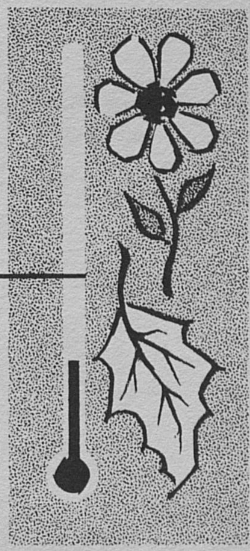
LATE SPRING & EARLY FALL FREEZES in KENTUCKY



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PREFACE

This publication is intended as a handbook on Kentucky freezes for farmers and industrialists in Kentucky. Application of the data for agricultural interests is treated at some length in the text. However, owing to the variability of industrial applications, these are mentioned only briefly on the premise that each industrialist will be able to make his own application after the data are made available.

Spring and fall freezes are discussed in the text without mathematical or statistical references on the assumption that most users are not likely to be interested in mathematical derivations. For those interested, a bibliography is presented, which contains sufficient reference material for documentation of the mathematical background and soundness of the data presented.

CONTENTS

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By Doyle Cook*

During the course of producing and marketing a profitable crop, the Kentucky farmer has many hazards to deal with. One of the more important of these is, in many instances, the risk of a damaging late frost or freeze in the spring and the risk of a similar occurrence early in the fall. The truck farmer and orchardist are possibly the most concerned with late spring and early fall freezes, but those who raise some of the other more basic field crops such as cotton, corn, and tobacco sometimes experience losses from unusually late freezing temperatures in spring. Likewise, some late-maturing crops are also subject to damage by early fall freezing.

Since it is not always economically feasible to attempt to prevent the occurrence of freezing temperatures in Kentucky fields and orchards, the next best thing is for the farmer to plan and carry out his operations in such a way that his risk of damage will be minimized. To do this it is necessary that he have information regarding the chance or risk of freezing temperatures occurring in his part of the state after certain dates in the spring and before certain dates in the fall. In some instances the length of the growing season (the number of days between spring and fall freezes) determines the economic feasibility of growing certain crops. The purpose of this study is to provide the needed information concerning growing season and spring and fall freezing temperatures.

While the effect of sub-freezing temperatures on agriculture is of greater importance, other significant interests such as construction, sale of seasonal items, maintenance, heating, etc., are affected to varying degrees.

The data in this pamphlet will inform the farmer, home gardener, or orchardist of the risks involved in early and late planting dates. These data should also be of considerable value to certain industries in planning their respective operations.

FREEZING TEMPERATURES AND PLANT INJURY

It is generally agreed that injury to plants by freezing usually occurs when ice crystals form within the plant tissues as a result of the freezing of the liquid in these tissues. The freezing point of the liquid within the plant tissues varies greatly from one plant to another and at different stages of development in the same plant. For this reason there is a wide range in the temperature necessary to cause major damage to growing plants. A temperature of freezing or slightly below will damage and possibly kill very tender young plants but may have little adverse effect on more hardy, older plants. Peach blossoms usually sustain little or no damage from a temperature of 30°F, but serious damage may be expected with temperatures of 28°F or below.

The duration of sub-freezing conditions is also an important factor in determining the extent of damage. If the temperature remains below freezing for only a short time, the damage may be negligible, while the same temperature over a period of several hours could cause major damage.

Other factors that seemingly have a definite bearing on the amount of damage are the temperatures present prior to the sub-freezing conditions, the suddenness of the

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temperature drop, and the wind speed. Several days of unseasonably warm weather in early spring will often cause perennials to come out of dormancy prematurely and become especially vulnerable to later freezing temperatures. Some types of plants seem to be more susceptible to sudden freezes than to slowly dropping temperatures, even though the same temperature may be reached in both cases. Drying winds, that often accompany unusually severe outbreaks of cold weather, can add considerably to the damage.

The appearance of frost has commonly been associated with plant injury. Frost is defined as the deposit of atmospheric moisture in the form of feathery ice crystals on the ground or other surfaces, the temperature of which has fallen to 32°F or lower. Frost and dew are actually the same phenomenon, the only difference being that, in the case of frost, the atmospheric moisture (water vapor) is deposited as ice crystals instead of water droplets when the temperature of the air at the surface is at the freezing point (32°) or below. Dew or frost can be expected to occur only on clear still nights. Since sub-freezing temperatures can and often do occur without the appearance of frost, plant injury may occur in the absence of frost. For this reason, air temperature is usually considered a better criterion for measuring the extent of plant injury than the occurrence or non-occurrence of frost.

Very little specific information is available regarding the critical temperatures for truck-garden crops. However, these crops are usually classified as tender, semi-hardy, or hardy according to their ability to withstand low temperatures. Tender plants will be damaged or killed by any temperature of freezing or below. Included in this group are watermelons, tomatoes, beans, and peppers. Temperatures slightly below freezing are necessary to cause injury to semi-hardy plants. This group includes carrots, lettuce, and celery. Hardy plants, which include cabbage, turnips, and garden peas, can withstand a fairly hard freeze without being killed.

FREEZE CLASSIFICATION

Freezes have been classified (4)*as light, moderate, or severe, as follows:

Light Freeze	- temperatures 29° through 32°
Moderate Freeze	- temperatures 25° through 28°
Severe Freeze	- temperatures 24° or lower

It may be generally assumed that a light freeze will kill only the tenderest plants; a moderate freeze will damage most plants to some extent, with heavy damage to fruit blossoms and tender and semi-hardy plants; and a severe freeze will cause heavy damage to most plants.

The purpose of this study is to present the probability that a freeze of at least light, moderate, or severe intensity will occur after any date in the spring or before any date in the fall.

FAVORABLE CONDITIONS FOR LATE SPRING AND EARLY FALL FREEZE

In late spring and early fall, temperatures in Kentucky usually remain above freezing during the daylight hours and drop below freezing only at night. The last spring freeze and the first fall freeze are more likely to occur on clear nights. Fair skies permit the invisible heat waves, which are constantly leaving the earth's surface, to pass more readily through the atmosphere. Each day a large amount of heat is lost from the soil and plant surfaces by these heat waves.

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* Numbers in parentheses refer to "Literature Cited," p. 31.

Because of the loss of heat, the earth's surface and the air near the surface gradually become cooler on clear nights. The cooling process continues throughout the night, with the lowest temperature occurring near sunrise. If the air is sufficiently cool to start with, below-freezing temperatures will result.

When skies are overcast, the heat waves leaving the earth are reflected back to the earth in some degree by the cloud cover and not so much heat is lost from the surface. By this means, cloud cover prevents the temperatures near the surface from falling so much, and freezing temperatures are not so likely to occur.

Wind may prevent the occurrence of freezing temperatures. On clear nights, the temperature near the surface is cooler than the temperature a few feet above the surface. The wind mixes the cooler air near the surface with warmer air above it. This prevents cool air from accumulating within the plant cover, and sub-freezing temperatures are not likely to be observed. One should remember that the speed of the wind is usually less at night than during the day. An afternoon breeze may die down during the night, and the mechanism for mixing the air may be lost. Producers of freeze-sensitive plants should observe the wind after sundown before concluding that the wind will prevent the occurrence of sub-freezing temperatures.

The first prerequisite for late spring and early fall freeze is the presence of cool Canadian air over Kentucky. If this air is so cool that its temperature is below freezing upon reaching Kentucky, freeze damage will result even if the skies are cloudy and the wind is blowing.

Producers may be warned of such conditions by the Weather Bureau forecasts which will, in such cases, warn of "much cooler temperatures," "cold wave," "becoming cooler tonight," "frost or freeze tonight," etc.

Not all locations in an area have the same temperature. On clear, calm nights, temperatures are cooler in valleys than on the adjacent hillsides. Cool air, being more dense than warm air, moves down the slopes of hills, accumulating in the valleys. Owing to the cooler valley temperatures, orchard and garden sites should be located on slopes. Because of less erosion and higher soil fertility, truck gardens are often placed in bottom lands; but farmers should recognize that there is a greater risk of late spring and early fall freeze damage in the valley locations.

SOURCE OF FREEZE DATA

Fifty-three U.S. Weather Bureau climatological stations in Kentucky and eight stations immediately adjacent to Kentucky in neighboring states are the source of the temperature data presented in the accompanying charts.

National Weather Records Center Project No. 1013 provided summarized freeze data for 38 of the stations used. Freeze data for 23 stations were summarized by the author from data available in the Annual Summary of Climatological Data for Kentucky, published by the U. S. Weather Bureau.

Statistical tools, such as mean freeze day numbers, variance of freeze dates, and total years of record were provided in these summaries for the last spring occurrence of 32° or lower, 28° or lower, and 24° or lower, as well as similar data for the first occurrence in the fall. With the devices thus provided, it was possible to use the Normal Curve Area Tables for computation of the risk of freeze for any given date.

H.C.S. Thom and R. H. Shaw (1) have shown that the statistical variance of freeze data for individual stations are not significantly different within the area of one state. This makes it possible to analyze the variances for a state as a whole and to derive a single variance and standard deviation to use for all stations within a state. The variances and standard deviations for station freeze date, as computed, for Kentucky are as follows:

Table 1 — Variances and Standard Deviations

Freeze Threshold	Variances	Standard Deviations
	Spring	
32° or lower	133.06	11.54
28° or lower	163.93	12.80
24° or lower	208.56	14.44
	Fall	
32° or lower	134.79	11.61
28° or lower	123.17	11.10
24° or lower	161.36	12.70

These standard deviations may be used with any individual station mean to obtain the freeze hazard distribution for that station.

The location of the stations from which data were used is shown in Fig. 10, page 28. The thermometers were exposed in standard Weather Bureau instrument shelters, usually at a height of 5 to 6 feet above the ground. Temperatures thus obtained should be representative of the general area. However, on clear, still, nights temperatures may vary greatly in short distances. Under such conditions, the lowest values will usually be found in low places and near the ground. Also temperatures in and near the larger cities will usually average somewhat higher than those in surrounding areas.

EXPLANATION OF CHARTS AND GRAPHS

For the vast majority of operations there is a quick method for determining the statistical chance that the last spring freeze will occur later than a certain date for any given area of the state. While not strictly correct, mathematically speaking, the following method is considered adequate for normal farm or industrial operations.

Figures 1, 2, and 3 show the average dates of the last occurrence in the spring of 32° or lower, 28° or lower, and 24° or lower in Kentucky. Accompanying each figure, and indicated by a corresponding number, is a graph based on the data in Table 1. Graph 1 is a curve to determine the date after which there is a given risk of 32° or lower occurring; Graph 2 is the same sort of curve for 28° or lower; and Graph 3 is the curve for the last occurrence of 24° or lower.

In the past, considerable attention has been given to the average date of the last killing freeze in the spring and the first killing freeze in the fall. This has been used by many as an indication of the progress of the spring and fall seasons. From an operational point of view, little knowledge is gained by this figure, since it represents only the halfway point. There remains a 50-50 chance of freeze occurring after the average date in the spring or before the average date in the fall. This certainly is a greater risk than most farmers can afford to take.

After determining, from Fig. 1, the mean date of the last occurrence of 32^o or lower in the spring, Graph 1 may be used to determine the statistical risk that the last temperature of 32^o or lower will occur on any date.

For example: If a farmer near Paducah (McCracken county) wishes to postpone planting a particular crop until the statistical chance that a temperature of 32^o or lower will occur is less than 30 percent, he would first read from Fig. 1 that the average date of the last occurrence of 32^o or lower in Paducah is April 3. Using Graph 1 at the 30 percent line and reading from the curve downward, he would read +6. By adding 6 to April 3, we see that there is a 30 percent chance that a temperature of 32^o or lower will occur in Paducah after April 9. After this date the farmer should have 32^o or lower only 3 years out of 10; in 7 out of 10 years, the last occurrence of 32^o or lower will have taken place before this date. Conversely, if this same farmer needed to know what the statistical risk of temperatures 32^o or below was after March 24, he need only enter the bottom of Graph 1 at the -10 line (March 24 comes 10 days before April 3, the mean freeze date ... thus the -10), and proceed upward to the curve and read 80 percent. There is an 80 percent chance that the last occurrence of 32^o or lower will take place in Paducah after March 24. If, owing to the contemplated crop, the farmer's interest was in the last occurrence of 28^o or lower or 24^o or lower, this data may be obtained from Fig. 2 or 3 and their accompanying graphs.

Freezes in the fall damage late-maturing crops. At times farmers are forced, by unfavorable weather in the spring, to plant crops later than normal. When this occurs, they often desire some knowledge of the probability that a crop will mature before a damaging freeze occurs. These data are obtained from Figs. 4, 5, and 6 and their accompanying graphs in the same manner used to obtain the data for the last spring freeze.

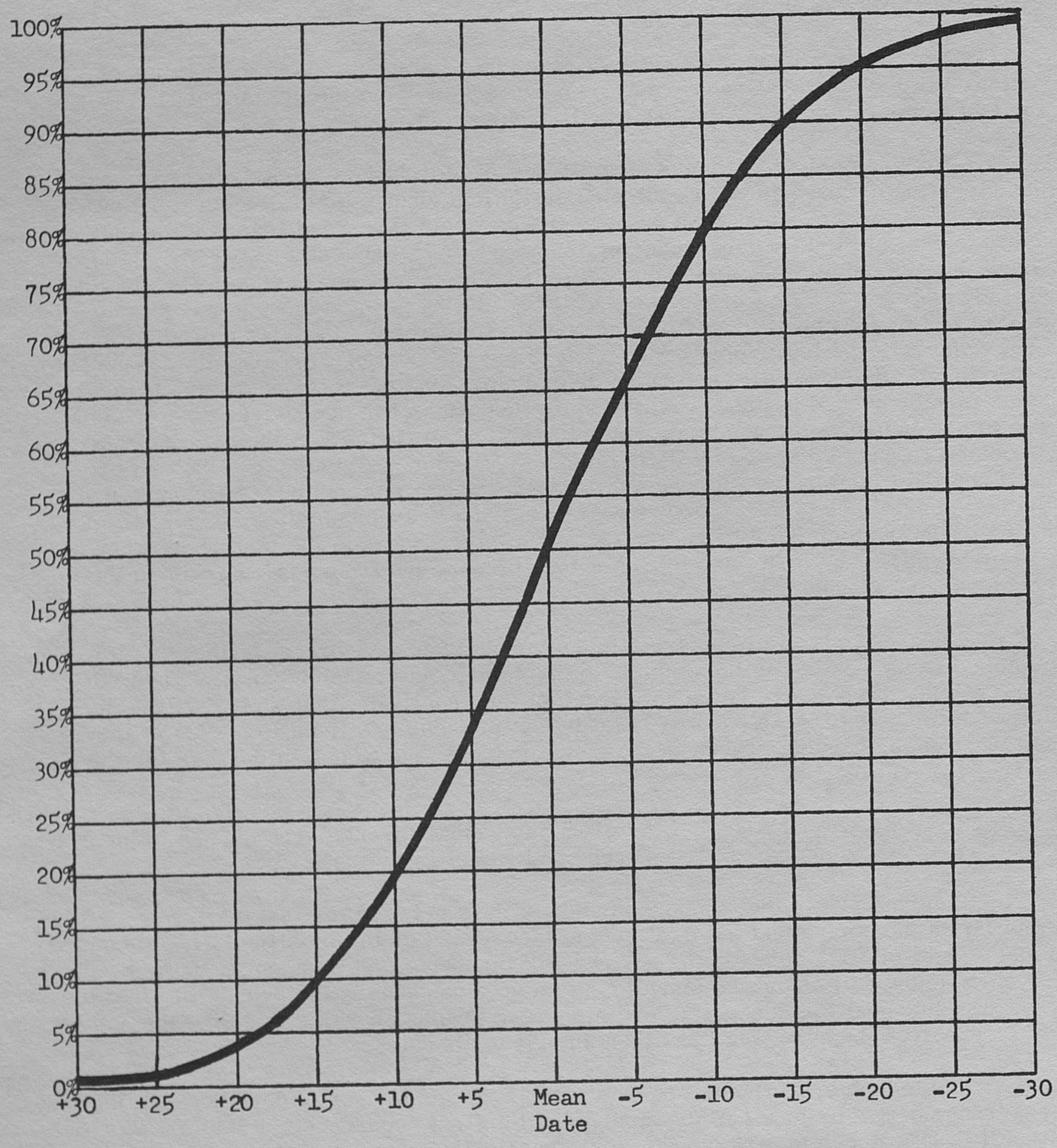
The relative shortness of the growing season, "freeze-free days," influences greatly the choice and use of many crops and varieties by the farmer.

Figure 7 shows the average number of days between the last occurrence of 32^o or lower in the spring and the first occurrence of 32^o or lower in the fall. Figures 8 and 9 show similar data for the 28^o and 24^o thresholds. The accompanying graphs for each figure will enable farmers to obtain data concerning the probability that the growing season will be any given length. These graphs show the risk that the number of "freeze-free days" will be less than any given amount.

For instance, at Henderson where the average number of days between the last occurrence of 32^o or lower in the spring and the first occurrence of 32^o or lower in the fall is 197, there is a 10 percent risk that the number will be less than 176 (the average or mean minus 21 as read from Graph 7). In 9 out of 10 years, the number of days between the last occurrence of 32^o or lower in the spring and the first occurrence of 32^o or lower in the fall should be greater than 176. In 1 year out of 10, there should be a shorter growing season in Henderson.

PROPER USE OF THIS DATA

Data in this study should be used only to determine the probability that spring and fall freezes will occur before or after certain dates. These data are obviously not forecasts that freezes in any given year will or will not take place by a certain date.



Graph 1.—Curve to determine the date after which there is a given risk of 32° or lower in the spring.

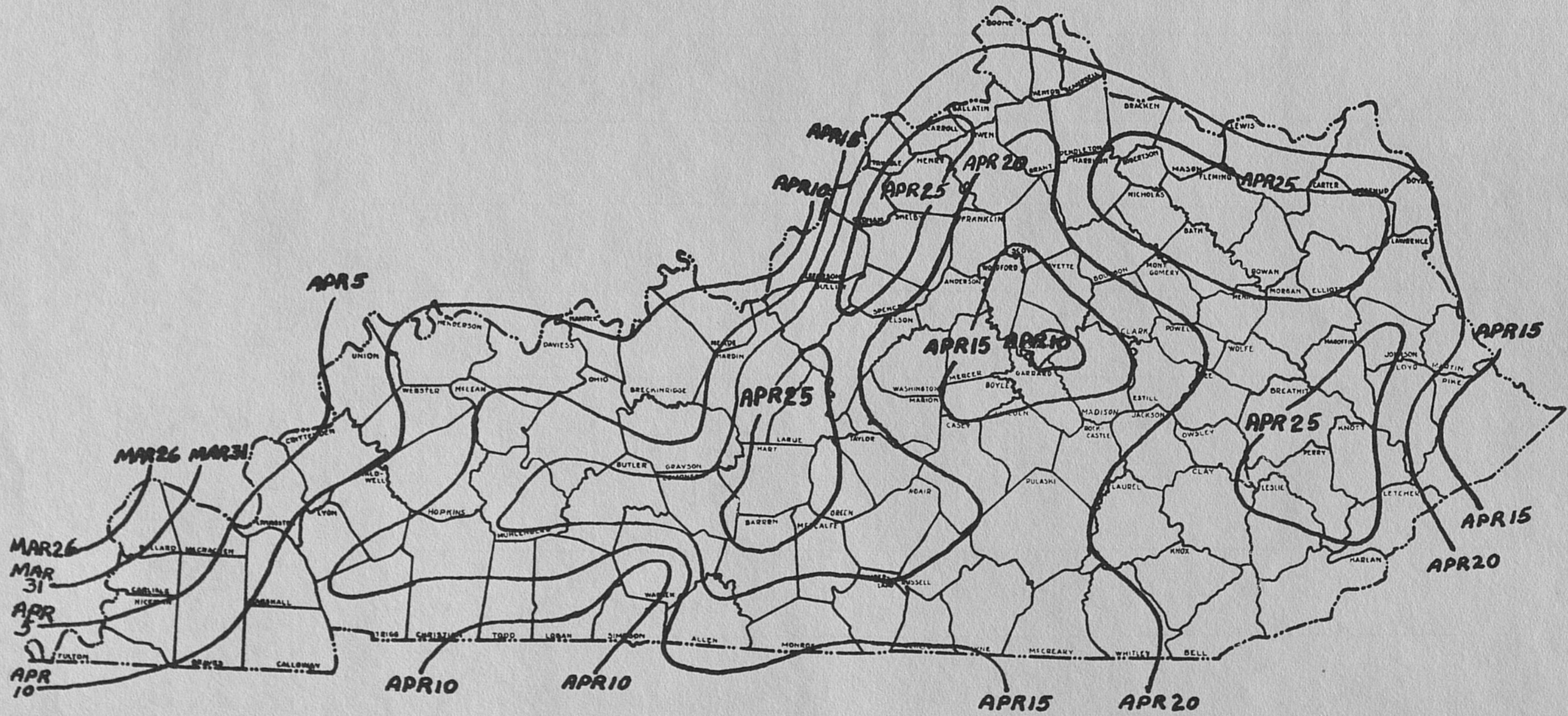
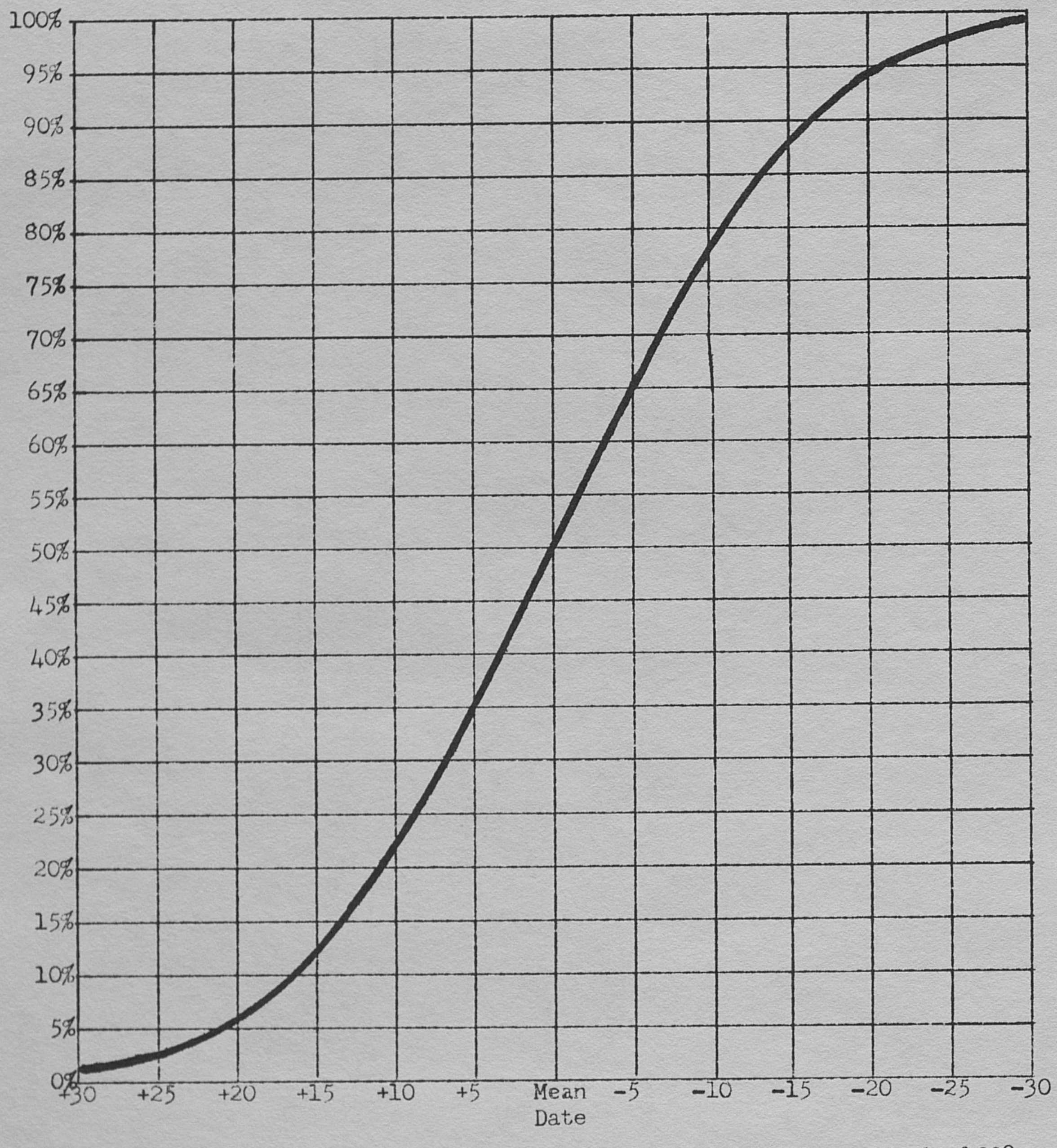


Fig. 1.—Average date of the last occurrence of 32° or lower in the spring.



Graph 2.—Curve to determine the date after which there is a given risk of 28° or lower in the spring.

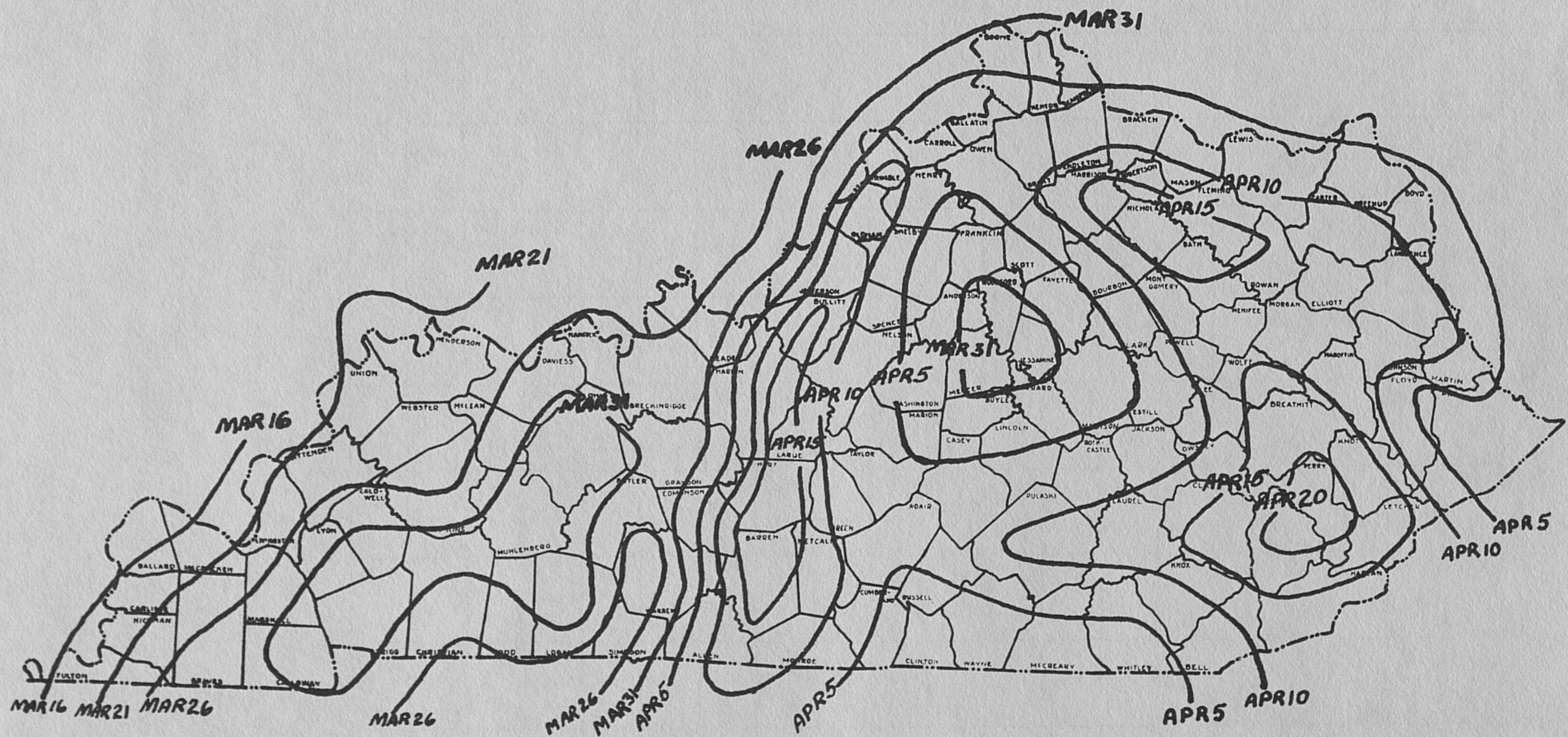
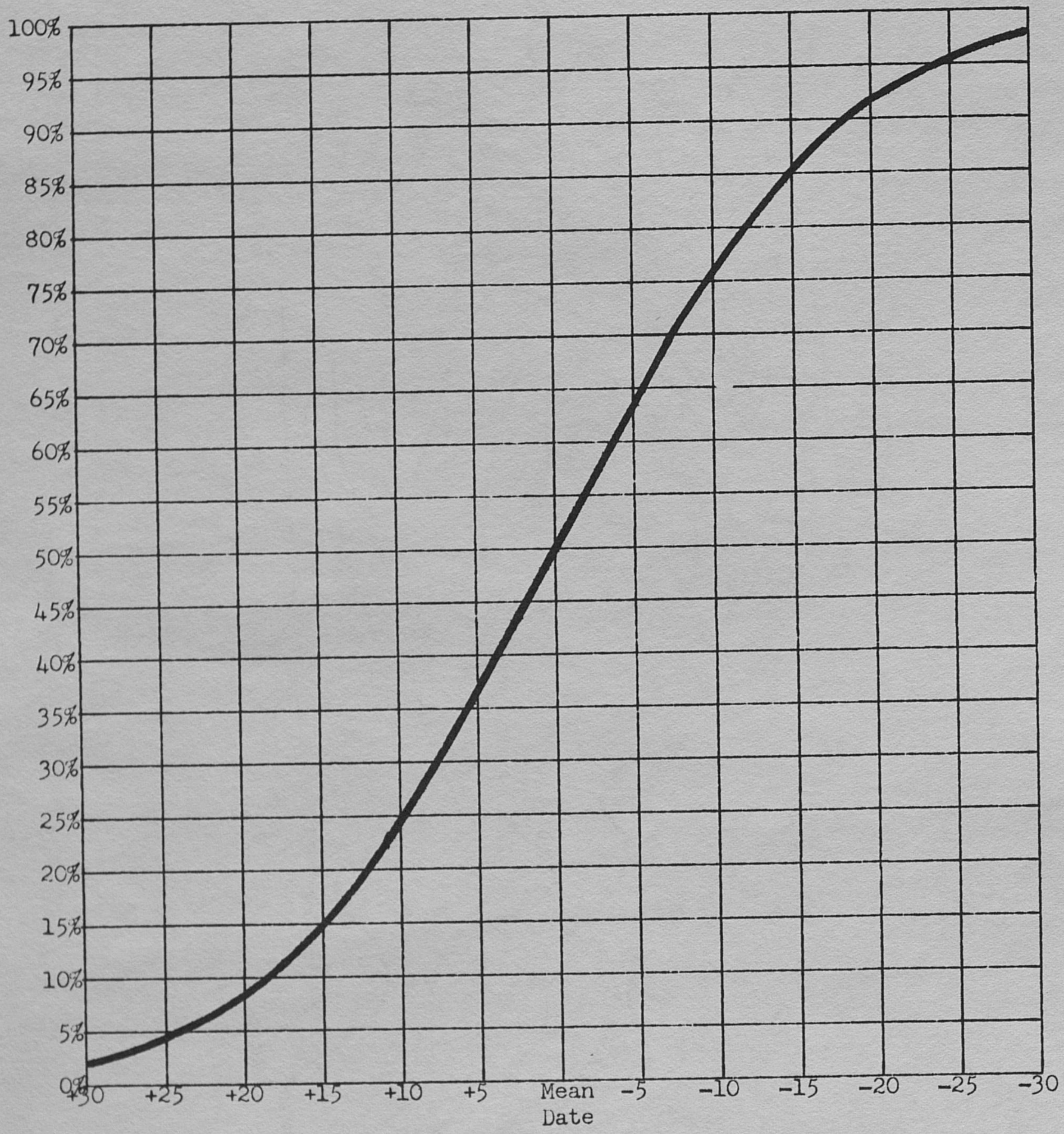


Fig. 2.—Average date of the last occurrence of 28° or lower in the spring.



Graph 3.—Curve to determine the date after which there is a given risk of 24° or lower in the spring.

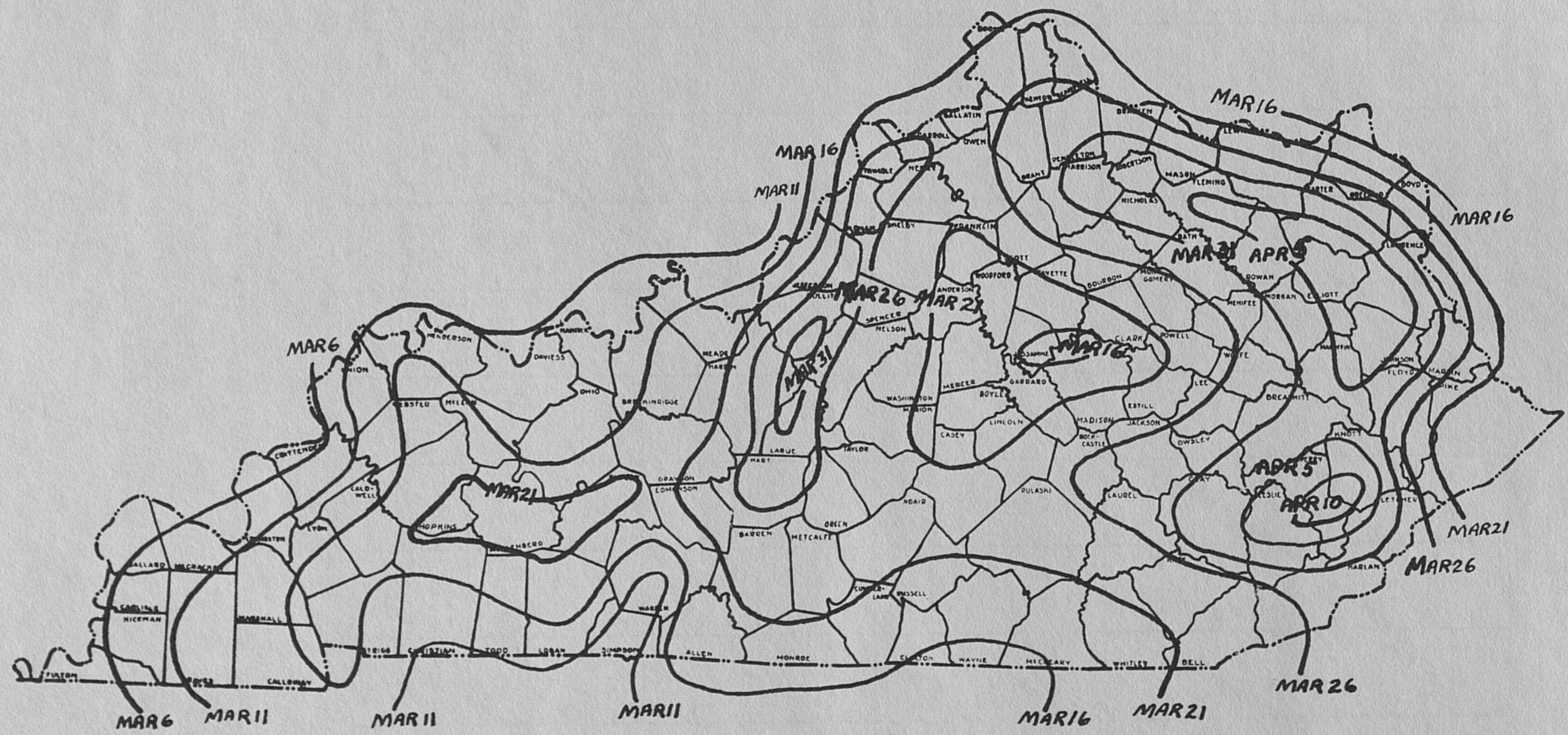
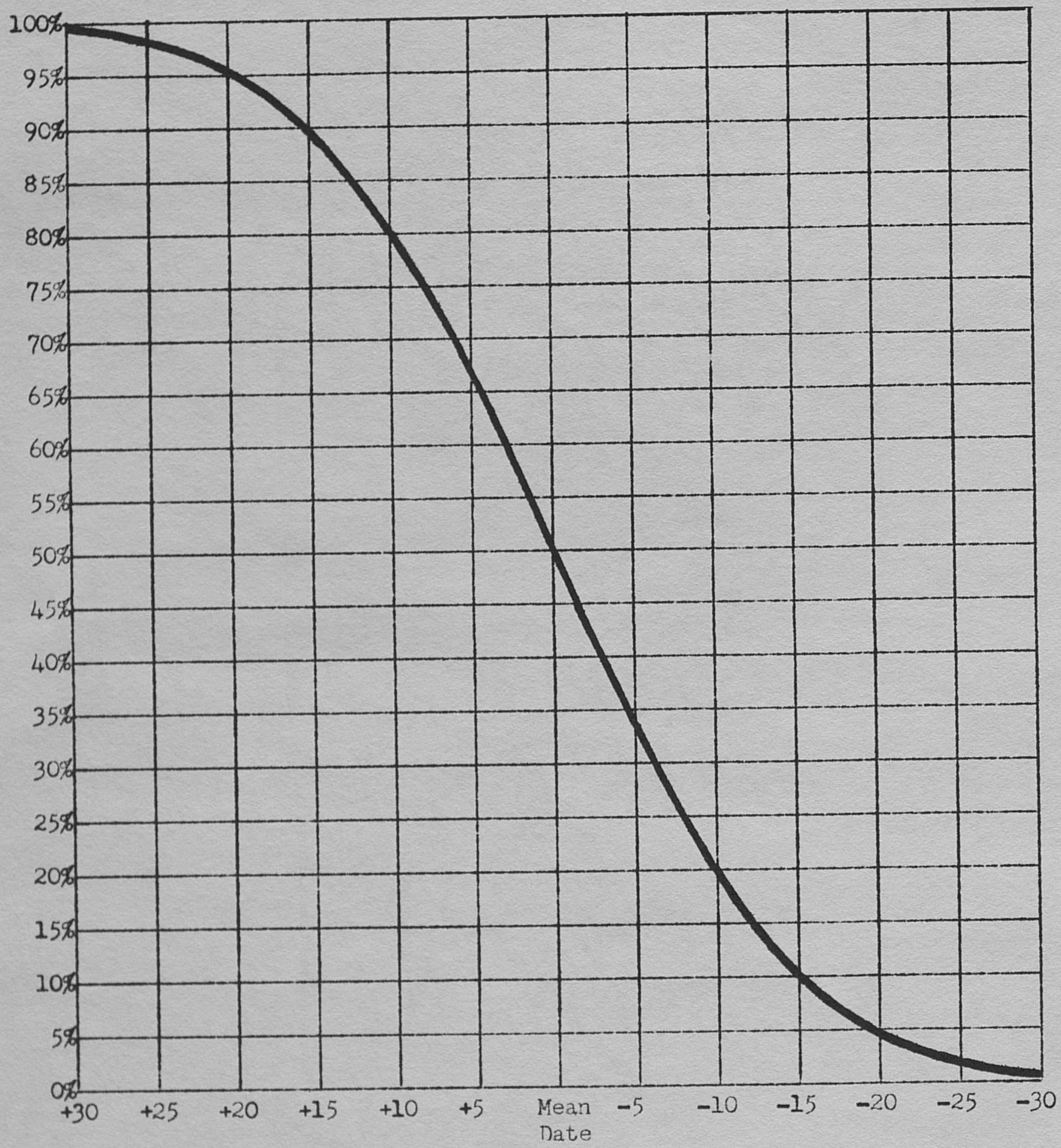


Fig. 3.—Average date of the last occurrence of 24° or lower in the spring.



Graph 4.—Curve to determine the date before which there is a given risk of 32° or lower in the fall.

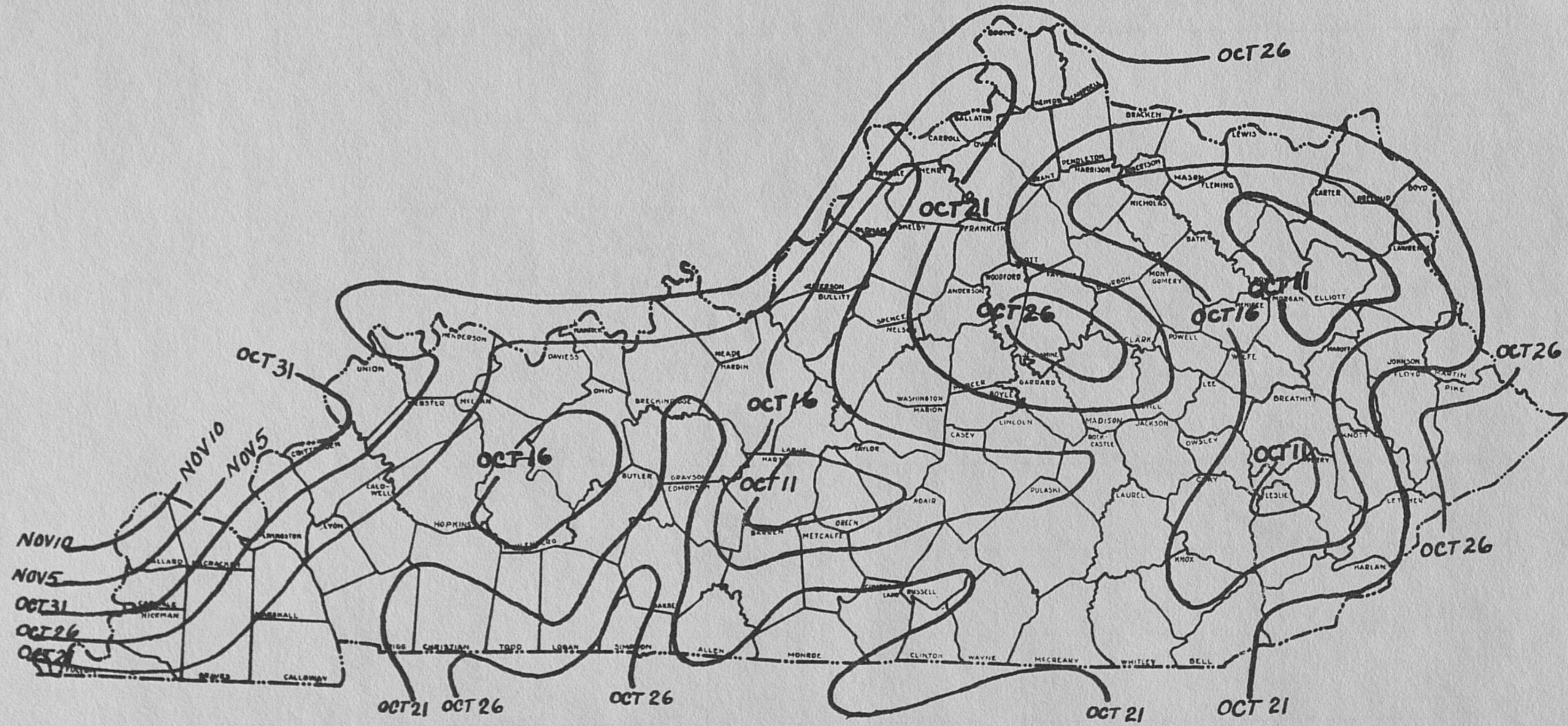
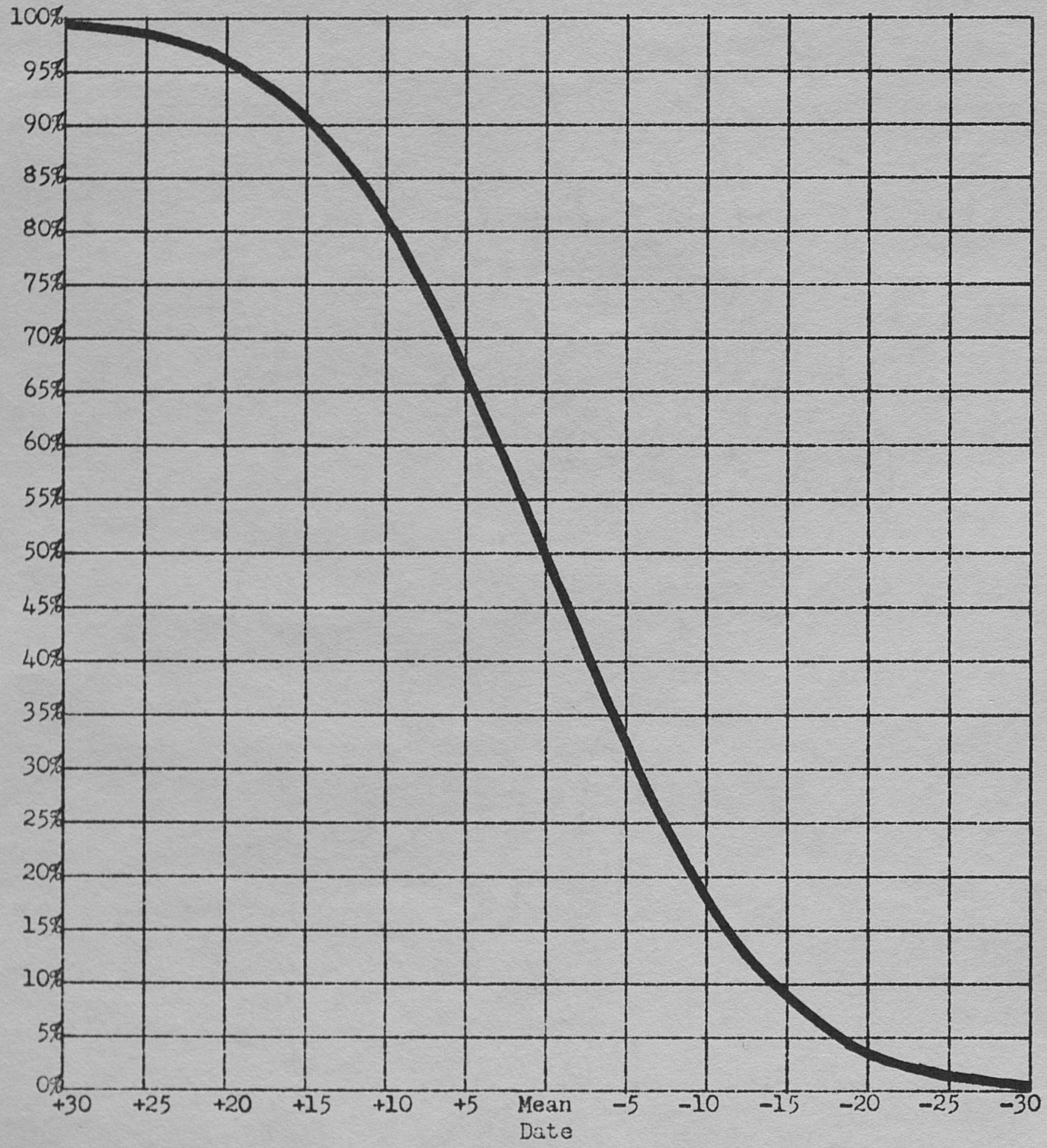


Fig. 4.—Average date of the first occurrence of 32^{o} or lower in the fall.



Graph 5.—Curve to determine the date before which there is a given risk of 28° or lower in the fall.

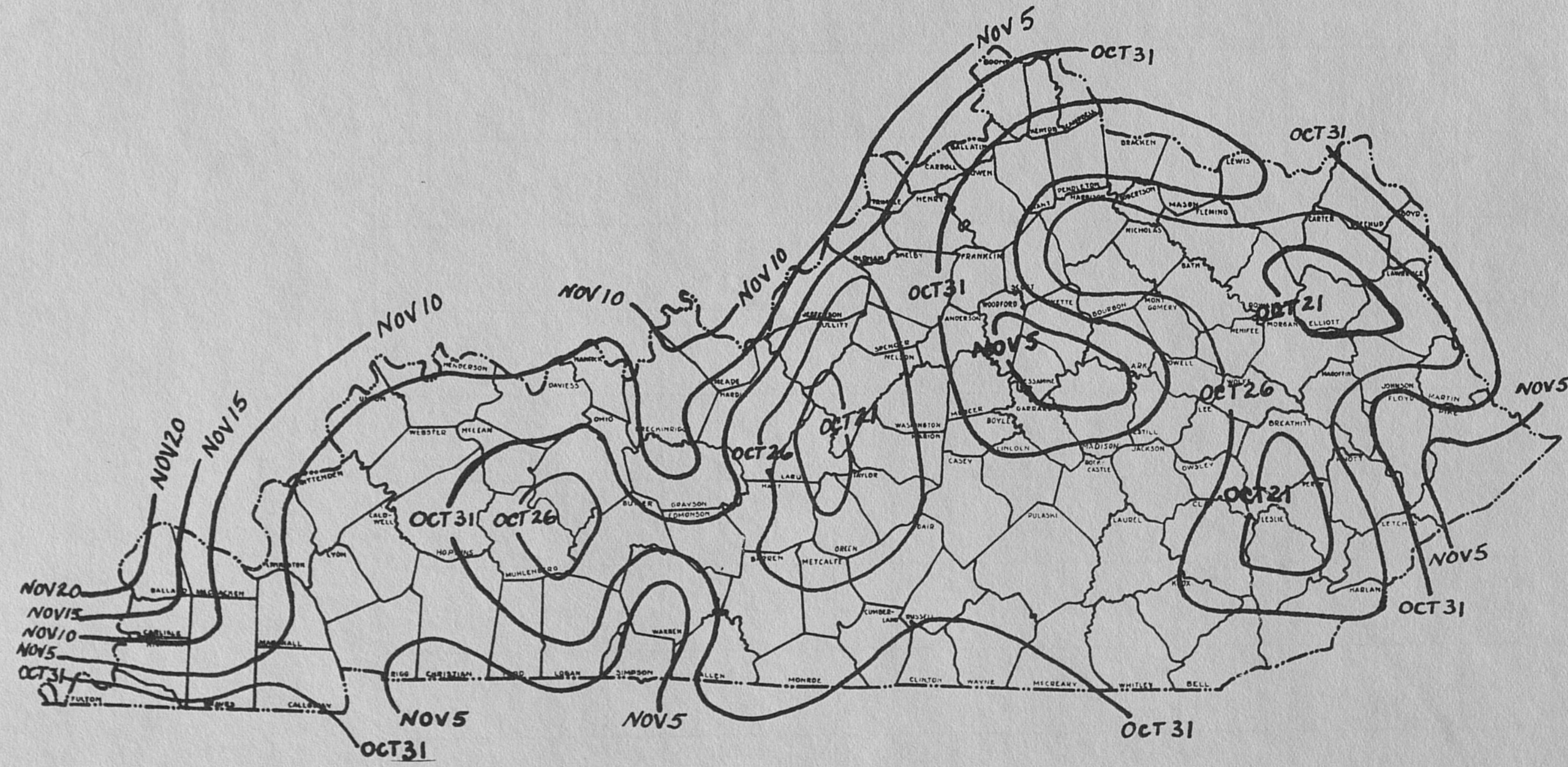
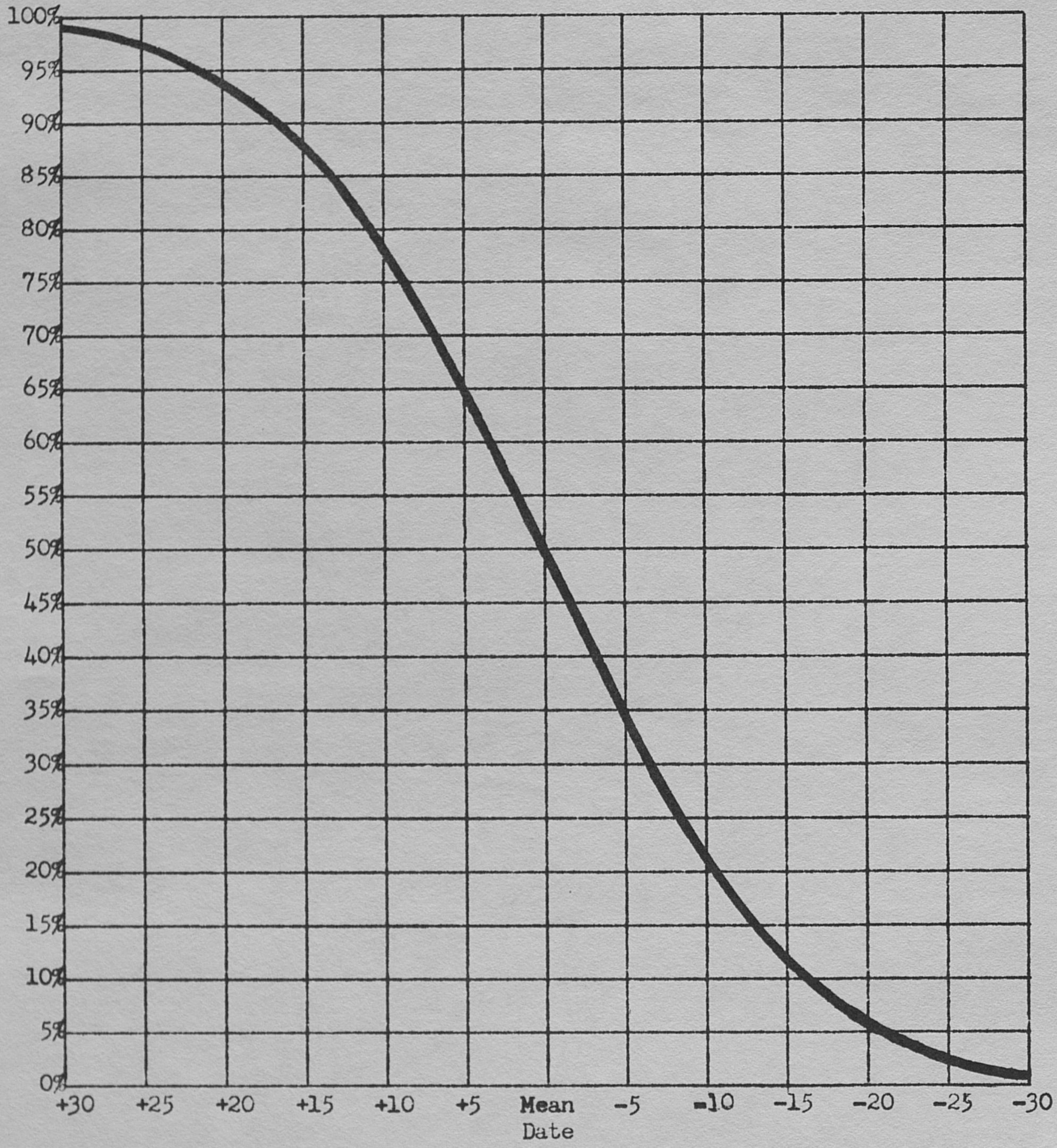


Fig. 5.—Average date of the first occurrence of 28° or lower in the fall.



Graph 6.—Curve to determine the date before which there is a given risk of 24°
or lower in the fall.

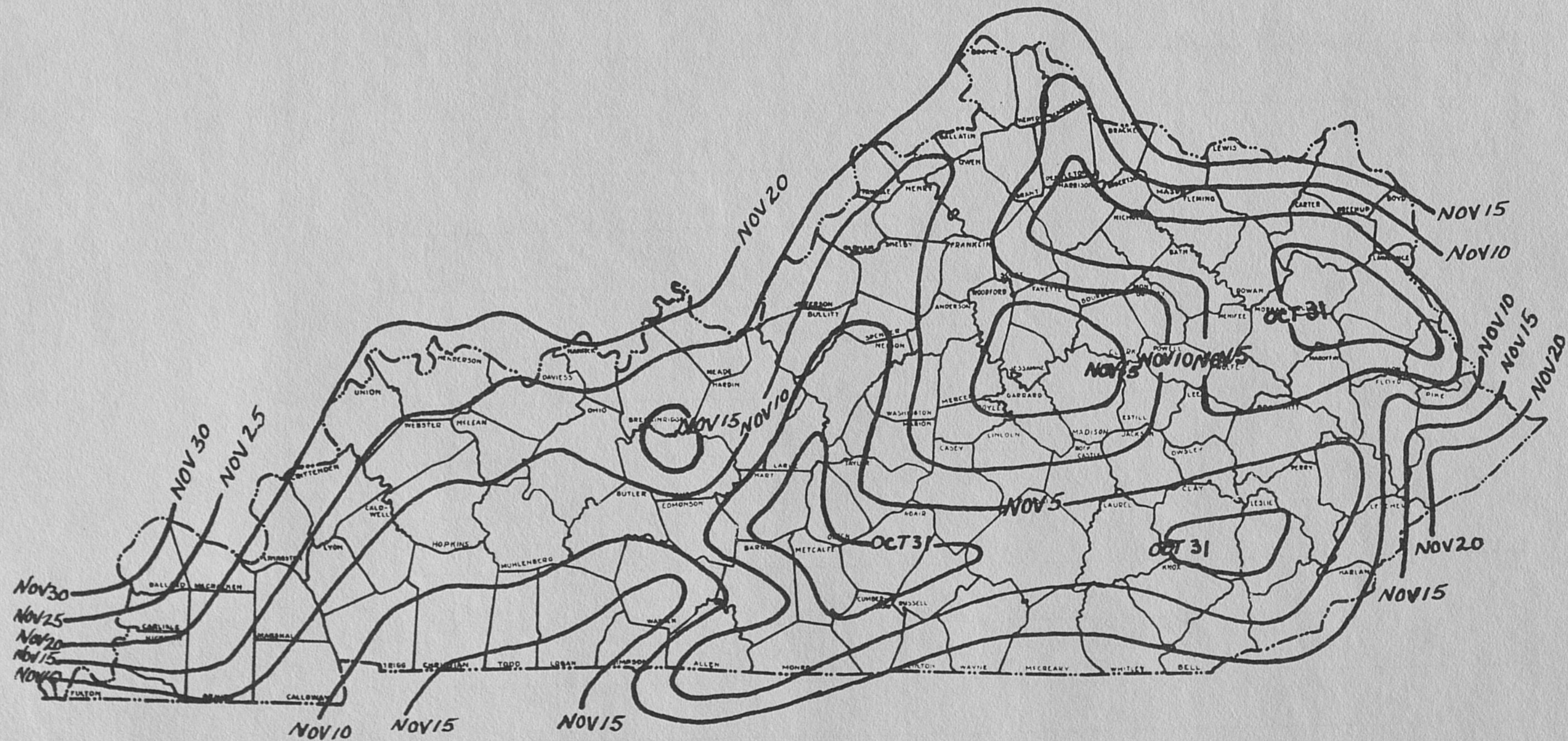
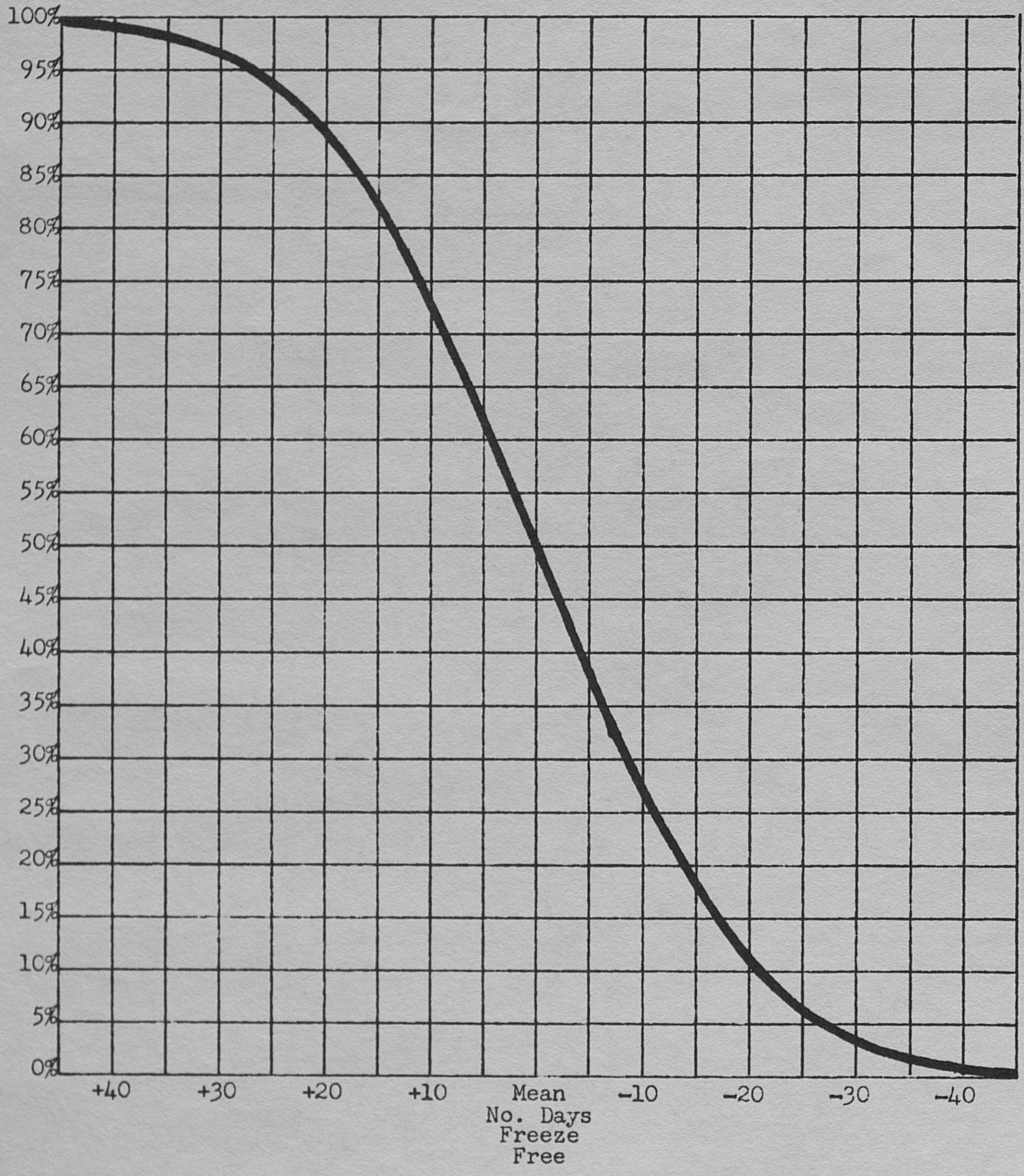


Fig. 6.—Average date of the first occurrence of 24° or lower in the fall.



Graph 7.—Curve to determine the risk that the period from the last occurrence of 32° or lower in spring to the first light freeze in the fall will be less than any given number of days.

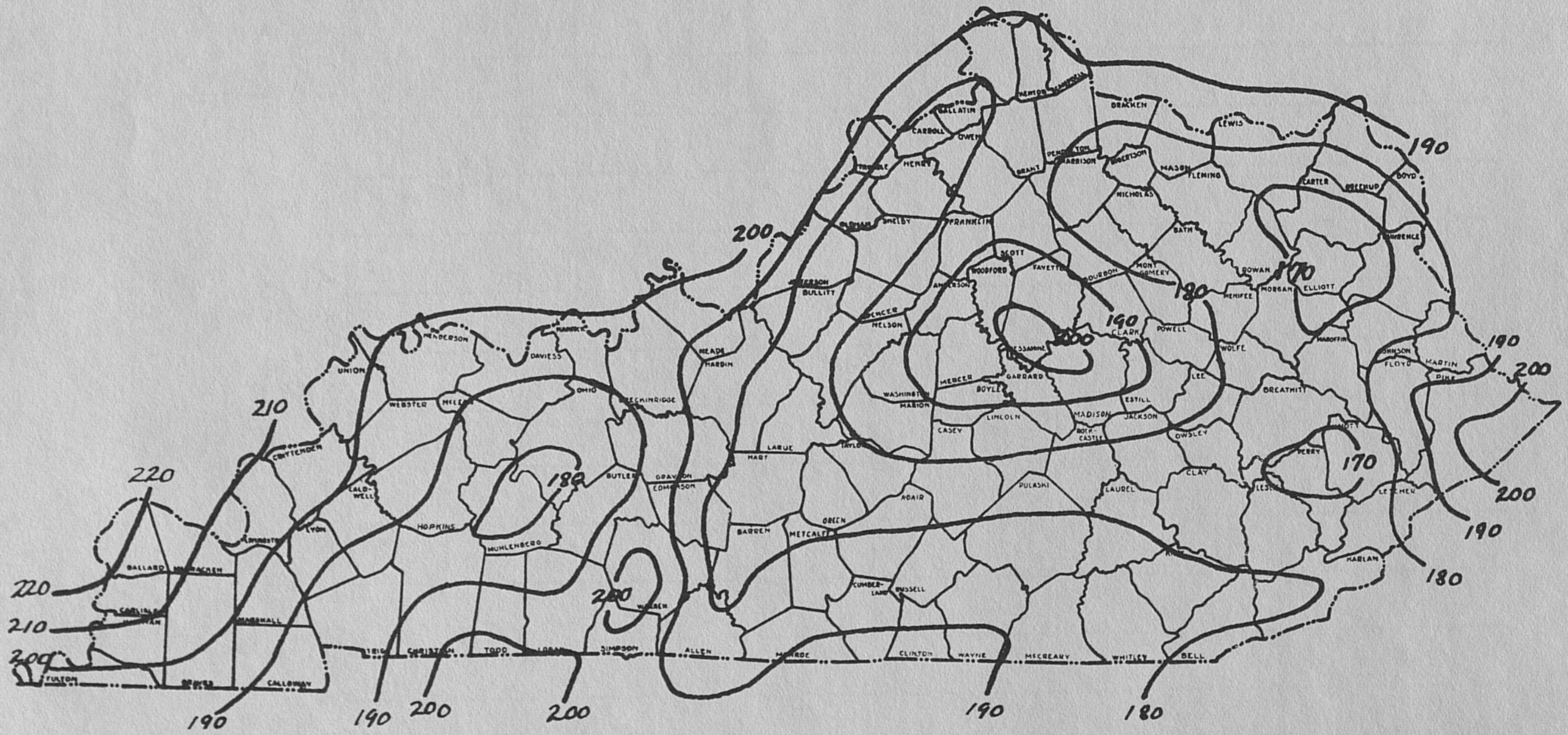
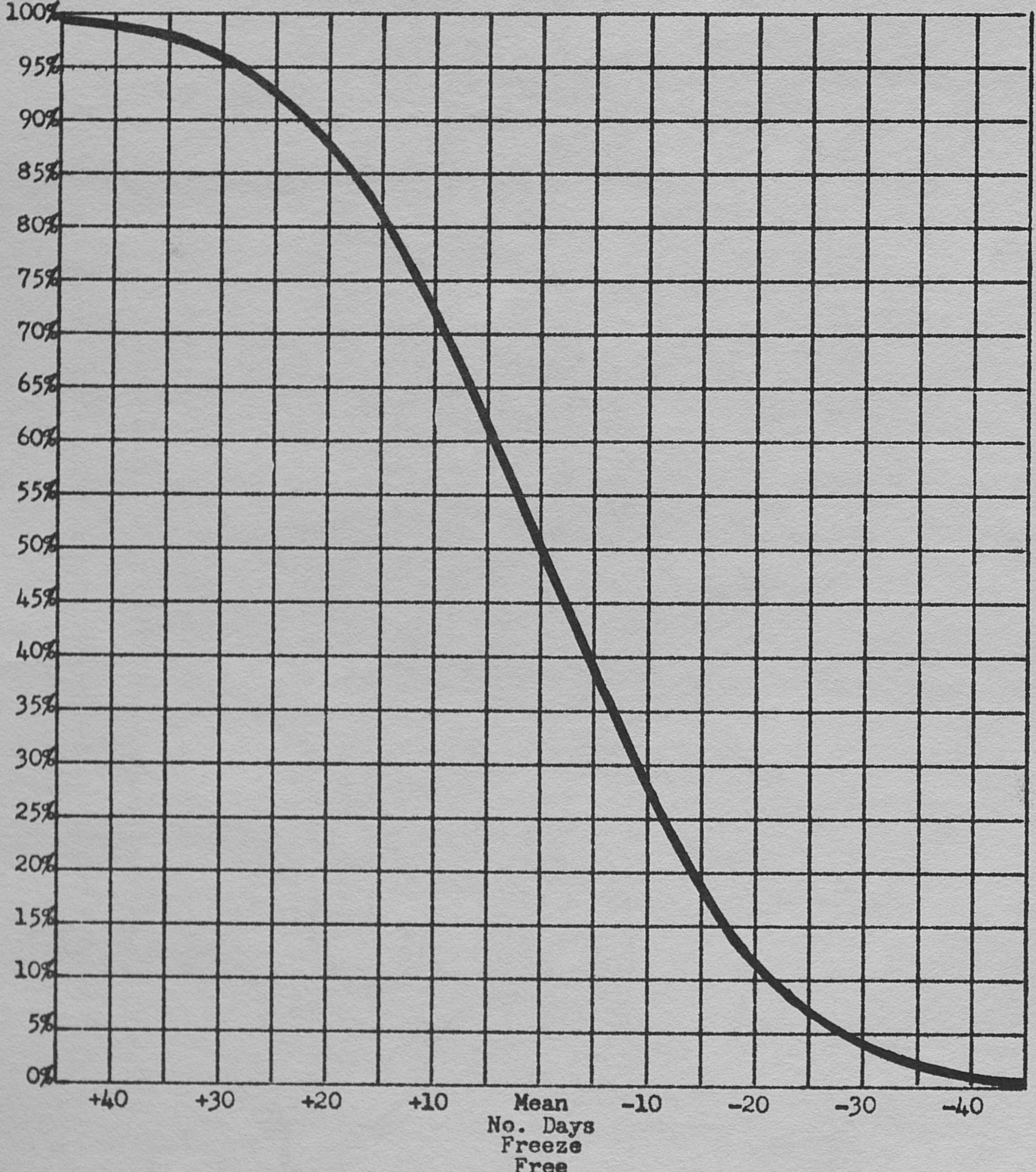


Fig. 7.—Average number of days from the last occurrence of 32^{o} or lower in the spring to the first occurrence of 32^{o} or lower in the fall.



Graph 8.—Curve to determine the risk that the period from the last occurrence of 28° or lower in the spring to the first occurrence of 28° or lower in the fall will be less than any given number of days.

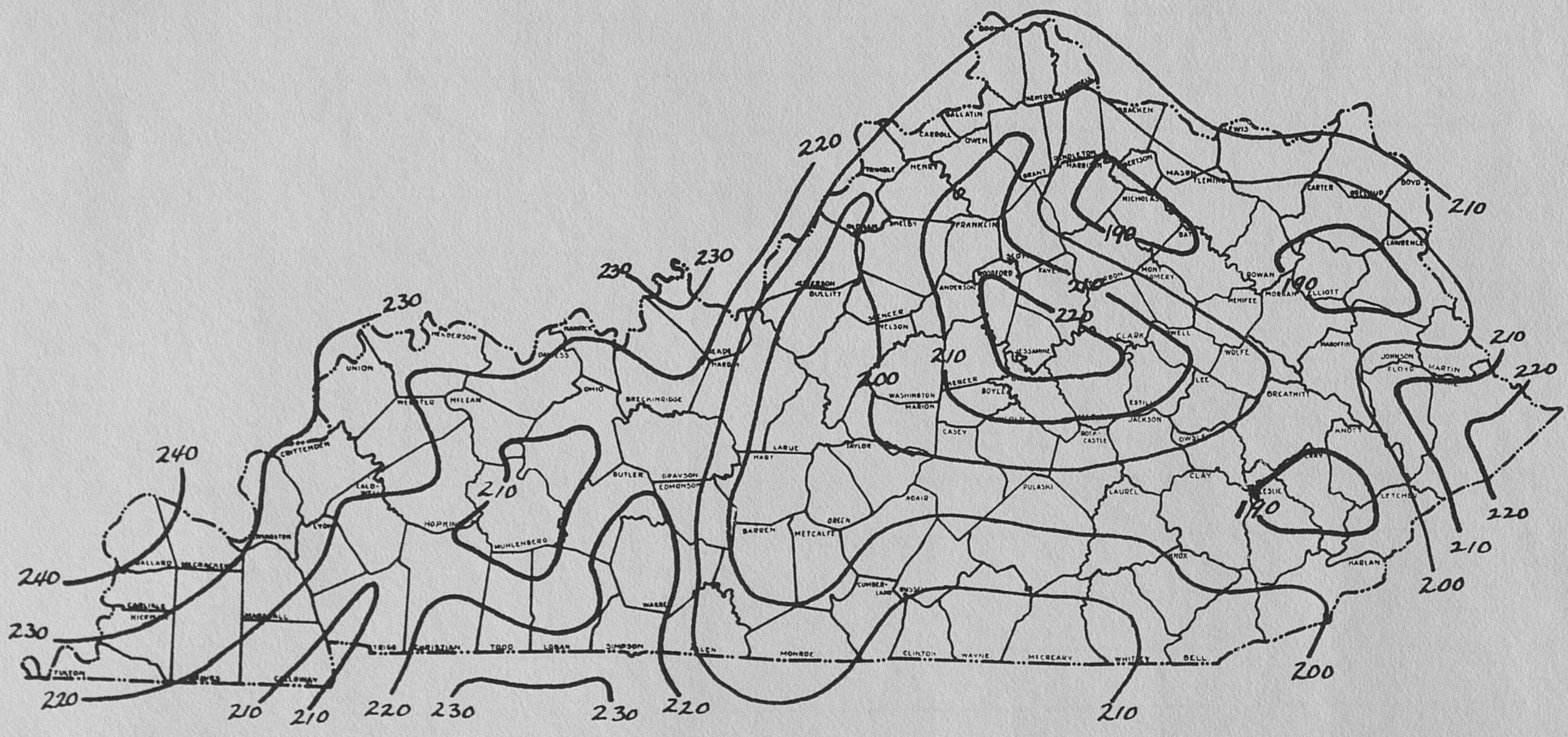
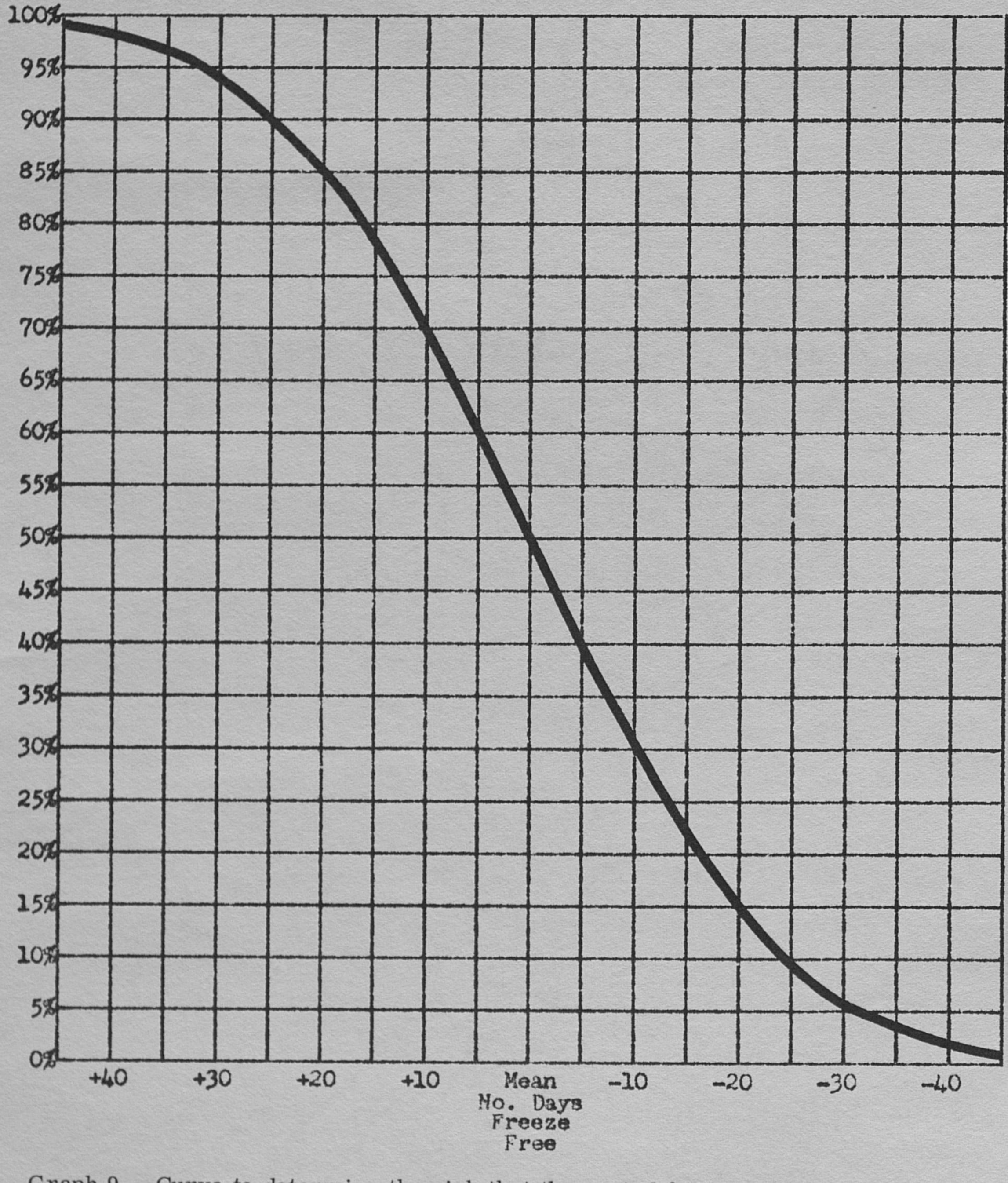


Fig. 8. —Average number of days from the last occurrence of 28^{o} or lower in the spring to the first occurrence of 28^{o} or lower in the fall.



Graph 9. —Curve to determine the risk that the period from the last occurrence of 24° or lower in the spring to the first occurrence of 24° or lower in the fall will be <u>less</u> than any given number of days.

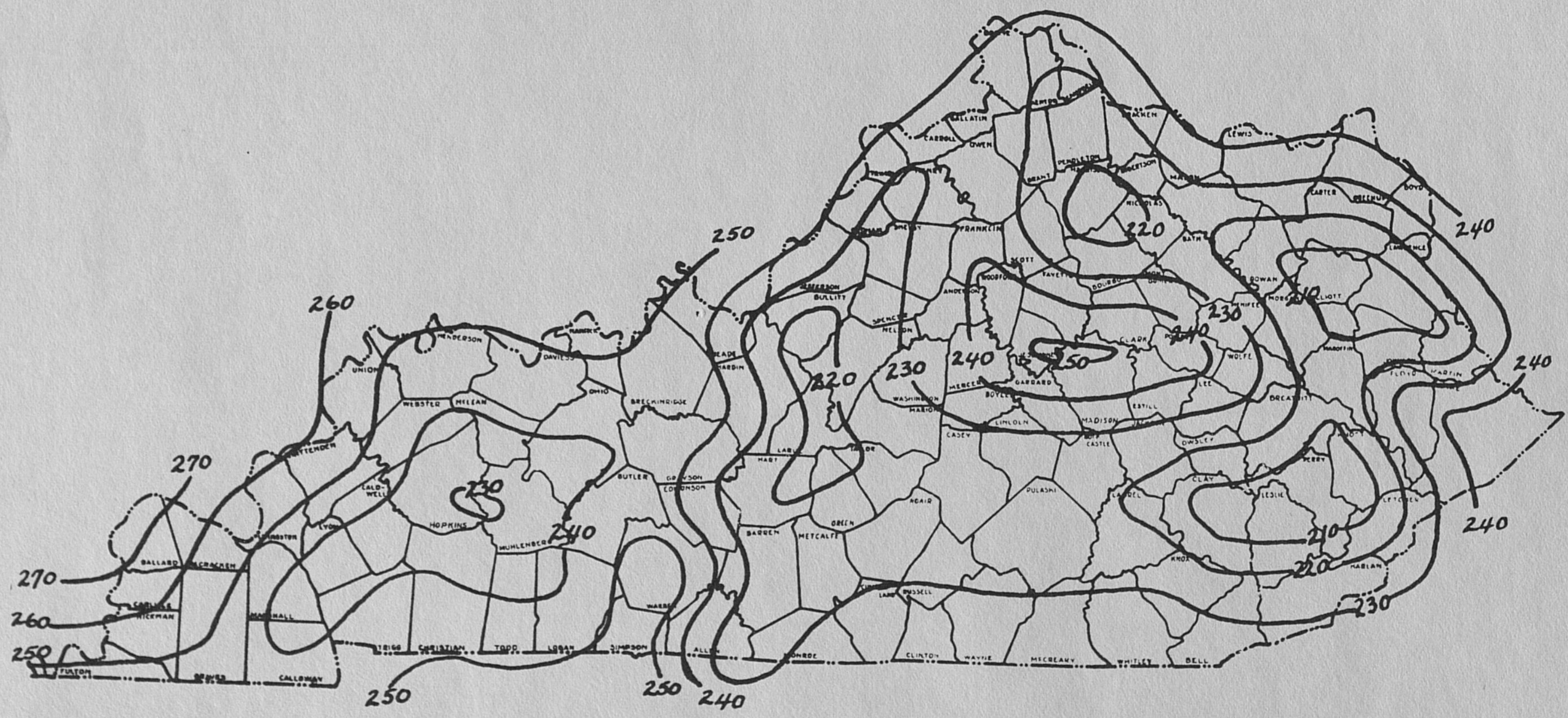


Fig. 9.—Average number of days from the last occurrence of 24° or lower in the spring to the first occurrence of 24° or lower in the fall.

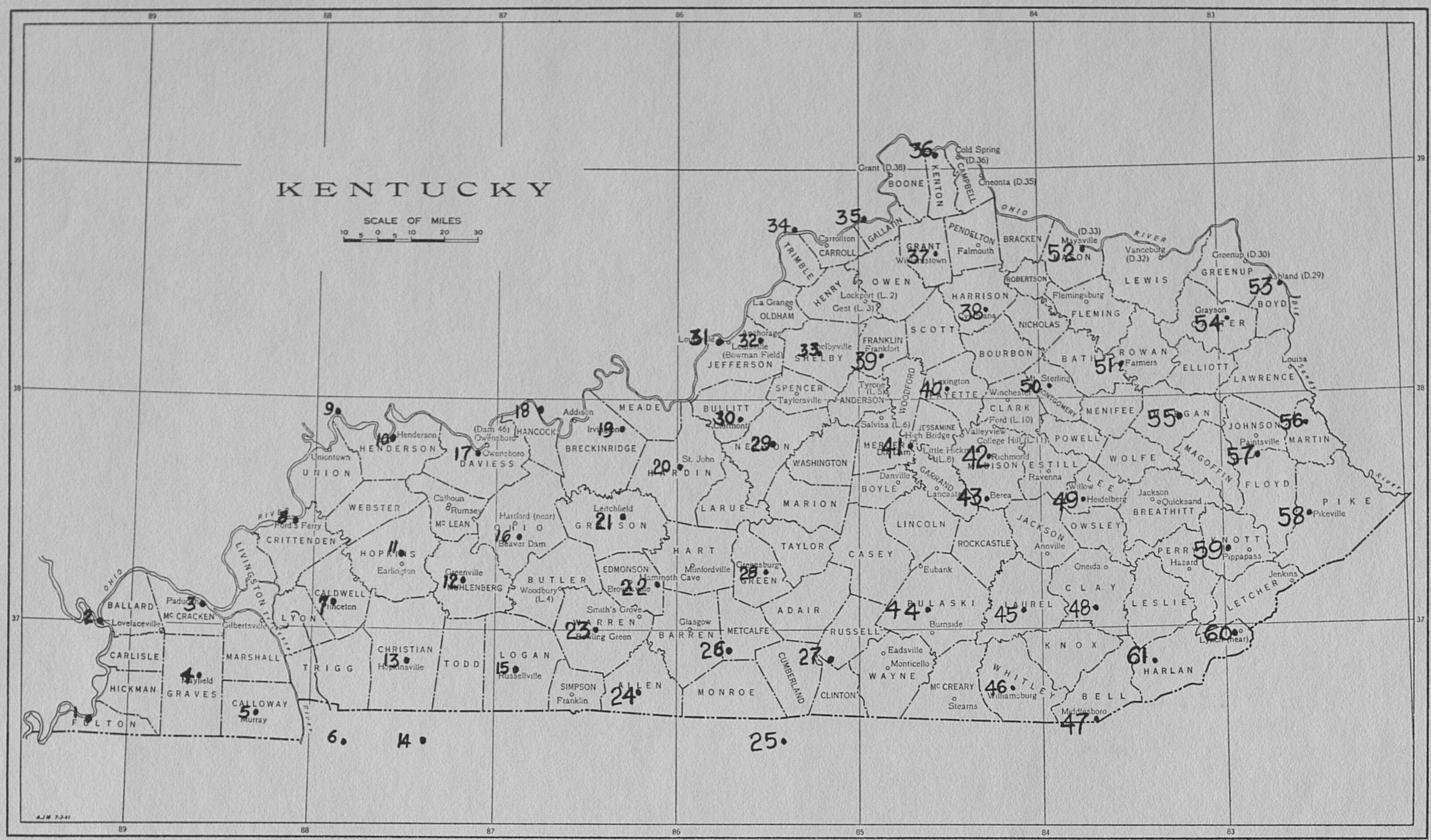


Fig. 10. —Stations from which temperature records were used.

(Numbers are identified on opposite page.)

STATIONS FROM WHICH TEMPERATURE RECORDS WERE USED

1. Hickman
2. Cairo, Ill.
3. Paducah
4. Mayfield
5. Murray
6. Dover, Tenn.
7. Princeton
8. Fords Ferry
9. Mt. Vernon, Ind.
10. Henderson
11. Madisonville
12. Greenville
13. Hopkinsville
14. Clarksville, Tenn.
15. Russellville
16. Beaver Dam
17. Owensboro
18. Tell City, Ind.
19. Irvington
20. St. John
21. Leitchfield
22. Mammoth Cave
23. Bowling Green
24. Scottsville
25. Dale Hollow, Tenn.
26. Summer Shade
27. Wolf Creek
28. Greensburg
29. Bardstown
30. Clermont
31. Louisville
32. Anchorage
33. Shelbyville
34. Madison, Ind.
35. Markland, Ind.
36. Covington
37. Williamstown
38. Cynthiana
39. Frankfort
40. Lexington
41. Dix Dam
42. Richmond
43. Berea
44. Somerset
45. London
46. Williamsburg
47. Middlesboro
48. Manchester
49. Heidelberg
50. Mt. Sterling
51. Farmers
52. Maysville
53. Ashland
54. Grayson
55. West Liberty
56. Inez
57. Dewey Dam
58. Pikeville
59. Hindman
60. Benham
61. Baxter

Daily forecasts are issued by the U.S. Weather Bureau for all of Kentucky. These forecasts contain detailed temperature forecasts and should be used as day-to-day guides in planning for protection against late spring or early fall freezes. For longer-range planning purposes, five-day forecasts are issued three times each week on Monday, Wednesday, and Friday. These provide, in more general terms, temperature and precipitation forecasts for the up-coming five-day period and may be used to plan farming operations for that time.

Twice each month, on the first and fifteenth, 30-day forecasts are issued which give an estimate of the average rainfall and temperature for the next 30 days.

It should be kept in mind that nearly always there are changes in the weather every few days, sometimes of a sudden and severe nature. Notice of these changes is widely disseminated in the daily forecasts and in occasional warnings.

This study of Kentucky freeze data should prevent farmers from taking undue risk with regard to freeze-susceptible crops. However, if a farmer, owing to his own economic situation, is willing to take a chance on an early planting or late harvest date, this study will at least answer his question, "what are my chances of success?"

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