NOAA Technical Memorandum NWSTM CR 38

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Weather Service

SNOW FORECASTING FOR SOUTHEASTERN WISCONSIN

Rheinhart W. Harms

CENTRAL REGION
KANSAS CITY, MO
NOV. 1970

NOAA TECHNICAL MEMORANDUM*

Central Region Subseries

The Central Region Subseries provides a medium for quick dissemination of material not appropriate or not yet ready for formal publication. Material is primarily of regional interest and for regional people. References to this series should identify them as unpublished reports.

1 Precipitation Probability Forecast Verification Summary Nov. 1965 - Mar. 1966.

2 A Study of Summer Showers Over the Colorado Mountains.

3 Areal Shower Distribution - Mountain Versus Valley Coverage.

4 Heavy Rains in Colorado June 16 and 17, 1965.

5 The Plum Fire.

6 Precipitation Probability Forecast Verification Summary Nov. 1965 - July 1966.

7 Effect of Diurnal Weather Variations on Soybean Harvest Efficiency.

8 Climatic Frequency of Precipitation at Central Region Stations.

9 Heavy Snow or Glazing.

10 Detection of a Weak Front by WSR-57 Radar.

11 Public Probability Forecasts.

12 Heavy Snow Forecasting in the Central United States(An Interim Report).

13 Diurnal Surface Geostrophic Wind Variations Over The Great Plains.

14 Forecasting Probability of Summertime Precipitation at Denver.

15 Improving Precipitation Probability Forecasts Using the Central Region Verification Printout.

16 Small-Scale Circulations Associated With Radiational Cooling.

17 Probability Verification Results (6-Month and 18-Month).

18 On The Use and Misuse Of The Brier Verification Score.

19 Probability Verification Results (24 Months).

20 Radar Depiction of the Topeka Tornado.

21 Wind Waves On The Great Lakes.

22 Seasonal Aspects of Probability Forecasts: 1. Summer.

23 Seasonal Aspects of Probability Forecasts: 2. Fall.

24 The Importance of Areal Coverage In Precipitation Probability Forecasting.

25 Meteorological Conditions As Related To Air Pollution, Chicago, Illinois, April 12-13, 1963.

26 Seasonal Aspects of Probability Forecasts: 3. Winter.

27 Seasonal Aspects of Probability Forecasts: 4. Spring.

28 Minimum Temperature Forecasting During Possible Frost Periods At Agricultural Weather Stations In Western Michigan.

(Continued on back inside cover)

*Prior to T.M. 37 this series was labeled as the ESSA Technical Memoranda.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

NOAA Technical Memorandum NWSTM CR-38

SNOW FORECASTING FOR SOUTHEASTERN WISCONSIN

Rheinhart W. Harms

CENTRAL REGION

KANSAS CITY, MISSOURI
November 1970

SNOW FORECASTING FOR SOUTHEASTERN WISCONSIN

Rheinhart W. Harms
WSO, Milwaukee, Wisconsin

1. INTRODUCTION

There are several types of winter storms which can produce very heavy snow in southeastern Wisconsin and the lower Great Lakes region. Two of these appear to be readily recognizable in their early stages of development. To facilitate discussion by forecasters these have been designated by the popular names, "Panhandle Hook" and "Alberta Clipper". A third type, the "Lower Mississippi" storm, is more erratic and considerably more difficult to forecast, as are the "Westerly Storms" which travel south of Wisconsin and generally begin with snow but usually change to freezing rain and then rain or drizzle.

This paper presents a model for each of these types of storms, and a snow depth forecasting scheme with modifications for types where appropriate. The models are highly useful in training new people on station. They also serve as a seasonal refresher and guide for all on station as well as providing quick estimates of possible snow accumulation once the storm track is forecast. The models are based on a file of weather charts pertinent to heavy snows (4 inches or more) in Wisconsin, which has been accumulated at WSO, Milwaukee since the winter of 1961-62. At present, the file contains data on 32 storms including surface and upper-air charts, precipitable water and average relative humidity charts, snow accumulation and storm track information. The file has been arranged in four sections according to direction from which these storms approach, i.e., northwesterly, westerly, southwesterly and southerly. They are discussed in the order of importance.

2. SOUTHWESTERLY STORMS - The "Panhandle Hook"

The "Panhandle Hook" has been so named because the configuration of its track resembles a hook. It might be defined as a storm which organizes in the vicinity of the Oklahoma Panhandle, moves slowly southeastward, picks up Gulf moisture and then recurves and accelerates somewhat as it heads northeastward toward the lower Great Lakes region. Cold air is fed into this type of storm from a surface High which is moving slowly eastward north of Lake Superior. During the winter and early spring months these storms can be particularly disastrous to Milwaukee and the Chicago metropolitan areas as the high water content of their snowfall makes plowing and shoveling difficult. They frequently produce 10 inches or more of snow in the lower Great Lakes region. In most cases the storm starts to organize under an innocuous low-amplitude 500 mb flow but with relatively strong southwesterly windflow over the western Great Lakes. A closed Low at 500 mb usually develops in the area from Oklahoma to southwestern Iowa, with increased positive vorticity advection (PVA), as the storm continues to move eastward.

In the study of Illinois snowstorms, Changnon (1) has determined that 45% of the storms producing heavy snow in Illinois have originated in Colorado. This would include the Panhandle Hook type, which generally has its beginning near southeastern Colorado. Petterssen (2) has shown, in a study of winter storms for the period 1899 to 1939, that a maximum of cyclogenesis occurs in the lee of both the Colorado and Alberta mountain ranges (Figure 1). An area of cyclogenesis is also shown over Lake Michigan and lower Michigan, where the relatively warm waters of this rarely-frozen-over lake tend to further deepen and perhaps retard the storms in this area.

Thus, the Panhandle Hook storms begin in one of the major cyclogenetic areas and move to another cyclogenetic area.

In constructing a model of this type of storm it has been found that the heaviest snow generally falls 120-140 nautical miles to the left (roughly northwest) of the track of the surface Low center. This appears to be about the same as in (6). This means that Lows passing over Goshen or South Bend, Indiana, produce the heaviest snowfalls in Milwaukee, whereas those passing over Indianapolis precipitate heaviest in the Chicago region. The January 26-27, 1967 storm, which precipitated the record 23-inch, city-paralyzing snowfall in Chicago, was a Panhandle Hook type which moved slightly south of Indianapolis, putting Chicago and lower Michigan in the heavy snow belt about 130 nautical miles from the track of the surface Low. Milwaukee, 180 nautical miles from the track, received only 6.2 inches of snow and Cedarburg, 22 nautical miles north-northwest of Milwaukee, received only a trace.

The average water content of the Panhandle Hook type of storm is higher than most due to the fact that its slow southeasterly movement for a time allows Gulf moisture to advance well east and north of the storm center. Precipitable water in the surface to 500 mb layer will frequently reach one inch or more in the moist tongue across northern Illinois in advance of the Low center. In precipitation, a snow-water ratio of about 8 to 1 appears to be about average for these storms.

Examination of 17 cases with this type of storm track indicates that they travel from their recurvature longitude in central Oklahoma to the longitude of central Indiana at an average speed of 27 knots or 31 MPH, and snow generally begins in Milwaukee when the surface Low reaches central Missouri (see Figure 2). In the lower Lake Michigan area precipitation may start as rain; however, it will generally change to snow as the surface High moving southeastward from central Canada begins to move eastward north of Lake Superior, advecting colder air into the area.

During the early stage of the Panhandle Hook storm it is usually difficult to properly forecast whether rain or snow will occur later in southeastern Wisconsin. This is because the 850 mb temperature of 0°C (the prime critical temperature for rain-snow delineation) is generally close to the southern tip of Lake Michigan at this time. The combined use of several critical parameters, such as surface temperature (generally 27°F to 35°F), 1000-500 mb thickness values (5410 meters), 500 mb temperature (-19°C and colder), and the 850 mb temperature (-4°C), is important in determining the probability of heavy snow (3). In general, the 500 mb isotherm will remain nearly stationary in areas where precipitation is occurring, or move with about 50% of the wind component normal to the isotherm in the winter months if precipitation is not occurring (4).

3. FORECASTING SNOW DEPTHS

Factors which determine the amount of snowfall in southeastern Wisconsin from a given storm are:

1. The path of the surface (sea-level) Low center.
2. The speed (or change in speed) of movement of the surface Low.
3. The precipitable water available along the storm track.
4. The intensity or change in intensity of the system.
5. Temperature, particularly at and near the surface.
6. The distance from the Lake Michigan shoreline.

Snowfall amounts tend to be heavier adjacent to Lake Michigan than away from the Lake due to the increased heat and moisture added to the cold air, and to increased frictional convergence as the air moves from water to land (5). The fluffiness of snow (the snow-water ratio) and the amount of melting depend on temperature. Examination of past records of Milwaukee heavy snows indicates that 70% occur with surface temperatures between 27°F and 35°F (Figure 4).

In general, it can be stated that the rapidly deepening (intensifying) and very deep surface Lows will distribute the snow over a wider area, with light snow occurring sometimes more than 250 miles to the left of its track. A model constructed from snow distribution patterns is shown in Figure 3. While this model was developed from the Panhandle Hook type of storm, due to its high frequency of occurrence as a heavy snow producer (17 of 32 storms investigated), it has been found to be generally applicable to the Alberta Clipper type with proper modification of the precipitable water area (see text under each type of storm). It should be used only in a general way with the lower Mississippi type of storm and is not intended for use with Westerly storms. The procedure for using the model with a Panhandle Hook is as follows:

1. Forecast the maximum amount of precipitable water (surface to 500 mb) expected along the storm track in the northern half of Illinois. (For the Alberta Clipper extend the area to include northeast Iowa.)

2. Multiply the forecast precipitable water by 10 to approximate the greatest depth of snowfall (in inches) along the axis of heaviest snow. This axis generally lies 120 to 140 nautical miles to the left (roughly northwest) of the track of the surface Low center, depending on storm intensity and precipitable water available (see Figure 3).

3. Plot past positions of the surface Low center, and extrapolate

future positions and track location according to 500 mb flow, pressure tendencies and guidance information.

4. Lay out a forecast band of snow based on the curves shown on Figure 3.

5. Use Figure 2 to approximate the time of snow start in Milwaukee.

6. Bracket the objective snow accumulation estimate with forecast amounts which appear most reasonable for the storm situation. Suggested forecast values (in inches) are:

1 or 2	4 or more
1 to 3	4 to 8
2 to 4	6 or more
3 to 6	6 to 12

4. NORTHWEST STORMS - The "Alberta Clipper"

The "Alberta Clipper" has been so designated because of the speed it travels across the Dakotas enroute to the lower Great Lakes. It might be defined as a storm which has its early beginning in the cyclogenic region lee of the Alberta range (Figure 1), and, once organized, it accelerates to 40 or 50 knots in its southeastward movement across the Dakotas, gradually decelerating to about 20-25 knots in an eastward curve across northern Illinois and northern Indiana (Figure 2). One will frequently organize a day or two after a Panhandle storm, moving rapidly southeastward in the strong 500 mb windflow established in its wake. The synoptic features include a deep, slowly-moving trough at 500 mb over the western Great Lakes region and a surface High which drives rapidly southeastward across eastern Montana and the western Dakotas behind the storm.

Snow from these storms is usually very dry and quite fluffy, with about a 20-1 snow-water ratio over most of the state, possibly reaching

40-1 along the western shores of Lake Michigan. As in the Panhandle Hook type, heaviest snow from the Alberta Clipper storm also occurs about 120-140 nautical miles left of the track. The snow-depth scheme developed from Panhandle storms is useful in estimating snow distribution from an Alberta Clipper type. The extra fluffiness of the snow is apparently a compensating factor which makes up for the shorter snow-occurrence time at a point due to the higher speed of the Low. In forecasting for southeastern Wisconsin, precipitable water should be forecasted along the track in advance of the Low in an area encompassing northern Illinois and northeastern Iowa.

These storms generally produce considerable additional snow as Lake snow near Lake Michigan due to the quite cold air existent over the Lake north of the storm track. Rothrock (5) points out that the best single parameter correlating with significant Lake snows is the temperature difference between the lake water and 850 millibars. A difference of 13°C approximately equals the dry lapse rate in this layer, and his investigation reveals that this was equaled or exceeded in 97% of the cases of significant snow occurrence. Snow amounts estimated from the precipitable water method should be increased by 100% or more in the on-shore wind area near Lake Michigan with 850 mb temperatures of -15°C or lower near the southern tip of the Lake.

Snow will generally begin in Milwaukee after the storm center passes east of a line from Rochester, Minnesota, to Omaha, Nebraska, ending except for perhaps a few flurries, after it reaches central Ohio (Figure 2). Snow from this type of storm is relatively easy to plow and shovel due to its dryness; however, drifting can be a problem with winds of moderate or strong intensity and it is sometimes necessary to issue travelers' warnings when high wind conditions cause restricted visibility from the blowing snow.

5. SOUTHERLY STORMS - "Lower Mississippi" Type

This type of storm might be defined as one which organizes in the western Gulf of Mexico or along the Texas Gulf coast (Figure 1) and moves roughly northward over the lower Mississippi River region toward the western Great Lakes. These storms are difficult to forecast, since the direction of their track is highly unpredictable north of the Ohio River, as they will sometimes veer northeastward across Lake Huron or perhaps take a north-northwesterly track across western Lake Superior. Lower Mississippi type storms generally develop when a major trough becomes established at 500 mb in the central United States with a blocking ridge in the eastern United States. As cold air advects into the upper trough, a Low center aloft will likely develop in the upper plains with a rapidly moving short wave trough to the south which accompanies the surface Low on its northern track to the Great Lakes.

Surface pressure tendencies are perhaps most useful in anticipating the movement of the storm center for a 12-hour period, particularly if the 3-hour falls are great (4.0 mb or more). Prognostication of the 850 mb Low (6) has been helpful; however, the uncertainty of these storm tracks requires close scrutiny of 3-hourly surface charts, and occasional plotting of an intermediate chart from hourly aviation reports. These storms invariably have high water content due to their Gulf origin. Many of them average about 6 to 1 snow-water ratio, which makes plowing difficult. They are generally relatively warm, with 850 mb temperatures near the storm center very close to the freezing point.

Although the heavy snow band generally centers approximately 120-140 nautical miles to the left of the track, rain is a distinct possibility along the track due to the rapid advection of warm air into the storm at low levels. This fact, coupled with the relative unpredictability of the storm track, makes use of a storm model somewhat uncertain and prediction of snow amounts should be governed accordingly.

6. WESTERLY STORMS

A large percentage of these storms originate in the cyclogenetic region in the lee of the Colorado Mountain range (1,2), and although they sometimes produce excessive snowfall in the upper plains region west of the Mississippi River, objective forecasting of snow amounts has not been very successful for southeastern Wisconsin. The eastward movement of these storms is sometimes quite erratic as they will frequently change direction, stall, or accelerate, depending on the orientation with respect to the 500 mb trough or Low center. Each storm is a special case which requires continuous monitoring of synoptic reports and guidance material.

A major problem with this type of storm is the change in precipitation type as it progresses eastward because of the low level warming that takes place with the influx of Gulf air into the system. Also, heavy snow accumulations west of the Mississippi River (upslope a major factor) tend to induce pessimism in the forecaster in the lower Lake Michigan area causing him to forecast a heavy snow which may not materialize. A case in point was the blizzard of March 2-5, 1966, which produced 15-25 inches of snow in the Dakotas with 12-15 foot drifts, and 10-15 inches of snow in much of Minnesota and extreme northwestern Wisconsin. The storm veered southeastward from southern Minnesota across northern Illinois and northern Indiana producing less than one inch of snow in Milwaukee.

7. ISSUANCE OF STATEMENTS, WATCHES AND WARNINGS

Since the forecast of the storm track is so critical in estimating snow amounts, it is well to delay the issuance of warnings until the storm is well enough organized that its direction and speed of movement are fairly certain. However, meaningful statements can usually be written about Panhandle and Alberta storms when they are 18-24 hours away from their closest proximity to Milwaukee, and watches can be issued when the event is expected in the third period of the forecast. Warnings in these two cases should generally be initiated in the second period of the forecast.

Although the tracks of the Lower Mississippi and Westerly type storms are more erratic, it is possible to write statements, with about the same lead times as above, which are useful to travelers and the general public if they are not too specific. Watches and warnings may have to slip to the second and first periods of the forecast with these storm types. Figure 2 shows a peripheral area which should be used as guidance in writing preliminary weather statements and issuing watches about approaching storms. The inner area shown should be considered as an area where warnings and additional statements can be written, as more definite estimates of snow accumulation can be made.

Advisories should be provided the Street Sanitation Department whenever snow is anticipated which will cause slippery driving conditions, in order that proper planning for salting and plowing operations can be made. Plowing is generally done with a "snow emergency" which has been arbitrarily defined as accumulations of 3 inches or more. The cost of snow removal has been estimated at approximately $20,000 per inch on a seasonal basis. Heavy, wet snows from the southerly storms are more costly to remove than the dry, fluffy snows which arrive from the northwest storms. An estimate of the snow-water ratio is useful information for sanitation officials in discussing the approaching storm. In general, the deeper snows are less common with surface-observed temperatures of 25 degrees or less (Figure 4). Temperature outlooks should be provided to municipal and airport users when pertinent to the salting operation, as the efficiency of salting varies directly with temperature (7). Calcium chloride, considerably more costly, is mixed with rock salt at temperatures below 15°F.

8. SUMMARY

The accuracy of forecast snow accumulation for a particular area depends to a great extent upon the predictability of the track of the associated surface Low center. Of four basic track types which produce heavy snows in southeastern Wisconsin and the lower Great Lakes region, two can be readily recognized in their early stage of development and their deviations are less pronounced and less common. These have been labeled the "Panhandle Hook" and the "Alberta Clipper" for easy identification. "Lower Mississippi" and "Westerly" type storms are highly unpredictable, not only because of the difficulty in forecasting their track and speed of movement, but because of the likelihood of change in precipitation type or amount.

Models constructed of various types of storms indicate most precipitate their heaviest snow 120 to 140 nautical miles to the left of the track of the surface Low depending on the intensity of the storm and the precipitable water available along the storm track. Since the model for the Panhandle Hook storm appears to be most predictable and with less frequent deviations, a method of forecasting snow accumulation based on this type is suggested. Snow amounts in the heavy snow band correlate very well with the forecast precipitable water in advance of the storm along the storm track at a

10 to 1 ratio. Precipitable water forecast for the area in the northern half of Illinois is used with the Panhandle storm. It has been found that the method works reasonably well with the Alberta storm provided the precipitable water area is extended to include northeastern Iowa. It is not recommended for Lower Mississippi or Westerly storms. Since snow measurements vary considerably in a given area, objective values should be bracketed by amounts which appear reasonable for the storm situation. These values have been suggested.

It is believed the method can be adapted at other locations along the Great Lakes provided the proper area is selected for forecasted precipitable water and by study of the snow distribution patterns which may vary as the result of local topographical features. Undoubtedly, much similarity exists in snowstorm models universally due to the physical laws which govern the formation of snow. Most certainly the model used for southeastern Wisconsin will be improved with the input of additional data.

ACKNOWLEDGEMENTS

The author is appreciative of the ideas and suggestions contributed by the forecasters at WSO, Milwaukee which have been of use in writing this paper. Special thanks are given to Mr. Rolland F. Wendlick and Mr. Ernest E. Sauve for their assistance in data reduction, to Miss Alice M. Heuer for her stenographic work, and to Mr. Lawrence A. Hughes, Regional Meteorologist, for his editorial assistance and suggestions.

REFERENCES

1. Changnon, Jr., S. A., 1969: Climatology of Severe Winter Storms in Illinois. Bulletin 53, State of Illinois, Illinois Water Survey.

2. Petterssen, Sverre, 1956: Motion and Motion Systems, Weather Analysis and Forecasting, 2nd Edition, Vol. 1, p. 267

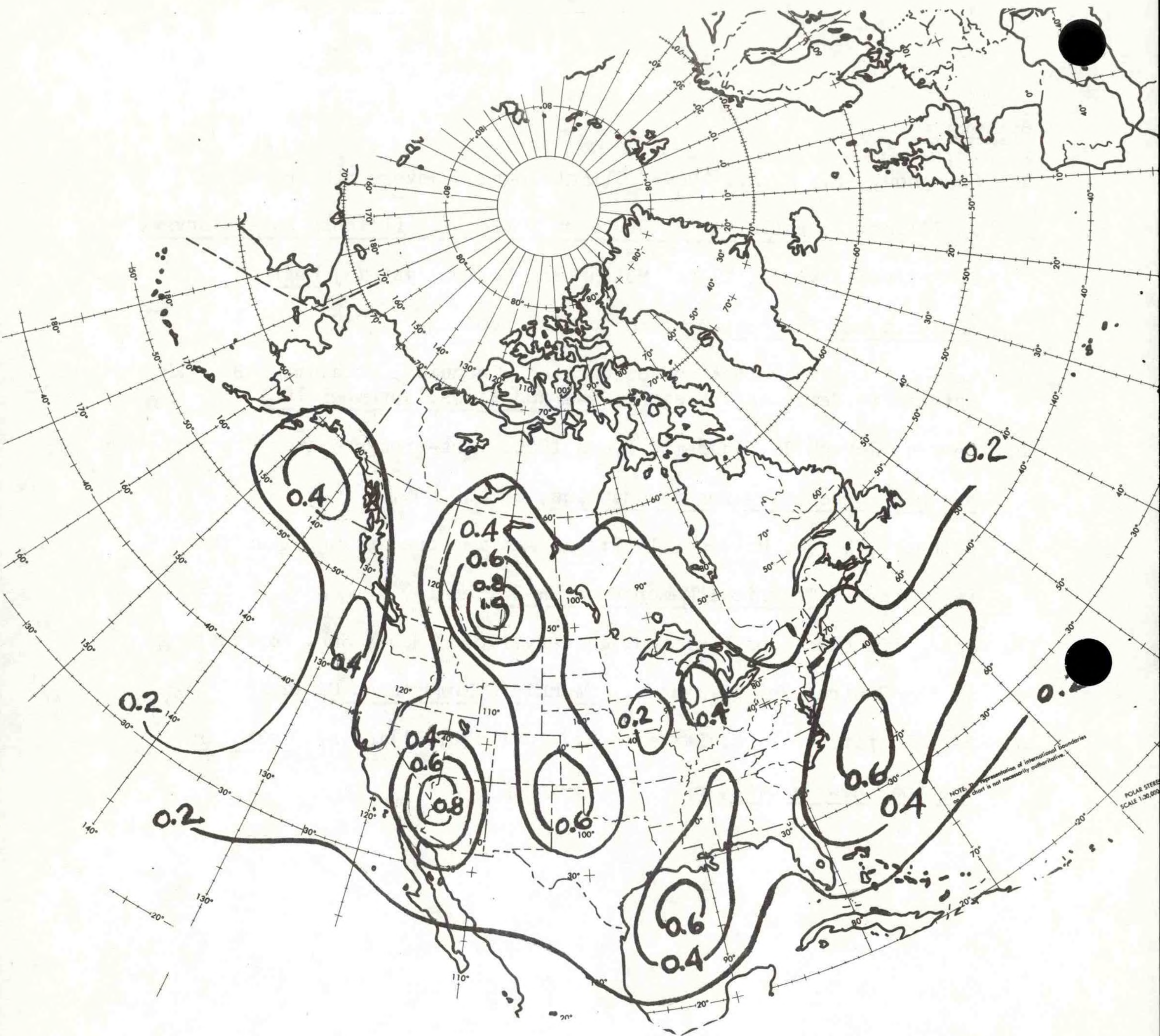
3. Comments on Precipitation Forecasting, Technical Attachment B, CRH Scientific Services Division, News and Views, November 1969

4. George, Joseph J., Academic Press 1960: Pre-trough Winter Precipitation. Weather Forecasting for Aeronautics, pp 400-406.

5. Rothrock, H. J., November 1969: An Aid in Forecasting Significant Lake Snows. Technical Memorandum CR-30, pp 1-5

6. Scientific Services Division, January 1967: Heavy Snow Forecasting in the Central United States. Technical Memorandum CR-12

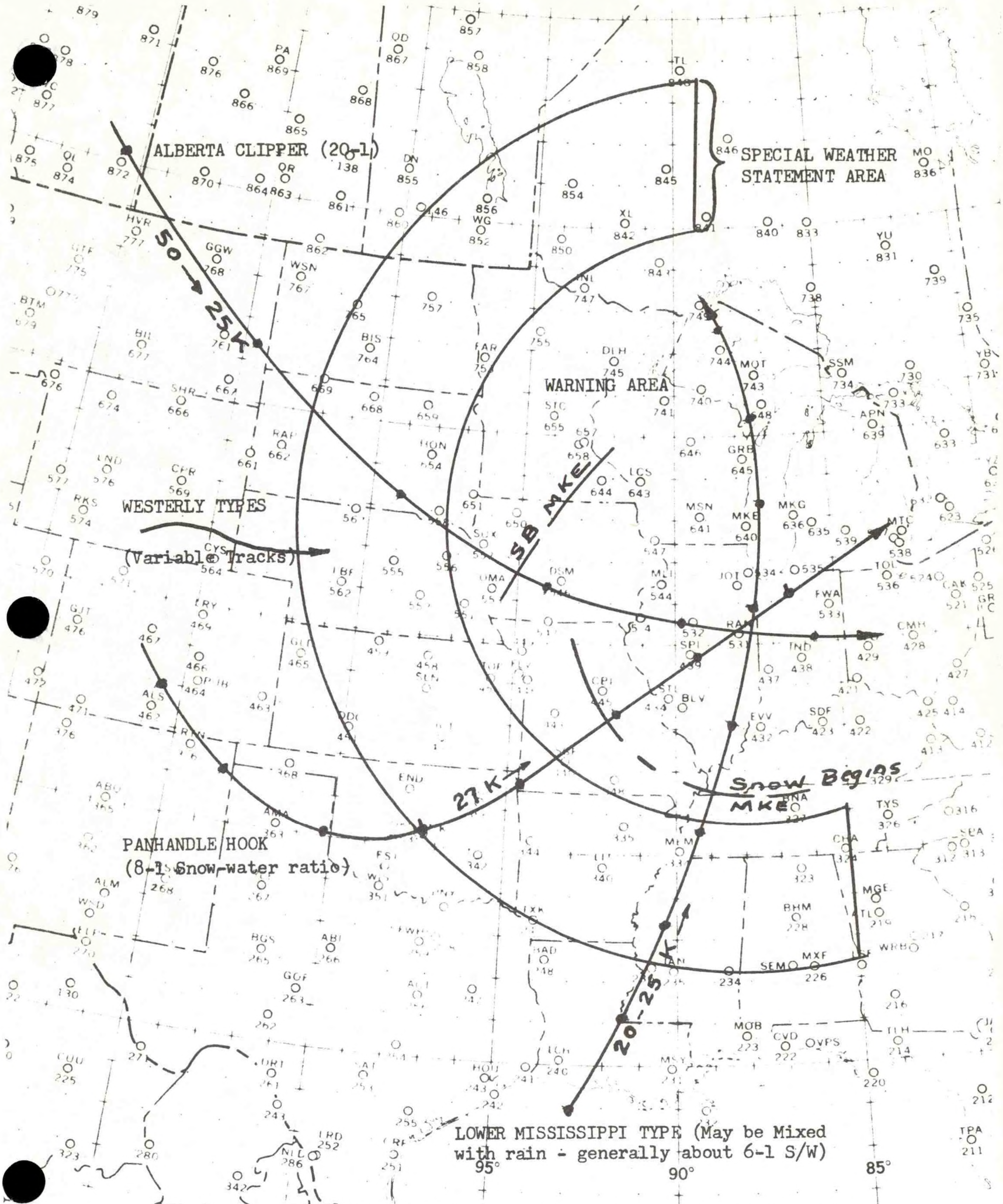
7. Salt Institute, 33 N. La Salle St., Chicago, Illinois. Salt for Ice and Snow Removal, p 5



PERCENTAGE FREQUENCY OF OCCURRENCE
OF CYCLOGENESIS IN SQUARES OF 100,000
Km^2 IN WINTER (1899 to 1939)

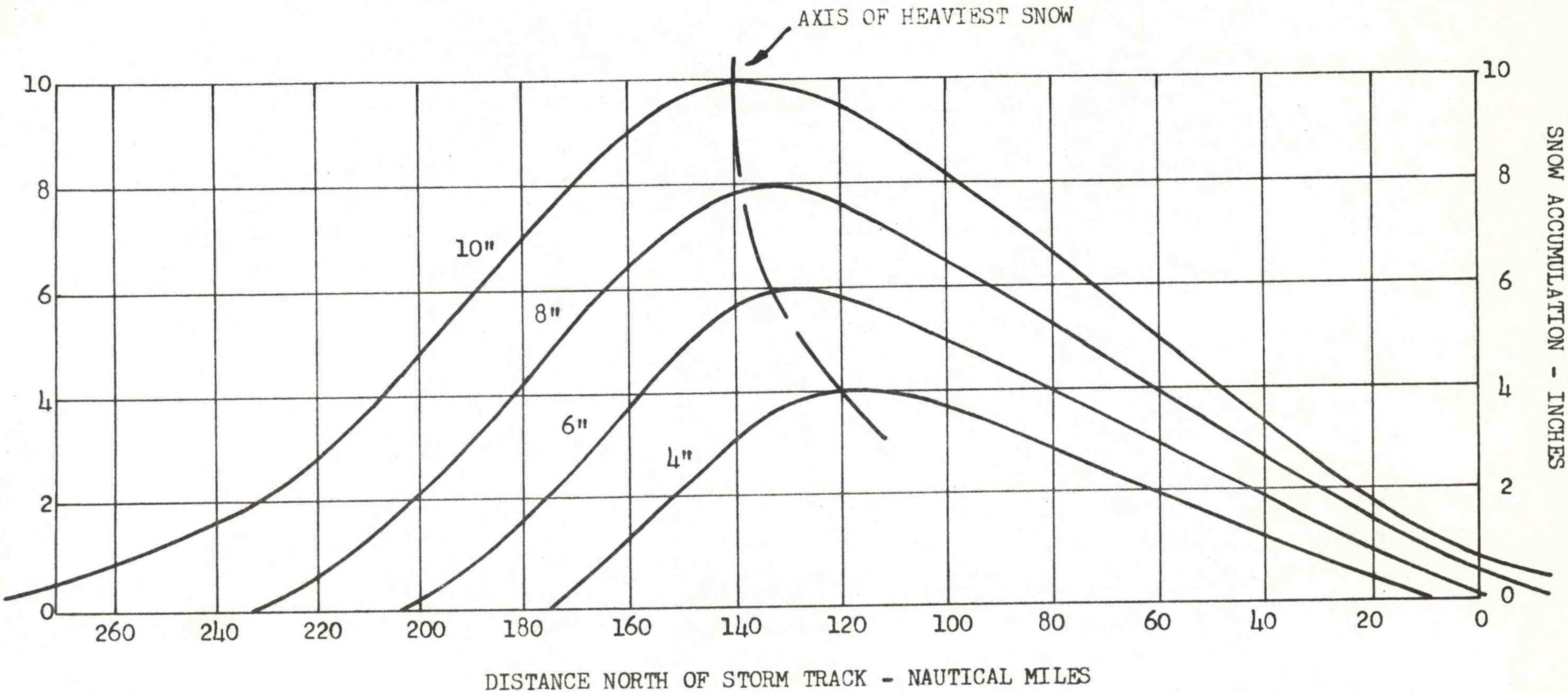
(After Petterssen)

Figure 1



WINTER STORM TYPES AFFECTING SE WISCONSIN AND LOWER LAKES REGION

Figure 2



SNOW DISTRIBUTION MODEL - PANHANDLE STORM (4, 6, 8 and 10 INCH PRECIPITABLE WATER)

Figure 3

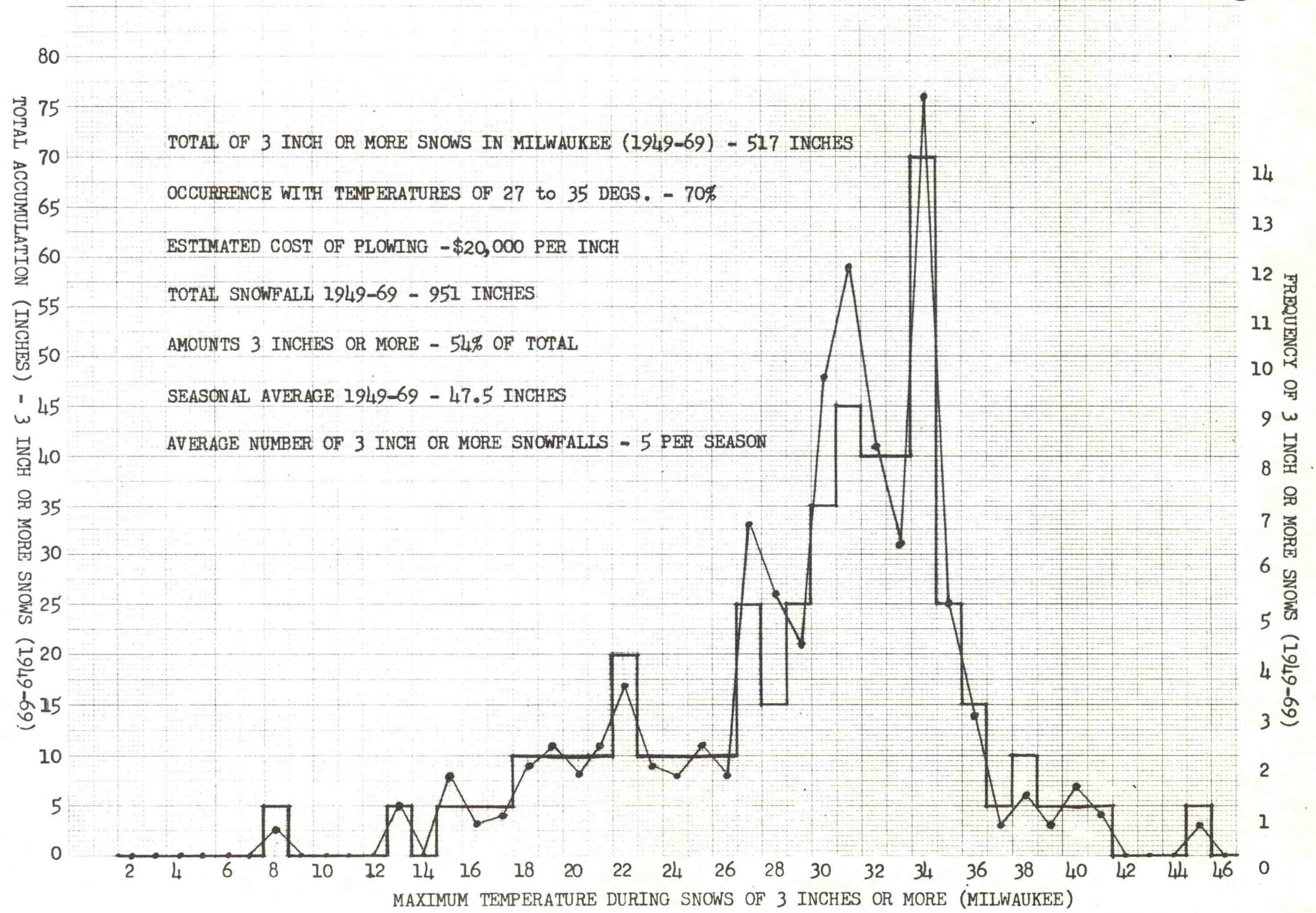

TOTAL OF 3 INCH OR MORE SNOWS IN MILWAUKEE (1949-69) - 517 INCHES
OCCURRENCE WITH TEMPERATURES OF 27 to 35 DEGS. - 70%
ESTIMATED COST OF PLOWING -$20,000 PER INCH
TOTAL SNOWFALL 1949-69 - 951 INCHES
AMOUNTS 3 INCHES OR MORE - 54% OF TOTAL
SEASONAL AVERAGE 1949-69 - 47.5 INCHES
AVERAGE NUMBER OF 3 INCH OR MORE SNOWFALLS - 5 PER SEASON
TOTAL ACCUMULATION (INCHES) - 3 INCH OR MORE SNOWS (1949-69)
FREQUENCY OF 3 INCH OR MORE SNOWS (1949-69)
MAXIMUM TEMPERATURE DURING SNOWS OF 3 INCHES OR MORE (MILWAUKEE)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 4

29 An Aid For Tornado Warnings.

30 An Aid in Forecasting Significant Lake Snows.

31 A Forecast Aid for Boulder Winds.

32 An Objective Method For Estimating The Probability of Severe Thunderstorms.

33 Kentucky Air-Soil Temperature Climatology.

34 Effective Use of Non-Structural Methods in Water Management.

35 A Note On the Categorical Verification of Probability Forecasts.

36 A Comparison of Observed and Calculated Urban Mixing Depths.

37 Forecasting Maximum and Minimum Surface Temperatures at Topeka, Kansas, Using Guidance from the PE Numerical Prediction Model (FOUS).