DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1973/166

LAKE GEORGE, N.S.W.: ITS RELEVANCE TO SALINITY PROBLEMS IN AGRICULTURE

by

G.M. Burton and E.G. Wilson

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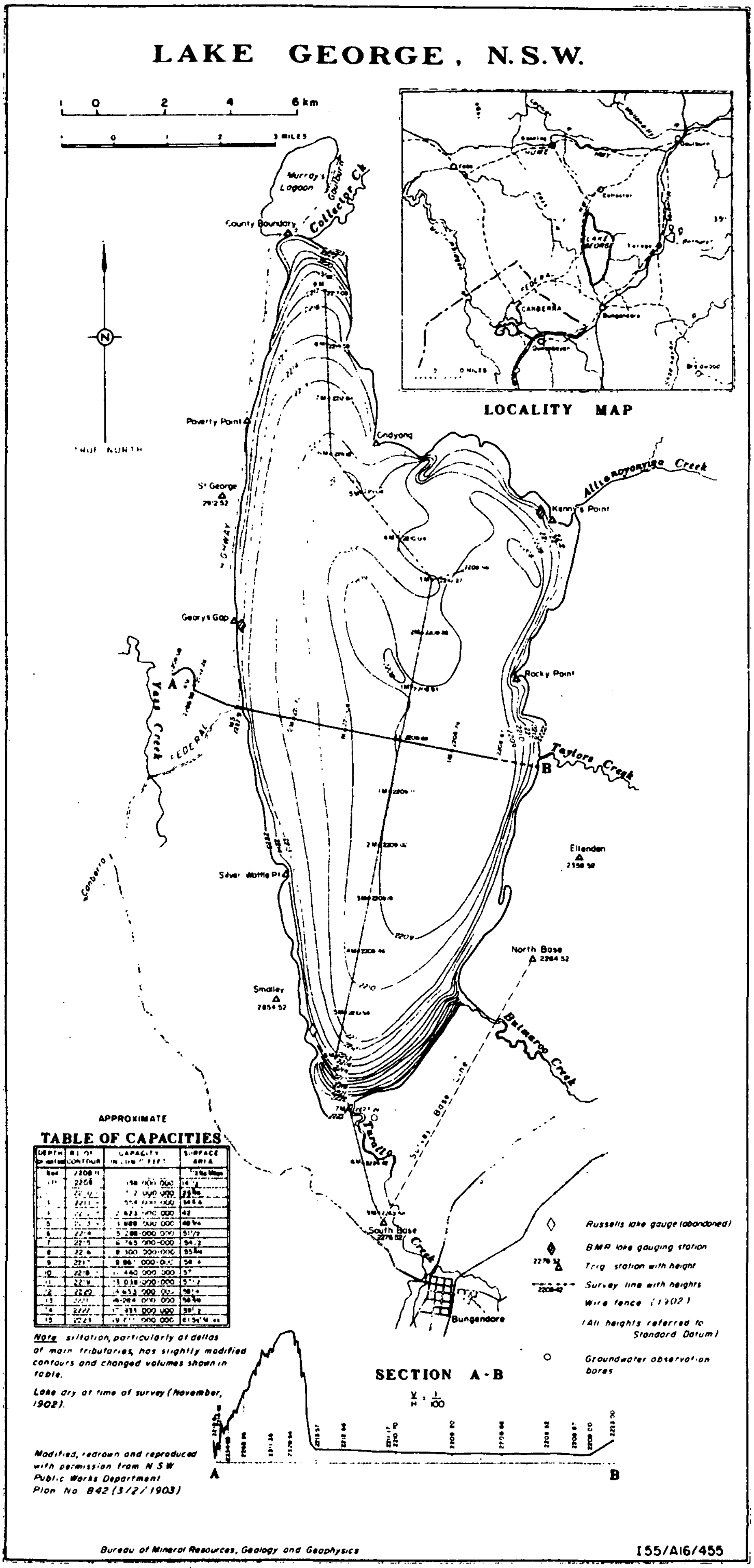

DEPTH [illegible]	R.L. OF CONTOUR	CAPACITY IN CUBIC FEET	SURFACE AREA
Bed	2208 ft		[illegible] Miles
[illegible]	2208	[illegible] 000 000	14 [illegible]
[illegible]	22[illegible]	[illegible] 2 000 000	2[illegible]
3	2211	[illegible] 000 000	3[illegible]
4	22[illegible]	2 623 000 000	42
5	22[illegible]	3 [illegible] 000 000	48 [illegible]
6	2214	5 288 000 000	51½
7	2215	6 765 000 000	54 [illegible]
8	2216	8 300 000 000	55[illegible]
9	2217	9 [illegible] 000 000	56 [illegible]
10	2218	[illegible] 440 000 000	57
11	2219	13 038 000 000	57[illegible]
12	2220	14 653 000 000	58[illegible]
13	2221	16 284 000 000	58[illegible]
14	2222	17 [illegible] 000 000	59[illegible]
15	2223	19 [illegible] 000 000	61 [illegible] Miles

To accompany Record 1973/166

FOREWORD

This record was prepared from the notes of a lecture entitled 'Trends in water levels and salinity in Lake George' which was delivered to the Symposium on Salinity Problems, at Mildura N.S.W., by G.M. Burton, in April 1971. A draft of this record was being prepared by Burton at the time of his death in November, 1972. It was subsequently completed by E.G. Wilson in accordance with the content and form of presentation followed by Burton.

SUMMARY

The Lake George inland drainage basin now contains a small lake which is surrounded by lacustrine sediments deposited from a much larger lake that existed in earlier geological times. The lake hydrograph over the last 153 years is a reflection of climatic conditions of that period, and water balance studies show that the level of the lake at any one time is a normal response to the seasonal and other changes in rainfall, evaporation, and runoff in the basin. For the agriculturalists, changes in the quantity and quality of the water of the lake may be found to coincide with changes in the quality of the soils or of the crops. Such changes may foreshadow the onset of a major change in the hydrology of the basin, and would provide an opportune time for the reassessment of agricultural practices. Additional investigation of the hydrology of Lake George, with monitored stream flows and salinities would provide useful statistical information, and with some refinements may also provide an early indication of major climatic change.

INTRODUCTION

Lake George is the focus of drainage for an internal drainage basin of 932 km^2 (360 square miles) within the Great Dividing Range of southeastern New South Wales. The floor of the lake is 673 m (2208 ft) above sea level and only 105 km (65 miles) inland from the sea. The lake lies at latitude 35°05'S and longitude 149°25'E, 30 km (18 miles) northeast of the national capital, Canberra (Fig. 1).

The level of the lake falls rapidly during major droughts, and on several occasions it has been completely dry. It is a relatively shallow body of water compared to major lakes of the world (Lake Baikaal, USSR depth 1740 m (5710 ft) and Lake Tahoe, USA, 500 m (1643 ft). Over the last 150 years the depth of water in Lake George has rarely exceeded 6.0 m (20 ft) at its deepest point and, as far as is known, has not exceeded 7.5 m (25 ft). Studies of the lake undertaken by geologists and hydrologists have clearly demonstrated that the fluctuation in levels is a normal response to the wide range of climatic conditions encountered in the area.

Within Lake George inland drainage basin, stock-raising and wheat growing are the dominant rural activities, and water for irrigation is mainly drawn from the inflowing streams, rather than from the lake. Much of the alluvium of the lower part of the basin was deposited under lacustrine conditions when the lake was a much larger body of water, and major development of the agricultural potential of the basin could ultimately lead to greater use of irrigation within the basin itself. Study of the lake has indicated that it can provide a considerable amount of data relating to the time factor in the development of salt problems, and its relation to evaporation and rainfall.

CLIMATE

The Lake George area has a continental climate, hot summers and cold winters, typical of most of the tableland agricultural area; however, the bed of the lake is 673 m (2207 ft*) above M.S.L. and the effect of this altitude is to moderate the summer temperature and lower the winter temperature.

Rainfall is about 600 mm (24 in) per annum, and is uniformly distributed throughout the year with about 50 mm (2 in) each month; falls are more reliable in winter and spring than in the other months. Drought conditions do occur from time to time, and occurrences of prolonged rainfall cause flooding in the lowlands within the basin.

The evaporation rate is 1250 mm (50 in) per annum, with the average monthly evaporation rate ranging from over 175 mm (7 in) in December and January, to about 31 mm (1.25 in) in June and July.

Because evaporation is so high in the summer months, soil water for plant growth is available only from autumn to spring; however, because heavy frost inhibits plant growth in winter, the main growth periods are during autumn(from late March to May) and spring (from late September to November), or on those occasions during the summer when rainfall temporarily recharges the soil water for a limited period (Slatyer, 1960).*

LAKE GEORGE HYDROGRAPH

Lake George had a maximum depth of 1.78 m (5.85 ft) and an area of 129 km^2 (50 square miles) on the first January, 1971. The lake is classified as a tectonic lake by Hutchinson (1957, 1967), its origin being ascribed to disruption by faulting of a prior drainage system to form the lake. The hydrograph of an internal lake such as Lake George is believed by many to show important changes in climate more clearly than do the direct measurements of individual meteorological parameters.

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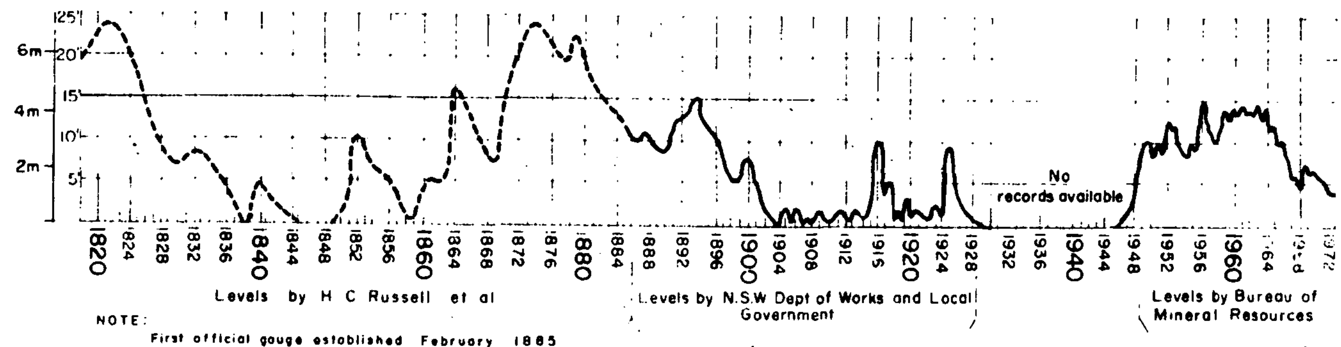
* Data for Lake George are being converted progressively and will be completed in 1973; conversion factors are given in Appendix, Table 1.

* The conclusions set out by Slatyer in his report apply specifically to the Yass valley. His evaporation figures were based on Canberra records and they correlate well with the figures for Yass, Queanbeyan, and Goulburn; in the absence of more representative records, Slayters conclusions can be applied to the agricultural part of the southern tableland.

LAKE GEORGE, N.S.W.
HYDROGRAPH - DEPTH
1819-1972



(Adapted from Jennings, Noakes, Burton 1964.)
(Updated to December, 1972)

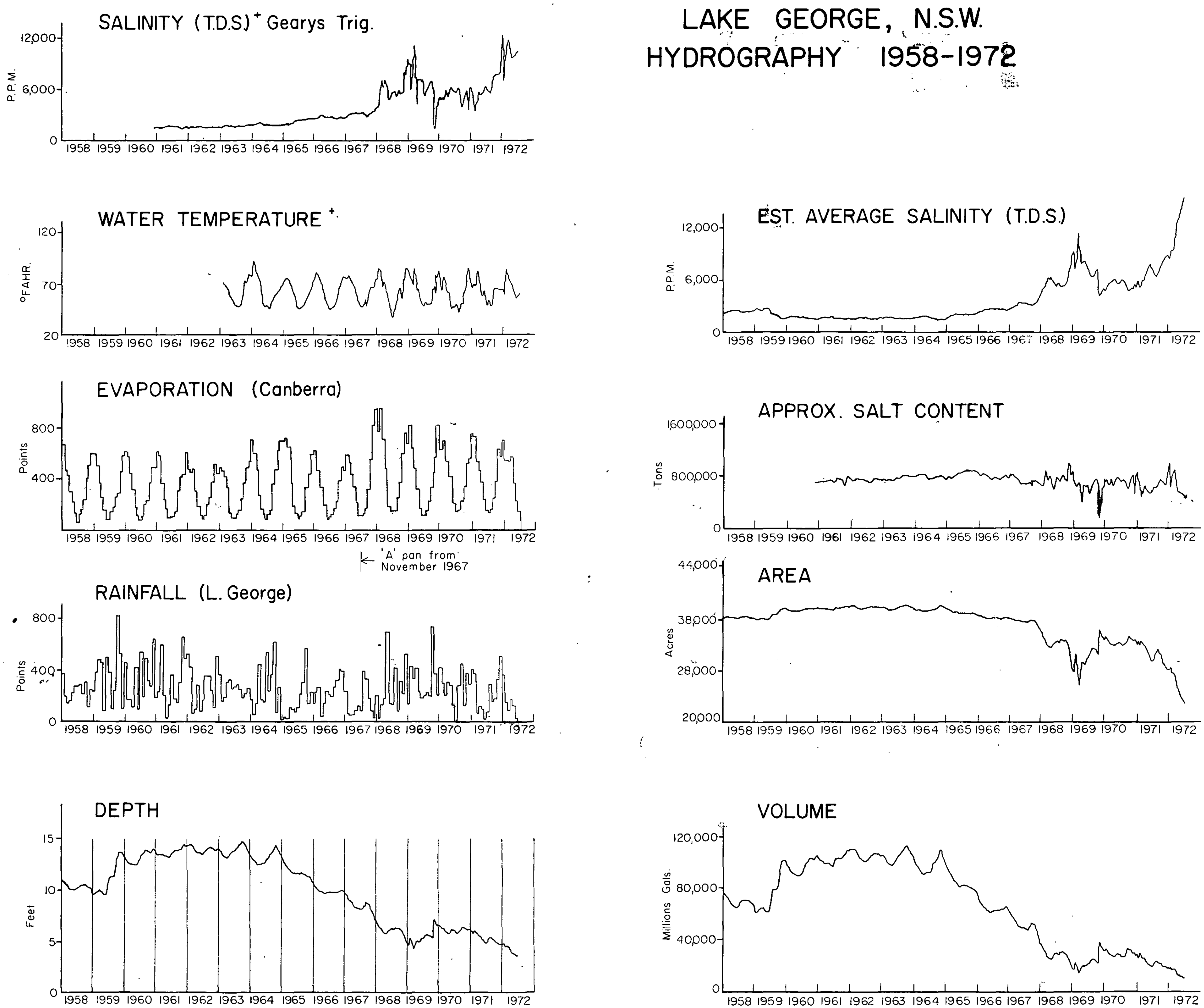


Figure 3.

+Readings at B.M.R. Gauging Station, Gearys Trig.

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M(G) 150

The hydrograph of the maximum depth of the lake (Fig. 2) is one of the longest recorded (152 years) in Australia, and it provides a hydrological record of events against which other factors dependent on the hydrograph can be compared, such as salinity. The hydrograph (Fig. 2) is a composite record, showing variations of pattern which reflect the detail and reliability of the original observations; other variations could be attributable to some changes in land management. After making allowances for such variations, the hydrograph appears to fall into three segments with different characteristics.

1819 - 1900 water depths ranging to 7.4 m (24 ft)

1900 - 1950 lake dry or lake bed only partially covered with water; depths generally less than 1.5 m (5 ft)

1950 - 1973 lake depth generally between 3 and 4.5 m (10 and 15 ft) but falling rapidly from mid 1964 to December 1972

Lamb (1966) considered that the unexpected large changes in the level of a number of lakes in Africa in the early 1960's was a response to abnormal rainfall which in turn can be traced to a marked shift in the pattern of wind circulation. He regards this change as a major change that is likely to persist for a decade, rather than a transitory change. He concluded from his lake studies and other data that significant and widespread changes in climate took place in 1895 and in 1960.

Figure 1 shows that within a few years of 1895 and 1960, a lowering of the water level in Lake George commenced and led to the lake drying up in 1903, and to its present low level of less than one metre in 1973.

From the study of the hydrograph of a lake such as Lake George, agriculturalists may be able to prove the existence of significant climatic changes in the past. Climate affects not only the quantity of the water supply, but also the quality of the water, and the latter, depending on the method of water application, is reflected in plant growth. At the same time, other climatic changes such as temperature apply stresses directly to plant growth. It is possible that the agriculturalists may find variations in the hydrograph reflected in changes in quality of the soils, or in the quality of the crops. The possible early recognition of such a change, whilst the change is taking place would provide an opportunity of assessing current agricultural practices in the light of possible climatic change, and of adjusting those practices accordingly.

Water quality

Changes in the quality of the water in Lake George have been studied in some detail (Burton, 1972). Analyses of lake waters in January 1969 and February 1973 are set out in Tables 2 and 3. Salinity of the lake water has ranged from 1500 parts per million (ppm), total dissolved solids, to over 40 000 ppm, and the sodium absorption ration (SAR) has ranged from 14 to over 50 (1969); for the higher concentrations of brine in February 1973, the very high figure for the SAR serves no useful purpose.

During the latter part of the 1965-68 drought, the high rates of evaporation brought about the formation of thin deposits of salts around the lake margin when the salt concentration exceeded 12 000 ppm; the salts were subsequently dispersed and carried away by winds. The problems of agricultural use of brine and highly saline waters are well documented; however, the fluoride content of waters of lesser salinity should always be noted.

Water balance studies (Burton, 1972) show that Lake George responds normally to seasonal and longer changes in rainfall, evaporation and run-off (Fig. 3). Table 1 is derived from the following water balance equation.

Change in storage equals Rainfall on lake plus Run-off into lake less Evaporation from the lake.

TABLE 1: ESTIMATED ANNUAL WATER BALANCE

LAKE GEORGE N.S.W. (1958-1970)

Hydrological Seasons and Month	Precipitation Points (A)	Lake Level Ft. (B)	Change in Volume Ac.-Ft. (C)	Precipitation on Lake Ac.-Ft. (D)	Evaporation from Lake (v. approx.) Vol. Ac.-Ft. (E)	Depth Ft. (F)	Inflow to Lake (v. approx.) Ac.-Ft. (G)
'Winter'							
May	222	0.00	-85	6489	7078	0.20	504
June	167	0.13	4613	4938	2380	0.07	2055
July	239	0.24	9035	7277	2352	0.07	4110
Aug.	246	0.18	6480	7272	2195	0.06	1403
Sept.	271	0.15	5545	8173	4690	0.13	2062
Oct.	376	0.17	6095	11288	8468	0.24	3275
Total	1521	0.87	31683	45437	27163	0.77	13409
'Summer'							
Nov.	260	-0.07	-2559	7821	10494	0.29	114
Dec.	310	-0.33	-11510	9249	20759	0.59	0
Jan.	253	-0.27	-9959	7634	17593	0.49	0
Feb.	194	-0.26	-9394	5663	15057	0.42	0
Mar.	201	-0.23	-8340	5764	14104	0.40	0
Apr.	209	-0.11	-4105	6069	10174	0.28	0
Total	1427	-1.27	-45867	42200	88181	2.47	114
Annual Total	2948	-0.40	-14184	87637	115344	3.24	13523

Note: The period covers the severe drought of 1965-1968.

Method slightly underestimates evaporation, particularly in 'winter', and slightly underestimates run-off particularly in 'summer'.

(A) Average of monthly rainfalls at Bungendore and Collector ; (B) Monthly change in lake level ; (C) Area for particular stage of lake x (B); (D) Area for particular stage of lake x (A); (E) Area for particular stage of lake x (F); (F) Monthly evaporation in feet (Canberra figures); (G) = (C) and (E) - (D)

TABLE 2

WATER ANALYSES - LAKE GEORGE - 1969

Sampling Point (Date) BMR Sample No.		Geary's Trig (30/1/69) 69270001		Kenny's Point (30/1/69) 69270002	
pH		8.9		8.9	
Conductivity (umhos/cm 25°C)		16250		11900	
		ppm	meq/L	ppm	meq/L
T.D.S.		9893		7163	
Calcium	Ca	18	0.9	22	1.1
Magnesium	Mg	205	16.9	152	12.5
Sodium	Na	3506	152.5	2504	108.9
Potassium	K	17	0.4	13	0.3
Iron	Fe				
Manganese	Mn	0.02	0.001	0.03	0.001
Boron	B				
Fluoride	F	1.88	0.10	1.54	0.08
Chloride	Cl	4995	140.9	3535	99.7
Sulphate	SO_4	470	9.8	325	6.8
Bicarbonate	HCO_3	1085	17.8	930	15.2
Carbonate	CO_3	66	2.2	33	1.1
Phosphate	PO_4	0.94	0.03	1.01	0.032
Silica	SiO_2	4.56	0.15	3.14	0.11
Nitrate	NO_3	0.16	0.003	0.10	0.002
Nitrite	NO_2	ND $<$ 0.05		ND $<$ 0.05	
Bromide	Br	23	0.29	16	0.20
Aluminium	Al_2O_3				
Copper	Cu	0.02		0.02	
Zinc	Zn	0.04		0.01	
Strontium	Sr	0.75	0.017	0.72	0.016

TABLE 3

WATER ANALYSES - LAKE GEORGE - 1973

Sampling point		Off Gearys Trig.		Off Kennys Point	
Date of sampling		2/2/73		2/2/73	
Sample Number		73270001		73270003	
pH		8.9		8.9	
Conductivity (umhos/cm 25°C)		54052		45953	
		ppm	meq/L	ppm	meq/L
Total Dissolved Solids		44800		38900	
Calcium	Ca	35	1.7	35	1.7
Magnesium	Mg	860	70.7	740	60.9
Sodium	Na	15900	691.7	13700	596.0
Potassium	K	47	1.2	40	1.0
Iron	Fe	0.5	0.018	0.35	0.013
Manganese	Mn	0.17	0.006	0.17	0.006
Boron	B	0.9	0.250	1.3	0.360
Fluoride	F	1.1	0.058	1.05	0.055
Chloride	Cl	23005	648.7	20160	568.5
Sulphate	SO_4	2823	58.8	2391	49.8
Bicarbonate	HCO_3	1565	25.7	1515	24.8
Carbonate	CO_3	565	18.8	450	15.0
Phosphate	PO_4	1.09	0.034	1.04	0.033
Silica	SiO_2	4.5	0.150	1.3	0.043
Nitrate	NO_3	0.25	0.004	0.25	0.004
Nitrite	NO_2	0.03	0.001	0.03	0.001
Bromide	Br	100	1.3	90	1.1
Aluminium	Al	0.40	0.044	0.40	0.044
Copper	Cu	0.10	0.003	0.05	0.002
Zinc	Zn	0.07	0.002	0.12	0.004
Strontium	Sr	2.70	0.062	2.35	0.054

Burton (1972) identified the following important factors affecting the salinity of Lake George:

1. water losses attributable to evaporation in the annual cycle (annual evaporation, 141.85 x 10^6 cubic m^3 (115 000 acre ft) equals the total storage at 1.89 m (6.2 ft stage) calculated in 1971.

2. the variation in salt content of precipitation derived from maritime, continental, and upper atmosphere air masses.

3. the leaching processes in the soils of the catchment.

4. the chemical composition of ground water.

5. the hydrographs of major floods.

In order to understand more fully the factors affecting lake salinity, there is a need for systematic chemical analysis of rainfall to define the chemical characteristics of precipitation from the various air masses; in addition, the salinity of run-off during all stages of flow, the salinity of water in storages and in major streams should be systematically monitored.

CONCLUSIONS

1. Statistical methods of hydrology alone can be inadequate to warn the agriculturalist of the long term severity of salinity problems and to indicate whether or not the drought he encounters is transitory, or is part of a change to a regime of water shortfall. When considered in relation to increases in salinity and higher evaporation, basic changes in farm management and economics may be indicated.

2. It is important that all elements of the hydrological cycle, including groundwater, are monitored, and that chemical studies of the meteorological elements of the cycle are initiated.

3. These studies, when related to the hydrograph of a basin, may have the elements for early detection of significant climatic trends.

REFERENCES

AMBE, Y., 1967 - Secular variation of aridity in the World. Jap. J. Geol. & Geophys., 38, 1, 43-77.

BUREAU OF METEOROLOGY, 1968 - Climatic Survey, Canberra and the Australian Capital Territory. Meteorological Summary, Dec., 1968.

BURTON, G.M., 1972 - Lake George, N.S.W. - notes for Sedimentologists' Excursion, November 1970. Bur. Miner. Resour. Aust. Rec. 1972/79 (unpubl.).

HUTCHINSON, G.E., 1957 and 1967 - A TREATISE ON LIMNOLOGY. (2 Vols - Vol. 1, 1957; Vol. 2, 1967) J. Wiley, New York.

JENNINGS, J.N., NOAKES, L.C., & BURTON, G.M., 1964 - Notes on the Lake George and Lake Bathurst excursion, in Canberra Excursions, Bur. Miner. Resour. Aust. Pamph.

LAMB, H.H., 1966 - Climate in the 1960s. Geogr. J. 132(2), 183-212.

MATVEYEV, A.A., & BASHRNAKOVA, O.I., 1966 - Chemical composition of atmospheric precipitation in some regions of the U.S.S.R. Soviet Hydrology.

SLATYER, R.O., 1960 - Agricultural climatology of the Yass valley. Sci. ind. Res. Org. Aust. Div. Land Res. Reg. Surv. tech. Paper 6.

APPENDIX

Conversion Factors

Inches x 25.40	= Millimetres
Feet x 0.3048	= Metres
Miles x 1.609	= Kilometres
Acres x 4047	= Square metres
Square miles x 2.59	= Square kilometres
Gallons (imp.) x 0.0045	= Cubic metres
Acre-feet x 1234	= Cubic metres
Tons x 1016	= Kilograms