Table 52.—Comparison of Gauge Heights.

Period.	Average difference (Bellevue-Jobra) with Naraj gauge at			
	75 feet.	80 feet.	85 feet.	90 feet.
1	2	3	4	5
1866—76	—4·95	3·16	4·21	6·59
1877—96	—6·09	2·73	4·83	6·73
1897—1920	—6·00	0·30	5·03	6·39

The average values are collected together in Table 52. It will be seen from this table that as the flood rose higher at Naraj, the difference in gauge readings at Bellevue and Jobra increased systematically, showing that the Katjuri took an increasing share of the flood at higher levels. This is, of course, well-known.

A more important point is the question of any progressive change with time. If we concentrate our attention on a particular height, say, a level of about 80 feet at Naraj (which represents a moderate discharge, since the danger point is at 88 feet) we find from Table 52 that the difference (Bellevue-Jobra) has been steadily decreasing with time*. This shows that up to a level of 80 feet the Mahanadi has been taking an increasing share of the discharge. The situation is, however, quite different at 85 feet. The difference (Bellevue-Jobra) is here increasing, which appears to indicate that at about this level the Katjuri is taking an increasing share of the water. Finally, at the really important level of 90 feet (which represents high floods) apparently the difference has remained practically steady, showing that there has been no appreciable change in the average relative discharge through the Mahanadi and the Katjuri.

Instead of considering average levels, we may work with the maximum level attained in each year. This will be more instructive inasmuch as it will throw some light on the actual position during high floods. The average values of yearly maximum levels at Bellevue and Jobra are given in Table 53. In this table we have only considered floods above 88 feet at Naraj, since it is only beyond this level that the flood becomes really serious. Also we have grouped the data in decades, excepting for the earliest and the latest periods in which we have included 11 years.

Table 53.—Comparison of Gauge Heights.

Period.	Height of Naraj gauge.	Average of yearly maximum readings at		Difference Bellevue-Jobra.
		Bellevue.	Jobra.	
1	2	3	4	5
1885—1895	88 feet and above	81·38	73·66	+7·72
1896—1905	Do. ...	80·82	73·75	+7·07
1906—1915	Do. ...	79·21	72·27	+6·94
1916—1926	Do. ...	81·06	74·20	+6·86
†1923—1937	Do. ..	79·05	72·02	±7·03

* Mr. Shaw, Special Flood Officer, in his letter of the 8th March 1938, informed me that average of Gauge readings for the period 1921—1937 confirm this result. With 80·39 at Naraj, 68·72 at Bellevue and 67·90 at Jobra, the difference was 0·82. With 84·17 at Naraj, height at Bellevue was 74·21, and 69·51 at Jobra, giving a difference of 4·70. With Naraj, 89·39, Bellevue was 79·47 and Jobra 72·62 giving a difference of 6·85.

†The data for this period (1923—1937) were put in later being taken from Mr. Shaw's letter dated the 8th March, 1938. See footnote in page 82.

It will be seen from the above table, that the average difference of yearly maximum readings (Bellevue-Jobra) has been decreasing steadily. This shows that the Mahanadi has been probably taking an increasing share of the discharge during yearly maximum floods in recent years.†

Mr. Rhind calculated his flood discharges for the two rivers in 1872. In that year the gauge readings were 92·10 feet at Naraj, 83·20 feet at Bellevue and 75·95 at Jobra above weir. The difference between Bellevue and Jobra readings was thus 7·25 feet. The difference between the gauge readings at Bellevue and Jobra is 7·03 feet during high floods at the present time. This would indicate that the proportional discharge through the main branch has increased since 1872 with slight deviations. This bears out Captain Harris's contention regarding the effectiveness of the Naraj weir in decreasing the volume of the flood in the Katjuri. This result is all the more striking when it is remembered that for a considerable period prior to 1855 the volume of flood had been most probably increasing in the Katjuri branch and lessening in the main channel (Inglis, page 3).

The discharge through the different branches of the Mahanadi.

In 1872, Mr. Rhind made a detailed calculation of the discharge through various branches of the Mahanadi. These figures were given on a large scale map (1″=2 miles) in the report of the Orissa Flood Committee, 1928. I am reproducing the data here in a condensed tabular form as well as in the form of a diagram Figure 2.

Rhind also gave certain estimates of discharges in the Koakhye and its branches in the flood of 1885. Mr. J. Shaw, Assistant Executive Engineer, in his typewritten note of April 6th, 1929, gave the estimates of discharges made by Stevenson in 1921 for Naraj gauge at 87·00, and by Ganguli in 1923 for Naraj at 87·8 feet. These are reproduced in accompanying Figures 3 and 4 Comparative tables are given below.

The relative discharge for the different branches depends on the height of the Mahanadi above Naraj, and although the accuracy of the different estimates cannot be precisely compared as the height of the river is different in the three cases, they appear to be in general agreement so far as the order of the relative discharges in the different main channels are concerned.

The carrying capacities of the Orissa rivers are of course, much less than the actual discharges during high floods. In May 1858 Captain Harris, in the second portion of his report on the Mahanadi, showed, as the results of the sections which had been taken, that the capacity of the discharge of the channels into which the Mahanadi is divided midway between Cuttack and the sea, and allowing for embankments as at the time existing, was only 900,000 cusecs, or just one-half of the estimated volume of the 1855 flood. He also calculated that any flood rising higher than 20½ feet (=75·5 reduced) on the Lalbagh gauge must cause some inundations.

Table 54.—Discharge (in cusecs) through the Channels of the Mahanadi.

Rivers.		Rhind (1872).	Stevenson.	Ganguli.	Rhind (1885).
Mahanadi at Naraj	..	1,503,637*	977,292	980,531	
Mahanadi below Naraj	..	721,875	532,132	513,111	
Mahanadi ..	..	609,213	404,111	436,692	
Beropa ..	..	112,662	47,991	76,420	
Katjuri below Naraj	..	649,217	455,190	466,419	
Katjuri ..	..	447,279	383,546	384,529	
Koakhye ..	..	201,936 *(334,483)	71,644	81,891	250,229
Kushbhadra ..	..	..	19,322	...	50,425
Bhargovi ..	..	..	18,202	..	73,782
Daya ..	..	..	*34,110	..	*125,522

*Inclusive of spill.

† Mr. J. Shaw, Special Flood Officer, in his letter dated 8th March, 1938, sent me corresponding data for the period 1923—1937. The average height was 79·05 at Bellevue and 72·02 at Jobra with a difference of 7·03. This suggests that the Mahanadi has not been increasing in strength in recent years.

Table 55.—Relative Discharge through the Channels of the Mahanadi.

Name of river.	Rhind. (1872)	Stevenson. (1921)	Ganguli. (1923)
Mahanadi above Naraj ..	100	100·0	100
Mahanadi below Naraj ..	46	53·4	52
Mahanadi below Jobra ..	39	41·3	44
Beropa	7	12·1	8
Katjuri below Naraj ..	54	46·6	48
Katjuri	37	39·2	39·5
Koakhye	17	7·4	8·5
Kushbhadra	..	2·0	
Bhargovi	..	1·9	
Daya	...	2·6	
Spill	..	0·9	

Figure 2.——Rhind's Estimate of Discharge in 1872.

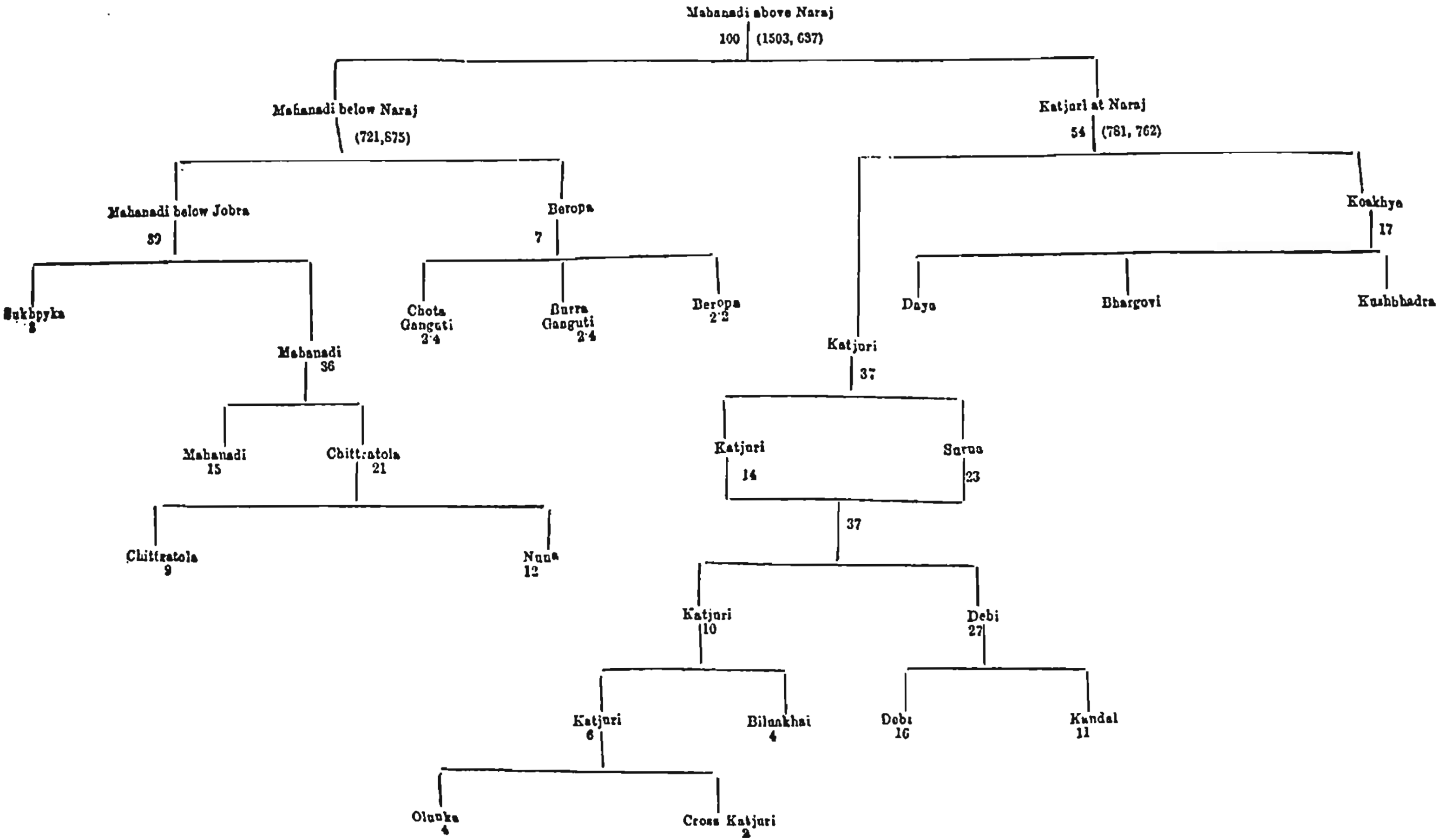


Fig. 3.——Discharge estimated by Mr. G. Stevenson in 1921.

(With Naraj Gauge at 87·00 feet.

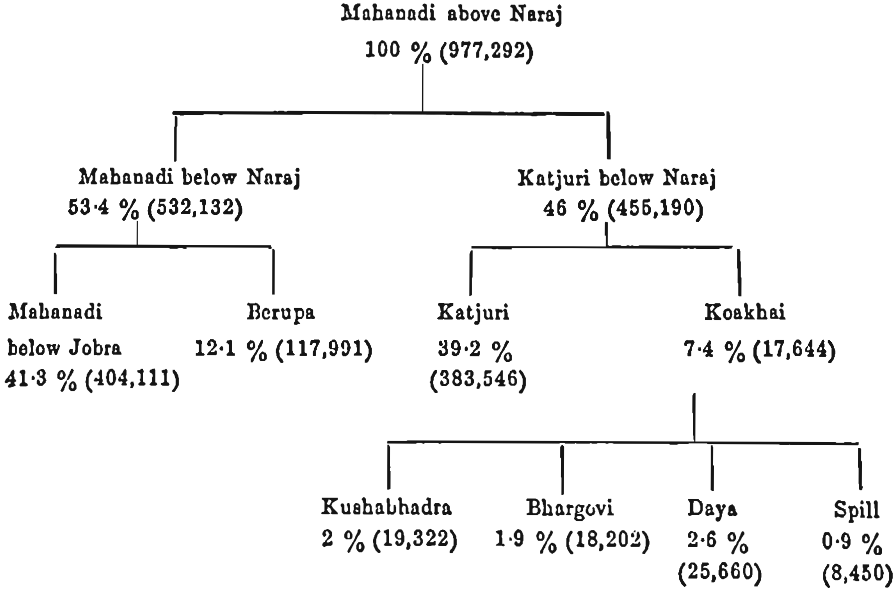
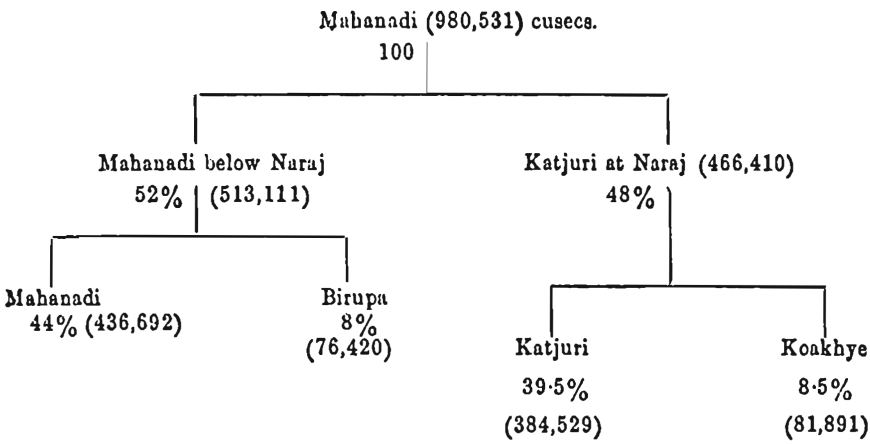


Fig. 4. Discharge estimated by Rai Sahib Nibaran Chandra Ganguli in 1923.



N.B.—The figure outside brackets gives the percentage discharge, and the figure within brackets the actual discharge in cusecs.

Rhind calculated that the volume actually received by the Koakhye in 1872 was 334,483 cusecs, but this quantity was partly due to breaches in the embankments near Naraj, and to the fact that the Naraj weir was seriously damaged. After making alterations to allow for these exceptional circumstances which may not occur again, Rhind estimated that the maximum volume which might be expected to pass down the Koakhye was 277,180 cusecs. According to Rhind's calculations the volume entering the Kushbhadra in 1885 was 50,425 cusecs, and the Bhargovi 73,782 cusecs. The maximum discharges of the Kushbhadra may therefore be taken to be 54,000 cusecs, of the Bhargovi 75,000 cusecs, and hence, of the Daya 148,000 cusecs. The capacity of the Kushbhadra on the other hand was estimated to be not more than 35,000 cusecs (Thomson, p. 16), and of the Bhargovi in its lower part with its branch Kanchi to be not more than 45,000 cusecs. As the capacity of the Daya is about the same as that of the Bhargovi (Thomson, p. 24) or say 35,000 cusecs, the combined capacity of these three rivers would appear to be about 115,000 cusecs which would leave about 162,000 cusecs to be passed through escapes and spill channels.

Mr. J. Shaw in his note of April 6, 1929, (as revised in his letter of the 8th March 1938) mentioned that the following velocities in feet per second were observed by Stevenson and Ganguli :—

Table 56.—Velocities in the River Channels in feet for second.

———	Naraj Gauge.	Mahanadi below Jobra.	Beropa.	Koakhye.	Katjuri.
Stevenson (1921) ...	86·0	5·00	5·86	7·18	6·05
Ganguli (1923) ...	87·8	5·58	6·36	7·50	6·30

Practically no information is available regarding the discharges or carrying capacities of the many tributaries of the Mahanadi above Naraj. The maximum flood discharge of the Tel (which joins the Mahanadi at Sonpur about 140 miles above Cuttack) was estimated to be 260,000 cusecs. (Inglis, p. 21.)

CHAPTER XVI. THE BRAHMINI.

The Brahmini enters the delta about 10 miles above Jenapur and 8 miles above the Bengal-Nagpur Railway. At Jenapur is situated the outfall of the High Level Canal Range I. The river also sends off a branch, the Patia, at this place. Both the Brahmini and the Patia are dammed by weirs to feed the High Level Canal Range II and to maintain a navigable channel between the two ranges of the Canal. Mr. Thomson remarked in 1904 (p. 27) that as far as the Brahmini was concerned the channel was of little use because it was silted up and navigation was maintained with great difficulty.

The Brahmini weir is 4,000 feet long with its crest at 58·00 feet. The Patia weir is 783 feet long. The highest flood level recorded at Jenapur above Brahmini weir, since the construction of the weir, was 70·6 on the 17th August, 1926. The level exceeded 70 on three other occasions in recent times (70·1 on the 23rd July, 1920, and 31st July, 1927, and 70·2 on the 31st July, 1929).

Twelve miles below Jenapur the Brahmini sends out a branch to the right, the Kimiria. The main river is called Sankra from here. The Kimiria again joins the main stream near Indupur after joining with the Ganguti and the Beropa. The combined stream is joined by the Kharsua and then by the Baitarani, and falls into the Bay of Bengal as the Dhamra river.

The main branch of the Brahmini, namely the Patia, runs for about nine miles below the Patia weir under such name when it joins another branch, the Kharsua, with its off-take from the Brahmini at Manpur. The Kharsua between Manpur and its confluence with the Patia is a dead channel, its head having been permanently closed by the embankment no. 17A (Thomson, p. 30.)

During high floods the united flood waters of the rivers Brahmini, Kharsua and Burah cover the country to the extreme distress of the people. But Thomson was of opinion (1905, p. 30) that :—

"For this state of affairs there is no practical remedy. The rivers cannot carry within their respective channels the volume of water brought down during floods. It has been decided to be impracticable for financial reasons, as well as inadvisable to fully embank them; and it is, therefore, necessary that a certain area of country shall be left open as an escape for the surplus water."

There are other escape channels from the Brahmini called 'Ghais' (such as Janardan, Simili, Tanti, Dobil, Rahapur, Palsahi, etc.). Enormous damage is sometimes caused by the water flowing through the 'Ghais,' as the land in the neighbourhood is usually unprotected. These ghais usually originate in breaches caused in the river embankments during high floods.

Mr. H. A. Gubbay, Superintending Engineer, in his printed report, dated the 18th December 1923 (Orissa Floods, 1920, p. 8), stated in a table that the maximum discharge of the Brahmini in 1868 was 840,000 cusecs, but he did not give any authority for this estimate.

I have had the opportunity of examining certain old handwritten notes in this connexion which are almost certainly by Mr. Rhind himself. I find from these notes that the highest level of the Brahmini rose to 70·68 in 1868. It was estimated that a volume of 335,342 cusecs were carried by the river channel, while the total spill over either banks was 507,167 cusecs. This would appear to give a total discharge of 842,509 cusecs. (It is extremely likely that Mr. Gubbay's statement is based on this estimate.) But it is distinctly mentioned in these notes that the above estimate for the spill was an uncorrected one, as no allowances had been made for obstructed flow. After applying suitable corrections, Rhind came to the conclusion that the true spill was 307,948 cusecs, so that the true discharge was 643,290 cusecs. This is exactly the figure given by Shaw in 1929. The Orissa Flood Report of 1928 (p. 31) mentions the highest known flood in the Brahmini as 650,000 cusecs which is also evidently the same estimate in round numbers.

In 1891 with a high flood of 68·75 at Jenapur, Rhind calculated that the maximum volume of the flood was 421,147 cusecs out of which the Brahmini took 307,349 cusecs and the Patia 113,789 cusecs.

In 1883 Rhind (letter no. 3226 of 28th September 1883 to the Chief Engineer, Bengal) gave a table of discharge of the Brahmini for different heights of the river which was based on the theoretical fall of the river as a parabolic curve between Indulva and Jenapur. Shaw in his note of April 6, 1929, states, however, that this table is now totally unreliable as the section of the river at Indulva has changed considerably and much silting has taken place above the Brahmini anicut. I have reconstructed Rhind's Table 57 from Mr. J. Shaw's calculations of the discharge of flood of 1926.

Mr. Gubbay (Report, dated the 18th December 1923, on Orissa floods of 1920, p. 10) stated that from a comparison of cross-sections both up-stream and down-stream of the Patia weir and the Brahmini weir taken in 1884 (before the weirs were built), in 1895 (five years after the construction of the weirs), and in 1923 he was of opinion that rivers were deteriorating to a very small and normal extent above the weirs, but that the deterioration below weirs were much more pronounced. He did not, however, give actual figures.

In the Brahmini the tide reaches up to the 24th mile of the Pattamundai Canal near village Mahakalpara, 2 miles above village Indupur.

Thomson remarked in 1904 (p. 28):—"The Brahmini like other rivers of Orissa has a broad, shallow sandy bed with a fall of about 14 inches per mile in the plains. The river is almost dry in the hot weather, the minimum recorded discharge being 130 cusecs."

Table 57—Discharge in the Brahmini.

Year.	Height at Indulva.	Discharge.	Height at Indulva.	Discharge (from the graph).
1923 ..	70·2	23,169	70·5	25,400
	70·8	27,549	71·0	28,100
	71·4	30,809	71·5	31,000
	72·0	33,508	72·0	33,508
	72·6	37,721	72·5	37,100
	72·7	38,423	73·0	40,500
	72·8	39,125	73·5	44,000
	73·4	43,296	74·0	47,446
	74·0	47,446	74·5	51,500
	74·3	49,767	75·0	55,185
	75·0	55,185	75·5	59,800
	76·0	66,980	76·0	66,980
	76·2	71,272	76·5	77,800
	76·6	79,857	77·0	88,000
	77·1	89,234	77·5	94,800
	77·5	92,400	78·0	101,200
	79·0	112,128	78·5	106,500
	80·0	123,628	79·0	112,128
	81·5	140,440	79·5	118,100
	82·5	152,879	80·0	123,628
	84·4	188,471	80·5	129,200
			81·0	134,600
			81·5	140,400
			82·0	146,600
			82·5	152,879
			83·0	160,400
			83·5	169,200
			84·0	179,600
			84·5	190,800

CHAPTER XVII. THE BAITARANI.

The river Baitarani rises in the hills in the Keonjhar Tributary States and enters the plains about 25 miles above Akhoyapada. At this place the Burah branch takes off; and seven miles below, at Jajpur, there is another branch, the Ganguti. The Baitarani flows due east towards the Bay of Bengal uniting with the Brahmini and the Kharsua about ten miles east of Chandbali.

It forms the boundary between the districts of Cuttack and Balasore. Koyangola and Chandbali are the two principal market places on this river, the latter being important as the chief port of Orissa. The river at Jajpur is looked upon by the Hindus as one of the most sacred places, and numerous pilgrims resort to the town. At Akhoyapada there is a ferry crossing for the Orissa Trunk Road; and about seven miles above is the Bengal-Nagpur Railway bridge.

A mile below the Trunk Road, at Tikora, is the headquarters of the Canal subdivision, and here are the head-lock of the High Level Canal, Range III. and the Baitarani weir; the outfall lock of the High Level Canal, Range II, is on the opposite bank at Rorya.

The Baitarani weir is 1,026 feet long with its crest at R. L. 55·50. There are under-sluices on the left side only. The High Level Canal, Range III, is a navigable channel, 19 miles long, and ends at the town of Bhadrak on the Salindi river. The full supply is 600 cusecs; the area commanded by the distributaries is 56,313 acres, and the area found suitable for irrigation 39,349 acres.

The Burha branch starts a little below the Rorya Lock. The weir across the Burha nearly adjoins the Baitarani weir, the two being separated by the narrow point of land at the bifurcation. The weir is 526 feet long, with crest level at 55·50 R. L. here are under-sluices at either end.

The head lock of the Jajpur Canal is situated at the point of the strip of land between the Burha and Baitarani rivers. The canal runs for six miles to the outskirts of the town of Jajpur. It was originally intended to be navigable, and is so for boats of shallow draft; but, for financial reasons at the time of its construction, it was not designed to hold up sufficient water at its lower end. The full discharge of the canal is 600 cusecs, and the area commanded by the present system of distributaries is 35,644 acres.

The Burha river runs in one channel for a length of about 15 miles and falls into the river Kharsua opposite Kamalpur inspection bungalow.

The Ganguti branches off from the Baitarani opposite Jajpur town. Running in one channel for some distance, it gives off a branch, the Bagchirka, and both unite with the Kopali; and the combined stream ultimately joins the Baitarani. Its banks are open; a few embankments here and there protect only village sites.

In a very old manuscript note (without date but with a signature which is almost certainly that of Mr. Rhind) I found a good deal of information regarding the maximum discharge of the Baitarani.

The writer of the note states that from district maps he found the area of the Baitarani catchment to be 3,761 square miles, but mentions that in Mr. Odling's opinion the area was 3,920. Using Dickens's formula for the run off with a co-efficient of 508 (which was found to be applicable to the Mahanadi-river) the maximum discharge would be 251,670 cusecs.

Col. Rundall gave 200,000 cusecs, and Mr. Odling estimated the discharge inclusive of spill water to be 240,000 cusecs. Mr. Odling, however, apparently mentioned in one place that from observation made during the rains of 1874 he found that the maximum discharge was approximately 315,000 cusecs. Rhind commented that "it is not known in what manner this latter discharge of 315,000 cusecs was obtained but it seems to be probable that it was calculated by means of Eytelwin's formula $v=0{\cdot}9\sqrt{(2f.\ d)}$ in which case it should be reduced to 278,040 cusecs which would accord with the Missisipi formula".

Rhind estimated that the maximum discharge in the flood of 1881 was 259,926 cubic feet per second, of which 162,177 cusecs passed over the Baitarani weir, and 97,749 cusecs over the Burrah weir. The gauge rose to 66·60 above the Baitarani weir, and to 67·10 above the Burrah weir in this year. According to Rhind, the embankments could safely pass 180,000 cusecs through the Baitarani, and 106,000 cusecs through the Burrah, or discharge of 286,000 cusecs altogether. Rhind further calculated at this time that with a rise of one foot above 66·60 feet, i.e. with a gauge level of 67·60 above the Baitarani weir there would be an additional discharge of 23,678 cusecs or 275,348 cusecs altogether.

The Discharge of the Baitarani at Akhoyapada.

I find it mentioned in a departmental note that Rhind had constructed in 1881 a discharge table for the Baitarani for different heights of the river at Akhoyapada. Mr. J. Shaw in a note prepared at the time of the investigations by the Flood Committee of 1928 mentioned that this table had become totally unreliable as the section had changed considerably.

I have, however, reconstructed Table 58 from the figures given by Mr. J. Shaw in his calculations for the discharge during the two floods of 1896 and 1920 respectively which were prepared by him for the 1928 Committee.

Table 58—Discharge of the Baitarani at Akhoyapada.

Year.	Height.	Discharge.	Height.	Discharge.
1896 ..	56·16	11,317	56·5	19,600
	56·80	25,957	57·0	29,500
	58·96	65,326	57·5	39,257
	59·96	84,097	58·0	48,200
	60·13	87,460	58·5	57,100
	60·30	90,874	59·0	66,500
	62·60	140,115	59·5	75,400
	63·10	151,731	60·0	84,600
	63·13	152,465	60·5	94,000
	63·80	168,857	61·0	104,000
	65·46	212,562	61·5	115,647
			62·0	125,200
			62·5	136,800
1920	56·8	25,948	63·0	148,000
	56·9	28,235	63·5	160,500
	57·2	34,021	64·0	173,000
	57·4	37,512	64·5	186,800
	57·5	39,257	65·0	200,200
	58·1	49,788	65·5	213,800
	58·2	51,594	66·0	229,800
	58·3	53,400	66·5	247,200
	59·7	79,209	67·0	266,800
	60·2	88,866	67·5	
	60·3	90,873		
	61·5	115,647		
	63·6	163,964		
	64·6	189,402		
	66·9	263,755		

The Baitarani Discharge in 1927.

The Orissa Expert Flood Committee, 1928, were of opinion :—"After consideration of all available information regarding the 1927 flood we do not think that it would be safe to put the volume discharged at a lower figure than 400,000 cubic feet per second." They also mentioned that "the highest flood previously recorded was 250,000 cubic feet per second."

This Committee recommended that special attempts should be made to ascertain the volume of the discharge of the Baitarani during the 1927 flood. A party was, therefore, sent out on the 25th September, 1928, under Mr. J. Shaw, Subdivisional Officer, Cuttack Embankment Subdivision, to make investigations on the spot. The following extracts are taken from the Report* submitted by Mr. Shaw in 1929:—

" Investigations were made at Anandpur where the river commenced to spread itself over the plain and after local enquiry and study of contour maps a site 6 miles above Anandpur was selected as it was below the inflow from all the chief tributaries of the Baitarani with the exception of the Mohan and Kusai rivers. The Mohan is a small stream entering immediately below the site selected, and not being in appreciable flood at the time of the great flood, the Baitarani water backed up the Mohan and practically formed a backwater so the Mohan may be excluded as a factor "

" The Kusai river, a big tributary, was out of the region of the very heavy rainfall and was only in normal flood when the Baitarani water backed up and caused it to spill. An estimate has been made of the amount of spill sent down by the Kusai tributary."

" A stretch of 1,000 feet was selected as being the maximum length within which the banks of the river were uniform and cross sections were taken at the beginning and end of the 1,000 feet length. These were so similar that no other intermediate sections were necessary, the banks being fairly uniform. The sections were extended on to the country and near to the point where amidst the jungle and other obstructions and according to local evidence the velocity of the flood was practically negligible and the area may be counted as still water or backwater."

" Evidence of the height of the flood was found in the deposit of flood-washed grass, etc., in the branches of the trees near the bank. At the lower end of the section there was plenty of evidence which corresponded fairly well and checked with the report of the Public Works Department Overseer that the flood rose 10 feet above the parapet of the Mohan bridge. Although strict investigation was made no reliable flood marks could be found actually at the upper section and certainly not any reliable enough to form a basis for the flood slope but intermediate levels checked the general flood level throughout. It was expected that from some evidence taken at Anandpur town, sufficiently reliable levels could be got, but on levelling up the marks as pointed out on the houses and pathways it was found that these were quite unreliable and showed the river as flowing uphill slightly. This might be due to the difficulty in observing a representative level amidst the flood waves and surges. The slope of the river with an average depth of 3 feet of water was found at the time of survey to be 1 in 1,000. The big flood was about 47 feet above this water level."

As reliable information regarding the flood slope was not available, Mr. Shaw assumed it to be " 1 in 1,000 from Kutter's formula with a maximum friction co-efficient of n=0·35 ". Assuming an approximate velocity of 15 feet per second in the river channel, 8 feet per second in the semi-obstructed bank area, and about 3 feet per second in the jungle-obstructed area he originally obtained an estimate of 1,130,000 cusecs as the flood discharge of the Baitarani in 1927. In his letter of the 8th March, 1938, he revised this calculation and stated :—

" In 1928 a discharge observation was made at the Railway Bridge on the Baitarani during a flood lower than normal and an average velocity of 4·6 feet per second was obtained with a flood level of 72·5. The 1927 flood level was 87·30 on this bridge and as velocities of 7·18 were found in the Katjuri in high flood by Stevenson, it may be assumed that a velocity of 7·5 feet per second was in force during the big 1927 flood here. This would give a discharge of 97,500×7·5=731,250 cusecs for the bridge waterway alone. But the Baitarani left embankment was breached and overtopped above the bridge and the whole country upstream was deeply flooded and the railway line breached and overtopped for miles: so it would seem that the approximate maximum discharge of the Baitarani as it burst forth on the plains must have been about 8½ lakhs."

*As corrected in Mr. Shaw's letter dated 8th March 1938.

Mr. Shaw had also calculated the average precipitation in the catchment, and found it to be about 725,000 cusecs on an average on the 29th and 30th July. Owing to the saturated condition of the soil due to the heavy rainfall between the 22nd and 25th July, he assumed a run-off of about 85 per cent. This would give a daily run-off of about 615,000 cusecs on the 29th and the 30th or 773,000 cusecs on the 30th only from the rainfall on these two days. As the river was just commencing to decrease after the previous flood of the 25th July, Shaw assumed a depth of 18 feet of water in the river with a velocity of 12 feet per second which gave 283,000 cusecs as the discharge from the previous flood. Shaw, therefore, estimated the total volume to be 615,000+283,000 or 898,000 cusecs as average daily discharge for 29th and 30th.

It is difficult, however, to accept Shaw's estimate of eight or nine lakhs of cusecs as the discharge of the Baitarani in 1927. According to his own statement quoted above, the evidence regarding the height of the flood was conflicting. Also no reliable data were available for the flood slope*.

His discussion of the rainfall data is open to objection. He calculated a precipitation of 725,000 cusecs on the 29th and 30th July. This was not impossible, but I think was somewhat over-estimated. The actual average intensity of rainfall was 6·18" and 6·25" respectively for those two days, and the equivalent rate of precipitation would be about 660,000 and 708,000 cusecs. Shaw worked with a run-off of 85 per cent which would give 560,000 and 600,000 cusecs respectively as the maximum discharge. This furnishes, I believe, an upper limit; for with such heavy rainfalls a run-off of 85 per cent in the first or the second day is highly improbable. We know in fact that the river was discharging at a fairly high rate on the 31st July (about 184,000 cusecs corresponding to 64·4 feet), the 1st August (123,000 cusecs, 61·8 feet), and on the 2nd August. Such a high rate of discharge could not have been maintained if most of the water had already passed away.

Further, Shaw added 283,000 cusecs as the residual flow from the previous flood of the 25th July. This also is doubtful. For we know definitely that the gauge had fallen to 56·9 feet on the 28th July, when the discharge could hardly have exceeded 30,000 cusecs. Even on the morning of the 29th July the reading was 58·7 foot which would probably give a discharge of about 60,000 cusecs.

On the 29th July the level was rising rapidly. The readings were 58·7 feet (with an approximate discharge of 60,000 cusecs) at 6-0 A.M., 63·2 feet (or about 153,000 cusecs) at 3-0 P.M., and 68·3 feet at 11-0 P.M. No records could be registered after that height. The maximum was reached towards dawn on the night of the 29th and the early hour of the 30th July. The gauge thus rose 5·1 feet in 8 hours between 3-0 P.M. and 11-0 P.M. on the 29th July. The maximum height was reached about 3-0 or 4-0 A.M., or say 4 or 5 hours after 11-0 P.M. If the rate of rise of 5·1 feet in 8 hours was maintained during this time, the additional rise would be about 2·5 feet or the highest level would be about 70·8 feet. A higher value is extremely improbable, for we must remember that the level fell to 65·1 feet at 6-0 A.M. on the 30th July. The discharge corresponding to a height of 67·6 feet was estimated by Rhind to be about 275,000 cusecs. He also estimated that for a rise of 1 foot at this level there would be an additional discharge of about 24,000 cusecs. Adopting this rate of increase, the discharge at 70·8 feet would appear to be about 350,000 cusecs. This may perhaps be taken as a lower limit.

The general conclusion would appear to be that, in the great flood of 1927, the maximum discharge of the Baitarani was almost certainly greater than 350,000 cusecs and could very well have been 400,000 cusecs. It is unlikely, however, that it exceeded 450,000 or 500,000 cusecs, and it is highly improbable that it exceeded 600,000 cusecs.

*Mr. Shaw in his letter of the 8th March 1938 wrote to me :—

" From your evidence put forward regarding the possible discharge at Akhoyapada before the big flood it is evident that the local evidence was wrong which said that the river was 19 feet high at Anandpur before the flood."

CHAPTER XVIII. THE SUBARNAREKHA AND THE MINOR RIVERS OF BALASORE.

The Subarnarekha which rises in the Chota Nagpur Hills, enters the plains of Orissa at Ulmara, and after traversing for about 40 miles, a strip of delta about 25 miles wide runs into the sea in one undivided channel. It is crossed by the Bengal-Nagpur Railway a little below Jaleswar and by the Orissa Trunk Road at Rajghat. About 12 miles below this, on the left bank, is Bhograi lock at the end of Range III of the Orissa Coast canal; and on the right bank about 3 miles further down is Jamcoonda lock at the end of Range IVA. The river is tidal, and is navigable up to Kamada, about 4 miles above Jamcoonda.

Owing to the hilly character of its catchment area, the Subarnarekha is subject to sudden floods of short duration. It spills freely on the left bank, and during high floods considerable damage is done to an area of about 24 square miles in Orissa. When the Bhograi and certain other embankments are damaged other areas in Orissa, and a very large tract of land in the Contai subdivision of Bengal are subject to inundations from the Subarnarekha.

The maximum discharge of the Subarnarekha has been estimated to be 300,000 cusecs (Contour Survey, 1923, page 8).

Between the Baitarini and the Subarnarekha there are a number of hill streams most of which have their origin in the Keonjhar, Mayurbhanj or Nilgiri hills.

The Salindi, which is a tributary of the Baitarani, rises in the Keonjhar hills. Its source being so very near, and it being a hill stream, its flood, as observed at Bhadrak, is very sudden and rises several feet in a few hours. There is one gauge on the river in a pier of the railway bridge about 2 miles above Bhadrak.

The Rebo rises in the Keonjhar hills, above Moraigaon inspection bungalow. It flows south-east in one channel, passes under the High Level Canal, Range III, at the aqueduct in the 11th mile, and falls into the Kopali river. It is really a drainage channel, and hardly spills over its banks. There is no embankment or gauge in any part of this river.

The Kopali also rises in the Keonjhar hills, and passing under the High Level Canal, Range III, at the aqueduct in the 14th mile, and joining with the Rebo and the Ganguti, it ultimately falls into the Baitarani. Down to the canal aqueduct the stream is practically a drainage channel, hardly spilling its banks, but below the aqueduct the country is normally subjected to slight flooding. There is one gauge at the aqueduct which rose to R. L. 56·50 on the 16th July, 1881.

The Matai is fed from two drainage channels, or khals, Kanchari and Garamat, about 6 miles above Charbatia lock on Range V, Orissa Coast canal. It is a good navigable channel and falls into the Dhamra, some 15 miles below the lock, at the junction of the Baitarani with the latter river. It is tidal and navigable throughout the year.

The Kansbans, Goomai and Atilabad are branches of one river, called the Kansbans, which rises in the Betai hills. They cross the Coast canal in the 117th, 122nd and 115th miles, respectively and the flooding from the Kansbans and the Goomai are due to the unsatisfactory condition of the estuaries, the efficiency of which has been destroyed by the crossings of the Coast Canal.*

The Jamka rises in the Nilgiri hills and crosses the Canal at mile 107.

The Barabulong rises in the Mayurbhanj hills. Four miles north-northwest of Balasore it is joined by the Soni river, and then flows on past Balasore Seven miles below Balasore on the left bank is the Nulcool lock of the Coast Canal, Range IVB, and about two miles further down, on the right bank, is the Chargachia lock of Range V. The Barabulong, after winding about very considerably, flows into the sea near Chandipore. It is tidal and navigable ordinarily up to the town of Balasore; and in the rains for a little further.

The Panchpara which is fed from several Khals draining about 40 square miles is tidal, and is navigable throughout the year up to Choorakhia about 6 miles above Sulpatta.

The Sartha which rises in the Mayurbhanj hills used to flow to the sea but has been diverted to the Panchpara by an artificial cut.

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*Mr. Shaw, special flood officer, Orissa, in his letter of the 8th March 1038 informs me that the Orissa Coast Canal except north of Subarnarekha has since been abandoned and cuts made at the Gumai estuary.

CHAPTER XIX. ORISSA CANALS.

A brief description of the main systems of the Orissa canals is given below.

Taldanda Canal.—Its head lock and the head sluice is situated near the south abutment of the Jobra weir. It is navigable, 51¾ miles long and has a full discharge of 1,150 cusecs. It is capable of irrigating, together with its branch the Machgong canal, an area of 63,250 acres. Total area commanded by it is 157,301 acres. This canal falls into the Mahanadi at Paradip.

Machgong Canal.—It is for irrigation only. It leaves the Taldanda canal at Biribbati, 7 miles from the head and is 32 miles long. It is navigable up to the first 4 miles only.

Kendrapara Canal.—It starts from the south end of the Berupa weir and is navigable. It extends to Jambu which is 54 miles from the head. The outfall lock admits boat traffic to the Jambu tidal river, which runs into the harbour of False Point a few miles from the lock.

Gobri Canal.—This canal starts from the 28th mile of the Kendrapara canal. It is a navigable channel and runs for 15½ miles to the Gandakia river.

Gobri Extension Canal.—This canal starts from the opposite side of the river Gandakia. It is six miles long and falls into the Brahmini at Alba.

Pattamundai Canal.—It takes off from the Kendrapara canal half a mile below its head. It is an irrigation canal and is not navigable. It is 47 miles long. From the escape fall at its end a feeder channel over 3 miles long supplies fresh water to the Gobri Extension canal.

The capacity of the Kendrapara canal system taking the main canal and the Gobri canal together is 11,000 cusecs at the head. These two command an area of 144,588 acres ; of this 68,393 acres are suitable for irrigation.

Pattamundai and Gobri Extension canal together have a supply of 500 cusecs and command an area of 78,400 acres, of this 40,600 acres are suitable for irrigation.

High Level Canal, Range I.—1½ miles from the offtake of Berupa from the Mahanadi is the masonry weir impounding the water for the supply of this canal, which starts from the north side of the weir. It is navigable, and is 33 miles long, and ends in the Brahmini river at Jenapur. Available supply at head is 500 cusecs. It commands an area of 47,737 acres ; of this 24,568 acres are suitable for irrigation.

High Level Canal, Range II.—This canal has its head sluice and lock at the Pattia weir. It is 12 miles in length, and is navigable. It ends at Rorya on the Baitarani river and commands a gross area of 10,000 acres of which 5,974 acres were irrigated in 1902-03. The full supply of the canal at the head is 600 cusecs*.

High Level Canal, Range III.—It takes off at the Baitarani river, and is navigable. It is 19 miles long and ends at the town Bhadrak on the Salindi river. Full supply is 600 cusecs, and the area commanded by distributaries is 56,313 acres, of which 39,319 acres are suitable for irrigation.

Jajpur Canal.—The head lock is situated at the point of the strip of land between the Burha and Brahmini rivers. It runs for 6 miles to Jajpur and commands 35,644 acres, of which 21,677 acres are suitable for irrigation. Its full discharge is 600 cusecs.

The Orissa Coast Canal.—This canal is a continuation of the older Hijili Tidal canal in the Midnapore district. The Hijili Tidal canal leaves the Hooghly river at Gowankhali, 45 miles from Calcutta. Range I, which is 11 miles long, ends at Etamagra on the left bank of the Huldi river ; and about a mile lower down on the right bank is the entrance lock of Range II at Terapakia. Range II ends at Kalinagar, the 30th mile, on the left bank of

*Mr. Shaw states in his letter dated 8th March 1938 that this canal has been abandoned.

the Rasoolpur river. At Bhatigur, about half a mile down on the right bank, the Coast canal commences. Three and a half miles from Bhatigur is Surpai river which has been canalised as far as Contai in the 47th mile.

From the canalised Surpai, at the 40th mile, the Coast Canal, Range III, continues to Bhograi, mile 65, on the Subarnarekha river, Range IVA leaves the Subarnarekha at Jamcoonda, 69th mile, and ends at Panchpara lock on the river of the same name at mile 86. On the opposite bank of the Panchpara is Sulpatta lock, the entrance to Range IVB, which continues to Nulcool, 93rd mile, on the Barabulong. The town of Balasore is seven miles up the river from Nulcool. About 2 miles below Nulcool, on the right bank, Range V begins at Chargachia, and continues to the Matai river at Charbattia, 131¾th mile. The Coast canal is for navigation only. Dudhai Canal is a minor irrigation canal*.

More recent information is given below in Table 58(A) from the *Administration Report of the Irrigation Branch of the P. W. D., Orissa, for 1936-37.*

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*Mr. Shaw states in his letter of 8th March 1938 that the Dudhai Canal is abandoned as also the Orissa Coast Canal except from Bhograi to the Bengal border reach.

Table 58A—Some recent details about canals of Orissa. (Vide Administration Report of the Irrigation Branch of the Public Works Department, Orissa, for the year 1936-37.)

Name of canals.	Length of canals opened. For navigation and Irrigation (miles).	Length of canals opened. For Irrigation only (miles).	Length of distributaries and minors (miles). Miles.	Length of distributaries and minors (miles). Feet.	Area irrigated. Kharif including hot-weather (Acres).	Area irrigated. Rabi (Acres).	Area irrigated. Total (Acres).	Remarks.
1	2	3	4		5	6	7	8
(A) Taldanda Canal	51¾	..	135	5,223	20,010	45	20,055	
Machagaon Canal	4	28	278	427	42,745	58	42,803	
Kendrapara Canal and its extension.	39¾+14¾	..	383	2,586	65,948	426	66,374	
			0	5,255				
Gobri Canal	24	..	44	1,180	4,949	78	5,027	*Excluding hot-weather crops total acres irrigated come to 202,552 for the season.
Gobri extension canal ..					3,021	22	3,043	
Pattamundai Canal ..	..	47	137	781	24,682	422	25,104	
High Level Canal Range I ..	33	..	134	2,435	21,926	439	22,365	
High Level Canal Range II ..	6½	..	2	740	1,986	40	2,026	
High Level Canal Range III ..	19	..	91	4,449	3,649	233	3,882	
Jajpur Canal	6½	..	94	1,103	12,682	407	13,089	
Total ..	199¼	75	1,302	3 059	201,598	2,170	203,768*	

(B) Rushikulya Canal system—(Main canal).	..	98·0	..		1st crop	2nd crop	112,053·89	On creation of the separate Orissa province these were transferred to Orissa. This system of canals does not occur in the Orissa delta.
Rushikulya Canal system (distributaries).	..	..	230·0		..	..		
Total ..	..	98·0	230·0		..	..	112,053·89	
Grand Total ..	199¼	173	1,532	3,059	..	..	315,822	

PART IV. AN ANALYTIC STUDY OF THE MAHANADI.

CHAPTER XX. SECULAR CHANGE OF RAINFALL IN THE MAHANADI BASIN.

In this chapter I shall describe the general rainfall characteristics of the Mahanadi Basin. The data consist of the daily average rainfall for each day from 1st July to 30th September for the years 1891—1928. The average rainfall for each of the 5 sections into which we divided the Mahanadi catchment is available separately as well as the total daily rainfall for the catchment as a whole.

A description of the different sections has been already given in chapters 5—8. The daily average rainfall for each section was calculated directly by taking the average of the rainfall for all stations situated within a given section. As the number of rainfall stations has steadily increased, the averages are not, therefore, of equal statistical weight. This is a defect inherent in almost all rainfall data, and in the first study no attempt has been made to make any allowances for it.

General results.

The mean values (m) of daily rainfall in inches, the standard deviations (s), and the coefficients of variation (100 s/m) are shown for each section for each month and for the combined period in Tables 59—61.

The average rainfall in July and August is nearly equal in all sections, and varies from about 0·40″ to 0·50″ per day. The average rainfall in September is substantially less, varying from 0·25″ to 0·30″ per day. For the total catchment the averages are 0·48″ in July and August, and 0·28″ in September.

Table 59.—Mean rainfall in inches in 5 catchments.

Sections.	July.	August.	September.	July—September.
Mahanadi I ..	0·4158	0·4082	0·3040	0·3667
,, II ..	·5091	·4916	·2814	·4289
,, III ..	·5682	·5580	·2752	·4694
,, IV ..	·4614	·5076	·2813	·4185
,, V ..	·4468	·4361	·2581	·3816
Whole Mahanadi ..	·4803	·4803	·2800	·4150

Table 60.—Standard deviations.

Sections.	July.	August.	September.	July—September.
Mahanadi I ..	0·4637	0·4754	0·3834	0·4427
,, II ..	·7988	·7334	·5040	·6906
,, III ..	·6181	·5718	·4062	·5394
,, IV ..	·7036	·8044	·5148	·6848
,, V ..	·5060	·4717	·3478	·4505
Whole Mahanadi ..	·6301	·6217	·4359	·5718

Table 61.—Coefficient of variation (=100 s/m): 1891—1928.

Sections.	July.	August.	September.	July—September.
Mahanadi I ..	111·5	116·5	126·1	120·7
„ II ..	156·9	149·2	179·1	161·0
„ III ..	108·8	102·5	147·6	114·9
„ IV ..	152·5	158·5	183·0	163·6
„ V ..	113·3	108·2	134·8	118·1
Whole Mahanadi ..	131·2	130·7	155·7	137·8

The intensity of rainfall is not equal everywhere. The amount varies from 0·37″ to 0·47″ per day in different sections, M-III receiving the greatest and M-I the lowest amount.

Glancing at Table (60) we find that the variability of the rainfall from day to day is very great. For purposes of comparison it is convenient to convert these into proportional variabilities given by the coefficients of variation (100 s/m) which are shown in Table (61). Rainfall in July and August is almost equally variable, while the fluctuations in September are considerably greater. Among different sections we find that M-II and M-IV are distinctly more variable than the other sections. This of course, is partly a spurious effect caused by the fact that up to 1901 the daily averages for M-II and M-IV merely represented the rainfall at one single station only.

Secular change.

Section I (M-I).—We may now consider the secular or progressive change with time. The mean daily rainfalls in Section I for each of the three months July, August and September for each year together with the corresponding standard deviations are given in Table 62. (The mean rainfall for the combined period will be found in Table 63.) The figures within brackets give the number of rainfall stations available in each year.

The rainfall in July, August and September is not quite concordant which, of course, merely indicates the great variability of the rainfall.

The fluctuations from year to year are, however, not completely sporadic in character. The graph certainly suggests that we have stretches of increasing or decreasing rainfall. For example, in August, the average rainfall appears to have increased steadily during the period 1892—1907 (16 years) and then decreased steadily between 1908—1921 (14 years). In the same way, we may, if we like, divide the figures for other months also into several periods of increasing or decreasing rainfall. In July, for example, rainfall appears to be gradually increasing since 1918.

A comparison of these 'trends' (if they may be so called) shows that they are not even roughly parallel. We must conclude, therefore, that these tendencies are local or peculiar to each month and are not characteristics which are true for the whole season. It will also be noticed that these tendencies persist for comparatively short periods (of the order of 10 years varying roughly from about 3 to 15 years), and do not occur in regular sequence.

Table 62.—Mean daily rainfall in inches for July, August and September.

Mahanadi Catchment Section I, 1891—1928.

	July.			August.			September.		
Year.	n	Mean.	S. D.	n	Mean.	S. D.	n	Mean.	S. D.
1891	31 (2)	·28	·43	31	·39	·47	30	·41	·59
92	31 (6)	·43	·38	31	·27	·33	30	·36	·30
93	31 (7)	·25	·16	31	·37	·36	30	·34	·52
94	31 (7)	·47	·42	31	·27	·17	30	·23	·23
95	31 (7)	·34	·28	31	·39	·41	30	·31	·48
96	31 (7)	·33	·26	31	·43	·39	30	·19	·21
97	31 (7)	·34	·34	31	·35	·27	30	·43	·33
98	31 (7)	·38	·32	31	·35	·39	30	·28	·40
99	31 (7)	·28	·26	31	·31	·27	30	·12	·18
1900	31 (7)	·28	·23	31	·47	·60	30	·40	·47
01	31 (8)	·30	·27	31	·35	·40	30	·19	·31
02	31 (9)	·54	·48	31	·44	·37	30	·20	·15
03	31 (8)	·54	·49	31	·44	·41	30	·39	·32
04	31 (10)	·43	·42	31	·42	·32	30	·32	·48
05	31 (11)	·44	·45	31	·38	·46	30	·34	·27
06	31 (12)	·52	·66	31	·30	·22	30	·34	·31
07	31 (12)	·29	·22	31	·72	·74	30	·27	·33
08	31 (12)	·45	·42	31	·64	·41	30	·28	·22
09	31 (12)	·45	·46	31	·27	·24	30	·26	·25
10	31 (12)	·50	1·03	31	·45	·57	30	·27	·25
11	31 (12)	·25	·31	31	·44	·42	30	·28	·35
12	31 (12)	·43	·32	31	·47	·37	30	·24	·27
13	31 (11)	·58	·66	31	·39	·44	30	·17	·24
14	31 (10)	·49	·50	31	·40	·37	30	·46	·42
15	31 (11)	·38	·53	31	·33	·47	30	·35	·28
16	31 (13)	·38	·26	31	·39	·29	30	·25	·19
17	31 (13)	·39	·24	31	·35	·34	30	·35	·25
18	31 (13)	·22	·35	31	·30	·28	30	·21	·28
19	31 (12)	·56	·45	31	·64	·58	30	·18	·26
20	31 (13)	·75	·85	31	·28	·37	30	·24	·25
21	31 (13)	·40	·41	31	·29	·25	30	·50	·75
22	31 (13)	·64	·55	31	·37	·39	30	·47	·43
23	31 (13)	·36	·27	31	·31	·20	30	·32	·22
24	31 (13)	·26	·30	31	·41	·76	30	·30	·22
25	31 (13)	·60	·54	31	·48	·39	30	·32	·78
26	31 (13)	·35	·25	31	·80	1·32	30	·42	·56
27	31 (12)	·46	·45	31	·53	·48	30	·30	·48
1928	31 (13)	·59	·62	31	·31	·28	30	·27	·16

[The figures within brackets in column (3) give the numbers of rainfall stations.]

Section II (M-II).—The monthly mean values are given in Table 63.

In this section the figures up to 1901 are based on one single rainfall station, and it is not surprising to find that they are not concordant for the different months. In fact they are sometimes definitely opposed in character. For example, in July, the rainfall steadily decreased from 1892—1900, the average value falling from about 0·60″ in 1893 to 0·24″ in 1900. But in August, during the same period, rainfall increased from 0·18″ in 1892 to 0·56″ in 1900. The averages from 1902 being based on not less than 6 stations are far more reliable. It will be noticed that the fluctuations are now much less violent, and in this section the trends also appear to be slightly more concordant for the different months.

Table 63.—Mean daily rainfall in inches for July, August and September.

Mahanadi Catchment Section II.

	July.			August.			September.		
Year.	n	Mean.	S. D.	n	Mean.	S. D.	n	Mean.	S. D.
1891	31 (1)	·59	·81	31	·53	·99	30	·56	1·02
92	31 (1)	1·22	2·12	31	·18	·30	30	·24	·34
93	31 (1)	·60	·74	31	·35	·68	30	·50	1·02
94	31 (1)	·74	1·05	31	·27	·49	30	·19	·49
95	31 (1)	·36	·52	31	·51	·72	30	·11	·24
96	31 (1)	1·13	2·14	31	·91	1·62	30	·21	·43
97	31 (1)	·53	1·21	31	·64	·85	30	·36	·63
98	31 (1)	·61	·86	31	·58	1·17	30	·15	·33
99	31 (1)	·46	·79	31	·32	·51	30	·70	·20
1900	31 (1)	·24	·36	31	·56	·83	30	·90	1·25
01	31 (1)	·30	·33	31	·72	1·36	30	·19	·45
02	31 (6)	·64	·74	31	·40	·43	30	·19	·21
03	31 (6)	·46	·53	31	·39	·44	30	·28	·39
04	31 (6)	·42	·69	31	·48	·48	30	·18	·29
05	31 (6)	·44	·59	31	·39	·48	30	·47	·68
06	31 (8)	·52	·55	31	·37	·39	30	·30	·25
07	31 (8)	·31	·33	31	·58	·56	30	·32	·56
08	31 (8)	·43	·29	31	·77	·68	30	·27	·20
09	31 (8)	·59	·50	31	·26	·25	30	·24	·43
10	31 (8)	·56	1·11	31	·57	·91	30	·22	·17
11	31 (8)	·19	·27	31	·83	·97	30	·25	·27
12	31 (8)	·49	·43	31	·46	·46	30	·21	·37
13	31 (8)	·41	·55	31	·47	·78	30	·15	·20
14	31 (8)	·48	·39	31	·32	·36	30	·29	·26
15	31 (9)	·38	·49	31	·40	·75	30	·34	·50
16	31 (9)	·44	·29	31	·46	·38	30	·18	·17
17	31 (9)	·49	·44	31	·45	·50	30	·30	·26
18	31 (9)	·32	·40	31	·37	·40	30	·31	·43
19	31 (10)	·51	·43	31	·74	·86	30	·15	·25
20	31 (11)	·84	·81	31	·49	·82	30	·18	·28
21	31 (11)	·30	·30	31	·46	·49	30	·40	·68
22	31 (11)	·57	·36	31	·39	·43	30	·46	·52
23	31 (11)	·31	·22	31	·45	·35	30	·20	·20
24	31 (11)	·31	·25	31	·42	·62	30	·23	·24
25	31 (11)	·64	·71	31	·54	·42	30	·21	·23
26	31 (11)	·35	·80	31	·87	1·01	30	·37	·53
27	31 (11)	·53	·68	31	·52	·45	30	·24	·52
1928	31 (11)	·63	·83	31	·27	·34	30	·23	·09

[The figures within brackets in column (3) give the numbers of rainfall stations.]

Section III (M-III).—Table 64 gives the monthly mean rainfall for July, August, September and the corresponding standard deviations. As in other sections, the tendencies are not persistent over the whole period, and are not concordant for the different months. In the case of M-III, the fluctuations appear to be slightly smoother. For example, the trend for September shows only one minimum, and is almost regular.

The most prominent short period trend is the decrease in rainfall for 6 years from 1·08″ in 1892 to 0·43″ in 1897 for the month of July.

Table 64.—Mean daily rainfall in inches for July, August and September.

Mahanadi—Section III.

	July.			August.			September.		
Year.	n	Mean.	S. D.	n	Mean.	S. D.	n	Mean.	S. D.
1891	31 (5)	·68	1·62	31	·52	·47	30	·63	·86
92	31 (5)	1·08	1·37	31	·36	·31	30	·29	·78
93	31 (6)	·57	·49	31	·44	·61	30	·41	·44
94	31 (6)	·76	·73	31	·59	·56	30	·20	·24
95	31 (6)	·56	·71	31	·60	·56	30	·01	·12
96	31 (6)	·81	·63	31	·66	·66	30	·13	·22
97	31 (6)	·43	·49	31	·72	·59	30	·21	·32
98	31 (6)	·55	·50	31	·40	·41	30	·20	·22
99	31 (6)	·47	·52	31	·44	·45	30	·60	·15
1900	31 (5)	·49	·51	31	·69	·79	30	·52	·48
01	31 (6)	·44	·34	31	·70	·62	30	·24	·54
02	31 (7)	·64	·66	31	·47	·52	30	·23	·26
03	31 (7)	·48	·56	31	·48	·45	30	·37	·36
04	31 (7)	·49	·50	31	·51	·50	30	·12	·21
05	31 (7)	·62	·95	31	·34	·26	30	·49	·57
06	31 (8)	·62	·59	31	·37	·35	30	·41	·48
07	31 (8)	·30	·31	31	·82	·59	30	·19	·37
08	31 (8)	·78	·47	31	·71	·49	30	·17	·11
09	31 (8)	·71	·41	31	·34	·37	30	·23	·43
1910	31 (8)	·39	35	31	·58	·58	30	·31	·29
11	31 (8)	·25	31	31	·67	·63	30	·40	·44
12	31 (9)	·63	·48	31	·52	·46	30	·21	·38
13	31 (10)	·47	·55	31	·44	·64	30	·16	·23
14	31 (10)	·81	·66	31	·57	·77	30	·24	·24
15	31 (10)	·37	·44	31	·45	·57	30	·41	·43
16	31 (11)	·42	·39	31	·66	·51	30	·28	·24
17	31 (11)	·64	·41	31	·76	·69	30	·33	·24
18	31 (11)	·26	37	31	·67	·53	30	·14	·20
19	31 (11)	·46	·38	31	·68	·51	30	·23	·48
1920	31 (13)	91	·99	31	·69	·88	30	·14	·22
21	31 (13)	·43	·51	31	·34	·38	30	·27	·31
22	31 (13)	59	44	31	·61	·44	30	·45	·37
23	31 (13)	51	·44	31	·95	·79	30	·20	·21
24	31 (13)	·49	·36	31	·43	·33	30	·32	·29
25	31 (13)	·70	·51	31	·52	·45	30	·25	·41
26	31 (13)	56	·36	31	·74	60	30	·49	·50
27	31 (13)	·62	·69	31	·55	·67	30	·25	·39
1928	31 (13)	·58	·70	31	·34	·10	30	·22	·26

[The figures within brackets in column (3) give the numbers of rainfall stations.]

Section IV (M-IV).—The actual values of average daily rainfall for July, August and September each year are given in Table 65.

Up to 1901 the figures represent the rainfall at one single station and are not reliable. Hence much reliance cannot be placed on the decrease in July and August during the 9 years 1891—1899. The short period tendencies are neither regular nor similar for all the three months, and we must conclude that there is no persistent trend covering the whole period.

Table 65.—Mean daily rainfall in inches for July, August and September.

Mahanadi Catchment—Section IV.

	July.			August.			September.		
Year.	n	Mean.	S. D.	n	Mean.	S. D.	n	Mean.	S. D.
1891	31 (1)	·63	·99	31	·42	·74	30	·54	·75
92	31 (1)	·39	·64	31	·45	·69	30	·32	·56
93	31 (1)	·65	·91	31	·55	·89	30	·50	·67
94	31 (1)	·73	1·66	31	·40	·70	30	·31	·77
95	31 (1)	·30	·40	31	·50	·64	30	·13	·29
96	31 (1)	·57	1·01	31	·56	1·47	30	·10	·30
97	31 (1)	·20	·36	31	·55	·83	20	·34	·45
98	31 (1)	·57	·56	31	·38	·65	30	·21	·48
99	31 (1)	·25	·54	31	·51	·82	30	·07	·23
1900	31 (1)	·40	·59	31	·66	1·84	30	·97	1·21
01	31 (2)	·56	·64	31	·48	·55	30	·12	·28
02	31 (2)	·36	·51	31	·43	·66	30	·11	·16
03	31 (4)	·48	·88	31	·59	·74	30	·21	·21
04	31 (5)	·25	·36	31	·45	·52	30	·10	·16
05	31 (7)	·38	·81	31	·37	·37	30	·47	·64
06	31 (7)	·56	·69	31	·36	·52	30	·20	·34
07	31 (6)	·27	·27	31	·60	·46	30	·36	·73
08	31 (7)	·39	·31	31	·59	·56	30	·18	·18
09	31 (7)	·57	·48	31	·17	·19	30	·18	·48
1910	31 (7)	·43	·71	31	·68	1·38	30	·32	·45
11	31 (7)	·20	·36	31	·82	·94	30	·20	·25
12	31 (7)	·60	·53	31	·58	·71	30	·30	·59
13	31 (7)	·46	·53	31	·35	·55	30	·16	·27
14	31 (7)	·57	·67	31	·41	·50	30	·36	·38
15	31 (7)	·60	·96	31	·68	1·28	30	·42	·73
16	31 (7)	·32	·27	31	·34	·42	30	·21	·27
17	31 (8)	·35	·51	31	·45	·52	30	·27	·25
18	31 (9)	·42	·95	31	·62	·71	30	·23	·52
19	31 (9)	·51	·18	31	·70	·71	30	·19	·32
1920	31 (9)	·53	·91	31	·41	·76	30	·14	·27
21	31 (9)	·35	·47	31	·53	·57	30	·33	·51
22	31 (9)	·51	·38	31	·41	·94	30	·45	·50
23	31 (9)	·46	·45	31	·45	·49	30	·25	·27
24	31 (9)	·26	·26	31	·45	·05	30	·35	·40
25	31 (9)	·83	·93	31	·63	·54	30	·27	·55
26	31 (9)	·32	·34	31	·79	·96	30	·39	·61
27	31 (9)	·54	·81	31	·66	·59	30	·21	·32
1928	31 (9)	·57	·71	31	·34	·41	30	·22	·29

[The figures within brackets in column (3) give the numbers of rainfall stations.]

Section V. (M-V).—Daily average rainfall figures are given in Table 66. They are irregular in sequence, and dissimilar for the different months. The most pronounced tendency was, for the average daily rainfall in July, to decrease from 0·81″ in 1892 to 0·22″ in 1899. This tendency, however, did not persist in later years.

Table 66.—Mean daily rainfall in inches for July, August and September.

Mahanadi Catchment—Section V.

Year.	July. n	July. Mean.	July. S. D.	August. n	August. Mean.	August. S. D.	September. n	September. Mean.	September. S. D.
1891	31 (6)	·56	·85	31	·39	·46	30	·50	·38
92	31 (6)	·81	·94	31	·33	·31	30	·23	·30
93	31 (6)	·45	·44	31	·45	·58	30	·40	·33
94	31 (6)	·67	·64	31	·44	·41	30	·34	·47
95	31 (6)	·34	·35	31	·46	·49	30	·12	·23
96	31 (6)	·70	·96	31	·68	·78	30	·74	·18
97	31 (7)	·43	·46	31	·49	·49	30	·24	·30
98	31 (7)	·55	·42	31	·41	·57	30	·23	·23
99	31 (7)	·23	·35	31	·47	·59	30	·97	·23
1900	31 (7)	·45	·41	31	·52	·67	30	·57	·65
01	31 (7)	·46	·41	31	·47	·41	30	·30	·60
02	31 (12)	·40	·40	31	·32	·36	30	·22	·23
03	31 (12)	·52	·53	31	·47	·41	30	·27	·31
04	31 (13)	·25	·23	31	·44	·40	30	·18	·34
05	31 (14)	·44	·49	31	·32	·25	30	·42	·48
06	31 (19)	·54	·48	31	·28	·31	30	·26	·31
07	31 (19)	·28	·22	31	·45	·36	30	·17	·28
08	31 (19)	·47	·31	31	·64	·50	30	·24	·26
09	31 (19)	·50	·30	31	·24	·21	30	·16	·37
1910	31 (19)	·33	·46	31	·53	·71	30	·34	·25
11	31 (19)	·26	·36	31	·57	·43	30	·22	·19
12	31 (19)	·48	·41	31	·52	·50	30	·23	·36
13	31 (19)	·36	·38	31	·34	·61	30	·12	·17
14	31 (19)	·56	·40	31	·32	·20	30	·33	·42
15	31 (19)	·43	·49	31	·42	·63	30	·32	·34
16	31 (19)	·34	·22	31	·39	·39	30	·22	·24
17	31 (19)	·38	·30	31	·50	·51	30	·36	·24
18	31 (19)	·31	·47	31	·43	·39	30	·14	·19
19	31 (19)	·51	·45	31	·58	·44	30	·14	·20
1920	31 (19)	·49	·70	31	·31	·39	30	·12	·22
21	31 (19)	·32	·22	31	·37	·36	30	·27	·43
22	31 (19)	·47	·34	31	·26	·34	30	·34	·29
23	31 (19)	·54	·39	31	·49	·37	30	·33	·29
24	31 (19)	·32	·25	31	·34	·46	30	·36	·19
25	31 (19)	·59	·56	31	·46	·32	30	·19	·23
26	31 (19)	·31	·23	31	·60	·62	30	·38	·54
27	31 (19)	·50	·79	31	·56	·55	30	·20	·28
1928	31 (19)	·43	·56	31	·29	·30	30	·19	·19

[The figures within brackets in column (3) give the numbers of rainfall stations.]

Whole Mahanadi Catchment.—The average daily rainfall in July, August and September (and the combined period) for the whole of the Mahanadi catchment are given in Table 67 and Chart (1). The trend lines are naturally smoother than those for individual sections. The curves for July, August and September are, however, not in agreement, showing that the short period tendencies were different in different months. Although the sequences of increasing or decreasing rainfall do not appear to be entirely random in character, they are neither regular nor periodic. Particular tendencies persist for a short period only (of the order of 10 years), and different tendencies appear in an irregular manner.

Our general conclusion is that we have some evidence of particular tendencies (of increasing or decreasing rainfall) to persist for a few years, but we do not find definite or regular trends persisting for a long time or affecting the season as a whole.

Table 67.—Mean daily rainfall in inches for July, August and September.

Whole Mahanadi Catchment, 1891—1928.

Year.	Number of stations.	July.	August.	September.	Combined.
1891	15	0·55	0·40	0·51	0·51
92	19	·79	·28	·27	·45
93	21	·50	·42	·43	·48
94	21	·67	·49	·25	·47
95	21	·38	·54	·14	·37
96	21	·71	·61	·14	·49
97	22	·39	·57	·30	·42
98	22	·53	·44	·21	·40
99	22	·34	·44	·08	·29
1900	21	·37	·57	·63	·54
01	33	·42	·55	·20	·39
02	36	·52	·39	·18	·37
03	35	·50	·40	·30	·42
04	40	·35	·46	·17	·34
05	43	·51	·34	·43	·45
06	54	·55	·35	·29	·40
07	54	·29	·54	·25	·37
08	53	·50	·62	·22	·45
09	54	·57	·29	·21	·36
1010	54	·44	·54	·28	·43
11	54	·23	·65	·26	·38
12	55	·52	·48	·23	·41
13	55	·45	·41	·16	·34
14	54	·58	·43	·32	·45
15	56	·43	·47	·36	·43
16	59	·37	·46	·22	·35
17	60	·45	·50	·31	·42
18	61	·31	·48	·20	·33
19	61	·51	·67	·17	·45
1920	64	·70	·42	·16	·43
21	65	·36	·40	·34	·37
22	65	·56	·41	·42	·47
23	65	·44	·53	·25	·41
24	65	·33	·41	·30	·35
25	65	·67	·52	·24	·57
26	65	·38	·70	·39	·51
27	64	·53	·56	·23	·45
28	65	·56	·31	·22	·37

Combined period: July—September.

Having described the fluctuation of rainfall in individual months, I may now consider the average daily rainfall in each year in each section for the combined period of 92 days (1st July—30th September). The relevant data will be found in Table 68.

Table 68.—Mean daily rainfall for the period July—September in the Mahanadi Catchment.

Mahanadi Catchments, 1891—1928.

Year.	M-I.	M-II.	M-III.	M-IV.	M-V.	Whole Catchment.
1891	0·360	0·558	0·610	0·527	0·483	0·510
92	·353	·550	·573	·385	·458	·449
93	·209	·502	·475	·569	·436	·457
94	·323	·403	·523	·480	·483	·474
95	·346	·332	·421	·315	·313	·368
96	·318	·759	·537	·415	·490	·493
97	·372	·510	·453	·358	·390	·423
98	·337	·447	·374	·386	·398	·397
99	·239	·296	·326	·278	·267	·290
1900	·384	·563	·567	·675	·514	·537
01	·281	·403	·461	·386	·410	·392
02	·388	·443	·450	·301	·313	·366
03	·458	·378	·445	·430	·424	·423
04	·391	·362	·374	·270	·300	·338
05	·378	·433	·487	·475	·390	·428
06	·386	·395	·468	·378	·362	·403
07	·428	·405	·438	·411	·301	·372
08	·458	·493	·560	·389	·452	·452
09	·329	·365	·424	·307	·303	·365
1910	·406	·451	·424	·479	·399	·427
11	·325	·427	·440	·406	·351	·384
12	·381	·388	·464	·495	·409	·414
13	·385	·343	·360	·325	·168	·343
14	·452	·363	·543	·447	·401	·450
15	·353	·374	·411	·569	·395	·427
16	·331	·361	·456	·291	·330	·355
17	·362	·415	·578	·353	·415	·424
18	·244	·335	·357	·428	·295	·332
19	·461	·469	·461	·468	·413	·454
1920	·426	·508	·550	·363	·311	·432
21	·395	·389	·349	·406	·318	·371
22	·491	·475	·552	·456	·357	·467
23	·331	·321	·557	·387	·456	·410
24	·323	·320	·413	·357	·337	·350
25	·468	·464	·497	·579	·416	·572
26	·523	·531	·596	·503	·433	·512
27	·431	·435	·489	·471	·425	·446
28	·389	·379	·383	·376	·302	·368

We notice, therefore, that the fluctuations from year to year are proportionally much greater than flucutations within the year. The statistical significance can, however, be precisely tested by using R. A. Fisher's Z-statistics.

I have used Fisher's method of analysis of variance to test the significance of the fluctuation from year to year. For section I (M-I), I find that the total sum of squares of 3,496 daily deviations from the general mean value is 696·5787. The estimated variance 0·1993 is given by dividing this sum 696·5787 by 3,495 (which is one less than the total number of days 3,496, and represents what is usually called the number of statistical degrees of freedom).

The total sum 696·5787 may, however, be divided into two portions:—(1) the fluctuation from one year to another, and (2) fluctuations for different days within the same year. It is possible to separate these two terms. Doing so, we find that the portion due to fluctuations from year to year is 15·1236. But this represents only 37 degrees of freedom (for there are 38 years altogether, and 38—1=37 represents the number of independent comparisons possible), and hence the variance is 0·4090. The remaining portion 681·4551 must then be attributed to the fluctuations within years represented by 3,495—37=3,458 degrees of freedom. The corresponding variance is 0·1971, which is practically the same as the total variance 0·1993.

In this case we find that Z = 0·3650, which is more than three times its approximate standard error 0·1170. We conclude that Z may be taken to be significantly greater than zero, that is, the two variances compared are statistically different. The analysis of variance may be exhibited in the following way:—

Table 69.—Analysis of variance—Rainfall in Mahanadi, Section I.

—	Degrees of Freedom.	Sum of squares.	Mean variance.	S. D.
Between years	37	15·1236	·4090	6395·
Within years	3458	681·4551	·1971	·4440
Total	3495	696·5787	·1993	·4464

The general conclusion is that the years are significantly differentiated. That is, the average daily rainfall in different years is significantly different from one another.

We can apply the same test to the other sections. The analysis of variance for the sections II, III, IV and V are given in Table 70. The value of Z for section II is just below twice its (approximate) standard error, and is on the verge of significance. All the other values of Z are more than twice the corresponding standard errors, and may be considered to be significant.

Our general conclusion is, then, that the average rainfalls in different years are significantly different in each section.

Table 70.—Analysis of variance—Seasonal Rainfall in the Mahanadi Catchment.

Catchment.	Mode of variation.	Degrees of freedom.	Sum of squares of Deviations.	Mean variance.	Observed value of Z.
Section I ..	Between years ..	37	15·12 36	0·40 90	0·36 50
	Within years ..	34 58	6 81·45 51	0·19 71	
	Total ..	34 95	6 96·57 87	0·19 93	
Section II ...	Between years ..	37	27·47 85	0·74 27	0·21 09
	Within years ..	34 58	16 84·27 66	0·48 71	
	Total ..	34 95	17 11·75 51	0·48 97	
Section III ..	Between years ..	37	20·00 19	0·54 06	0·27 99
	Within years ..	34 58	10 68·31 81	0·30 89	
	Total ..	34 95	10 88·32 00	0·31 14	
Section IV ..	Between years ..	37	28·31 74	0·76 53	0·23 57
	Within years ..	34 58	16 51·97 22	0·47 77	
	Total ..	34 95	16 80·28 96	0·48 07	
Section V ..	Between years ..	37	16·15 82	0·43 67	0·30 82
	Within years ..	34 58	7 22·98 29	0·20 91	
	Total ..	34 95	7 39·14 11	0·21 15	
Whole Mahanadi Catchment.	Between years ..	37	13·16	0·35 56	0·32 78
	Within years ..	34 58	6 38·18	0·18 45	
	Total ..	34 95	6 51·34	0·18 64	

This being so, I thought it worthwhile to fit straight line trends by the method of least squares. (One great defect in this method is that the averages for different years are given equal weights although they were based on widely different numbers of rainfall stations. Weighting would have increased the labour of computation very greatly; and I did not use it for this reason.)

The straight lines fitted to the annual mean of daily averages for different sections are given below :

Whole Catchment	R=0·42+·00 02 (Y—1910).
Section I	R=0·37+·00 29 (Y—1910).
Section II	R= 0·41—·00 16 (Y—1910).
Section III	R=0·46+·00 03 (Y—1910).
Section IV	R=0·41+·00 09 (Y—1910).
Section V	R=0·38—·00 12 (Y—1910).

The coefficients are all small, the largest +·0029 for section I representing a change of less than ·003″ or three-thousandth of an inch per year, and is less than 1 per cent of the mean value. But the most striking thing about the coefficients is that three are positive and two negative, indicating apparently that the rainfall is increasing in sections (M-I, M-III, M-IV) and decreasing in the two other sections (M-II and M-V). This shows that the trends (if real) must be local peculiarities.

This is clearly brought out in the straight line fit to the data for the whole catchment. The coefficient of increase is +·0002″ and is negligibly small. In other words, the average daily rainfall in the whole Mahanadi catchment, although differing significantly from year to year, fluctuates steadily round a constant value of about 0·37″, and does not show any progressive change with time during the period 1891—1928.

In view of this steadiness of the average rainfall over the whole catchment we shall not be justified in attaching much importance to the local peculiarities of particular catchments. It is interesting to note that M-III, which has the largest area, has also the lowest coefficient among the sections. It is not impossible that the local peculiarities noticed in the case of other sections arise from the fact that the area of these sections is not large enough to average out the bias introduced by peculiarities in the distribution of rainfall stations.

CHAPTER XXI.—SEASONAL CHANGE IN RAINFALL.

I shall now briefly describe the change in the daily rainfall as the monsoon advances. The average daily rainfall for each day from July 1 to September 30 for each section and the whole catchment will be found in Tables 71—76.

The analysis of variance for all the sections and the whole catchment is given in Tables 77·1—77·5. It will be seen that the fluctuations between one date and another ("between dates") are invariably greater than fluctuations for the same date in different years ("within dates"). The Z-test is definitely significant in every case. In other words, the seasonal change in rainfall may be considered quite real in the case of all the sections as well as for the whole catchment.

The graphs fully corroborate these results. The rainfall increases as the monsoon season advances from the 1st July, attains the highest value in the last week of July or the 1st week of August, decreases slowly at first and then quite rapidly in September. The change is typical, and is practically identical in all the sections.

Table 71.—Mean daily rainfall for different dates of July, August and September.

Mahanadi Catchment, Section I, 1891—1928.

	July.			August.		September.	
Date.	n	Mean.	S. D.	Mean.	S. D.	Mean.	S. D.
1	38	0·39	0·46	0·53	0·51	0·38	0·34
2	38	·33	·32	·53	·51	·37	·44
3	38	·41	·33	·47	·48	·39	·36
4	38	·44	·90	·38	·53	·41	·50
5	38	·36	·36	·39	·60	·47	·59
6	38	·30	·32	·37	·27	·43	·42
7	38	·27	·24	·53	·49	·41	·66
8	38	·38	·49	·46	·43	·32	·26
9	38	·39	·37	·30	·33	·32	·29
10	38	·41	·43	·33	·36	·32	·36
11	38	·45	·46	·31	·31	·37	·27
12	38	·66	·61	·35	·38	·39	·45
13	38	·37	·26	·42	·40	·32	·31
14	38	·44	·44	·37	·41	·37	·45
15	38	·37	·43	·33	·45	·25	·30
16	38	·36	·41	·47	·87	·25	·28
17	38	·41	·40	·52	·95	·29	·48
18	38	·30	·30	·43	·57	·34	·38
19	38	·36	·30	·39	·41	·26	·42
20	38	·45	·35	·49	·63	·19	·16
21	38	·34	·31	·40	·29	·19	·23
22	38	·49	·61	·37	·34	·27	·32
23	38	·48	·47	·37	·33	·34	·53
24	38	·51	·52	·44	·40	·36	·47
25	38	·49	·44	·37	·32	·27	·25
26	38	·49	·48	·42	·37	·19	·19
27	38	·48	·51	·41	·47	·16	·20
28	38	·38	·35	·40	·27	·20	·26
29	38	·40	·42	·42	·35	·19	·26
30	38	·36	·45	·27	·24	·10	·13
31	38	·58	·77	·40	·45		

Table 72.—Mean daily rainfall for different dates of July, August and September.
Mahanadi Catchment, Section II, 1891—1928.

Date.	July. n	July. Mean.	July. S. D.	August. Mean.	August. S. D.	September. Mean.	September. S. D.
1	38	0·40	0·57	0·78	0·80	0·52	0·81
2	38	·47	·61	·81	1·24	·40	·54
3	38	·45	·44	·83	1·27	·61	·89
4	38	·57	·90	·52	·84	·54	·67
5	38	·42	·68	·30	·41	·45	·51
6	38	·42	·45	·48	·59	·51	·65
7	38	·30	·27	·53	·56	·40	·36
8	38	·41	·40	·49	·61	·44	·74
9	38	·44	·51	·42	·88	·22	·83
10	38	·53	·90	·30	·49	·28	·42
11	38	·43	·50	·68	1·03	·22	·27
12	38	·74	·87	·46	·61	·35	·83
13	38	·47	·55	·58	·62	·31	·47
14	38	·45	·63	·67	1·02	·20	·27
15	38	·42	·50	·45	·68	·30	·37
16	38	·30	·46	·47	·67	·25	·53
17	38	·49	·77	·48	·82	·25	·50
18	38	·52	·67	·62	1·16	·37	·78
19	38	·53	·57	·29	·31	·89	·18
20	38	·52	·58	·34	·41	·17	·37
21	38	·40	·48	·34	·48	·15	·27
22	38	·78	1·39	·53	·75	·20	·32
23	38	1·03	1·08	·28	·33	·22	·31
24	38	·57	·74	·51	·51	·19	·23
25	38	·51	·78	·47	·55	·17	·25
26	38	·68	1·00	·44	·72	·13	·16
27	38	·51	·51	·46	·62	·09	·17
28	38	·68	1·42	·42	·43	·22	·43
29	38	·42	·42	·53	·49	·12	·20
30	38	·42	·48	·34	·38	·07	·20
31	38	·43	·52	·32	·50		

Table 73.—Mean daily rainfall for different dates of July, August and September.
Mahanadi Catchment, Section III, 1891—1928.

1	38	0·40	0·40	0·83	0·91	0·46	0·83
2	38	·49	·49	·67	·62	·38	·37
3	38	·50	·47	·63	·54	·43	·51
4	38	·55	·58	·48	·52	·42	·32
5	38	·61	·49	·47	·64	·42	·40
6	38	·66	·57	·72	·66	·46	·44
7	38	·46	·40	·75	·72	·40	·39
8	38	·45	·39	·60	·54	·36	·38
9	38	·40	·31	·49	·44	·30	·31
10	38	·65	·50	·50	·49	·26	·37
11	38	·54	·54	·53	·51	·28	·35
12	38	·84	1·06	·52	·53	·39	·77
13	38	·58	·51	·65	·62	·48	·62
14	38	·43	·36	·67	·72	·26	·41
15	38	·58	·70	·46	·40	·25	·33
16	38	·59	·56	·43	·47	·21	·24
17	38	·49	·51	·54	·59	·24	·32
18	38	·48	·44	·72	·82	·25	·43
19	38	·62	·43	·54	·51	·13	·20
20	38	·58	·66	·45	·48	·14	·21
21	38	·69	·52	·46	·39	·19	·24
22	38	·72	·88	·53	·52	·23	·40
23	38	·73	1·08	·48	·44	·21	·29
24	38	·60	·52	·64	·59	·19	·31
25	38	·72	·80	·64	·50	·23	·29
26	38	·79	·90	·44	·44	·14	·16
27	38	·61	·60	·46	·55	·12	·16
28	38	·53	·44	·40	·43	·15	·28
29	38	·58	·52	·40	·45	·12	·18
30	38	·58	·52	·53	·44	·10	·18
31	38	·62	·68	·49	·41	..	..

Table 74.—Mean daily rainfall for different dates of July, August and September.

Mahanadi Catchment, Section IV, 1891—1928.

Date.	July.			August.		September.	
	n	Mean.	S. D.	Mean.	S. D.	Mean.	S. D.
1	38	0·37	·65	·62	·63	·53	·60
2	38	·40	·60	·76	·90	·29	·42
3	38	·49	·51	·68	·80	·40	·49
4	38	·49	·86	·64	1·29	·41	·51
5	38	·45	·62	·47	·71	·38	·57
6	38	·51	·68	·67	·09	·35	·52
7	38	·30	·47	·69	·80	·39	·68
8	38	·26	·29	·75	1·37	·32	·45
9	38	·40	·58	·38	·60	·21	·34
10	38	·51	·75	·34	·50	·34	·58
11	38	·32	·40	·45	·68	·20	·31
12	38	·60	·78	·65	1·64	·40	·70
13	38	·60	·66	·50	·64	·43	·60
14	38	·40	·59	·48	·76	·26	·41
15	38	·30	·35	·39	·59	·25	·34
16	38	·37	·58	·38	·50	·25	·45
17	38	·51	·62	·28	·42	·36	·82
18	38	·58	1·45	·50	·88	·36	·63
19	38	·36	·48	·28	·33	·29	·50
20	38	·44	·47	·26	·32	·11	·64
21	38	·42	·63	·45	·54	·22	·43
22	38	·42	·56	·57	·76	·24	·46
23	38	·50	·76	·32	·49	·19	·55
24	38	·54	·99	·57	·70	·25	·41
25	38	·52	·67	·62	·70	·24	·43
26	38	·54	·67	·62	·78	·26	·47
27	38	·57	·79	·50	·62	·06	·09
28	38	·41	·63	·52	·87	·32	·75
29	38	·52	·78	·49	·94	·07	·17
30	38	·50	·99	·39	·53	·06	·13
31	38	·51	·71	·50	·67	..	..

Table 75.—Mean daily rainfall for different dates of July, August and September.

Mahanadi Catchment, Section V, 1891—1928.

Date.	July.			August.		September.	
	n	Mean.	S. D.	Mean.	S. D.	Mean.	S. D.
1	38	·38	·33	·61	·58	·38	·38
2	38	·49	·45	·65	·62	·37	·41
3	38	·40	·35	·64	·65	·42	·44
4	38	·51	·50	·53	·69	·32	·30
5	38	·46	·41	·42	·42	·35	·37
6	38	·52	·50	·53	·51	·33	·36
7	38	·41	·38	·56	·54	·28	·28
8	38	·30	·30	·60	·75	·32	·32
9	38	·41	·40	·35	·35	·23	·27
10	38	·45	·48	·34	·35	·22	·25
11	38	·33	·26	·42	·46	·25	·29
12	38	·52	·59	·43	·47	·25	·22
13	38	·63	·79	·40	·38	·27	·31
14	38	·33	·36	·48	·56	·27	·30
15	38	·40	·33	·36	·40	·22	·24
16	38	·44	·46	·28	·40	·26	·42
17	38	·30	·35	·32	·33	·23	·34
18	38	·44	·49	·42	·53	·25	·38
19	38	·40	·38	·32	·31	·24	·42
20	38	·42	·37	·28	·23	·14	·22
21	38	·35	·35	·35	·25	·27	·37
22	38	·41	·47	·37	·28	·21	·36
23	38	·46	·49	·39	·45	·21	·36
24	38	·52	·84	·45	·30	·33	·56
25	38	·66	·85	·48	·53	·31	·41
26	38	·52	·57	·43	·40	·21	·27
27	38	·54	·78	·41	·41	·14	·17
28	38	·40	·57	·50	·50	·25	·44
29	38	·43	·43	·44	·57	·12	·21
30	38	·40	·45	·38	·41	·10	·18
31	38	·43	·38	·38	·39	..	..

Table 76.—Mean daily rainfall for different dates of July, August and September.

Whole Mahanadi Catchment, 1891—1928.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
July, 1	0·39	August, 1	0·68	September, 1	0·46
2	·42	2	0·68	2	·36
3	·45	3	·65	3	·46
4	·51	4	·51	4	·42
5	·44	5	·42	5	·41
6	·47	6	·55	6	·41
7	·35	7	·61	7	·38
8	·36	8	·58	8	·35
9	·42	9	·39	9	·26
10	·49	10	·38	10	·28
11	·42	11	·48	11	·26
12	·67	12	·49	12	·35
13	·53	13	·51	13	·36
14	·41	14	·54	14	·28
15	·42	15	·40	15	·25
16	·43	16	·39	16	·25
17	·46	17	·43	17	·28
18	·47	18	·54	18	·32
19	·44	19	·36	19	·19
20	·48	20	·36	20	·15
21	·42	21	·40	21	·21
22	·56	22	·48	22	·23
23	·65	23	·37	23	·24
24	·55	24	·52	24	·26
25	·58	25	·51	25	·25
26	·61	26	·47	26	·19
27	·55	27	·45	27	·12
28	·50	28	·47	28	·23
29	·47	29	·47	29	·12
30	·47	30	·38	30	·09
31	·51	31	·42	..	..

Analysis of variance.

Mahanadi Catchment (1891—1928).

	D·F.	Sum sq.	Mean sq.
Table 77·1, Section M-I—			
Between dates	91	31·1459	·3422
Within dates	3404	665·4328	·1954
	3495	696·5787	·1993
Z= ·2800. Standard error =·0741			
Table 77·2, Section M-II—			
Between dates	91	108·7319	1·1948
Within dates	3404	1603·0232	·4709
	3495	1711·7551	·4897
Z=·4655 Standard error =·0741			
Table 77·3, Section M-III—			
Between dates	91	104·2972	1·1461
Within dates	3404	984·0228	·2891
	3495	1088·3200	·3114
Z=·6876 Standard error =·0741			
Table 77·4, Section M-IV—			
Between dates	91	96·7131	1·0628
Within dates	3404	1597·5765	·4693
	3495	1694·2896	·4848
Z=·4087 Standard error=·0741			
Table 77·5, Section M-V—			
Between dates	91	51·3659	·5645
Within dates	3404	687·7752	·2020
	3495	739·1411	·2115
Z=·5138 Standard error=·0741			

CHAPTER XXII.—THE FREQUENCY DISTRIBUTION OF INTENSITIES OF RAINFALL.

The frequency distributions of different intensities of rainfall in July, August, September, and for the combined period for each of the 5 sections of Mahanadi and the whole catchment are given in Tables 78—83 The distributions cover the 38 years 1891—1928, and under each range give the number of days on which the actual rainfall was of an amount lying within the given range. For example, for Section I, July, range 0·40″—0·50″, we find the figure 110. We know then that on 110 days in July during the 38 years 1891—1928 the average daily rainfall in Section I was not less than 0·40″ or not greater than 0·50″ Thus, on an average, this intensity of rainfall had occurred about 3 days in each reason.

In using these Tables care should be taken to note that the size of the group or range has been changed at many places. The figures for "zero" rainfall actually refer to all cases from real zero to 0·01″, since rainfall less than 0·01″ are not reported in the Meteorological records. The class interval here is then 0·01″. From 0·01″ to 0·10″ the class interval is ·09″. From 0·10″ to 1·00″ we have grouped the frequencies at intervals of 0·10″. From 1·00″ to 2·00″, the interval is 0·20, while beyond 2·00″ it is 0·50″. The change in class intervals explains the lumping together in the ranges 1·00—1·20 or 2·00″—2·50″.

In M-I the average daily rainfall apparently never exceeded 25 on even a single day in 38 years. In M-II the limiting value lies in the range 3·5″—4·00″, and in M-III in 6·00″—6·50″. The extreme range in M-IV is 8·5″—9 00″ but this merely refers to single rainfall stations and need not be taken seriously. In M-V the limiting range is 4·50″—5·00″.

Table 78.—Frequency distribution of rainfall intensities for July, August and September and the combined period of July—September.

Mahanadi I.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	60	42	127	229
0·01— ·1	193	244	246	683
— ·2	171	194	220	585
— ·3	181	168	132	481
— ·4	122	112	110	344
— ·5	110	99	83	292
— ·6	83	73	74	230
— ·7	61	57	35	153
— ·8	38	36	32	106
— ·9	29	24	24	77
—1·0	21	19	16	56
—1·2	30	44	16	90
—1·4	24	15	7	46
—1·6	8	13	5	26
—1·8	12	11	4	27
—2·0	3	6	..	9
—2·5	11	..	..	11

Table 79.—Frequency distribution of rainfall intensities for July, August, September and the combined period of July—September.

Mahanadi II.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	162	166	282	610
0·01— ·1	184	223	298	705
— ·2	159	167	149	475
— ·3	99	113	97	309
— ·4	99	84	60	243
— ·5	96	57	55	208
— ·6	54	64	44	162
— ·7	45	45	26	116
— ·8	48	35	27	110
— ·9	36	20	18	74
—1·0	29	29	13	71
—1·2	45	39	21	105
—1·4	34	32	11	77
—1·6	19	26	3	48
—1·8	8	24	8	40
—2·0	9	9	6	24
—2·5	16	15	11	42
—3·0	8	8	2	18
—3·5	6	..	..	6
—4·0	1	1	..	2

Table 80.—Frequency distribution of rainfall intensities for July, August and September and the combined period of July—September.

Mahanadi III.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	57	44	216	317
0·01— ·1	164	181	296	641
— ·2	145	148	166	459
— ·3	110	132	127	369
— ·4	119	95	80	294
— ·5	102	106	54	262
— ·6	74	77	47	198
— ·7	70	61	38	169
— ·8	52	55	23	130
— ·9	53	42	14	109
—1·0	28	39	20	87
—1·2	70	62	19	151
—1·4	40	37	17	94
—1·6	35	24	6	65
—1·8	9	25	4	38
—2·0	16	13	5	34
—2·5	17	19	7	43
—3·0	6	12	..	18
—3·5	4	5	..	9
—4·0	2	1	..	3
—4·5	2	..	1	3
—5·0	2	..	..	2
—5·5	..	..	..	..
—6·0	..	..	..	..
—6·5	1	..	..	1

Table 81.—Frequency distribution of rainfall intensities for July, August and September and the combined period of July—September.

Mahanadi IV.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	224	214	389	827
0·01— ·1	200	254	244	707
— ·2	159	133	127	419
— ·3	98	87	84	269
— ·4	85	80	59	224
— ·5	67	66	45	178
— ·6	47	50	31	128
— ·7	27	44	18	89
— ·8	44	25	18	87
— ·9	34	26	23	83
—1·0	20	19	18	57
—1·2	43	56	19	118
—1·4	26	27	17	70
—1·6	28	21	12	61
—1·8	11	13	5	29
—2·0	10	12	6	28
—2·5	16	29	14	59
—3·0	12	15	5	32
—3·5	11	5	3	19
—4·0	2	..	1	3
—4·5	2	2	1	5
—5·0	2	..	1	3
—5·5	..	..	..	..
—6·0	..	..	..	..
—6·5	..	..	..	..
—7·0	..	..	..	..
—7·5	..	..	..	..
—8·0	..	..	..	..
—8·5	..	..	..	..
—9·0	1	..	..	..

Table 82.—Frequency distribution of rainfall intensities for July, August and September and the combined period of July—September.

Mahanadi V.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	58	53	223	334
0·01— ·1	198	300	292	790
— ·2	185	127	180	492
— ·3	163	137	111	411
— ·4	115	99	80	294
— ·5	88	100	62	250
— ·6	75	72	48	195
— ·7	55	51	33	139
— ·8	55	56	24	135
— ·9	30	35	19	84
—1·0	25	34	11	70
—1·2	35	39	28	102
—1·4	36	28	12	76
—1·6	20	18	7	45
—1·8	15	15	2	32
—2·0	3	3	1	7
—2·5	11	2	6	19
—3·0	5	..	..	5
—3·5	1	..	1	2
—4·0	1	..	..	1
—4·5	3	..	..	3
—5·0	1	..	..	1

The next Table 83 shows the frequency distribution for July, August, September for the Mahanadi Catchment as a whole. The limiting range is now 3·50"-3·75". The daily average in the Mahanadi Catchment apparently never exceeded 3·75" in 38 years. In fact values in excess of 3·25" are extremely rare, there being only 2 cases in 38 years.

Table 83.—Frequency distribution of rainfall intensities for the months of July, August and September and July—September combined.

Whole Mahanadi Catchment.

Range of rainfall in inches.	July.	August.	September.	Combined.
Zero	23	9	65	97
0·01— ·1	128	158	282	568
— .2	178	190	247	615
— ·3	162	162	154	478
— ·4	154	141	113	408
— ·5	117	99	85	301
— ·6	101	83	51	235
— ·7	88	60	40	188
— ·8	63	78	30	171
— ·9	33	41	15	89
—1·0	27	37	7	71
—1·25	39	58	31	128
—1·5	28	38	13	79
—1·75	12	12	..	24
—2·0	9	5	3	17
—2·25	4	2	3	9
—2·5	6	2	1	9
—2·75	..	1	..	1
—3·0	5	1	..	6
—3·25	1	..	..	1
—3·5	..	..	..	..
—3·75	..	1	..	1

The next Table 84 gives the accumulated totals of the frequencies, so that the number of days on which the daily average rainfall equalled or exceeded any assigned value may be obtained directly. For example, for Section I for the combined period we find the figure 209 against the assigned limit of 1·00″. This shows that on 209 days (out of 3,445* days in July, August and September in 38 years) the daily average rainfall in Section I equalled or exceeded 1·00″.

Table 84.—Accumulated frequency distribution of rainfall over Mahanadi Sections July—September (1891—1928).

In excess of inches of rainfall.	M·I.	M·II.	M·III.	M·IV.	M·V.	Whole catchment.
Zero	3445	3445	3496	3496	3496	3496
0·01	3216	2835	3179	2669	3162	3399
0·1	2533	2130	2538	1962	2363	2831
·2	1948	1635	2079	1543	1871	2216
·3	1467	1346	1710	1274	1460	1738
·4	1123	1103	1416	1050	1166	1330
·5	831	895	1154	872	916	1029
·6	601	733	956	744	721	894
·7	448	617	787	655	582	606
·8	342	507	657	568	447	435
·9	265	433	548	485	363	346
1·0	209	362	461	428	293	275
1·2	119	257	310	310	191	174
1·4	73	180	216	240	115	101
1·6	47	132	151	179	70	57
1·8	20	92	113	150	38	40
2·0	11	68	79	122	31	27
2·5	..	26	36	63	12	8
3·0	..	8	18	31	7	1
3·5	..	2	9	12	5	..
4·0	..	..	6	9	4	..
4·5	..	..	3	4	1	..
5·0	..	..	1	1	..	..
5·5	..	..	1	1	..	..
6·0	..	..	1	1	..	..
6·5	..	..	..	1	..	..
7·0	..	..	..	1	..	..
7·5	..	..	..	1	..	..
8·0	..	..	..	1	..	..
8·5	..	..	..	1	..	..

From a flood point of view heavy rainfall continuing for a number of days is far more important than the freak rainfall on a single day. For this purpose we require the moving average for 2, 3, 4 ...... or a larger number of consecutive days. The work was extremely laborious but in view of its importance, moving averages up to 5 consecutive days were completed for the whole catchment. The results are given in Tables 85—88.

Let us consider Table 88 for 5 days. For the combined period we notice that the limiting range is 1·50″—1·75″. We find, therefore, that the average daily rainfall in the Mahanadi catchment for a period of 5 consecutive days never exceeded 1·75″. In fact there were only 8 occasions in 38 years on which the average for 5 consecutive days exceeded 1·5″.

The corresponding accumulated totals for the combined period are given in Table 89. This table gives us directly the total number of occasions on which the average rainfall for 2, 3, 4, or 5 days reached or exceeded any assigned value. The graduated values have been shown in Table 90. Dividing the graduated accumulated values of Table 90 by 38 (the number of years of the total experience) we obtain the probability Table 91. This table gives the probability of occurrence of any assigned intensity of rainfall for 2, 3, 4, or 5 consecutive days.

*In sections M-I and M-II, some of the data were missing thus yielding 3445 days instead of 3496 days in July—September in 38 years.

Table 85.—Frequency distribution of rainfall intensities based on two consecutive days' averages, July—September, 1891—1928.

Whole Mahanadi Catchment, 1891—1928.

Range of rainfall in inches.	July.	August.	September.	Combined.
0·01—·1	103	116	333	552
·2	143	169	235	547
·3	159	163	167	489
·4	147	151	126	424
·5	157	128	88	373
·75	245	231	116	592
1·00	98	130	49	277
1·25	34	53	13	100
1·50	25	23	8	56
1·75	17	6	3	26
2·00	4	2	2	8
2·25	5	4	..	9
2·50	..	1	..	1
2·75	2	..	..	2
3·00	1	1	..	2

Table 86.—Frequency distribution of rainfall intensities based on three consecutive days' averages, July—September, 1891—1928.

Whole Mahanadi Catchment, 1891—1928.

Range of rainfall in inches.	July.	August.	September.	Combined.
0·01—·1	85	154	277	516
·2	104	157	253	514
·3	152	153	175	480
·4	173	183	150	506
·5	179	238	101	518
·75	270	183	124	577
1·00	72	84	40	196
1·25	38	13	13	64
1·50	19	7	6	32
1·75	8	2	1	11
2·00	0	2	..	2
2·25	5	2	..	7
2·50	1	..	..	1

Table 87.—Frequency distribution of rainfall intensities based on four consecutive days' averages, July—September, 1891—1928.

Whole Mahanadi Catchment.

Range of rainfall in inches.	July.	August.	September.	Combined.
0·01—0·1	69	70	241	380
·2	72	113	245	430
·3	148	158	189	495
·4	185	168	173	526
·5	178	173	103	454
·75	277	332	136	745
1·00	81	128	39	248
1·25	31	25	12	68
1·50	11	5	2	18
1·75	9	3	..	12
2·00	3	3	..	6

Table 88.—Frequency distribution of rainfall intensities based on five consecutive days' averages, July—September, 1891—1928.

Whole Mahanadi Catchment.

Range of rainfall in inches.	July.	August.	September.	Combined.
0·01—·1	46	50	226	322
— ·2	76	123	220	419
— ·3	138	139	209	486
— ·4	188	174	182	544
— ·5	172	190	121	483
— ·75	283	358	138	779
—1·00	78	120	36	234
—1·25	28	16	8	52
—1·50	11	4	..	15
—1·75	4	4	..	8

Table 89.—Accumulated frequency distribution of rainfall intensities based on 2—5 days' averages: July—September, 1891—1928.

Whole Mahanadi Catchment.

In excess of inches of rainfall.	2 days.	3 days.	4 days.	5 days.
·0	3458	3424	3382	3344
·1	2906	2908	3002	3022
·2	2359	2394	2572	2603
·3	1870	1914	2077	2117
·4	1446	1408	1551	1573
·5	1073	890	1097	1090
·75	481	313	352	311
1·00	204	117	104	77
1·25	104	53	36	25
1·50	48	21	18	10
1·75	22	10	6	2
2·00	14	8	..	..
2·25	5	1	..	..
2·50	4	..	..	..
2·75	2	..	..	..

Table 90.—Accumulated frequency distribution of rainfall intensities (from free-hand graduation).

Whole Mahanadi Catchment.

In excess of inches of rainfall.	2 days.	3 days.	4 days.	5 days.
—1·0	380	180	150	125
—1·2	148	80	50	50
—1·4	80	48	35	30
—1·6	49	25	28	17
—1·8	25	20	6	2
—2·0	20	16	2	..
—2·2	15	10	..	..
—2·4	12	2	..	..
—2·6	10	..	..	..
—2·8	5	..	..	..

Table 91.—Probability of occurrence in number of days per period of July—September of different rainfall intensities.

In excess of inches of rainfall.	2 days.	3 days.	4 days.	5 days.
1·0	10·00	4·74	3·95	3·29
1·2	3·89	2·10	1·32	1·32
1·4	2·10	1·26	·92	·79
1·6	1·29	·66	·74	·45
1·8	·66	·53	·16	·05
2·0	·53	·42	·05	..
2·2	·39	·26	..	..
2·4	·32	·05	..	..
2·6	·26	..	..	..
2·8	·13	..	..	..

In view of the fact that during heavy floods the rainfall sometimes continued for a much longer period than 5 days, I decided to push this analysis up to 10 consecutive days. As the additional labour involved is very great, I decided to neglect the lower range of rainfall. By a careful scrutiny of 5 days' totals, all values of heavy rainfall likely to lead to substantially heavy averages for a larger number of consecutive days were marked in pencil. These selected totals were then used for the formation of moving averages up to 10 days.

The results are given in Table 92. Owing to the cutting off of the lower range of rainfall these tables are not complete ; it may even be that at the lower end of the tables a few more additional isolated values would come in on a fuller analysis. But I believe that on the whole, and especially, at the upper end, say beyond 1·0", these tables are quite reliable.

Table 92.—Frequency distribution of rainfall intensities over 0·8 inch based on 6, 7, 8, 9 and 10 days' averages.

Whole Mahanadi Catchment (1891—1928).

Range of rainfall in inches.	6 days.	7 days.	8 days.	9 days.	10 days.
·8— ·9	112	74	72	70	57
1·0	43	38	24	35	33
1·1	21	24	26	17	19
1·2	12	16	8	12	11
1·3	13	7	8	6	...
1·4	8	7	4	..	...
1·5	2	3	..	..	..
1·6	2	2	..	..	..
1·7	1	..	..	..	—

The corresponding accumulated totals, and probability tables calculated from free-hand graduations are given in Tables 93—94.

Table 93.—Accumulated frequency distribution of rainfall intensities over 0·8 inch based on 6, 7, 8, 9 and 10 days' averages.

In excess of inches of rainfall	6 days.	7 days.	8 days.	9 days.	10 days.
·8	214	171	142	140	120
·9	102	97	70	70	63
1·0	59	59	46	35	30
1·1	38	35	20	18	11
1·2	26	19	12	6	
1·3	13	12	4	..	..
1·4	5	5	..	..	..
1·5	3	2	..	..	..
1·6	1				..

Table 94.—Probability of occurrence in number of days of different rainfall intensities during the period July to September.

Whole Mahanadi Catchment (1891—1928).

The figures give the probable number of days in one monsoon season (July—September) on which the intensities of rainfall in excess of the figure given in column 1 may be expected.

In excess of inches of rainfall	6 days.	7 days.	8 days.	9 days.	10 days.
·8	5·63	4·50	3·74	3·68	3·16
·9	2·68	2·55	1·84	1·84	1·66
1·0	1·55	1·55	1·21	·92	·79
1·1	1·00	·92	·53	·47	·29
1·2	·68	·50	·13	·16	..
1·3	·34	·13	·10	..	..
1·4	·13	·05	..	..	..
1·5	·08	..	..	..	..
1·6	·03	..	..	..	..

The analysis of the rainfall in the Mahanadi Catchment is reasonably complete for the purpose of flood studies. We have the frequency distribution of the daily rainfall for 38 years for different months and different sections. We are also in a position to obtain with the help of Tables 90, 91, 93 and 94 the probability of occurrence of any assigned intensity of daily rainfall for any number of consecutive days from 2 to 5, and beyond an intensity of 0·8″ for any number of consecutive days from 6 to 10.

CHAPTER XXIII.—THE AREAL DISTRIBUTION OF RAINFALL.

The distribution of rainfall over the Mahanadi Catchment is an important question in flood studies. The isohyet method must be used for this purpose. For each year from 1891 to 1928 I selected the period of heaviest rainfall over 3, 4 and 5 consecutive days. (As this work was taken up before calculating the moving averages it had to be done by scrutiny). The total rainfall for the selected periods were then entered on maps. Records for stations outside the catchment were also used, as they often gave valuable information regarding the position of the isohyets. For 38 years and 3 days altogether 114 maps were drawn for this study.*

The area between two isohyets lying within each section was measured directly by a planimeter. The measured areas were then entered in a tabulation sheet against the mean value of the bordering isohyets. The accumulated totals of the area figures were then determined and a graph drawn on squared paper. This curve gives the areal distribution of intensity of rainfall.

The areas corresponding to each inch of rainfall were then found by direct interpolation from these graphs, and these tabulated values will be found in Tables 95—109†.

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* As a matter of fact I had prepared maps for 6, 7 and 10 days also. But as the measurement of all these maps could not be completed in time, I am obliged to leave them out of the present discussion I may note that records for 1910 were not available; and also that records for 1904 and 1918 were missing in a few cases.

† I ought to note here a slight discrepancy between the tabulated values and the original graphs. In measuring the areas on maps three different planimeters were used, and it was subsequently discovered that owing to slight differences in adjustments, the results given by these planimeters differed slightly from one another. Fortunately it was found that taking the first as standard the second gave readings approximately 10 per cent in defect, and the other 5 per cent in excess. The graphs were drawn with the raw data. But the tabulated values were later on corrected by applying corrections of + 10 per cent and — (minus) 5 per cent respectively, and these corrected values are given in Tables 95—109,

TABLES 95—109.

Table 95.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
1891	6061	6061	5738	5548	4902	4484	3876	3268	2622		
92	6270	6270	4807	3648	2508	1577	950	532	323	209	152
93	6080	6080	6080	2565	1615						
94	6270	5700	4655	3800	3135	2413	1330	418			
95	6175	6175	6175	6175	6175	6175	4750	3040	1026	171	
96	5966	5966	5966	5016	1577	38					
97	6270	5700	3705								
98	6270	6270	5567	4845	3705	3230					
99	5700	3325									
1900	6270	6270	4446	3071	2071						
01	4085	2000	1311								
02	6080	6080	4750	2304							
03	6080	6080	4712	1919	532						
04	6270	6270	5434	4902	4579	4332	4047	3914	3705	3553	
05	6346	3325	4180								
06	5985	5985	5548	4712	3705	2660					
07	6270	3325	1140								
08	6270	5035									
09	5890	1938	950								
1911	5624	3648	2717	2204	1900	1634	1425	1264	1102	931	779
12	4598	2156	950								
13	5928	5928	5928	4788	3306	2356	1672	1140	779	494	
14	6232	6232	6232								
15	6023	6023	4807	3287	2584	2204	1691	1107	703	228	
16	6327	6327	4484	760							
17	6289	6289	1634								
18	6213	6213	5187	4427	3810	3287	2755	2304	2033		
19	6270	6270	5871	4731	3857	3059	2318	1672			
1920	4959	4959	4959	4959	4959	3705	2407	1387	779	551	380
21	5434	4237	3021	1824							
22	5871	5567									
23	4427	3040	2299	1653							
24	5985	5985	5624	4940	4237	3534					
25	6080	6080	6004	5843	5130	4598	4028	3468	2774	2128	1368
26	6270	6270	6270	6270	6270	6270	6270	6270	5225	4655	4142
27	6460	5624	5624	4142	3724	2622	1501	874	589	437	380
28	6365	6365	5871	4712	3857	3124	2318	1387	950	760	627

—M-I—3 days.

during the most severe storms of each year.

12′	13′	14′	15′	16′	17′	18′	19′	20′	21′	22′	23′	Year.
												1891
95												92
												93
												94
												95
												96
												97
												98
												99
												1900
												01
												02
												03
												04
												05
												06
												07
												08
												09
627	456											1911
												12
												13
												14
												15
												16
												17
												18
												19
												1920
												21
												22
												23
												24
380												25
3667	3211	2812	2432	2062	1710	1406						26
												27
570												28

Table 96.

Areas in square miles under different intensities of rainfall

Year.	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
1891	11704	11704	11628	11405	11229	9785	570				
92	12331	10241	7676	6270	5510	4978	4484	4237	3971	3761	3550
93	11628	11628	11590	11419	10830						
94	11022	11022	10868	9329	7201	5225	3496	1634			
95	11818	11818	11768	11438	9880	7144	3743	2603	2071	1558	1273
96	12445	12217	11286	7733	1349						
97	11837	11837									
98	11970	11970	10640	9310	7980	6745	5415				
99	11709	11709	11709								
1900	11685	11665	11685	11685	6840	4180	3325	2945			
01	3455	3135	1140	627	418						
02	12179	12179	11970	8360	5035	1710					
03	11405	11405	722								
04	11780	11020	9310	7030	4405						
05	11780	2185	1903								
06	11590	9823	8569	7733	6574	6365	6363	6270			
07	11609	11305	11210	11020	10640	10070	9215				
08	11685	11685	11683	11020	6550	2280					
09	11495	11495	9880	7220	4180						
1911	12331	12331	12331	12331	12203	12217	12008	11590	11077	9918	8360
12	11742	10659	8569	6498	4180	1672					
13	11331	10368	8957	6270	3553						
14	11552	10563	6873	6270	3553	931					
15	12103	12103	12103	12008	5510	5510	4959	1900	1083		
16	11780	11780	11780	9880	7600	5985	4180	2280	285		
17	11685	11020	8170	475							
18	11709	11790	11799	11704	11704	11590	11495	11260	10063	7042	7106
19	11780	11780	11780	11780	8170	7410	7030	6840	6650		
1920	11405	11495	11493	11172	10650	9918	7315	2304	1767	1254	418
21	11685	11020	9690	6460	4750	4275	2850	2185			
22	12160	12160	6460	6225	4560						
23	11590	10830	1140	95							
24	11894	11604	11804	9890	7980	7030	6305	5605	4180	570	
25	11381	11381	11381	11286	10868	9614	4508	513			
26	12008	12008	12008	12008	11913	11790	11495	11172	10754	10336	9614
27	11951	11951	11951	11951	10146	7771	4863	1805			
28	11837	11837	6460	5225	4750	4370	3895	3420	2660		

M-II—3 days.

during the most severe storms of each year.

12″	13″	14″	15″	16″	17″	18″	19″	20″	21″	22″	Year.
											1891
3287	2945	2755	2565	2318	1900	1672					92
											93
											94
950											95
											96
											97
											98
											99
											1900
											01
											02
											03
											04
											05
											06
											07
											08
											09
7201	5434	4180	2717								1910
											12
											13
											14
											15
											16
											17
6479	6479	6156	5852	5016	3648	1970	1349	1140	1045	931	18
											19
418	418	418	304	209							1920
											21
											22
											23
											24
											25
8987	8151	6092	5852	4275	2000						26
											27
											28

Table 97.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"
1891	14155	14155	14098	13908	12958	11381	10450	10032
92	13813	13167	12008	10450	9196	8151	7106	6156
93	13870	11020	6080	8135	95			
94	13889	13889	13376	12426	10868	836		
95	13305	11210	10640	9785	9310	8835	2280	
96	13889	13794	13080	10868	8762			
97	13756	11742	7828	4693				
98	13775	3900	3230	2565				
99	13300	13300	13300	13300	13300			
1900	..	13680	4180	1900	1140	760	880	
01	13642	13585	13262	11077	8151			
02	13832	13832	13281	11020	7581	3166		
03	13823	11286	6574	513				
04	12823	11400	8170	6060	3705	1000		
05	13889	13585	12640	9405	6320	4180	3439	2926
06	13471	9709	2147					
07	14136	11400	6840	4370	3420	2660	1995	
08	14022	7790						
09	13908	11400	6840					
1911	11704	9196	6807	4902	3344	2289	1254	
12	13927	13927	12331	9291				
13	13338	13338	13338	11172	6897	4484	2020	1672
14	13034	13034	12540	11381	10241	9201	8360	7524
15	13908	13908	13908	13908	13908	4522	1900	1254
16	13870	13870	11210	8360	2660			
17	13414	13414	13414	11875	8730			
18	13851	12730	10450	8455	5985	4750	3610	2850
19	14022	14022	12160	8170				
1920	13680	13680	13680	12844	11704	10336	8303	7106
21	13680	11780	9975	8075				
22	13680	13680	13680	10127	6270	3439		
23	13965	13965	13110	12160	11020	9500	7885	
24	..	11305	8455	6270	4560	3040	1900	
25	13585	13585	13585	8550	3553	1140	627	418
26	13870	13870	13870	13870	11970	8835	6935	5700
27	13813	12274	8664	6232	4066	1805	456	
28	13965	12730	10545	9310	8170	6650	4940	3325

M-III—3 days.

during the most severe storms of each year.

9"	10"	11"	12"	13"	14"	15"	16"	17"	18"	Year.
										1891
5111	4275	3439	2717	2185	1672	1254	931	627	418	92
										93
										94
										95
										96
										97
										98
										99
										1900
										01
										02
										03
										04
2603	2394	1976	1672	1235	1045					05
										06
										07
										08
										09
										1911
										12
304										13
6574	5738	4507	3971	3439	2508	1881	1249	836	418	14
893	627									15
										16
										17
2185	1710	1235	760	285						18
										19
5947	4598	3639	2394							1920
										21
										22
										23
										24
304	95									25
4655	3610	2470	1330	285						26
										27
										28

Table 98.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"
1891	6289	6289	6289	6289	6289	5035	2508	95	
92	6213	6213	3249	2945	2717	2622	2280	2090	1672
93	6270	6270	4180						
94	6213	6213	4921	3762	3249	3044			
95	6213	6213	6175	3800	1615				
96	6042	6042	6042	5415					
97	6232	6042							
98	6156	4040							
99	6308	6308	6308	6308	6308				
1900	5985	5985	5985	5890	5795	5605	5320	4085	3420
01	5225	3344	1140						
02	6403	6403	6403						
03	5700	5643	4180	3344					
04	6137	5225	2204						
05	6270	1425							
06	6004	6004	6004	4674	4180	3971	1577		
07	6270	6270	6270	6270	5510	5415	5415		
08	6270	5985	5700						
09	6270	6270	5434	3344	95				
1911	6175	6175	6175	6175	6175	6050	5985	5320	4465
12	6270	3876	1463						
13	6080	6080	6080	6080	3553	1672	1254	1045	760
14	6289	6289	2717	1577	836	380			
15	6403	6403	6403	6403	5966	5605			
16	6080	6080	5890	4845					
17	6270	4275	2470	1615	1140	855			
18	6251	6251	6251	6251	6251	6251	6251	5890	5415
19	6213	6213	6213	4085	3800	3705	3610		
1920	6080	6080	6080	6080	5852	5320	4503	3553	2508
21	6175	4370	3800	3420					
22	6156	6156	5510	4180	2850				
23	5985								
24	6175	6175	6175	6175	6175	5795	5320	4655	3553
25	6156	6156	6156	6156	6156	5130	3458	3135	3040
26	6289	6289	6289	5795	5320	5130	4940	4750	3420
27	6270	6270	3515	1995	1444	988			
28	6175	6175	6175	6175	6080	5605			

M-IV—3 days.

during the most severe storms of each year.

10"	11"	12"	13"	14"	15"	16"	17"	18"	19"	20"	Year.
											1891
1349	1045	627	823								92
											93
											94
											95
											96
											97
											98
											99
											1900
											01
											02
											03
											04
											05
											06
											07
											08
											09
3705	2945	2185									1911
											12
627											13
											14
											15
											16
											17
6320	5225	5225	4845	4085	3515	2660	1900	1330	855	570	18
											19
836	418	418	380	380	380	380					1920
											21
											22
											23
2375											24
											25
1900											26
											27
											28

Table 39.

Areas in square miles under different intensities of rainfall

Year.	1″	2″	3″	4″	5″	6″
1891	11077	10982	10982	10982	10868	10032
92	11153	10868	10146	9405	8778	7847
93	11115	10830	9975	8360	5415	
94	10545	9120	8550	7980	6460	4085
95	10830	9880	5605	8325		
96	10868	10868	10868	5434	5130	4807
97	11115	10735	9310	7790	6080	3990
98	8360	3230				
99	10925	10925				
1900	9595	7220	5605	4370	3895	3420
01	10659	9823	6802	3971	3040	2717
02	10070	7505	5225	3420	2470	1995
03	10925	10925	9937	7942	4807	437
04	5985					
05	10925	7600	5225			
06	10735	10735	10241	6384	2926	
07	9880	7600	5700	4180	3420	3325
08	10944	7410	4560	2280	1235	855
09	10830	7505	4370	1995	760	
1911	10640	9405	7125	4560	3420	3135
12	10982	8360	5035			
13	10716	10760	10697	8569	6802	6650
14	10735	10735	8151	3225	1786	
15	11115	11115	9785	6555	3895	190
16	10849	9880	8170	6365	4370	
17	11020	10735	9785	8550	7030	5415
18	10545	10545	10545	10545	8265	5890
19	11210	11020	9785	7410	4710	4750
1920	10716	10716	10659	10032	8778	7030
21	11210	6270	3895			
22	10260	7980				
23	9785	8930	8740	8265	7505	6680
24	11001	11001	10450	9310	7980	6565
25	10697	10697	10165	9880	8474	7011
26	11210	11210	11210	9500	7790	6127
27	11058	9310	5870	2945	1140	475
28	11153	11153	9975	7600		

M-V—3 days.

during the most severe storms of each year.

7"	8"	9"	10"	11"	Year.
7638	3762	2204	1672	1330	1891
7011					92
					93
1140					94
					95
					96
1805					97
					98
					99
2945	2375	1810			1900
2413	2000				01
1710	1425	1140	855	570	02
					03
					04
					05
					06
3325					07
					08
					09
2850					1911
					12
6384	5389	3135	209		13
					14
					15
					16
					17
3610					18
2660	570				19
4807	2831	1672	950		1920
					21
					22
5605	4560	3010	1330		23
5035	3610	2375			24
5434					25
4370					26
265					27
					28

Table 100

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"
1891	6175	6175	4237	2717	1881	1140	760			
92	6574	6574	5130	4180	3135	2375	1805	1425	1197	1007
93	6460	6460	4940	3477						
94	6156	6156	5700	5244	4009	2717	1710	1045	513	
95	6460	6460	6460	6460	6460	6460	6042	5624	5187	
96	6308	6308	5282	4275	3515	2280				
97	6175	5643	4712	3781						
98	6080	6080	4997	3553	3078	2926	2850			
99	6080	4883	3135	1140						
1900	6460	6460	5690	4636	3515	2717	2000	1577		
01	4275									
02	6175	6175	4180							
03	6460	6460	4275	3743						
04	6365	6365	6365	5035	4465	4009	3477	3002	2622	2356
05	6327	6327								
06	6232	6232	6232	6232	4180	2185				
07	5985	5605	4845	3648						
08	6536	6536	5016	3230	1368					
09	5966	2147	950							
1911	5130	3800	3192	2736	2337	1976	1634	1349	1121	931
12	6213	6213	3268	2014	1311	912	665			
13	6384	5662	5064	4522	3033	3382	2793	2052	1235	
14	6422	6422	5520	3990	2850	1843	1292	950		
15	6422	6422	6422	4522	3534	2755	2185			
16	6099	6099	6099	3762	418					
17	6365	6365	5263	3990	2432					
18	6137	6137	5510	4427	3990	3420	2983	2622	2261	1938
19	6080	6080	5605	5073	4465	3667	2717	1482		
1920	6270	6270	6270	6270	5700	4370	3249	2508	1957	1558
21	6403	4275	2850	1995	1425	1045				
22	6080	5757	5035							
23	6251	5377	4464							
24	6061	6061	5548	5225	4712					
25	6365	6365	6365	6365	6365	5800	5415	4769	4028	3249
26	6175	6175	6175	6175	6175	6175	6175	6080	5985	5800
27	6175	6175	6175	5415	4769	4180	2907	2090	1615	912
28	6460	6460	6460	5719	4940	4180	3382	2736	2242	1805

M-I—4 days.

during the most severe storms of each year.

11"	12"	13"	14"	15"	16"	17"	18"	19"	20"	21"	22"	Year
												1891
817	703	570	475	380	247	190						92
												93
												94
												95
												96
												97
												98
												99
												1900
												01
												02
												03
2109	1919	1786	1672									04
												05
												06
												07
												08
												09
779	605	570	494	466								1911
												12
												13
												14
												15
												16
												17
1672	1425	1107	1007	779	627	532	418	342	323			18
												19
1159	855	684										1920
												21
												22
												23
												24
2432	1767	1235	1026									25
6472	4940	3895	3135	2679	2223	2071	1900	1729	1463	1254	1007	26
												27
												28

Table 101.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"
1891	11419	11419	11419	11381	8360					
92	11709	10830	9025	7600	6270	5415	4655	4275	3895	3515
93	12027	11085	11115	10545	9880					
94	11476	11476	11470	10963	9918	8360	6365	3553	1349	
95	12027	12027	12027	12027	8360	5700	4275	3325	2660	218
96	11495	11495	11495	11405	11495	11495				
97	11476	11476	11476	11172	9405	6270	2812			
98	11913	11115	9500	7880	6365	4750				
99	12065	12065	11875	11780						
1900	12255	12255	12255	5985	5605	5605	5605	5605	5510	
01	10808	8987	6897	5016	2717	144				
02	11571	11571	11571	10108	9310	4693	1976			
03	12065	12065	10640	8075	5510	2755	190			
04	11875	11875	11875	11875	11875	11495	9405	5510	3040	2090
05	11970	11070	7410	2755						
06	11405	6330	7010	7410	7410	7315	7201			
07	11381	11381	11381	11381	11286	10808	9614	7942	6270	4484
08	11070	11070	11590	10735	8740	7600				
09	11590	10963	9709	8151	6479	5111	3553			
1911	11780	11780	11780	11780	11780	11780	11405	10640	7790	6270
12	11647	11405	9018	7942	5852	4066	2603	1140	209	
13	11836	10925	9975	9405	8740	7980	6555	4180	1710	
14	11552	11077	9823	7820	4275	931				
15	11875	11875	11875	11875	10925	8030	7030	5320	3805	2660
16	11495	11405	11405	1463	513	418	418	304	304	304
17	11837	10830	9025	7220	5225					
18	12160	12160	12160	11970	11875	11685	11405	11400	11305	11020
19	11495	11495	11495	11405	11403	10450	8030	7610	6156	4693
1920	11085	11685	11085	11085	9310	7220	5005	4180	3230	2565
21	11875	11875	11875	11115	1616					
22	11495	11172	10545	4066	3762	3553				
23	11590	7733								
24	11590	11590	11600	11590	10868	10241	9082	7315	4807	2603
25	11970	11970	11970	11780	11305	10640	9595	8075	4940	1140
26	11780	11780	11780	11780	11780	11780	11210	10735	10355	9975
27	12160	12160	12160	8740	8455					
28	12008	12008	11970	11305	7600	1900	1330	1140	950	855

M-II—4 days.

during the most severe storms of each year.

11"	12"	13"	14"	15"	16"	17"	18"	19"	20"	21"	22"	23"	Year.
													1891
3230	2850	2470	2185	1805	1615	1330	1045	855	570				92
													93
													94
1710	1425												95
													96
													97
													98
													99
													1900
													01
													02
													03
1520	1140												04
													05
													06
													07
													08
													09
5225	4560	4085	3705	3515	3325								1911
													12
													13
													14
1520	605												15
304	209												16
													17
10185	8075	6715	5985	5320	4750	4275	3705	3230	2650	2090	605		18
3230	1881	418											19
2185	1620	1140	760	380	100								1920
													21
													22
													23
													24
475	380	190	190										25
9600	9405	8740	7980	6270	4275	2090							26
													27
665	570	475	285										28

Table 102.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"
1891	13680	13376	12958	12331	11495	10545	9196	7790	6365	4807
92	13718	13718	13452	12730	11913	11020	10013			
93	3851	13851	12635	7581	6954					
94	13262	13262	13202	12844	11913	10450	8569	6061	2603	
95	13547	13091	12179	11381	10460	0823	8930	7410	2527	
96	13471	13471	13471	13262	12540	11590	9500	7106	4807	2290
97	13202	13202	8509	5111	3135	1558				
98	13775	4370	2600	2470	2470	2470	2375			
99	13528	13528	8132	3078						
1900	13718	13718	8227							
01	13585	13262	12740							
02	13080	13080	11709							
03	13905	13965	13905	9785	5700					
04	12633	10545	8087	6897	4693	1463				
05	13338	13338	13205	12635	11780	10830	0215	7605	6270	5130
06	12331	9614	6897							
07	11381	8455	6479	5018	3553					
08	13813	11438	8604	2888	1539	1083				
09	13585	12331	11077							
1911	9785	8300	7600	6935						
12	..	13471	10659	9018	8604	6688	4180	1463		
13	13946	13946	13946	13870	13300	12665	9075	7695	5415	3040
14	13300	13300	13300	13110	13015	12350	11210	9500	7410	6080
15	13414	13414	13414	13414	13357	10735	8037	4769	2527	
16	..	13471	12331	11704	11280	10659	9092	7410	5434	3857
17	13963	13965	13965	13966	13905	11115	7686	5035		
18	13565	13585	12217	10450	8360	6574	4902	4066	3230	2508
19	8930	0555	253							
1920	..	13452	13357	13202	12096	12103	10640	9025	6954	5605
21	12033	11700	11172	10241	6897					
22	13585	12958	11913	10450	8300	5643	2508			
23	..	13471	13167	13053	12058	12749	12426	11700	10963	10032
24	13471	13471	13471	10868	8151	5738	3021			
25	13566	13566	13566	9576	2356	1178	817	722	551	456
26	13490	13490	13452	12096	11020	8664	3344	2356	1805	1539
27	..	11647	9037	8398	6859					
28	..	13452	12274	10923	8604	6403	4332	2888	1710	722

M-III—4 days.

during the most severe storms of each year.

11″	12″	13″	14″	15″	16″	17″	18″	10″	20″	21″	22″	23″	24″	Year.
3344														1891
														92
														93
														94
														95
														96
														97
														98
														99
														1900
														01
														02
														03
														04
4085	3040	1805												05
														06
														07
														08
														09
														1911
														12
														13
														14
4560	3800	2945	2660	2375	2090	1900	1710	1520	1330	1140	855	665	475	15
2090	304													16
														17
1881	1340													18
														19
4617	3781	3240	2717	2661	1639	651								1920
														21
														22
8987	8037	6897	5434	3762										23
														24
361														25
988	551													26
														27
														28

Table 103.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"
1891	6061	6061	6061	6061	6061	6061				
92	6270	6270	4370	3325	2850	2565	2280			
93	6061	6061	6061	5700	4940	4845	3515	2850	2090	
94	6023	6023	4085							
95	6270	6270	6270	6270						
96	6023	6023	6023	6023	5472					
97	6137	6137	5510	5054						
98	6175	5605	4655	3800	3515					
99	6270	6270	5985	4940	1330					
1900	5985	5985	5985	5985	5890	5795	5795	5700	5415	4845
01	6061									
02	6137	6137								
03	6289	6289	5149	2888						
04	6346	6346	6346							
05	6270	6270								
06	6023	6023	5947	5947	5852	5852				
07	6127	6127	6127	6127	6127	6127	5643	4503	3249	2413
08	6441	5705	5415	5320						
09	5928	5928	5852	4921	3971	2926	1995	1045	19	
1911	6270	6270	6270	6175	6080					
12	6061	4503	3040	1577						
13	6080	6080	6080	6080	5035	4160	3230	2185	1045	
14	6403	3610								
15	6270	6270	6270	6175	6080					
16	5966	5966	5966	5434	3135					
17	6175	6175	6175	3135	1520	760	475			
18	5966	5966	5966	5966	5966	5966	5966	5966	5966	5757
19	6061	6061	5966	5966	5757	5016	4085	2926		
1920	6365	6365	6365	6365	6365	5510	4085	3135	2660	2185
21	6270	6270	6270	1235	1140	1045	950	760	570	95
22	6042	6042	6042	5434	4085	2831				
23	5947	5947	5947							
24	6061	6061	6061	6061	6061	6061	6061	5225	4503	3667
25	6270	6270	6270	6270	6270	6175	6080	5985	5700	3515
26	6175	6175	6175	5985	5890	5700	5415	4560	2945	
27	6175	6175	6175	6175	6080	5890	5795			
28	6365	5510	4655	3800	3420	3325				

M-IV—4 days.

during the most severe storms of each year.

11"	12"	13"	14"	15"	16"	17"	18"	19"	20"	21"	22"	23"	Year.
													1891
													92
													93
													94
													95
													96
													97
													98
													99
3325	380												1900
													01
													02
													03
													04
													05
													06
1368													07
													03
													09
													1911
													12
													13
													14
													15
													16
													17
5339	4807	4294	3067	2717	2090	1672	1463	1253	1045	836	418		18
													19
1805													1920
													21
													22
													23
2926													24
													25
													26
													27
													28

Table 104.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"
1891	10773	10773	10773	10773	10773	10773	10659	9690
92	11020	11020	10450	9595	8645	7600		
93	11020	11020	11020	11020	10735	10070	9272	7752
94	10697	10697	10697	9823	8151	8379		
95	11020	11020	8588	6287				
96	10716	10716	10032	8683	7315			
97	10773	10773	9728	8292	8569	8474	8056	7220
98	8360	4750	3515	3135	2850	2755	2470	2185
99	11020	10830	10089	7410	399			
1900	11077	11077	8512	5472	4446	4066	3610	3154
01	10773	10773	9106	5434	2508	1672	1254	950
02	10640	10032	7942	1881				
03	11020	11020	9690	6360				
04	11020							
05	11096	11096	9825	6850	3900			
06	11020	9690	9310	6270				
07	10241	7220	6139	5225	5130			
08	10830	10830	6270	3325	1886	1330		
09	10754	10032	7847	3344	2413			
1911	10735	9785	8550	7220	5890	4750	3610	2755
12	10640	7942	5130					
13	10982	10982	10982	10640	9690	8550	7410	5700
14	11077	11020	8987	5491	1843	361		
15	11153	11153	10260	5510	4085	2565		
16	10773	9785	8892	6175				
17	11020	10925	10640	9690	7980	5700	2945	
18	10868	10868	10868	10830	10450	9405	8430	7106
19	11020	9075	7410					
1920	10906	10906	10640	10165	9690	8930	7885	6460
21	10530	9785	7790	4055	190			
22	10659	9519	6056	6061	3071	1767	95	
23	10659	7524	4180	3040	2622	2299	2000	1881
24	10754	10754	9823	8569	7638	6479		
25	11020	11020	10925	10450	9405	7600	5225	2850
26	11039	11039	10735	9823	8341	6479	4066	2128
27	9680	8778	7600	5415	3040	1520		
1928	10773	10773	10545	10260	8360	5700	2470	

M-V—4 days.

during the most severe storms of each year.

9"	10"	11"	12"	13"	14"	15"	Year.
9037	8474	6061	2717				1891
							92
							93
							94
							95
							96
6270	5130	3876	2508	1254			97
							98
							99
2584	2033	1482	779				1900
741	532	323					01
							02
							03
							04
							05
							06
							07
							08
							09
							1911
							12
3705	1710						13
							14
							15
							16
							17
5757	4503	3344	2204	1254	532	209	18
							19
4750	2850	950					1920
							21
							22
1577	1254	836	418				23
							24
1425	950	665					25
							26
							27
							28

Table 105.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"
1891	6080	6080	5130							
92	6460	6460	5225	4370	3401	2812	2375	1976	1330	1064
93	6251	6251	5605	3990	3686	3154	2071			
94	6403	6403	5035	3990	3382	2584	1756			
95	6156	6156	6156	6156	6156	6156	5463	5320		
96	6327	6327	6327	4579	2793					
97	6422	6422	5795	5643	4275					
98	6346	6346	5282	4180	3477	3344	3154	2660	1710	
99	5985	5700	4807							
1900	6308	6308	6308	2850	2413	2128	1558	1349	893	
01	5263	3667								
02	6327	6327	6327	6327						
03	6498	6498	4750	3040	1330					
05	6441	6441	4100	1967						
06	6251	6251	5947	5172	4826	4142				
07	5985	5985	5434	4256						
08	6384	6384	6384	3553	1178					
09	6194									
1911	6517	4160	3648	3325	3040	2430	2223	1710	1387	1064
12	5852	5035	4370	3762	3097	2508	1843	1235		
13	6194	6194	6194	5149	4237	3534	2983	2660	2033	1710
14	6384	6384	5795	4579	3382	2185				
15	6365	6365	5700	4405	3173	1967	1159	760	570	475
16	6270	6270	5605	4218						
17	6270	6270	5130	3136	1520	969				
18	6403	6251	5833	5263	4370	3477	2793	1900	1159	703
1920	6175	6175	6175	6175	5225	3477	2698	1900	1387	963
21	6460	4750	2660	1862	1235					
22	6213	6213	1938	1406						
23	6403	5795	4056							
24	6156	6156	6137	5548	4940	4332	3762			
25	6000									
26	6251	6251	6251	6251	6251	6213	6194	6156	6023	5852
27	6356	6356	5833	5111	3990	2337	1273	950	798	703
1928	6460	6460	6460	6289	5814	5472	3805	3572	1900	1501

M-I—5 days.

during the most severe storms of each year.

11″	12″	13″	11″	15″	16″	17″	18″	19″	20″	21″	22″	Year.
												1891
												92
												93
												94
												95
												96
												97
												98
												99
												1900
												01
												02
												03
												05
												06
												07
												08
												09
931	817	722	570	475	380	285						1911
												12
1349	855	247										13
												14
437												15
												16
												17
437												19
855												1920
												21
												22
												23
												24
												25
5700	5472	5149	4693	4123	3477	2717	2090	1558	1330	1083	950	26
608	475	285										27
1273	1083											28

Table 106.

Areas in square miles under different intensities of rainfall

Year	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"
1891	11400	11400	11400	11400	11400					
92	11400	11400	9595	8075	6745	5700	4845	4085	3420	2850
93	11590	11590	11590	11590	11172	10754				
94	11590	11590	11590	9690	8170	6150	5130	4085	1900	760
95	11628	11628	11628	9690	8745	5700	4565	3610	3040	2375
96	11799	11799	11799	11799	10640	9120	8265	7885	7600	7600
97	11685	11685	11685	11685	11400	11210				
98	11875	11875	11590	11210	10735	10070	9215	7600	4845	1995
99	11495	11495	11286	10963						
1900	11495	11495	11495	9082	8873	8664	8037	7106	6061	4807
01	9918	7201	5320	3648	1976	95				
02	11666	11666	11060	9576	5320	1178				
03	12065	12065	12065							
05	11913	10032	6479	3135						
06	11438	10241	8341	6783	5852	5016	4389	3857		
07	11381	11381	11381	11020	10450	9082	8151	7828	7619	7410
08	11685	11685	11685	11685	11685	11500	11305	9595	1520	
09	11495	9614	7201	5738	5016	4864	2717			
1911	11780	11780	11780	11780	11780	11685	11590	11495	11115	4370
12	12008	12008	12008	10830	8740	6555	4370	2185		
13	11381	10868	9823	8569	7106	5643	3857	2090	1045	
14	11970	11970	11970	5320	3040	2280	1995	1805	1520	1235
15	11709	11799	11709	11709	4560	4275	4275	4180	3895	2660
16	11913	11913	11913	3610	1007	798	722	627	627	551
17	11286	11286	9082	6897	4598					
19	12027	12027	12027	12027	11685	10830	9880	6650	3515	2660
1920	11381	11381	11381	11172	10659	8645	1072	626	418	304
21	12065	12065	9025	6460	4560	3230	2375	1615	950	
22	11286	8360	8037	6061	4068	3648				
23	11267	8778	5016	3135	1881					
24	11704	11704	11704	11077	9709	8455	7106	5947	4902	
25	11571	11571	11571	11571	11571	11495	11305	10640	8835	6080
26	11286	11286	11286	11286	11286	11077	10754	10127	9500	9196
27	11685	11085	11685	11085	11085	7885	5320	2850	285	
1928	12160	12160	12160	12160	9785	6080	4370	3705	3325	2470

M-II—5 days.

during the most severe storms of each year.

11″	12″	13″	14″	15″	16″	17″	18″	19″	20″	21″	22″	Year.
												1891
2375	1995	1900	1710	1520	1425	1235	1140	950	760			92
												93
												94
1900												95
7505												96
												97
												98
												99
3135	418											1900
												01
												02
												03
												05
												06
6270	1558											07
												08
												09
3040	2470	1995	1710	1330	1045							1911
												12
												13
												14
1140												15
456	456	361										16
												17
2090	1900											19
304	200											1920
												21
												22
												23
8420	1520											24
8987	8987	8664	8151	6688	4598	2185	1140	627	513			25
												26
1235												27
												28

Table 107.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
1891	13167	13167	12958	12664	12331	11013	11210	10659	9937	8987	8056
92	13623	13623	13623	13623	13623	13547	12198	10735	9215	7771	6688
93	13718	13718	13718	11913	8132	4408	912				
94	13642	13642	13642	13642	13642	13642	5871	2451	1368		
95	13357	13357	13357	13357	13357	11742	9842	7030	722		
96	13908	13395	12445	11400	10450						
97	13623	13623	11400	8360	4940	1330					
98	13965	5510	3800	3040	2280	1710	1330	855	475	95	
99	13452	13452	10982	6270							
00	13433	13433	9728	3344	1881	1045	741	532	323		
01	13319	13319	12977	12064	12122						
02	13832	13832	13091	9215	4603						
03	13623	12445	10013	7676	5035						
04											
05	13965	13908	13794	13699	13585	13376					
06	13338	12445	10450	8056	4598						
07	13319	11818	8569	7942	3762	2413	1463				
08	13718	13718	9937	5833							
09	13547	13547	11286	6802	2204						
11	13547	12540	10830	6320	3244	2451	1805	1178	722		
12	13300	13110	12635	11400	7030	760					
13	13623	13623	13623	13623	13490	12749	10868	7011			
14	13813	13813	13718	13623	13357	12008	8227	7125	6498	6061	5605
15	13642	13452	13167	12996	12274	11286	9386	7220	3971		
16	13490	13490	12996	12274	11457	10298	9025	7581	5966	3800	722
17	13585	13585	13585	13585	13585	11286	9101	7011			
18											
19	13718	13433	12635	11742	10460	8303	5415	2090			
1920											
21	13433	12464	11286	9918	7600						
22	13490	13490	12749	10868	7042	5434					
23	13490	13490	13490	13490	13376	13281	12692	10659	6479	6239	4598
24	13585	13585	13585	10450	7315	4180	2090.	1045	418		
25											
26	13585	13585	13585	13490	12958	11704	3135	1005	1577	1308	1159
27	13452	13452	12996	12103	10108	7220	4256	2166	1083	190	
28	13965	13965	13110	11875	10735	8455	5700	3705	1425		

M-III—5 days.

during the most severe storms of each year.

12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	Year.
6897													1891
5510	4427	3420	2350	1634	1178	912	722	551	361				92
													93
													94
													95
													96
													97
													98
													99
													1900
													01
													02
													03
													04
													05
													06
													07
													08
													09
													1911
													12
													13
5244	4883	4427	4066	3610	3154	2889	2356	2014	1634	1273	912	456	14
													15
													16
													17
													18
													19
													1920
													21
3702	3136	2508	1995										22
													23
													24
													25
950	741												26
													27
													28

Table 108.

Areas in square miles under different intensities of rainfall

Year	1"	2"	3"	4"	5"	6"	7"	8"	9"
1891	6061	6061	6061	6061	6061	6061			
92	6422	6422	6005	4040	4180	3420			
93	6137	6137	6137	6137	6137	6137	5759	4921	4085
94	6365	6365	6365	5605	4040	4180			
95	6270	6270	6270	6270	6270				
96	6270	6270	6270	6270					
97	6327	6327	5800	4940	3900	3040			
98	6118	6118	5800	5700	5415				
99	6061	6061	6061	5757	5434				
1900	6080	6080	6080	6080	5985	5800	5705	5605	5415
01	6175	6175							
02	6365	6365	6365						
03	6308	6308	6130	2060					
04	6232	6232	5871	5244	1368	532	190		
05	6175	6175	5434	4180					
06	5928	5928	5928	5928	2926				
07	5965	5965	5965	5965	5965	4712	4204	4085	3702
08	6384	6384	5890	4940	3990				
09	5956	5956	5956	5671	5225				
1911	6232	6232	6232	6232	6232	6137	6042	5871	5225
12	6270	6270	6270						
13	6061	6061	6004	5130	4921	3553	2299	1995	
14	6175	6175	6175	3230	1425	475	285		
15	6289	6289	6289	6289	6289	6560			
16	6270	6270	6270	5510	3895				
17	6175	6175	6175	3971	1572				
18	6270	6270	6270	6270	6270	4180	4095	3990	3240
19									
1920	6080	5130	3135	1160					
21	6061	6061	5966	5434	3667				
22	6061	6004	6061	5076	5225	4389	3344	2185	950
23	6061	3040							
24	5966	5966	5966	5966	5966	5852	5757	5339	4598
25	6365	6365	6365	6365	6365	6365	6365	6365	6365
26	5928	5928	5757	5434	5339	5225	4921	4204	2926
27	6365	6365	5415	5225	4465	3135	1045		
28	6175	6080	6085	5985	5795	5700	5415	4370	2850

M-IV—5 days.

During the most severe storms of each year.

10"	11"	12"	13"	14"	15"	16"	17"	18"	19"	Year.
										1891
										92
3249	2413	1672								93
										94
										95
										96
										97
										98
										99
4845	2470	2185	2090							1900
										01
										02
										03
										04
										05
										06
3553	3040	930								07
										08
										09
4515	2166	1273	817	722						1911
										12
										13
										14
										15
										16
										17
										18
										19
1710										1920
										21
										22
										23
3458	2185									24
6365	6365	6365	6365	6080	5605	4940	4085	3135	2185	25
										26
										27
1140										28

Table 109.

Areas in square miles under different intensities of rainfall

Year.	1"	2"	3"	4"	5"	6"	7"	8"	9"
1891	10564	10564	10564	10564	10355	10032	9728	9196	7315
92	11020	11020	11020	10735	10070	8835	6935	5130	3420
93	10640	10640	10640	10640	10450	10032	8892	7106	5016.
94	11020	11020	10735	10184	9728	9253	1038		
95	10982	10982	10982	10982					
96	10982	10982	10982	10982	10982				
97	11096	11096	10925	7125	6069	6289	5833	5187	4541
98	11020	8075	5700	3800	2660	2090	1900	1710	1425
99	10659	10659	10659	6479	2508				
1900	10716	10716	9823	7847	6270	4921	4294	3762	3125
01	10659	10659	9102	7733	6175	4712	3249	1786	
02	11020	10830	9120	6840	4560	3040	2280	1710	1235
03	11020	11020	7410	6764					
04	9614	8151	1577						
05	10773	10773	8265						
06	10659	10659	10659	6384					
07	10754	8240	5778	7011	4598	2413	741		
08	11020	11020	9025	2907	1577	1102	836	551	285
09	10716	8398	1995	1672	1463				
1911	11020	9550	9120	7220	5320	3895	3040	2660	
12	11096	10925	9619	6745					
13	10754	10754	10754	10754	8892	7106	5225	3463	1672
14	11115	11115	11115	1038	1102	931	836	836	
15	10982	10982	10450	9310	6897	4085	665		
16	11096	10925	9690	7885	5510	3135			
17	10659	10659	10564	10146	8569	5339	2299	1254	950
18									
19	10659	9937	8360	6802					
1920	10659	8360	6061	3762					
21	11115	10184	6764	1862	190				
22	10659	9519	7038	5548	3458	1463	418		
23	10659	10032	8151	5643	2299	1140	836	627	532
24	10811	10811	10450	9519	8265	6503	4807	2996	950
25	11210	11210	11210	11210	11020	10735	10260	9690	9025
26	10659	10659	10659	7733	6384	4180	1463		
27	11210	9785	6935	4465					
28	11020	11020	11020	9538	8246				

M-V—5 days.

during the most severe storms of each year.

10"	11"	12"	13"	14"	15"	16"	17"	18"	19"	Year.
5226	3553	2204								1891
1000	700									92
2831										93
										94
										95
										96
3800	3059	2223	1387	551						97
1235	950									98
										99
2622	2090	1672								1900
										01
665	190									02
										03
										04
										05
										06
										07
										08
										09
										1910
										12
										13
										14
										15
										16
741	418	209								17
										18
										19
										1920
										21
										22
532	418	418	418	323						23
										24
8265	7410	6050								25
										26
										27
										28

The data represent one maximum storm for each year. In certain years there was more than one severe storm out of which only one, the maximum, was selected. This means that in certain years there were rejected storms, which were more severe than selected storms in other years. Within this limitation the curves give a good picture of the character of the distribution of rainfall in each section.

Average Intensity—area curves.

For each section and each period we can easily form the average curve for the single-year maximum intensities of rainfall. These average values have been given in Tables 110—112.

Table 110.—Area in square miles (average values) under different intensities of rainfall (3 days).

Rainfall in inches.	M-I.	M-II.	M-III.	M-IV.	M-V.
1"	5947	11717	12931	6052	10528
2"	5292	11000	12384	5584	9213
3"	4024	9876	10262	4541	7383
4"	2814	7627	8121	3492	5489
5"	2113	5970	5463	2637	3979
6"	1913	4047	2998	2119	2738
7"	1221	3181	2020	1366	1809
8"	856	2126	1332	939	703
9"	610	1499	771	752	428
10"	382	956	623	435	135
11"	211	937	469	260	51
12"	144	739	348	228	
13"	99	633	201	150	
14"	76	553	141	122	
15"	67	467	86	106	
16"	55	319	61	84	
17"	46	207	40	51	
18"	38	99	23	36	
19"	..	36	..	23	
20"	..	30	..	15	
21"	..	29			
22"	..	25			

Table 111.—Area in square miles (average values) under different intensities of rainfall (4 days).

Rainfall in inches.	M-I.	M-II.	M-III.	M-IV.	M-V.
1"	6183	11746	12920	6172	10775
2"	5761	11354	12418	5820	9890
3"	4801	10581	10916	4980	8672
4"	3610	9534	8409	4171	6694
5"	2567	6635	6983	3029	4625
6"	1908	5386	5280	2508	3388
7"	1463	3811	4058	1822	2149
8"	1062	2761	2778	1374	1617
9"	809	2118	1853	1075	994
10"	530	1469	1245	739	741
11"	390	1079	836	500	473
12"	323	884	564	150	234
13"	268	656	403	116	182

Table 111—*concld.*

Rainfall in inches.	M-I.	M-II.	M-III.	M-IV.	M-V.
14"	192	570	292	99	15
15"	116	467	226	74	5
16"	84	382	99	57	
17"	76	207	66	46	
18"	63	129	46	40	
19"	55	110	42	34	
20"	48	93	36	28	
21"	34	57	30	23	
22"	27	27	23	11	
23"	..	..	17		
24"	..	..	13		

able 112.—Area in square miles (average values) under different intensities of rainfall (5 days).

Rainfall in inches.	M-I.	M-II.	M-III.	M-IV.	M-V.
1"	5753	11603	12116	6004	10841
2"	5383	11214	11704	5892	10304
3"	4025	10568	10803	5373	9124
4"	3431	8921	9358	4514	6908
5"	2356	7254	7613	3593	4556
6"	1708	5820	5257	2453	3091
7"	1243	4224	3393	1545	2124
8"	872	3452	2461	1362	1600
9"	663	2466	1623	1100	1096
10"	380	1663	914	773	773
11"	314	1231	726	517	524
12"	236	593	604	346	372
13"	173	369	357	258	49
14"	143	331	279	188	25
15"	124	272	228	156	
16"	105	204	143	137	
17"	82	96	118	114	
18"	57	65	103	87	
19"	42	46	84	61	
20"	36	36	68		
21"	29	..	53		
22"	27	..	34		
23"	..	..	25		
24"	..	..	11		

Limiting curves.

For each individual section we may select the maximum area under each particular inch of rainfall (irrespective of the year) and then use these values to build up a kind of observed boundary curve. Such observed maximum values for each section and each period of 3, 4, and 5 days are given in Table 113.

Table 113.—Actual boundary values for intensity distribution of rainfall in the Mahanadi Catchment.

[Areas in square miles. Rainfall in inches (total).]

Rainfall in inches.	M-I			M-II			M-III			M-IV			M-V		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
1"	6400	6400	6400	12400	12110	12110	14300	14110	14110	6600	6560	6580	11250	11250	11300
2"	6310	6400	6400	12280	12110	12110	14300	14110	14110	6600	6560	6580	11250	11250	11300
3"	6270	6400	6400	12280	12110	12110	14240	14110	13940	6600	6530	6530	11070	11110	11300
4"	6270	6400	6270	12280	11980	12110	14050	14110	13840	6600	6530	6530	11070	11110	11300
5"	6270	6400	6200	12240	11650	11740	14050	14110	13780	6600	6530	6530	10960	10860	11110
6"	6270	6400	6160	12170	11730	11640	11500	13150	13780	6600	6310	6530	10120	10800	10730
7"	6270	6120	6140	11960	11450	11550	10560	12560	13090	6600	6210	6530	7700	10740	10340
8"	6270	6020	6100	11540	11350	11450	10140	11920	10770	6020	6120	6530	5380	10740	9770
9"	5180	5930	5970	11030	11260	11070	6640	11070	10040	5530	6100	6530	3640	10020	9100
10"	4610	5840	5800	10290	10980	9160	5800	10140	9080	5440	5880	6530	1690	8540	8330
11"	4110	5420	5650	9578	10140	8950	4860	9080	8140	5340	5400	6530	1480	6110	7470
12"	3630	4900	5420	8052	9390	8950	4010	8160	6970	5340	4910	6530	..	2740	6710
13"	3180	3860	5100	8120	8820	8630	3460	6070	4930	4950	4390	6530	..	1260	6400
14"	2700	3110	4650	6970	7930	6120	2530	5470	4470	4180	3750	6210	..	540	5560
15"	2410	2660	4090	5830	6240	6060	1900	3600	4110	3590	2780	5730	..	210	3390
16"	2030	2200	3450	5000	4730	4580	1150	2110	3050	2720	2140	5050			
17"	1600	2050	2700	3630	4200	2170	630	1920	3190	1940	1710	4190			
18"	1390	1880	2070	1970	3690	1140	520	1720	2920	1300	1490	3200			
19"	..	1710	1540	1340	3220	620	..	1540	2380	870	1280	2230			
20"	..	1460	1320	1140	2830	510	..	1340	2040	580	1070				
21"	.	1240	1070	1040	2080	..	..	1150	1650	..	650				
22"	.	1000	940	920	1060	..	..	960	1200	..	430				
23"	..	..	..	..	..	..	..	670	920						
24"	..	..	..	..	..	..	..	480	460						

As the observed boundary curves are irregular in character I smoothed them by free-hand graduation and the tabulated values corresponding to these free-hand graduations have been given in Table 114. From these tables we can form some idea regarding the possibility of occurrence of different space distributions of maximum intensity of rainfall.

Table 114.—Graduated limiting curves for intensity distribution of rainfall in Mahanadi Catchment.

[Areas in square miles. Rainfall in inches.]

Rainfall in inches.	M-I			M-II			M-III			M-IV			M-V		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
1"	6400	6400	6400	12400	12400	12400	14300	14300	14300	6600	6600	6600	11250	11250	11300
2"	6400	6400	6400	12400	12400	12400	14300	14300	14300	6600	6600	6600	11250	11250	11300
3"	6400	6400	6400	12400	12400	12400	14300	14300	14300	6600	6600	6600	11250	11250	11300
4"	6400	6400	6350	12400	12100	12400	14300	14300	14300	6600	6600	6600	11250	11250	11300
5"	6400	6400	6300	12400	11980	12000	14000	14300	14300	6600	6600	6600	11000	11250	11150
6"	6400	6400	6250	12200	11800	11850	13250	13500	13700	6600	6600	6600	10100	11250	10800
7"	6400	6300	6200	11950	11600	11800	12150	12800	13000	6600	6400	6600	8000	11100	10400
8"	6270	6200	6100	11600	11500	11500	10450	12000	12000	6450	6300	6600	5650	10700	9750
9"	5720	6020	6000	11050	11300	11150	8700	11050	10800	6250	6100	6600	3700	10000	9100
10"	4960	5840	5900	10400	11000	10700	7100	10100	9450	6000	5900	6600	2250	8600	8300
11"	4200	5450	5600	9800	10450	10150	5820	9100	8200	5700	5500	6600	1500	6250	7550
12"	3650	4950	5450	9000	9600	9500	4700	8150	7050	5350	4950	6600	..	4050	6850
13"	3200	4300	5100	8150	9000	8850	3850	7000	6000	4950	4400	6500	..	2200	6400
14"	2800	3850	4650	7000	8000	5120	2800	5050	5000	4350	3800	6200	..	850	5700
15"	2410	3100	4100	6050	6820	6300	2100	4450	4250	3600	3250	5700	..	250	
16"	2050	2700	3500	5000	5400	4800	1550	3500	3700	2700	2700	5050			
17"	1700	2280	2700	3650	4200	3000	1000	2750	3300	2000	2200	4200			
18"	1400	1980	2060	2400	3800	1250	550	2150	2950	1400	1700	3300			
19"	..	1720	1600	1600	3400	800	..	1750	2450	920	1320	2200			
20"	..	1480	1300	1150	2880	600	..	1400	2050	580	1050				
21"	..	1250	1100	1040	2200	..	..	1200	1650	300	880				
22"	..	1020	960	1000	1050	..	..	900	1300	180	..				
23"	..	..	..	..	..	..	..	850	1000						
24"	..	..	..	..	..	..	..	600	750						

Limiting curves for whole Mahanadi Catchment.

In order to gain some idea regarding the distribution of maximum rainfall for the whole catchment, curves of heaviest rainfall were selected by scrutiny. For the period of 5 days it was found that the 1926 curve represented the heaviest rainfall. The areas for each section for this curve were tabulated together in Table 115, and adding the areas under 1" in each section we get the total area under 1" for the whole catchment. In the same way the area for the whole catchment under 2", 3", 4", etc., of rainfall were obtained directly. In the same way we picked up the 1918 and 1926 curves as representing the heaviest rainfall over 4 days. For a period of 3 days the curves for 1926, 1920, 1918 and 1892 were selected and charted in Table 115.

We can use this material for making an estimate of the possible maximum rainfall for the whole catchment. For 3 days, for example, we can take the bounding values of the curves (irrespective of the particular storm) to give the observed maximum rainfall. From 1″ to 12″ the 1926 curve is in the extreme position, but between 12″ and 13″ the curve for 1918 cuts the other curve and goes beyond it. We can take the observed bounding curve to be given by 1926 between 1″ and the point of intersection between 12″ and 13″, and by the 1918 curve beyond the point of intersection. These observed bounding values have been given in column (2) of Table 115. In the same way the observed boundary values for the period of 4 days and 5 days have been given in columns (3) and (4) of Table 115.

These observed boundary curves are, naturally, rather irregular in character I next tried to form a smooth limiting curve by free-hand graduation. The areas interpolated from these smooth limiting curves have been given in Table 115, column (5), for 3 days; Table 115, column (6), for 4 days; and Table 115, column (7) for 5 days. These figures represent a kind of limiting maximum values for intensities of rainfall based on the total experience of 38 years (1891—1928).

Table 115.—Limiting values of areas under different intensities of rainfall for whole Mahanadi Catchment.

[*Areas in square miles. Rainfall in inches.*]

Rainfall in inches.	Observed			Graduated		
	3 days	4 days	5 days	3 days	4 days	5 days
1″	51000	49920	48890	51000	51000	51000
2″	50930	49920	48890	51000	51000	51000
3″	50930	49510	48710	51000	51000	49000
4″	48670	47910	45290	48750	48500	46500
5″	44390	44270	43260	45000	45200	43500
6″	39210	39760	39350	40300	41700	39700
7″	34910	34540	27120	35000	38000	36500
8″	28050	31930	23130	30500	34400	33200
9″	24650	29220	20520	26500	30200	29500
10″	19060	26360	16820	22500	26500	26300
11″	16620	22950	16240	19500	23300	23500
12″	14320	18300	15790	16800	20300	20100
13″	12790	13820	14910	14300	17000	17500
14″	11210	11460	13610	12000	14700	14000
15″	10180	9240	11070	10200	12100	11200
16″	8310	7650	8270	8500	10000	8500
17″	6070	6640	4980	6500	8300	6000
18″	3390	5720	3310	4700	6500	4000
19″	2260	4940	2240	3200	5000	2500
20″	1750	4320	1890	2000	4200	1800
21″	1070	3000	1110	1000	3000	1200
22″	950	1110	970	1000	1200	1000

Average maximum Rainfall.

It will be useful to give the average total rainfall during year-maximum rain storms in the different sections of the Mahanadi catchment. These are given in Table 116. The figure within brackets gives the size of the sample in each case.

Table 116.—Average total rainfall per day during year-maximum rain storms.

Section	3 Days	4 Days	5 Days
1	2	3	4
Mahanadi I	(37) 4·2496 ± ·2818	(37) 4·8580 ± ·2914	(36) 4·8668 ± ·2921
II	(37) 5·15[illegible]5 ± ·3243	(37) 5·8110 ± ·3007	(36) 6·1071 ± ·2758
III	(37) 4·3205 ± ·2715	(37) 5·2041 ± ·2712	(36) 5·5606 ± ·2619
IV	(37) 4·713[illegible] ± ·2765	(37) 5·3367 ± ·3382	(30) 5·6778 ± ·3413
V	(37) 8·7920 ± ·1744	(37) 4·7973 ± ·2764	(36) 4·7233 ± ·2178
Whole Mahanadi Catchment	(37) 4·4910 ± ·2627	(37) 5·2351 ± ·2070	(36) 5·4361 ± ·2715

The order of the mean rainfall is the same for 3, 4, and 5 consecutive days, Section II coming highest, then Section IV, Section III and Section I, rainfall being lowest in Section V. The differences in value are, however, scarcely significant.

It will be noticed that the total rainfall in 4 days is slightly greater (by about 0·6" or 0·7" inches) than the rainfall in 3 days, but the total rainfall in 5 days does not show any appreciable increase. This indicates that heavy rainfall usually persists for 3 or 4 consecutive days but begins to fall off from the fifth day.

Total Maximum Rainfall.

Instead of the average values of the precipitation we can also calculate the total maximum rainfall from the maximum boundary curves. These figures are given in Table 117. It will be noticed that Section V has again the lowest values. Each figure in this table gives a kind of upper limit, which although not actually observed so far, is indicated by the available data. The limiting values also show the same charateristics as the mean values: heavy rainfall is not likely to continue for more than three or four consecutive days. The physical explanation is obvious. Rain-storms usually pass out of the catchment area in this time.

Table 117.—Total maximum rainfall during the year-maximum rain-storm.

Section	3 days	4 days	5 days
Mahanadi I	13·21	14·94	16·34
II	12·84	14·24	13·41
III	11·39	12·88	13·44
IV	14·34	14·76	17·46
V	8·13	11·03	12·33
Whole Mahanadi Catchment ...	9·4259	10·2662	7 3946

Absolute Maximum Rainfall.

The absolute maximum (irrespective of the year), intensities of average rainfall in inch per day for each section and for the whole catchment for 1, 2, 3......................10 consecutive days are shown in Table 118. This table contains a summary of the experience of the heaviest rainfall actually observed during the period 1891—1928, and will give some idea of the risk of maximum rainfall. It will be noticed that although there are differences among the different sections there is a good deal of agreement for the larger periods of consecutive days.

Table 118.

Section. Days.	1	2	3	4	5	6	7	8	9	10
Mahanadi I	6·91	6·57	4·20	3·41	2·77	2·30	2·02	1·83	1·72	1·69
Mahanadi II	6·04	4·59	3·28	2·78	2·26	2·09	1·99	1·71	1·54	1·45
Mahanadi III	6·01	4·76	3·77	3·06	2·60	2·30	2·26	2·16	1·98	1·80
Mahanadi IV	7·18	4·44	3·65	3·29	2·77	2·33	2·02	1·84	1·68	1·33
Mahanadi V	4·63	3·60	2·67	2·15	1·85	1·57	1·33	1·66	1·32	1·42
Whole Mahanadi Catchment ...	3·78	2·91	2·24	1·94	1·85	1·72	1·54	1·57	1·24	1·18

Maximum Intensity of Rainfall.

The maximum intensity of rainfall in each year has also an interest of its own. I have tabulated these values for the different sections and the whole Mahanadi catchment for 1 day, and for 2, 3, 4, or 5 consecutive days. The actual values with dates are given in Tables 119—124. They are shown in the form of accumulated totals in Table 125. The extreme values enclosed within brackets in the case of M-II and M-IV are of course untrustworthy as they represent merely the record at one single station each.