the vegetable covering the smaller and slower will be the temperature changes of the ground surface and the less probability will there be of the appearance of the mirage. This is the basis of the argument that the turning of the prairies into farms has affected the frequency of the appearance of the mirage, for during the summer season, the time when mirages are most frequent, the crop covering is much more dense than that of the prairie grass covering. It is claimed that for a year or two following the great fires which occasionally swept the prairies in the early days, the mirage was unusually common. The fires burned the dry, dead vegetation which accumulated on the ground with the years and for several months thereafter there was more bare ground exposed to the sun's rays, etc., thus making the conditions more favorable for the formation of the mirage.

While such evidence as we have does not *prove* nor even *indicate* that the mirage has entirely disappeared from any extensive region, it does lend strong support to the statement of Mr. Wright that much of the beauty and glory of the mirage has vanished. That the phenomenon is occasionally seen around Dodge City and in other parts of southwest Kansas we have the positive statements of eye witnesses, many of them, that it is not seen nearly so often to-day as formerly is the positive assertion of many eye witnesses, with none, so far as the writer knows, claiming the contrary.

SIMPLIFIED RAIN-INTENSITY FORMULAS

By C. E. GRUNSKY

[57 Post Street, San Francisco, Calif., October, 1930]

The account given by George V. Fish, United States Weather Bureau Office, Fla., in the MONTHLY WEATHER REVIEW, June, 1930, of a record rainfall at Miami from May 29 to June 2, inclusive, prompts the submission of formulas for the determination of probable maximum rain intensity during time periods of any length (less than a year) when the maximum rain rates during one or more storms of the extreme type are known.

It has been customary, heretofore, in such formulas to express time in minutes and the rain intensity in inches per hour. The formulas will take on a more convenient form if the duration of the rain be expressed in hours instead of in minutes.

No one has yet suggested a simple, single formula for rain intensity, satisfactorily applicable to such periods as a small fraction of an hour, an hour, a day, a week, a month, and an entire season. It is believed that the desired near approach to actual fact and a wide range of the time period can be obtained with the two formulas below noted. It is well known that for short periods of time the summation or mass curve of rainfall of maximum intensity has a shape closely approximating a parabola. The elements of a parabola, however, which will fit conditions of rain intensity for periods up to 24 or even 48 hours, indicate too much rain for materially longer periods. It is this fact which has led to the suggestion of two very simple formulas, one for rainstorms of relatively short and the other for storms of long duration. It is hoped that these formulas may prove helpful in determining from measured heavy rain rates the probable maximum rainfall in other than the observed time period.

Let I_t represent the maximum average rate of rainfall, expressed in inches per hour, during any definite time period t.

Let t represent the time, expressed in hours, during which rain falls with the average intensity I.

Let C represent a coefficient which is to be ascertained for any locality from records of rainfall of extreme intensity.

Let R represent the maximum rainfall in one hour, expressed in inches.

Let R_t represent the total rainfall from the beginning of a rain storm of maximum intensity, during the t hours of its duration.

The probable maximum intensity of rainfall during various periods of time can then be determined with the aid of the formulas:

$$I_t=\frac{C}{\sqrt{t}} \text{ when } t \text{ is less than 64 hours.} \qquad (1)$$

$$I_t=\frac{2C}{\sqrt[3]{t^2}}=\frac{2C}{t^{2/3}} \text{ when } t \text{ is greater than 64 hours.} \qquad (2)$$

These formulas in this simple form and their combination, which results in a continuous curved line, with a single negligible angle, will be found particularly helpful in approximating maximum rainfall for periods which do not differ too widely from the period of observed heavy rainfall which determines the value of the coefficient C.

It follows from (1) and (2) that—

$$R_t=\frac{C}{\sqrt{t}}t=C\sqrt{t} \text{ when } t \text{ is less than 64 hours.} \qquad (3)$$

$$R_t=\frac{2C}{t^{2/3}}t=2C\sqrt[3]{t} \text{ when } t \text{ is greater than 64 hours.} \qquad (4)$$

Moreover the coefficient C will be equal to the maximum rain in one hour, because for $t=1$ it will be found from equations (1) and (3) that

$$I_1=C=R_1$$

Rain at Miami, Fla., May 29 to June 2, 1930, Compared with Computed Maxima

Period	Observed rainfall		Computed by formula		Remarks
	Intensity per hour	Amount	Maximum intensity per hour	Maximum amount	
Hours	*Inches*	*Inches*	*Inches*	*Inches*	
0.167	-----	-----	6.1	1.02	10 minutes.
.50	-----	-----	3.5	1.77	30 minutes.
1	1.87	1.87	2.5	2.50	
2	1.54	2.07	1.77	3.54	
3	-----	-----	1.44	4.33	
4	1.10	4.39	1.25	5.00	
5	.80	4.53	1.12	5.59	By the formula.
6	-----	-----	1.02	6.13	$R_t=2.5\sqrt{t}$.
12	-----	-----	.94	8.65	
24	.38	9.36	.51	12.25	
44	.375	16.49	.378	16.60	
48	-----	-----	.360	17.3	
72	-----	-----	.286	20.6	
96	-----	-----	.242	23.2	
120	.161	19.28	.205	24.6	By the formula.
240	-----	-----	.108	26	$R_t=5\sqrt[3]{t}$.
[1] 545	.061	[1] 33.16	075	41	
720	-----	-----	.062	45	
1,440	-----	-----	.0395	57	Duration 1 month.
8,640	-----	-----	.0119	103	1 year.

[1] This includes a period of 49 consecutive hours on May 27, 28, and 29 after the beginning of the storm, in which no rain fell.

Consequently when the maximum rainfall in one hour for any place has been ascertained, this can be taken as a first approximation of the value of C.

Thus for example, based on the 1 hour maximum record during the Miami storm, and no other approximation, the value $C=1.87$ would be indicated. (See MONTHLY WEATHER REVIEW, June, 1930, Vol. 58, p. 152.)

But, in this storm, as stated by Mr. Fish, on May 31 and June 1 the rainfall was 16.49 inches in 43 hours 56 minutes (43.93 hours). This was at an average rate or intensity of 0.375 inches per hour. Consequently for Miami—

$$I_{44}=\frac{C}{\sqrt{43.93}}=0.375$$

or

$$R_{44}=C\sqrt{43.93}=16.49$$

From either of these equations it follows that $C=2.48$.

As a check on this value it is to be noted that on May 31 in the same storm, the rainfall was 4.39 inches in 4 hours, or at the rate of 1.10 inches per hour. Therefore

$$R_4=C\sqrt{4}=4.39$$

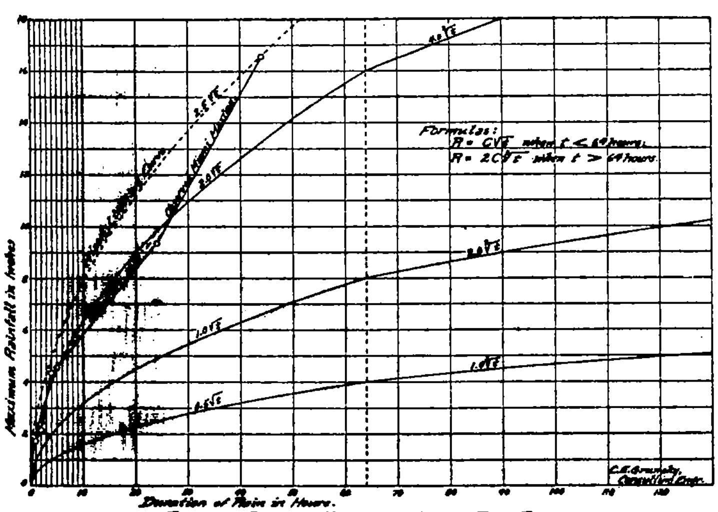
and $C=2.20$ a second or check determination.

It appears, then, that for Miami the value of C should be taken at about 2.5. The formulas for maximum rain at Miami may now be written:

$$I_t=\frac{2.5}{\sqrt{t}} \text{ and } R_t=2.5\sqrt{t} \text{ when } t<64 \text{ hours}$$

$$I_t=\frac{5}{\sqrt[3]{t^2}} \text{ and } R_t=5\sqrt[3]{t} \text{ when } t>64 \text{ hours}$$

In the above table the measured rain during this May-June storm at Miami is compared with the computed probable maxima.



PROBABLE RAINFALL MAXIMA IN VARIOUS TIME PERIODS.

As shown in this table, the Miami storm may be accepted as having established a near record for the short-time periods of 1 hour, 2 hours, 4 hours, and a full day, as well as for the longer period of 44 hours.

It may be of interest to note that for Pacific coast (lowland conditions) the approximate range of the value of C is 0.5 to 1.5.

For Middle West and Atlantic Slope conditions the approximate range of the value of C is 2.0 to 4.0.

Probably the heaviest short-time rainfall ever measured was that on April 5, 1926, at Orpid's Camp, about 20 miles northeasterly from Los Angeles, Calif., on the slope of a high mountain range at an altitude of 4,480 feet where, early in the morning, observations were made with two recording rain gages about 4 feet apart. The one gage showed that in the one minute from 4:43 to 4:44 a. m. the rainfall was 1.03 inches. The other gage recorded 0.92 inch in one minute. In the 10 minutes from 4:40 to 4:50 a. m. the rainfall was 1.17 inches and from 2:40 to 3:40 a. m. the rainfall was 2.20 inches.

Taking the maximum rainfall of this storm at 1 inch in one minute, or 0.0167 of an hour, the value of C is found to be (because I for the one minute equals 60 inches).

$$C=60\sqrt{.0167}$$
$$C=7.8$$

At Campo near the south boundary of California, in the mountains easterly from San Diego, Calif., on August 12, 1891, there was a rainfall of 11.5 inches in 80 minutes. Here

$$I_t=8.65 \text{ and } t=1.33$$
$$C=8.65\sqrt{1.33}$$
$$=10.0 \text{ (in round number)}$$

By computing the probable maximum rate of rainfall for one minute with this value of C it is found that

$I_{0.0167}=77$ inches per hour for one minute.

$R_{0.0167}=1.3$ inches, the probable maximum rainfall in the one minute of greatest intensity.

It therefore appears probable that even for the short-time period of one minute the rainfall at Campo in 1891 exceeded the measured rain in one minute at Orpid's Camp.

On the island of Oahu, Hawaii, at Dam No. 4 in the upper end of Nuuanu Valley in January, 1921, there was a rainfall of 20 inches in 24 hours. The caretaker at the dam, Mr. L. A. Moore, states that this rain fell in the 3 hours 7 to 10 a. m. The average rainfall was, therefore, about 6.67 inches per hour for a value of $t=3$. Consequently

$$I_3=6.67=\frac{C}{\sqrt{3}}$$

And $C=11.5$

Consequently

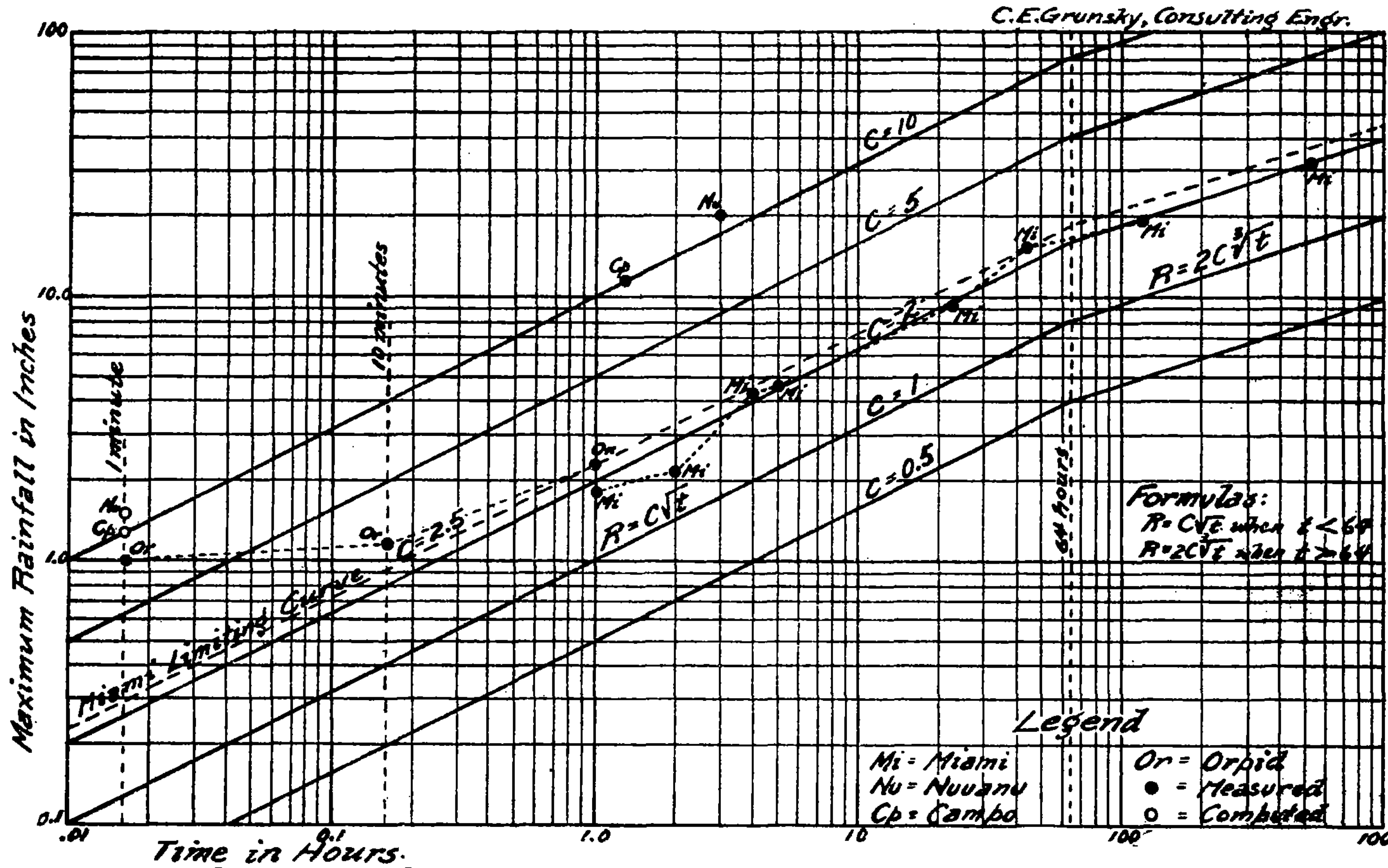
$$R_{0.0167}=11.5\sqrt{.0167}$$
$$=1.49 \text{ inches, the probable rain in the one minute of greatest rain intensity.}$$

This, too, was probably a storm which produced more rain in a single minute than the storm at Orpid's Camp.

It remains to be noted that such excessive rainfall is generally confined to small areas. Thus, for example, at a point 1½ miles from Campo during the great downpour above noted only 3 inches of rain fell. This was the record for the full duration of the storm.

Two diagrams have been prepared (figs. 1 and 2) to illustrate the shape of the curves which according to the suggested formulas would represent the limiting curves of maximum amounts of rain in various periods of time. In the one diagram natural scales have been used and in the other logarithmic scales.

The experienced meteorologist will know that values of the coefficient C determined by actual measurement of very heavy rainfall during short periods of time, such as a few minutes or an hour or two, may not be applicable to long periods of time such as a week, month, or longer, and vice versa. The formulas are particularly helpful in approximating probable maximum amounts of rain over a considerable range of time in both directions from the time periods covered by actual observation.



PROBABLE RAINFALL MAXIMA IN VARIOUS TIME PERIODS.

LOGARITHMIC SCALES.

ANALYSIS OF THE PRECIPITATIONS OF RAIN AND SNOW, DURING 1929–30, AT MOUNT VERNON, IOWA

By WILLARD C. STEWART

Under the direction of Dr. Nicholas Knight, of Cornell College, advanced students of chemistry have made analyses of the rains and snows that have been precipitated here for the past 20 years. The results of most of the work have been published in scientific journals.

The precipitations are collected in clean granite pans, 18 inches in diameter, away from trees and buildings and stored in glass-stoppered bottles. The village has no factories, and, exclusive of the college, has a population of about 1,700.

In estimating the chlorides, it has been found necessary to deduct 3.55 parts per million from the reading, to allow for the formation of the color. For the most part, the precipitations come from the East or South which signifies that the salt is carried by the winds from the Atlantic Ocean or the Gulf of Mexico. As our previous results in chlorides have received some criticism as seeming rather high, we have taken special pains to secure the accuracy of the results given in this paper, and we believe they are correct.

The processes of these analyses are taken from Standard Methods of Water Analysis, sixth edition, published by the American Health Association. Practically all the samples analyzed were colorless. The results are given in the following tables. The numbers express the parts of the various substances in a million parts of water.