山地流域における降雨量の変化

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Variation in Storm Rainfall over Mountainous Basin

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We deal here with the problem how variation in average storm rainfall over mountainous basin is caused by the number of rain-gages installed in those area. Two methods——Thiessen polygon method and isohyetal method——are compared as regard to computation of average rainfall. Also examined is the relation between the point rainfall and areal-average rainfall over a drainage basin which varies with the size of the governing area when a single rain-gage is located in the basin. In these cases a single storm is taken as a unit of rainfall.

The total runoff is computed for each single storm, and the relation between areal-average rainfall and total runoff is taken into account.

Introduction

In order to obtain "precise data" on precipitation and discharge, we have chosen the greater part of the Kanna River basin (one of the upper tributaries of the Tone River shown in Fig. 1) as experimental basin and started field observations in 1948. While the first three years were spent in arranging various measuring instruments and in training of observers, and since 1951 we have been getting pretty accurate data.

In our experimental basin 30 rain-gages are located as shown in Fig. 2. For the convenience of observation, three types of self-recording rain-gages are used separately as follows: one day rain-gages along the main stream, a fortnight rain-gages in the basins along the main tributaries, and "Sugaya" rain-gages* all around the basin.

Elevation and type of each rain-gage are indicated in Table 1.

We have a gaging station at the lowest end of the experimental basin. At this station discharge is measured twice a day usually and many times during flood time.

Features of the basin

Fig. 3 shows that proportion of the length of the stream to the size of the basin is approximately defihite, as it would be guessed from the shape of the basin. The profile of the main stream is shown in Fig. 4: total length is 66 kilometers, the elevation of the headwaters 1974 meters and that of the gaging station 130 meters. The Kanna River flows into the Karasu River (a branch of the Tone River) at a point 15 kilometers below the station.

The river bed maintains nearly uniform slope of $\frac{1}{110}$ for about 50 kilometers above the station.

The area-elevation curve of the experimental basin is shown in Fig. 5.

Basic data

Rainfall may be differently determined according to the length of time of observation. And we use in this paper a single storm as the basis of study. Table 2 indicates 42 cases (with rainfall over 10 millimeters) which are selected out of the data obtained from 1951 to 1953.

Average rainfall calculated by Thiessen polygon method

Each of the Figs. 6 (1), (2), (3), (4) and (5) shows Thiessen polygon for 30, 16, 8, 4 or 2 stations respectively in the whole basin. In each case every station has its governing area shown in Table 3. Gages had been so located that they may have governing areas of approximately same size, but some fluctuation occurred especially along the border-line of the basin: (the average of area being calculated by dividing total basin area by the number of station installed in it). Then differences between the average rainfall for 16, 8 4 and 2 stations and the average rainfall for 30 stations respectively for each storm should be computed. The error is defined as the difference divided by the average rainfall for 30

* A galvanized recording rod is dipped in the solution of sulphuric acid. Each single storm is marked on the surface of rccording rod as a bite.

stations for each of 29 storms. Fig. 7 shows the relation between the average governing area and the error for these storms.

Average rainfall calculated by isohyetal method

30, 16, 8 and 4 stations are selected as are in the case of the Thiessen polygon method. Isohyetal lines are drawn for 30, 16, 8 and 4 stations and average rainfall is computed from each map. Fig. 8 (1), (2), (3) and (4) show the isohyetal maps for 30, 16, 8 and 4 stations in the case of No. 12 storm. The error means the difference divided by the average rainfall for 30 stations for each of 29 storms as it is in the Thiessen polygon method. The relation between the governing area and the error for each storm are shown in Fig. 9.

Comparing the average rainfall computed by both the Thiessen polygon method and the isohyetal methed at 30 stations, we found no greater difference that 4.5 % for 30 storms.

The envelopes for points in Fig. 7 and 9 are shown in Fig. 11. These two envelopes are very close each other and synmetry about the horizontal axis.

Represantativeness of point rainfall method

While the amount of rainfall over a drainage basin is computed by means of several rain-gages located on the basin, it may be sometimes determined, if necessary, by means of a single rain-gage directly. The foregoing two cases correspond to the former, and the present case falls to the latter.

The original basin is subdivided as illustrated by Fig. 10. For respective subdivisions the average rainfall is computed by isohyetal maps for 24 storms. In each subdivision a representative station is decided on condition that the station has sufficient data, the station lies near the center of it and the variance on the station is small. Fig. 12 shows the relation between the governing area by a single rain-gage and the error for each storm. In this case an envelope cannot be drawn, but we find the smaller is an area, the less variance exists.

Normal recession curve

Out of the numerous time-discharge curves obtained by our measuring station from 1948 to 1953, 45 recession curves for dry days are picked up. A normal recession curve as shown in Fig. 13 is obtained, by drawing these curves of the same scale for all the cases and overlapping the same portion of time-discharge curves starting from the smallest discharge. This diagram shows that features for each rain remains for a certain period then they vanish gradually until every curve coincides with a single curve named normal recession curve. The initial part of this curve is considered affected by inter flow as well as by ground water flow, but the final one by ground water flow only.

The limit of application of this curve is as follows : maximum discharge is 80 cubic meters per second, minimum discharge 2.5 cubic meters per second and duration about 60 days.

This curve is plotted on a semi-log paper and the final part of this curve is considered as a straight line, while the initial one cannot be considered so though as a whole it may be said so.

Computation of runoff

It is assumed that the time-discharge curve ABCDEF shown in Fig. 14 (1) is already obtained. If the curve AB coincides with the normal recession curve, it would continue to trace the extension of the normal recession curve BG (G lies at the infinity), supposed there is no rain after B. Total runoff due to the precipitation after B may be represented by the area GBCDEF. Also assumed is that the curve CDEF coincides with the normal recession curve after D. Drawing a line parallel to the abscissa from the point B (BI means "discharge at beginning of rise") the point E is obtained on the curve DF. It is obvious that BI = EJ. The curve BG and curve EF are parallel because they both are a portion of the normal recession curve and the starting points are of the same value. Accordingly it is evident that GBEF = IBEJ. Therefore, the total runoff GBCDEF = IBCDEJ. The total runoff caused by a single storm is to be computed by summing up the discharge over a period from the beginning of rise to the time corresponding to a point of the same ordinate on the falling discharge hydrograph.

When the falling curve due to the first precipitation is too near the next rising curve due to the second precipitation as shown in Fig. 14 (2), the point corresponding to E in the former diagram cannot be observed. If a portion of curve CDK coincides with the normal recession curve, the curve DK should be extended along the normal recession curve and the point E corresponding to the point B should be obtained on the curve KF. The total runoff caused by a single storm in this case is obtained by the same way mentioned above.

There may be some cases when curve AB or CD does not coincide with the normal recession curve exactly. Two cases are shown in Fig. 14 (3) and (4) . In such cases the total runoff is computed by assuming that point B or D passes through the normal recession curve. Then, the accurate value is estimated as more or less than the computed value by giving a symbol ↑ and ↓ to each case.

Runoff and Runoff Coefficient

Table 4 indicates the average rainfall, runoff, runoff coefficient and discharge at beginning of rise for 28 cases. From these values the relation between the average rainfall and runoff using discharge at beginning of rise as a parameter is shown in Fig. 15. When the discharge at beginning of rise increases, the straight line passing through the origin and inclining at 45 degrees to the abscissa should be a asymptote for these points. The same relation is observed between the average rainfall and runoff coefficient using the discharge at beginning of rise as a parameter. (Fig. 16)

Summary

It should be emphasized that this study is based on the limited data obtained from for a single locality. We can use either the Thiessen polygon method and the isohyetal method for the computation of average rainfall, if a rain-gage is located in every 12 square kilometers and error of 5 % is permitted.

There is little difference between Fig. 7 and 9 showing the relation between the governing area of stations and the error. If error is not permitted to be more than 10 %, a rain-gage should be located for every 25—30 square kilometers.

If a single rain-gage is located in a certain basin, the variance for the station becomes smaller by narrowing its governing area as shown in Fig. 12.

In Fig. 15 and 16 we are unable to get separate curves using the discharge at begining of rise as a parameter. It may be due partly to difficulty of field observation, and partly to an inadequate methed of computation of runoff. At any rate it may be said that there is a certain relation between them.

Table 1. Elevation and type of rain-gages

Rain-gage No.	Elevation (m)	Type
01	980	Self-recording, for one day
02	700	Self-recording, for one day
03	540	Self-recording, for one day
04	600	Self-recording, for one day
05	700	Self-recording, for one day
06	820	Self-recording, for one day
07	340	Self-recording, for one day
08	250	Self-recording, for one day
09	130	Self-recording, for one day
11	800	Self-recording, for two weeks
12	900	Self-recording, for two weeks
13	720	Self-recording, for two weeks
14	450	Self-recording, for two weeks
21	1828	Sugaya
22	1549	Sugaya
23	1700	Sugaya
24	1580	Sugaya
25	1280	Sugaya
26	1060	Sugaya
27	1460	Sugaya
28	1220	Sugaya
29	900	Sugaya
30	780	Sugaya
31	1420	Sugaya
32	970	Sugaya
33	770	Sugaya
34	716	Sugaya
35	700	Sugaya
36	650	Sugaya
41	370	Non self-recording

Table 2. (2) Data of Storm Precipitation

Storm Precipitation	Period (Rain-gage No. →)	12	03	13	27	04	28	05
1	June 15—16, 1951		54					
2	July 2, 1951		91				87	
3	July 4—5, 1951		20				36	
4	July 8—9, 1951		6					
5	July 10—17, 1951		66					
6	September 24—27, 1951		37				48	
7	September 29—30, 1951		1					
8	October 13—15, 1951		33				60	
9	May 27—28, 1952	14	14	13	21	10	15	14
10	June 2, 1952	15	13	19	14	13	21	18
11	June 8—10, 1952	24	18	26	24	16	30	23
12	June 22—25, 1952	82	81	87	94	80	90	77
13	July 2—3, 1952	26	26		33	27		28
14	July 3—4, 1952	15	25		10	31		22
15	July 4, 1952	21	22	8	18	14	25	25
16	July 9—12, 1952	44	38	40	46	46	52	43
17	July 13—15, 1952	32	42	40	33	43	42	40
18	July 17—20, 1952	27	19	17	49	26	29	19
19	August 7—8, 1952	49	25	40	60	33	30	27
20	August 31— , September 1, 1952	25	13	14	12	15	16	13
21	September 6—10, 1952	34	30	25	34	24	51	31
22	September 11—16, 1952	25	26	26	20	17	25	26
23	October 6—8, 1952	20	21	18	29	28	30	29
24	October 27—28, 1952	22	19	18		16	23	19
25	November 4—5, 1952	28	30	34		32	31	
26	May 5—6, 1953		9			7		10
27	May 7—9, 1953		22	32	27	23	33	24
28	May 23—24, 1953	55	47	50	44	47	56	49
29	June 6—8, 1953	66	54	45		48		53
30	June 10—12, 1953	17	17	18		18		21
31	July 3—4, 1953	61	58	57		54		60
32	July 7—8, 1953	20	13	18		14		16
33	July 9—11, 1953	31	26	30		27		37
34	July 16—19, 1953	34	33	35		35	33	30
35	July 20, 1953	59	75	77		76		73
36	July 20—23, 1953	49	45	42		40		42
37	September 23—25, 1953	109	100	107	107	117	120	116
38	September 29—30, 1953	18	10	7	8	7	15	12
39	September 30— , October 2, 1953	28	32	47	54	51	36	36
40	October 9, 1953	19	14	17	14	16	21	14
41	October 28, 1953	6	8	6	9	9	11	8
42	October 28—30, 1953	8	18	11	36	21	15	23

Table 2. (1) Data of Storm Precipitation

Storm Precipitation	Period			21	22	01	23	24	11	02	25	26
1	June	15−16,	1951							54		
2	July	2,	1951	83	86			68		88		
3	July	4−5,	1951	13	19			24		18		
4	July	8−9,	1951							5		
5	July	10−17,	1951	83	81			81		71		
6	September	24−27,	1951	48	42		47			41	56	
7	September	29−30,	1951							0		
8	October	13−15,	1951	26			30			30	39	41
9	May	27−28,	1952	15	9	13	20	16	15	16	20	17
10	June	2,	1952		12	11	16	15	13	11	21	23
11	June	8−10,	1952	27	24	18	13	22	17	15	36	34
12	June	22−25,	1952	87	86	81	92	90	80	79	94	96
13	July	2−3,	1952			26		27		27		30
14	July	3−4,	1952			31		33		29		39
15	July	4,	1952			6				4		18
16	July	9−12,	1952	17		51		68	37	40		47
17	July	13−15,	1952	20		41		47	35	40		42
18	July	17−20,	1952	27		29		57	22	26		27
19	August	7−8,	1952			24			15	22	27	
20	August September	31−, 1,	1952	15	29	21	21	23	23	24	30	34
21	September	6−10,	1952	27	31	33	40	32	29	30		
22	September	11−16,	1952	15	22	24	31	27	30	33		
23	October	6−8,	1952	18	19	20	23	27	11	17	52	15
24	October	27−28,	1952	14	16	16	16	19	18	20	27	
25	November	4−5,	1952	40	34	38	40	32	28	31	29	45
26	May	5−6,	1953			5				8		
27	May	7−9,	1953	21	30	23	29		21	20	35	35
28	May	23−24,	1953	42	48	46	53	61	52	49	60	56
29	June	6−8,	1953	47	59	58	69	56	60	57	83	71
30	June	10−12,	1953	8	10	11	15	17	19	18	26	29
31	July	3−4,	1953	45	57	52		68	59	59	72	77
32	July	7−8,	1953	8	11	11	15	16	15	13	27	26
33	July	9−11,	1953	39	29	21		25	21	25	44	54
34	July	16−19,	1953	31	35	41	43		33	35	42	38
35	July	20,	1953	84	75	79	83		68	76		60
36	July	20−23,	1953	38	39	42	56		50	48		60
37	September	23−25,	1953	124	99	118	117	111	110	107	123	160
38	September	29−30,	1953	15	11	12	13	17	15	12	18	18
39	September October	30−, 2,	1953	43	50	45	50	43	37	39	39	53
40	October	9,	1953	15	20	7	21	27	24	6	23	23
41	October	28,	1953	12	8	11	8	7	6	8	11	9
42	October	28−30,	1953	29	15	14	15	5	9	10	12	14

Table 2. (3) Data of Storm Precipitation

Storm Precipitation	Period			29	14	30	41	31	32	06
1	June	15−16,	1951		61		56	68	63	71
2	July	2,	1951	80	83		78	84	74	
3	July	4−5,	1951	31	24	33	28	38	34	
4	July	8−9,	1951		6		4			
5	July	10−17,	1951	78	75		95	89	84	
6	September	24−27,	1951		51		53	75		
7	September	29−30,	1951		2		1			
8	October	13−15,	1951		58		63	63		
9	May	27−28,	1952	15	10		12	15	15	13
10	June	2,	1952	21	17		22	26	23	24
11	June	8−10,	1952	39	16		24	34	26	
12	June	22−25,	1952	100	73		82	88	90	
13	July	2−3,	1952	27	37		39	60	42	54
14	July	3−4,	1952	12	27		18	24	18	29
15	July	4,	1952	12	26		27	52	51	37
16	July	9−12,	1952	30	47		44		30	
17	July	13−15,	1952	39	34		39		52	
18	July	17−20,	1952	30	22		27	34	41	31
19	August	7−8,	1952	45	25		28	35	18	20
20	August September	31−, 1,	1952	15	11	13	19	15	8	12
21	September	6−10,	1952		25		29	42	31	29
22	September	11−16,	1952		18		28	20	15	19
23	October	6−8,	1952		28	37	31	28	33	33
24	October	27−28,	1952		17	21	19	21	27	20
25	November	4−5,	1952			50	29	37	30	30
26	May	5−6,	1953				7			7
27	May	7−9,	1953	24	20	41	33			31
28	May	23−24,	1953	45	45	50	51	47	57	50
29	June	6−8,	1953	54	43	65	52	30	56	55
30	June	10−12,	1953	17	14	17	23		17	23
31	July	3−4,	1953	56	52	42	56			60
32	July	7−8,	1953	26	26	21	19			20
33	July	9−11,	1953	69	22	41	45			60
34	July	16−19,	1953	42	31	27				38
35	July	20,	1953	69	76	81				
36	July	20−23,	1953	35	40	63				43
37	September	23−25,	1953	123	110	136	122	100	110	120
38	September	29−30,	1953	8	8	11	8	15	12	11
39	September October	30−, 2,	1953	47	35	44	38	32	38	36
40	October	9,	1953	14	12	15	15	17	17	15
41	October	28,	1953	11		14	12	11	14	
42	October	28−30,	1953	44		33	38	21	33	

Table 2. (4) Data of Storm Precipitation

Storm Precipitation	Period			07	33	08	34	35	36	09
1	June	15−16,	1951		66	51	68	66		55
2	July	2,	1951	64	69	65	86	78	74	
3	July	4−5,	1951	25	44	36	51	41	41	33
4	July	8−9,	1951	5		2				2
5	July	10−17,	1951	104	84	85	87	113	105	73
6	September	24−27,	1951	46		52		59	56	46
7	September	29−30,	1951	2		3				2
8	October	13−15,	1951	53		60		63		48
9	May	27−28,	1952	11	15	13	14	17	13	10
10	June	2,	1952	22	23	29	23	30	39	30
11	June	8−10,	1952	22	8	22	29	26	29	22
12	June	22−25,	1952	85	180	100	113	103	120	93
13	July	2−3,	1952	38	75	27	39	29	27	22
14	July	3−4,	1952	16	24	11	12	13	18	12
15	July	4,	1952	51	52	15	11	28	28	5
16	July	9−12,	1952	40	15	30	20	17	36	23
17	July	13−15,	1952	31	90	26	40	26	24	27
18	July	17−20,	1952	33	31	135	146	109	100	87
19	August	7−8,	1952	14	23	9	12			6
20	August September	31−, 1,	1952	10	14	10	11	11	9	9
21	September	6−10,	1952	24	30	27			30	24
22	September	11−16,	1952	16	6	12			22	11
23	October	6−8,	1952	28		26		28		31
24	October	27−28,	1952	19		19	16	13		18
25	November	4−5,	1952	28		27	38	24		24
26	May	5−6,	1953	7		5				4
27	May	7−9,	1953	28	41	38	50	48	47	51
28	May	23−24,	1953	52	50	55	59	50	56	57
29	June	6−8,	1953	47	86	49	50	56	53	50
30	June	10−12,	1953	22	39	23	21	20	21	17
31	July	3−4,	1953	51	59	53	57	56	53	56
32	July	7−8,	1953	17		21	22			19
33	July	9−11,	1953	40	42	51	68		66	47
34	July	16−19,	1953	44		30	35	29		26
35	July	20,	1953	69		69	65			59
36	July	20−23,	1953	28		35	39		29	34
37	September	23−25,	1953	102	104	97	114	104	107	109
38	September	29−30,	1953	8	12	13	18	12	11	10
39	September October	30−, 2,	1953	36	60	39	47	39	36	35
40	October	9,	1953	14	15	14	15	15	15	15
41	October	28,	1953	13	15	16	17	18	18	16
42	October	28−30,	1953	32	26	27	23	44	53	19

Table 3. Governing Area of Rain-Gage determined by Thiessen Polygon Method.

Number of Rain-gage	30	16	8	4	2
Average Governing Area (km²) / Rain-gage No.	12.5	23.5	47.0	94.0	188.0
21	6.6				
22	11.8				
01	16.1	35.6	56.1		
23	12.9	13.7	23.1		
24	8.8				
11	14.9	28.2		112.0	
02	18.4				191.6
25	3.7				
26	13.7				
12	15.2	26.7	51.4		
03	16.8	41.0			
13	13.2				
27	6.4				
04	14.0	25.9		95.0	
28	6.0	17.0			
05	16.8		61.1		
29	9.6	13.0	35.8		
14	18.5	29.8			
30	3.7				
41	11.9			78.2	
31	10.8				
32	7.1				
06	11.2	25.4	52.8		
07	19.8	29.2			184.4
33	11.6	15.4	45.1		
08	20.2			90.8	
34	11.9	20.6			
35	20.1	26.6			
36	11.2	14.6	50.6		
09	13.1	13.3			
Total	376.0	376.0	376.0	376.0	376.0

Table 4. Average Storm, precipitation, runoff, runoff coefficient and discharge at beginning of rise.

Storm Precipita-tion	Period		Average Storm Precipitation (mm)		Runoff (mm)	Runoff Coefficient (%)	Discharge at beginning of rise (3 m/sec)
1	June 15−16,	1951		58.5	29.7	50.8	3.2
2	July 2,	1951	77.4	104.7	98.8	94.4	4.3
3	July 4 − 5,	1951	27.3				
4	July 8 − 9,	1951	3.2	84.2	59.1	70.2	15.2
5	July 10−17,	1951	81.0				
6	September 24−27,	1951	50.6	52.4	38.6	73.7	3.7
7	September 29−30,	1951	1.8				
8	October 13−15,	1951		47.8	35.8	74.9	4.5
9	May 27−28,	1952		13.4	3.5	26.1	5.0
10	June 2,	1952		19.5	5.3	27.2	4.9
11	June 8 −10,	1952		23.1	9.8	42.4	4.3
12	June 22−25,	1952		90.6	85.5	94.4	4.9
13	July 2 − 3,	1952	31.9				21.6
14	July 3 − 4,	1952	22.9	75.7	72.3	95.5	
15	July 4,	1952	20.9				
16	July 9 −12,	1952	38.6				20.2
17	July 13−15,	1952	36.1	118.7	99.7	84.0	
18	July 17−20,	1952	44.0				
19	August 7 − 8,	1952		23.9	14.2	59.4	22.9
20	Aug. 31−Sep. 1,	1952		16.2	3.7	22.8	4.3
21	September 6 − 10,	1952		29.5	12.6	42.7	3.8
22	September 11−16,	1952		21.7	5.7	26.3	4.4
23	October 6 − 8,	1952		24.6	13.9	56.5	3.1
24	October 27−28,	1952		18.3	8.8	48.1.	3.2
25	November 4 − 5,	1952		30.7	22.8	74.5	3.5
26	May 5 − 6,	1953	5.9	36.7	24.4	66.5	2.4
27	May 7 − 9,	1953	30.8				
28	May 23−24,	1953		51.4	31.2	60.7	2.7
29	June 6 − 8,	1953	55.5	74.4	64.5	86.7	4.4
30	June 10−12,	1953	18.9				
31	July 3 − 4,	1953		57.9	58.6	101.2	26.0
32	July 7 − 8,	1953	17.7	55.6	54.1	97.3	35.0
33	July 9 −11,	1953	37.9				
34	July 16−19,	1953	34.1				18.0
35	July 20,	1953	70.2	147.6	142.9	96.8	
36	July 20−23,	1953	43.3				
37	September 23−25,	1953	110.6	122.8	128.5	104.6	11.7
38	September 29−30,	1953	12.2				
39	Sep. 30−Oct. 2,	1953		40.8	36.7	90.0	20.5
40	October 9,	1953		15.2	4.7	30.9	13.3
41	October 28,	1953	11.3	34.7	8.9	25.6	4.7
42	October 29−30,	1953	23.4				

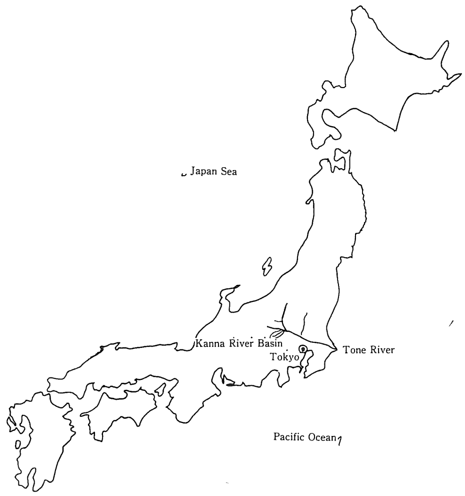

Fig. 1. Location of the experimental basin.

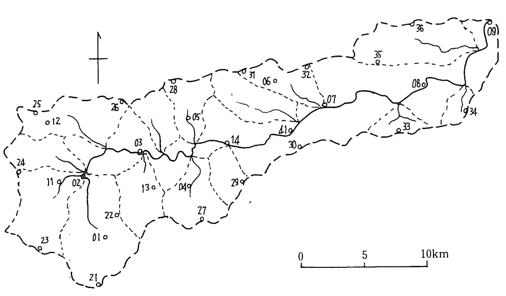

Fig. 2. Map of rain-gage network

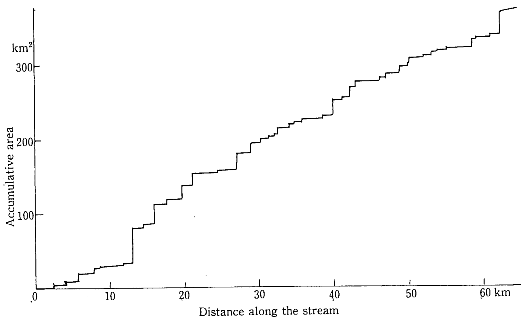

Fig. 3. Accumulative area

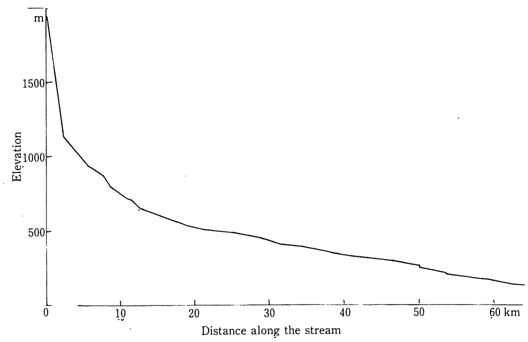

Fig. 4. Profile of the mainstream

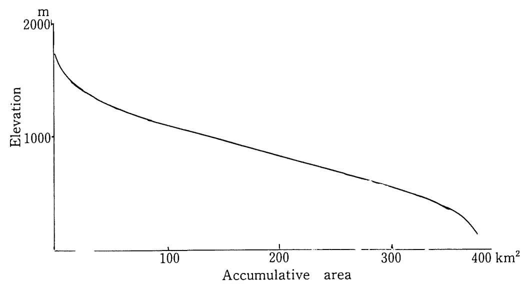

Fig. 5. Area—elevation curve

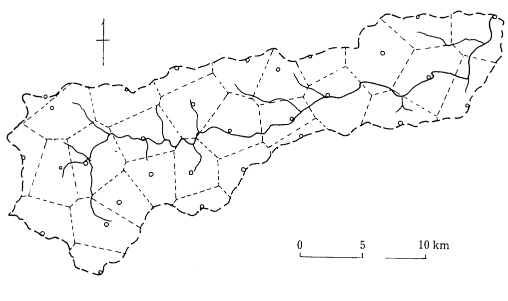

Fig. 6 (1) Thiessen polygon for 30 stations

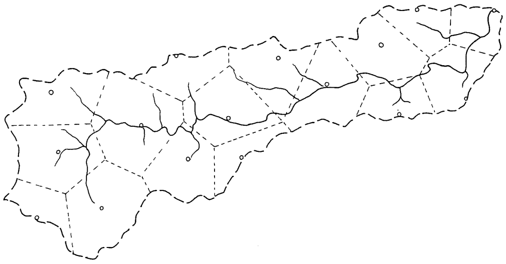

Fig. 6 (2)　Thiessen polygon for 16 stations

Fig. 6 (3)　Thiessenpolygon for 8 stations

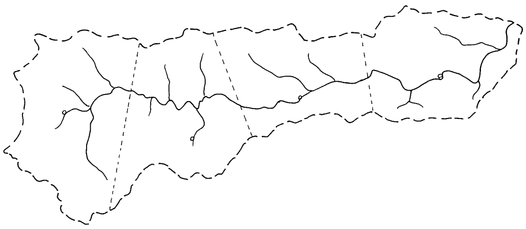

Fig. 6 (4)　Thiessen polygon for 4 stations

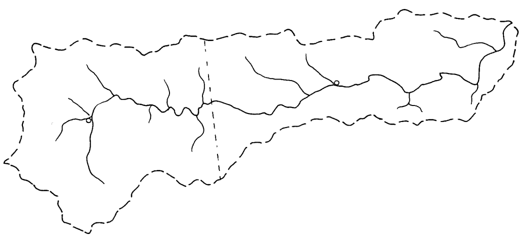

Fig. 6 (5)　Thiessen polygon for 2 stations

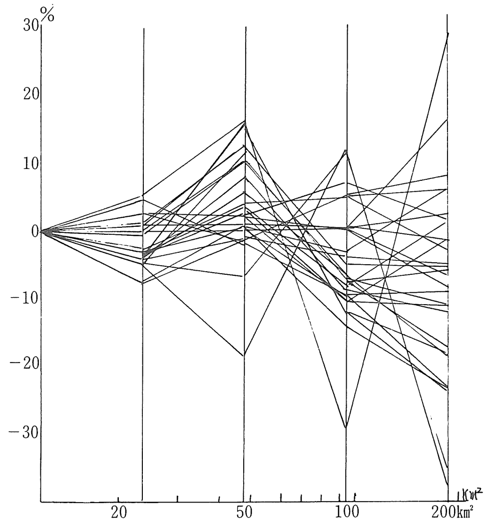

Fig. 7.　Relation between the average governing area and the error in the Thiessen polygon method.

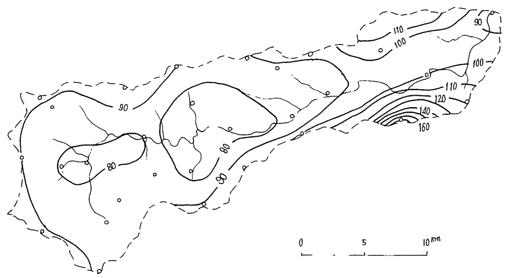

Fig. 8 (1)　Isohyetal map for 30 stations in the case of No. 12 storm precipitation

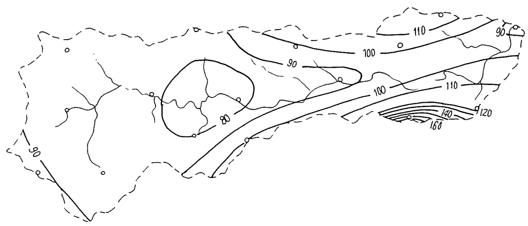

Fig. 8 (2)　Isohyetal map for 16 stations in the case of No. 12 storm precipitation

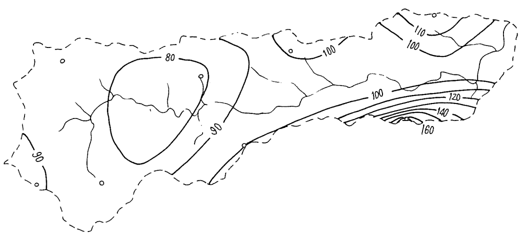

Fig. 8 (3)　Isohyetal map for 8 stations in the case of No. 12 storm precipitation

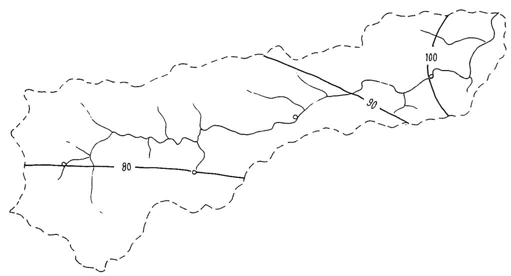

Fig. 8 (4) Isohyetal map for 4 stations in the case of No. 12 storm precipitation

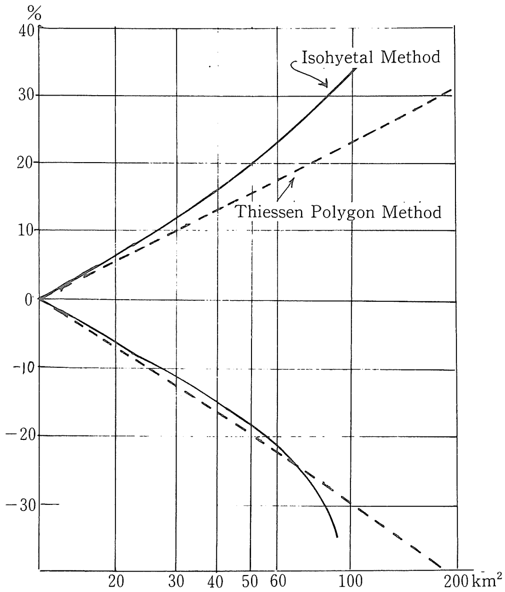

Fig. 11 Relation between the average governing area and the error for the envelopes of points in Fig. 7 and 8.

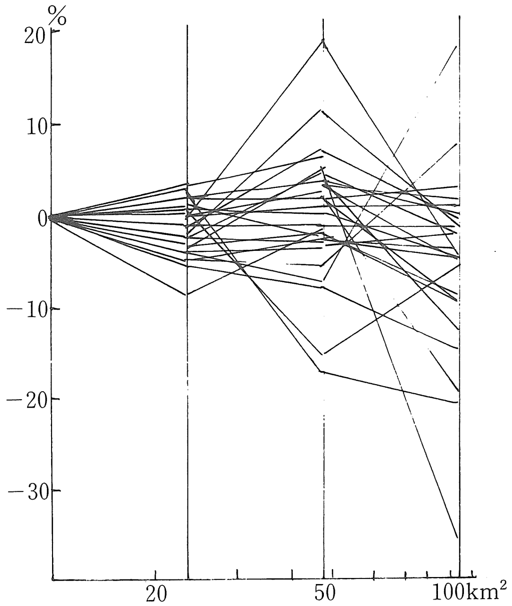

Fig. 9 Relation between the average governing area and the error in the isohyetal method

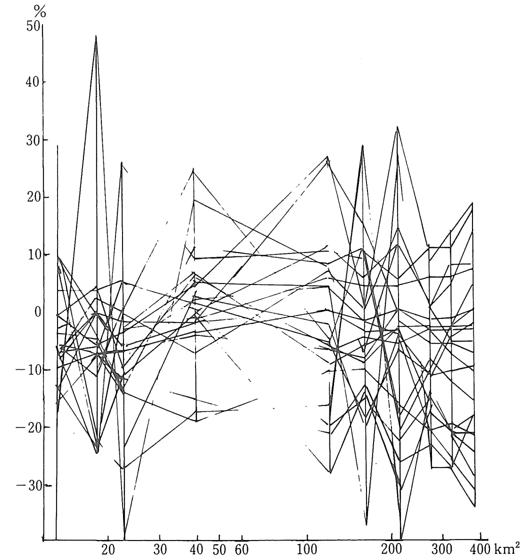

Fig. 12 Relation between the average governing area and the error in point rainfall method

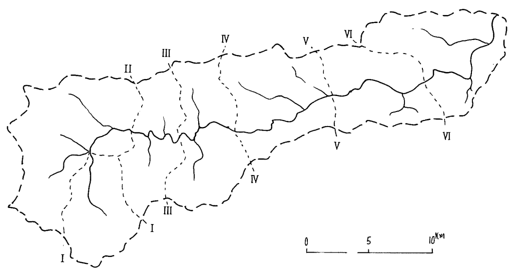

Fig. 10 Subdivision in the Original basin

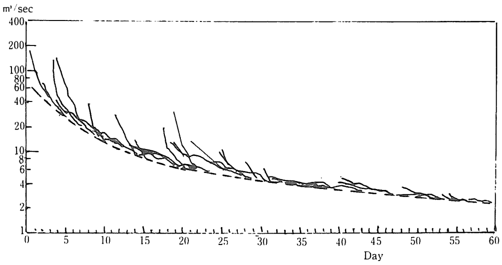

Fig. 13 Normal recession curve

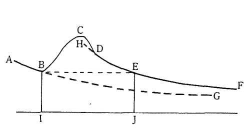

Fig. 14 (1)
Computation of runoff

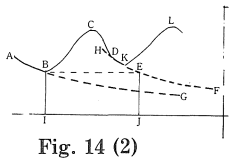

Fig. 14 (2)
Computation of runoff

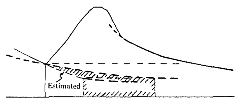

Fig. 14 (3)
Computation of runoff

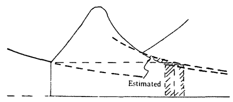

Fig. 14 (4)
Computation of runoff

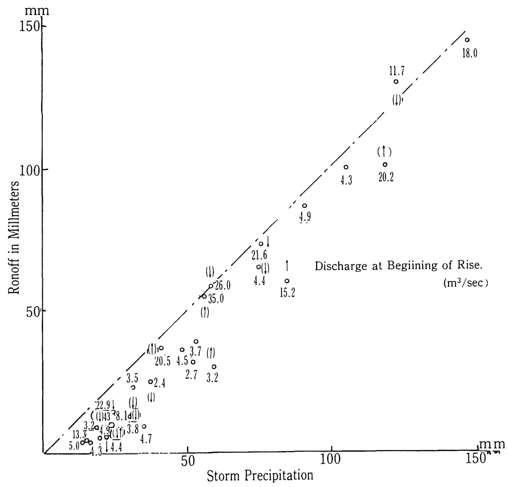

Fig. 15 Relation between storm precipitation discharge at beginning of rise and runoff

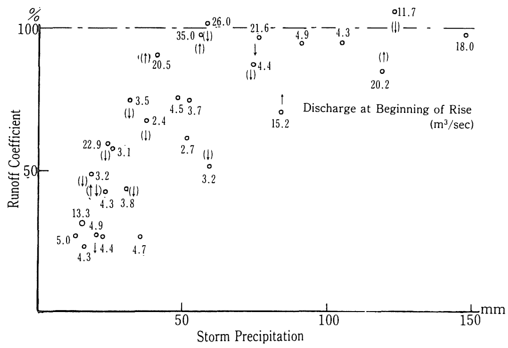

Fig. 16 Relation between storm precipitation, discharge at beginning of rise of rise and runoff coefficient

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