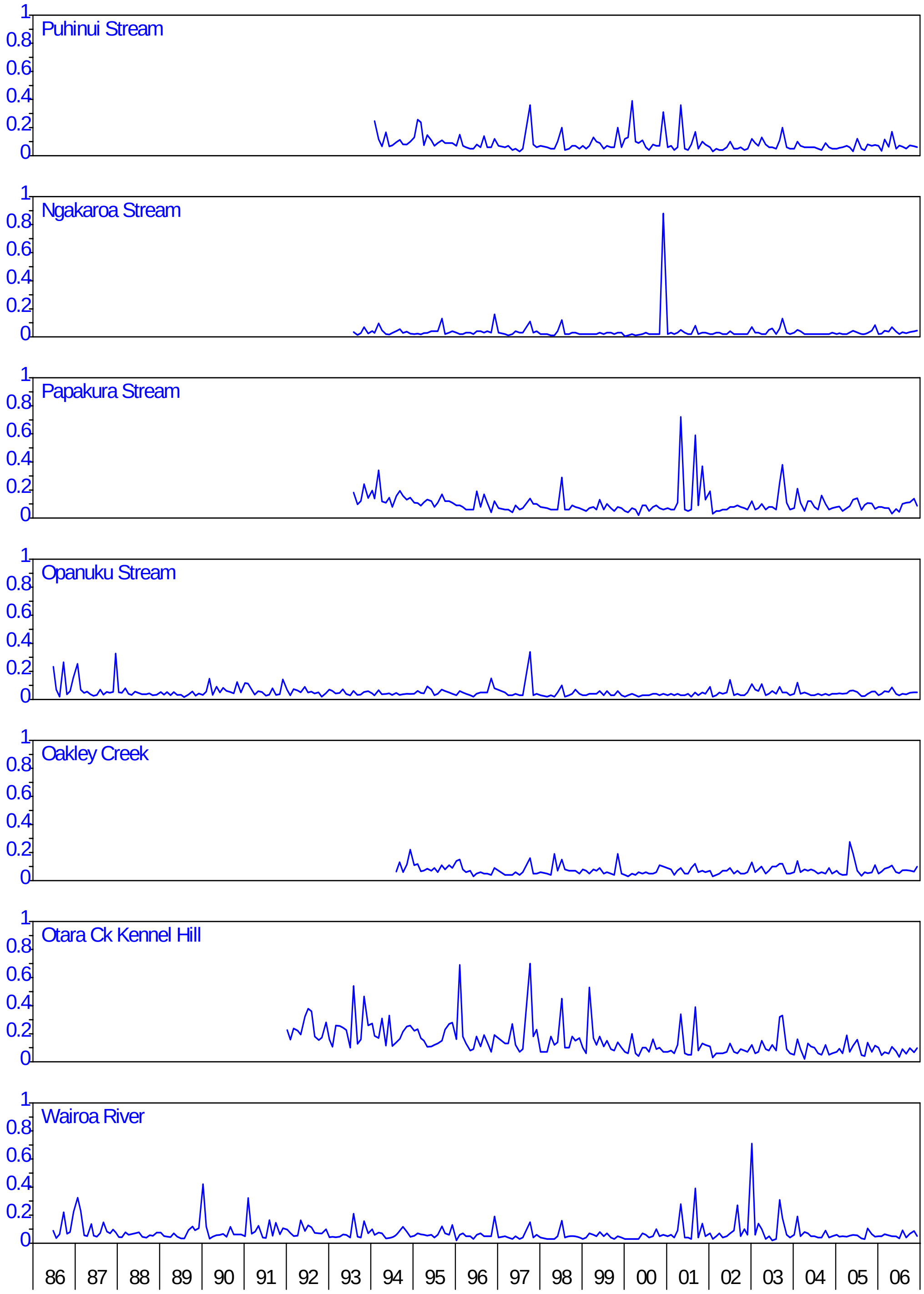


Figure 28: Southern streams – dissolved reactive phosphorus (gP.m^{-3})

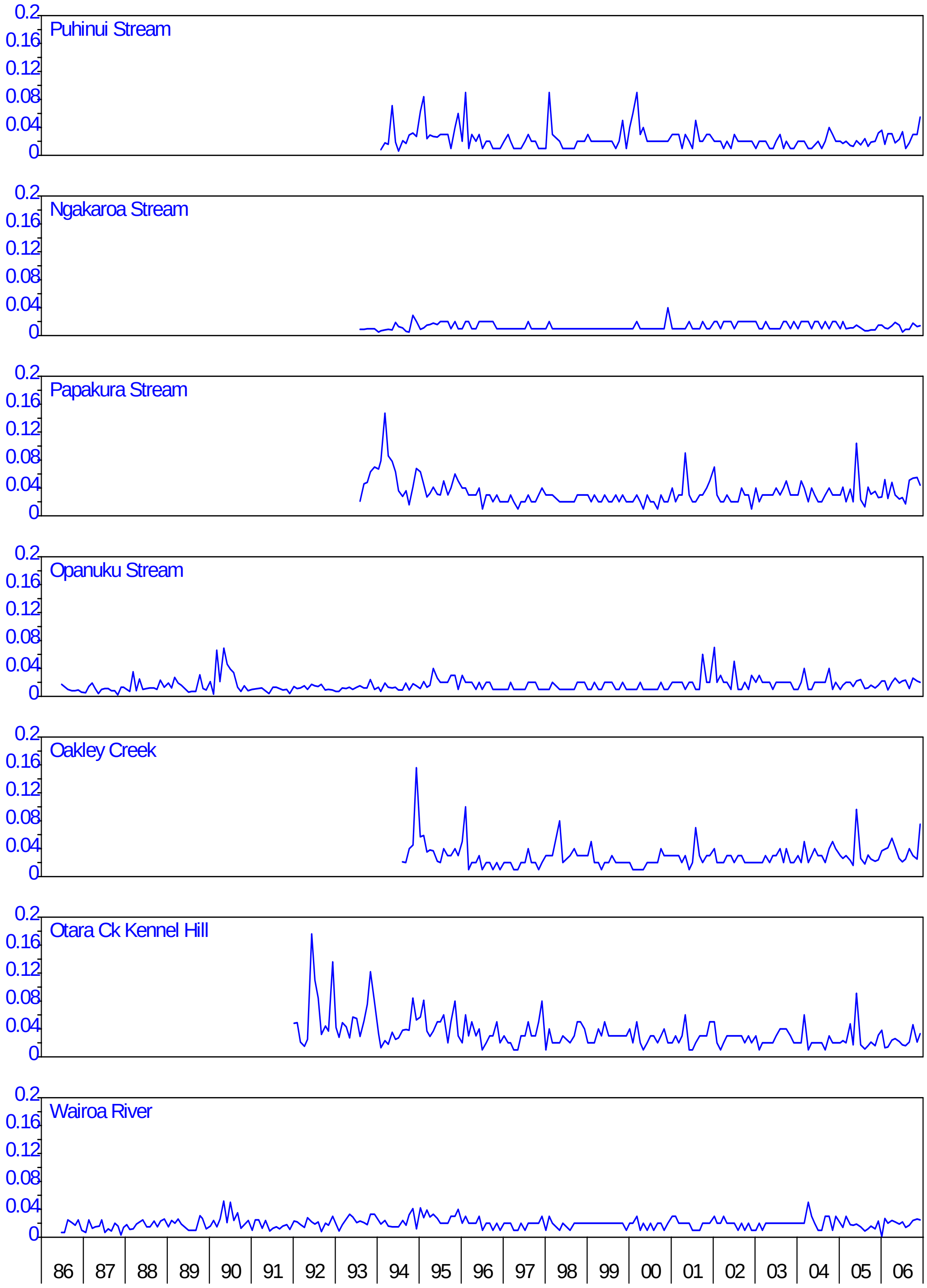


Figure 29: Southern streams – faecal coliforms (MPN/100ml)

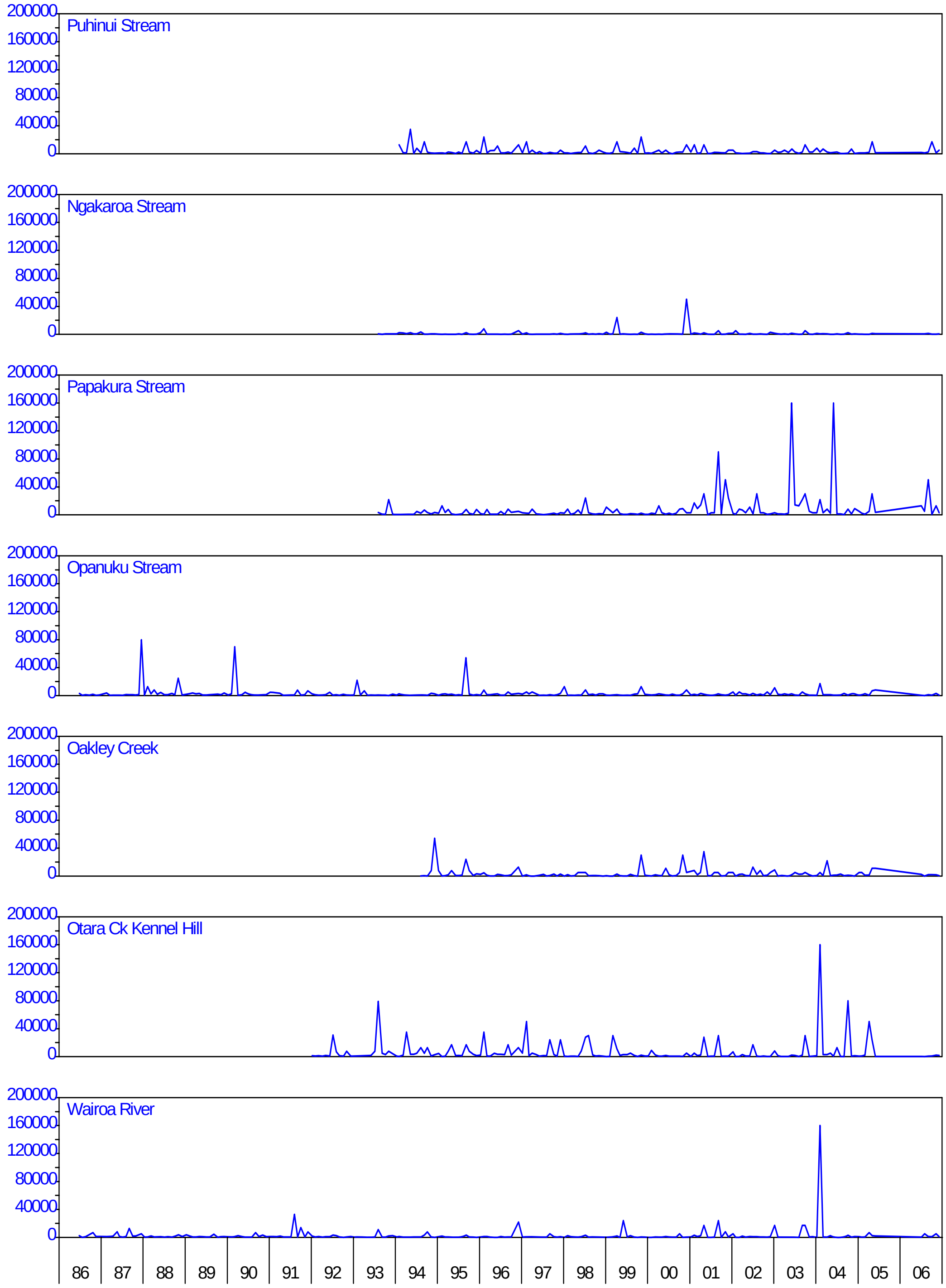


Figure 30: Tamaki streams - conductivity (µS.cm^{-2})

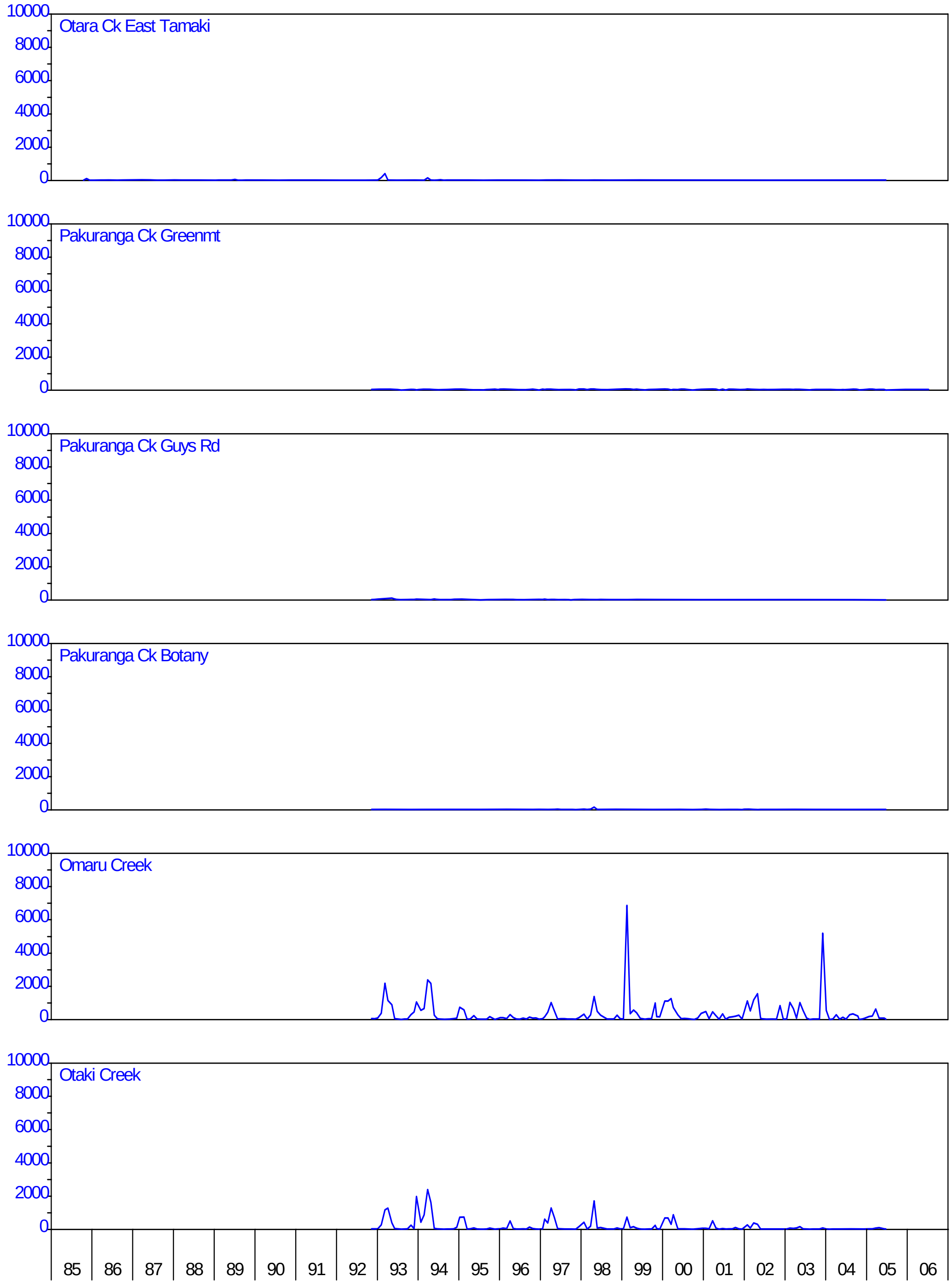


Figure 31: Tamaki streams – turbidity (NTU)

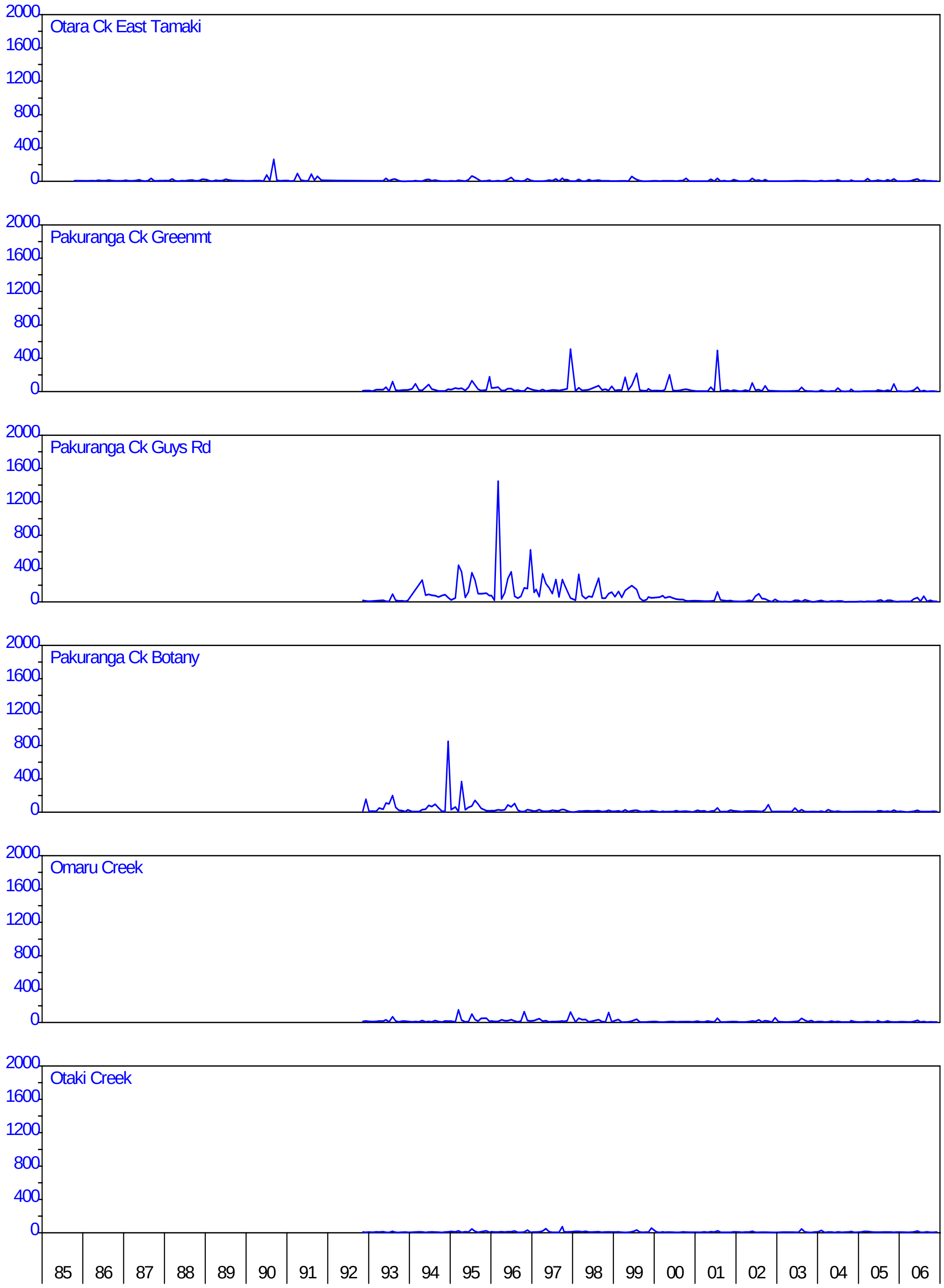


Figure 32: Tamaki streams – temperature (°C)

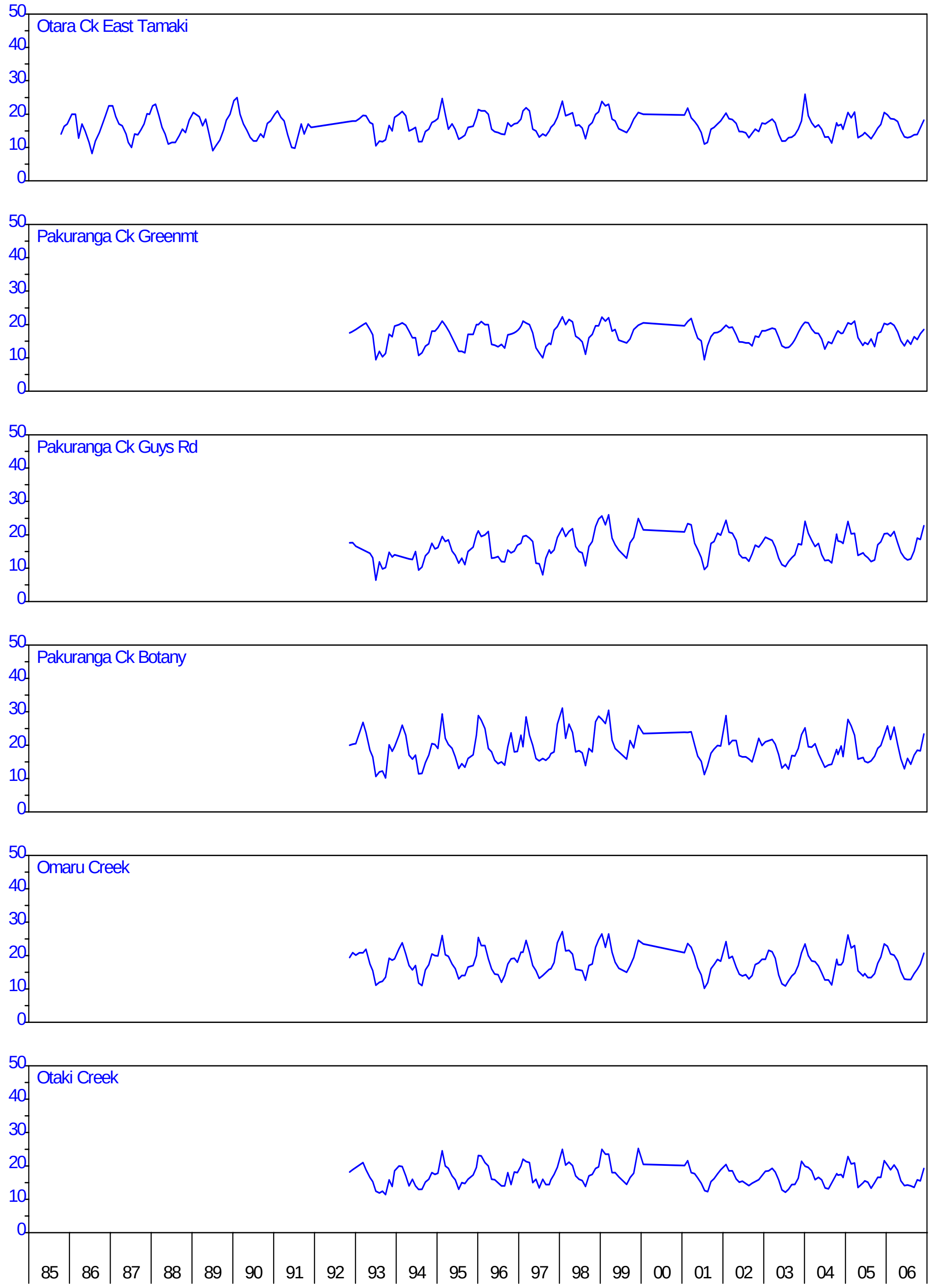


Figure 33: Tamaki streams - pH

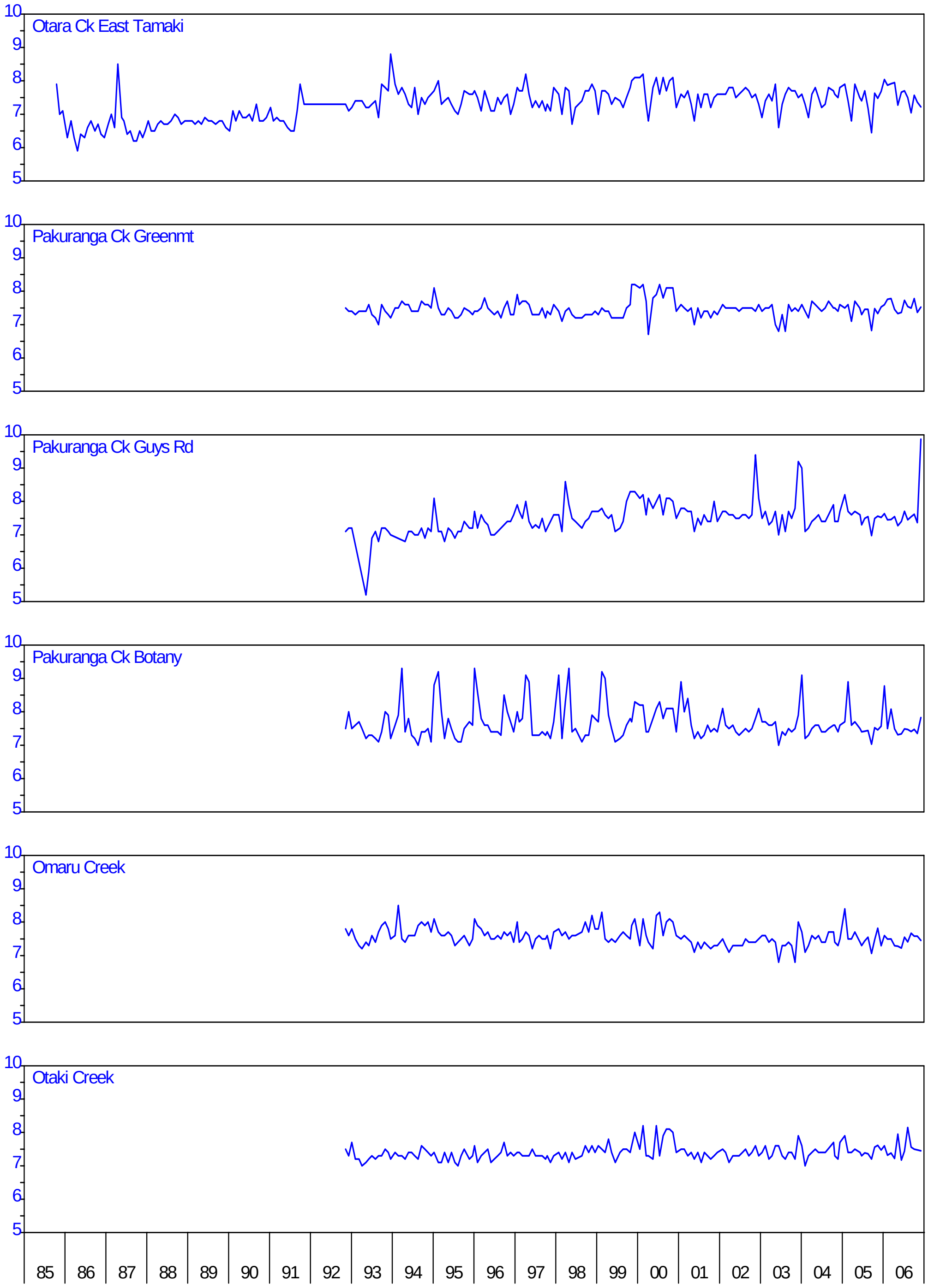


Figure 34: Tamaki streams – suspended solids (ppm)

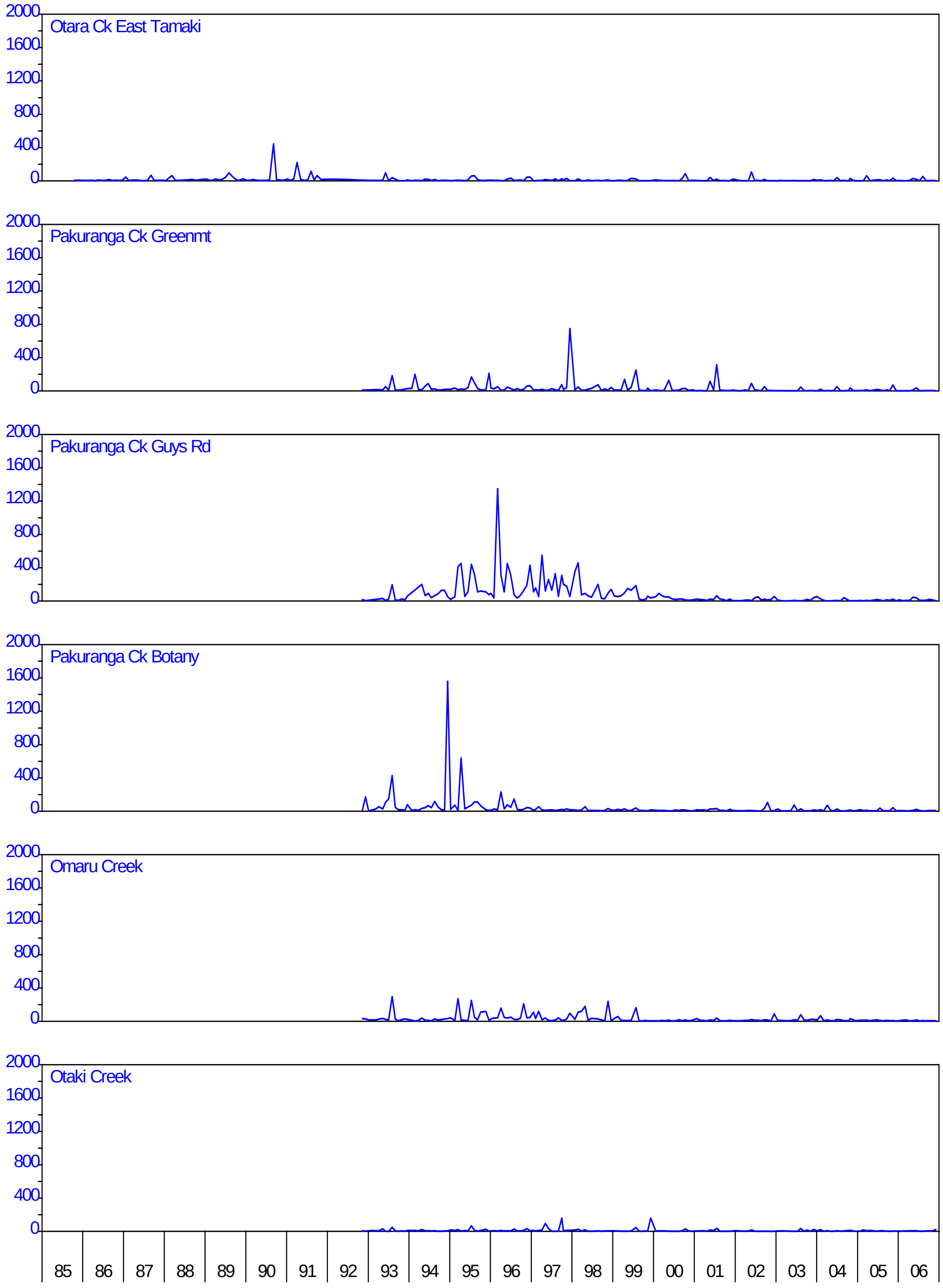


Figure 35: Tamaki streams – nitrate+nitrite (gN.m^{-3})

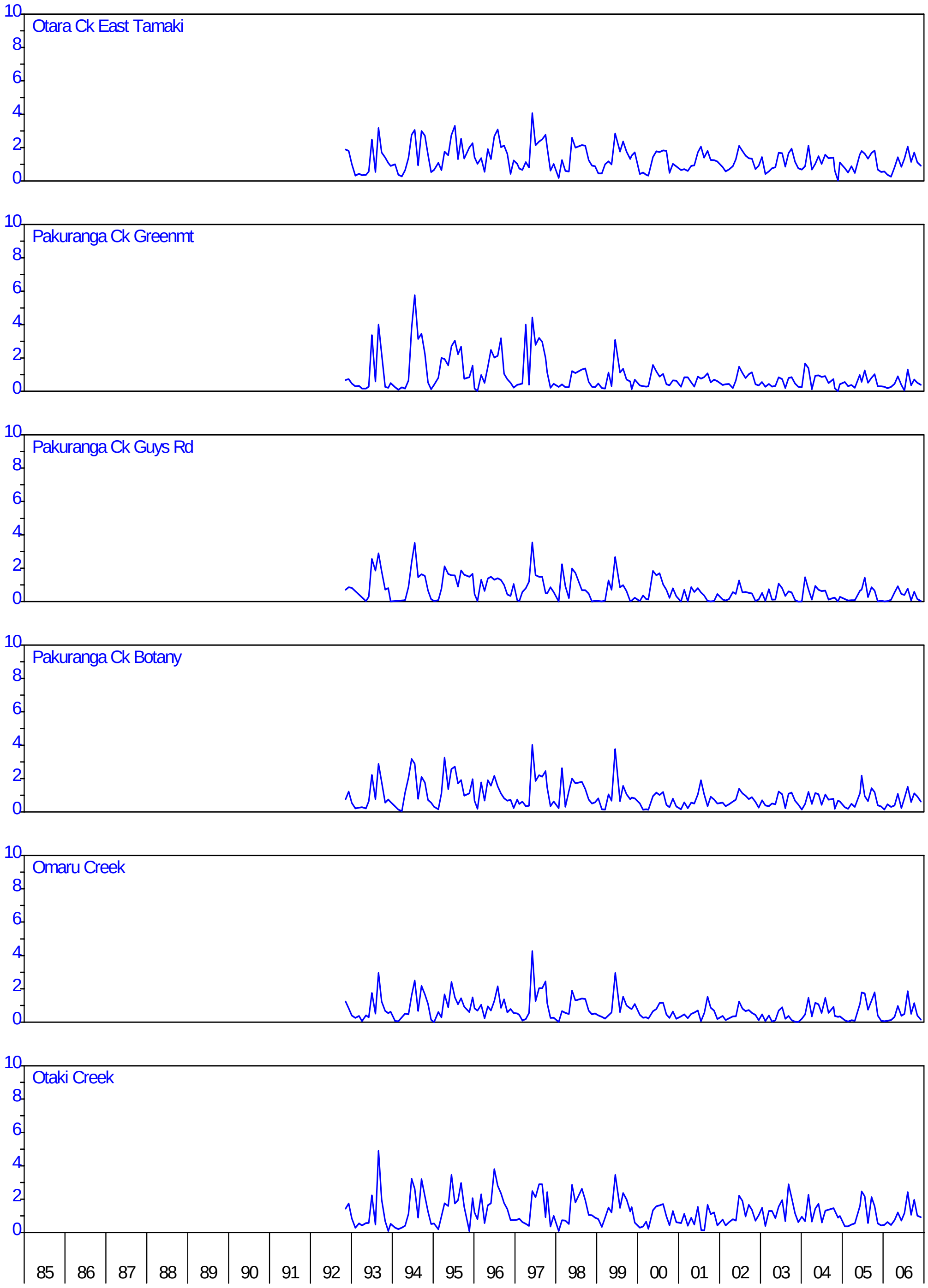


Figure 36: Tamaki streams – ammoniacal nitrogen ($gN.m^{-3}$)

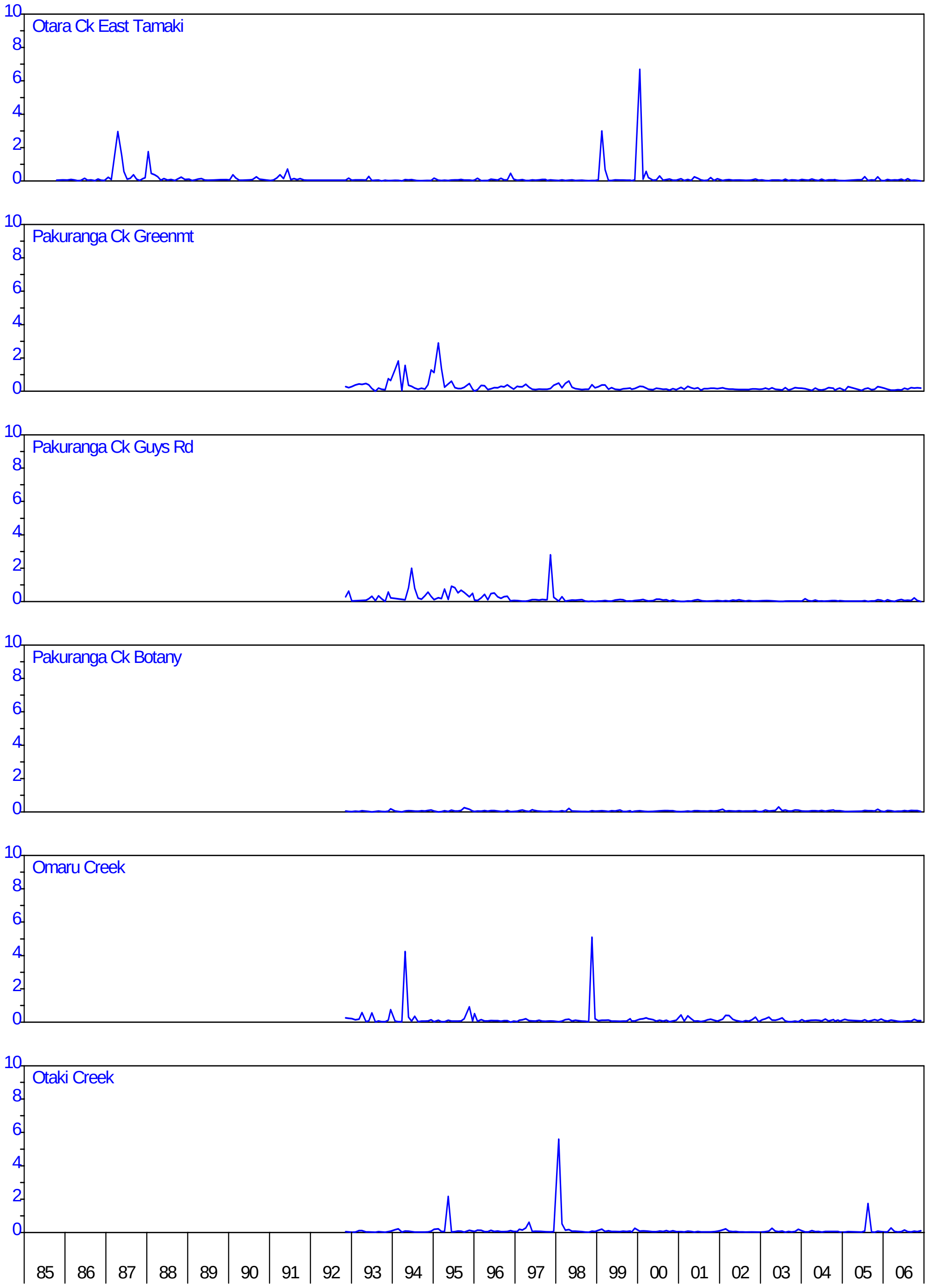


Figure 37: Tamaki streams - total kjedhal nitrogen (gN.m^{-3})

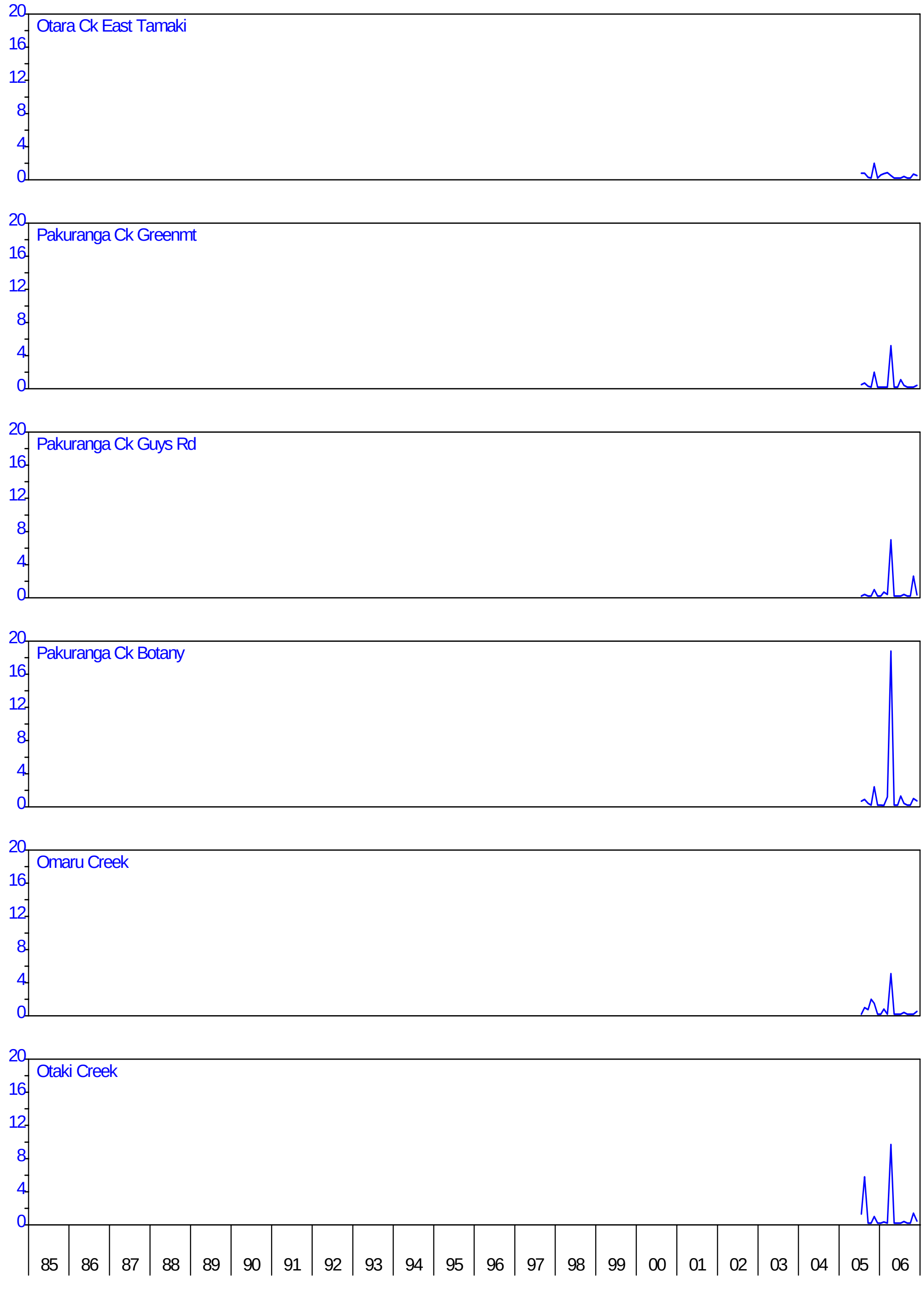


Figure 38: Tamaki streams – dissolved oxygen (% saturated)

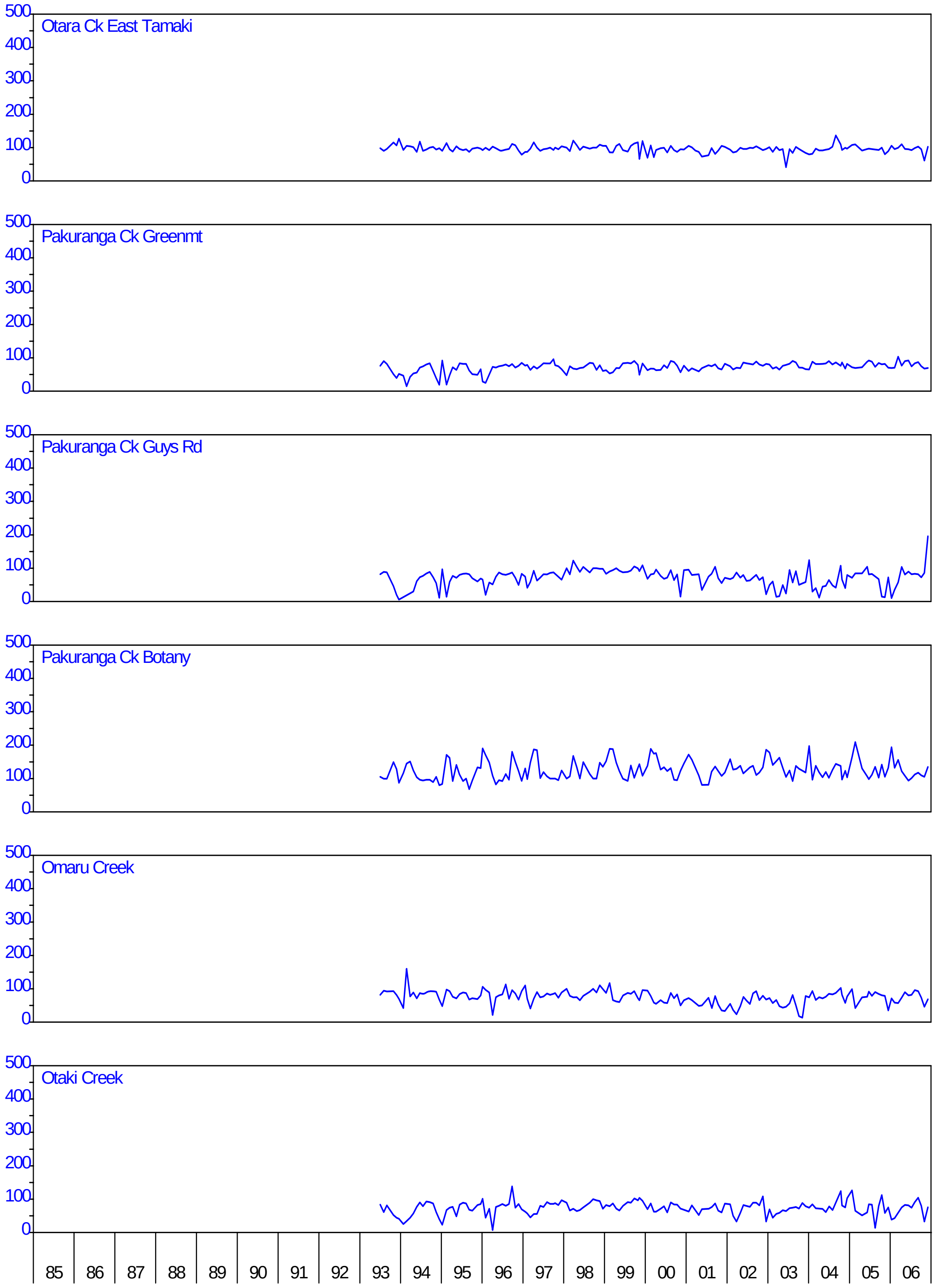


Figure 39: Tamaki streams – dissolved oxygen (ppm)

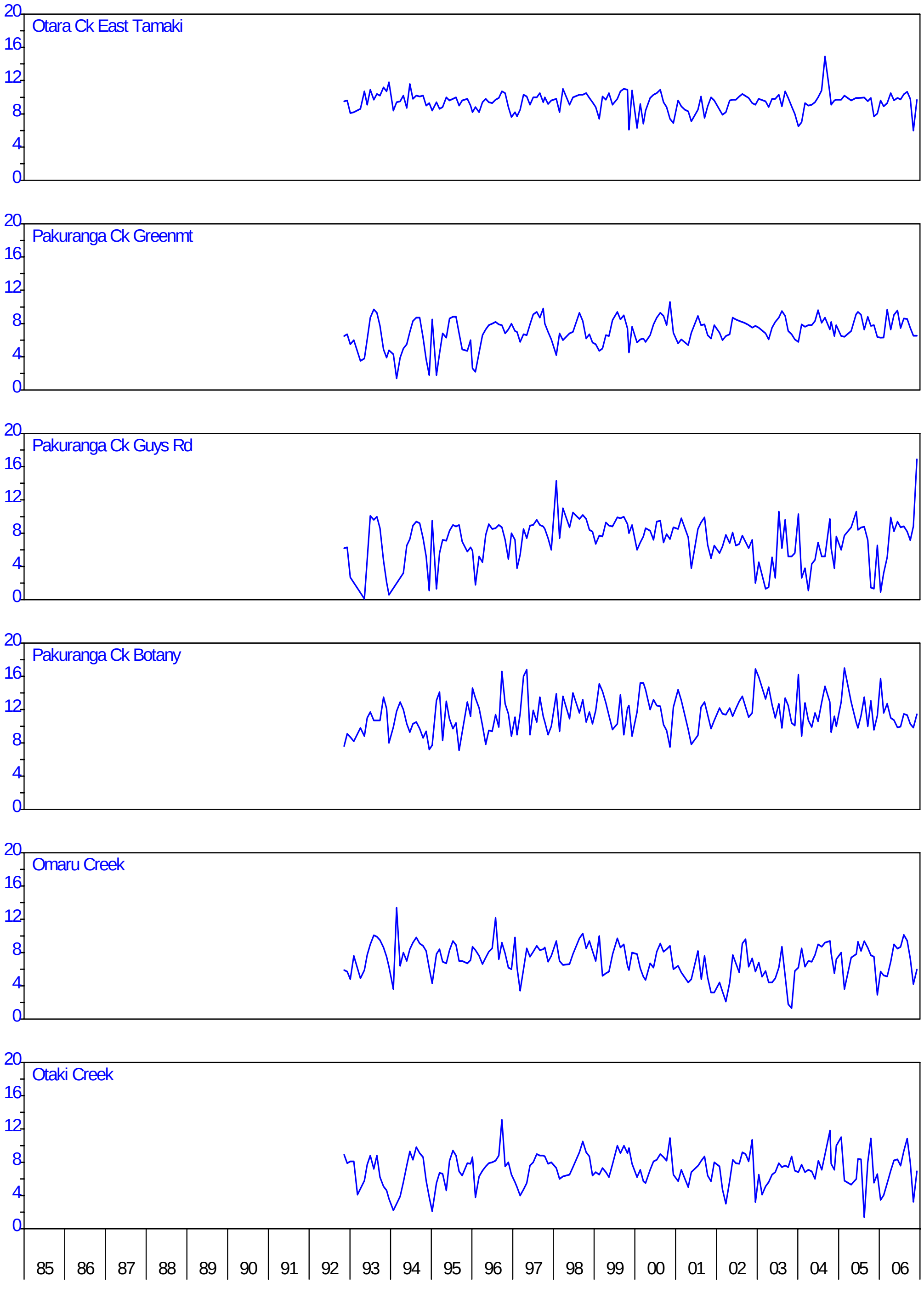


Figure 40: Tamaki streams – total phosphorus (g.m[-3])

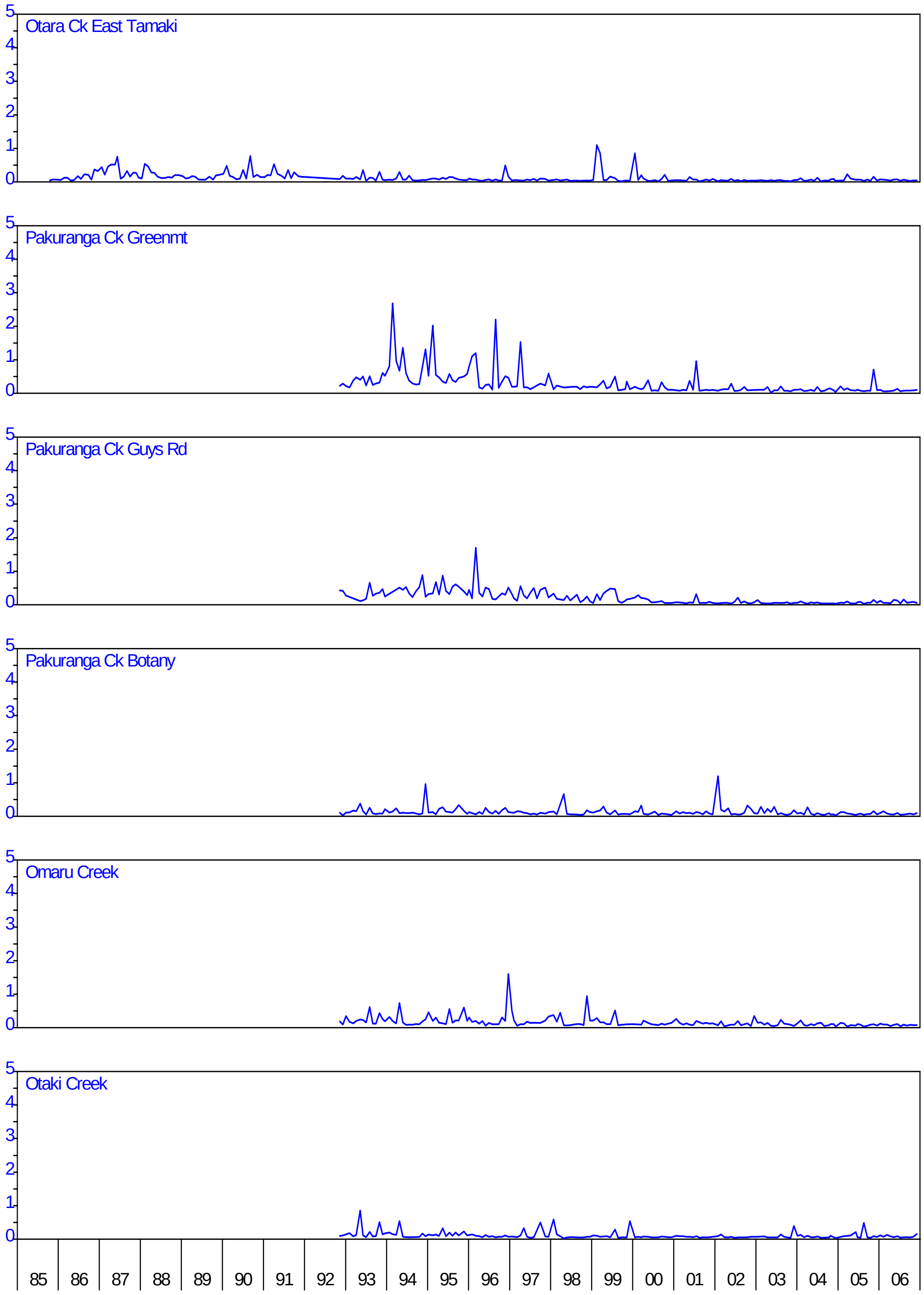


Figure 41: Tamaki streams – dissolved reactive phosphorus (gP.m^{-3})

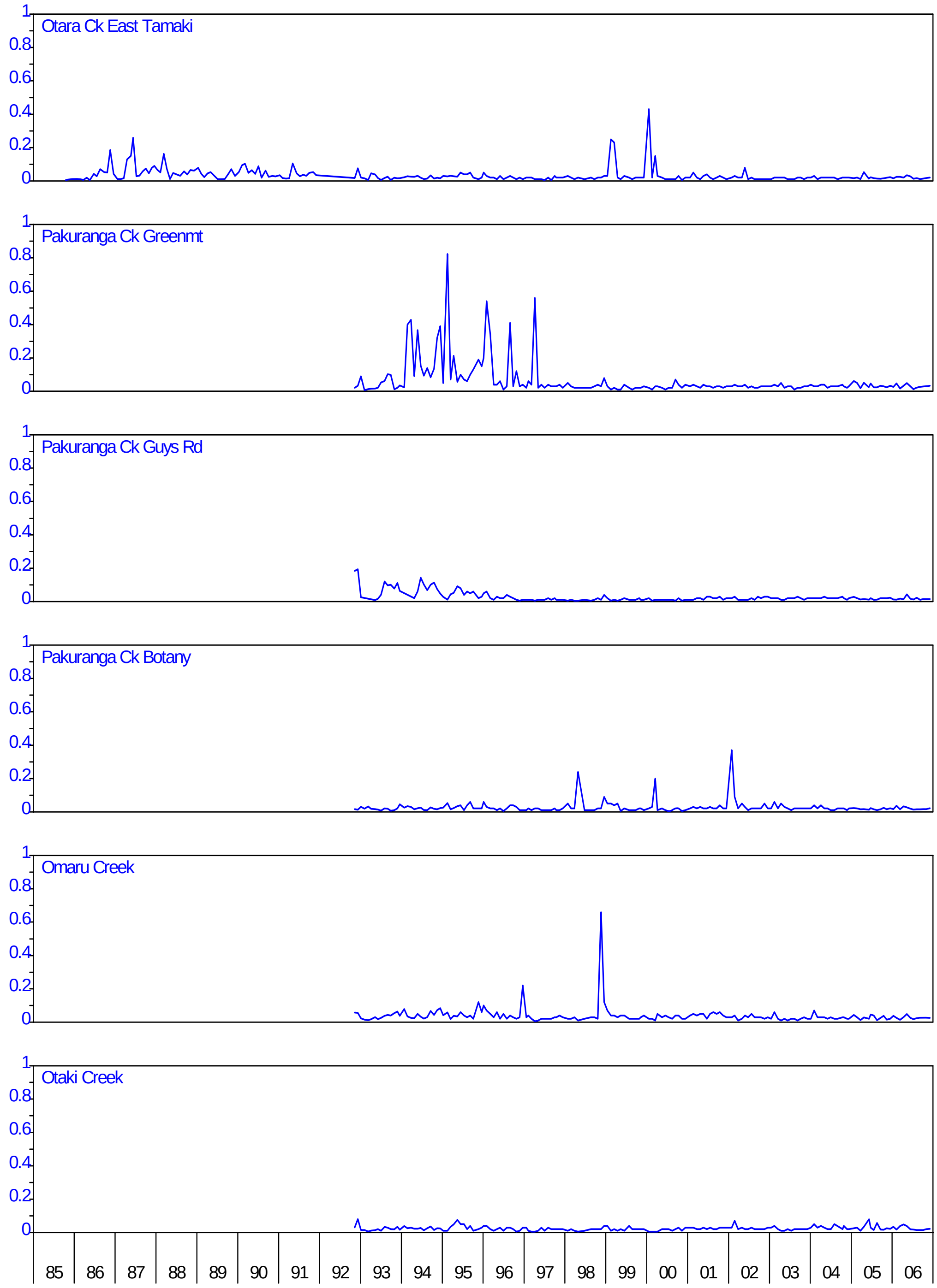


Figure 42: Tamaki streams – faecal coliforms (MPN/100ml)

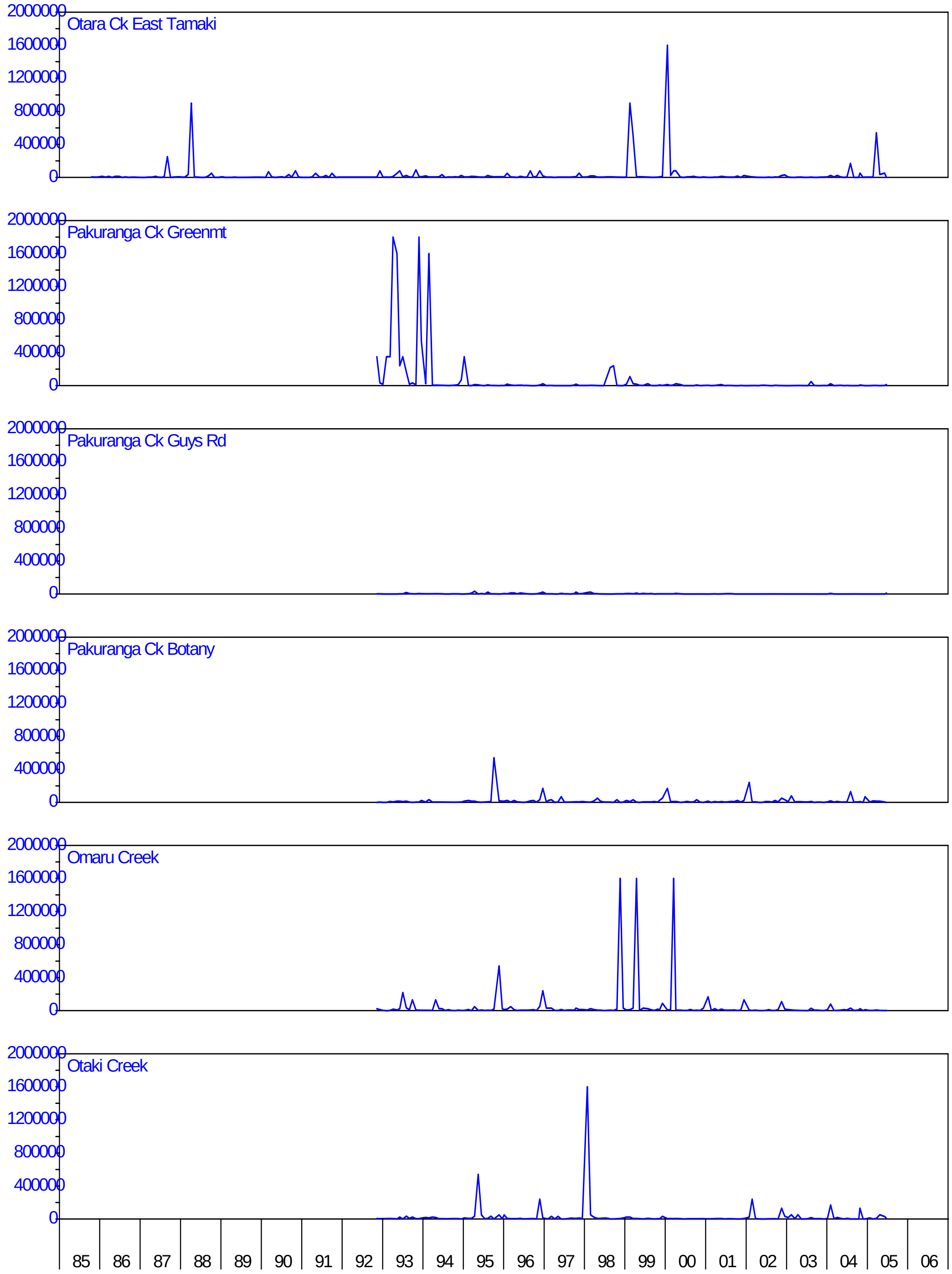


Figure 43: Tamaki streams - E.coli (CFU/100ml)

Figure 44: North eastern & Mahurangi streams – turbidity (NTU)

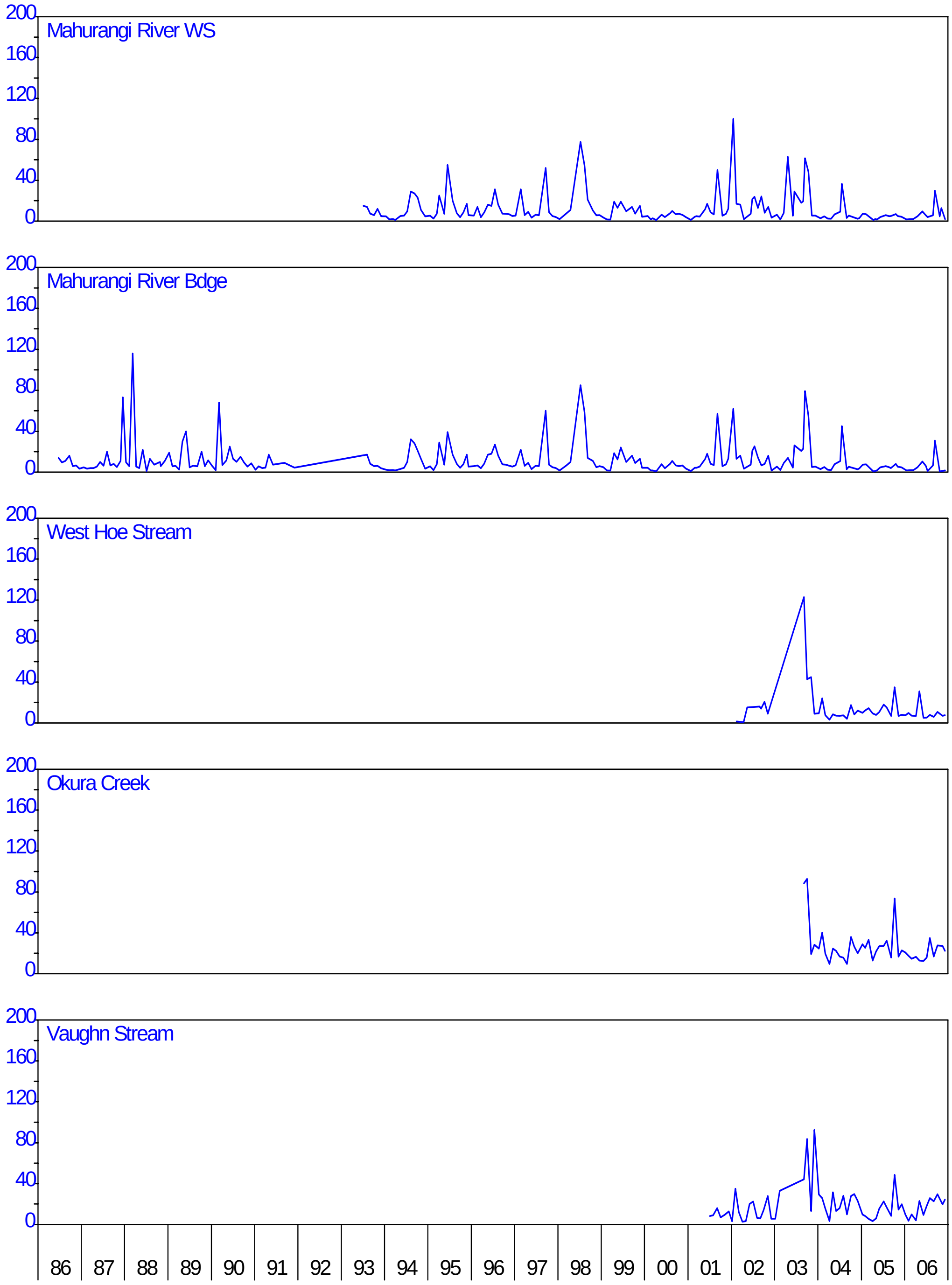


Figure 45: North eastern & Mahurangi streams – temperature (°C)

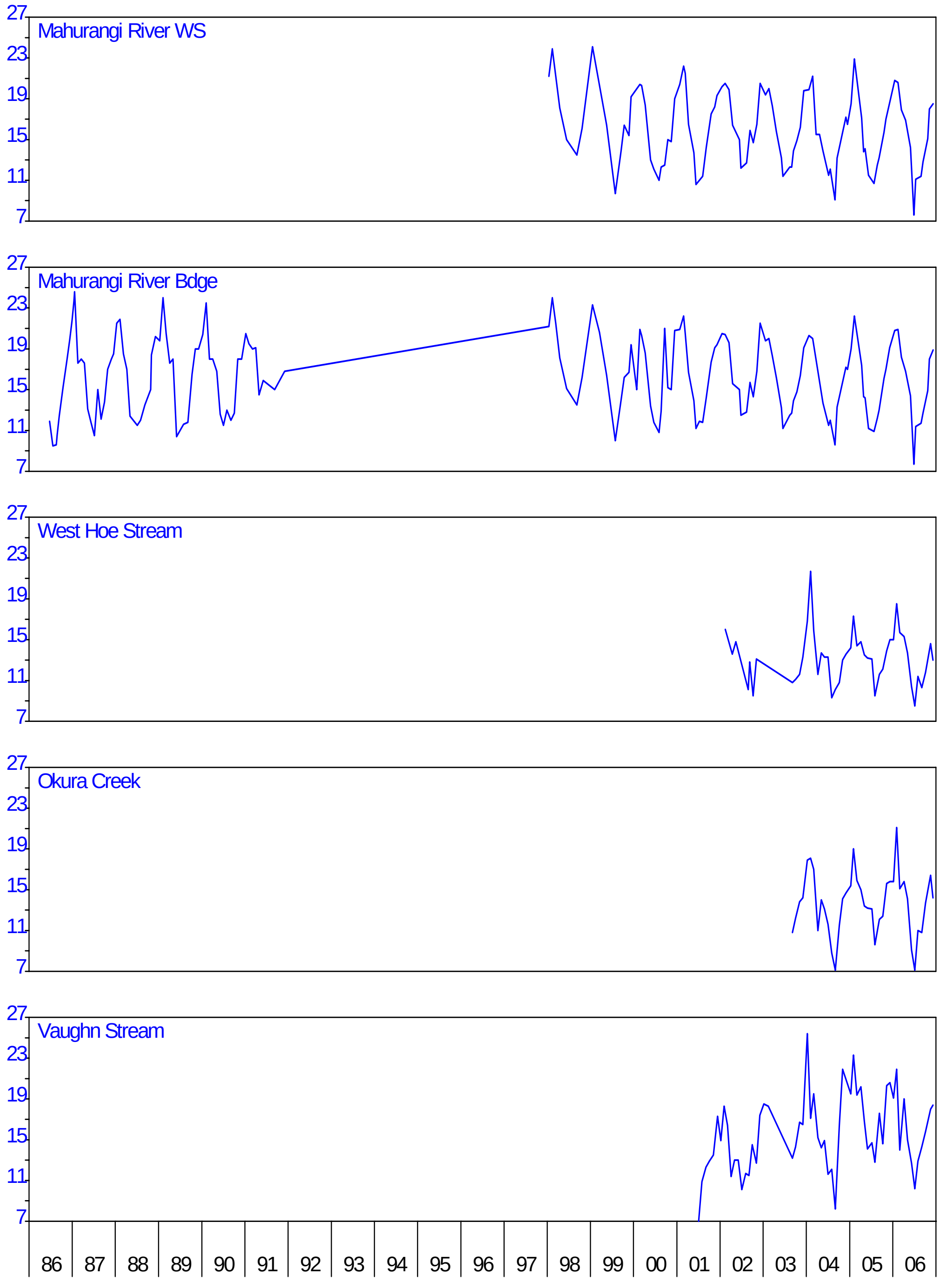


Figure 46: North eastern & Mahurangi streams - pH

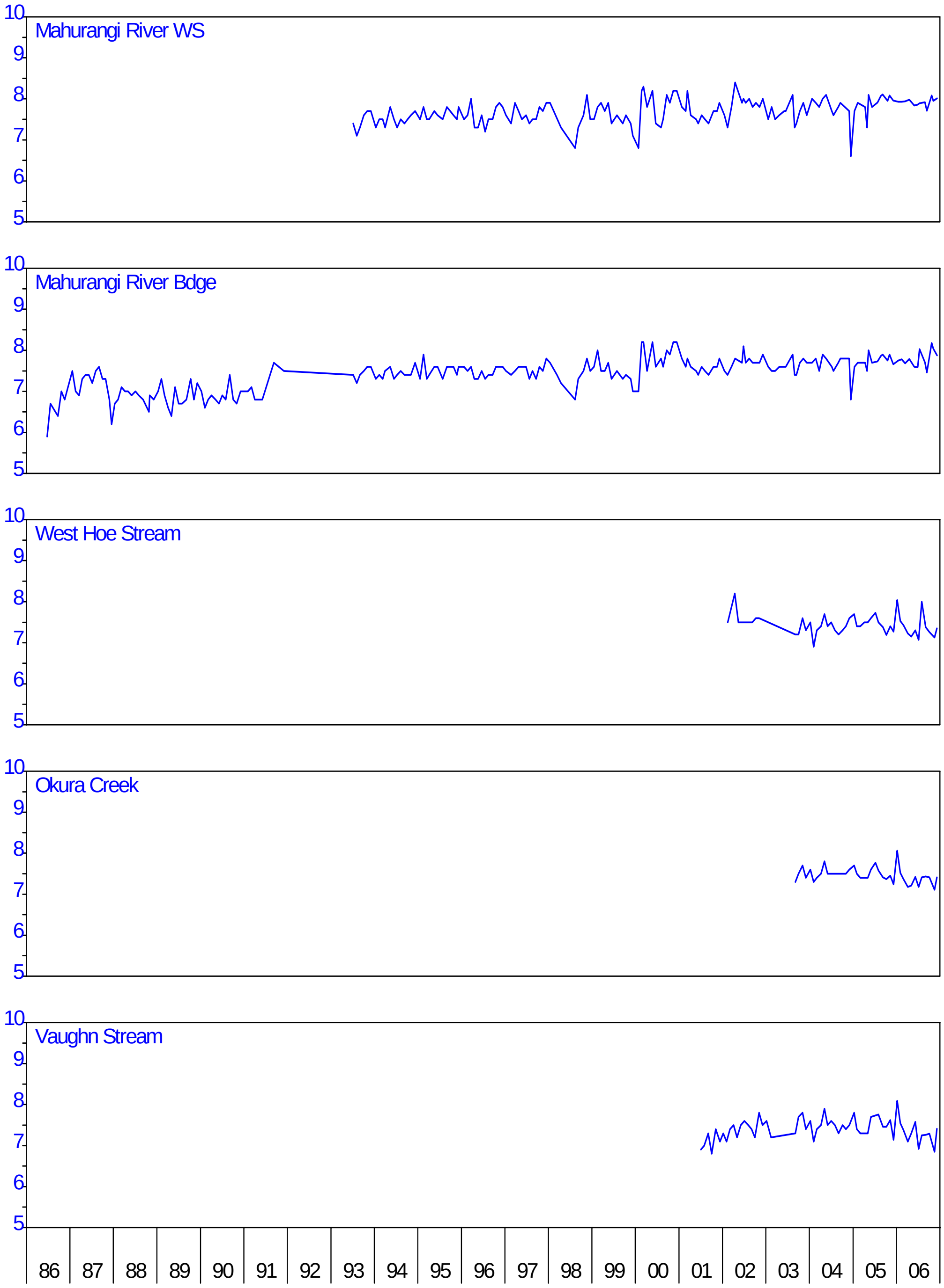


Figure 47: North eastern & Mahurangi streams – suspended solids (ppm)

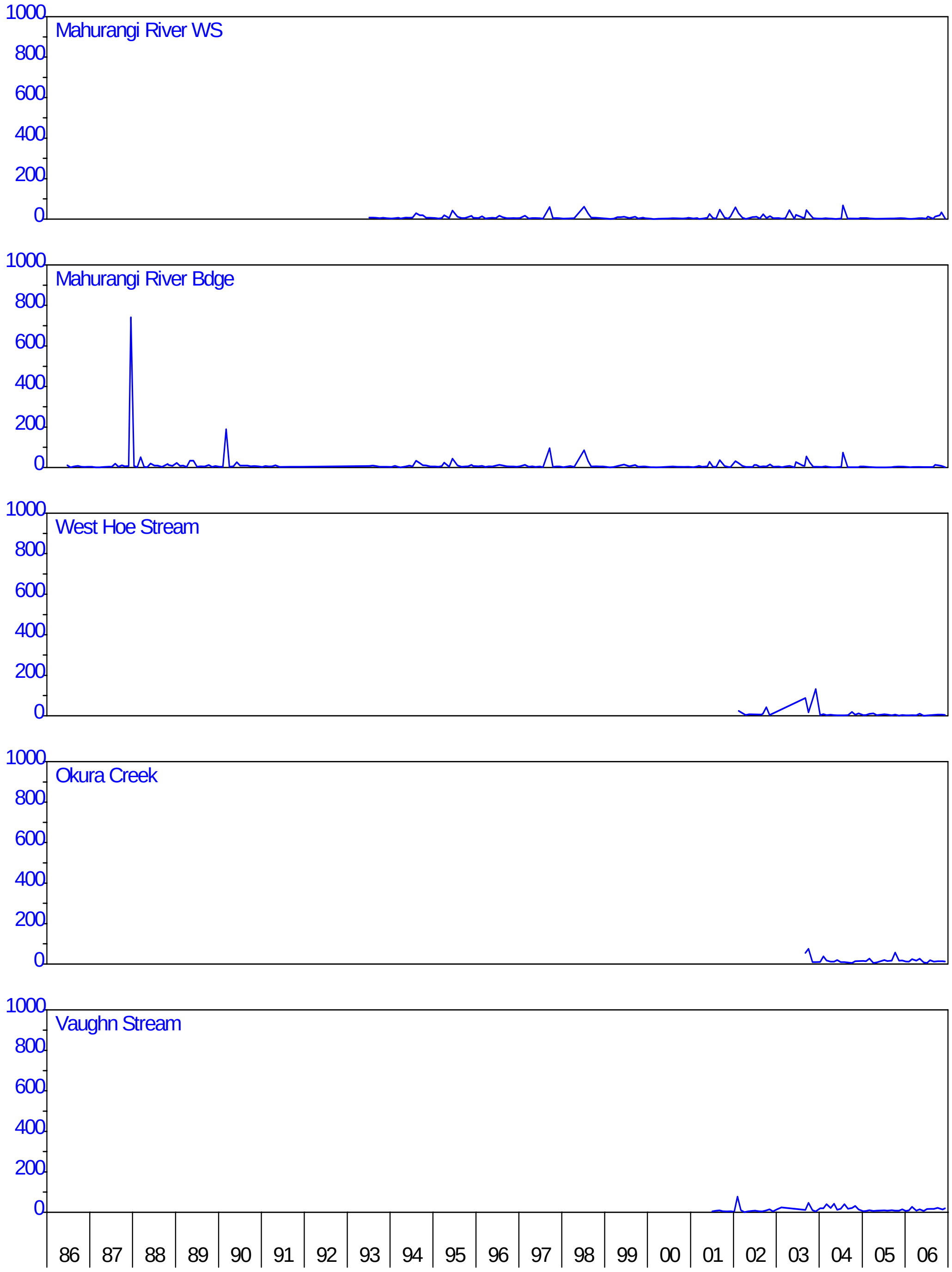


Figure 48: North eastern & Mahurangi streams – nitrate+nitrite (gN.m^{-3})

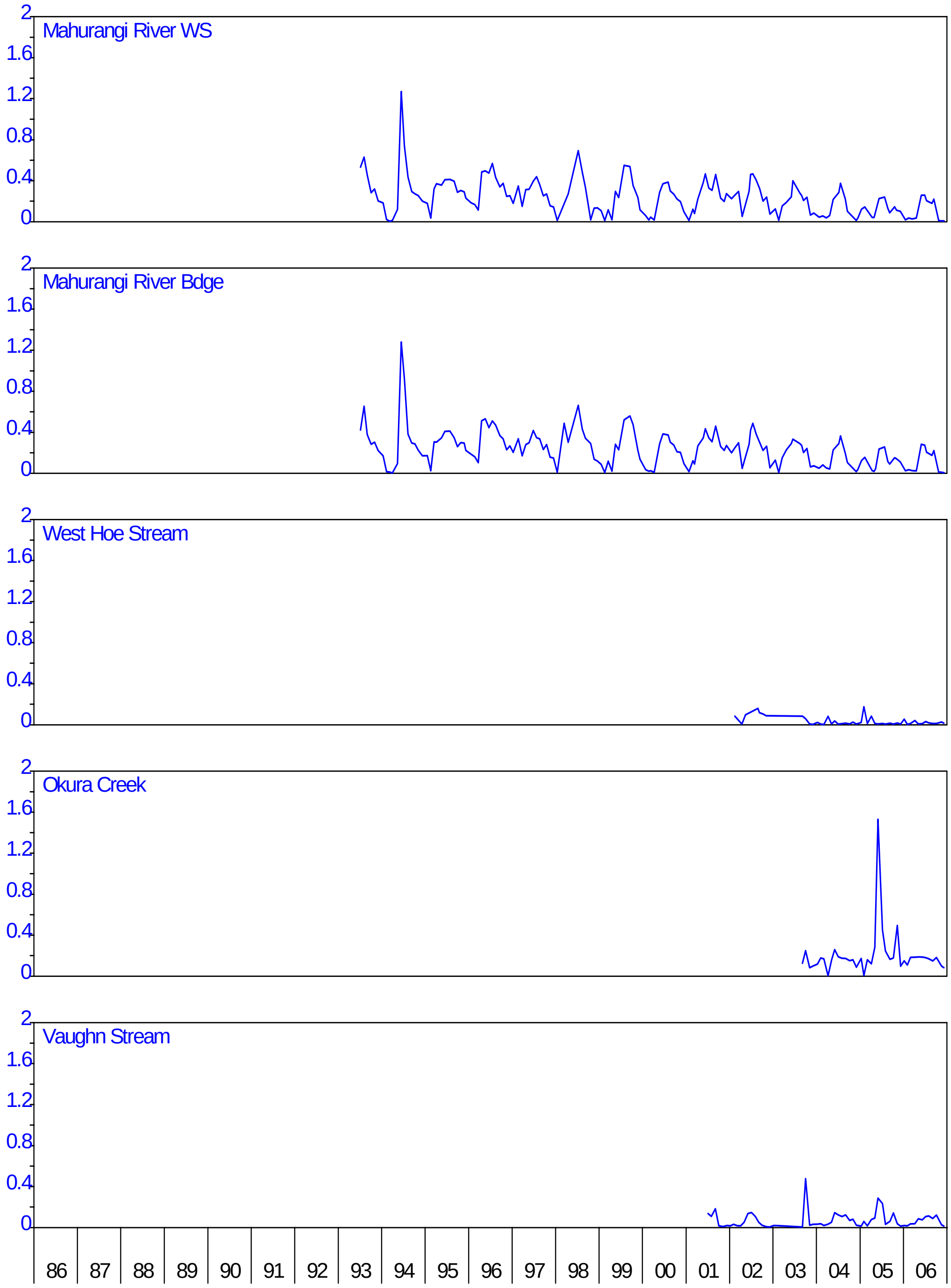


Figure 49: North eastern & Mahurangi streams – ammoniacal nitrogen ($gN.m^{-3}$).

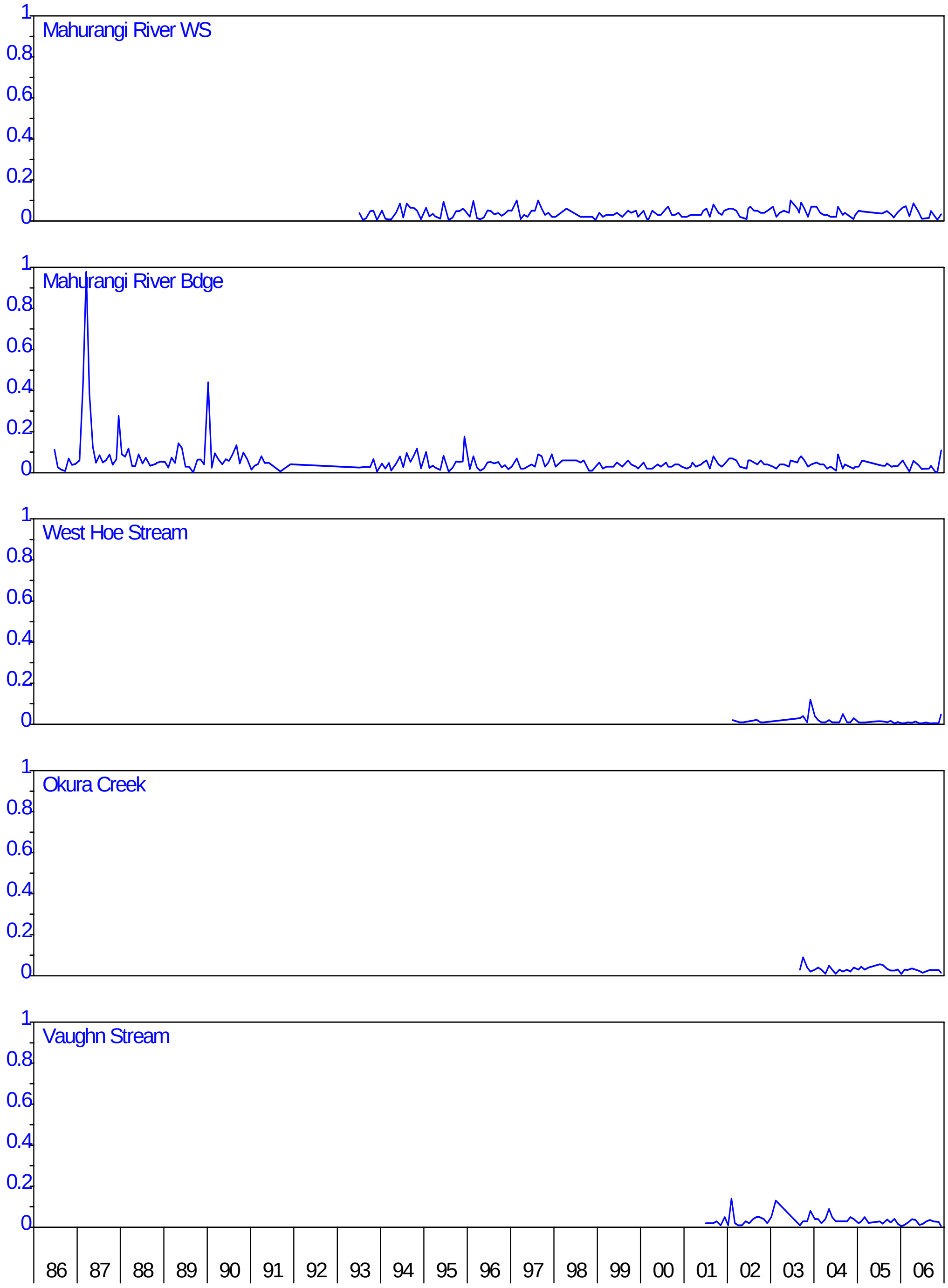


Figure 50: North eastern & Mahurangi streams – dissolved oxygen (% saturated)

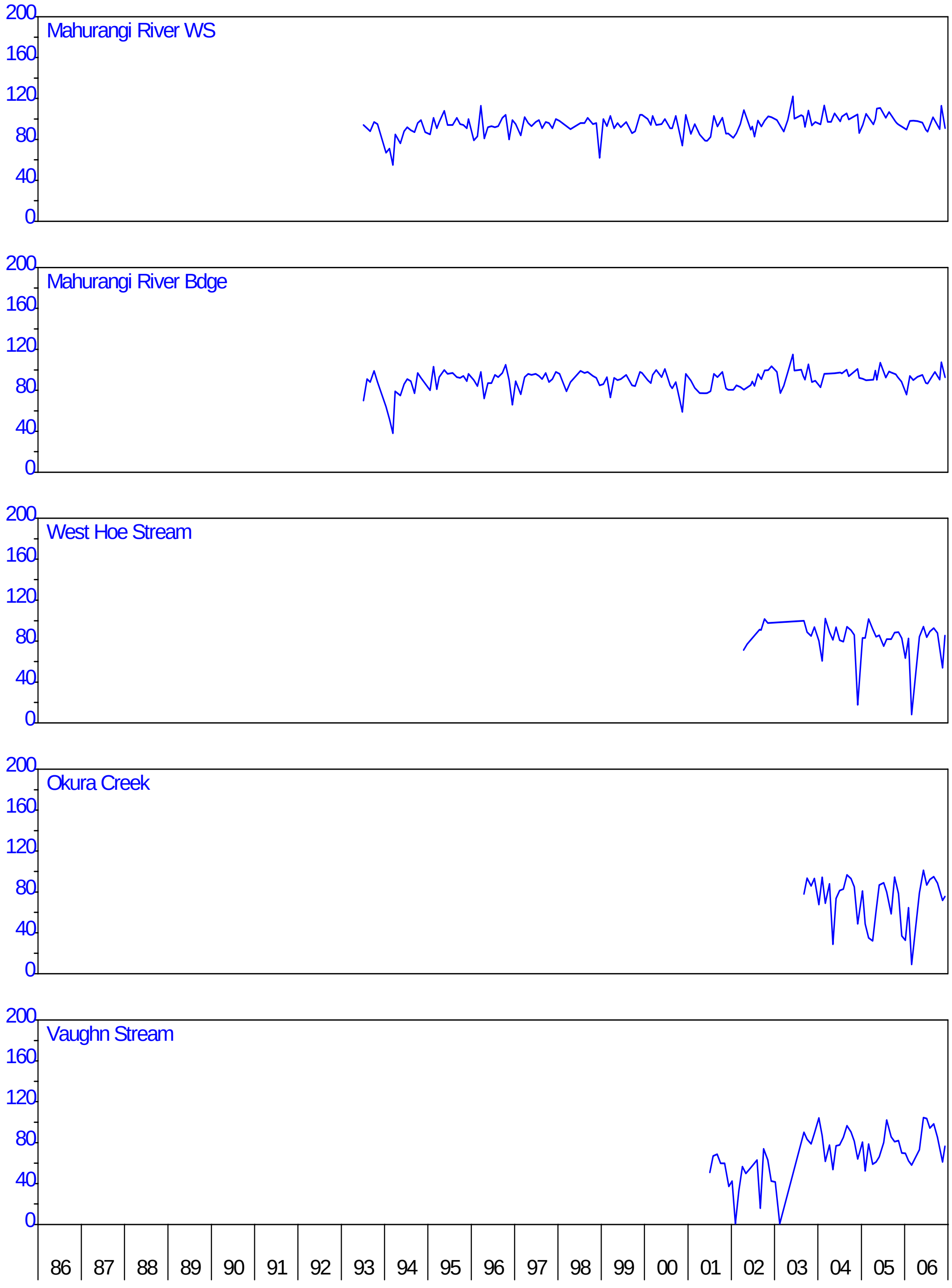


Figure 51: North eastern & Mahurangi streams – dissolved oxygen (ppm)

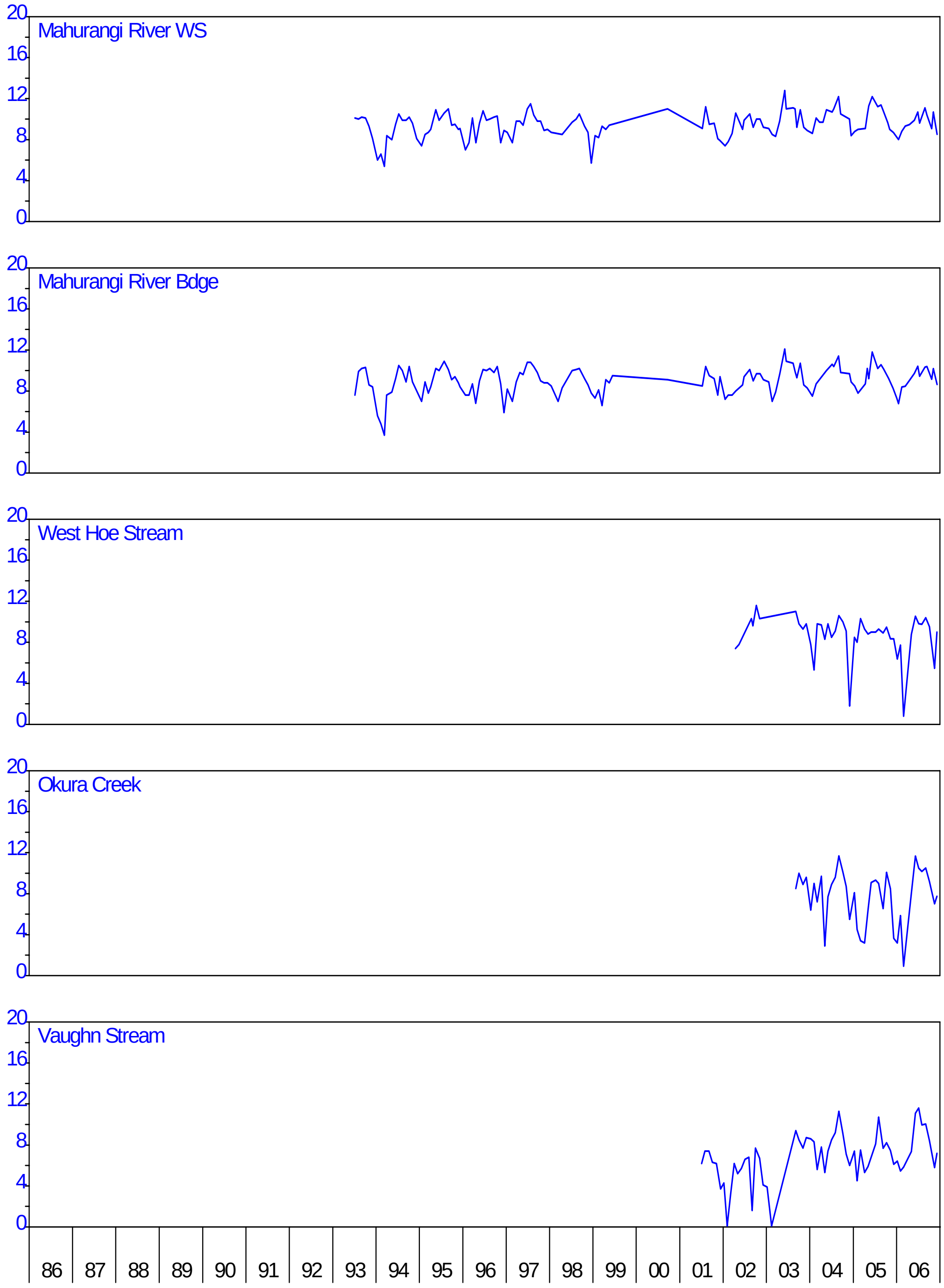


Figure 52: North eastern & Mahurangi streams – total phosphorus ($g.m^{-3}$)

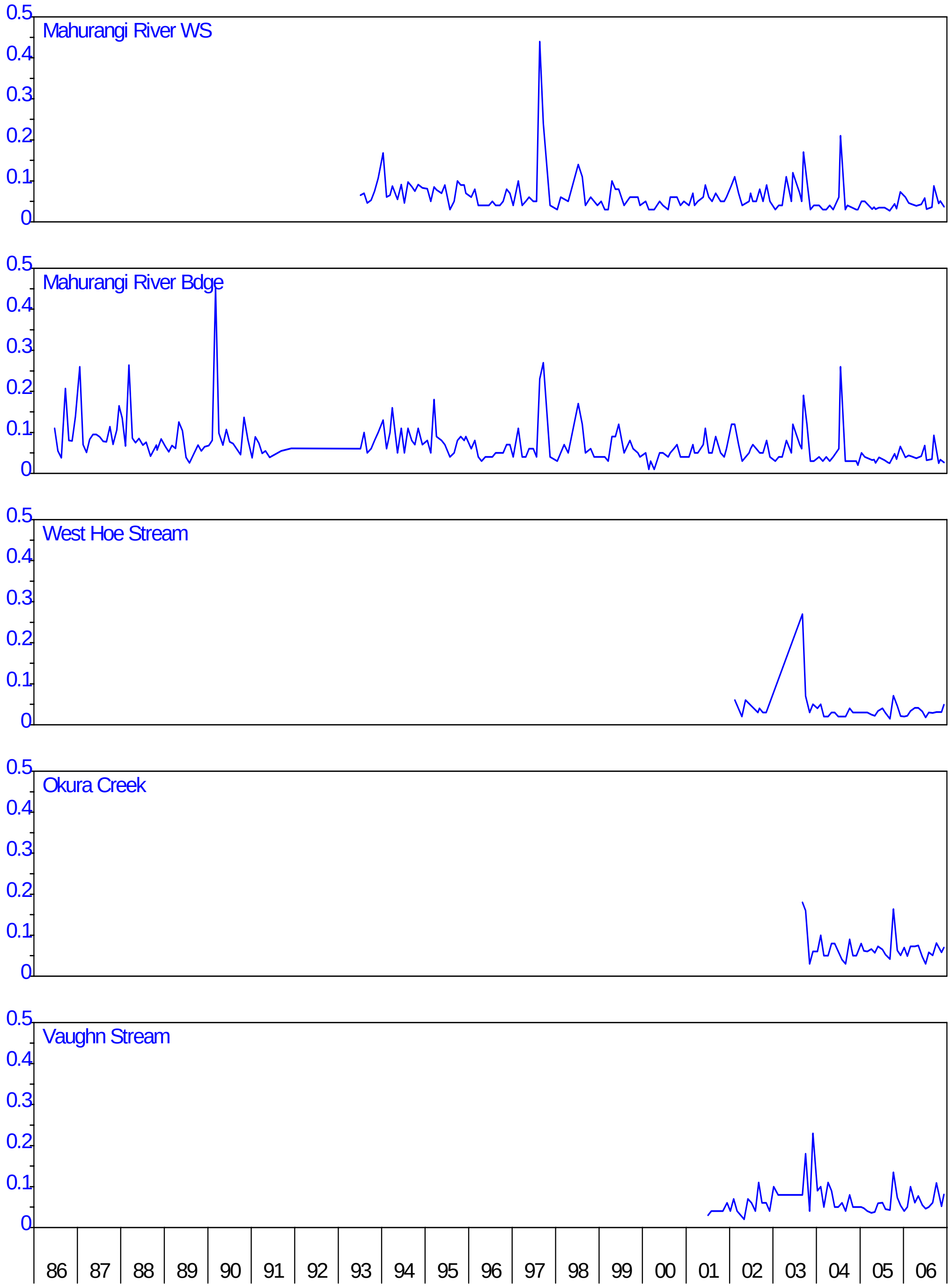


Figure 53: North eastern & Mahurangi streams – dissolved reactive phosphorus (gP.m^{-3})

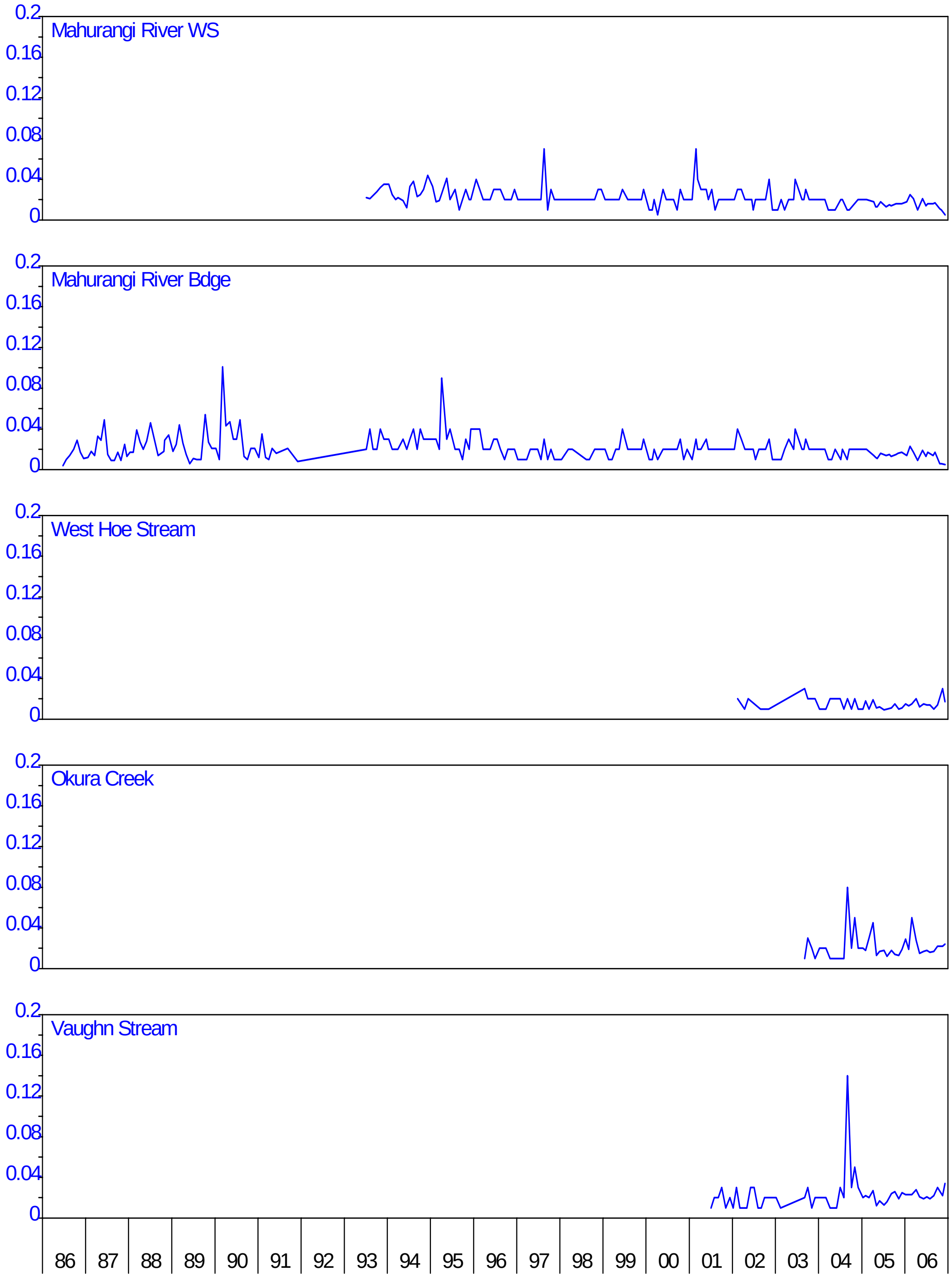
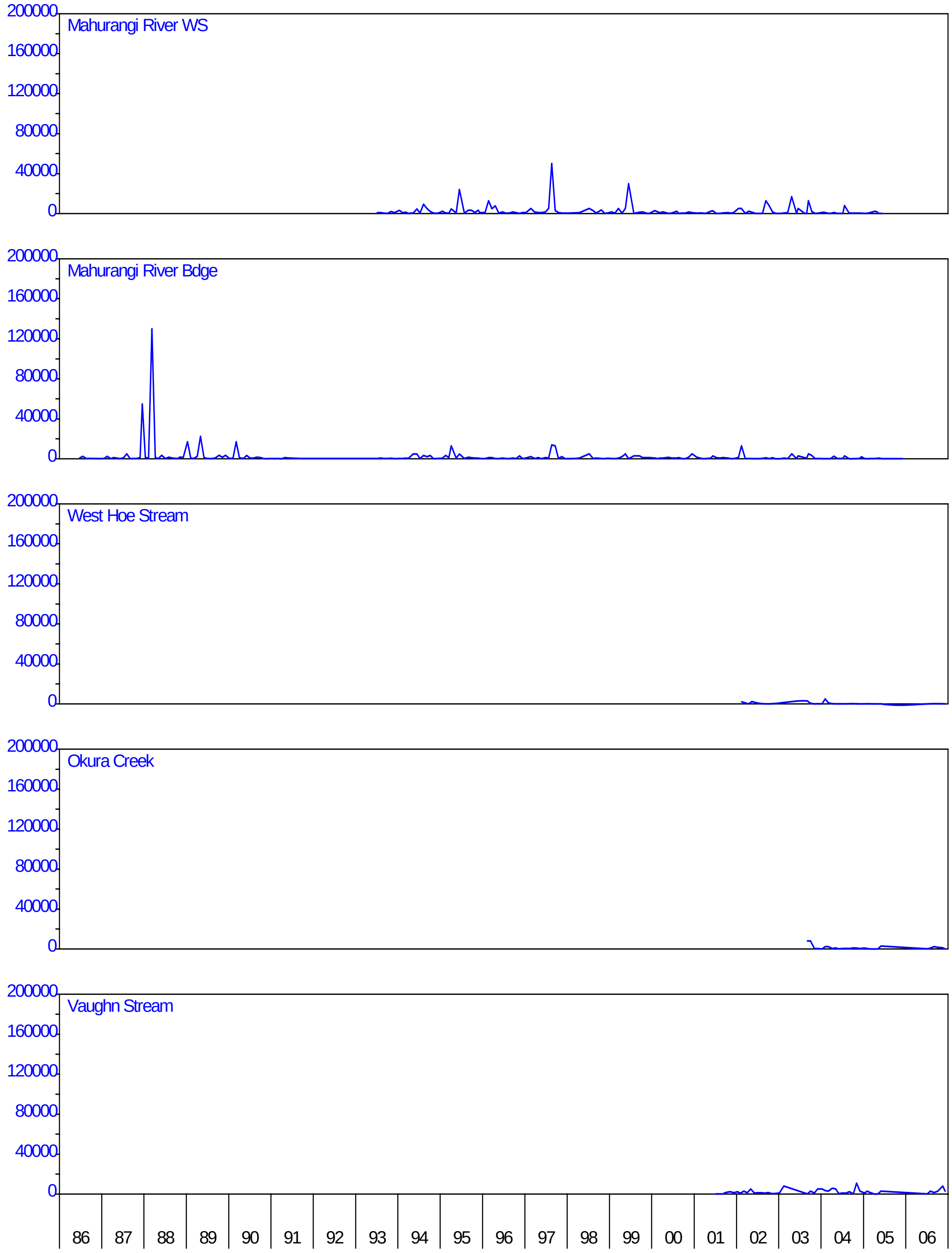


Figure 54: North eastern & Mahurangi streams – faecal coliforms (MPN/100ml)



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Appendix I: Water Quality Monitoring Parameters

Table 3: Summary of Water Quality Monitoring Parameters

Water quality parameter	Relevance to programme	Parameter monitored	Comments
Dissolved oxygen - concentration - saturation	- indicator of ability to sustain aquatic life - indicator of organic pollution - indicator of primary productivity	DO (conc) DO (%sat)	Routine (field)
Temperature	-indicator of ability to sustain aquatic life - indicator of primary productivity - mixing processes	Temp	Routine (field)
Conductivity	- indicator of total salts dissolved in water	Cond @ 25°C	Routine (lab)
Chloride	- major salt - indicator groundwater or saline influence	Cl	Routine (lab)
pH	- aquatic life protection - indicator of pollution	pH	Routine (lab)
Suspended solids	- catchment land use activity (erosive forces) - moderator of primary productivity - abrasive to aquatic life	SS	Routine (lab
Water clarity - turbidity - black disk	- light availability - moderator of primary productivity - aesthetic value	Turbidity Black disk	Routine (lab) Routine (field)
Nutrients (N and P)	- important for plant growth (nutrient limitation) - enrichment, excessive productivity - indicator of point and non-point pollution	NH4-N, NO3-N+NO2-N, TKN, TN, DRP, TP	Routine (lab)
Metals - copper - lead - zinc - cadium	- potentially toxic to aquatic life. - indicator of urban pollution	Cu, Zn, Pb, Cd(all ppm). Total and soluble reported.	Routine (lab) at high disturbance urban sites
Faecal indicators - faecal coliforms - E. coli	- measure of faecal contamination - indicator of sanitary condition & disease risk	Faecal coliforms (MPN/100ml) E. coli (cfu/100ml)	Routine (lab) E. coli routine at Tamaki and Mahurangi sites.

Physio-chemical Measures

Dissolved Oxygen

Dissolved oxygen saturation gives a direct measure of the quantity of oxygen diffused into the water column and consequently is an important indicator of a waterbody's ability to support aquatic life. Dissolved oxygen fluctuates both diurnally (throughout the day) and seasonally. Diurnal changes are caused predominantly by the respiratory activities of aquatic biota, particularly plants at night, and photosynthetic activity during the day.. Seasonal variations mainly follow changes in temperature, which is inversely related to oxygen solubility.

Supersaturation of water is not unusual where aquatic plants in the form of macrophytes, periphyton or free-floating algae are abundant. During the hours of daylight the release of oxygen during photosynthesis augments the transfer of oxygen through the surface of the waterbody by diffusion. The negative side to the presence of these plants is the consumption of oxygen at night (i.e., by respiration), which can lead to serious oxygen depletion and subsequent effects on other biota. Depression in dissolved oxygen levels caused by this phenomenon is usually greatest in the early hours of the morning.

Temperature

Water bodies generally show seasonal patterns in temperature that are correlated with air temperature. Heat transfer between the atmosphere and water surface primarily influences stream temperature. Stream temperatures, in the absence of industrial discharges of heated water, are primarily regulated by the extent of shading of the waterway. In catchments developed for urban uses or intensive agriculture, natural sources of shading have been removed and as a result stream temperatures tend to be elevated.

Elevated water temperature can influence aquatic biota in the following ways:

- Community structure in compromised waterways dominated by thermotolerant species that can survive fluctuations in temperature, particularly those experienced in summer.
- An increase in water temperature results in a reduction in the dissolved oxygen carrying capacity of the water. This may be critical for sensitive organisms particularly where dissolved oxygen is already reduced (see next section).

Conductivity

Conductivity is used to estimate the total dissolved solids (soluble salts) content of the water. The soluble salts concentration is an important consideration in relation to abstraction of water for horticultural use and in extreme situations the suitability of water for stock use.

Chloride

The major natural source of chloride is from groundwater, which in the Auckland Region ranges from 17-40 mg/L depending on the geology concerned. High chloride levels are present in wind blown spray in coastal environments and in rural and urban wastewater. Thus, high chloride levels are often used to indicate the presence of other contaminants in freshwater aquatic systems.

pH

The pH is a measure of the hydrogen ion concentration and therefore indicates the acid or alkaline nature of the water. The pH range is from 0-14 and each unit represents a ten-fold change in hydrogen ion concentration. Natural freshwaters have a pH of around 7 although 6-9 is considered within the normal range. In the absence of contaminant discharges the major influence on pH levels is likely to be the photosynthetic activity of aquatic plants. This occurs when carbon dioxide is absorbed upsetting the carbon dioxide-bicarbonate equilibrium of the stream waters and elevating pH. This problem is most likely to occur in waterways with high nutrient levels and little overhanging vegetation to limit light levels and thereby in-stream plant growth.

pH does not have a directly toxic effect on aquatic biota although many species are not tolerant to wide fluctuations in pH. The principal influence of pH is on the toxicity or mobility of other contaminants present in the water column or sediments. In urbanised situations receiving water sediments may contain large amounts of heavy metals such as zinc, copper and lead from stormwater runoff. Decreases in pH would tend to mobilise some of these bound contaminants. The toxicity of other contaminants such as ammonia, which is elevated in some rural waste discharges, generally increases with higher pH and temperature.

Suspended Solids

Suspended solids (SS) is a measurement of the suspended material in the water column, including plankton, non-living organic material, silica, clay and silt. High SS levels reduce light penetration and provide media for pollutants to attach to, resulting in a reduction in water quality for a variety of uses, such as horticulture, irrigation, stock water supply, and recreational and ecological functions. Under the appropriate conditions the suspended material can settle out as sediment thereby causing further problems, such as smothering of biota.

Water Clarity

Public perception of water quality is often based on their observation of water quality or clarity, in that poor water clarity is aesthetically unpleasing, regardless of other water quality parameters. Stream water clarity is expressed by measuring turbidity and black disk transparency. The black disk reflects very little light and black disk transparency is the distance at which it becomes visible to an observer (using an underwater viewer).

Turbidity

Turbidity is a measure of the passage of the degree to which light is scattered in water by suspended particles and colloidal materials. Samples are analysed in the laboratory using a meter and the results are given as nephelometric turbidity units (NTU). When turbidity levels are high light penetration is reduced, thereby limiting the ability of aquatic plants (algae and macrophytes) to photosynthesise (i.e., a reduction in the so-called euphotic depth). Organisms that are visually oriented may have difficulty locating and catching prey in turbid water and the fine suspended material that is characteristic of turbid water may detrimentally affect gill structures of aquatic organisms.

Nutrients (nitrogen and phosphorus)

Nutrients are chemical compounds that are necessary for normal plant growth and are divided loosely into macro and micro-nutrients. Routine water quality monitoring records two groups of essential macro-nutrients; nitrogen and phosphorus.

The availability of readily assimilated forms of the nutrients nitrogen and phosphorus are commonly accepted as factors limiting aquatic plant growth. Anthropogenic activities increase the nutrient loading through the discharge of waste products, fertilisers and general storm-water runoff. Nutrient enrichment can result in a proliferation of algae and macrophytes in waterways, which potentially has a number of detrimental effects including:

- Choking waterways leading to reduced drainage capacity,
- Loss of amenity values,
- Physical habitat reduction,
- Excessive fluctuations in dissolved oxygen and pH,
- Reduced suitability for stock watering or horticultural irrigation.

Ammonia

Ammoniacal nitrogen is a macro-nutrient but is considered in general water quality evaluations in terms of its toxicity to many aquatic animals.

Ammonia occurs in a number of waste products, which if discharged to the environment can result in elevated ammonia levels. Ammonia is reported as a combination of un-ionised ammonia (NH3) and the ammonium ion (NH4), at normal pH values the latter form predominates. Un-ionised ammonia is the more toxic form to aquatic life. The toxicity of ammonia is very dependent on water temperature, salinity and pH (USEPA, 1985). Regulatory agencies, such as the ARC Environment, have tended to rely on overseas criteria such as those promulgated by the USEPA. The ARC has commissioned studies on Auckland freshwater biota, which corroborate that USEPA criteria are appropriate – ARC Environment and Planning Division TP23 (1992).

Ammonia toxicity for given pH and temperature combination can be calculated using a mathematical equation. As a generalisation a chronic or long term exposure limit of 0.77 mg/L is appropriate for sensitive freshwater organisms under ambient conditions. In saline waters ammonia toxicity is influenced by salinity in addition to pH and temperature. The chronic exposure limit for sensitive saline organisms under ambient conditions is 2.3 mg/L.

Nitrite plus Nitrate Nitrogen

Nitrite is the intermediate step in the conversion of ammonia to nitrate. It is usually short lived in the aquatic environment in the presence of oxygen and is therefore indicative of a source of nitrogenous waste in the immediate vicinity of the sampling site.

Nitrate is the end product of the breakdown (oxidation) of ammonia through the intermediate step of nitrite by microbial decomposition. It is not particularly toxic to aquatic life (USEPA, 1986). Water for use as potable supply is limited to 10 mg/L on public health grounds. In terms of crop irrigation water requirements higher nitrate levels could be seen as an advantage saving on fertiliser costs and to a limit. For stock drinking water requirements the recommended limit is 100 mg/L.

Sources of nitrate in aquatic systems are similar to those discussed for ammonia. Nitrate is poorly bound to the soil and is therefore highly mobile. It is readily leached into local groundwater systems, particularly under high rainfall events. In winter when ground conditions become saturated the capacity of the soil to assimilate waste is reduced, resulting in elevated nitrate levels in runoff.

Nitrate is an important plant nutrient (which is generally non-limiting), which in conjunction with sufficient available phosphorus can lead to proliferation of aquatic plants (algae and macrophytes). Respiration of aquatic plants at night can lead to reductions in dissolved oxygen to the point that other aquatic organisms may become stressed or killed. Photosynthetic activity of aquatic plants also leads to elevated stream pH, which has an effect on the toxicity of other contaminants in the water such as ammonia.

Total and Dissolved Reactive Phosphorus

Total phosphorus is a measure of all the phosphorus present in the sample and includes the soluble (bioavailable) fraction that is adsorbed onto sediment particles and present in the form of algae and other organic matter.

Dissolved reactive phosphorus (DRP) is considered to be the bioavailable fraction of phosphorus and is an important indicator of water quality. It is frequently cited as the nutrient limiting the proliferation of algae and other aquatic plants in New Zealand waterways.

Metals (copper, lead, zinc, cadmium)

Copper, lead, cadmium and zinc are associated with urban areas with the source of these contaminants linked to air pollution, automobiles, and industrial land uses. Total and soluble metal concentrations are measured at urban sites because levels rarely exceed effect levels in non-urban areas.

Microbiological

Microbial indicator organisms are typically used in water quality monitoring to provide a measure of faecal contamination and hence the sanitary quality of water resources. A number of different indicator organisms and monitoring strategies can be used depending on whether the purpose of sampling is simply to detect and quantify the level of contamination, or whether some measure or index of public health risk is required.

The indicator organisms used for water quality monitoring are generally bacteria that are present as normal inhabitants in the gut of healthy warm-blooded animals, including humans, and are shed in large numbers in faecal matter (at a rate of 106 – 109 per gram). They are not usually considered to present a risk to public health when present in natural waters (i.e., they are not generally disease causing or pathogenic when contacted through this route), but their presence is taken to indicate faecal contamination and hence the possibility that pathogenic micro organisms that are found in the gut may also be present.

It is necessary to use indicator organisms for routine monitoring purposes because there is such a wide variety of pathogens that may be present in faecal matter, that it is impossible to test for all of them at once. Detection of some pathogens, particularly viruses, is also expensive and time consuming. Also, the infective doses for many pathogens, particularly of viruses, are so low as to make routine measurement impracticable.

In New Zealand three bacterial indicator groups have been routinely used for water quality monitoring. These are the presumptive coliform, faecal coliform, and enterococci groups.

Presumptive Coliforms

The term coliform is used to describe a heterogeneous group of bacteria belonging to the family Enterobacteriaceae, which are characterised by their ability to ferment lactose with the production of acid and gas at 35°C. Included within this definition are members of the Escherichia, Klebsiella, Enterobacter, Serratia, and Citrobacter genera. While members of all of these genera are typically found in faecal material, only one, Escherichia coli, is truly faecal specific.

The results of coliform or presumptive coliform tests are often highly variable and do not necessarily indicate the degree of faecal contamination present in a waterway. This is because members of the coliform group are also found as natural inhabitants of soil and decaying vegetation, and therefore elevated levels in waters may be due to naturally occurring organisms. Nevertheless, the presumptive coliform test may provide useful information on the level and nature of contamination when used in association with other analyses such as the faecal coliform test.

Faecal Coliforms

Faecal coliforms represent a subset of the coliform group that are differentiated by their ability to ferment lactose with the production of acid and gas at the elevated temperature of 44.5°C. This group are more specific indicators of faecal contamination than the coliform group, although the functional definition still includes some organisms that are natural inhabitants of soil and decaying vegetation. The use of the term faecal" in the group description is therefore somewhat misleading, and has lead to the use of the term "thermotolerant coliforms" as an alternative group name.

Faecal coliforms have historically been the indicator of choice for assessment of the sanitary quality of natural waters and have formed the basis of the previous microbiological guidelines for recreation and shellfish growing waters. However, the fact that non-faecal derived organisms are also included in the group lead to recommendations that the bacterium Escherichia coli provides a better index of health risk than just faecal coliforms. For further information on this topic refer to the "Recreational Water Quality Guidelines" published by Ministry for the Environment and Ministry of Health, Wellington, November 1999.

However, despite this the faecal coliform group is still considered appropriate for qualitative monitoring of faecal contamination in natural waters, and for assessment of long terms trends in water quality over time. It is in this context that the indicators are used in the baseline water quality studies. *Escherichia coli* has been monitored at selected sites since 1986 and widened to all sample locations in July 2006.

Regardless of indicator bacteria or group of bacteria used, impediments to their overall usefulness is the inability to discriminate between contamination of human and non-human origin. Such assessments must be made empirically using other more complex and expense analytical techniques including sterol and stanol ratios, and florescent whitening agents.

Table 4: Analytical methods of analysis

Identifier (+ unit)	Parameter	Method
DO (ppm)	Dissolved oxygen	Handheld meter (YSI-85)
DO (% sat)	Dissolved oxygen saturation	Handheld meter (YSI-85)
Temp (°C)	Temperature	Handheld meter (YSI-85)
Cond @ 25 °C(μS.cm^{-2})	Conductivity	Handheld meter (YSI-85)
Salinity (ppt)	Salinity	Handheld meter (YSI-85) or calculation
pH	pH	APHA (1998) 4500-H B
SS (g.m^{-3})	Suspended solids	APHA (1998) 2540 D
Turb (NTU)	Turbidity	APHA (1998) 2130 B
Black Disk (m)	Black Disk	Black disk set
BOD (g.m^{-3})	Biochemical Oxygen Demand	APHA (1998) 5210 5-2
NO3-N (gN.m^{-3})	Nitrate Nitrogen	Calculation NNN (gN.m^{-3}) – NO2 (gN.m^{-3})
NO2-N (gN.m^{-3})	Nitrite Nitrogen	APHA (1998) 4500-NO2 B
NH4-N (gN.m^{-3})	Ammoniacal nitrogen	APHA (1998) 4500-NH3 G
NO3-N+NO2-N (aka NNN) (gN.m^{-3})	Nitrate/Nitrite nitrogen	APHA (1998) 4500-NO3 F
TKN (g.m^{-3})	Total Kjeldahl nitrogen	APHA (1998) 4500 C
TN (g.m^{-3})	Total nitrogen	Calculation NNN (gN.m^{-3}) + TKN (gN.m^{-3})
DRP (g.m^{-3})	Dissolved reactive phosphorus	APHA (1998) 4500-P F
TP (g.m^{-3})	Total phosphorus	APHA (1998) 4500-P B, F
Cd Soluble (ppm)	Soluble Cadmium	USEPA 200.8
Cd Total (ppm)	Total Cadmium	USEPA 200.8
Cu Soluble (ppm)	Soluble Copper	USEPA 200.8
Cu Total (ppm)	Total Copper	USEPA 200.8
Zn Soluble (ppm)	Soluble Zinc	USEPA 200.8
Zn Total (ppm)	Total Zinc	USEPA 200.8
Pb Soluble (ppm)	Soluble Lead	USEPA 200.8
Pb Total (ppm)	Total lead	USEPA 200.8
Pres (MPN/100ml)	Presumptive coliforms	APHA (1998) 9221 B
FaeC (MPN/100ml)	Faecal colifoms	APHA (1998) 9221 E
E. coli (cfu/100ml)	Escherichia coli	APHA (1998) 9213 F