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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

Record 1983/16

HEAVY METAL POLLUTION
IN THE MOLONGLO RIVER, 1982

by

G. Sparksman

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SUMMARY

A detailed program of water and sediment sampling of the Molonglo River and Lake Burley Griffin was carried out by the Bureau of Mineral Resources during 1982. The study was commissioned by NCDC and undertaken in conjunction with macroinvertebrate sampling by Dr R. Norris, Canberra College of Advanced Education.

Water analyses showed that during dry periods, zinc pollution of the Molonglo River is caused by springs on the northern slopes of the rehabilitated North Dump at Captains Flat. The zinc level in the Molonglo River is slightly less than that recorded in previous investigations. After rainfall, higher zinc levels were recorded and zinc was detectable 50 km downstream of Captains Flat. During dry periods (November 1982), the Molonglo River had initially high zinc levels and low pH in the Captains Flat area, but neutralizing action of the river caused zinc levels to decrease to below the detection limit, about 20 km downstream. Other metal levels (copper and lead) in the Molonglo River were below instrument detection limits.

Sediment analyses show that the highest metal levels are present in sediments of the upper 2 km of the Molonglo River. Zinc levels are high at most sampling stations on the Molonglo River, reaching the lowest level at Dairy Flat (Station 13). Copper and lead levels decrease with distance downstream from Captains Flat. The high levels of lead and zinc in sediments of the Molonglo River will be a continuing source of metal pollution to Lake Burley Griffin. High zinc levels are present in sediments of Lake Burley Griffin.

INTRODUCTION

The purpose of this study was to determine the present level of metal pollution in the Molonglo River from the mine and rehabilated waste dumps at Captains Flat. The study, commissioned by NCDC, was conducted in two parts during 1982. The first part deals with metal levels in the Molonglo River and Lake Burley Griffin waters and sediments. This report details the results of that study.

The second part of the study, conducted by Dr R. Norris of the Canberra College of Advanced Education, was concerned with the macro-invertebrate distribution in the Molonglo River and Lake burley Griffin.

PREVIOUS INVESTIGATIONS

Since the early 1960's numerous investigations have been conducted on the Molonglo River. Previous works by Weatherly et al., 1967; Haldane, 1971; Ash, 1976; Cullen et.al., 1978; Craze, 1979; and Brooks, 1980 give descriptions of the mining and pollution history of the Captains Flat district.

SAMPLING CONDITIONS

Thirteen sites (stations 1 to 13), were sampled along the Molonglo River in 1982. These sites were similar to those sampled by Weatherly and are shown on Figure 1. Nine additional sites (stations 14 to 22 on Figure 2) were chosen in the Captains Flat area to locate pollution sources and ascertain metal levels. Table 1 describes each sample stations.

Sediments were samples at ten stations along the Molonglo River. Sediment sampling on 6.5.82 and 23.7.82 was undertaken in conjunction with detailed water sampling and Dr R. Norris's collection of macro-

Figure 1 LOCATION OF SAMPLING STATIONS

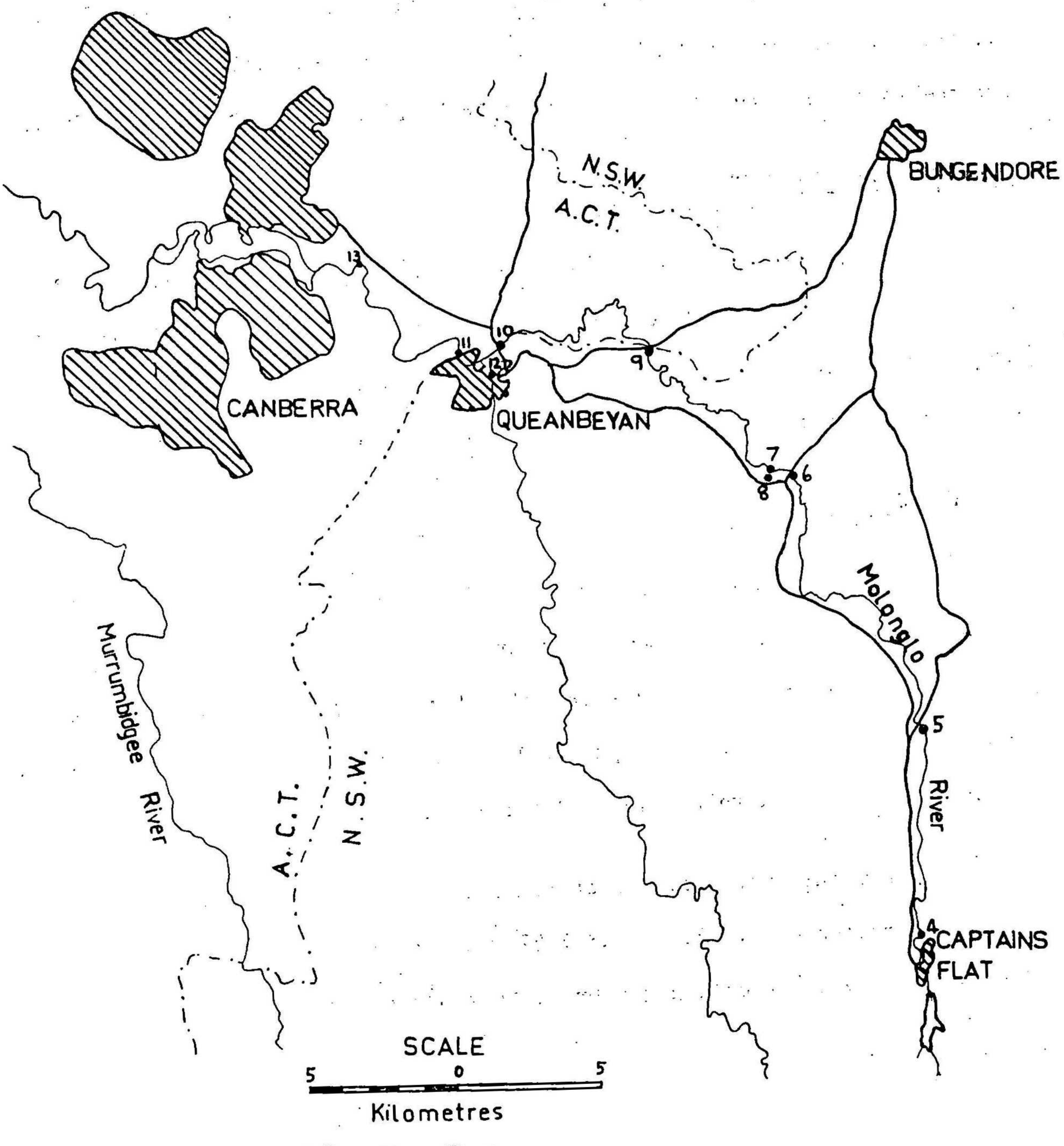
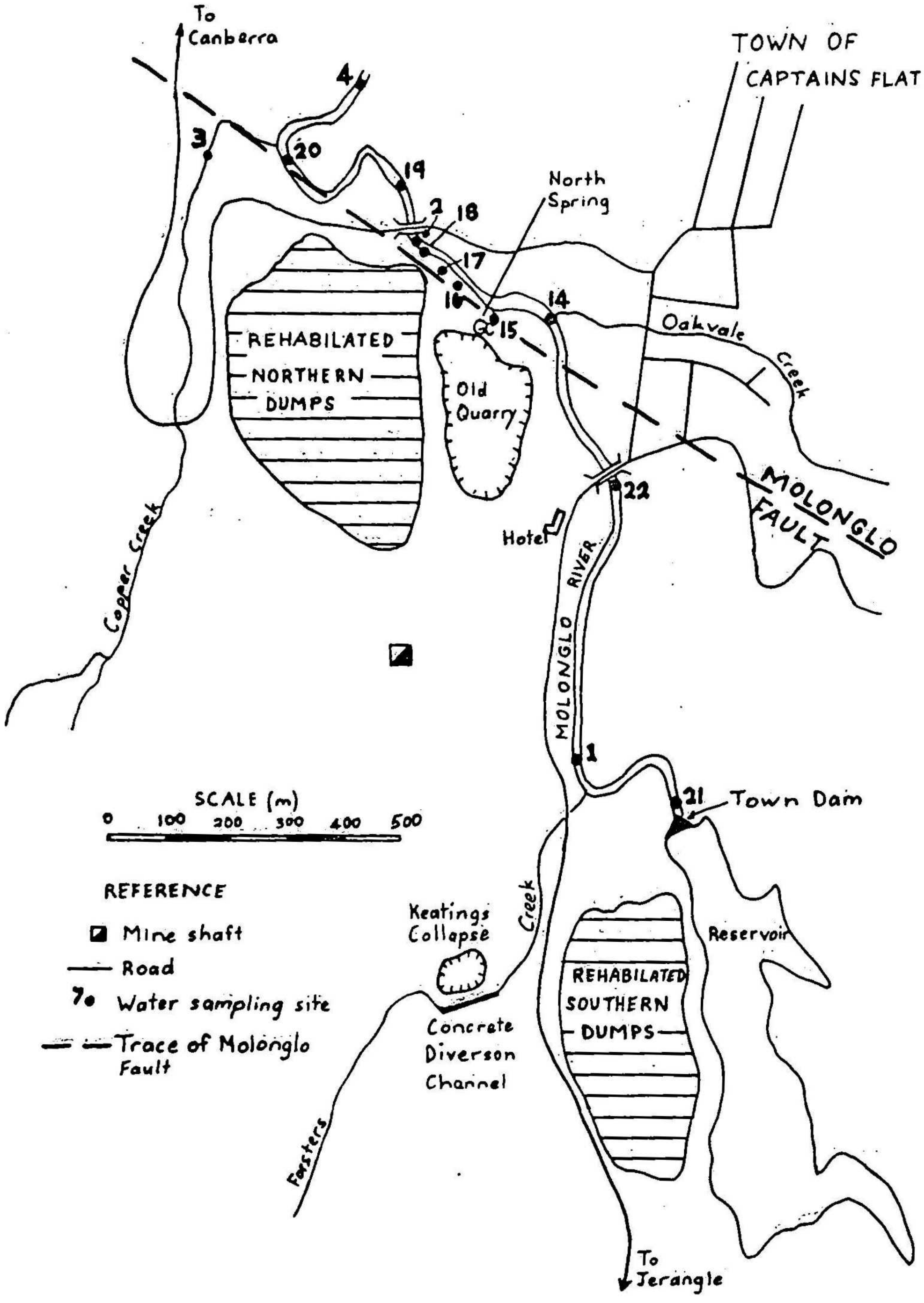


FIGURE 2 WATER SAMPLING STATIONS AT CAPTAINS FLAT, 1982.



invertebrates. The same methods were used in sampling Lake Burley Griffin on 4.5.82 and 21.7.82.

Rainfall during 1982 in the Canberra-Captains Flat region is shown in Figure 3. Annual rainfall for 1982 was the lowest recorded since records began in 1939. November 1982 was the hottest and driest month on record, (Winters, personnal communication).

Flow rates for the Molonglo River were low to zero during 1982. Four stations on the Molonglo River, Stations 4, 5, 9 and 11 as well as the North Spring, Station 15, have instantanous flow records available from the Department of Transport and Construction. The instantanous flow data was used to calculate daily zinc load in the Molonglo River (Table 2). Flow from the North Spring was fairly constant during 1982 and was sampled on four occasions in the latter part of 1982. Forsters Creek did not flow during the sampling period. Oakvale and Copper Creeks contributed minor flows to the Molonglo River.

Figure 3 Rainfall distribution in 1982 (from Bureau of Meteorology and Dept. of Transport and Construction)

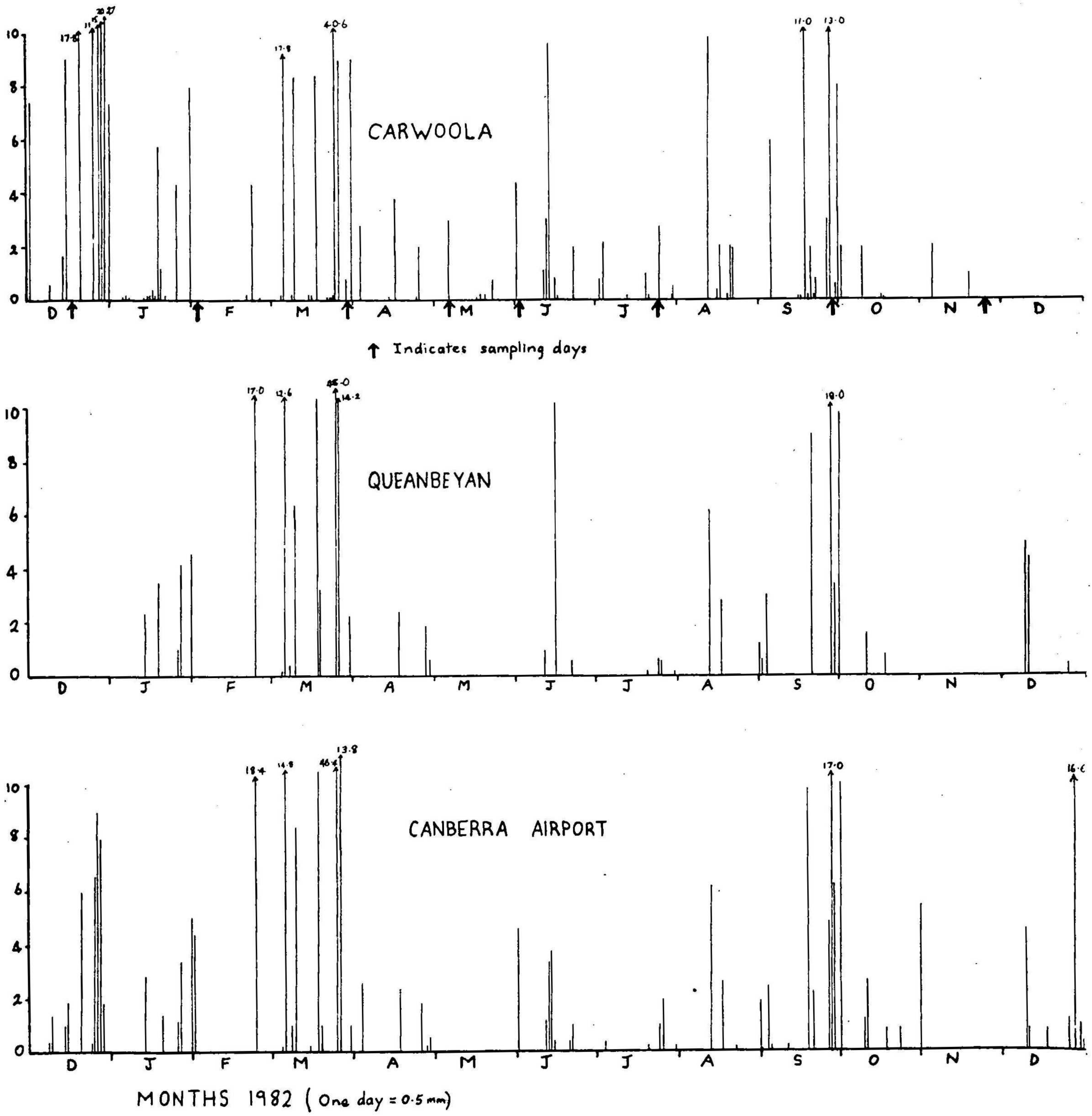


TABLE 1. Description of sampling stations

Station	River distance downstream from town dam wall (km)	Station Description
21	0.01	Molonglo River, about 10 metres downstream from Captains Flat dam.
1	0.35	Molonglo River, at junction of Forsters Creek
22	0.75	Molonglo River, at Hotel bridge.
14	1.1	Molonglo River, at junction of Oakvale Creek.
15		North Spring, at Rehabilated Northern Dump
16	1.25	Fractured Rock Spring
17	1.28	Explosive Shaft Spring
18	1.32	Drain Pipe from Northern Dump
2	1.33	Molonglo River, at road bridge below Captains Flat
19	1.5	Molonglo River, 20 metres downstream from Station 2
20	1.8	Molonglo River, upstream from junction with Copper Creek
3		Copper Creek 150m upstream from junction with Molonglo
4	2	Molonglo River, downstream from Copper Creek.
5	12	Molonglo River at Hoskinstown road bridge
6	28	Molonglo River at Bungendore road bridge

TABLE 1. (Continued)

Station	River distance downstream from dam wall (km)	Station Description
7	29	Molonglo River, downstream from junction with Whiskers Creek
8		Whiskers Creek, 100 m upstream from junction with Molonglo
9	38	Molonglo River at Burbong Bridge
10	49	Molonglo River at Queanbeyan-Sutton road bridge
11	51	Molonglo River at Oakes Estate
12		Queanbeyan River below weir at Caravan Park
13	59	Molonglo River, upstream from Dairy Flat road bridge.

FIELD METHODS

Water samples were collected in one litre bottles made of translucent low density polythene. This type of polythene has low adsorption (Brooks, 1980). The bottles were washed with hydrochloric acid, rinsed three times with distilled water and filled with distilled water prior to sampling. Sample bottles were filled to the top to exclude air and stored in an esky. As the Molonglo River was in a period of low flow, careful water sampling was required so that sediment was not disturbed. In some cases where flow was very low, a nearby pool of water was sampled. Water samples were measured for electrical conductivity and pH upon returning from the field, then acidified with 10 mls of 5M nitric acid prior to being analysed for total dissolved metals, copper (Cu), lead (Pb) and zinc (Zn) the following day.

Sampling for suspended metals and major cations and anions involved a different procedure in the field. The sampling was carried out in conjunction with macroinvertebrate collection by Dr R. Norris (C.C.A.E.) on 6.5.82 and 23.7.82. Only stations on the Molonglo were sampled. Sample bottles of low density polythene were provided by C.C.A.E. and were acid washed and rinsed in distilled water. Three bottles were used for sampling at each station; two 250 ml bottles used for suspended and total dissolved metals and a 500 ml bottle for major cations and anions. Field measurement of pH was undertaken for this sampling. To obtain a sample for the determination of suspended metal levels, the samples were filtered in the field. A 0.45 micron Millipore membrane was used in a plastic Millipore filtration apparatus and a hand operated Nalgene vacuum pump. Samples for suspended and total metals were acidified in the field with 5 mls of 5M nitric acid. All samples were stored in an esky and refrigerated until analysed.

Sediment samples were also collected at each Molonglo River station, in wide-top polythene containers. Where the river bed was gravelly, sites were selected nearby water sampling stations, to provide suitable fine grained sediment. Sediments were sampled as close as possible to the centre of the river channel so as to avoid contamination from alluvium on river banks. Sediment samples were stored frozen until sample preparation and analysis could be undertaken.

The same procedure was followed when Lake Burley Griffin was sampled on 4.5.82 and 21.7.82. However, water samples for analysis of suspended metal levels were filtered and acidified in the laboratory on the day samples were collected. An Eckman Grab sampler was used to collect sediment. The lake water samples for suspended and total metal levels were analysed on a Carbon Rod Atomic Absorption Spectrophotometer by C.C.A.E. as B.M.R. did not have an operating Carbon Rod Unit.

LABORATORY METHODS

A. WATER ANALYSIS

All analyses were undertaken in the Chemical Laboratory of the BMR. Results for each station are given in Appendix 1A. The parameters measured and the methods used are listed below.

Parameter	Method
pH	pH electrode
Electrical Conductivity (E.C.)	Philips Model PW 9501
Bicarbonate (HCO_3^-)	Titration against standardised acid
Chloride (Cl)	Specific ion electrode
Sulphate (SO_4)	Barium chromate addition, precipitation of Barium sulphate, analysis of Cr by A.A.S.

Parameter	Method
Calcium (Ca)	Atomic Absorption Spectrophotometer (A.A.S.)
Magnesium (Mg)	
Potassium (K)	
Sodium (Na)	
Copper (Cu)	
Lead (Pb)	
Zinc (Zn)	
Chromium (Cr)	
Nickel (Ni)	
Cadmium (Cd)	

B. SEDIMENT ANALYSIS

Sediment samples were thawed overnight and then transferred to aluminium trays for drying. Excess water was removed by initial heating of samples under ultra-violet heat lamps. Sediments were oven dried at about 100°C and then ground in a mortar and pestle before digestion.

Two digestion methods were used and, when time permitted, duplicate sediment samples were digested. In the first method, 1g of dried powdered sediment was digested in 300 ml Kjeldahl flasks with 50 mls of nitric acid until the volume of acid was reduced to about half, 10 mls of perchloric acid added and heating continued until the volume was about half. When cooled, 25 ml water was added and the solution transferred to 100 ml volumetric flasks. Kjeldahl flasks and funnel were rinsed with 10 mls hydrochloric acid 1:1, transferred to volumetric flasks and the solution made up to the mark with distilled water.

In the second method, 1g of dried powdered sediment was digested in platinum dishes with 5 ml perchloric acid and 10 ml hydrofluoric acid.

Dishes were heated by waterbath for 4 hours and then by hotplate till all acid had avaporated. Hydrochloric acid 1:1 (5 ml) was added, the solutions heated and transferred to 25 ml volumetric flasks and made up to the mark.

Blanks and standards were used throughout both digestions and good results obtained.

Metal levels in sediments using both digestion methods, are shown in Appendix 2A and 2B.

DISCUSSION

The Canberra region experienced the driest year on record during 1982, resulting in very low flow in the Molonglo River. During these low flow conditions, the major source of zinc pollution came from several springs, discharging mine water directly into a 150-metre section of the river, adjacent to the rehabilitated north dump. The mine waters are acid (minimum recorded pH 2.8), with high electrical conductivity (maximum recorded 8600 µmho/cm), up to 220 mg/l zinc and less than 2 mg/L copper and lead.

The springs include the North Spring (Station 15), several fractured rock springs (Station 16), and an abandoned explosives adit (Station 17). The North Spring flowed continuously during 1982, decreasing in the latter part of the year. The other springs had a noticeable decrease in flow, and several of the fractured rock springs ceased to flow. The spring on the eastern side of the rehabilitated southern dump also ceased flowing in the latter part of 1982; this spring was not sampled during the investigation.

In 1982, the North Spring was the main source of zinc pollution at Station 4, with higher Zinc loads at lower flows in the Molonglo River (Table 2). During 1977, the North Spring contributed 20 to 30% of total zinc pollution at Station 4 (Craze, 1977). In the period 1973 to 1974, Zinc level of the North Spring decreased from a constant level of 230 mg/L to 190 mg/L Zn. It was suggested that this decrease may indicate a limitation in oxidation and leaching in the mine (Joint Government Technical Committee, 1974). Lower zinc levels (maximum recorded 180 mg/L Zn) in waters from the North Spring during 1982 seem to confirm this suggestion.

The springs result from the high water pressure head in groundwater in the mine. The discharge points of springs along the river are due to increased permeability from stress release caused by underground mining and/or from fracturing associated with the Molonglo Fault. Figure 2 shows the trace of the Molonglo Fault, after Oldershaw, 1965.

Analyses of Molonglo River samples indicates a rise in zinc levels from a mean for 1982 of 1.2 mg/L at Station 1, to 3.0 mg/L Zn at Station 22, both above the main pollution sources (Figure 6). This small increase may be due to groundwater from the mine flowing along fractures into the river or from polluted sediment in the upper parts of the Molonglo River. The sudden increase in zinc levels and decrease in pH occurs at the section of the river where the springs discharge, resulting

Figure 4. Zinc and pH levels of the Molonglo River. (Adapted from N.C.D.C. Technical paper 30, 1981)

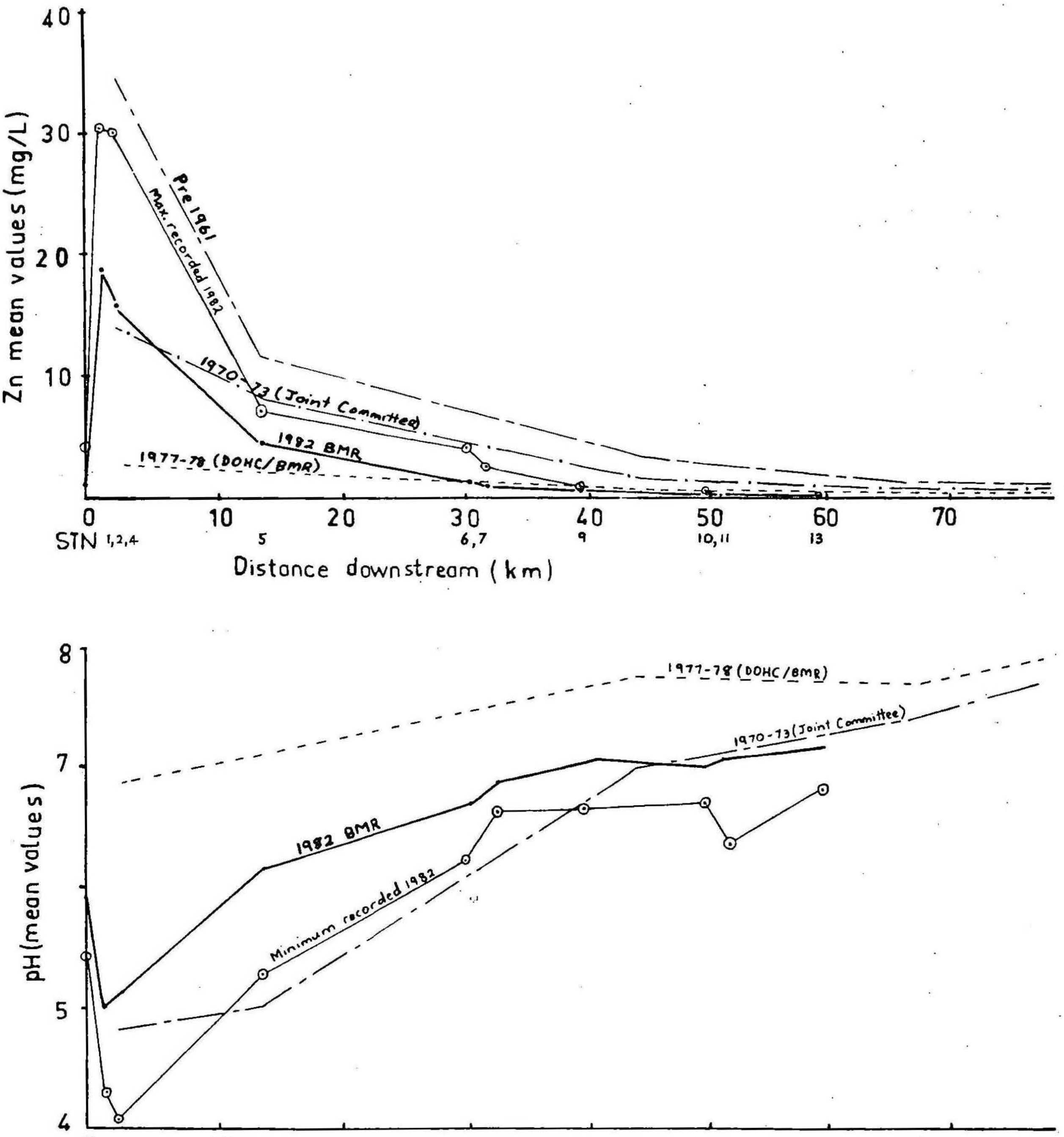
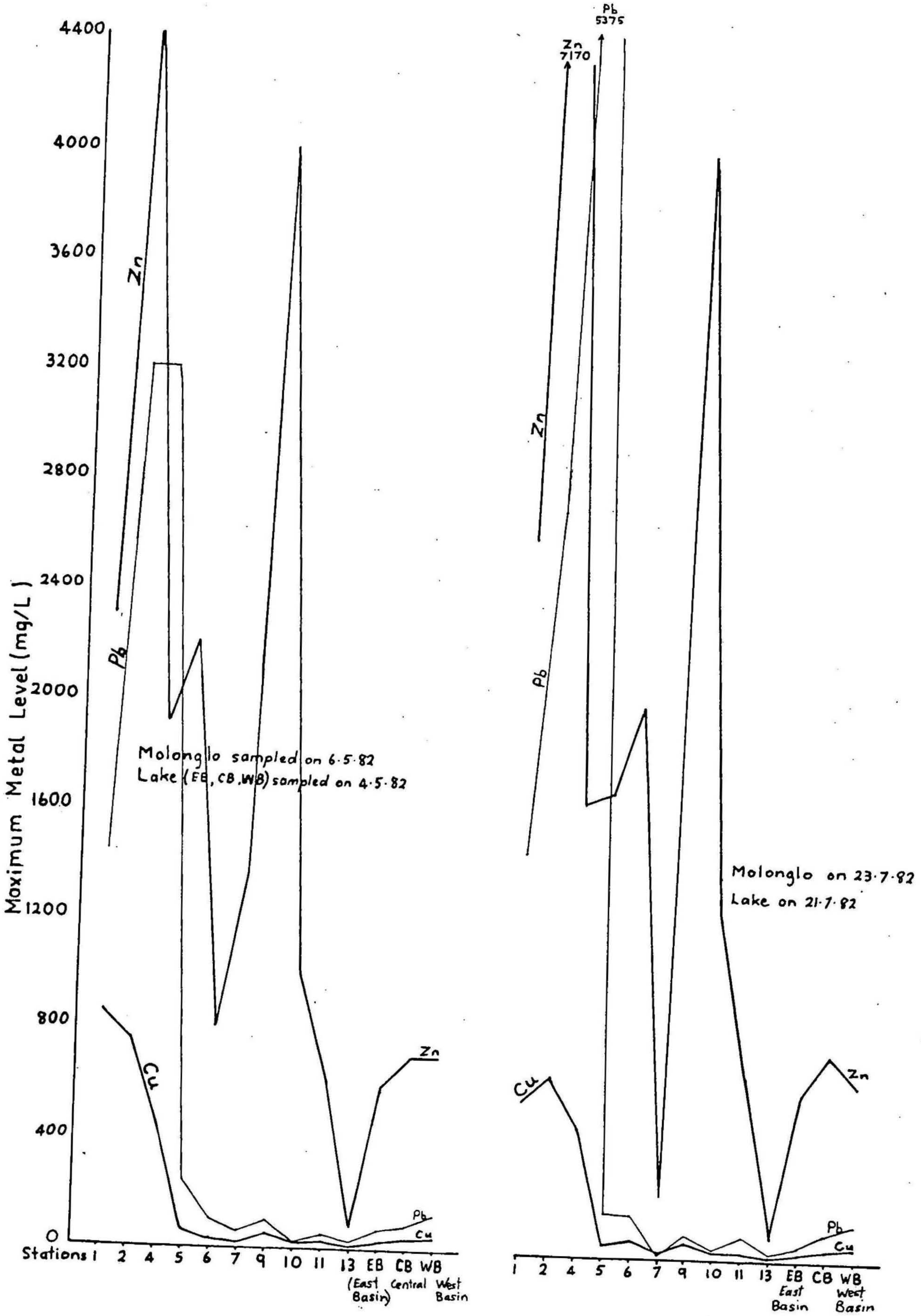


Figure 5. Copper, Lead and Zinc levels in sediments of the Molonglo River and Lake Burley Griffin.



in maximum recorded zinc levels of 30 mg/L at Station 2. The low pH and high zinc levels remain constant for about 0.5 km, with the addition of polluted waters from the Copper Creek catchment, upstream from Station 4 (Figures 6 and 7). At Station 5, 10 km downstream, water quality improves with a decrease in zinc levels to a mean of 4.0 mg/L and pH rising to near neutral. This is shown diagramatically in Figure 4. Metals precipitate out of solution with increasing pH of the river. Copper precipitates as a basic copper sulphate over a range of pH 4 to 5.5; precipitation of zinc as a carbonate occurs at higher pH (Haldane, 1971). The springs and Copper Creek also contribute high levels of calcium, magnesium and sulphate (see Appendix 1B). Gypsum, calcium sulphate, was crystallising from water at the drainpipe (Station 16). Water quality continues to improve as the Molonglo flows through the Carwoola district. Zinc levels gradually decrease further downstream, though zinc persists in solution as far downstream as Burbong Bridge (Station 9). The maximum recorded level at Station 9 was 0.5 mg/L Zn after heavy rain in late March. All stations had the highest zinc levels on 29.3.82. This was due to heavy rainfall in the days preceding sampling, the increased river flow raising suspended sediments loads giving higher zinc levels and hence higher zinc loads further downstream (Table 2). During November, the Molonglo River was at its lowest flow and was initially highly polluted from the springs, but zinc levels decreased rapidly downstream to below detection levels at Station 5 (Figure 6). At Dairy Flat (Station 13), the level of zinc decreased to below the detection limit, i.e. less than 0.01 mg/L Zn, during 1982.

Figure 4 compares the zinc and pH levels in the Molonglo River with previous investigations. It can be seen that during 1982, the zinc levels were lower than those recorded in 1961 and 1970 to 1973. This indicated an improvement in water quality since rehabilitation of the mine dumps. However due to the very low flow of the Molonglo River during

1982 pollution from the springs had a noticeable effect on pH and zinc levels in the upper parts of the Molonglo. Also, the very low river flow did not disturb river bed sediments resulting in decreased zinc levels with increasing pH further downstream.

The highest level of metals in the sediments occurs in the upper 2 km of the Molonglo River, at Stations 2, 2 4 and 5. The source of the high metal levels was from erosion of mine tailings from the dumps before rehabilitation, mine dewatering and at present, the continuing discharge of mine springs. Figure 5 shows the levels of copper, lead and zinc in sediments of the Molonglo River and Lake Burley Griffin, sampled in May and July of 1982. The highest level of copper was 850 mg/L at Station 1. Copper levels decrease rapidly relative to zinc, to fluctuating levels of 20-40 mg/L further downstream. Lead has a similar trend of decreasing levels, but is present at very high levels in river sediments near Captains Flat; the highest lead level was 5400 mg/L at Station 4. Copper and lead levels are lowest at Dairy Flat (Station 13), and then both metal levels increase from the East Basin (Stations ES, EC, EN) to the West Basin (Stations WS, WC, WN) of Lake Burley Griffin. Since the lake filled in 1964, sediment and metals have accumulated on the lake bottom. Measurements have shown that lake sediment increases in thickness towards the downstream end of the lake, indicating that a gradual migration of sediment occurs, mainly in active stages of flood flow through it (Fitzgerald, 1975). Therefore metal levels can be expected to increase in the Western Basin of Lake Burley Griffin, associated with more sedimentation after high river flows. Cullen et al. (1978) suggests that additional lead enters the lake via Sullivans Creek, from fuel combustion and petrol in urban runoff.

Zinc is also at the highest levels in sediments of the upper Molonglo River; the maximum recorded Zn level was 7200 mg/L at Station 2. All stations except Station 4 have zinc levels higher than copper and

Figure 6. Total Zinc in water samples from the Molonglo River, during 1982

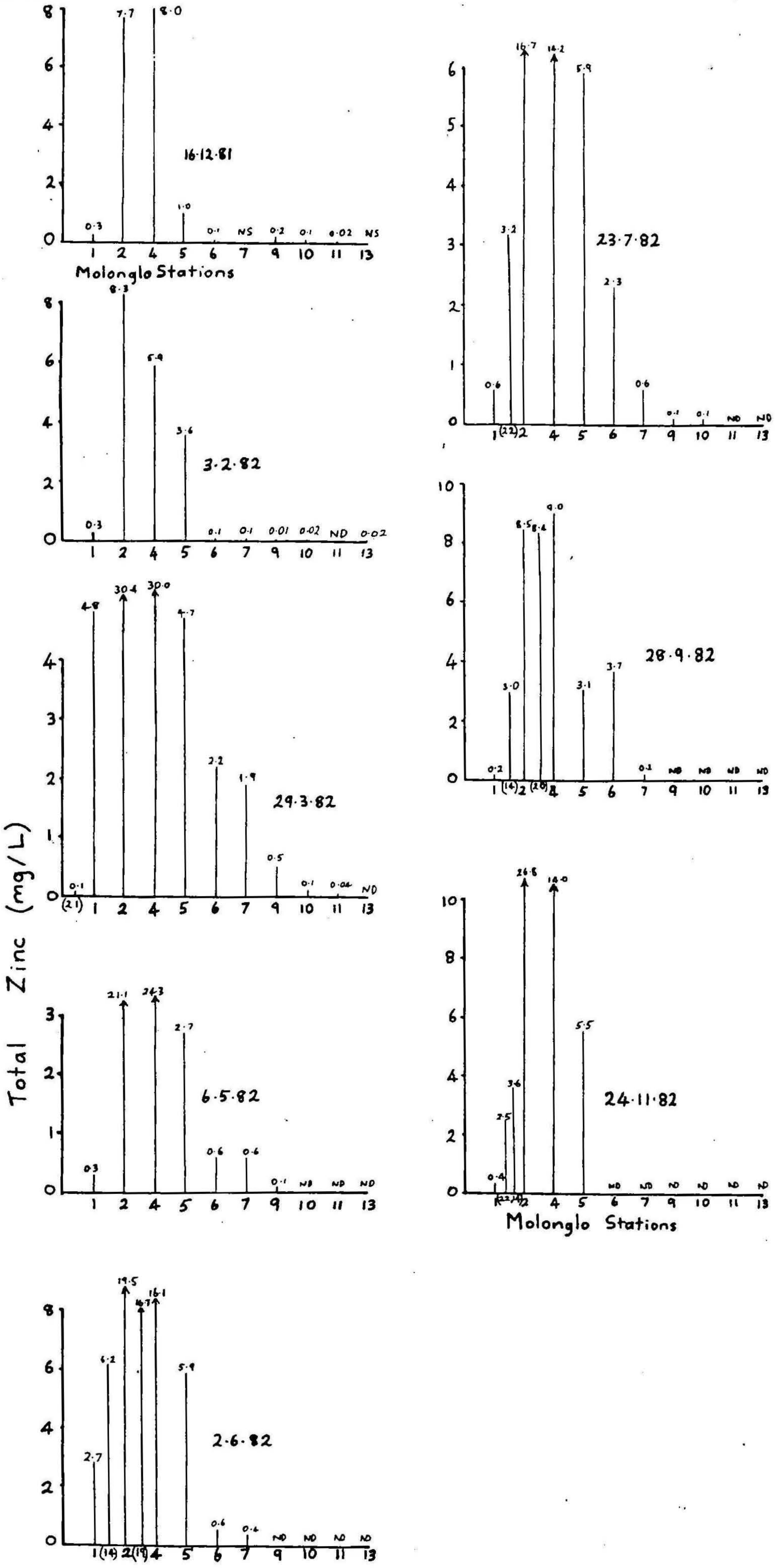
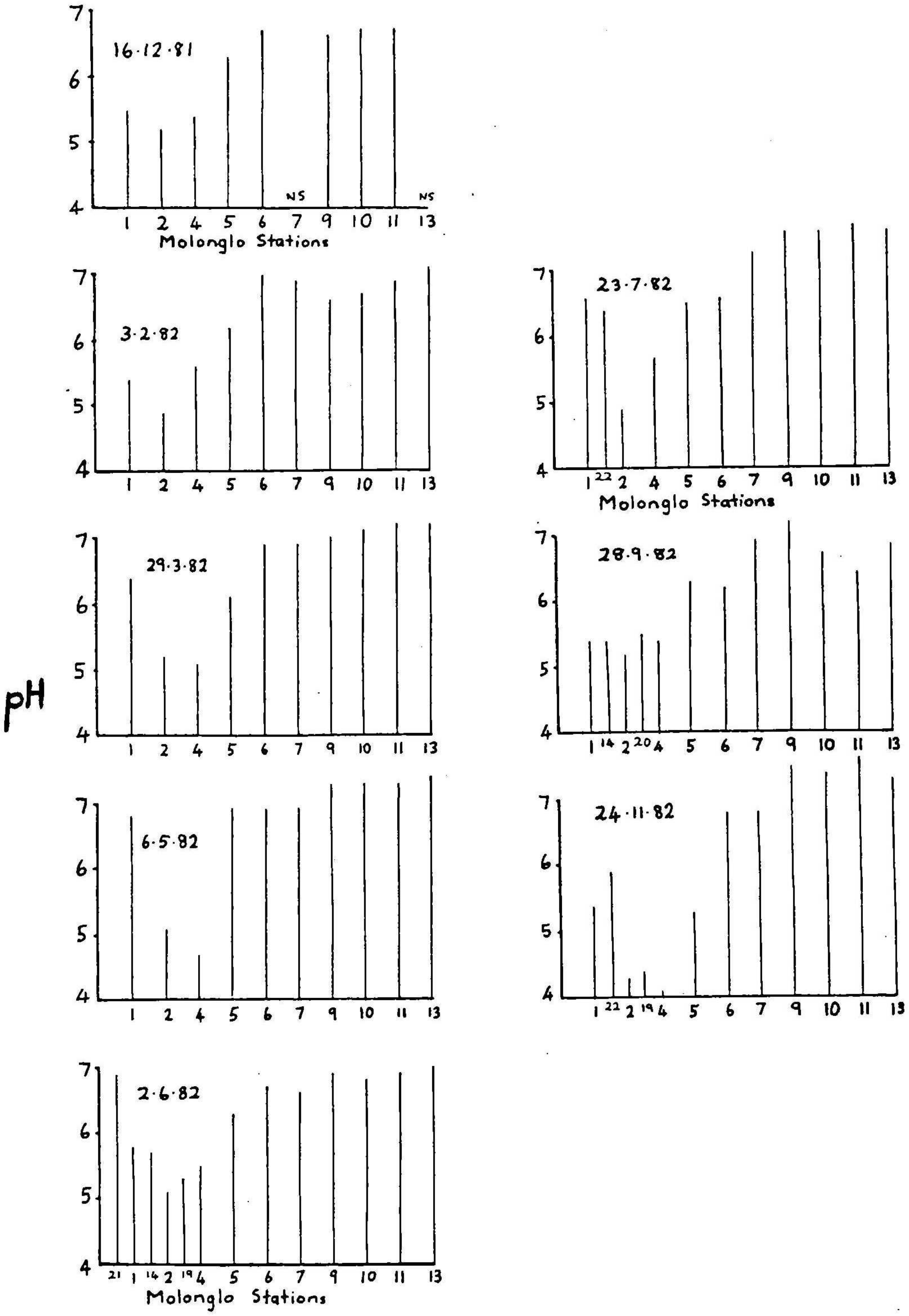


Figure 7. Distribution of pH in water samples from the Molonglo River.



lead. At Station 4, on both sampling days, lead levels were higher than zinc. The levels of Zinc fluctuate further downstream, rising at Station 9 then decreasing to a minimum level at Dairy Flat. Zinc levels then increase in lake sediments.

Chromium and Nickel are present at relatively low levels in river and lake sediments. Higher levels were found in lake sediments (Appendix 2). However not all sediment samples were analysed for chromium and nickel and no conclusions can be drawn.

Metal levels in sediments are similar to the levels determined in investigations by Cullen et al. (1978) and by Brooks (1980). The high levels of lead and zinc in sediments of the Molonglo River will be a continuing source of metal pollution to sediments in Lake Burley Griffin, especially during high river flow conditions.

TABLE 2 Zinc Pollution in the Molonglo River 1982

	Station 4				Station 5			
Date Sampled	pH	Zn (mg/L)	Flow (m^3/s)	Zn Load (kg/d)	pH	Zn (mg/L)	Flow (m^3/s)	Zn Load (kg/d)
16.12.81	5.4	8.0	0.042	29.0	6.3	1.0	0.313	27.0
3.2.82	5.6	5.9	0.048	24.2	6.2	3.6	0.0015	0.5
29.3.82	5.1	30.0	0.024	62.2	6.1	4.7	0.080	32.5
6.5.82	4.7	24.3	0.010	21.0	6.9	2.7	0.001	0.2
2.6.82	5.5	16.1	0.010	13.9	6.3	5.9	0.001	0.5
23.7.82	5.7	14.2	0.013	15.9	6.5	5.9	0.002	1.0
28.9.82	5.4	9.0	0.028	21.8	6.3	3.1	0.010	2.7
24.11.82	4.1	14.0	0.003	3.6	5.3	5.5	0.0003	0.1

	Station 9				Station 11			
Date Sampled	pH	Zn (mg/L)	Flow (m^3/s)	Zn Load (kg/d)	pH	Zn (mg/L)	Flow (m^3/s)	Zn Load (kg/d)
16.12.81	6.6	0.16	0.098	1.4	6.7	0.02	0.461	0.8
3.2.82	6.6	0.01	0.0003	0.00025	6.9	ND	0.126	<0.1
29.3.82	7.0	0.46	0.134	5.3	7.2	0.04	0.581	2.0
6.5.82	7.3	0.10	0.003	0.025	7.3	ND	0.315	<0.3
2.6.82	6.9	ND	0.003	<0.0025	6.9	ND	0.360	<0.3
23.7.82	7.6	0.5	0.005	0.22	7.7	ND	0.275	<0.2
28.9.82	7.2	ND	0.10	<0.086	6.4	ND	0.360	<0.3
24.11.82	7.5	ND	0	0	7.7	ND	0.126	<0.1

Station 15 (North Spring)

Date Sampled	pH	Zn (mg/L)	Flow (m^3/s)	Zn Load (kg/d)	% of Load at Station 4
2.6.82	3.2	153	0.00065	8.6	62
23.7.82	2.9	160	0.00105	14.5	92
28.9.82	3.1	160	0.00039	5.4	25
24.11.82	2.8	180	0.00039	6.1	169

Station 4 (S.P.C.C., 1977)

Date	Flow (m^3/s)	Zn (mg/L)	Zn Load (kg/d)
9.2.77	0.580	11.2	562
16.2.77	0.060	9.3	53
18.2.77	0.272	12.0	282
2.3.77	0.640	1.8	99
4.3.77	0.852	4.8	353
17.3.77	0.350	4.3	130
23.3.77	0.341	4.1	121

Notes for Table 2 and Appendices

1. Flow data is instantanous flow recorded at stations by Department of Transport and Construction.
2. Copper and lead were not detected in most samples (see note 4).
3. Where zinc load is less than (<), zinc was not detected in the sample; the value for zinc load was obtained by multiplying flow by zinc detection limit on A.A.S. (ie 0.01 mg/L).
4. ND = Not Detected, Detection limit for Zn is 0.01 mg/L; for Cu 0.05 mg/L; for Pb 0.13 mg/L.

CONCLUSIONS

The successful rehabilitation of the Captains Flat mine dumps in 1976 has apparently stopped the supply of mine tailings to the Molonglo River sediments. Under the very low river flow conditions experienced during 1982, the springs were the major source of metal pollution to the Molonglo River and the contribution of Copper Creek was minor. However during high rainfall-high flows, increased metal levels will result from the Copper Creek mill area.

The upper 2 km of sediments in the Molonglo River contain very high levels of lead and zinc. Higher flows in the Molonglo River would reduce the polluting effect of the springs, but would transport polluted sediment further downstream, eventually depositing sediments and metals in Lake Burley Griffin. It must be emphasised that under higher flow conditions in the Molonglo River, the river sediments constitute a continuing source of metal pollution to the waters of the Molonglo River and Lake Burley Griffin.

RECOMMENDATIONS

1. Monitoring of sediment movement and metal levels in Molonglo and North Spring waters should be carried out regularly and during initial stages of high flow conditions.

2. Treatment of mine water discharging from the North Spring should be considered. An effective treatment would be a cement channel with crushed limestone, at the outlet of the North Spring.

3. Control of existing minor erosion, mainly on the eastern side of the South Dump and the northern side of the North Dump. These areas should be revegetated before deeper erosion occurs. Also sheep grazing of dump slopes should be banned as sheep tracks will increase erosion.

4. Stabilization and revegetation of mill material in the Copper Creek catchment, recommended by Brooks in 1980, should be carried out as soon as possible.

5. To protect the lake fauna and sediments from increasing metal pollution, sediment traps should be constructed upstream from the lake, in the Dairy Flat area.

ACKNOWLEDGEMENTS

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The Department of Transport and Construction, Hydrographic Section, supplied stream flow data on the Molonglo River.

The Bureau of Metrology supplied rainfall data.

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APPENDIX 1A Results of Molonglo Water analyses - Metals (mg/L)

	STATION 1					STATION 2					STATION 3				
Date	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn
16.12.81	5.5	97	N.D.	N.D.	0.29	5.2	340	0.06	N.D.	7.66	4.7	1860	0.09	0.13	15.79
3. 2.82	5.4	105	N.D.	N.D.	0.28	4.9	275	0.46	1.08	8.29	4.6	1700	N.D.	N.D.	13.00
29. 3.82	6.4	195	N.D.	N.D.	4.83	5.2	950	0.20	0.14	30.36	5.0	1350	0.12	0.19	20.41
6. 5.82	6.8	330	N.D.	N.D.	0.30	5.1	570	0.03	0.02	21.10	4.6	1500	0.03	0.01	12.60
2. 6.82	5.8	125	N.D.	N.D.	2.70	5.1	550	0.05	N.D.	19.50	5.3	1560	0.03	N.D.	13.60
23. 7.82	6.6	100	N.D.	N.D.	0.57	4.9	535	0.33	0.62	16.70	5.3	1800	0.06	0.18	13.95
28. 9.82	5.4	125	N.D.	N.D.	0.20	5.2	480	0.10	0.14	8.50	4.3	2140	0.04	0.16	26.70
24.11.82	5.4	200	N.D.	N.D.	0.40	4.3	1560	0.10	N.D.	26.80	4.3	2650	0.10	0.20	11.30

	STATION 4					STATION 5					STATION 6				
Date	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn
16.12.81	5.4	400	0.06	N.D.	7.97	6.3	191	N.D.	N.D.	0.95	6.7	200	N.D.	N.D.	0.13
3. 2.82	5.6	260	N.D.	N.D.	5.90	6.2	295	N.D.	N.D.	3.57	7.0	280	N.D.	N.D.	0.09
29. 3.82	5.1	810	0.30	0.12	30.00	6.1	280	N.D.	N.D.	4.72	6.9	240	N.D.	N.D.	2.18
6. 5.82	4.7	780	0.03	0.01	24.30	6.9	300	N.D.	N.D.	2.70	6.9	320	N.D.	N.D.	0.60
2. 6.82	5.5	630	N.D.	N.D.	16.10	6.3	380	N.D.	N.D.	5.90	6.7	350	N.D.	N.D.	0.60
23. 7.82	5.7	570	N.D.	N.D.	14.20	6.5	400	N.D.	N.D.	5.90	6.6	370	N.D.	N.D.	2.33
28. 9.82	5.4	485	0.10	N.D.	9.00	6.3	380	N.D.	N.D.	3.10	6.2	540	N.D.	N.D.	3.70
24.11.82	4.1	1250	N.D.	N.D.	14.00	5.3	850	N.D.	N.D.	5.50	6.8	670	N.D.	N.D.	N.D.

	STATION 7					STATION 8					STATION 9				
Date	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn
16.12.81	N.S.					7.2	820	N.D.	N.D.	0.02	6.6	245	N.D.	N.D.	0.16
3. 2.82	6.9	295	N.D.	N.D.	0.07	7.1	690	N.D.	N.D.	N.D.	6.6	290	N.D.	N.D.	0.01
29. 3.82	6.9	270	N.D.	N.D.	1.90	6.9	410	N.D.	N.D.	N.D.	7.0	420	N.D.	N.D.	0.46
6. 5.82	6.9	340	N.D.	N.D.	0.60	N.S.					7.3	420	N.D.	N.D.	0.10
2. 6.82	6.6	370	N.D.	N.D.	0.40	N.S.					6.9	470	N.D.	N.D.	N.D.
23. 7.82	7.3	480	N.D.	N.D.	0.57	N.S.					7.6	560	N.D.	N.D.	0.05
28. 9.82	6.9	850	N.D.	N.D.	0.20	N.S.					7.2	910	N.D.	N.D.	N.D.
24.11.82	6.8	880	N.D.	N.D.	N.D.	N.S.					7.5	1210	N.D.	N.D.	N.D.

	STATION 10					STATION 11					STATION 12				
Date	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn	pH	E.C. umho/cm	Cu	Pb mg/L	Zn
16.12.81	6.7	250	N.D.	N.D.	0.08	6.7	250	N.D.	N.D.	0.02	6.5	200	N.D.	N.D.	N.D.
3. 2.82	6.7	390	N.D.	N.D.	0.02	6.9	320	N.D.	N.D.	N.D.	7.0	260	N.D.	N.D.	N.D.
29. 3.82	7.1	290	N.D.	N.D.	0.11	7.2	265	N.D.	N.D.	0.04	7.2	190	N.D.	N.D.	N.D.
6. 5.82	7.3	425	N.D.	N.D.	N.D.	7.3	320	N.D.	N.D.	N.D.	N.S.				
2. 6.82	6.8	600	N.D.	N.D.	N.D.	6.9	300	N.D.	N.D.	N.D.	6.8	220	N.D.	N.D.	N.D.
23. 7.82	7.6	610	N.D.	N.D.	0.06	7.7	310	N.D.	N.D.	N.D.	N.S.				
28. 9.82	6.7	940	N.D.	N.D.	N.D.	6.4	370	N.D.	N.D.	N.D.	6.6	260	N.D.	N.D.	N.D.
24.11.82	7.4	1360	N.D.	N.D.	N.D.	7.7	500	N.D.	N.D.	N.D.	7.5	270	N.D.	N.D.	N.D.

APPENDIX 1A (contd)

	STATION 13					STATION 14					STATION 15				
Date	pH	E.C.	Cu	Pb	Zn	pH	E.C.	Cu	Pb	Zn	pH	E.C.	Cu	Pb	Zn
		umho/cm		mg/L			umho/cm		mg/L			umho/cm		mg/L	
16.12.81	N.S.					N.S.					N.S.				
3. 2.82	7.1	310	N.D.	N.D.	0.02	N.S.					N.S.				
29. 3.82	7.2	350	N.D.	N.D.	N.D.	N.S.					N.S.				
6. 5.82	7.4	320	N.D.	N.D.	N.D.	N.S.					N.S.				
2. 6.82	7.0	350	N.D.	N.D.	N.D.	5.7	210	0.04	N.D.	6.2	3.2	3100	0.17	1.51	153.0
23. 7.82	7.6	405	N.D.	N.D.	N.D.	N.S.					2.9	3300	0.20	1.62	160.0
28. 9.82	6.8	570	N.D.	N.D.	N.D.	5.4	210	N.D.	N.D.	3.0	3.1	4200	0.20	1.87	160.0
24.11.82	7.3	600	N.D.	N.D.	N.D.	5.9	410	N.D.	N.D.	3.6	2.8	6050	0.20	1.80	180.0

	STATION 16					STATION 17					STATION 19				
Date	pH	E.C.	Cu	Pb	Zn	pH	E.C.	Cu	Pb	Zn	pH	E.C.	Cu	Pb	Zn
2. 6.82	3.0	5800	2.48	1.62	218.0		Not sampled				5.3	530	0.06	N.D.	16.7
24.11.82	2.8	6100	2.0	1.70	214.0	2.7	6400	0.20	1.40	210.0	4.4	1650	0.10	N.D.	32.9

	STATION 18					STATION 20					STATION 22				
Date	pH	E.C.	Cu	Pb	Zn	pH	E.C.	Cu	Pb	Zn	pH	E.C.	Cu	Pb	Zn
29.3.82	5.4	5000	N.D.	N.D.	59.0	N.S.					N.S.				
2. 6.82	N.S.					6.2	410	0.03	N.D.	16.2	6.4	140	N.D.	N.D.	3.09
23. 7.82	5.3	5300	N.D.	0.4	54.5	N.S.					6.4	200	N.D.	N.D.	3.24
28. 9.82	N.S.					5.5	470	0.10	N.D.	8.4	N.S.				
24.11.82	5.5	8600	N.D.	0.1	79.0		Not sampled				5.9	300	N.D.	N.D.	2.50

	STATION 21				
Date	pH	E.C.	Cu	Pb	Zn
29.3.82	6.9	100	N.D.	N.D.	0.11

APPENDIX 1B Results of Molonglo Water Analyses - Cations and Anions

Date sampled 6.5.82 All element levels in mg/L

Station	pH	E.C.	Ca	Mg	Na	K	HCO_3	Cl	SO_4	Dissolved Zn	Total Zn
1	6.8	330	5	5	6	1	28	3	14	0.3	0.3
2	5.1	540	55	29	12	1	9	8	270	20.6	21.1
4	4.7	780	78	44	20	2	7	8	410	24.3	24.6
5	6.9	300	19	12	14	1	41	10	68	2.5	2.7
6	6.9	320	21	16	31	2	95	26	64	0.5	0.6
7	6.9	340	25	19	23	3	80	25	84	0.5	0.6
9	7.3	420	30	23	36	2	163	44	55	0.1	0.1
10	7.3	425	24	22	41	1	186	56	31	N.D.	N.D.
11	7.4	320	22	18	28	2	140	36	25	N.D.	N.D.
13	7.4	320	20	12	33	4	139	33	20	N.D.	N.D.

Date Sampled 23.7.82

Station	pH	E.C.	Ca	Mg	Na	K	HCO_3	Cl	SO_4	Dissolved Zn	Total Zn
1	6.6	100	4	5	5	1	27	2	15	0.55	0.57
2	4.9	535	46	32	15	1	7	4	304	15.70	16.70
4	5.7	570	49	31	17	1	11	4	292	14.00	14.20
5	6.5	400	30	21	18	1	35	10	150	5.86	5.90
6	6.6	370	22	17	26	2	93	25	96	2.27	2.30
7	7.3	480	32	26	32	2	108	38	93	0.51	0.60
9	7.6	560	29	29	49	2	194	96	56	0.03	0.05
10	7.6	610	26	34	55	1	213	92	50	0.03	0.06
11	7.7	310	18	16	25	2	123	38	23	N.D.	N.D.
13	7.6	405	21	17	42	4	155	50	30	N.D.	N.D.
22	6.4	200	9	10	6	1	23	4	47	N.S.	3.24
15	2.9	3300	412	720	28	3	N.D.	1	428	N.S.	160.0
18	5.3	5300	480	40	160	11	46	10	373	N.S.	55.0
3	5.3	1800	196	100	80	3	25	14	540	N.S.	14.0

Nb. Levels of dissolved and total Cu and Pb were not detected on flame A.A.S. in most samples. Levels of Cu and Pb are Stations 3, 15 and 18 on 23.7.82 are given in Appendix 1A.

APPENDIX 1C Results of Lake Burley Griffin Water Analyses

All element levels in mg/L, E.C. in umho/cm

Date sampled 4.5.82

Location	pH	E.C.	Ca	Mg	Na	K	HCO_3	Cl	SO_4
East Basin, South (ES)	7.8	280	18	12	28	3	108	27	15
East Basin, Central (EC)	8.0	280	18	11	30	3	108	29	22
East Basin, North (EN)	7.9	280	18	11	30	3	108	25	18
Central Basin, South (CS)	7.8	270	18	11	27	3	104	25	20
Central Basin, Central (CC)	7.8	245	18	11	28	3	104	25	15
Central Basin, North (CN)	7.9	260	18	11	26	3	104	23	15
West Basin, South (WS)	8.0	290	18	11	27	3	102	25	22
West Basin, Central (WC)	8.0	270	18	11	26	2	102	23	25
West Basin, North (WN)	8.1	265	18	11	27	2	103	23	22

Date sampled 21.7.82

Location	pH	E.C.	Ca	Mg	Na	K	HCO_3	Cl	SO_4
ES	8.0	260	18	11	25	3	117	27	15
EC	8.0	290	19	12	27	3	120	27	17
EN	8.0	290	19	12	27	3	118	38	16
CS	8.0	285	19	12	26	3	115	40	20
CC	7.9	290	19	12	26	3	116	33	16
CN	8.0	300	19	11	26	3	116	31	17
WS	8.0	290	19	11	24	3	110	29	19
WC	8.0	290	18	11	25	3	110	27	18
WN	8.0	295	19	11	25	3	110	27	16

Note. Copper, Lead, Zinc were not detected on any lake water sample using Flame A.A.S. Samples were analysised by Carbon-rod A.A.S. at C.C.A.E., and results published by Dr R. Norris of C.C.A.E.

APPENDIX 2A Results of Molonglo River Sediment Analyses (mg/L)

	Sampled on 6.5.82								Sampled on 23.7.82					
	Kjeldahl Flask Digestion					Platinum Digestion			Kjeldahl Digestion			Platinum Digestion		
Station	Cu	Pb	Zn	Cr	Ni	Cu	Pb	Zn	Cu	Pb	Zn	Cu	Pb	Zn
1	852	1440	2278	32	24	817	1355	2263	560	1449	2539	541	1465	2648
1	854	1421	2312	32	13				526	1519	2441			
2	753	3142	4361	24	18	761	3004	4556	601	2600	7119	649	2451	6779
2	747	3182	4409	28	21				644	2731	7169			
4	436	3199	1866	28	13	403	3101	1921	464	5211	1566	444	5375	1643
4	402	3044	1751	24	13				446	5009	1532			
5	49	154	1892	31	10	60	235	2183	49	155	1517	43	164	1683
5									45	141	1492			
6	28	61	658	41	16	35	104	804	65	112	1523	73	141	1992
6									73	152	1916			
7	23	10	1303	53	22	25	60	1355	20	N.D.	231	11	13	224
7									26	N.D.	211			
9	54	79	4011	69	32	52	97	3737	59	84	3727	51	87	4020
9									53	84	3542			
10	25	21	1005	61	22	25	26	976	34	38	1123	31	44	1270
10									33	38	1152			
11	32	48	583	40	26	27	52	618	31	88	622	29	74	658
11									30	76	611			
13	10	22	71			7	30	88	8	15	52	6	13	87
13	8	17	57						7	14	52			

Note Cadium was analysed on samples from stations 4 to 8, collected on 6.5.82, and was not detected in these sediments.

APPENDIX 2B Results of Lake Burley Griffin Sediment Analyses - Metals (mg/L)

	Sampled on 4.5.82							Sampled on 21.7.82							
	Kjeldahl Digestion				Platinum			Kjeldahl Digestion					Platinum		
Location	Cu	Pb	Zn	Cr	Cu	Pb	Zn	Cu	Pb	Zn	Cr	Ni	Cu	Pb	Zn
ES	11	74	154		10	55	133	9	51	119	42		14	88	184
ES	11	68	166												
EC	20	44	493		23	55	493	7	10	106	31		8	16	144
EC	22	50	546												
EN	26	59	611		27	52	587	29	51	613	76		28	54	601
EN	24	47	594												
CS	24	47	421		26	47	408	21	35	340	58		24	44	383
CS	22	53	398												
CC	30	74	538		34	71	569	15	43	377	49		18	36	437
CC	33	71	582												
CN	35	89	697	100	38	91	693	39	91	745	76		38	90	732
WS	23	67	473	76	29	68	501	33	64	634	81	22	33	74	618
WC	33	105	698	89	36	102	668	38	74	547	84	25	35	78	519
WN	39	124	530	91	42	117	519	46	124	565	102	30	44	130	523

Appendices Notes

1. N.D. = Not Detected
2. N.S. = Not Sampled
3. Cu = Copper, Pb = Lead, Zn = Zinc
4. Where result is blank, analysis was not performed.
5. Results of metals in water samples are results for Total of each species in solution, unless stated otherwise, i.e. Dissolved. All results in milligrams per Litre (mg/L)
6. Major Cations : Ca = Calcium, Mg = Magnesium, Na = Sodium, K = Potassium
   Major Anions : Cl = Chloride, SO_4 = Sulphate, HCO_3 is Alkalinity expressed as Bicarbonate.
7. E.C. = Electrical Conductivity in umho/cm