

# Snow Forecasting

## DDT II: COMPUTERIZED LAKE-EFFECT SNOW FORECASTS

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### ABSTRACT

*This paper extends the author's work on 6-hr. quantitative precipitation forecasting of lake-effect snowfall using LFMII numerical output, to use of the nested grid model and RAFS output. We compare results using FOUS predictor values with those of the newer nested grid model (and associated RAFS output). More importantly, a method is introduced that computerizes the decision tree process, producing 6-hr snowfall forecasts within seconds after the arrival of 0000 GMT or 1200 GMT numerical output. Results after a full season at test site Cleveland, Ohio, were quite favorable through much of the winter, becoming decreasingly accurate as lake water chilled to near freezing. Surprisingly, LFM II performed better overall compared to NGM (mainly due to more precise boundary layer wind forecasts), though the latter was designed to handle lake-effect modified air masses more effectively.*

### 1. INTRODUCTION

The summary of the author's previous lake-effect snow publication (2) contained certain goals and expectations from which to derive a follow-up paper. However, natural advances within operational synoptic meteorology prompted a change in agenda. To summarize, an intent to study the variation between LFM II and NGM—with respect to the author's original decision tree (DDT) for snowfall QPF—was modified for two reasons:

- a) As NGM became operational, LFM II numerical data (FOUS) quickly took an undeserved but inevitable back seat to nested grid output (referred to as "RAFS" here). Though still available, FOUS was—and is to this day—often overlooked on an operational basis. It had become a victim of underexposure, as LFM II products on facsimile charts suddenly were limited to 500-mb initial to 36 hr forecast panels. Moreover, the DDT, having been applied strictly to LFM II guidance, needed critical adaptations for use with RAFS to keep up with the times.
- b) A hard reality was that forecasters, public or private, normally could not afford to spend valuable time performing visual estimates and judgments required by a decision tree to derive 6-hr snow accumulations. As long as the air was sufficiently cold, the possibility existed for some local accumulation. In the Great Lakes area, such was the case a majority of the winter, so the extra task of manually sending four or more sets of data through a decision tree became rather laborious [in contrast to a seldom-needed but occasionally vital heavy rainfall decision tree such as the Scofield technique (3) operationally used by NESDIS and others, which would likely be used enthusiastically during each opportunity].

It was essential to try streamlining the process so that snowfall QPF values could be obtained rapidly and efficiently. Before this step, however, certain NGM parameters needed to be tested, accepted, and applied to the DDT to be comparable to LFM II's proven predictors.

### 2. SELECTED PREDICTORS AND NGM ADAPPTIONS

As detailed in the original study, several numerical guidance predictors have been proven invaluable when applied to lake-effect snow occurrences. FOUS parameters DDFB (boundary-layer wind direction and speed) and VV (vertical velocity) are especially useful. Together they indicate the proper fetch over open water (from DD) with sufficient wind speed (FF) under conditions with or without upper-level (i.e., 500 mb) dynamics (VV). Snowfall under the presence of upper level support (+ VV) can occur under warmer low-level conditions (i.e., 850 mb temperature =  $-5^{\circ}\text{C}$ ) than that without any upper level support ( $-$  VV). In the latter case, it has been well documented that  $T_{850}$  must be =  $-10^{\circ}\text{C}$  or lower to cause lake-effect snow of any consequence.

As the NGM/RAFS output was studied for lake-effect applicability, its predictors were found to be interchangeable with FOUS after some suitable modifications. For instance, the FOUS VV value listed for each 6-hr period is actually averaged over a time period from  $-3$  hr through  $+3$  hr relative to the valid time. RAFS VV, on the other hand, represents an instantaneous value for the same valid time. Therefore, an average of two time-consecutive values must be calculated to better represent the given 6-hr period. This is done as simply:

$$(VV_1 + VV_2) / 2, \text{ Calling the sum } VV_R \text{ (RAFS)}$$

So if the first VV is heavily positive and the second lightly negative the sum would still be positive, better representing a 6-hr period which experiences upward motion for a majority of the time. Even after averaging, though, there is still a time difference between models; FOUS arguably covers 12 hr. Hence, RAFS should better represent the given 6-hr period.

Incidentally, it should be noted that the first 6-hr period QPF cannot strictly be calculated for FOUS, as there is no VV value at initialization. Thus, a dummy neutral value of zero can be inserted. Obviously this adds a margin of error in results, but only affecting the first 6-hr period. Operationally, such an error becomes rather insignificant because computer guidance is normally unavailable for at least 3 hr after each initialization.

Another crucial predictor, 850-mb temperature, is unavailable numerically for stations (specific geographical locations) for 6-hr periods for either model. FOUS does offer one as part of its tried-and-true trajectory package, but only at valid time 24 hr. RAFS, meanwhile, includes approximate 850-mb level readings per 6 hr by averaging two of its five sigma layer

mean temperatures. This represents merely a 'ball park' figure tested over two winter seasons by the author. This approximation is:

$$T_{850} = (T_3 + T_5) / 2$$

Where  $T_3$  = Sigma layer 3 (862 mb – 922 mb)  
and  $T_5$  = Sigma layer 5 (745 mb – 806 mb)

To compare models for 850-mb temperature verification, in as unbiased a way as possible, it was necessary to have 6-hr FOUS projections calculated numerically from available data (rather than the original method of visual estimates from LFM II facsimile charts). The method used, perhaps biased in another way, is interpolation—by way of RAFS! The sole FOUS (i.e., trajectory) forecast value, valid at time = 24 hr, is measured against the simultaneous RAFS value. The difference between the two numbers is time-weighted and used as an *adjustment value* (J) as follows:

$$J = T_{850 \text{ RAFS time} = 24 \text{ hr}} - T_{850 \text{ TRAJ time} = 24 \text{ hr}}$$

The reasoning is that if the RAFS and trajectory forecasts differ by 4°C at time = 24 hr, then they would likely differ by 2°C at time = 12 hr, or similarly by 8°C at time = 48 hr. By definition, then, for FOUS:

$$T_{850 \text{ FOUS time} = t} = T_{850 \text{ RAFS time} = t} + (t \cdot J) / 24$$

Where  $t$  is the number of hours since initialization.

Remarkably, throughout several seasons of testing (before and after the incorporation of the method described above), LFM II's trajectory forecast predicted the correct 850-mb temperature as well or better than NGM (either from the  $T_3/T_5$  method or estimates from NGM 850-mb fax charts). In fact, the same findings have existed regarding boundary layer wind (DD), with FOUS holding the edge. Considering that the nested-grid model includes heat flux of the Great Lakes to some degree (whereas LFM II treats each of the Great Lakes as only a smooth, dry plain without temperature or moisture transfer), it is surprising and rather disappointing news. In essence there is no substantial evidence thus far that the NGM can better handle the error of arctic Highs remaining unmodified over the Great Lakes than can LFM II.

### 3. ANTICYCLONIC CURVATURE

The presence of anticyclonic surface curvature (normally accompanied by a high-pressure ridge at 850 mb and higher levels) has become increasingly recognized as a major deterrent to lake-effect snow, even when all other factors point to significant snowfall. Under these circumstances, snowfall is not totally eliminated, but usually thin bands (as little as 10 mi wide sometimes, though normally wider) produce locally moderate snow squalls. There is a strong tendency for these bands to exist near the center of a given lake, rather than along a parallel shore. This is a point to consider if, for example, the surface boundary-layer wind (the accepted steering current for snow squall bands) forecast is 260° (DD=26) for station Cleveland (CLE). Since this wind is virtually parallel to the lake shore east of Cleveland, the bands would likely form or remain well offshore until intersecting New York State near Buffalo.

The above would not apply to a standard lake-effect situation: normally, a 260° wind could bring snow squalls into northern Ashtabula County in Ohio, Erie County in Pennsylvania, and much of the snow belt of western New York.

So what key factor could indicate the approach of an anticyclonic curvature pattern? After some experimenting, a simple yet accommodating method found is a comparison of DD at one station (in the above case, CLE) to a simultaneous DD value at the nearest station downwind and to the right of the flow (Pittsburgh). If the DD value at the first station (e.g., DD at CLE = 26) is considered a veering wind with respect to the downwind station (e.g., DD at PIT = 27), boundary-layer divergence is assumed over most (or all) of the given region. It follows, then, that anticyclonic curvature is present at the boundary layer—and at the various elevations of the Great Lakes (Lake Superior–602 ft MSL, Lake Michigan/Huron–580 ft MSL, Lake Erie–570 ft MSL, and presumably Lake Ontario—only 246 ft MSL). Testing has supported this hypothesis.

A geographical limit exists, however, with respect to station Cleveland. The use of Pittsburgh (for a fetch over western Lake Erie) or Dayton (for a northerly fetch from over Lake Huron) as downstream reference points would result in a finite right-front quadrant. In other words, Pittsburgh is a good reference point for a 260° wind (DD CLE = 26), a 270° wind, etc.; by the same token, Dayton is excellent for 350° wind (DD CLE = 35). However, a wind from 310° (DD CLE = 31), for example, does not apply well to either station because Pittsburgh is almost directly downwind of Cleveland and Dayton is arguably positioned in the right-rear quadrant with respect to Cleveland. Fortunately, the consequences are not serious, as such a wind flow is considered a *dead spot* for northeast Ohio (Fig. 1). Here the boundary wind centers over neither Lake Huron nor an elongated portion of Lake Erie, so significant lake-effect snowfall is at a relative minimum. The exception is during the presence of upper-level dynamics, when snowfall can be generated from a smaller fetch over Lake Erie (lake-enhanced . . . discussed below). But in such a case, synoptic scale subsidence does not pre-

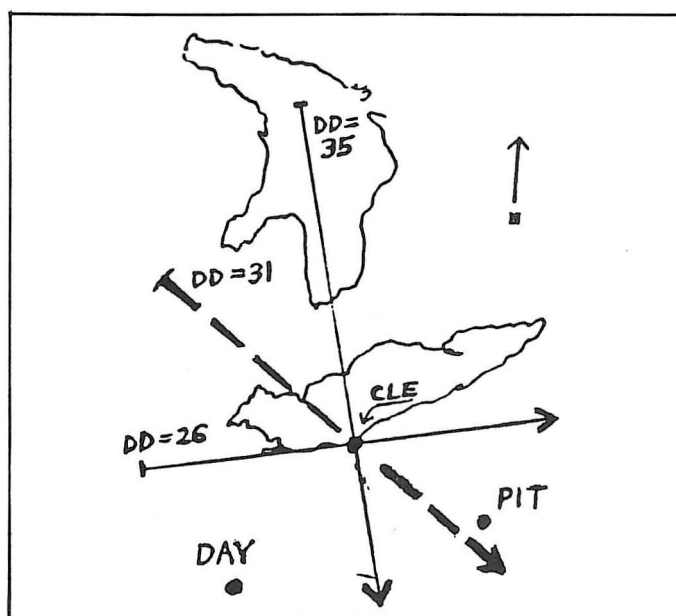


Fig. 1. Various boundary-layer wind direction (DD) trajectories for Cleveland (CLE). Pittsburgh (PIT) is within the right-front quadrant with respect to Cleveland when DD CLE = 26. Dayton (DAY) is within the right-front quadrant when DD CLE = 35. The *dead spot* referred to in the text is the northwest wind (e.g., DD = 31) which carries a minimum fetch.

dominate (as VV values would be positive in sign) so it can be tacitly assumed that surface divergence is not occurring. Hence, anticyclonic curvature is not a factor here so there is no need to test neighbor stations.

#### 4. LAKE-ENHANCED CASES

There are occasions, especially during a synoptic scale snowfall, when the presence of the lake(s) causes higher amounts than could be accounted for without its influence. This is termed *lake-enhanced* snowfall and always exists under some form of upper level dynamics, whether accompanying a major cyclone or a surface trough. There are several important differences between this type and *lake-effect* snowfall. First, the 850-mb temperature can be higher (in fact, as warm as  $-3^{\circ}\text{C}$  in early winter, but  $-5^{\circ}\text{C}$  is a more tested threshold value). Second, the minimum fetch needed is less than half the distance (only 40 mi roughly). The theory behind the above-stated criteria is discussed in the original paper.

#### 5. COMPUTER PROGRAMMED DDT

Once the appropriate RAFS predictors had been chosen and redefined (with previous lake-effect fundamentals remaining intact) it was time to streamline the DDT by computerizing the entire process. With this goal in mind, each section of the decision tree was reviewed to determine if logical steps could be built into a computer program without losing the integrity of the original DDT. This was rather easy in some respects, more difficult in others. Clear-cut examples included predictors such as vertical velocity, in which negative or large positive value indicate obvious trends. 6-hourly 850-mb temperature forecasts could be estimated by both models after some ground rules were set. As described above, it was determined that wind speed (FF) could be maintained as is, but boundary-layer wind direction (DD) was another story. In the process of estimating the fetch over one or more of the Great Lakes, the interpretation of DD for affected areas downwind could no longer be ambiguous (i.e., could not rely on an individual forecaster's mere eyeballing of a geographical area).

To universalize these judgments, and to form a base from which to build a kind of numerical model—riding on the coattails of existing NMC guidance—the following retooling was performed:

1. Each Great Lakes FOUS/RAFS station (e.g., CLE) was assigned to a finite geographical area (e.g., NE Ohio).
2. For each area, particular boundary-layer wind directions were decreed as *most significant fetch winds* (for lack of a better term), with adjacent wind directions denoted as somewhat less significant, and so on, until the point is reached in which no fetch of any consequence exists for a selected DD.
3. A determination of typical snowfall amounts per common time period (i.e., 6-hr) was made for specific DD values within a station's area, ultimately reliant on variables of T 850 mb, VV, and to some extent FF. Numerous case studies helped to distribute the snow QPF allocations, though interpolation of data along with the author's judgments filled in the gaps, so to speak, until new cases could apply.

Table 1 shows the DDT II decision-tree algorithm.

This would be the framework for a set of snowfall tables—the final step within the computerized decision-tree (DDT II)

**Table 1. DDT II decision-tree algorithm.**

Main Branch
<p><b>Algorithm:</b>  <b>STEP 1:</b>  a) If <math>\{T_1 &lt; -10\}</math> AND <math>\{T_2 &lt; -10\}</math>,  continue to STEP 2.  b) Else if <math>\{T_1 \leq -10\}</math> AND <math>\{-9 \geq T_2 \geq -10\}</math>  OR <math>\{-9 \geq T_1 \geq -10\}</math> AND <math>\{T_2 \leq -10\}</math>,  continue to STEP 2 but mark as <i>Marginal</i>.*  c) Else if <math>\{T_1 &lt; -3\}</math> AND <math>\{-3 &gt; T_2 &gt; -9\}</math>  OR <math>\{-3 &gt; T_1 &gt; -9\}</math> AND <math>\{T_2 &lt; -3\}</math>,  jump to STEP 6 (ENHANCED BRANCH).  d) Else,  no Lake-Effect/Lake-Enhanced snow QPF.</p> <p><b>STEP 2:</b>  a) If <math>\{DD_1 \geq 31 \text{ OR } DD_1 \leq 04\}</math> AND <math>\{DD_2 \geq 31 \text{ OR } DD_2 \leq 04\}</math>  OR <math>\{DD_1 = 30 \text{ AND } 31 \leq DD_2 \text{ AND } DD_2 \leq 34\}</math>  OR <math>\{31 \leq DD_1 \text{ AND } DD_1 \leq 34 \text{ AND } DD_2 = 30\}</math>,  go to step 3H (as Lake Huron values).  b) Else if <math>\{23 \leq DD_1 \text{ AND } DD_1 \leq 30\}</math> AND <math>\{23 \leq DD_2 \text{ AND } DD_2 \leq 30\}</math>  OR <math>\{26 \leq DD_1 \text{ AND } DD_1 \leq 29 \text{ AND } \{DD_2 = 31 \text{ OR } DD_2 = 32\}\}</math>  OR <math>\{DD_1 = 31 \text{ OR } DD_1 = 32\}</math> AND <math>26 \leq DD_2 \text{ AND } DD_2 \leq 29\}</math>,  go to step 3E (as Lake Erie values).  c) Else if <math>\{DD_1 \leq 08 \text{ OR } DD_1 \geq 27\}</math> AND <math>\{DD_2 \leq 08 \text{ OR } DD_2 \geq 27\}</math>,  jump to STEP 6 (ENHANCED BRANCH).  d) Else,  little or no Lake-Effect/Lake-Enhanced snowfall QPF.</p> <p><b>STEP 3H:</b>  a) For FOUS, If <math>\{VV_1 \leq 0 \text{ AND } VV_2 \leq 0\}</math>,  go to 4H (for Lake Huron values).  For RAFS, If <math>\{VV_R \leq .5\}</math>,  go to 4H (for Lake Huron values).  b) Else,  jump to STEP 5H (COMBINATION BRANCH).</p> <p><b>Lake Huron Values</b>  <b>STEP 4H:</b>  a) If <math>\{DD_{CLE1} \geq DD_{DAY1} \text{ AND } DD_{CLE2} \geq DD_{DAY2}\}</math>  AND <math>FF_1 &gt; 10 \text{ AND } FF_2 &gt; 10\}</math>,  if <i>Marginal</i>*,  go to Table 2;  else,  go to Table 1.  b) Else if <math>\{FF_1 &lt; 6 \text{ OR } FF_2 &lt; 6\}</math>,  little or no Lake-Effect/Lake-Enhanced snowfall QPF.  c) Else if <i>Marginal</i>*,  go to Table 12.  (There is anticyclonic curvature present, so any lake effect snow is suppressed and falling in a "thin band.")  d) Else,  go to Table 11.  (There is anticyclonic curvature present, so any lake effect snow is suppressed and falling in a "thin band.")</p> <p><b>Lake Erie Values</b>  <b>STEP 3E:</b>  a) For FOUS, If <math>\{VV_1 \leq 0 \text{ AND } VV_2 \leq 0\}</math>,  go to 4E (for Lake Erie values).</p>

*Continued*



**Table 1. DDT II decision-tree algorithm.—Continued**

Main Branch	
For RAFS, If $\{VV_R \leq .5\}$ , go to 4E (for Lake Erie values).	
b) Else, jump to STEP 5E (COMBINATION BRANCH).	
STEP 4E: (Lake Erie values)	
a) If $\{DD_{CLE1} \geq DD_{PIT1}$ AND $DD_{CLE2} \geq DD_{PIT2}$ AND $FF_1 > 10$ AND $FF_2 > 10\}$ , if <i>Marginal*</i> , go to Table 4; else, go to Table 3.	
b) Else if $\{FF_1 < 6$ OR $FF_2 < 6\}$ , little or no Lake-Effect/Lake-Enhanced snowfall QPF.	
c) Else if <i>Marginal*</i> , go to Table 14. (There is anticyclonic curvature present, so any lake effect snow is suppressed and falling in a "thin band.")	
d) Else, go to Table 13. (There is anticyclonic curvature present, so any lake effect snow is suppressed and falling in a "thin band.")	
Combination Branch	
STEP 5H:	
a) For FOUS, If $\{VV_1 \leq 1$ OR $VV_2 \leq 1$ OR if <i>Marginal*</i> }, go to Table 5. For RAFS, If $\{VV_R \leq 1.5$ OR if <i>Marginal*</i> }, go to Table 5.	
b) Else, go to Table 7.	
STEP 5E:	
a) For FOUS, If $\{VV_1 \leq 1$ OR $VV_2 \leq 1$ OR if <i>Marginal*</i> }, go to Table 6. For RAFS, If $\{VV_R \leq 1.5$ OR if <i>Marginal*</i> }, go to Table 6.	
b) Else, go to Table 8.	
Enhanced Branch	
STEP 6:	
a) For FOUS, If $\{VV_1 > 0$ AND $VV_2 > 0\}$ , continue to STEP 7. For RAFS, If $\{VV_R > .5\}$ , continue to STEP 7.	
b) Else, little or no Lake-Effect/Lake-Enhanced snowfall.	
STEP 7:	
a) If $\{T_1 < -5$ AND $T_2 < -5\}$ , continue to STEP 8.	
b) Else, go to Table 15 ( <i>Marginal Enhanced*</i> )	
STEP 8:	
a) For FOUS, If $\{VV_1 \leq 1$ OR $VV_2 \leq 1\}$ , go to Table 9. For RAFS, If $\{VV_R \leq 1.5\}$ , go to Table 9.	
b) Else, go to Table 10.	

process. For example, the DDT II results in 15 tables for Cleveland. A sample of 3 is shown in the Appendix. The keystone predictor is DD, designated as the *ordinate* (Y-axis) for snowfall tables. The *abscissa* (X-axis), meanwhile, represents slices of the geographical area, with topographic features playing a vital part. The first paper emphasized the importance of lake moisture reaching higher terrain, resulting in higher snow amounts. So maximum upslope areas are drawn (Fig. 2) to highlight the "snow belt" sections of the map served by the given station. In this case, Cleveland is the station, with resultant snowfall either from a north-south fetch over Lake Huron (Fig. 3) or a west-east fetch over western Lake Erie (Fig. 4).

Maximum upslope areas are marked as either HX (Huron max) or EX (Erie max). Areas H of zero through H of 6, and similarly E of zero through E of 4, are divided in vector fashion, largely determined by boundary wind direction DD. Compensation is made for unchanging values of DD over 6-hr periods, as a higher snowfall amount is assigned to certain DD values. For example, a FOUS or RAFS forecast of DD1 (time = t) = 35 (wind from 350°) through DD2 (time = t + 6HR) = 35 (again, wind from 350°) would result in a higher snow QPF value for the Akron area (at least for the time period 6 hr–12 hr) than either Ashland (360° or 010° degrees is better suited) or Youngstown (340° is ideal from a fetch off of Lake Huron). Youngstown also resides outside of a maximum upslope area, further diminishing its snowfall potential. A veering or backing wind in time (i.e., 360° to 340° or vice-versa) would spread out the snow over a wider region, thus offering a lower snow QPF for the local area in question.

Some adjustments have been made to better accommodate marginal temperature situations. For instance; some accumulation may be generated for a 6-hr period in which the air is sufficiently cold enough for only a part of that period. This is done by allowing values of  $T$  (temperature at 850 mb) to be slightly warmer than its normally accepted threshold. For lake-effect cases,  $-9^\circ \geq T \geq -10^\circ$  merits its own tables, computing roughly half of the snow QPF of *fully qualified* cold air ( $T < -10^\circ$ ), providing all other conditions remain the same. Also, shifting DD values are interchangeable: a boundary wind of 270° shifting to 250° (27, 25) is treated identically as a 250° wind becoming due westerly (25, 27). Although an argument can be made that more snow would fall over the Ohio shoreline, for example, in one case rather than the other, not enough significant difference exists to warrant twice as many QPF combinations.

## 6. DDT II FOR LAKE-ENHANCED AND COMBINATION CASES

Testing in the lake-enhanced decision branch occurs for values not qualifying for the DDT II lake-effect main branch. One example is air which is clearly too warm for any of a given 6-hr time period. Values are checked for air colder than  $-3^\circ\text{C}$  at 850 mb at both ends of the period. Any warmer values would likely result in a rain or rain/snow event with little or no accumulation, especially in November. In fact, air as cold as  $-5^\circ\text{C}$  at 850 mb may be necessary for much of the winter. At present, no monthly adjustment has been included because the actual dependence is on lake temperature. Forecasters must still use discretion to determine if the precipitation will be rain or snow or a mix. The precipitation values (PTT) from both models are printed on DDT II at the tail end of each test, remaining in water-equivalent form. The program does not perform the conversion because some

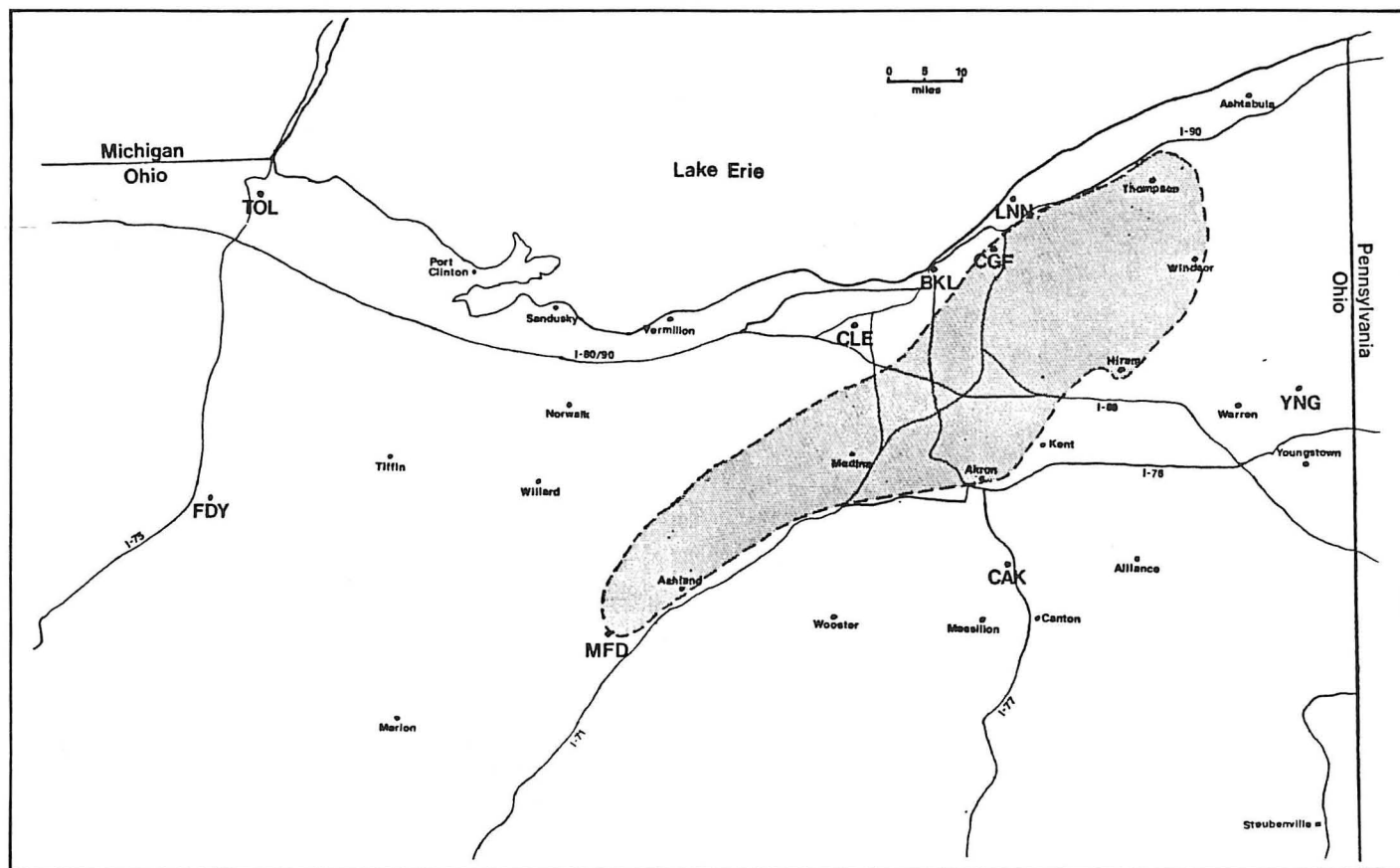


Fig. 2. Maximum upslope area (shaded) for northeast Ohio.

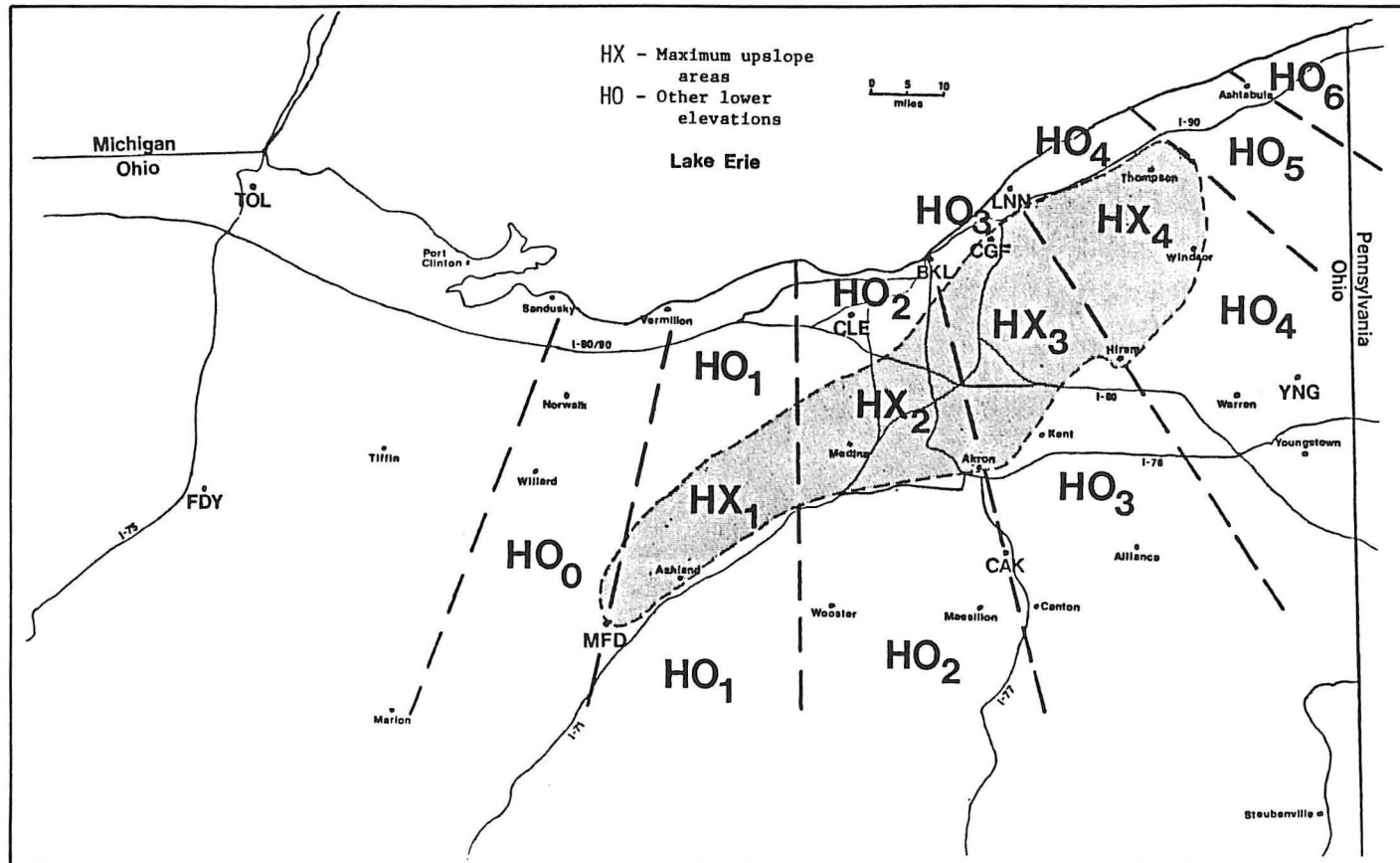


Fig. 3. Lake Huron fetch map.

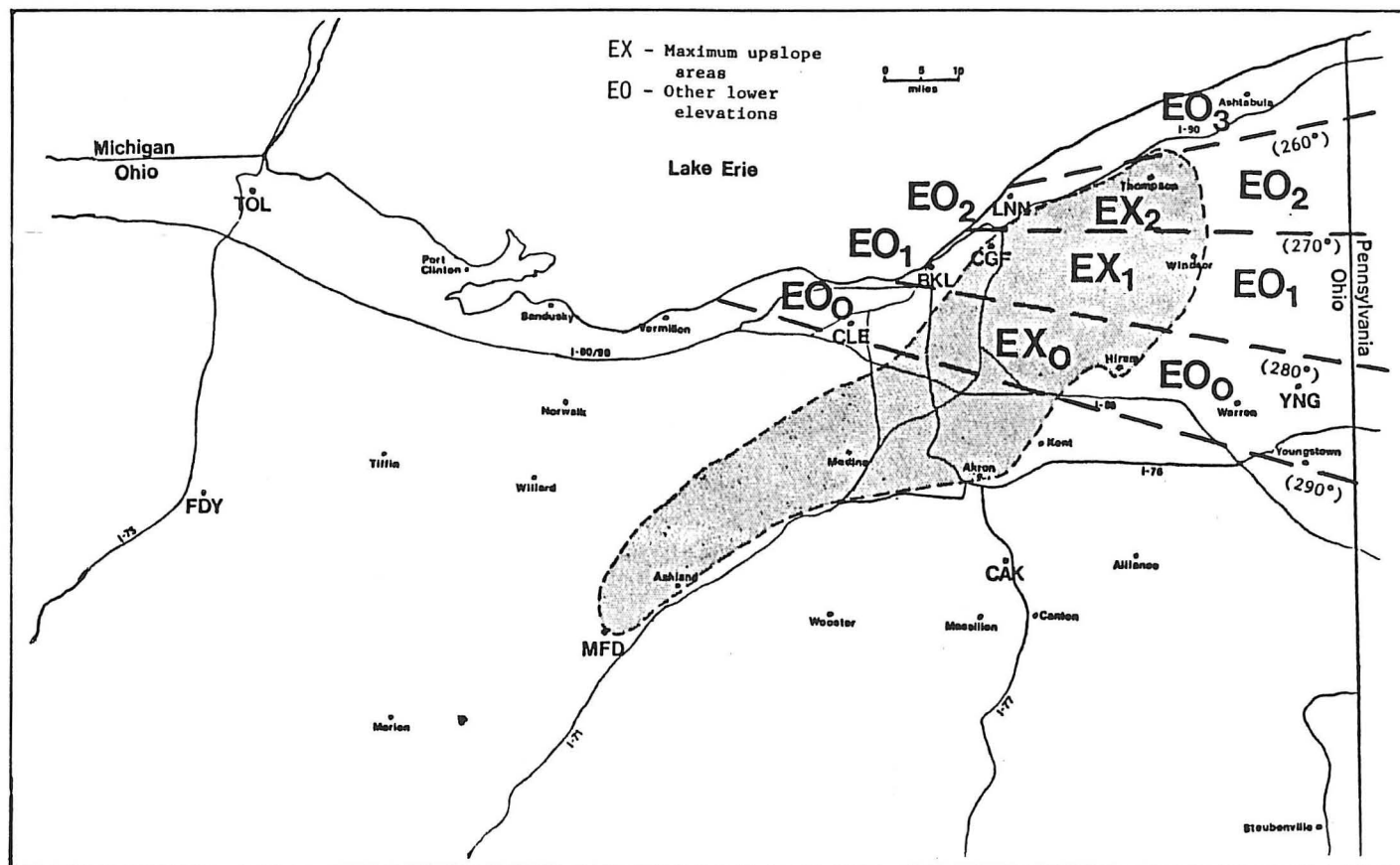


Fig. 4. Lake Erie fetch map.

assumptions would have to be made about the individual case, and so it is left to subjective discretion of forecasters. Generally, though, few cases contain these borderline temperatures for very long, so this is not a major detriment to the program.

Another example in which lake-enhanced cases serve as a safety net for values not qualified for lake-effect is when the wind direction (DD) contains a fetch under 100 mi but more than 40 mi. For the Cleveland area, these are DD values 05° and 06°—important wind components during a synoptic-type snowfall when a cyclone tracks up the Ohio Valley. It is not just coincidence, by the way, that 850-mb temperatures are nearly always warmer than  $-9^{\circ}\text{C}$  in these situations. Virtually all of Lake Erie qualifies as a moisture tap for northern Ohio if the wind gradually swings around. But even a boundary wind of 020° offers the necessary 40-mi fetch for the entire “north coast” of the state. So for lake-enhanced cases, DD values at either end of a given 6-hr period are averaged (“D” value) and rounded down to the nearest whole value. A QPF of wider geographic dimensions results, as each derived “D” value may represent a predetermined imaginary line across the area (e.g., northern Ohio). The various possibilities, still somewhat dependent on upslope factor, are indicated on the lake-enhanced map (Fig. 5). It must be underlined that the lake-enhanced snow QPF does not include synoptic related snowfall in the 6-hr estimate; rather, the PTT value is tacked on at the end for the forecaster to establish one’s own rain-to-snow conversion ratio to figure the balance per period.

The combination decision branch is saved for the best of both worlds: cold air ( $T < -10^{\circ}\text{C}$ ) and upper-level dynamics

( $VV > 0$ ). They are documented to be the heaviest snowfall events, regardless of the presence of a cyclone. Regarding DDT II, values are tested within the lake-effect main branch through to the upper-level support test. Positive VV values are sent to the combination branch, while neutral and negative values continue within the main branch. The resultant tables of the combination branch resemble that of the lake-effect branch, except that the snowfall rate is higher. Actually, the amounts are nearly double for cases in which  $VV > 1$  and  $T < -10^{\circ}\text{C}$ . Another table is a rough interpolation between the two tables described above, reserved for values of  $0 < VV \leq 1$  or marginal cases of  $-9^{\circ} \leq T \leq -10^{\circ}\text{C}$ .

A brief note on the anticyclonic cases: They have their own tables, and contain the lowest snow QPF estimates of any of the tables. (Of the 15 tables for Northeast Ohio, 4 of them correspond to anticyclonic curvature cases, including 2 for marginal temperature situations—one for Lake Huron and the other for Lake Erie fetch). The shortest table is number 14, remarkably reserved for marginal lake-effect cases applied to a Lake Erie fetch and showing anticyclonic curvature. Fortunately, the computer program simply refers to it as table 14 and tabulates the results. In any event, no one can argue that most all bases are not covered in some respect.

## 7. EARLY RETURNS AND SUMMARY

The DDT II became operational on AFOS at the National Weather Service office in Cleveland, Ohio, in November, 1987, programmed by a meteorologist employed at the Columbus, Ohio, NWS local office. The full 1987–88 winter,

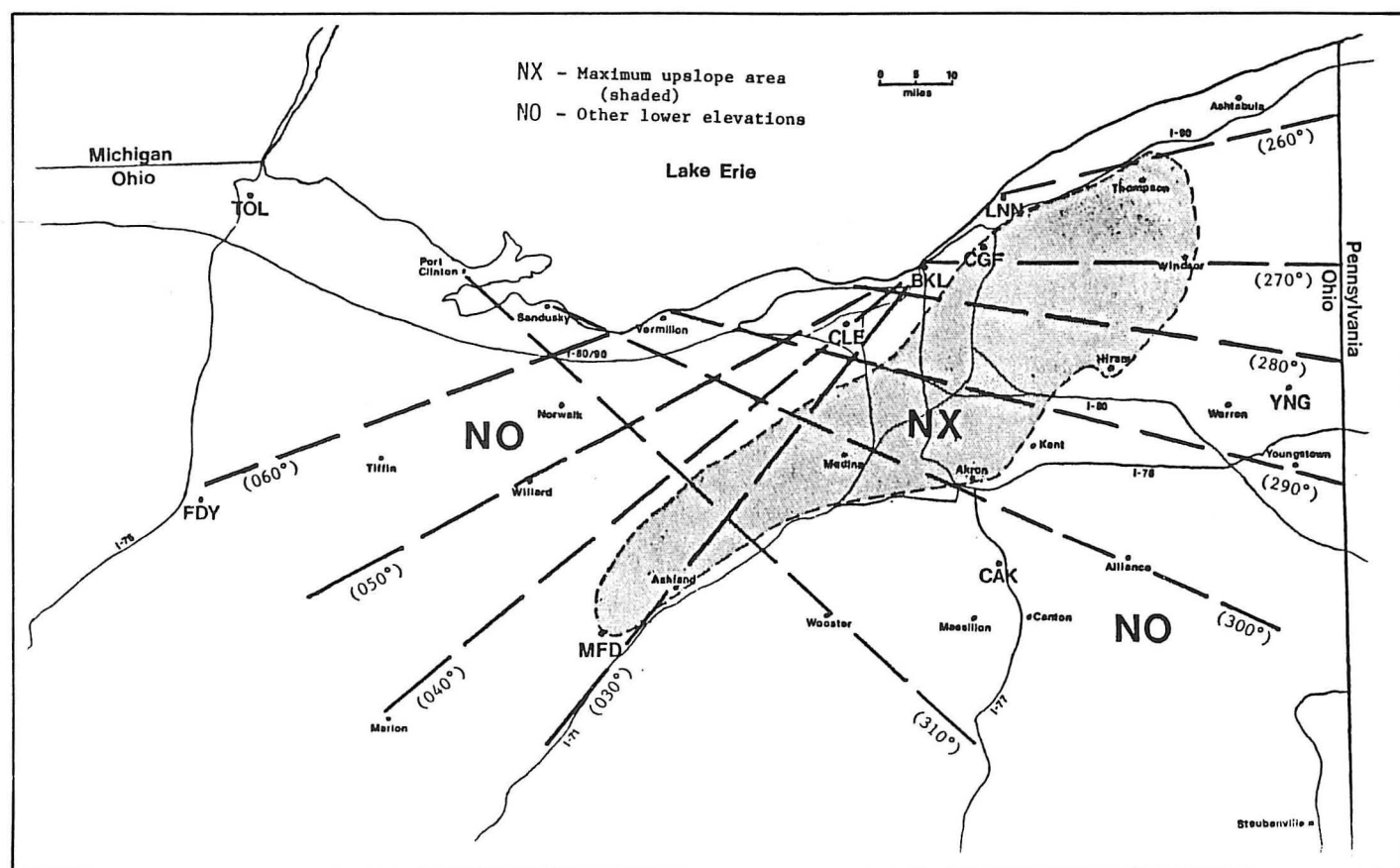


Fig. 5. Lake-enhanced map.

generally perceived to be a normal lake-effect winter, was monitored for case testing. Results have been quite encouraging for at least the period of November through mid-January. During this time period, a majority of cases indicated remarkably high verification, especially with LFM II/FOUS guidance. Several cases were virtually on target, within an inch of volunteer observers' or NWS official reports. Highest accuracy was found for snow QPF calculated from the 0000/1200 GMT model run closest to the onset of the event, to no one's surprise. From late January through the rest of the winter, however, snowfall forecasts were often overestimated (sometimes to extreme). It was important to note that the NGM/RAFS fared closer in its snow QPF projections during this period. Overall, DDT II earned its keep under present form, and NWS forecasters in Cleveland will be using its guidance again in the upcoming winter. No major changes are planned, as at least one more winter of monitoring will be necessary before more permanent modifications are attempted. A bright sign is that seldom was DDT II underestimating snowfall. Considering that the nested grid model by itself is yet unable to print out more than several hundredths of melted precipitation related to lake-effect snow, it can be stated that an alternative method has been developed which is able to at least sound a warning bell for (or perhaps even verify) the event. Moreover, it is available immediately upon the arrival of 0000/1200 GMT RAFS output. The goal is that more consistency and higher accuracy can be achieved using a computerized method rather than from map and data interpretation of the original DDT. It appears that this goal is realistic, and fine-tuning of the program is likely.

## ACKNOWLEDGMENTS

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## FOOTNOTES AND REFERENCES

1. Dale Dockus received his B.S. in Meteorology from Penn State University, and is presently employed at Federal Express Corporation, Memphis, TN, providing aviation weather forecasts.
2. Dockus, Dale A., 1985: Lake-Effect Snow Forecasting in the Computer Age, *Nat. Wea. Dig.*, 10:4, pp. 5-19.
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# APPENDIX

Sample Table 1. From Lake-Effect Main Branch—Lake Huron Fetch

DD <sub>1</sub> DD <sub>2</sub>	HO0	HO1	HX1	HO2	HX2	HO3	HX3	HO4	HX4	HO5	HO6
30, 32	—	—	—	—	—	—	—	—	—	—	1"
30, 33	—	—	—	—	—	—	—	—	—	—	1"
31, 32	—	—	—	—	—	—	—	—	—	1"	2"
31, 33	—	—	—	—	—	—	—	—	1"	2"	2"
31, 34	—	—	—	—	—	—	—	—	1"	2"	2"
31, 35	—	—	—	—	—	—	1"	1"	2"	1"	1"
32, 32	—	—	—	—	—	—	—	—	1"	2"	3"
32, 33	—	—	—	—	—	—	1"	2"	3"	3"	3"
32, 34	—	—	—	—	1"	1"	2"	2"	3"	3"	3"
32, 35	—	—	—	—	—	—	1"	1"	2"	1"	1"
32, 36	—	—	—	—	1"	—	1"	—	1"	—	—
33, 33	—	—	—	—	—	1"	2"	3"	5"	3"	2"
33, 34	—	—	—	—	1"	2"	4"	3"	5"	3"	2"
33, 35	—	—	—	1"	2"	2"	3"	2"	3"	1"	—
33, 36	—	—	1"	1"	2"	1"	2"	—	1"	—	—
33, 01	—	—	1"	—	1"	—	1"	—	1"	—	—
32, 34	—	—	—	1"	2"	3"	5"	3"	5"	1"	—
34, 35	—	—	1"	2"	4"	3"	5"	2"	4"	1"	—
34, 36	—	1"	2"	2"	3"	2"	3"	1"	2"	—	—
34, 01	—	1"	2"	1"	2"	—	1"	—	1"	—	—
34, 02	—	—	1"	—	1"	—	1"	—	1"	—	—
35, 35	—	1"	2"	3"	5"	3"	5"	1"	2"	—	—
35, 36	1"	2"	4"	3"	5"	2"	4"	—	1"	—	—
35, 01	1"	2"	3"	2"	3"	1"	2"	—	—	—	—
35, 02	1"	1"	2"	—	1"	—	1"	—	—	—	—
35, 03	—	—	1"	—	1"	—	1"	—	—	—	—
36, 36	2"	3"	5"	2"	4"	1"	2"	—	—	—	—
36, 01	2"	2"	4"	2"	3"	—	1"	—	—	—	—
36, 02	2"	2"	3"	1"	2"	—	—	—	—	—	—
36, 03	—	—	1"	—	1"	—	—	—	—	—	—
36, 04	—	—	1"	—	1"	—	—	—	—	—	—
01, 01	3"	1"	2"	—	1"	—	—	—	—	—	—
01, 02	2"	—	1"	—	1"	—	—	—	—	—	—
01, 03	2"	—	—	—	—	—	—	—	—	—	—
02, 02	1"	—	—	—	—	—	—	—	—	—	—

Note: Each of the 15 tables corresponding to the algorithm outcome could not justifiably be printed here, due to lack of space. However, copies of all tables are available from the author or from the National Weather Service Forecast Office in Cleveland.



**Sample Table 3. From Lake-Effect Main Branch—Lake Erie Fetch**

DD <sub>1</sub>	DD <sub>2</sub>	EO0	EX0	EO1	EX1	EO2	EX2	EO3
23,	27	—	—	—	—	—	—	1"
24,	28	—	—	—	—	—	—	1"
24,	27	—	—	—	—	—	1"	2"
24,	26	—	—	—	—	—	—	1"
25,	29	—	—	—	1"	—	1"	2"
25,	28	—	—	—	1"	1"	2"	2"
25,	27	—	—	—	—	1"	2"	2"
25,	26	—	—	—	—	—	—	2"
26,	30	—	—	—	1"	—	1"	1"
26,	29	—	—	1"	2"	1"	2"	1"
26,	28	—	—	1"	2"	1"	2"	2"
26,	27	—	—	—	1"	2"	3"	3"
26,	26	—	—	—	—	—	1"	3"
27,	31	—	1"	—	1"	—	1"	—
27,	30	—	1"	1"	2"	1"	2"	1"
27,	29	—	—	2"	3"	2"	3"	1"
27,	28	—	—	2"	3"	2"	4"	2"
27,	27	—	—	—	1"	3"	5"	3"
28,	32	—	—	—	1"	—	—	—
28,	31	—	1"	1"	2"	—	—	—
28,	30	1"	2"	1"	2"	—	—	—
28,	29	1"	2"	2"	3"	1"	2"	—
28,	28	—	—	2"	3"	1"	2"	1"
29,	32	—	—	—	1"	—	—	—
29,	31	—	1"	—	1"	—	—	—
29,	30	1"	2"	1"	2"	—	—	—
29,	29	1"	2"	2"	3"	—	1"	—
30,	30	—	1"	—	1"	—	—	—

**Sample Table 9. From Lake-Enhanced Branch**

"D"	NO	NX	Application
26	1"	—	north of LNN—Ashabula County Airport line (260)
27	1"	2"	north of BKL—Chesterland—Windsor line (270)
28	1"	2"	north of Rocky River—Bedford Heights line (280)
29	1"	2"	north of Vermillion—Hudson—Youngstown line (290)
30	1"	2"	north of Sandusky—Akron—Alliance line (300)
31	1"	2"	north of Port Clinton—Wooster line (310)
32	1"	2"	for entire Lake-Enhanced Map area
33	1"	2"	for entire Lake-Enhanced Map area
34	1"	2"	for entire Lake-Enhanced Map area
35	1"	2"	for entire Lake-Enhanced Map area
36	1"	2"	for entire Lake-Enhanced Map area
01	1"	2"	for entire Lake-Enhanced Map area
02	1"	2"	for entire Lake-Enhanced Map area
03	1"	2"	west of BKL—Ashland line (030)
04	1"	—	west of BKL—CLE—Marion line (040)
05	1"	—	west of BKL—Willard line (050)
06	1"	—	west of Vermillion—FDY line (060)