Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 3543.*)

"On the Rainfall of Central Queensland and Floods in the Fitzroy River."

By Herbert E. Bellamy.

Observations on the Rainfall.—The general fluctuation of rainfall in central Queensland, although similar to that in other parts of the world, possesses several distinctive features. The greater part of the annual rainfall is confined to the hot summer months, namely, December to March, and more than half the year is practically rainless. During the really wet months the rainfall is much heavier than in temperate countries. The floods on record are confined to the first three months of the year; and the mean annual rainfall inland is less, the greater the distance from the sea.

Two cases are on record in which falls of 24 inches and 17 inches respectively were gauged in 24 hours. These occurred at Rockhampton in the years 1875 and 1888. The annual rainfall for the 33 years, 1871 to 1903, and the number of days on which rain fell in each year during that period, are tabulated in Appendix I. The Table shows that the mean annual rainfall during the period was 40·63 inches; that the fall was less than this amount in sixteen of the years, whilst in the remaining seventeen years the mean fall was exceeded; that there were, on an average, 87·39 wet days annually during the period; and that only in five years was the rainfall for January less than 2 inches, whilst in fifteen years the fall during the first month of the year exceeded 5 inches. In those years in which the fall during the month of January was less than 2 inches, droughts were experienced. The lowest fall for any one year occurred in 1902, and the highest in 1890, the rainfall for these years being 15·80 inches and 81·90 inches respectively; the greatest flood, however, occurred in 1896, with a fall of 59·80 inches. The two worst droughts experienced in central Queensland were those of 1883–1886 and 1900–1903. The drought of 1883–1886 began in January, 1883, and continued until the end of May, 1886, extending over a period of 3 years and 5 months, during which time the total rainfall amounted to only 76·73 inches. The drought of 1900–1903 commenced in January, 1900, and extended over 3 years and 4 months, ending in April, 1903, the total rainfall during that period being 66·75 inches. The rainfall, and the number of wet days, for each month during the floods of 1875, 1888, 1890, 1893, 1896 and 1898, are given in the following Table:—

Year.	Month.	Fall for Month. Inches.	Number of Days on which Rain fell.	Year.	Month.	Fall for Month. Inches.	Number of Days on which Rain fell.
1875	February.	34·08	9	1893	February.	23·67	21
1888	February.	32·14	17	1896	January .	27·00	14
1890	January .	21·16	27	1896	February.	20·44	25
1890	February.	9·34	20	1898	January .	17·70	15
1890	March .	25·06	28	1898	February.	18·46	22
1893	January .	12·39	8	1898	March .	10·41	16

The Fitzroy River.

The Fitzroy River drains a catchment-area of some 58,000 square miles, the greater portion of which is very flat, and of this area no less than 54,900 square miles is situated above Rockhampton, the capital of central Queensland, which lies on the south bank of the river, about 33 miles from its mouth and 420 miles north-west of Brisbane. The rateable property within the municipality of Rockhampton is valued at £1,041,365. During floods the city becomes an island, owing to the fact that, at a point situated about 6½ miles above the city, there is a natural depression in the southern bank, over which flood-waters break, flowing across-country through a chain of lagoons and over some low-lying alluvial flats of the town common, and rejoining the river below the town.

A large portion of the Fitzroy watershed is flat land. In times of drought these plains, consisting chiefly of black soil, become intersected by deep fissures caused by the extreme heat of the sun, and when the first fall of rain comes these fissures have a moderating effect on the floods, as no water runs off the surface until they are filled.

The extreme length of the river, including all bends, measured from the source of the Dawson River branch to its outlet in Keppel Bay, is 520 miles. The length within tidal influence, extending up to Alligator Creek, which is situated some 29 miles above Rockhampton, and 5 miles below the township of Yaamba, is only 62 miles. The main tributaries of the Fitzroy are the Dawson, Mackenzie, Isaacs, Comet and Nogoa rivers. The distances from Rockhampton to the various junctions and extreme heads of these tributaries, measured along the channels, are—

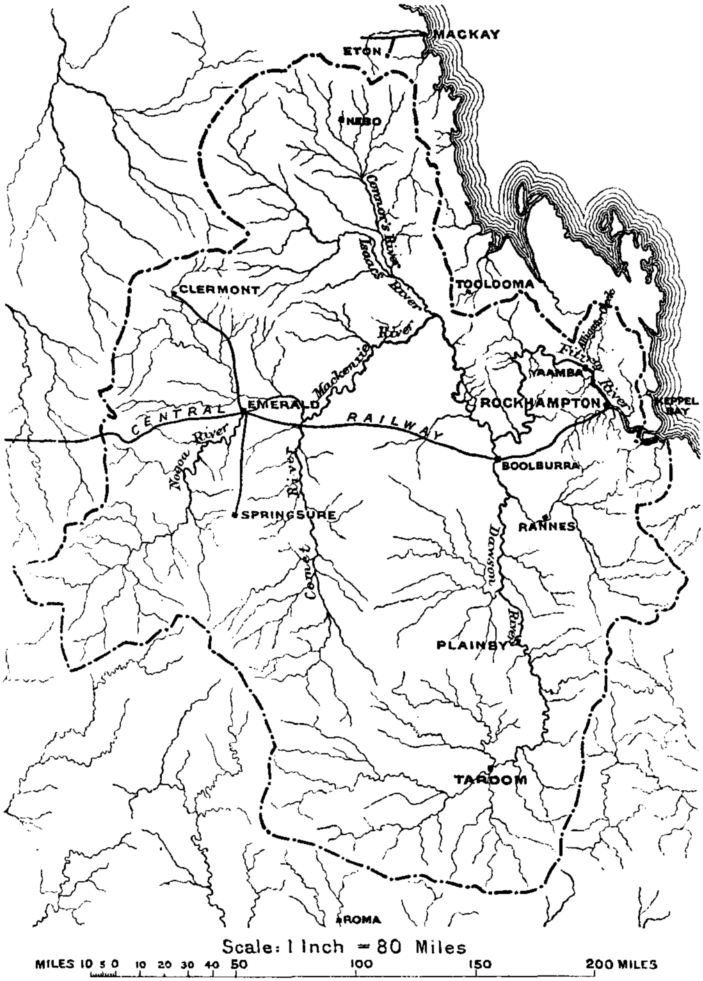
	Miles.
To the junction of the Dawson and Mackenzie rivers, forming the Fitzroy River	152
To the junction of the Isaacs and Mackenzie rivers	232
To the junction of the Comet and Nogoa rivers, forming the Mackenzie River	332
To the extreme head of the Dawson River	520
,, ,, ,, ,, Isaacs ,,	400
,, ,, ,, ,, Nogoa ,,	532

The head-waters of the Dawson River extend to within 30 miles of Roma, lying north-west of Brisbane, while from the north come the Connor's, Isaacs, Mackenzie and other streams, which, joining with the Dawson River, become the Fitzroy River. The catchment-area of the Fitzroy River is shown in *Fig. 1.*

Floods in the Fitzroy River.—The valley of the Fitzroy River is the scene of recurring floods, but there are certain causes which render it highly improbable that the town of Rockhampton may be seriously inundated in the event of excessive rainfall on the Fitzroy and its tributaries, notwithstanding its immense catchment-area. Even if the rainfall were general in the valley of the Fitzroy and its tributaries, the local rainfall, when it attains the dimensions of a flood, gets away before the waters of the Mackenzie, Isaacs, and Connor's rivers come down, and the flood-waters of these rivers largely disappear before the waters of the Dawson River reach Rockhampton. The flatness of the catchment-area also contributes to the safety of the town. Moreover, even with an exceptional rainfall over the whole of the tributary streams, the flood-waters are checked by a barrier known as the Gogango Range, through a gorge of which the river flows. The great volume of water is thus kept in check by the range, and spreads itself over the whole of the flat country for many miles around the township of Boolburra, and the valley of the Dawson River. In 1896 the flood-waters of the Dawson River at Boolburra extended to a width of 7½ miles. Passing this barrier and pursuing its course down the river, the flood-water, if excessive, escapes at a point some 6½ miles above the city, where, as already mentioned, a depression in the southern bank affords an additional safeguard. When the flood-waters break over this natural by-wash, the height of the flood-waters at Yaamba is exactly 48 feet 6 inches above mean summer water-level, and 24 feet 4 inches above low-water level at Rockhampton. The time taken by the flood-waters to come from Yaamba to Rockhampton is 6 hours.

There are five big floods on record at Rockhampton. These occurred in the years 1859, 1875, 1890, 1893, and 1896. Minor floods also occurred in the years 1888 and 1898. The flood of 1890

Fig. 1.



CATCHMENT-AREA OF THE FITZROY RIVER.

was caused by an immense rainfall which occurred over the whole of the southern watershed of the Dawson River. During this time the northern watershed, which includes the Connor's, Isaacs, and

Mackenzie rivers, was normal, excepting the backing up of the Mackenzie by the waters of the Dawson River. The flood of 1896 was the result of a cyclonic storm, and had its centre about Nebo, the head of the northern watershed of the Fitzroy River. To this flood the Dawson contributed little; on the other hand, it acted as a storage, the water from the Mackenzie backing up the Dawson water and thus relieving the Fitzroy to a large extent. The highest flood ever experienced at Rockhampton by white men occurred in February 1896, and was confined practically to two well-defined channels, namely, (1) the main channel of the river, which is tidal, and (2) the natural by-wash, already referred to, which is entirely above tidal influence. The time occupied by the rise of the flood-waters and the subsequent fall to ordinary level was 42 days.

During floods the river at Yaamba rises considerably above the mean summer level, as is shown by the following Table, in which are also given heights above low-water level recorded on a flood-gauge at Rockhampton. When the moon is in perigee, at full moon or new moon, the rise ordinarily recorded on the flood-gauge at Rockhampton is the extreme rise of tide at that place, namely, 10 feet, and a freshet of 27 feet at Yaamba will cause a rise of level of 20 feet at

Date.	YAAMBA. Height on Flood-Gauge above Mean Summer Level.		Date.	ROCKHAMPTON. Height on Flood-Gauge above Low-Water Level.	
	Feet.	Inches.		Feet.	Inches.
January, 1859	..		January, 1859	26	0
March, 1864	51	0½	March, 1864	27	9
March, 1875	52	1	March, 1875	27	6½
April, 1890	52	9	April, 1890	27	7
1 February, 1896	47	6	February, 1896	23	9
3 February, 1896	46	6	4 February, 1896	23	0
4 February, 1896	48	2	5 February, 1896	23	9
5 February, 1896	49	9	6 February, 1896[1]	24	5
6 February, 1896[1]	51	4	7 February, 1896	25	3
7 February, 1896	53	3	8 February, 1896	26	6
8 February, 1896	53	9	9 February, 1896	27	9
9 February, 1896	54	0½	10 February, 1896	28	0
10 February, 1896	54	0	11 February, 1896	28 top level.	2⅜
14 January, 1898	34	6	14 January, 1898	14	7½
19 January, 1898	35	10	20 January, 1898	16	4
16 February, 1898	50	8½	17 February, 1898	26	0
29 March, 1898	38	11	29 March, 1898	17	9
30 January, 1899	25	0	30 January, 1899	5	0
4 February, 1899	28	10	4 February, 1899	6	0
8 February, 1899	26	6	8 February, 1899	7	0

[1] On 6 February, 1896, the height of the flood-waters at the Dawson River was 66 feet.

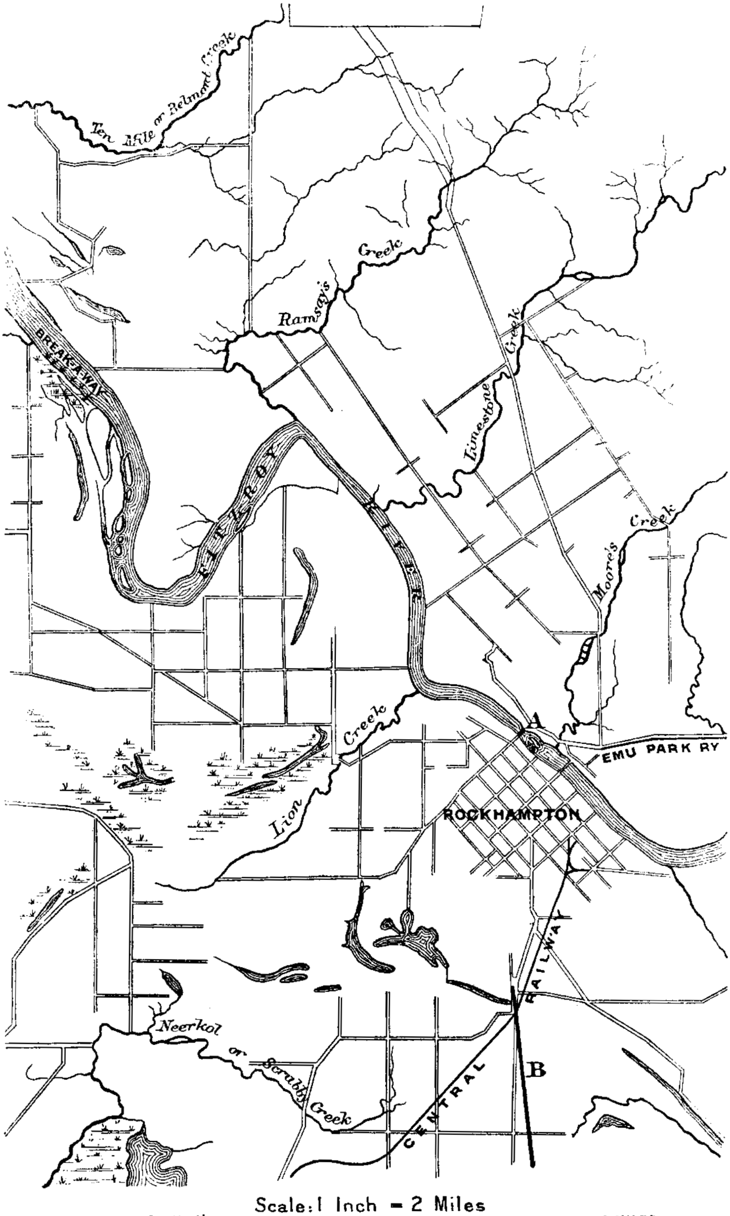
Rockhampton. If the moon is near the first or last quarter, and in apogee, the water-level at Yaamba will have to be raised 35 feet in order to produce a rise of 20 feet at Rockhampton.

Discharge of the Fitzroy River in 1896.—Information as to the discharge of rivers in times of flood being exceedingly interesting and useful, especially in reference to proposed schemes of irrigation or water-supply, the Author proposes to investigate the discharge of the Fitzroy River during a period of 24 hours when the flood of 1896 was at its maximum height. The highest levels attained are used as data in calculating the river and by-wash discharges respectively.

From a cross-section obtained at the point marked "A" in *Fig. 2* it was found that the sectional area was 41,627 square feet, of which some 23,960 square feet was below ordinary high-water level, thus leaving only 17,667 square feet of sectional area above high-water level, and some 20,440 square feet above mean sea-level. With regard to the natural breakaway, a cross-section taken along the line marked "B" in *Fig. 2* shows that the sectional area is approximately 73,000 square feet. The calculated mean velocity at the breakaway was 3 feet per second, and this multiplied by the sectional area gives a discharge of 219,000 cubic feet per second, or 4,915 million gallons per hour. With regard to the river-channel, it is very difficult to determine with accuracy the value as a conduit for the discharge of flood-waters which should be attached to that portion of the section of a tidal river which lies below sea-level. The question is one which calls for scientific inquiry; but the Author considers that the value must vary as the height of the flood, and that when this height is equal to, or greater than, the depth below mean sea-level, the whole cross-section becomes available for discharge, neglecting, of course, the effect of such obstructions as may exist in the course of the river lower down. A few chains from point "A" (*Fig. 2*) a reef of rocks extends across the river for quite three-fourths of its width, and acts as a great impediment to the flow in times of flood. In the following calculations, the resistance offered by these rocks to the flow, and the influence of tides, have been left out of consideration, the entire cross-section of the river being reckoned upon as available for flood-discharge. By adopting this course the discharge naturally errs on the side of excess. In the case of the breakaway, which is above tidal influence, there is no uncertainty.

The calculated mean flood-velocity in the river was 12·46 feet per second, which, multiplied by the sectional area, gives a discharge of 518,670 cubic feet per second, or 11,637 million gallons per hour.

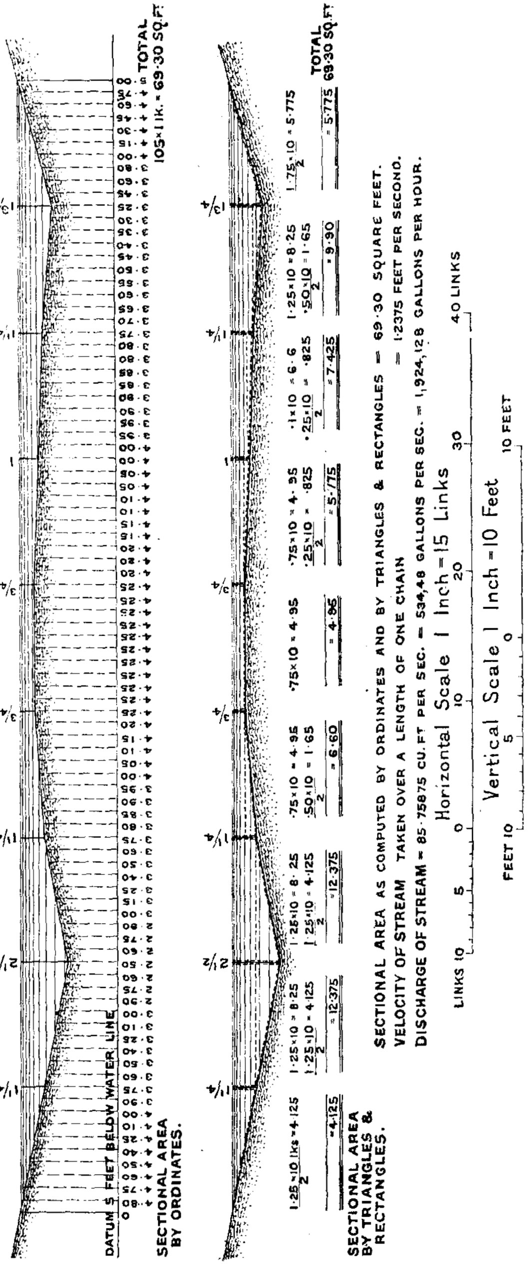
Fig. 2.



Scale: 1 Inch = 2 Miles

MILE 1 ¾ ½ ¼ 0 1 2 3 4 MILES

Figs. 3.



COMPUTATION OF CROSS-SECTIONAL AREA OF STREAM, BY TWO METHODS.

Taking the discharge of the river, and of its by-wash, for the highest level attained in February 1896, it is found that no less than 397,226 million gallons were discharged in the 24 hours.

Damage caused by Floods.—In central Queensland experience has shown floods to be, in general, more beneficial than otherwise. Beyond the delay caused by a few trains being prevented from running and by some small washaways of railway-lines, and the loss of a few hundred head of cattle and sheep by drowning, nothing of a very serious nature has so far occurred.

Minimum discharge of the Fitzroy River.—During the past few years the Author has carried out, in connection with water-supply investigations, many gaugings of the discharge of the Fitzroy River at Yaamba, which is about 5 miles above the reach of tidal influence. The lowest flow recorded occurred in the month of May, 1902, during a long period of drought. The cross-section of that part of the stream at which the gaugings were taken is plotted, both by ordinates and by rectangles and triangles, in *Figs. 3.* It may be mentioned that the stream was regular in cross-section over a measured chain, and in every way suitable for reliable gaugings to be made. The velocity, as ascertained by means of an ordinary float, from a number of experiments, was 1·2375 foot per second. The sectional area available for discharge was 69·30 square feet. Therefore the minimum discharge from the Fitzroy River watershed during the period of the worst drought on record was 46 million gallons in 24 hours.

In conclusion, the Author desires to express his indebtedness to Mr. J. B. Henderson, M. Inst. C.E., Government Hydraulic Engineer, Queensland, for valuable information and assistance, and for the statistics contained in Appendix I.; and to Mr. W. Davidson, Inspector-General of Public Works, Victoria, for many hints relating to river and hydraulic works.

The Paper is accompanied by three drawings, from which the Figures in the text have been prepared; and by the following Appendixes.

[APPENDIXES.

APPENDIXES.

Appendix I.—Rainfall of Central Queensland, 1871–1903 Inclusive.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	No. of Days on which Rain fell.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	
1871	9·85	14·64	2·65	0·32	0·77	0·54	0·11	0·29	1·87	3·55	3·65	2·86	41·10	74
1872	16·35	10·41	2·33	0·36	1·49	1·68	1·03	0·61	Nil.	Nil.	5·57	7·46	47·29	76
1873	7·22	4·20	2·40	0·77	Nil.	8·87	1·05	1·57	0·26	Nil.	5·25	6·78	38·37	41
1874	9·37	2·59	4·91	2·15	0·94	3·81	7·68	Nil.	2·34	0·17	Nil.	5·24	39·20	35
1875	3·09	34·08	1·62	10·30	2·03	0·47	1·00	Nil.	Nil.	1·92	1·53	1·84	57·88	53
1876	5·50	11·50	2·44	1·93	9·69	6·94	0·37	0·58	Nil.	2·63	3·58	3·20	48·36	66
1877	7·78	1·16	4·63	0·25	0·72	0·20	0·28	Nil.	1·94	0·39	2·79	5·99	26·13	79
1878	4·19	4·30	12·37	0·35	4·88	3·81	0·62	0·34	3·32	4·05	3·05	9·67	50·95	94
1879	4·37	4·48	5·59	4·01	2·22	2·10	2·09	3·14	0·83	1·00	1·61	2·18	33·62	84
1880	3·25	14·34	1·43	7·52	0·04	0·32	4·08	0·02	2·46	1·38	1·78	5·27	41·89	73
1881	1·55	2·75	8·87	2·04	1·91	0·97	0·13	0·08	4·23	1·56	1·53	1·06	26·68	80
1882	1·62	8·33	15·77	1·75	0·44	5·01	4·66	Nil.	0·68	6·02	0·98	4·54	49·80	75
1883	3·48	3·14	5·16	0·07	2·63	Nil.	Nil.	0·42	Nil.	2·13	2·18	3·62	22·83	73
1884	4·96	3·54	2·86	0·25	1·18	3·15	0·63	0·04	0·42	0·83	3·13	5·04	26·03	96
1885	5·03	1·03	0·80	0·55	1·80	0·62	0·03	0·06	1·39	0·51	0·68	4·02	16·52	84
1886	3·06	3·56	0·41	2·35	1·91	9·25	5·17	1·12	3·31	2·02	3·87	9·03	45·06	127
1887	3·88	11·09	7·84	4·11	0·22	0·92	3·85	2·75	1·50	0·62	1·81	6·19	44·78	120
1888	2·89	32·14	0·08	2·82	0·27	0·24	0·03	0·19	0·03	1·35	0·37	1·47	41·88	72
1889	1·81	4·27	6·58	5·25	2·37	1·45	3·66	0·59	2·79	0·98	4·61	5·48	39·84	120
1890	21·16	9·34	25·06	0·16	4·28	2·95	3·35	0·44	2·97	0·93	4·21	7·05	81·90	147
1891	23·64	1·72	3·24	1·50	2·45	6·16	1·62	1·11	0·99	1·32	0·28	3·46	47·49	120
1892	2·60	1·04	1·70	1·53	3·04	1·43	1·86	0·04	2·73	6·73	1·13	9·66	33·49	103
1893	12·39	23·67	3·58	0·71	1·17	6·30	1·90	3·15	0·46	0·46	2·27	1·02	57·08	112
1894	15·68	4·03	7·41	4·67	2·04	3·74	0·05	1·23	2·61	1·47	2·79	11·09	56·81	128
1895	11·63	2·78	0·44	2·71	0·72	0·48	3·00	Nil.	1·63	0·54	1·12	3·42	28·47	94
1896	27·00	20·44	0·59	1·01	0·26	2·28	0·62	1·53	0·12	0·31	4·16	1·48	59·80	95
1897	4·59	5·07	1·60	Nil.	1·04	0·53	2·31	1·23	1·30	5·73	1·92	6·18	31·50	77
1898	17·70	18·46	10·41	0·61	0·98	1·19	0·29	0·40	2·76	0·95	1·16	0·76	55·67	103
1899	17·18	9·88	3·59	4·42	2·49	0·40	2·23	1·71	1·96	2·36	1·22	11·02	58·46	106
1900	4·53	0·25	1·64	0·93	1·38	0·71	1·70	0·92	2·52	0·53	1·15	0·68	16·94	69
1901	0·49	8·25	5·53	2·84	0·79	0·24	2·29	3·04	1·78	0·51	0·41	0·19	26·36	77
1902	4·79	1·36	1·68	0·21	Nil.	Nil.	0·01	0·09	1·41	0·05	0·51	5·69	15·80	40
1903	0·92	1·88	3·73	1·12	6·93	0·84	3·73	0·59	0·50	1·84	7·42	4·08	33·08	91
Average for 33 years	7·68	8·47	4·81	2·10	1·91	2·35	1·86	0·82	1·54	1·66	2·35	4·74	40·63	87·39

APPENDIX II.—DISTRIBUTION OF RAINFALL AREAS IN AUSTRALASIA.

Rainfall.	Rainfall Areas in Square Miles.			
	Australia.	Tasmania.	New Zealand.	Australasia.
Less than 10 inches . . .	1,219,600	..	..	1,219,600
10 inches to 20 inches . .	843,100	9,440	..	852,540
20 ,, ,, 30 ,, . .	399,900	..	69,650	469,550
30 ,, ,, 40 ,, . .	225,700	8,380	17,410	251,490
40 ,, ,, 50 ,, . .	140,300	8,380	17,410	166,090
50 ,, ,, 60 ,, . .	47,900	..	..	47,900
60 ,, ,, 70 ,, . .	56,100	..	..	56,100
More than 70 inches . . .	14,100	..	..	14,100
Total . .	2,946,700	26,200	104,470	3,077,370