(*Paper No. 3883.*)

"Investigations Relating to the Yield of a Catchment-Area in Cape Colony."

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Owing to a considerable shortage in the water-supply to the southern suburbs of Cape Town, even in respect to existing requirements, and to the fact that sites for storage-reservoirs on Table Mountain, even if economically available, were owned by other Corporations it became necessary to seek a source of supply outside the Cape Peninsula. Accordingly, the investigations described in this Paper were undertaken to ascertain whether the total yield of the selected catchment-area would be sufficient for future requirements, and to obtain data relating to the river-flow during the dry seasons; with a view to determine the storage required for the earlier instalments of the scheme, and the quantity of compensation-water which should be provided to meet the claims of riparian proprietors. The rainfall returns are stated somewhat fully, as they emphasize the marked variation in the intensity of rainfall over small areas in mountainous districts. Further, the comparatively long period during which the investigations were carried on enables an opinion to be formed as to the value of figures for mean rainfall obtained by computation from readings at neighbouring gauges which have been read for several years. It is also hoped that the gaugings of the quantity of water flowing off the catchment-area may possess more than a local interest, as the rapid rise and fall of the river during rainy weather clearly contrast the percolation on barren surfaces with that on the weathered deposits of the valley and talus slopes, the latter storing the water during the earlier rains and supplying a constant flow throughout the summer months. The considerable difference in the permeability of the ground at various points indicates the danger of assuming an arbitrary percentage of the rainfall as the loss due to absorption and evaporation. The measurements of the flow of the Wemmers Hoek River emphasized the necessity for obtaining river-gaugings over at least twelve consecutive months, even if the investigator is possessed of considerable local knowledge of the run-off from similar catchment-areas.

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A range of mountains, with precipitous slopes, forms the peninsula at the northern end of which Cape Town is situated. Another but much longer range of mountains, running due north in a line about 25 miles east of Cape Town, forms the eastern boundary of a relatively flat, sandy plain which stretches westwards to the sea, except where it merges into the slopes of the Cape Peninsula range for a length of 12 miles. The rain-bearing winds from the north-west pass over this large area of sand-flats and precipitate their moisture along the main mountain range, thus providing important tributaries to the Berg River which, with four other large rivers, has its source at the southern end of the range. The Berg River takes its rise amidst rugged mountains, covering an area of 30 square miles, on which the mean rainfall probably averages more than 100 inches per annum. It is joined, at a short distance below where it emerges from this mountainous area, first by the French Hoek River and then, about 2 miles below this confluence, by the Wemmers Hoek River, after which it flows along the western slopes of the mountains in a sinuous course for about 58 miles northward; it is then joined by its last important tributary, and, flowing north-west, discharges into the sea at St. Helena Bay.

A Government Commission, appointed in 1902 to report on the water-supply to the Cape Peninsula, recommended *inter alia* that an increased supply should be obtained, equal to at least 10 million gallons per day, with capability of increase up to even four times this amount. There was no doubt that the head-waters of the Berg River were capable of yielding a supply largely in excess of these requirements, but the cost of storage, especially for the earlier instalments of the scheme, would have been unduly great. It was accordingly decided to investigate the yield from the catchment-area of the Wemmers Hoek River, which was the only important tributary to the Berg River along the first 50 miles of its course.

The Wemmers Hoek River has its source on the portion of the main range known as the Drakenstein Mountains, and takes its rise at either extremity of the longer axis of the catchment-area, which is approximately 11 miles long in a north-westerly to south-easterly direction by $3\frac{1}{2}$ miles wide. These two branches, augmented by several large tributaries from the steep slopes of the north-eastern boundary, unite near the centre of the catchment-area and emerge in one channel through a narrow opening near the middle of the south-western boundary, whence the river continues to flow westward to its junction with the Berg River. It is 800 feet above sea-level at the site of the proposed dam, and from there to its confluence with the latter river the distance is about $4\frac{1}{2}$ miles.

The catchment-area, situated 40 miles east of Cape Town, has an area of $34\frac{1}{2}$ square miles. It is surrounded by mountains composed of quartzitic sandstone belonging to the Table Mountain series, which reach a height of over 5,000 feet above sea-level on the north-eastern boundary, the average height of the south-western range being about 2,500 feet. The more lofty of these mountains, intersected by numerous ravines, are very precipitous and practically bare of vegetation at their higher levels, which are frequently covered with snow during the winter; their bases, flanked at the eastern end of the catchment-area with great talus slopes, merge at the northern end into a comparatively level plateau, having an elevation of about 2,500 feet above sea-level. This plateau, which rises nearly vertically from the streams which flow at the base of two of its sides, has an area of about 4 square miles, covered with grass and bush. Only a small portion of the valley, which is overlain with boulders and debris to a considerable depth, is cultivated; the remainder of it is covered with reeds, rank grass, and bushes. The slope of the river-bed near the confluence of the two main branches is about 50 feet per mile.

As previously stated, the prevailing wind during the wet season sweeps from the sea across the nearly level sandy plain, from the north-west quarter, and this half of the catchment-area, only a small portion of which is less that 2,500 feet above sea-level, receives the larger share of the rainfall. In summer the south-easterly gales cause occasional heavier falls on the south-east end.

The water in the Wemmers Hoek River is clear and colourless, and even in flood it carries very little silt.

Fig. 1, Plate 6, is a plan of the catchment-area, showing the approximate positions of the rain-gauges erected on it.

Rainfall.

Three rain-gauges were fixed originally at comparatively low levels in the valley. The first monthly readings at these gauges were obtained from Nos. 10 and 11 in September, 1903, and from gauge No. 9 in February, 1904, these readings being continued until the termination of the investigations in October, 1907. Eleven additional gauges were erected during 1905, namely, Nos. 1 to 8 and Nos. 12 to 14, the first monthly readings from which were obtained in September of that year; and during 1906 twelve more gauges were fixed, so that for nearly a year readings were obtained at twenty-six gauges. The whole time of two observers was taken up in reading these gauges, the valley gauges, namely, Nos. 8 to 11, 15, and 18 being read daily, and the remainder of the gauges regularly once a week.

The mean annual rainfall at gauges Nos. 9, 10, and 11, was computed from a comparison of the actual readings observed at the gauges themselves, and the readings of two other rain-gauges over a period of years. These two gauges used as a basis for the estimation were situated, one in Paarl, a town 8 miles to the north-west, and the other on a farm called Weltevreden, 6 miles to the south-west, measured from the centre of the catchment area. The gauge at Paarl had been read since 1882, and that at Weltevreden since 1893, the mean annual rainfall at Paarl being 34·35 inches for a period of 25 years, and 34·67 inches for the 14 years, 1893 to 1906, while at Weltevreden it was 35·97 inches during the latter period. Both gauges were near the Berg River, in open country, and removed from the influence of the mountains, so that the rainfall was much less than on the catchment-area.

The monthly rainfalls at the three gauges (Nos. 9, 10, and 11), and the method of computing the mean annual rainfall at these gauges, are shown in the Appendix, Table I. The results of the computation are also shown in Fig. 1, Plate 6, where the diameters of the circles are proportional to the computed mean annual rainfall.

The mean annual rainfalls at the remainder of the gauges were computed in the same manner by comparing the readings obtained at them with those obtained at gauges Nos. 9 and 10; except in the case of gauge No. 6, which was computed from gauge No. 11, these two gauges being situated in the same neighbourhood and both showing a low rainfall.

The monthly rainfalls and the results of the computations for the mean annual rainfall at gauges Nos. 1, 4, 12, and 13, are shown in the Appendix, Table II.

The following figures show a comparison between the values of the mean annual rainfall at each gauge, as computed at different dates.

Gauge Number.	Number of Previous Monthly Readings on which Computation was Based.			Computed Mean Rainfall.		
	1905	**1906**	**1907**	**1905**	**1906**	**1907**
	No.	No.	No.	Inches.	Inches.	Inches.
1	5	9	24	141	154	139
2	5	9	12	93	104	109
3	5	9	12	92	101	93
4	5	9	24	152	208	210
5	5	9	12	82	87	86
6	4	9	12	34	38	40
7	4	9	12	72	80	72
8	4	9	12	57	61	61
9	22	28	36	57	62	62
10	24	33	36	55	57	57
11	24	33	36	44	44	44
12	4	9	24	58	77	85
13	4	9	24	55	69	71
14	4	9	12	50	55	56

The arithmetical mean of the figures obtained in 1905 is 13·3 per cent. less than that obtained in 1907, and the variation in the arithmetical means of the figures for 1906 and 1907 is just over 1 per cent.

The mean annual rainfall at each of the gauges having been thus obtained, the average over the whole catchment-area was calculated by dividing up the 34½ square miles into four zones of different rainfall-intensity, then multiplying the area of each zone by the arithmetical mean of the computed mean annual rainfall at each of the gauges situated within that zone, and finally dividing the sum of these products by the total area of the catchment. As the investigations proceeded it became possible not only to obtain a mean annual rainfall at individual gauges, based on the comparison of readings for longer periods, but also, by means of the additional gauges, to determine more accurately the area of the different zones of rainfall-intensity; the result being that, whereas in May, 1906, the mean annual rainfall over the whole catchment-area was computed to be 86 inches, this figure was modified to 76 inches when a similar calculation was made in June, 1907. Owing to the inaccessibility of many parts of the mountains forming the boundaries of the catchment-area, and to the deep ravines which intersected them, it was impossible to space the rain-gauges so that each should serve an equal area, but the fact that in June, 1907, the arithmetical mean of all the gauges was 81 inches, as compared with 76 inches computed, showed that the distribution of the gauges was good.

The average of the driest three consecutive years at the Royal Observatory, Cape Town, is 73 per cent. of the mean rainfall during a period of 64 years. This gauge, which is situated about 30 feet above sea-level, and is not sufficiently close to Table Mountain to be affected by it, has a mean rainfall of 27·84 inches. Although the figures relating to 153 records, which are given in the Paper[1] by Sir Alexander Binnie, Past-President Inst. C.E., afford no support to the theory that the variation of the average of the three driest consecutive years from the mean rainfall is less in areas of heavy than in those of low rainfall, they do show that this percentage varies considerably, within certain limits, owing to local conditions. The effect of mountainous districts is to cause the rain which falls on them to be more equally distributed, both throughout the seasons and from year to year. On the Wemmers Hoek catchment-area, exposed as it is to the prevailing rainy wind, rain has frequently been observed when none fell on the areas of lower rainfall outside the catchment, so that in assuming the average of the driest three consecutive years at Wemmers Hoek as 80 per cent. of the mean rainfall, i.e., at 61 inches, the estimate was probably a conservative one.

The very heavy rainfall recorded at gauge No. 4 is evidently a "spot" rainfall, and in calculating the average rainfall over the whole catchment-area, only ½ square mile was allowed as the area to which this rainfall was applicable. This excessive rainfall was probably due chiefly to the precipitous face, on the leeward side of the gauge, of a projection from the high mountains on the north-western boundary, which tended to arrest and condense the current of moist air when, in the wet season, the wind was from the north-west. Also in summer the south-east and south-west winds, travelling along the valley of the catchment-area, encountered the nearly vertical face, about 1,400 feet high, which forms the boundary of the plateau near the edge of which the gauge is placed. The monthly readings at gauge No. 4 are given in the Appendix, Table II.

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[1] "Mean or Average Annual Rainfall and the Fluctuations to which it is subject." Minutes of Proceedings Inst. C.E., vol. cix, p. 133, and footnote to p. 89.

River-Flow.

Gaugings of the flow of the Wemmers Hoek River were obtained throughout four dry seasons and one wet season, as well as during the greater part of a second wet season. These gaugings showed that with an average rainfall over the whole catchment-area of 63·63 inches during the 12 months, May, 1906, to April, 1907, there had been a loss of 38 inches by absorption and evaporation; but, for reasons given subsequently, it is probable that the loss on the computed average rainfall of the driest three consecutive years, that is, 61 inches, will not exceed 34 inches.

In 1903 a trapezoidal weir, 20 feet long at sill-level by 30 inches deep, was erected across the river, but this gauge was not capable of measuring any but the smaller floods. Though it furnished data for the calculation of the storage-capacity required for the earlier instalments of the scheme up to 15 million gallons per day, and supplied information of great use when the quantity of compensation-water to be provided was under discussion, it was useless for determining the discharge during the wet season. For this reason, in May, 1906, additional gauges were erected across the flood-channels, capable of measuring all flows of the river except at times of exceptional floods; but even then the capacity of the gauges was sufficient to enable close approximations to the maximum flow to be made, as the peak of the flood never lasted more than a few hours.

The river gauge-weirs were constructed of 9-inch by 3-inch deal piling, which was driven 6 to 8 feet into the deposits of boulders and debris that overlay the solid rock to a depth of about 25 feet, and formed the bed and banks of the river-channels. Wrought-iron plates were fixed to the piling around the weir-openings, and the spaces between the gauges, where there was no piling, were embanked with bags filled with sand, packed solid with ground from the neighbourhood. There was probably some leakage under the gauge-weirs in times of flood, though none was noticed, and the channels by which the water approached the weirs were narrower than desired. Such errors as resulted from these causes tended to give a measurement of the flow less than the true one, so that the weirs, although of cheap construction, were reasonably efficient, and the purposes of the investigation did not warrant the large additional cost which would have been incurred with a more substantial construction.

During the later investigations, in consequence of the rapid rise and fall of the floods, gaugings of the river-flow were taken at regular intervals of 4 hours between 6 a.m. and 6 p.m., and at times of exceptionally heavy floods further intermediate gaugings were made. No serious error would have resulted from single daily readings over a wet season, but that it becomes appreciable for short periods is shown by the following figures:—

Period, 1896.	Total Flow, calculated from		Error, Measured in Percentage of True Flow, if only One Daily Gauging taken.
	One Daily Reading taken at 10 a.m.	Four Daily Readings.	
	Gallons.	Gallons.	
May	754,150,000	836,744,000	− 9·8
June	1,903,558,000	1,788,873,000	+ 6·4
July	1,523,932,000	1,525,845,000	
August	3,122,911,000	3,618,071,000	−13·4
September	1,640,034,000	1,635,901,000	
October	915,578,000	884,998,000	+ 3·4
Total for 6 months .	9,860,163,000	10,290,432,000	− 4·0

Curves showing the rate of flow during the greatest floods which occurred in the years 1906 and 1907 are given in Figs. 2, Plate 6. These curves, which are typical of the flow even during the smaller floods, show the rapidity with which rain increased the rate of flow, as well as the almost equally rapid decrease of the flood after it had reached its maximum. The maximum rate of flow measured during the flood in 1906 was 1,273,600,000 gallons per day, and in 1907 it was 1,454,500,000 gallons per day. With the catchment-area of 34½ square miles, these figures are respectively equivalent to a discharge of 6·4 and 7·3 cubic feet per minute per acre. It may not be out of place to mention here that during a great flood, in November, 1908, in the eastern province of Cape Colony, when much damage was done to the town of Port Elizabeth, it was estimated that the maximum rate of flow was 60 cubic feet per minute per acre from a catchment-area of 35 square miles. No flood approaching this in magnitude had previously been noted in Cape Colony.

The minimum discharges of the Wemmers Hoek River observed were:—

3,747,000 gallons per day on 5th February, 1904.
3,500,000 ,, ,, ,, ,, five days in February, 1905.
4,221,000 ,, ,, ,, ,, 9th February, 1906.

Comparing the minimum flows observed in the same year on different catchment-areas, in mountainous districts and under similar conditions of rainfall, it was found that the minimum rates of river-discharge were approximately:—

Area of Catchment. Square Miles.	Rate of Flow per Day. Million Gallons.
34·5	4·22
14·7	2·38
3·75	0·92

The rainfall during the summers 1903-4, 1904-5 and 1905-6 was considerably below the average for this period, but in December, 1906, an exceptional flood occurred. The average daily discharge of the Wemmers Hoek River for these dry seasons was:—

	1903–4	1904–5	1905–6	1906–7
	Million Gallons.	Million Gallons.	Million Gallons.	Million Gallons.
December . . .	10·95	13·43	9·21	21·60
January . . .	8·07	8·09	6·40	8·26
February . . .	4·84	4·22	5·50	4·91
March	5·38	..	7·02	9·65

Underground Storage.

A portion of the rain which falls during the earlier months of the wet season (May to October) is stored up in the deposits of the valley and talus slopes, thus causing the percentage yield in the wet season, as measured by the river-discharge, to appear less than its true quantity, and the yield during the dry season, when this stored water is given up and constitutes the larger portion of the river-flow, to appear greater than it actually is. The effect on the river-discharge produced by the earlier winter rains is shown by the following results from gaugings taken during periods at the end of

Period, 1906.	Average Rainfall.		River-Discharge.	Rainfall which Flowed Off.
	Total.	Per Day.		
	Inches.	Inch.	Gallons.	Per Cent.
4th May to 7th June	8·20	0·24	890,215,000	21·7
7th June to 12th July	11·40	0·34	2,295,555,000	40·0
12th July to 10th August	6·61	0·23	1,357,761,000	41·0
10th August to 12th October	16·78	0·28	5,105,098,000	60·0

which no rain fell, so that the percentages of available rainfall here given represent the true yield from the rainfall except for that portion of it which was stored underground. The earlier periods show a low percentage of discharge, which gradually increases in subsequent periods as the underground storage is replenished.

A comparison of these figures with some obtained from measurements taken, under similar conditions of rainfall, on a small catchment-area of 110 acres on Table Mountain, where practically all the soakage-water flows off during a dry spell before the next rain, enables an estimate to be made of the quantity of water stored underground at Wemmers Hoek during the foregoing period. The measurements obtained on the 110-acre area were :—

Period, 1906.	Average Rainfall.		Stream-Discharge.	Rainfall which Flowed Off.
	Total.	Per Day.		
	Inches.	Inch.	Gallons.	Per Cent.
4th May to 7th June	8·30	0·24	9,500,000	46·0
7th June to 12th July	7·39	0·21	12,500,000	68·0
12th July to 10th August	5·27	0·17	5,700,000	43·3
10th August to 12th October	10·55	0·17	13,900,000	53·0

Comparing these two catchment-areas during the period, 4th May to 12th October, the losses due to absorption and evaporation were 15·12 inches of the 31·51 inches of rain which fell on the 110-acre site, and 23·67 inches of the 43·04 inches which fell at Wemmers Hoek, or a loss at the latter of 8·55 inches more than on the smaller catchment-area. During this period the evaporation-losses would not have varied much, and it is probably correct to assume that the underground supply was full on the 10th August. If during the three earlier sub-periods any loss of rainfall in excess of the average daily loss between 10th August and 12th October is considered as so much water added to storage underground, the water thus stored would be equivalent to 3·02 inches, 3·34 inches and 1 inch of rain for the three sub-periods respectively, or a total for the whole period of 7·36 inches, a figure which agrees fairly closely with the 8·55 inches obtained from a comparison of the two catchment-areas. If 7·36 inches of rain were actually retained in the ground, there must have been further heavy losses from it before the supply was discharged into the river.

Dry-Season Yield.

The discharge of the Wemmers Hoek River during a portion of three dry seasons is shown in Figs. 3, Plate 6. It was evident that a large portion of the summer flow was due to the supply from underground storage, and an attempt to estimate the quantity of this supply is shown on the diagrams by the assumed curve of underground supply (shown dotted). The minimum river-flows decreased in each of the dry seasons nearly uniformly from November until February, when they gradually increased again in a similar curve. The rapid evaporation which takes place during the 5 or 6 months of the very low rainfall, normally occurring during summer in the western province of Cape Colony, accounts for the small quantity of available rainfall at this season of the year. On Table Mountain it has been noted that practically no water flows off the catchment-areas during summer unless the rainfall exceeds 1 inch in 24 hours.

Average of Driest Three Consecutive Years.—On the Wemmers Hoek catchment-area, during the 12 months May, 1906, to April, 1907, the average rainfall was 63·63 inches; the total quantity of water which flowed off was 12,670 million gallons, equivalent to nearly 35 million gallons per day; and the ratio of the water which flowed off to the rain that fell was 40 per cent., so that the loss of water, due to absorption and evaporation, was 38·2 inches. It remained to estimate what the yield would be from an average rainfall of the driest three consecutive years.

In view of the measurements of river-flow obtained between the 10th August and the 12th October, 1906, it is probable that, as soon as the winter rainfall has supplied all the water which the deposits of debris and boulders are capable of storing, about 60 per cent. of any additional rainfall during the wet season will flow off the catchment-area. Further, an analysis of the gaugings of river-discharge during the five dry months, November to March, showed that the portion of the total discharge due to the rain which fell in these months was less than 20 per cent. of the rainfall; and that even with the exceptionally heavy rain which fell in December, 1906, the proportion of rainfall flowing off during the five months was only 21 per cent. From these two facts it is evident that the yield from this and neighbouring catchment-areas depends much more on the rain which falls during the six wet months than on the annual rainfall.

For the purpose of comparing the rainfall of the six wet months, during which gaugings of the discharge of the Wemmers Hoek

River had been obtained, with the rainfall of similar periods of other years, a rain-gauge on Table Mountain, called Waai Kopje, was utilized. This gauge was subject to conditions of rainfall similar to those at Wemmers Hoek, and the mean rainfall for 25 years at Waai Kopje was 66·95 inches, as compared with 76 inches at Wemmers Hoek. The driest three consecutive years at Waai Kopje were 1894–96, with an average rainfall of 55·92 inches, or 83 per cent. of the mean, and the average rainfall of the next driest three consecutive years, 1885–87, was 57·08 inches. The rainfall during the six wet months was found to average 39·11 inches for the three seasons 1894–96, and 40·44 inches for the three seasons 1885–87. The rainfall during the six wet months of 1906 was 36·34 inches, or the lowest on record, the next lowest being 37·11 inches in 1887, and 37·9 inches in 1896. It was evident, therefore, that the distribution of the rainfall during the 12 months, May, 1906, to April, 1907, was exceptionally unfavourable for the production of a yield from the Wemmers Hoek catchment-area in proportion to the amount of rain which fell, owing to the deficiency of rainfall during the wet season and the great difference in the percentage of rainfall which flows off during the wet and dry seasons. The following figures, expressed as percentages of the mean rainfall, show the distribution of the rainfall at Waai Kopje during these periods:—

Period.	Wet Season, May to Oct.	Dry Season, Nov. to April.	Total for 12 Months.
	Per Cent. of Mean Rainfall	Per Cent. of Mean Rainfall	Per Cent. of Mean Rainfall
Average of 3 years, May, 1885–April, 1888	60·4	24·0	84·4
,, ,, ,, May, 1894–April, 1897	58·4	26·1	84·5
May, 1906–April, 1907.	54·4	35·3	89·5

From this analysis of the rainfall-records at Waai Kopje it is probable that the yield of the Wemmers Hoek catchment-area reached its minimum in 1906; and that the average yield during the driest three consecutive years will be between 37 and 38 million gallons per day.

Compensation-Water.

The scheme in connection with which these investigations were made received, in August, 1907, the sanction of the Cape Legislature by whom the quantity of compensation-water to be provided was fixed at $5\frac{1}{2}$ million gallons per day. Of this quantity 5 million gallons were to be delivered at the confluence of the Wemmers Hoek and Berg rivers, and the remainder was to be delivered, for domestic supply, to the neighbouring town of Paarl. The cost of the pipe-line for conveying the water to Paarl, estimated at £10,000, was also included in the compensation to be given. No compensation-water was required as regards the Wemmers Hoek River, as all riparian rights along the $4\frac{1}{2}$ miles of its course between the site of the proposed dam and its junction with the Berg River had been purchased previously.

The Berg River is about 136 miles long, and its course after emerging from the mountainous district in which it rises is through the nearly flat sand and boulder deposits referred to previously, so that occasionally in summer it contains no visible water at certain places until its supply is again augmented by the next lower tributary. Gaugings of flow, where it is joined by the Wemmers Hoek River, were not taken for a sufficient time to allow of more than a rough approximation to its discharge at this place, but it is probable that the latter river contributes here about 30 per cent. of the total flow. If the total yield, therefore, of the Wemmers Hoek *catchment-area*, less *compensation-water*, is finally required, this quantity will only represent about 26 per cent. $\left(\frac{37-5}{37} \times \frac{30}{100}\right)$ of the existing flow of the Berg River at the confluence in dry years. In summer, when water is required most by the riparian proprietors, no appreciable difference will be made to the flow of the Berg River. Farmers in South Africa depend on the rivers for irrigation, for watering cattle, and for domestic washing, so that they view the whole of the river-water as an inalienable birthright, and any interference with it as hurtful to them. Though water may be urgently required for the public benefit, any proposal to lead it away from one watershed to another is always strongly opposed, even if, as in the present case, very little of the river-water is used for irrigation.

The investigations on which these notes are based were carried out, from December, 1905, until their termination, under the direction and supervision of Mr. Thomas Stewart, M. Inst. C.E., the Author acting as his chief assistant.

The Paper is accompanied by two tracings, from which Plate 6 has been prepared, and by the following Appendix.

[APPENDIX.

APPENDIX.

TABLE I.—COMPUTATION OF MEAN RAINFALL AT GAUGES NOS. 9, 10 AND 11 BY A COMPARISON WITH THE RAINFALLS AT PAARL AND WELTEVREDEN FOR 36 MONTHS.

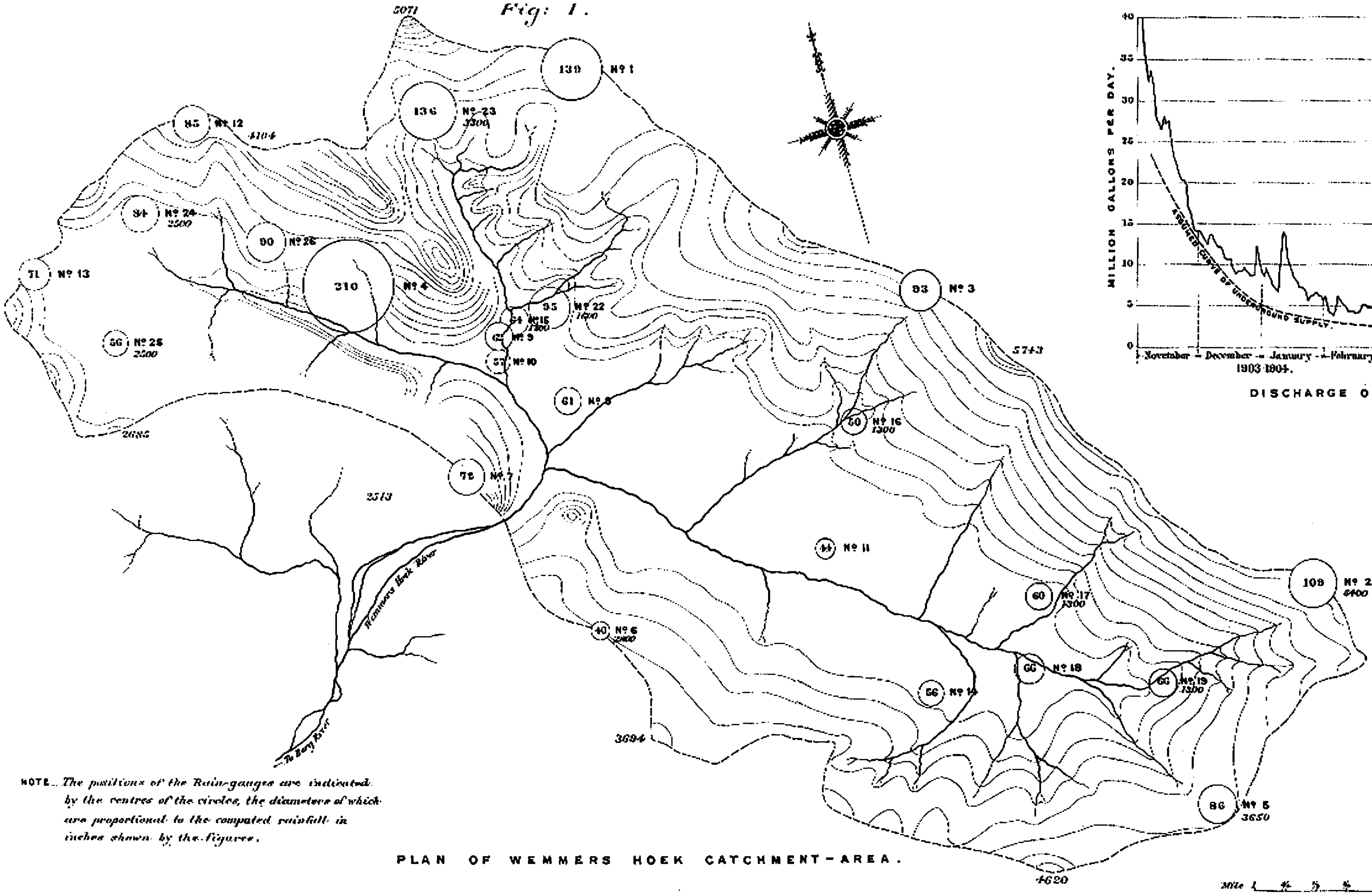
	Station	Paarl.	Welte-vreden.	Wemmers Hoek. Gauge No. 9	Wemmers Hoek. Gauge No. 10	Wemmers Hoek. Gauge No. 11
	Height above sea Feet	500	540	1,150	920	1,100
Rainfalls observed : Inches.	1904. March . . .	0·53	0·44	1·14	0·72	0·82
	April . . .	6·54	8·34	9·94	9·65	6·47
	May . . .	2·97	3·89	3·23	2·68	3·56
	June . . .	9·34	8·59	12·35	11·52	7·73
	July . . .	2·78	2·25	6·35	6·23	2·81
	August . .	7·60	6·88	18·77	18·55	13·84
	September .	2·89	2·97	6·63	6·68	5·49
	October . .	3·44	3·78	3·55	2·75	2·48
	November . .	2·02	1·85	4·15	3·83	3·30
	December . .	1·35	1·30	1·16	0·89	0·82
	1905. January . .	0·42	0·21	0·62	0·52	0·59
	February . .	0·15	0·20	1·24	0·24	0·23
	March . . .	0·86	1·30	0·84	0·84	0·58
	April . . .	0·00	0·13	1·18	1·12	0·60
	May . . .	6·24	5·69	8·70	7·96	7·59
	June . . .	12·31	9·02	17·49	16·61	14·04
	July . . .	1·32	3·20	2·24	2·22	1·49
	August . .	4·69	4·43	10·99	10·55	8·98
	September .	3·45	2·94	8·20	6·49	5·40
	October . .	4·76	4·36	7·88	6·21	6·89
	November . .	0·96	0·98	1·99	1·67	1·36
	December . .	0·49	0·70	1·41	1·23	1·16
	1906. January . .	1·38	1·06	0·68	0·52	0·55
	February . .	0·22	0·53	0·51	0·55	0·37
	March . . .	1·56	1·30	2·05	2·02	1·21
	April . . .	1·20	0·90	1·39	1·32	1·05
	May . . .	2·96	3·34	5·77	5·43	2·23
	June . . .	4·87	4·85	8·35	8·43	3·67
	July . . .	2·08	2·15	2·74	2·90	2·17
	August . .	5·85	5·34	12·70	11·98	8·59
	September .	2·01	1·76	2·57	2·47	1·24
	October . .	1·60	1·61	2·43	2·38	1·76
	November . .	0·78	0·65	1·39	1·38	1·05
	December . .	2·30	2·30	3·91	3·74	5·56
	1907. January . .	0·13	0·28	0·67	0·71	0·40
	February . .	0·10	0·10	0·74	0·57	0·69
	Totals . . . Inches	102·15	98·72	175·95	163·58	126·77
	Mean annual rainfall, 14 years, 1893–1906 Ins.	34·67	35·97			
	Ratio of total to mean	2·946	2·744			
		2·845 average				
	Computed mean $\left(\frac{1}{2\cdot 845}\right.$ of total) . . Inches	..	..	62·00	57·00	44·00

TABLE II.—COMPUTATION OF MEAN RAINFALL AT GAUGES NOS. 1, 4, 12 AND 13 BY A COMPARISON WITH THE RAINFALLS AT GAUGES NOS. 9 AND 10 FOR 24 MONTHS.

		Gauge number .	9	10	1	4	12	13
		Height above sea .	1,150	920	4,265	2,575	3,400	2,700
Rainfalls observed : Inches.	1905.	September	8·20	6·49	15·74	19·44	7·31	6·17
		October .	7·88	6·21	21·45	15·61	6·42	7·03
		November	1·99	1·67	4·20	5·67	2·90	2·36
		December	1·41	1·23	3·74	5·97	2·12	2·14
	1906.	January .	0·68	0·52	1·34	1·41	0·68	0·86
		February .	0·51	0·55	1·30	2·41	0·94	1·14
		March .	2·05	2·02	5·29	7·02	3·27	2·33
		April . .	1·39	1·32	3·43	4·02	2·57	2·12
		May . .	5·77	5·43	15·13	34·75	9·35	8·01
		June . .	8·35	8·43	19·43	36·30	12·65	11·28
		July . .	2·74	2·90	6·00	12·26	4·06	3·30
		August .	12·70	11·98	25·77	47·61	16·22	13·39
		September	2·57	2·47	6·13	9·18	4·10	3·60
		October .	2·43	2·38	4·59	4·81	3·87	2·38
		November	1·39	1·38	1·78	2·68	0·41	0·39
		December	3·91	3·74	8·17	9·33	3·82	3·53
	1907.	January .	0·67	0·71	0·48	2·05	0·70	0·47
		February .	0·74	0·57	2·33	0·99	0·90	0·50
		March .	2·39	2·51	8·15	10·52	6·12	4·93
		April . .	6·15	5·92	15·60	21·79	9·36	8·65
		May . .	16·76	14·75	35·44	47·27	26·13	20·28
		June . .	1·54	1·39	2·93	4·98	3·69	2·26
		July . .	1·94	1·68	0·75	5·83	2·01	1·82
		August .	5·63	4·61	13·47	23·96	6·18	4·96
		Totals . . Inches	99·79	90·86	222·64	335·86	135·78	113·90
		Mean taken from Table I Inches	62·00	57·00				
		Ratio	1·61	1·59				
			1·6 average					
		Computed mean Inches	..	..	139·00	210·00	85·00	71·00

YIELD OF A CATCHMENT-AREA IN CAPE COLONY.

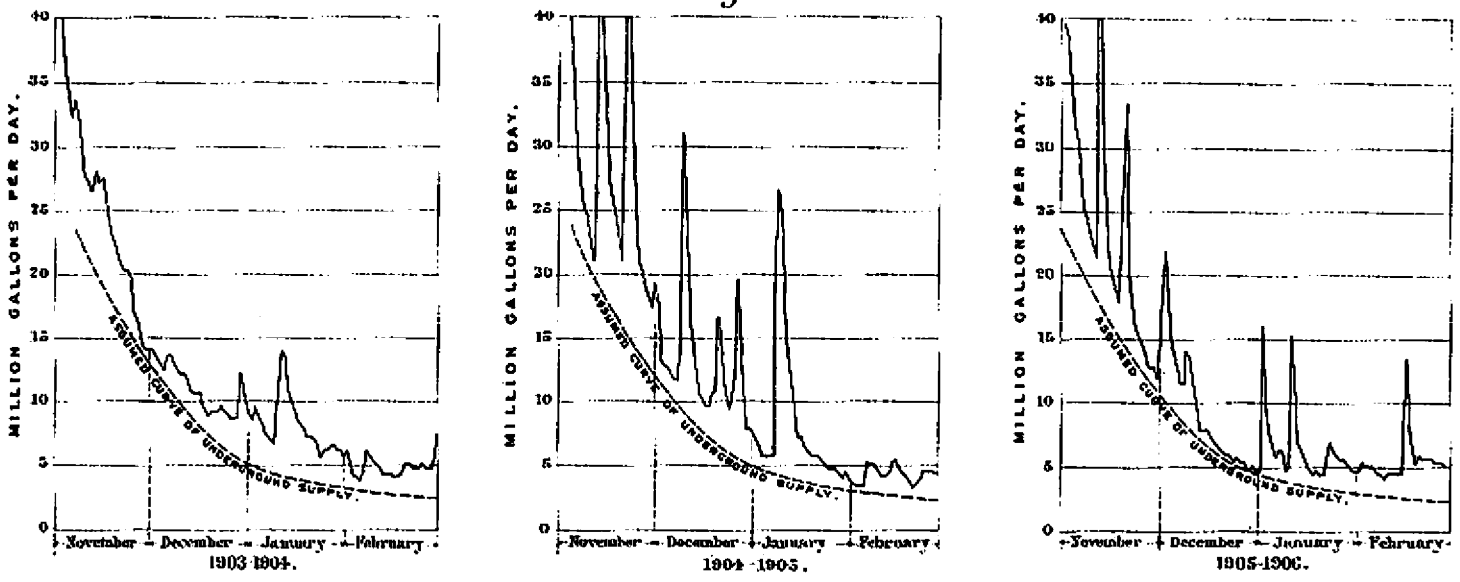
Fig: 1.



NOTE.. *The positions of the Rain-gauges are indicated by the centres of the circles, the diameters of which are proportional to the computed rainfall in inches shown by the figures.*

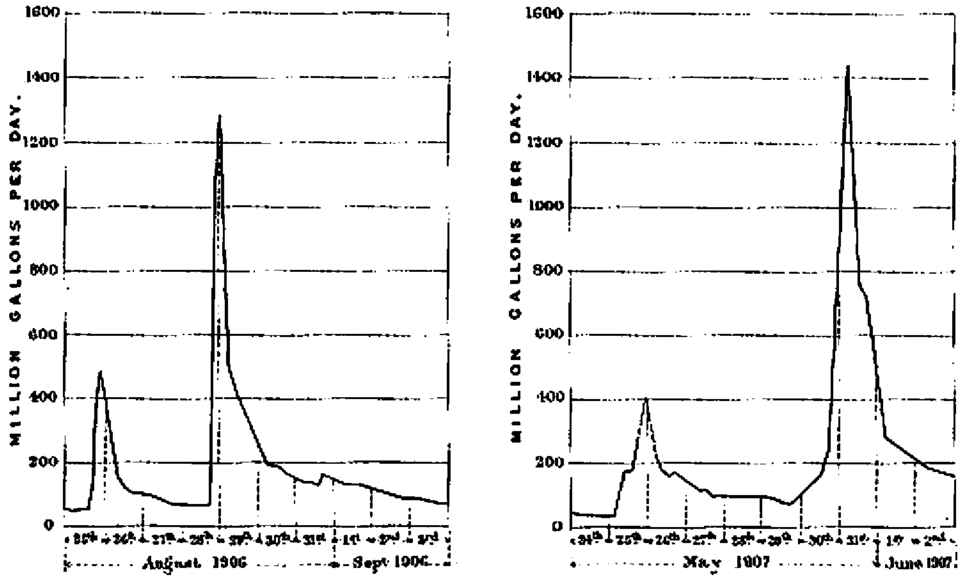
PLAN OF WEMMERS HOEK CATCHMENT-AREA.

Figs 3.



DISCHARGE OF RIVER DURING THREE CONSECUTIVE DRY SEASONS.

Figs 2.



MAXIMUM FLOOD-DISCHARGES.

Scale for Fig: 1.
Mile 1 ¾ ½ ¼ 0 1 2 Miles.

E. C. BARTLETT.