Lake Vanda monitoring report No. 7

NIWA Client Report:CHC02/57
Project No: NZA03501
July 2002

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Prepared for

Antarctica New Zealand

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Executive Summary

This report, the seventh in a series, collates results of a programme monitoring the nearshore aquatic environment in the vicinity of the decommissioned Vanda Station.

There is known contamination of the soils and groundwater in a small valley (Greywater Gully) to the Southwest of the old station site. Evidence of the potential for low level contamination of Lake Vanda by nutrients and heavy metals from Greywater Gully was clear in the first two years following decommissioning (up to January 1996). A stabilisation and subsequent lowering in water level in the lake has reduced the potential for contamination. Inundation of Greywater Gully has not occurred since the 1995/96 period. The level rose again in 2001/02 but no flooding of the gully occurred at that time.

The monitoring programme comprises the collection of water and microbial mat samples for nutrient composition, algal biomass and species composition. From January 1998 sampling was carried out by Antarctica New Zealand staff, and frozen samples have been returned to New Zealand for analysis by NIWA. In early years, samples were collected twice in a summer season, now a single sample is collected each year in January.

In January 2002 a period of unusually high meltwater flow in the Onyx River and tributary streams resulted in a large volume of high nutrient water entering the moat region of Lake Vanda. During this period, water nutrient concentrations in Vanda and Control Bays were considerably higher than in previous years. Vanda Bay water had higher nutrient concentrations than Control Bay, though this is likely to reflect its closer proximity to the Onyx River inflow. Increased glacial melt runoff and nutrient flushing from newly wetted soils is likely to be the major contributing factor for this observed increase.

Interannual variability within the two bays can be partially attributed to year-to-year changes in river flow and lake levels as well as the timing of sampling, in relation to onset of river flow. At present there is no clear indication of contamination of the lake.

This series provides a baseline of the environment within the vicinity of the former Vanda Station and its inherent variability. This baseline will permit an early indication of localised changes, due to contamination, should the lake begin to encroach onto Greywater Gully again.

1 INTRODUCTION

During the occupation of the Vanda Station (1968 to 1994), the New Zealand Antarctic Programme used a depression adjacent to the station as a dumping site for waste products. Through the dumping of these wastes the soil and groundwater in this region, now known as Greywater Gully, have become contaminated with a variety of organic and inorganic substances, including traces of heavy metals (Sheppard *et al.* 1993). Although approximately 15 000 kg of contaminated soil and 400 L of groundwater were excavated and removed from the site, some contamination is still present in the soils surrounding the former station site (Howard-Williams 1993).

In the 10 years prior to 1996 the level of Lake Vanda rose intermittently. As a result the lake began to encroach on the former station site. Of particular concern was the potential for lake contamination, via both groundwater seepage and flooding of contaminated soils, should the lake level continue to rise.

As part of Antarctica New Zealand's commitment to environmental stewardship and conservation in the Antarctic region, NIWA was commissioned to commence annual monitoring of the aquatic environment of the moat region of Lake Vanda in the vicinity of the former station during the summer season of 1994/95.

This report is the seventh in the series and provides a summation of the data collected since the commencement of annual monitoring in December 1994.

2 METHODS

Since the commencement of monitoring in 1994/95 two sites have been surveyed annually. The first site, Vanda Bay, lies adjacent to the former station and is at the head of the bay into which Greywater Gully drains. The potential for contamination of this site is high should a rise in lake level result in encroachment into Greywater Gully. The second site, Control Bay, is of similar orientation to Vanda Bay, but is situated away from potential contamination from Greywater Gully (Fig. 1). In 1996, a third site, a pool in Greywater Gully, was surveyed. However, since 1996, no water as ponded in Greywater Gully thus resulting in no further sampling of this site to date.

Surface water samples were collected and analysed for plant nutrients, as outlined in Hawes and Howard-Williams (1996). Cores were collected from well-developed cohesive microbial mats and analysed for nutrient composition, biomass (measured as chlorophyll-*a*) and algal species composition. From 1994/95 to 2000/01 water and mat samples were also collected and analysed for heavy metal content.

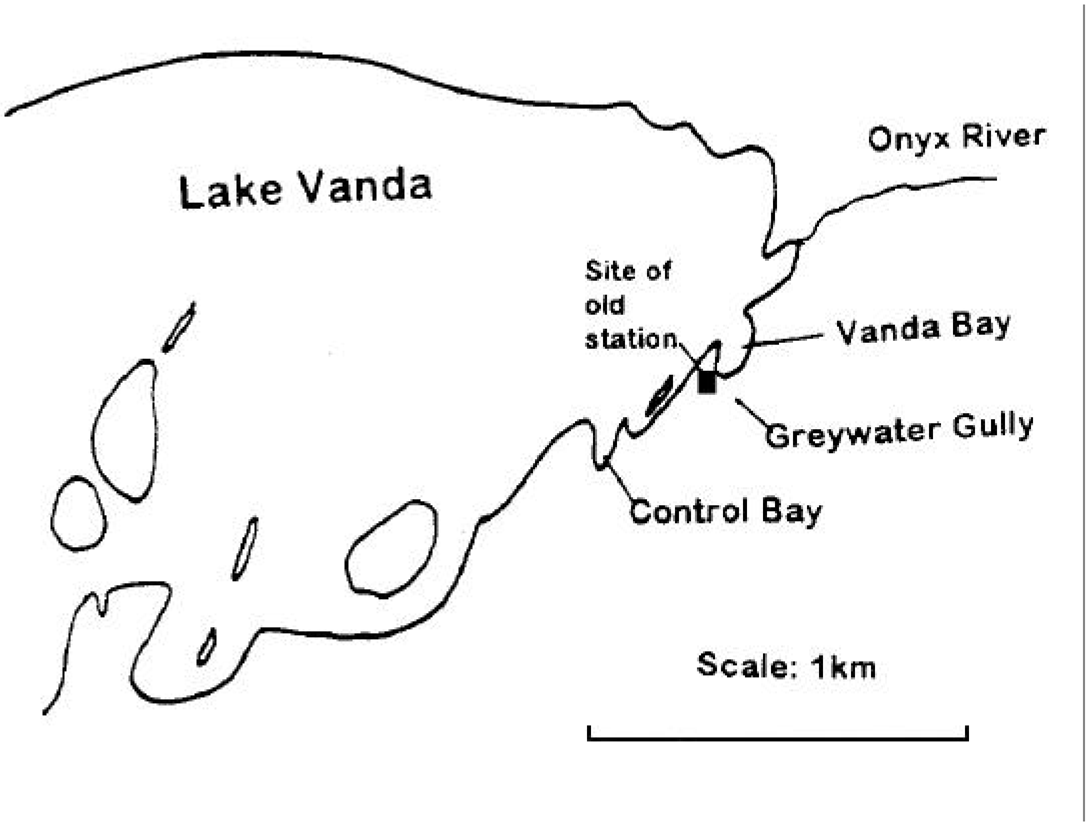

Figure 1: **Map showing location of Vanda and Control Bays, Greywater Gully and the Onyx River inflow.**

3 RESULTS AND DISCUSSION

January 2002 was a period of unusually high meltwater flow in the McMurdo Dry Valley Region. Flows in the Onyx River were amongst the highest on record, up to 12 m^3s^{-1} (LTER pers. comm.) (Fig. 2 and 3). This resulted in huge volumes of water entering the Vanda moat region, and an increase in lake level. This has had a significant impact on this year's monitoring programme.

3.1 Nutrients in water

During the 1994/95 and 1995/96 sampling periods, samples were collected from Vanda and Control Bays and from two meltwater ponds formed in Greywater Gully. Samples were collected only from Vanda and Control Bays during subsequent sampling periods as no meltwater had formed in Greywater Gully. The means of replicate nutrient analyses are shown in Table 1 and Figure 2.

At the time of the January 2002 sampling nitrate concentrations in Vanda and Control Bays were considerably higher than in previous years (Table 1 and Fig. 4). We believe this to be due to the increase in glacial and snow melt resulting in increased meltwater

Table 1: **Dissolved nutrient concentrations from water samples collected from Vanda and Control Bays, and two meltwater ponds formed in Greywater Gully. DRP – dissolved reactive phosphorus, DOP – dissolved organic phosphorus, DON – dissolved organic nitrogen, Cond – conductivity. All values are expressed as mg m^{-3} except conductivity, which is in mS cm $^{-1}$. --- data not available.**

Site	Date	DRP	NH_4-N	NO_3-N	DOP	DON	Cond
Vanda Bay	14-12-94	0.5	5.1	11.0	<1	52	102
Control Bay	14-12-94	<0.2	3.4	6.4	<1	30	206
Greywater Pond 1	14-12-94	76	396	2420	7	575	1430
Greywater Pond 2	14-12-94	385	970	2300	13	1160	2170
Vanda Bay	28-1-95	0.3	6.5	10.7	<1	40	---
Control Bay	28-1-95	0.5	6.7	9.7	<1	48	---
Vanda Bay	09-1-96	1.0	5.0	6.4	<1	51	105
Control Bay	09-1-96	1.0	5.5	13.7	<1	57	521
Greywater Pond 1	09-1-96	6.6	52.9	2299	69	2744	2540
Greywater Pond 2	09-1-96	2.9	38.6	160	65	3117	---
Vanda Bay	29-1-96	---	---	---	---	---	---
Control Bay	29-1-96	0.5	9.1	12.5	<1	64	---
Greywater pond	29-1-96	0.9	6.4	4.9	<1	59	---
Vanda Bay	Dec 96	0.2	2.2	12.6	<1	32	---
Control Bay	Dec 96	0.2	2.2	2.3	<1	22	---
Vanda Bay	16-1-97	1.1	8	3.9	<1	104	485
Control Bay	16-1-97	0.5	6.2	3.5	<1	46	505
Greywater Pond	1996/97	no water					
Vanda Bay	19-12-97	1.6	7.7	30.55	<1	102	103
Control Bay	19-12-97	0.9	4	22.95	<1	46	194
Vanda Bay	Jan 98	0.8	6	8.5	<1	16.5	---
Control Bay	Jan 98	0.65	4.15	7.05	<1	12.5	---
Greywater Pond	1997/98	no water					
Vanda Bay	22-12-98	0.26	8.27	3.6	<1	21.3	---
Control Bay	22-12-98	0.26	4.03	3.5	<1	17	---
Vanda Bay	Jan 99	0.5	4.15	5.6	<1	31.5	---
Control Bay	Jan 99	1.2	5.2	6.1	<1	36	---
Greywater Pond	1998/99	no water					
Vanda Bay	Jan 00	0.6	6.1	3.5	<1	59.5	---
Control Bay	Jan 00	0.75	8.75	5.6	<1	61	---
Greywater Pond	1999/00	no water					
Vanda Bay	18-12-00	<0.5	4.85	7	<1	42	---
Control Bay	18-12-00	<0.5	6.3	3.05	<1	27	---
Vanda Bay	Jan 01	0.85	46.8	17.55	<1	86.5	---
Control Bay	Jan 01	2.3	19.35	5.65	<1	32	---
Greywater Pond	2000/01	no water					
Vanda Bay	Jan 02	1.6	9.4	399	3.1	114	---
Control Bay	Jan 02	1	4.9	114	2.6	88	---
Greywater Pond	Jan 02	no water					

A.

B.

Figure 2. **The Onyx River a) during high flow in January 2002 and b) during more typical flow in 1993. Photo A courtesy of Polly Penhale, National Science Foundation. Photo B courtesy of Clive Howard-Williams , NIWA.**

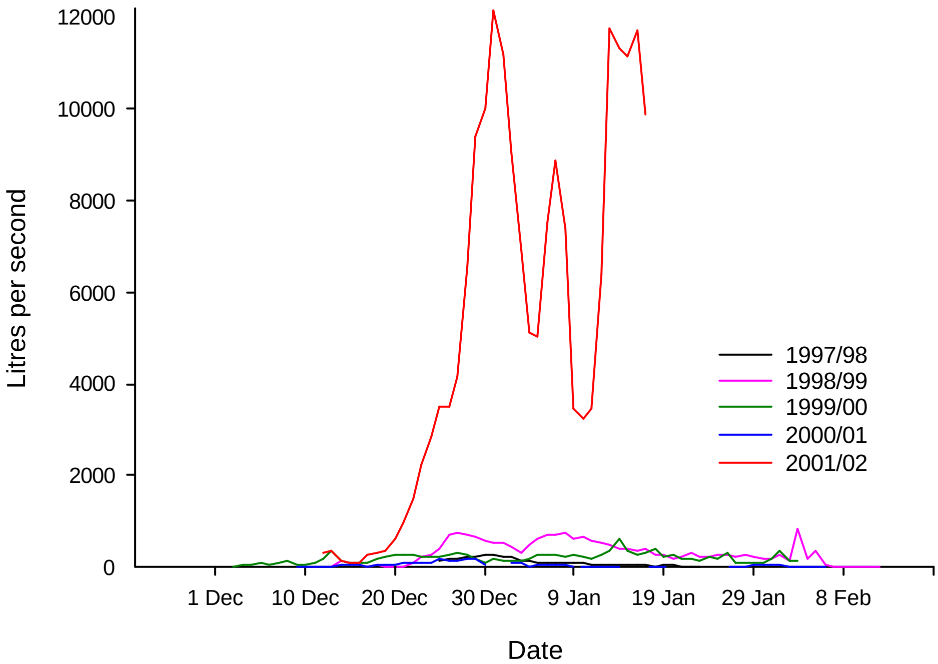

Figure 3: **Mean daily flow (L/s^{-1}) from the Onyx River into Lake Vanda, as measured at the Vanda Weir, for the summer seasons 1997/98 to 2001/02.**

and subsequent river flows. The Onyx River, Lake Vanda's only significant surface water source, has several sources of nutrients. These include glacial melt, snow melt, stream bed sediment release, stream bed weathering, groundwater and hyporheic exchanges (Howard-Williams *et al.* 1997). Tributary glaciers that fed into the Onyx River contain high concentrations of nitrate (Howard-Williams *et al.* 1997). Increased melt runoff from these glaciers as well as nutrient flushing from soils that had not been inundated for several years, is likely to be the major contributing factor to the observed increase in nitrate concentrations at Vanda and Control Bays. Antarctic soils in general tend to accumulate nitrate from dry depositions (Howard-Williams *et al.* 1986) and it is possible that flooding of marginal soils may also have led to increase in moat water concentration.

Over the course of the long-term monitoring a number of patterns have emerged. Water nutrient concentrations are typically higher in samples collected early in the summer season (during initial flow) than those collected later in the season. In December 1997 (at the onset of flow) nitrate levels at Vanda and Control Bays were 30.6 mg m^{-3} and 23 mg m^{-3}, respectively. Nitrate levels had dropped to 8.5 mg m^{-3} and 7.1 mg m^{-3} (in Vanda and Control Bays) at the time of the late season sampling (January 1998). Early flows entering Lake Vanda contain relatively high nutrient concentrations, which decline gradually over the course of the summer season (Howard-Williams *et al.* 1997). There is a general tendency for slightly higher nutrient

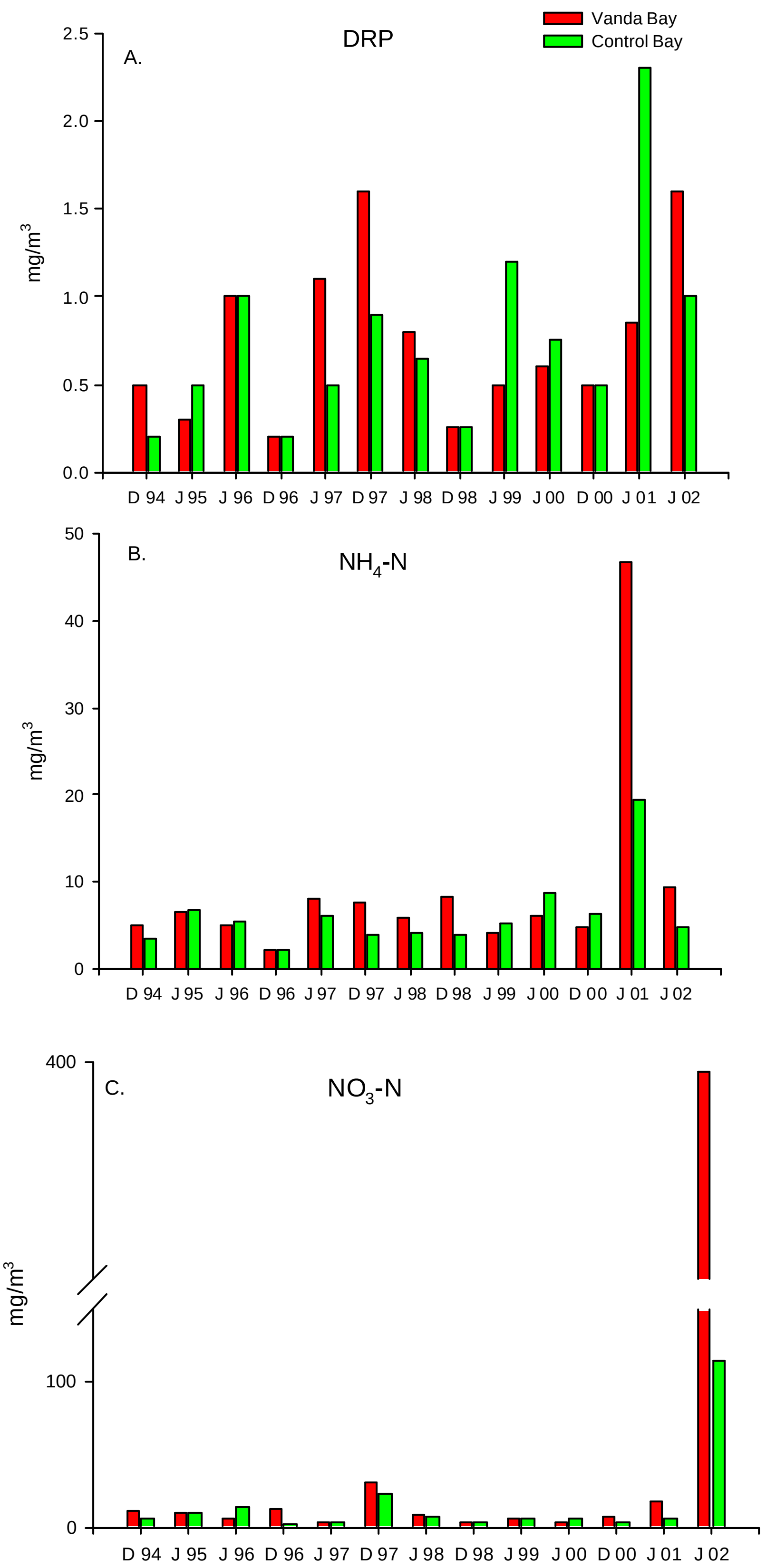

Figure 4: **Dissolved nutrients a) dissolved reactive phosphorus (DRP), b) ammonium (NH_4-N) and c) nitrate (NO_3-N) in both Vanda and Control Bays from December 1994 to January 2002.**

concentrations in Vanda Bay compared to Control Bay (Table 1 and Fig. 4). The position of the bays relative to the Onyx River inflow is most likely to account for this observed variation between the two bays (Fig. 1). Vanda Bay is situated very close to the entry of the Onyx River compared with Control Bay. The water received from the Onyx River is likely to be diluted by the time it reaches Control Bay.

There is a natural fluctuation in interannual nutrient concentrations at both Vanda and Control Bays. Elevated nutrient levels have been recorded in both bays on a number of occasions with high ammonium (January 2001) and high nitrate (January 2002) being of particular note. However, the elevation of nutrient levels at both bays indicates that it is not a result of contamination from Greywater Gully. There are a number of possible explanations for the fluctuations observed over time. Timing of flow and nutrient concentration of the Onyx River has varied between years (Fig. 5). There may also be an effect of the moat melting and subsequent release of nutrients from freeze-damaged algal cells within this zone. During freeze-thaw cycles organic solutes are known to leak from filamentous green algae (Hawes 1990) and cyanobacterial mats (Howard-Williams *et al.* 1997).

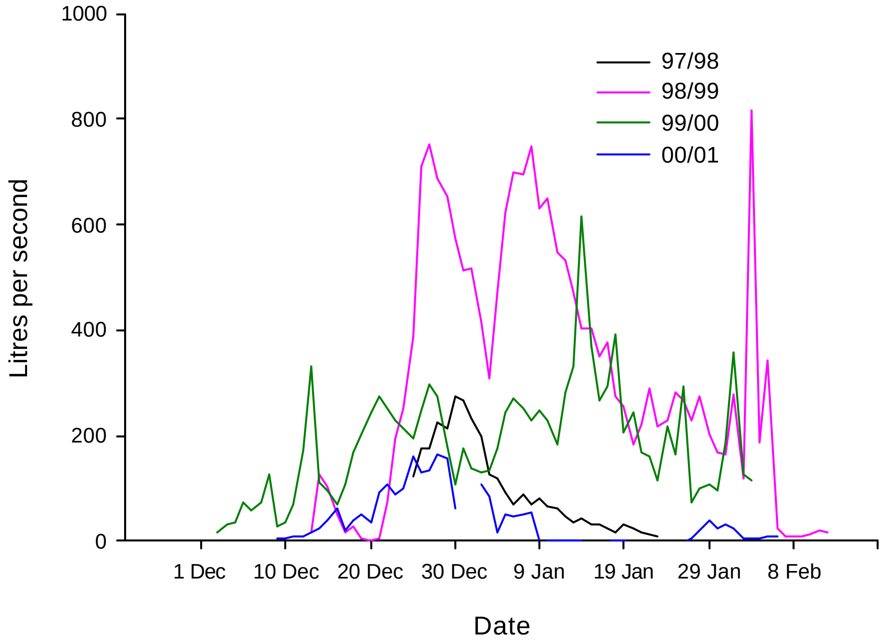

Figure 5: Variation in timing and mean daily flow (L/s^{-1}) from the Onyx River into Lake Vanda for the summer seasons 1997/98 to 2000/01.

3.2 Algal samples

Since December 1997 chlorophyll *a* (Chl *a*) concentrations at Vanda Bay have been slightly higher than at Control Bay, although there were no significant differences (t-test, P<0.05) between the sites (Table 2). There were also no significant differences in nutrient concentrations in the mats (as particulate nitrogen and particulate phosphorous) between the two bays from 1996 to 2002.

Table 2: Chlorophyll *a* (Chl *a*), particulate nitrogen (PN) and particulate phosphorus (PP) concentrations in algal mats from 1996 to 2002.

Site	Date	Chl *a* (ug cm^{-2})	PN (mg m^3)	PP (mg m^3)
Vanda Bay	Jan 96	0.34	69.2	72.5
	Jan 97	1.01	73.1	65.5
	Dec 97	0.98	not sampled	not sampled
	Dec 98	2.61	201.6	36.4
	Jan 00	1.04	428.32	95.2
	Dec 00	2.40	372.56	95.74
	Jan 01	not sampled	not sampled	not sampled
	Jan 02	0.06	1629.7	244.1
Control Bay	Jan 96	0.53	67.4	61.3
	Jan 97	1.26	82.0	48.6
	Dec 97	0.52	not sampled	not sampled
	Dec 98	1.19	209.4	56.4
	Jan 00	0.19	127.52	30.43
	Dec 00	0.53	403.49	70.88
	Jan 01	not sampled	not sampled	not sampled
	Jan 02	0.01	1469.7	102.1
Greywater Gully	Jan 96	1.06	not sampled	not sampled

At the time of the January 2002 sampling both nitrogen and phosphorous concentrations were notably higher than during previous sampling occasions, while Chl *a* was virtually absent (Table 2). Increased inflows from the Onyx River resulted in a rise in the lake level. This led to the moat region of both Vanda and Control Bays encroaching onto soil that had previously been exposed for a considerable period of time. The absence of algal cells (see below) and Chl *a* in the microbial mat samples suggest that the mats that were sampled were old ones that had decayed due to prolonged exposure to air.

There has been some interannual variability in both nutrient and Chl *a* concentrations within the microbial mats at both bays. Changes in the lake level results in the exposure of a microbial community at different developmental stages. Within the moat regions (<2 m water depth) the microbial mat communities typically become more developmentally advanced with depth (NIWA data unpublished). When lake levels are high the communities sampled are likely to be either in their infancy or have decayed as a result of prolonged exposure to air. As levels decrease the community available for sampling becomes older with a higher biomass and nutrient content.

3.3 Species composition

The species composition of microbial mats was determined microscopically. Over the course of the monitoring there have been no observed changes in algal species composition at either Vanda or Control Bays. The community is dominated by narrow cyanobacteria of the genus *Leptolyngbya*; in particular *Leptolyngbya fragilis* and *Leptolyngbya frigida*. A number of diatom species were also present including *Hantzschia amphioxys*, *Luticola muticopsis*, *Muelleria peraustralis*, *Muelleria meridionalis* and *Stauroneis anceps*. The algal species composition from these two sites is consistent with that which is found throughout the Dry Valley lake systems, in particular in Lake Vanda itself.

A conspicuous growth of filamentous green algae (*Stichococcus* sp.) was observed in water ponded in Greywater Gully during 1995/96. Such growth is atypical of the Wright Valley and has not been observed elsewhere in the Valley. It is likely that this growth was in response to the highly enriched nutrient concentrations and the presence of meltwater in the Gully. Algal growth has not been observed in Greywater Gully in subsequent years and no growth of *Stichococcus* sp. has been observed at either bay.

3.4 Heavy metals

During the 1995/96 sampling season the concentration of heavy metal species Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni) and Zinc (Zn) were elevated in surface water from Greywater Gully compared to Vanda and Control Bays (Table 3). Zinc was the only heavy metal species to show elevated concentrations in Vanda Bay compared to Control Bay, However, over subsequent years there has been a reduction in zinc concentration at Vanda Bay to levels almost identical with Control Bay. There have been no other detectable differences between the two bays over the course of the monitoring programme.

During the 1997/98 sampling season there was significantly higher (t-test, $P<0.05$) levels of lead and zinc in mats from Vanda Bay when compared to Control Bay. This was a result of lowered concentrations in Control Bay compared with previously measured concentrations (Table 4). This trend was not apparent in subsequent surveys. There is no evidence of elevated heavy metal contamination of Vanda Bay from Greywater Gully, compared to Control Bay, over the last five sampling seasons.

4 CONCLUSIONS

During the first two years following the station decommissioning there was clear evidence for the potential for low level contamination from Greywater Gully into Lake

Table 3. **Heavy metal concentrations in surface water from Vanda and Control Bay from 1996 to 2000 and from Greywater Gully in 1996. Concentrations are in mg m^3, * denotes concentration below limit of detection. Values are means of three samples.**

					Metal			
Site	**Date**	**Ag**	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
Vanda Bay	January 96	<0.1*	0.039	0.31	0.82	0.2*	0.18	6.57
	December 97	<0.5*	<0.1*	0.97*	0.69	<1.0*	<0.5*	3.0
	December 98	<0.5*	0.09*	0.75*	0.6	<0.3*	0.17*	1.6
	January 00	<0.5*	0.1	1.0	0.72	<0.5	<0.2*	4.6
	December 00	<0.0005	<0.0001	<0.001	0.0005	0.23	<0.0002	0.004
Control Bay	January 96	<0.1*	<0.01*	0.69	0.43	<0.1*	0.11	1.77
	December 97	<0.5*	<0.1*	1.1	<0.5*	<1.0*	<0.5*	3.0
	December 98	<0.5*	0.12	0.78*	0.6	<0.3*	0.2	1.6
	January 00	<0.5*	<0.1*	3.0	1.0	<0.3	<0.2	2.6
	December 00	<0.0005	<0.0001	<0.001	0.0003	<0.0003	<0.0002	0.003
Greywater Gully	January 96	<0.1*	0.2	2.43	20.0	0.75	0.15	5.83

Table 4: **Concentration of heavy metals in microbial mats from Vanda Bay and Control Bay from January 1996, December 1997, 1998, 2000. Concentrations are in mg/kg. * denotes concentrations below limit of detection.**

					Metal			
Site	**Date**	**Ag**	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
Vanda Bay	January 96	0.13	0.01	6.7	26.0	9.4	2.8	17.0
	December 97	0.06	<0.05*	6.47	20.67	8.3	2.23	20.33
	December 98	<0.02*	<0.05*	5.6	14.5	5.91	2.2	10.76
	December 00	0.04	0.02	4.9	16	6.2	1.7	13
Control Bay	January 96	0.15	6.7	8.7	24	9.6	2.0	17.3
	December 97	0.06	6.47	6.43	21.33	8.93	1.2	14.33
	December 98	<0.03*	5.6	4.8	16	6.41	0.9	5.85
	December 00	0.02	0.01	5.3	20	7.3	1.2	11

Vanda. Ponded water has not accumulated in Greywater Gully since the 1995/96 summer period and this area has not come into direct contact with the lake. Any contamination of the lake since will have had to arrive via groundwater. There is no evidence, to date, to suggest contamination has occurred in Vanda Bay. Any contamination of the lake is at concentrations not detectable over background levels. This is shown by the similarity in the environmental parameters measured at both Vanda and Control Bays.

There is an apparent interannual variability in dissolved nutrients and biomass at both bays, which generally move in parallel. This variation is likely to have resulted from year to year changes in river flow and lake level, resulting in different degrees of influence from the Onyx River and mats of different ages being sampled. For example in 2001/02 both sites had very high dissolved nitrate concentration, probably due to abnormally high flows in that summer. Timing, in relation to the onset of river flow and moat melt-out, is also an important influence on the variability.

This dataset provides a robust baseline that conveys the inherent variability in the environmental parameters being measured. An understanding of this variability will allow changes due to contamination to be identified at an early stage should inundation of Greywater Gully occur.

5 ACKNOWLEDGEMENTS

December 1996, 2000 and January 1998-2002 sampling was carried out by Antarctica New Zealand. Faye Richards carried out nutrient analyses and AgriQuality carried out heavy metal analyses.

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