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HYDROLOGY REPORT NO. 2003
M. FILE 2973/77

BYENUP, TOORDIT-GURRUP AND POORGINUP LAGOONS BASIC WATER QUALITY CRITERIA IN RELATION TO PEAT MINING

1. INTRODUCTION

Since April 1977 water samples have been collected, at three monthly intervals, from three lagoons near Lake Muir about 60 kilometres east of Manjimup (Figure 1). The three lagoons - Byenup, Toordit-Gurrup and Poorginup - are the subjects of applications for coal mining leases for the purpose of peat mining by Cladium Mining Pty. Ltd.

The granting of these leases to the mining company was delayed for two years to allow a program of water sampling to be undertaken by the Department of Fisheries and Wildlife in order to establish an 'annual base salinity level' for the lagoons.

This report details the results of this sampling program and discusses the applicability of the results to the proposed conditions of the lease, that were given at the commencement of the sampling program.

2. PROPOSED CONDITIONS RELATING TO WATER QUALITY

The proposed lease conditions as they affect water quality within the lagoons are presented on Folio 164 of Mines File 930/70 and state that:

"The Lessee taking such measures as are necessary and to the satisfaction of the Director of Fisheries and Fauna or his nominee to prevent the total soluble salt content of the waters of any lake, swamp or lagoon within the general area of the lease increasing by more than an amount of 2.5 parts per thousand (0.25%) salinity above the mean level of such salts contained therein at the corresponding times of the year during

a period of 23 months terminating before the commencement of mining, during which period the Director of Fisheries and Fauna or his nominee will carry out a program of water sampling and analysis agreed with the Department of Mines.

4. The lessee taking such measures as are necessary and to the satisfaction of the Director of Fisheries and Fauna or his nominee to prevent any increase in the pH reading of the waters of any lake, swamp or lagoon within the general area of the lease to a level in excess of 8 units of pH and to prevent any decrease of such pH reading in excess of 1 unit of pH during the period of 24 months terminating before the commencement of mining."

These conditions were subsequently recommended in an abbreviated form by the Acting Administrative Officer, Mining at Folios 166/7 of the same file.

It could be argued that the requirements for the control of total soluble salts (i.e. total dissolved solids) are couched in slightly ambiguous terms, for it could be taken that the requirements meant either an allowance of 2.5 parts per thousand (which is equivalent to 2 500 ppm or mg/litre) or an increase of 0.25% over the base level salinity for that particular month.

An allowable salinity increase of 2 500 ppm (mg/L) appears quite lenient and whilst being acceptable in one lagoon, may not be so in others. A rise of only 0.25% however is regarded as unmanageable and is less than the limits of repeated analysis For the purpose of this report, therefore, it is accepted that the original proposed conditions limited an increase in salinity to 2 500 ppm (mg/L).

In addition the period allowed for sampling to determine mean salinity levels may be inadequate. Although the rainfall station at Lake Muir ceased to function after 1968 rainfall figures from the nearest station at Manjimup (Table 1) indicate that over the period of sampling slightly below average rainfall wa was received.

TABLE 1 RAINFALL DATA

MANJIMUP AND LAKE MUIR (mm)

		J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
Manjimup	1976	92	52	9	127	118	56	111	133	82	77	113	22	1122
	1977	17	9	17	8	162	131	111	181	71	142	24	25	898
	1978	12	14	15	36	199	197	221	50	154	61	58	36	1053
	1979	11	12	32	58	92								
Long term average		19	20	33.5	64.5	143	181.6	182.9	152.1	112	82.8	43.7	26.4	1061.5
Lake Muir long term average		15	17	28.2	50.8	111.25	131.8	140.7	122,9	91.7	65.1	31.2	23.9	832.55

If the rainfall over the sampling period has varied considerably either side of the long term average then the resultant run-off and direct in-fill to the lakes would have differed from the normal. Owing to the shallowness of the lakes and consequently small storages, relatively small differences in the volumes of input could give rise to salinities which differed appreciably from the long-term average values. Erroneous salinities might therefore have become the reference values for control purposes.

It therefore appears that a reappraisal of the proposed salinity requirements is called for, and a later section will make suitable recommendations.

The requirements for control of pH also appear unrealistic. During the period of sampling both Byenup and Toordit-Gurrup gave samples with pH readings in excess of 8.0 and the pH of the latter also fluctuated over a range of up to 1.5 units. In fact a difference of 0.9 units was achieved from samples collected at the same site but at different levels. To apply controls to prevent pH rising above a figure that occurs normally does not appear to be justified.

3. METHOD OF SAMPLING

The proposed method of sampling to determine base levels of salinity was given on Folio 133 of MF 930/70. This was:

"Water samples will be taken, in plastic containers with a capacity not less than ½-gallon, at six sites to be agreed between the Director of Fisheries and Fauna and Mr. A. Burns acting on behalf of Cladium Mining. The sites will be distributed along the line of northerly drainage from Poorginup to Toordit-Gurrup to Byenup Lagoon. Each is to be sampled during the months of March, June, September and December over a continuous period of 24 months starting as soon as possible after the approval of the CMLs. The salinity of the water in each sample is to be determined immediately by means of a conductivity meter, and at least three of each batch of six samples resulting from a single time of sampling are to be subsequently analysed by Government Chemical Laboratories to check the conductivity meter results. Copies of all results are to be supplied after each sampling to Cladium Mining and to the Director of the Geological Survey Branch."

The full requirements were passed on to the then Department of Fisheries and Fauna. (Folios 136, 158 of MF 930/70)

The purpose of these samples was to determine a base level for salinity over the two year period and to establish pre-mining pH levels for the lagoons. The choice of measured criteria has not, however, remained consistent over the period, and at times all sites have not been sampled. There have been no pH measurements for any lagoon over the last 9 months and only two samples have been forwarded to the Government Chemical Laboratories in the last six months. Salinities have been expressed at various times as mg/litre of total dissolved solids, total soluble salts, sodium chloride and chloride.

A consistent series of samples and analyses are preferable to enable a reasonable estimate of base salinity levels to be established.

4. ANALYTICAL RESULTS

All analyses, as received, have been tabulated and are given in Table 2. The gaps in sampling and the variety of criteria are self evident.

Total dissolved solids, sodium chloride and pH are also presented in graph form in Figures 2, 3 and 4 respectively.

4.1 Salinity

On the basis of the data presented in Figures 2 and 3, a regular cyclic fluctuation is evident, with the lowest salinities being recorded at the end of winter and the highest at the end of summer. This pattern is evident in all three lagoons although Poorginup was, in fact, dry at the last sampling period.

The greatest range in salinities occur in Lake Byenup with a maximum being recorded at 5 900 mg/litre and a minimum of 2 340 mg/litre. At Toordit-Garrup the range is 1 460 to 760 mg/litre and at Poorginup 900 to 300 mg/litre.

The seasonal fluctuations in salinities are to be expected in shallow lagoons that rely on annual recharge from rainfall and run-off.

Using the limited data an average value can be obtained for salinity for each of the four sampling periods. Because of the similarity of values for salinity for top and bottom samples for each period an overall average has been obtained for each site. These values are given in Table 3. (See page 6)

4.3 pH

Analysis and interpretation of the pH measurements to determine an average value for each sampling period has been hindered by lack of data for the last three sampling periods. With the available data the seasonal fluctuations have not been as evident and no real pattern has emerged over the 15 months of results.

Using the limited results available, average values for pH have been determed and are presented in Table 4. The data in this table show that pH values in excess of 8 units are already common prior to mining and that there is up to 1.5 units of pH difference between the highest and lowest value for any one sampling point. This emphasises the difficulty that will be encountered in staying within the lease requirements.

TABLE 3

AVERAGE SALINITY VALUES 1977-79

Site	March		June		September		December	
I	Range	Average	Range	Average	Range	Average	Range	Average
I	3850-5900	4493	3550-4400	3833	2040-2340	2103	2520-3050*	2650
II	3830-5900	4403	3780-4200	3920	2260-2440	2365	2570-2968*	2686
III	1050*-1460	1330	1150-1170	1163	760-970	865	805*-970	914
IV	870*-1460	1262	1130-1180	1155	700-1000	840	840*-960	900
V	900	900	640-680	660	420-680	587	900*-960	923
VI	900	900	580-820	720	410-300	340	430-460*	443

N.B. Values in mg/litre total dissolved solids

Sites I, II Byenup Lagoon

Sites III, IV Toordit-Gurrup Lagoon

Sites V, VI Poorginup Lagoon

* estimated from Na Cl values.

TABLE 4

AVERAGE pH VALUES 1977-1979

Site	March		June		September*		December*	
	Range	Average	Range	Average	Range	Average	Range	Average
I (B)	8.1-8.4	8.2	7.8-8.2	8.0	7.7-7.9	7.8	7.8-7.9	7.85
(B)	8.4	8.4	7.8-8.2	8.1	7.9-8.1	8.0	7.9-9.0	8.5
III (TG)	7.7-8.3	8.1	7.3-7.5	7.4	7.3	7.3	7.3-7.8	7.55
IV (TG)	7.4-8.1	8.0	7.6-8.1	7.9	7.5-7.9	7.7	6.6-7.5	7.01
V (P)	5.5	5.5	6.1-6.2	6.15	6.1-6.3	6.2	6.3-6.6	6.45
VI (P)	5.5	5.5	5.4-5.7	5.5	5.6-5.78	5.65	5.9-6.4	6.15

* No readings for 1978.

4.3 Discussion

All three lagoons gave differing ranges in salinity throughout the year. Byenup is by far the most brackish whilst Poorginup is the freshest. It is therefore considered that to apply a blanket salinity requirement to all lagoons is

inappropriate when it is expressed as an allowable ppm change of concentration. It is better that each lagoon should be treated separately.

To allow Byenup to increase by up to 2 500 ppm will allow an already brackish lagoon to become more brackish and will probably have negligible or limited effect on the flora and fauna of the lagoon. However to allow Toordit-Garrup and Poorginup to increase by 2 500 ppm would result in two freshwater lagoons becoming very brackish. It would appear that the maximum permissable increase in salinity per lagoon should be limited to a flat percentage so that although each lagoon could increase by the same percentage the actual increase in mg/litre would be less in the fresher lagoon than in the brackish lagoon.

Each lagoon also has a different range in pH for the sampling periods throughout the year. Byenup is generally in excess of 8.0, Toordit-Garrup ranges from 7.05 to 8.1 and Poorginup ranges from 5.5 to 6.6. For the lease to require pH measurements to be kept below 8.0 units when one lagoon is already consistently above that figure and another's natural range takes it above that figure, is to place the Mining Company in an impossible position. Similarly the requirement to prevent a change in pH by 1 unit will be difficult to control particularly when there have been examples of greater differences in the lagoons natural state.

It would once more appear that each lagoon should be treated separately and a specific range given for each lagoon within which the pH should remain.

5. LAGOON HYDROLOGY

The previous sections have dealt exclusively with the two year set of chemical analyses. However, before proceeding with any recommendations for variations to the lease requirements, it would be well to consider the position of Byenup, Toordit-Gurrup and Poorginup within the general scope of shallow lake hydrology.

The three lagoons are principally sustained by rainfall and run-off from limited catchment areas. There may also be some groundwater input. Lack of suitable topographical maps has prevented an assessment of catchment sizes, but basically surface flow is from the south into Poorginup which on isolated occasions overflows into Toordit-Gurrup.

Most of the run-off to Poorginup is from forested areas and consequently the water is fresh though low in pH. As these forested areas are reserves, extensive clearing is unlikely in the future and it is likely therefore that there will be little change in the quality of run-off.

Run-off to other lagoons, apart from overflow from Poorginup, is not from forest areas or wholly from timbered areas; some additional run-off to Byenup is received from cleared areas. As clearing of previously timbered areas has led elsewhere to increases of salinity in both ground and surface waters the danger exists that there could be a natural increase in salinity occurring at least in Byenup.

There is an imbalance in the amount of rainfall falling in the cathcments and the amount of evaporation. The average annual rainfall for the study area is about 832 mm (Table 1) whilst evaporation is about 1 050 mm per annum (Fig.5), and it is possible that there is an increment of groundwater flow to the lagoons to balance the deficit. Although no definite evidence of groundwater flow into the lagoons has been located, a saline seepage on a cleared slope west of Byenup has been reported, and saline water has been sampled from a well eleven metres east of Byenup (Geotechnics 1972). If saline groundwater is maintaining a base level supply to the lagoons then it is likely that there will be an overall increase in salinity over the years irrespective of mining. Two years of sampling is totally inadequate to determine such a trend.

Lack of detail bore data in the area precludes any definite statements on groundwater quality however ample evidence elsewhere indicates that, under appropriate conditions, extensive clearing of previously timbered land has lead to a rise in groundwater levels bringing salt to the surface. The aforementioned saline

seep is evidence of this occurring in the study area.

Insufficient bore data exists to determine any groundwater flow patterns to the lagoons and a comprehensive drilling program would be essential to fully outline groundwater conditions in the area around and beneath the lagoons.

At present it is impossible to quantify the amount of salt in storage in the lagoons at any one time. For these figures to be obtained detailed contouring of the lagoon bottoms is required together with gauged water levels. The amount of salt in the lagoon at any time can then be obtained from the volume of water in the lagoon and its salinity. A consistent increase in salt storage from one sample period to the next would indicate increments from saline groundwater or run-off. if this annual increase could be determined, due allowance could be written into the lease requirements.

From these comments it can be seen that a considerable amount of data is required to enable a comprehensive study of these lagoons and their hydrology. The program to obtain these data would be costly and time consuming and would involve:

a) a detailed drilling program around and within the lake, with all bores being surveyed and levelled,
b) regular measurements of groundwater levels and quantities,
c) detailed contouring of the lagoons beds and the catchments areas, and
d) regular measurement of lagoon water levels.

Such a program would be justified if continued monitoring indicated the existence of an upward trend in lake salinities. if in the meantime mining had commenced, the proposed investigations should be undertaken, either by the Government, or by some joint arrangement with the Mining Company as part of the lease requirements. A joint financing arrangement is suggested primarily because even with the full data provided by a comprehensive investigation, it might not be possible to separate deleterios effects due to mining from those arising from other causes such as forest clearing.

6. CONCLUSIONS

6.1 Sampling

Sampling should continue on a three-monthly basis, but the components analysed should be more consistent. Total dissolved solids and pH should always be measured. Sampling should continue at the six designated locations, but because there is very little difference between top and bottom samples at each location, it is recommended that only one sample be taken from each site, ideally at mid-depth.

As well as conductivity and pH being measured on-site, samples should also be forwarded to the Government Chemical Laboratories for analyses and the results should be forwarded to the Geological Survey on a more regular basis than has been the case to date.

It is understood that mining at nearby Cowerup is likely to continue for about another five years and it is recommended that the current sampling program should continue throughout that period. Continued analysis of salinity trends can be carried out throughout this period on an annual basis.

6.2 Salinity

The salinity measurements to date have shown a regular six monthly cycle, with lowest salinities occurring at the end of winter and highest at the end of summer. This is to be expected in such shallow lake environments where recharge is derived from annual rainfall and run-off.

Byenup is the most brackish of the lagoons and has the wider range of salinities; Toordit-Gurrup is generally fresh but is close to becoming slightly brackish in summer. Poorginup is generally fresh, but being the smaller of the three is prone to drying-up during summer.

6.3 pH

The cycle of fluctuations evidenced in salinity measurements is not repeated in pH figures as far as can be ascertained from the limited data available

Byenup is the most alkaline lagoon and Poorginup the most acidic. In the two year period of measurements the pH of Byenup has consistently exceeded the 8 units of the proposed lease requirements and the late summer readings from Toordit-Gurrup have also been greater than 8.

A difference of more than 1 unit of pH has been observed in all lagoons at all sampling point during the observation period. Clearly there must be some adjustment of the lease requirements.

6.4 Lagoon Hydrology

Consideration should be given to implementing a program of drilling, levelling, sampling and testing, of bores and lagoons as outlined in section 5, to enable a study of the interaction of groundwater and lagoon water in this area.

This program could either be carried out by the Government with the objective of establishing the natural water and salt balances of the lagoons prior to mining, or on a jointly financed basis with the Mining Company subsequent to the commencement of mining and the identification of an upward trend in salinity.

As rainfall variability could possibly obscure salinity trends over a five year monitoring period, the assessment of such trends is best made in relation to successive estimates of the total amount of salt stored in each lagoon. This necessitates the monitoring of lagoon stages with the aid of an appropriate stage gauge when water samples are collected. An accurate bathymetric map of each lagoon should be prepared so that lagoon volume may be calculated from a stage reading. This may then be used with the salinity to estabish the salt storage at that time.

6.5 Proposed Lease Requirements

A blanket tolerance of 2 500 mg/litres is considered inadvisable in view of the freshness of Toordit-Gurrup and Poorginup and the possible effects of such an increase in their salinity. It is therefore proposed to amend the relevant

sections of the lease requirements.

It is important to note that the following recommendations are based on two years of sampling only. All figures given below must be regarded as subject to changes as further years of sampling prior to mining refines the base levels of salinity and pH.

It is recommended that consideration be given to limiting the allowed increase in salinity to a maximum figure 50% greater than the corresponding average figure for each of the four reference months, but that an absolute value should apply for each lake, above which the salinity should never rise. In this way Byenup would still remain brackish, Toordit-Gurrup would still remain fresh to slightly brackish, and Poorginup would remain fresh thus allowing the ecological balance to be maintained in the lagoon environments. The average lagoon salinities and the 50% increased figures are given in Table 5 below (in mg/litre) together with the relevant absolute values.

TABLE 5

AVERAGE LAGOON SALINITIES
WITH 50% INCREASE AND ABSOLUTE VALUES

Site	Absolute Values	March Average	March Plus 50%	June Average	June Plus 50%	September Average	September Plus 50%	December Average	December Plus 50%
I (B)	6000	4493	6000*	3833	5750	2103	3195	2650	3975
II (B)	6000	4403	6000*	3920	5880	2365	3548	2686	4629
III (TG)	1800	1330	1800*	1163	1745	865	1298	814	1221
IV (TG)	1800	1262	1800*	1155	1733	840	1260	900	1350
V (P)	1500	900	1350	660	990	587	881	923	1385
VI (P)	1500	900	1350	720	1080	340	510	443	665

* 50% increase would exceed absolute value

With regards to pH levels, the existing proposed lease requirement listing 8.0 units as the maximum level would place the mining company in an impossible situation as 8.0 is exceeded in normal conditions. Similarly ranges in excess of one unit are also recorded.

It is therefore recommended that consideration be given to placing the following limits on pH; that the pH does not exceed more than one unit above or below the average figure for that month and for that lake within the range 5-9. The relevant figures are given in Table 6 below.

TABLE 6

AVERAGE LAKE pH WITH ALLOWED LIMIT

	March		June		September		December	
	Average	With Limit	Average	With Limit	Average	With Limit	Average	With Limit
I (B)	8.2	7.2-9.0	8.0	7.0-9.0	7.8	6.8-8.8	7.85	6.8-8.8
II (B)	8.4	7.4-9.0	8.1	7.1-9.0	8.0	7.0-9.0	8.5	7.5-9.0
III (TG)	8.1	7.1-9.0	7.4	6.4-8.4	7.3	6.3-8.3	7.55	6.5-8.5
IV (TG)	8.0	7.0-9.0	7.9	6.9-8.9	7.7	6.7-8.7	7.05	6.1-8.1
V (P)	5.5	5.0-6.5	6.15	5.1-7.1	6.2	5.2-7.2	6.45	5.4-7.4
VI (P)	5.5	5.0-6.5	5.5	5.0-6.5	5.65	5.0-6.6	6.15	5.1-7.1

It is therefore recommended that, if the lease is to be granted, the proposed lease requirements for water quality be amended to read, that,

" the lessee, taking such measures as are necessary and to the satisfaction of the Director of Fisheries and Wildlife, or his nominee, to:

a) prevent the total dissolved solids content of the waters of any lake, swamp, or lagoon (as measured in mg/litre) increasing by more than a figure equal to or greater than 50% above the appropriate monthly mean level of the salts contained therein, up to an absolute value of 6 000 mg/litre for Byenup, 1 800 mg/litre for Toordit-Gurrup, and 1 500 mg/litre for Poorginup, and
b) prevent any change of pH reading of the waters of any lake, swamp or lagoon to a level in excess of 1.0 unit of pH above or below that appropriate monthly mean level and to prevent any divergence of pH outside the range 5.0 to 9.0, during the period of mining, during which time the Director of Fisheries and Wildlife, or his nominee, may carry out programs or water sampling and analysis as agreed with the Under Secretary for Mines."

The present mean levels and absolute values for salinity and pH are as established in Tables 5 and 6. However, if sampling continues up to mining commencement it is likely that these figures will be modified. In addition any natural increases in salinity may have been determined. Thus the tables of values would need to be updated each year during the period preceding mining.

A.T. Laws
Senior Hydrogeologist

ATL:AM
August 2nd 1979

REFERENCE

Geotechnics (Aust) Pty Ltd 1972, Report on the hydrology of the Lake Muir area, near Manjimup

TABLE 2

WATER ANALYSES - LAKES BYENUP, TOORDIT-GURRUP, AND POORGINUP

Site	Date / Criteria		April 1977	June 1977	Sept. 1977	Dec 1977	March 1978	June 1978	Sept. 1978	Dec 1978	March 1979
I	TDS	T	TDS 5900 NaCl 5290 pH 8.4	4400	1930	2470	3850	3550	2340		
		B			2040	2520	3820	3550	-		
	NaCl	T		3980	1910	2340	3350	3280	1240*	2850+	4000+
		B			1950	2360	3350	3250	-	2850+	-
	pH	T		8.2	7.9	7.9	8.2	8.1	-		
		B			7.7	7.8	8.1	7.8	-		
II	TDS	T		4200	2260	2570	3830	3780	2440		4040++
		B			2360	2520	3840	3780	2400		
	NaCl	T		3760	2230	2520	3400	3325	1310*	2800+	4000+
		B			2190	2360	3350	3325	1310*	2800+	4000+
	pH	T		7.8	8.1	7.9	8.4	8.2	-		8.4++
		B			7.9	9.0	8.4	8.2	-		
III	TDS	T		1150	970	970	1400	1170	760		
		B			960	960	1290	1170	770		
	NaCl	T		974	835	805	1120	1050	380*	700+	950+
		B	TDS T 1450 B 1460 NaCl T 1200 B 1190		835	841	1000	1050	382*	800+	-
	pH	T		7.3	7.3	7.3	7.7	7.5	-		
		B			7.3	7.8	8.2	7.5	-		
IV	TDS	T	pH T 8.3 B 8.3	1130	950	960	1400	1170	700		870++
		B		1140	1000	960	1290	1180	710		
	NaCl	T		927	814	770	1090	1020	350*	700+	900+
		B		927	814	790	1000	1030	352*	700+	900+
	pH	T		8.1	7.9	7.5	7.4	7.9	-		8.0++
		B		8.1	7.5	6.6	8.1	7.6	-		

TABLE 2 continued

WATER ANALYSES - LAKES BYENUP, TOORDIT-GURRUP, AND POORGINUP

Site	Criteria		April 1977	June 1977	Sept. 1977	Dec 1977	March 1978	June 1978	Sept. 1978	Dec 1978	March 1979
	Date										
	TDS	T		680	660	910		640	420		
		B			680	960		-	-		
V	NaCl	T		536	556	790		546	180*	750+	
		B			556	765		-	-		
	pH	T	DRY	6.1	6.3	6.3	TDS 900**	6.2	-		
		B			6.1	6.6	NaCl 740**	-	-		DRY
							pH 5.5**				
	TDS	T		580	300	430		760	410		
		B			310	440		820	-		
VI	NaCl	T		475	214	331		566	165*	350+	
		B			241	326		625	-		
	pH	T		5.7	5.7	5.9		5.5	-		
		B			5.6	6.4		5.4	-		

T = Top sample

B = Bottom sample

* in ppm Cl

** no site given

\+ in situ measurements

++ Gov. Chem. Labs measurements

Sites I & II L. Byenup Sites III & IV L. Toordit Gurrup Sites V & VI L. Poorginup

All readings from Govt. Chem. Labs. unless otherwise stated. TDS and NaCl in ppm (mg/litre)

TABLE 2

WATER ANALYSES - LAKES BYENUP, TOORDIT-GURRUP, AND POORGINUP

Site	Date / Criteria		April 1977	June 1977	Sept. 1977	Dec 1977	March 1978	June 1978	Sept. 1978	Dec 1978	March 1979
I	TDS	T	TDS 5900 NaCl 5290 pH 8.4	4400	1930	2470	3850	3550	2340		
		B			2040	2520	3820	3550	-		
	NaCl	T		3980	1910	2340	3350	3280	1240*	2850+	4000+
		B			1950	2360	3350	3250	-	2850+	-
	pH	T		8.2	7.9	7.9	8.2	8.1	-		
		B			7.7	7.8	8.1	7.8	-		
II	TDS	T		4200	2260	2570	3830	3780	2440		4040++
		B			2360	2520	3840	3780	2400		
	NaCl	T		3760	2230	2520	3400	3325	1310*	2800+	4000+
		B			2190	2360	3350	3325	1310*	2800+	4000+
	pH	T		7.8	8.1	7.9	8.4	8.2	-		8.4++
		B			7.9	9.0	8.4	8.2	-		
III	TDS	T		1150	970	970	1400	1170	760		
		B			960	960	1290	1170	770		
	NaCl	T		974	835	805	1120	1050	380*	700+	950+
		B	TDS T 1450 B 1460 NaCl T 1200 B 1190		835	841	1000	1050	382*	800+	-
	pH	T		7.3	7.3	7.3	7.7	7.5	-		
		B			7.3	7.8	8.2	7.5	-		
IV	TDS	T	pH T 8.3 B 8.3	1130	950	960	1400	1170	700		870++
		B		1140	1000	960	1290	1180	710		
	NaCl	T		927	814	770	1090	1020	350*	700+	900+
		B		927	814	790	1000	1030	352*	700+	900+
	pH	T		8.1	7.9	7.5	7.4	7.9	-		8.0++
		B		8.1	7.5	6.6	8.1	7.6	-		

TABLE 2 continued

WATER ANALYSES - LAKES BYENUP, TOORDIT-GURRUP, AND POORGINUP

Site	Criteria		April 1977	June 1977	Sept. 1977	Dec 1977	March 1978	June 1978	Sept. 1978	Dec 1978	March 1979
	TDS	T		680	660	910		640	420		
		B			680	960		-	-		
V	NaCl	T		536	556	790		546	180*	750+	
		B			556	765		-	-		
	pH	T	DRY	6.1	6.3	6.3	TDS 900**	6.2	-		
		B			6.1	6.6	NaCl 740**	-	-		DRY
							pH 5.5**				
	TDS	T		580	300	430		760	410		
		B			310	440		820	-		
VI	NaCl	T		475	214	331		566	165*	350+	
		B			241	326		625	-		
	pH	T		5.7	5.7	5.9		5.5	-		
		B			5.6	6.4		5.4	-		

T = Top sample

B = Bottom sample

* in ppm Cl

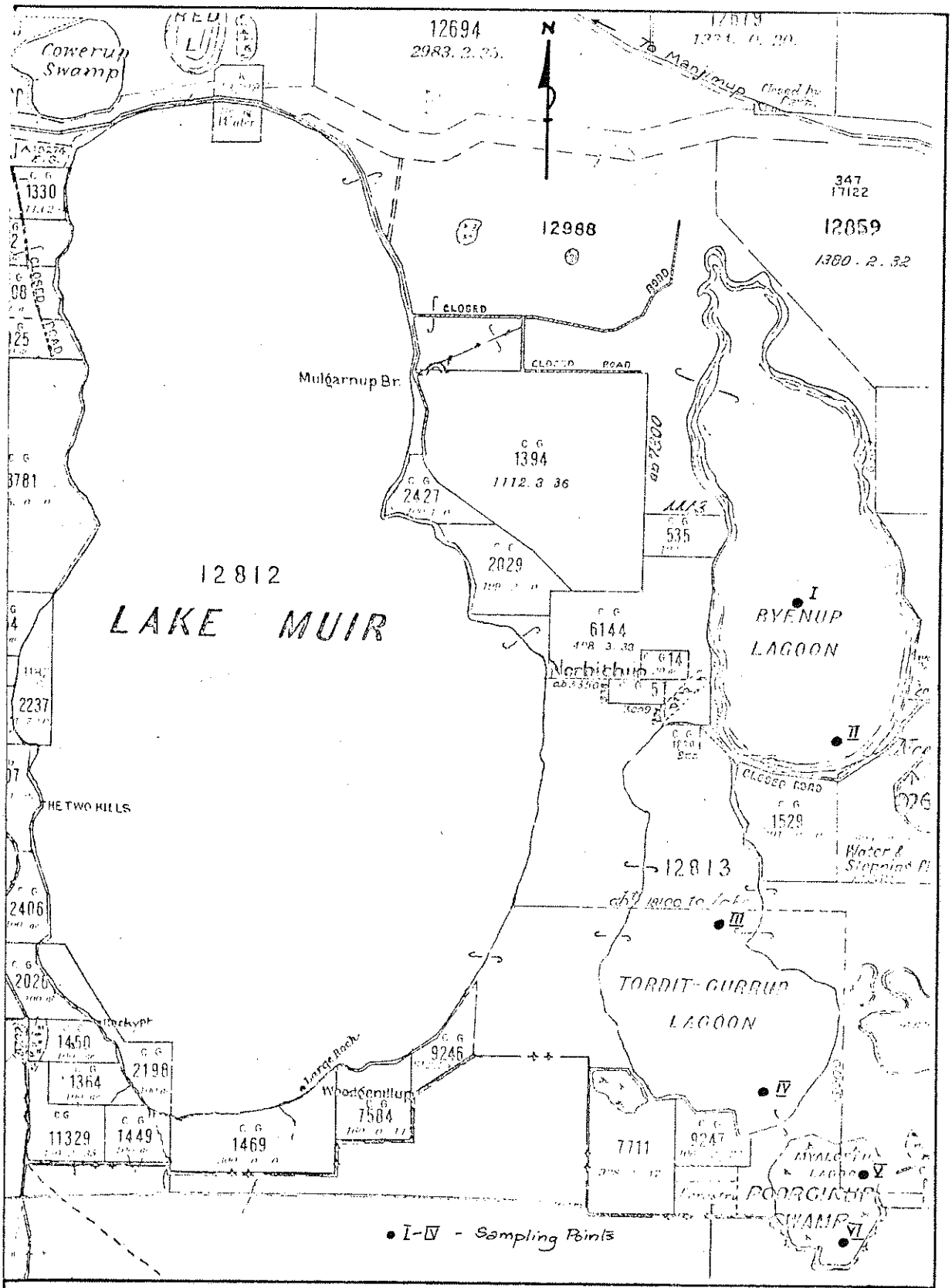
** no site given

\+ in situ measurements

++ Gov. Chem. Labs measurements

Sites I & II L. Byenup Sites III & IV L. Toordit Gurrup Sites V & VI L. Poorginup

All readings from Govt. Chem. Labs. unless otherwise stated. TDS and NaCl in ppm (mg/litre)



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

	Initial	Date
Comp	ATL	
Drawn	ATL	
Chkd		
Apvd		

LOCALITY MAP

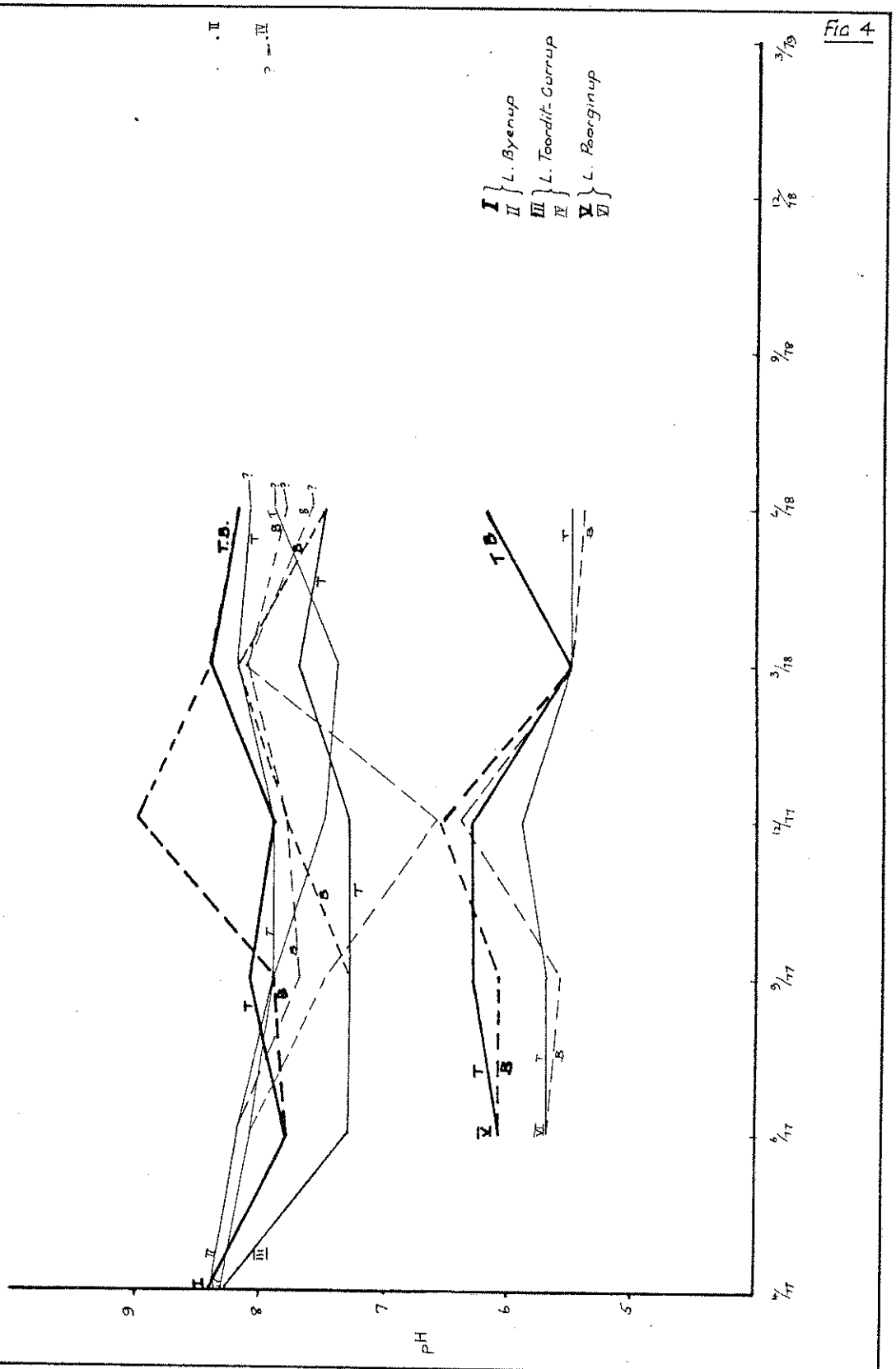
Map Index

To accompany Hydro Report 2003 by A.T. Lewis M.Sc. M.Aust.IMM

Figure 1

81712/12/78-2,250--R72

Fig 4



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

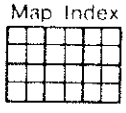
	Initial	Date
Comp	ATL	2/7
Drawn	ATL	2/7
Chkd		
Apvd		

pH MEASUREMENTS

L. BYENUP , L. TOORDIT-GURRUP , L. POORGINUP

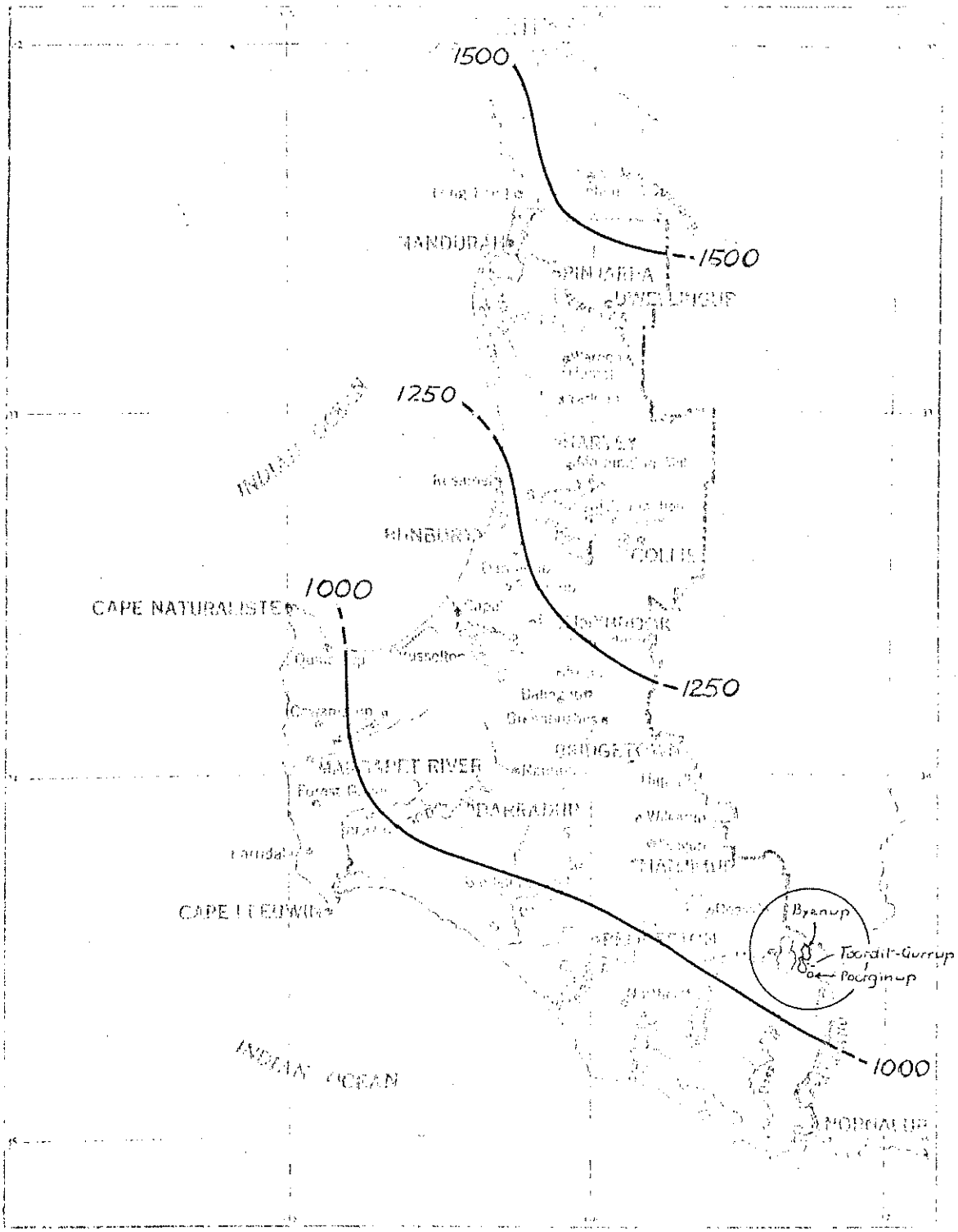
To accompany Hydro Report 2003 by A.T. Laws M.Sc. M.Aus.I.M.M.

Map Index



81712/12/78–2,250–R72

Fig. 5



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

	Initial	Date
Comp		
Drawn		
Chkd		
Apvd		

Average Annual Evaporation (in mms)

Map Index

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Figure 5

81712/12/78–2,250–R72