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Wood, I. R.

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THE UNIVERSITY OF NEW SOUTH WALES

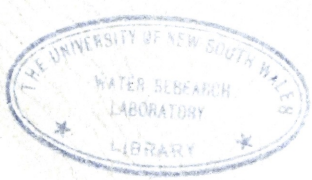
WATER RESEARCH LABORATORY

REPORT No. 30

Hydrologic Investigation of Cooling Water Reservoir Gardiner's Creek

by

I. R. Wood



SEPTEMBER, 1960

The University of New South Wales

WATER RESEARCH LABORATORY

HYDROLOGIC INVESTIGATIONS FOR THE HUNTER VALLEY POWER STATION NO.1

GARDINER'S CREEK

by

I.R.Wood

Project No.3

First Report to the Electricity Commission of New South Wales.

September 1960.

https://doi.org/10.4225/53/578860fd051a7

PREFACE

This study forms part of a series of hydraulic investigations undertaken by the Water Research Laboratory of the University of New South Wales at the request of the Electricity Commission of New South Wales. The study was commenced in March 1960 and completed in April 1960.

Throughout the course of the study, close liaison was maintained with the Electricity Commission through an engineer on the staff of the Commission's Project Development Section, Mr. N.Lamb, whose friendly co-operation in the supply of all necessary data is gratefully acknowledged. Internal progress reports of test results were made available to the Commission as data became available.

The study was carried out at the Water Research Laboratory, Manly Vale, N.S.W., by Messrs. J.R.Toomey, I.R. Wood and C.J.Mackenzie. The Electricity Commission programme is under the direct supervision of Mr. D.N.Foster of the Laboratory Research staff.

H.R.Vallentine
Assoc.Professor of Civil Engineering
Officer-in-Charge of the Water Research Laboratory.

22.11.60.

CONTENTS

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SUMMARY

As part of the Electricity Commission's future expansion programme it is planned to construct Power Stations on the Hunter River Valley near Maitland. For one of these stations it is proposed to build a cooling pond on Gardiners Creek a tributary of the Hunter River. Portion of the water for this pond will be pumped from the Hunter River and portion will be obtained from the yield from the Gardiners Creek catchment.

This report, which is in two sections, covers -

(1) the preliminary yield studies for Gardiners Creek, and

(2) the maximum probable inflow flood hydrographs to the cooling pond for various storm durations.

The yield studies which are based on the results from similar catchments close to the Gardiners Creek catchment show that the estimated average flow in Gardiner's Creek is 4.5 cusecs, this flow being equalled or exceeded 11 per cent of the time during [illegible] 4.5

The flood studies which are based on maximum probable rainfall estimates and synthetic unit graph procedures indicate a maximum inflow peak of 33,000 cusecs.

Very little rainfall and runoff data was available on which to base the above estimates. It is therefore recommended that they should be regarded as preliminary estimates only and fresh estimates should be made when data from the recently installed gauging station on Gardiners Creek becomes available.

In view of the unknown errors in synthetic procedures and the serious loss of life that could occur if the Gardiners Creek spillway was overtopped, it is particularly important that the flood estimate be checked when data becomes available.

SECTION I

GARDINERS CREEK COOLING WATER POND YIELD STUDIES.

INTRODUCTION:

The catchment area upstream of the dam site is comparatively small being only 28 square miles. No streamflow or rainfall records are available on the actual catchment. The only records which are of significance are some short term monthly streamflow records for Saltwater and Swampy Creeks. The location of these two catchments and that of the Gardiners Creek catchments are shown on Figure (1).

The Saltwater Creek records are for a drainage basin of 20 square miles and the records commence in 1956. Swampy Creek drains a much smaller area (6 square miles) and records of streamflow are available since March 1958.

The three catchments, Gardiners Creek, Saltwater Creek and Swampy Creek, have similar topography and are close enough to be considered as a meteorologically homogeneous area. The flow duration curve for Gardiners Creek could therefore be approximated by comparison with the curves derived for Swampy Creek and Saltwater Creek.

PROCEDURE:

From the monthly flow data for both Saltwater and Swampy Creeks, flow duration curves were plotted (Figure 2). These curves were so similar that their average was assumed as a reasonable estimate for the flow duration curve for Gardiners Creek. This average curve expressed in cusecs is plotted in Figure 3.

RESULTS:

Figure 3 shows that a flow of 0.4 cusecs is likely to be equalled or exceeded for 50 per cent of the time and that the average flow from Gardiners Creek would be 4.5 cusecs.

CONCLUSIONS:

The estimated annual flow duration curve for Gardiners Creek is in Figure (3). From this figure the average annual flow at the storage site was calculated as 4.5 cusecs, this flow being equalled or exceeded 11 per cent of the time. This indicates that the catchment is "flashy" with negligible groundwater flow. For this reason a large proportion of this flow will pass over the spillway during floods and the water available for use will be somewhat lower depending upon the storage available below spillway level.

SECTION II

GARDINERS CREEK COOLING WATER POND SPILLWAY STUDIES.

INTRODUCTION:

It is at present proposed that the cooling water pond dam be an earth structure. Thus the overtopping of the spillway could cause failure of the dam and considerable loss of life in the township of Liddel downstream of the damsite. It is therefore essential that the spillway be designed to safely pass the maximum probable flood and this section of the report gives details of the estimates of the inflow hydrographs of the maximum probable floods.

In the absence of adequate streamflow data upon which to base the estimates, use has been made of the synthetic unitgraph technique. For final spillway designs, it is considered essential that the results of this analysis be checked from observed hydrographs.

DERIVATION OF THE SYNTHETIC UNIT HYDROGRAPHS:

The synthetic unitgraph was derived by the Taylor-Schwartz method (Ref.1). Details of the derivation are given in Appendix A attached and the result is plotted in Fig.4.

DEPTH-AREA-DURATION DATA:

The United States Hydrometeorological Section has found that, except for special areas of high orographic or synoptic influence, the convective thunderstorm mechanism is the most rain-productive for areas up to about 500 square miles and for durations up to about 12 hours. As both catchments being studied had areas within this range depth-area-duration curves were based on data published by the U.S. Hydrometeorological section showing the maximum depth of thunderstorm rainfall at sea level over areas of 1,10,200 and 500 square miles, for durations up to 20 hours and a surface dewpoint of 78°F. These data were adjusted to accord with local conditions for the catchment under study (Ref.2).

Details of the derivation of the depth-duration curves are given in Appendix B and are shown plotted in Figure (5).

ESTIMATION OF INFLOW HYDROGRAPHS:

By application of the rainfall obtained from the depth duration curves to the derived unitgraph, the flood hydrographs resulting from maximum thunderstorm rainfalls of various duration were obtained. It was assumed that there was uniform rainfall intensity for the duration of the storm. These results are shown plotted in Figure 6 for Gardiners Creek and they have been tabulated for computer use in Table I of Appendix B.

PEAK INFLOW OF MAXIMUM PROBABLE FLOOD:

In Figure 7 the computed peak discharges have been plotted against duration of rainfall and the critical storm duration for the maximum probable inflow has been determined. These results are tabulated below:-

Catchment	Critical Storm Duration	Peak Discharge of Maximum Probable Flood.
Gardiners Creek	6½ hrs.	33,000 cusecs

CONCLUSIONS:

Before the preliminary spillway design can finally be ascertained it will be necessary to route the inflow hydrographs shown in Figure 6 through the appropriate reservoir storage. Storage elevation curves have been prepared (Figure 8) so that this procedure can be carried out once the final spillway level has been fixed.

At the present time there are two proposals for Gardiners Creek -

(1) a 1100 megawatt station requiring 1000 acres of cooling pond surface area and 10,000 acre feet of reserve storage giving a final storage RL of 380 and surface area of 1250 acres, and

(2) a 2100 megawatt station requiring surface area of 2000 acres and 20,000 acre feet of reserve storage giving a final RL of 380 and a surface area of 2250 acres. The catchment area is approximately 17,000 acres. It is therefore expected that these storages would reduce the peak of the flood by only a relatively small percentage.

As previously mentioned synthetic unitgraph derivations are subject to unknown errors and it is important that the above calculations be checked against actual flood hydrographs from the catchment. The Electricity Commission has made arrangements with the Irrigation Commission to instal an automatic recording streamgauging station on Gardiners Creek and as floods are fairly rare, it is important that this station be rated during the next flood.

References: (1) The first report on the Stormwater Standards Committee on Australian Rainfall and Runoff, 1959 - Appendix F p.59.

(2) Lovett N. Estimation of Maximum Probable Precipitation, Journal of the Institution of Engineers Aust. Oct. 1954.

(3) J. Walpole - Maximum Possible Rainfall in Australia Thunderstorm Model, Internal Report, Meteorological Bureau, Australia.

APPENDIX A.

Derivation of Synthetic Unitgraph for Gardiners Creek (Taylor-Schwartz Method).

(a) Area of catchment = 27.83 square miles.

(b) Length of main stream (L) = 6.7 miles.

(c) Distance from outlet of area to point on main stream closest to the centroid of the area and measured along the stream (L_{ca}) = 3.9 miles.

(d) Evaluation of S_{st} i.e. slope of uniform channel having the same length as longest water course and an equal time of travel from source to outlet.

$$S_{st} = \left[\frac{n}{\sum S_i^{-\frac{1}{2}}}\right]^2$$

where n is the number of equal reaches of the stream and S_i is the average slope of that reach.

TABLE 1.

Reach	Length (feet)	Fall (feet)	S_i	$S_i^{\frac{1}{2}}$	$S_i^{-\frac{1}{2}}$
1	5280	200	0.0378	0.194	5.16
2	5280	110	0.0208	0.144	6.95
3	5280	40	0.00757	0.0866	11.53
4	5280	60	0.0114	0.107	9.35
5	5280	10	0.00212	0.046	21.7
6	5280	5	0.00106	0.0326	30.7
7	5280	5	0.00106	0.0326	30.7
				$\sum S_i^{-\frac{1}{2}}$ =	116.09

$$\therefore \quad S_{st} = \left(\frac{7}{116.1}\right)^2$$

$$= 0.0601^2$$

$$= 0.00362$$

(e) Evaluation of Lag t_{pr}

$$L.L_{ca} = 7 \times 3.9 = 27.3$$

$$S_{st} = 0.00362$$

From Fig. F-1 "Australian Rainfall and Runoff"

$$t_{pr} = 11.7 \text{ hours}$$

(f) Evaluation of Peak flow q_{pr}

From Figure F-1 again, for $L.L_{ca} = 27.3$ and $S_{st} = 0.00362$

$q_{pr} = 95$ cusecs/square mile

$\therefore$ Peak of unitgraph = 95 x 27.83

= 2,650 cfs.

(g) Evaluation of base length of unitgraph (T)

$T = 5\ (t_{pr} + t_{\frac{r}{2}})$ where t_r = unit period in hours

$= 5\ (11.7 + \frac{2}{2})$

$= 5 \times 12.7$

= 63.5 hours

(h) Evaluation of unitgraph widths at 50 per cent and 75 per cent of Peak flow. From Fig. F-2 "Australian Rainfall and Runoff" for q_{pr} = 95 cfs/square mile width of unitgraph at 50 per cent peak flow = 5.6 hours, width of unitgraph at 75 per cent peak flow = 3.5 hours

50 per cent Peak Flow = 1,325 cusecs

75 " " " " = 1,990 "

(i) Construction of two hour unitgraph

(i) At commencement of excess rain plot t = o, q = o

(ii) Peak flow t = 11.7 hours, q = 2,650 cusecs

(iii) End of run off t = 63.5 hours, q = o

(iv) For 1,325 cusecs plot two points 5.6 hours apart and for 1,990 cusecs plot two points 3.5 hours apart. The positioning of these points must be done by judgment so as to give a unitgraph of reasonable shape in relation to the shape of the catchment.

(j) Adjust area under hydrograph such that it equals the total amount of one inch of excess rain.

Area of catchment = 27.83 x 640

= 17,800 acres

$\therefore$ Area under unitgraph should equal 17,800 acre-inches or 17,800 cusec-hours.

(k) The resulting two hour unitgraph is shown in Figure 4.

APPENDIX B

Details of Derivation of Depth-Duration Curves and Inflow Hydrographs for Maximized Thunderstorm Rainfall.

(a) Area = 27.83 sq. miles

(b) Extreme dew point persisting for at least 24 hours = 71°F (Ref. 3).

(c) From Fig.9 of "Estimation of Maximum Possible Precipitation" - Lovett Jnl. I.E. Aust. Oct.-Nov.1954 the effective precipitable water at Dew Point 71°F is 71 per cent of that at 78°F.

(d) Average height of catchment above sea level is 500 feet. Hence from Figure 10 of Lovett's paper the orographic depletion effect reduces the total precipitable water in the storm to 96 per cent of that at sea level.

(e) Total correction to be applied to depth-duration figures for storms at sea level and 78°F dew point from (c) and (d) above is 71 per cent x 96 per cent = 68.1 per cent.

(f) To derive the depth-duration curves for the catchment, figure 8 of Lovett's paper may be used. However, it is difficult to use his figure with accuracy so his results were plotted on other graphs from which depth and area could be easily read.

The following results can be easily read from Lovett's graph:-

Time	Area 500 sq. miles Depth inches	Area 200 sq. miles Depth inches	Area 10 sq. miles Depth inches	Area 1 sq. mile Depth inches
2 hours	8.9	10.2	15	17
4 "	14	15.2	20.5	22.5
6 "	16	17.8	24	27
8 "	18.5	20	28	29
12 "	21	23.3	31	32.5
24 "	25	28	35	36.5
30 "	26	29	36	37

From these results, on linear graph paper with depth plotted vertically and area horizontally, smooth curves were drawn for the seven durations.

(g) From the previously prepared graph in (f) for a catchment of 27.83 square miles the depth was found for periods of 2, 4, 6, 8, 12, 24 and 30 hours. These depths were corrected for the Gardiners Creek catchment by multiplying by 68.1 per cent. This gave the depth-duration curve shown in Figure 5.

The following results were obtained:-

Duration (Hours)	Depth over Gardiner's Creek (inches)
2	9.55
4	13.3
6	15.5
8	18.0
12	20.2
24	22.8
30	23.8

(h) Table 3 below gives the unitgraph ordinates for storms of the various unit periods shown. The two hour unitgraph is from Appendix A. The four hour unitgraph was derived by superimposing on the two hour unitgraph the same unitgraph but lagging two hours. The combined ordinates represent the hydrograph for 2 inches of rain over the catchment in 4 hours. If these ordinates are then halved the result is the hydrograph for 1 inch of rain over the catchment in 4 hours, or the 4 hour unitgraph.

The other unitgraphs were derived by extending this principle.

TABLE 3 - UNITGRAPHS FOR GARDINERS CREEK

Time	2 Hrs.	4 Hrs.	6 Hrs.	8 Hrs.	12 Hrs.	24 Hrs.
0	0	0	0	0	0	0
2	25	12.	8	6	4	2
4	125	75	50	37	25	12.
6	310	217	153	115	76	38
8	760	535	398	305	203	102
10	1980	1370	1017	793	533	266
12	2615	2297	1785	1416	969	485
14	1720	2167	2105	1769	1251	627
16	760	1240	1698	1768	1357	691
18	220	490	900	1329	1342	709
20	95	157	358	698	1232	717
22	75	85	130	287	914	723
24	65	70	78	113	489	729
26	60	62	67	74	212	732
28	55	57	60	64	95	726
30	51	53	55	58	66	704
32	50	50	52	54	60	646

Time	2 Hrs.	4 Hrs.	6 Hrs.	8 Hrs.	12 Hrs.	24 Hrs.
34	49	50	50	52	55	489
36	46	47.	48	49	52	270
38	42	44	46	47	49	130
40	40	41	43	45	46	70
42	35	37.	39	41	43	55
44	30	32	35	37	40	50
46	25	27	30	33	36	45
48	20	22.	28	27	32	42
50	18	19.	21	23	28	38
52	15	16.	18	20	24	35
54	14	14.	16	17	22	32
56	12	13	14	15	17	28
58	10	11	12	13	15	25
60	5	7	9	10	12	22
62	2	3	6	7	10	19
64	0	1	2	4	7	15
66		0	1	2	5	13
68			0	0.	3	10
70					1	8
72					0	6
74						5
76						3
78						2
80						1
82						

(i) If these unitgraph ordinates are each multiplied by the appropriate depth of rain over the catchment given in paragraph (g) or Fig.5, the following inflow hydrographs are obtained:-

TABLE 4.

MAXIMUM PROBABLE INFLOW HYDROGRAPHS FOR GARDINERS CREEK

Time Hours	Discharge in Cusecs for Storm Durations of					
	2 hrs.	4 hrs.	6 hrs.	8 hrs.	12 hrs.	24 hrs.
0	0	0	0	0	0	0
2	238	166	124	108	81	46
4	1193	997	764	666	505	285
6	2960	2890	2370	2070	1535	866
8	7250	7110	6160	5490	4100	2330
10	18,900	18,200	15,750	14,250	10,770	6,060
12	25,000	30,500	26,900	25,500	19,600	11,050
14	16,410	28,800	32,600	31,800	25,300	14,300
16	7,250	16,500	26,300	31,800	27,400	15,750
18	2,100	6,520	13,950	23,900	27,100	16,150
20	906	2,085	5,550	12,550	24,900	16,350
22	716	1,130	2,010	5,160	18,450	16,500
24	620	930	1,210	2,030	9,870	16,600
26	572	830	1,040	1,333	4,290	16,700
28	525	765	930	1,150	1,920	16,600
30	487	705	851	1,040	1,330	16,050
32	477	678	805	973	1,210	14,750
34	468	665	775	935	1,100	11,150
36	440	632	743	882	1,050	6,160
38	400	585	713	845	989	2,970
40	382	545	667	810	930	1,595
42	334	499	605	737	870	1,255
44	286	432	542	666	808	1,140
46	238	365	465	594	726	1,025
48	191	299	434	486	646	960
50	172	252	326	414	565	867
52	143	220	279	360	485	799
54	133	193	248	306	444	730
56	114	173	217	270	324	639
59	96	146	186	234	303	570
60	48	100	139	180	242	502
62	19	46.	93	126	202	433
64	0	13	31	72	141	342
66		0	13	36	101	297
68			0	9	61	228
70				0	20	183
72					10	137
74					0	114
76						68
78						46
80						20
82						10
84						5
86						0

[illegible] inflow hydrographs show the maximum expected discharge from

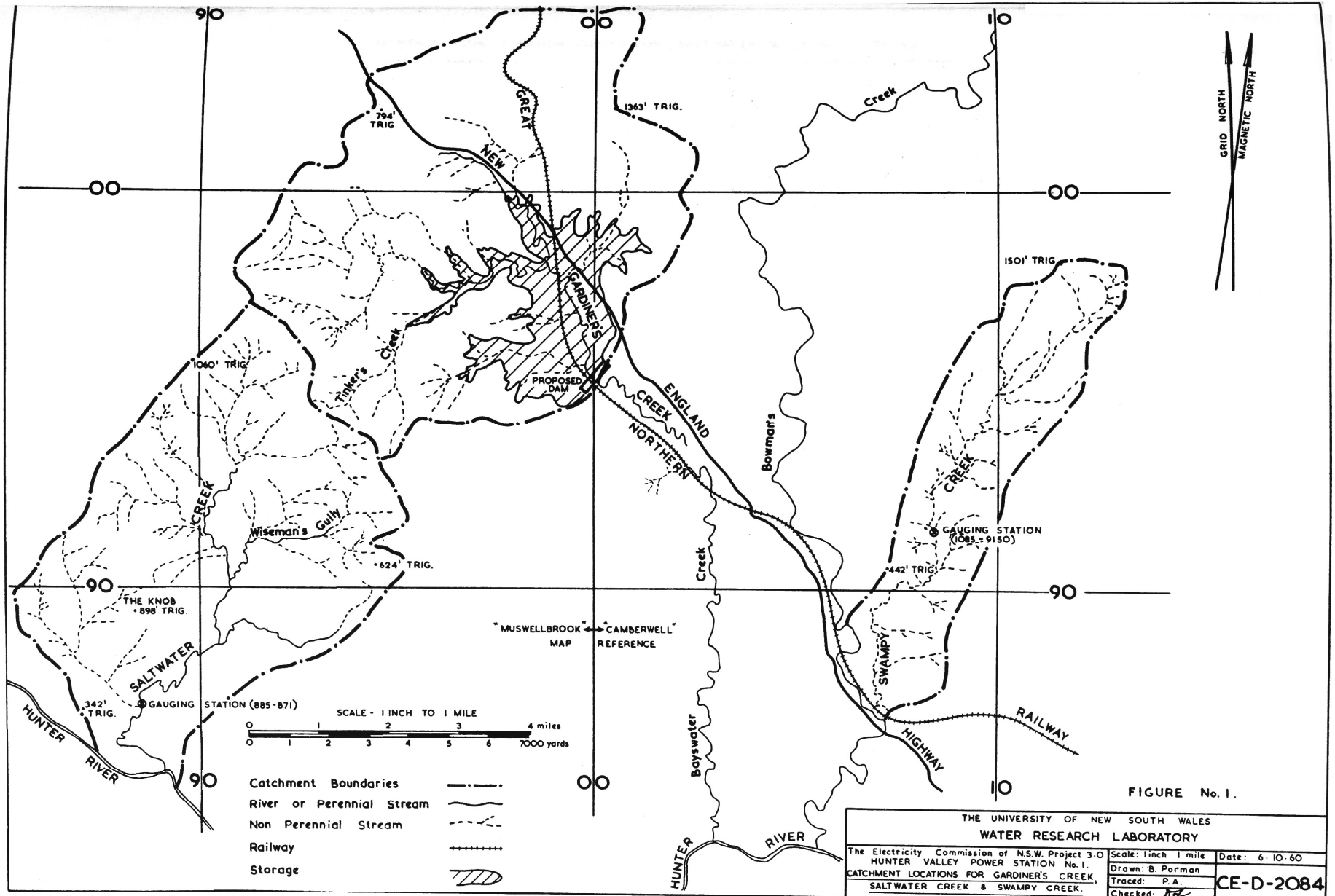

FIGURE No. 1.

THE UNIVERSITY OF NEW SOUTH WALES
WATER RESEARCH LABORATORY

The Electricity Commission of N.S.W. Project 3.0 HUNTER VALLEY POWER STATION No. 1. CATCHMENT LOCATIONS FOR GARDINER'S CREEK, SALTWATER CREEK & SWAMPY CREEK.	Scale: 1 inch 1 mile	Date: 6·10·60
	Drawn: B. Porman	CE-D-2084
	Traced: P.A.	
	Checked:	

MONTHLY FLOW DURATION CURVES FOR SALTWATER & SWAMPY CREEKS

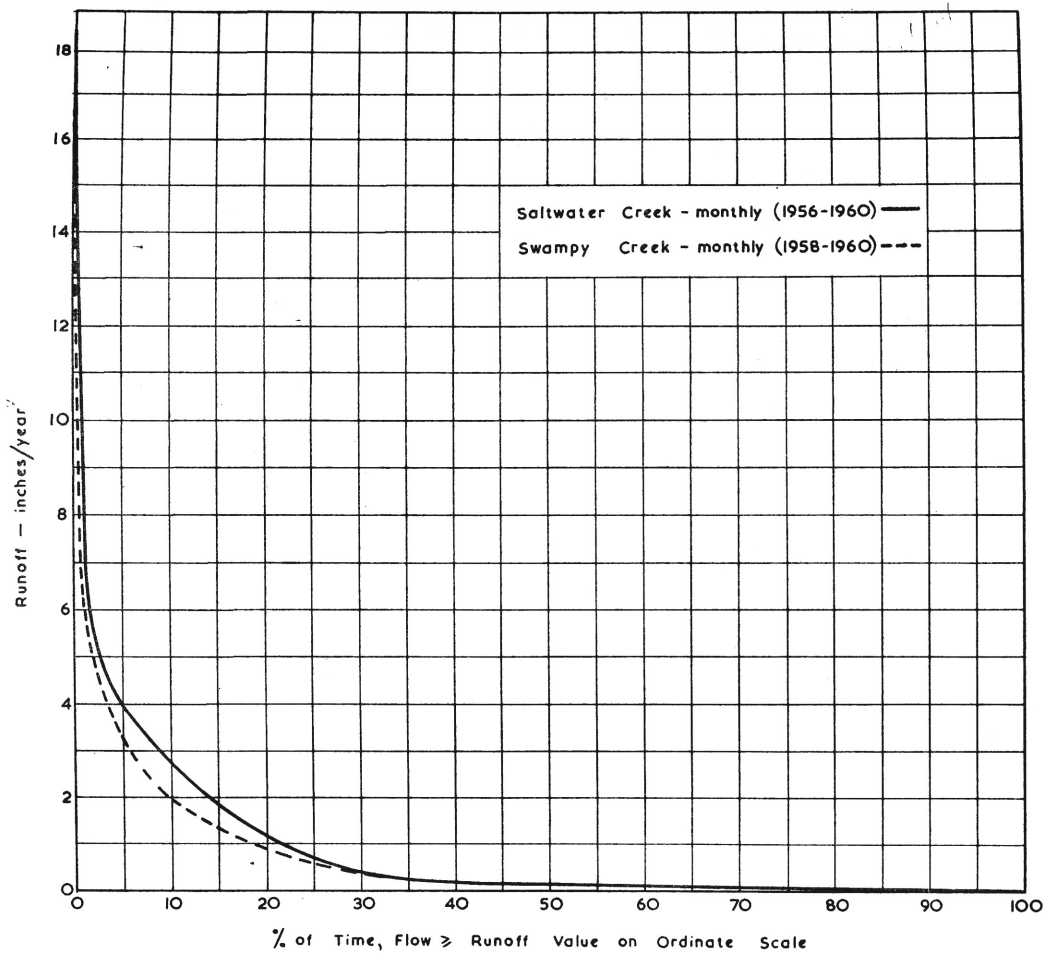

FIGURE No. 2.

THE UNIVERSITY OF NEW SOUTH WALES WATER RESEARCH LABORATORY		
The Electricity Commission of N.S.W. Project 4.0 HYDROLOGIC INVESTIGATION FOR GARDINER'S CREEK	Scale : Drawn: J Toomey Traced: P.A. Checked:	Date : 21·4·60 CE-D-1076

ESTIMATED ANNUAL FLOW DURATION CURVE

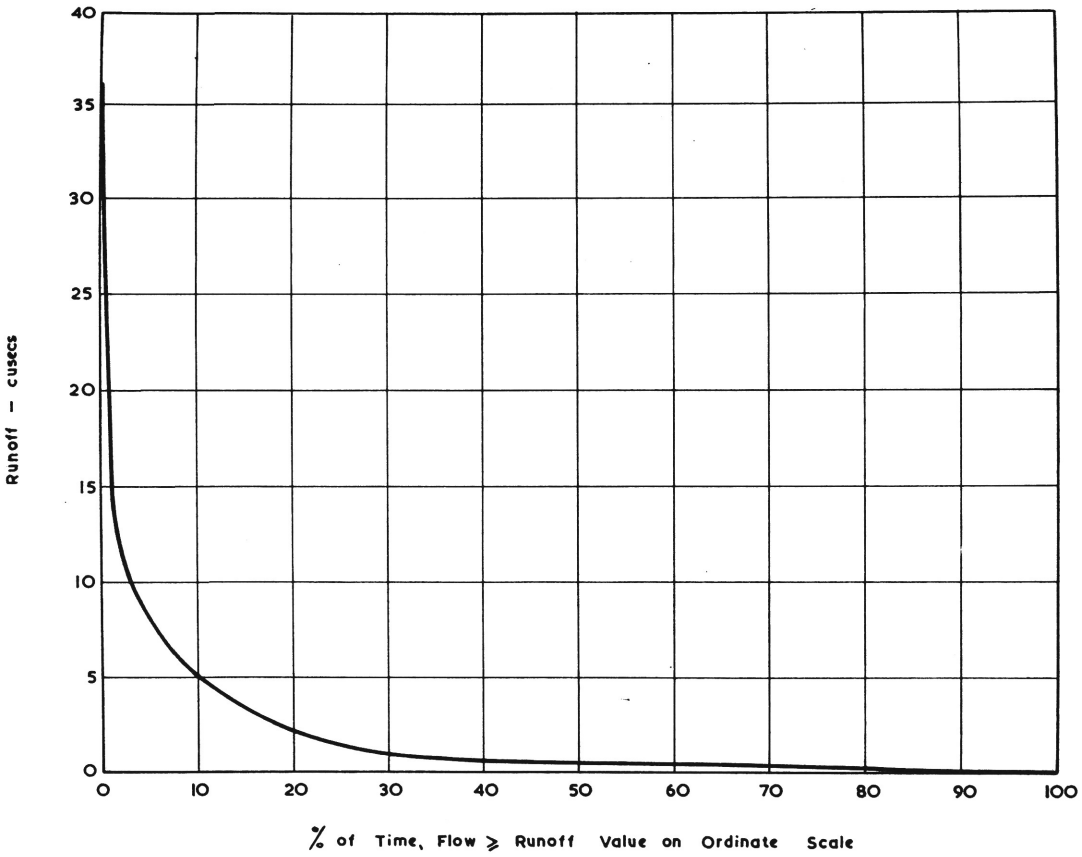

FIGURE No. 3.

THE UNIVERSITY OF NEW SOUTH WALES WATER RESEARCH LABORATORY		
The Electricity Commission of N.S.W Project 4·0 HYDROLOGIC INVESTIGATION FOR GARDINER'S CREEK	Scale: Drawn: B. Porman. Traced: P.A. Checked:	Date: 21·9·60 CE-E-2082 See CE - D - 1077

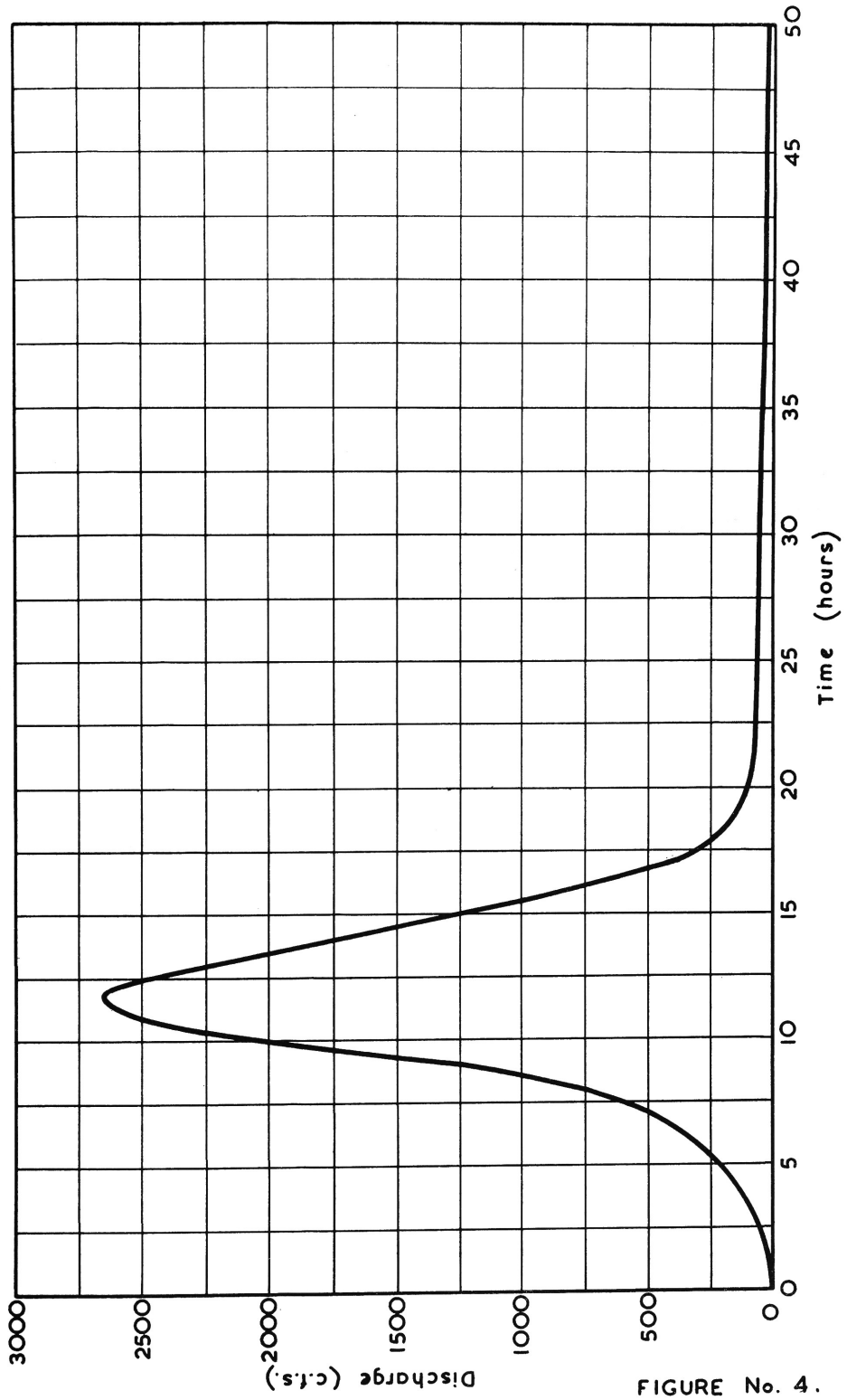

FIGURE No. 4.

THE UNIVERSITY OF NEW SOUTH WALES

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The Electricity Commission of N.S.W. Project 3·0 Hunter Valley Power Station No. 1. 2 HOUR UNITGRAPH FOR GARDINER'S CREEK	Scale:	Date: 31·3·60
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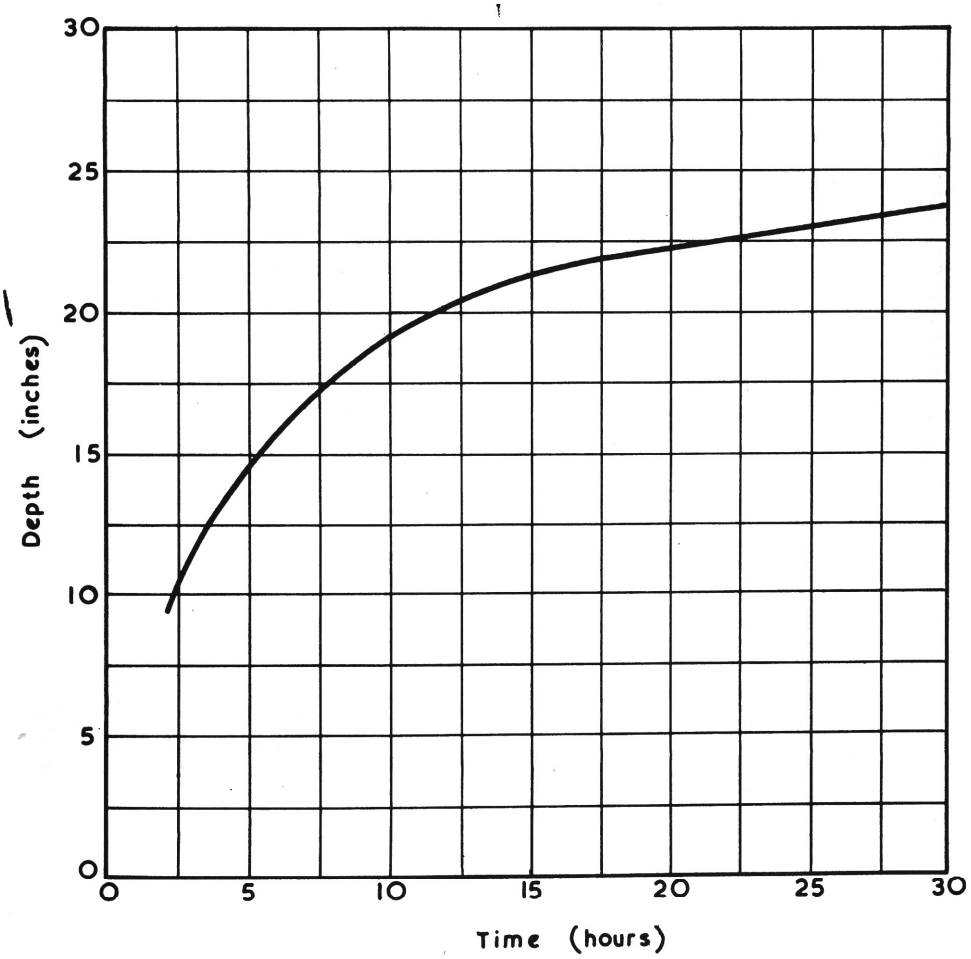

FIGURE No. 5.

THE UNIVERSITY OF NEW SOUTH WALES WATER RESEARCH LABORATORY		
The Electricity Commission of N.S.W. Project 3.0 Hunter Valley Power Station No. 1. MAXIMIZED DEPTH DURATION CURVES FOR GARDINER'S CREEK	Scale: Drawn: C.Mackenzie Traced: P.A. Checked:	Date: 1·4·60 CE-E-1057

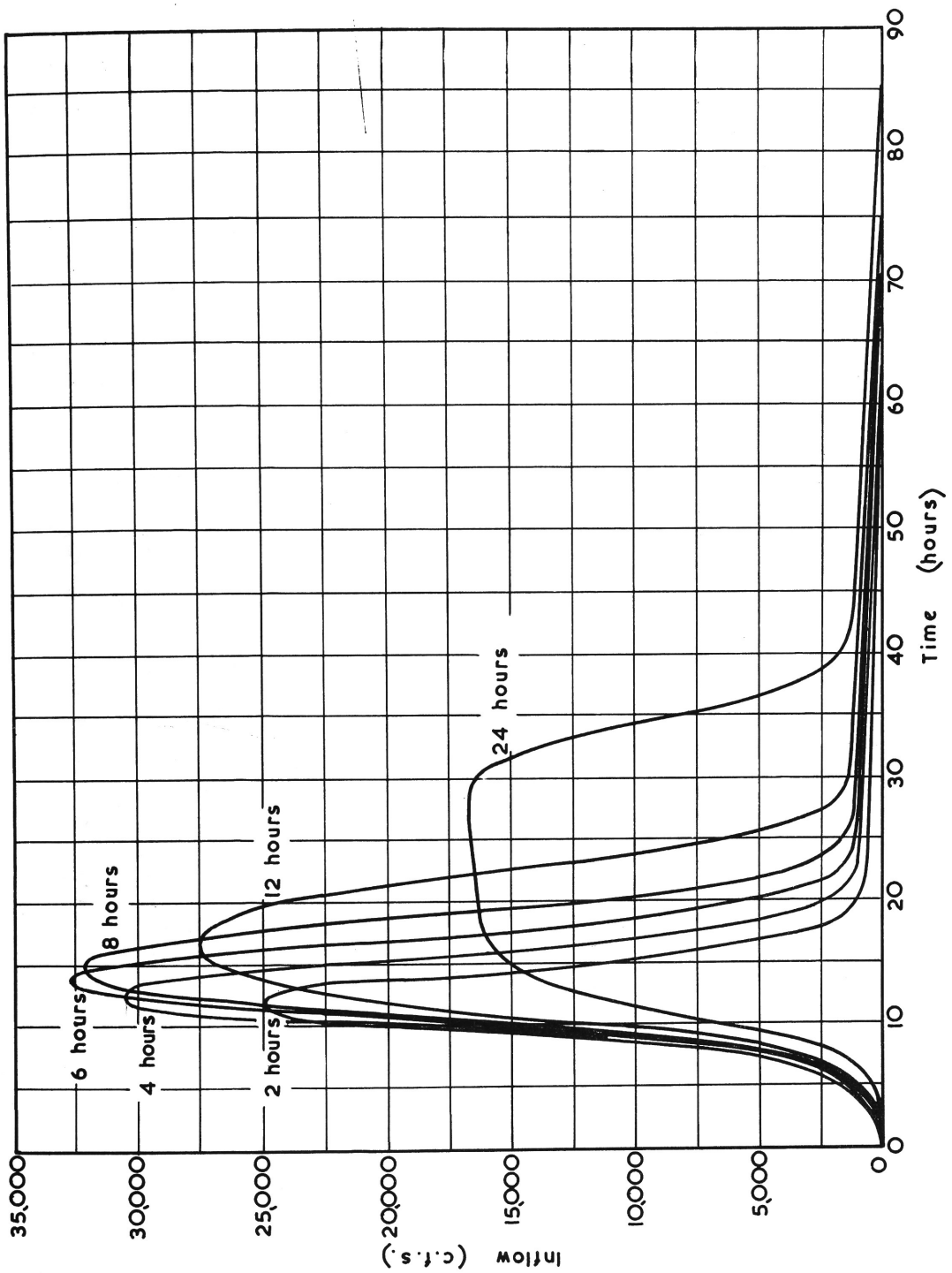

FIGURE No. 6.

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The Electricity Commission of N.S.W. Project 3·0 HUNTER VALLEY POWER STATION No. 1. MAXIMUM PROBABLE INFLOW HYDROGRAPHS INTO C.W. POND FOR STORMS OF VARIOUS DURATIONS AT GARDINER'S CREEK	Scale:	Date: 1·4·60
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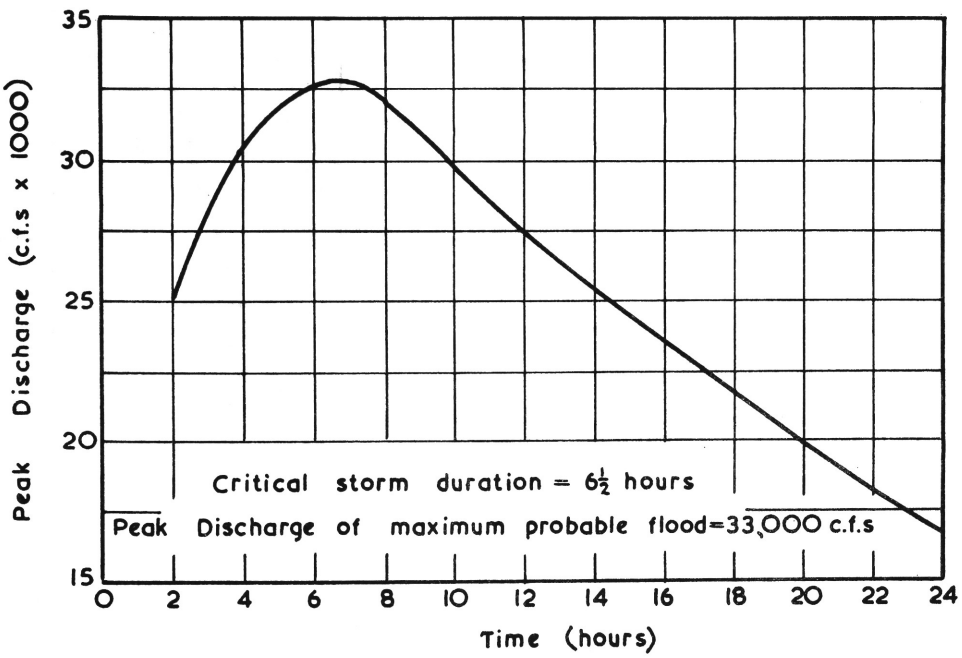

FIGURE No. 7.

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The Electricity Commission of N.S.W. Project 3-0 HUNTER VALLEY POWER STATION No. 1. PEAK INFLOW HYDROGRAPH DISCHARGE Vs STORM DURATION AT GARDINER'S CREEK	Scale:	Date: 4-4-60
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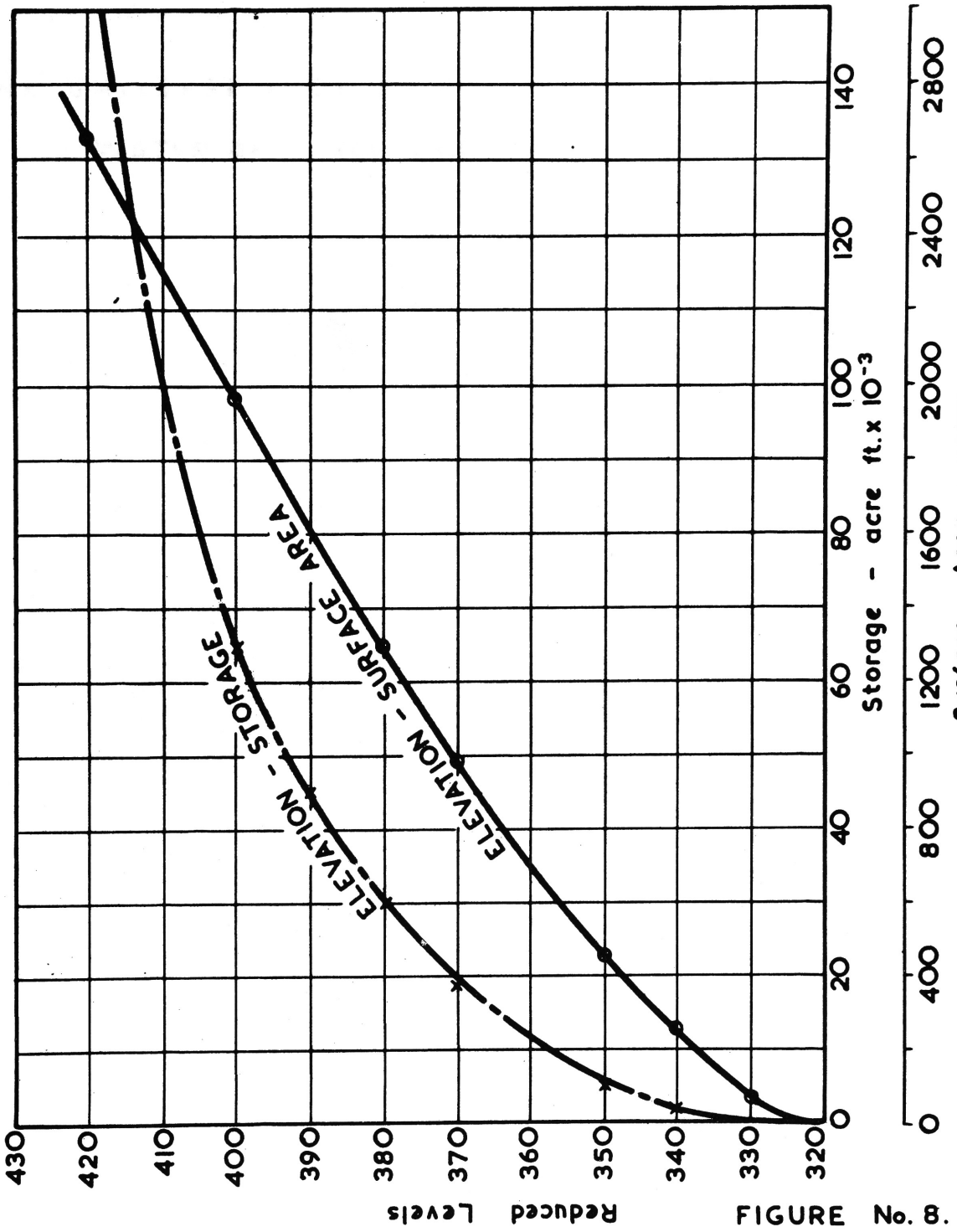

FIGURE No. 8.

THE UNIVERSITY OF NEW SOUTH WALES

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The Electricity Commission of N.S.W. Project 3·0

GARDINER'S CREEK

ELEVATION STORAGE & ELEVATION SURFACE AREA CURVES

Scale:

Date : 9·11·60

Drawn: B. Porman.

Traced: P. A.

Checked: I. Wood.

CE-E-2213