6A.4 DEVELOPMENT OF A GIS SNOWSTORM DATABASE

Michael F. Squires*, and Rich Baldwin
NOAA National Climatic Data Center, Asheville, North Carolina

Glen Reid
IMSG, Charleston, South Carolina

Clay Tabor
University of North Carolina at Asheville, Asheville, North Carolina

Anna Wilson
STG Inc, Asheville, North Carolina

1. Introduction

GIS applications are becoming more prevalent in weather and climate applications (Yuan 2005, Shipley 2005, Wilhelmi and Betancourt 2005, and Habermann 2005). NOAA's National Weather Service and National Climatic Data Center produce some spatial products in KML format for use in Google Earth and Google Maps. This paper discusses the development of a new GIS Snowstorm Database that will allow historical snowstorm data to be used by the public and researchers in GIS applications.

Kocin and Uccellini (2004) developed the Northeast Snowfall Impact Scale (NESIS) to characterize snowstorms in the Northeast. The index is based on the spatial extent of the storm, the amount of snowfall, and the juxtaposition of population and snowfall. Including population information ties the index to societal impacts. In 2005, NCDC began calculating NESIS scores operationally for large snowstorms affecting the Northeast (Squires and Lawrimore, 2006). NCDC is currently developing the Regional Snowfall Impact Scale (ReSIS) to characterize the societal impact of snowstorms in other regions of the lower 48 states (Squires at al., 2010). The generation of these new indices involves considerable data processing and quality control efforts which result in a GIS layer for each snowstorm. The data is put into GIS layers to facilitate spatial processing of the snowfall and population data. The authors decided to save these GIS layers and make them available with other demographic data to the public. Collectively these GIS layers are known as the GIS Snowstorm Database (GSDB).

* *Corresponding author address:* Michael F. Squires, NOAA/NCDC, 151 Patton Avenue, Asheville, NC 28801; e-mail: Mike.Squires@noaa.gov.

GSDB is an authoritative spatial dataset containing snowstorm information along with demographic information. The combination of snow and demographic information makes this product particularly useful for analyzing and studying the impacts of weather and climate on society.

2. Data and Storm Selection

The daily data used to construct the individual snowstorm datasets is drawn from the Global Historical Climate Network Daily (GHCN-D) dataset (http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/). GHCN-D was chosen as a data source for two reasons; it has undergone significant and consistent automated quality control (QC) for the entire period of record and it will eventually be the official data source for daily data from NOAA. Since the GSDB contains storms dating back to 1900, it is important that a consistent QC process be applied to the entire dataset. Durre et al. (2008) describes the strategies for constructing the QC algorithms used in GHCN-D. The automated QC procedures used to produce GHCN-D do not change values, rather elements that fail any checks are flagged. The data used in the current snowstorm study only uses snowfall values that are not flagged. However, upon manual inspection of mapped snowfall values, some of the snowstorm totals appear to be in error. In a typical snowstorm consisting of 1,500 to 2,500 stations about 1% of the stations will be eliminated because the validity of the total snowfall value is deemed incorrect. These errors at individual stations could adversely affect spatial analysis techniques and the subsequent development of regional and national snowstorm indices. Therefore, storm total snowfall at individual stations is subject to a manual QC process before being used in any analysis.

3. GIS Snowstorm Database

The snowstorm database will be a collection of GIS layers and tabular information for the top 200-300 snowstorms since 1900. While this data will be used to calculate the historical regional snowfall indices mentioned above, its intended purpose and functionality are much more ambitious. A conceptual diagram of the GSDB is shown in Figure 1. Each storm will contain both vector (points and polygons) and raster (grids) GIS layers. The individual snowstorm layers will contain information about snowfall, transportation networks (interstates and railroads), airports, hospitals, retail centers, and schools. The data will be made available in standards based GIS formats as defined by the Open Geospatial Consortium (OGC) such as web map services (WMS), web feature services (WFS) and KML (used in Google Maps, etc). Providing spatial datasets in a standards based manner ensures the information will be available to the widest possible group of users.

Besides the GIS layers, there will be tabular data that summarizes the societal impact information (transportation, for example) across all storms. Table 1 shows the interstate highway table which summarizes the number of highway miles receiving more than 4", 10", 15", 20", and 30" of snowfall by snowstorm. Finally, there will be tools to extract or analyze the data on-line. Thus the snowstorm database is suited for many different types of users including the general public, decision makers, and researchers.

Example of Using GSDB to Explore Societal Impacts for an Individual Storm Figure 2 shows an example of how the GSDB can be used to analyze the effect of an individual snowstorm on a transportation network. The total snowfall for the 6-9 January 1996 snowstorm is shown in Figure 2a. This was a particularly devastating event with snowfall totals as high 30" inches reported at some locations. The heaviest snowfall extended from Kentucky and the mountains of western North Carolina northeastward into New England. It's one thing knowing that there was heavy snowfall across a region, but it would also be useful to quantify the snow's effects on various sectors of society. The interstate highway system is superimposed over the snowfall totals in Figure 2b. At this point one is able to see the sections of highway that are affected by heavy snow. In Figure 2c, the highways are color-coded as a function of total snowfall. This is useful as a visual and qualitative indication of the snowstorm's effect on the transportation network, but it would be even more useful to have a quantitative measure of the storms impact. Table 1 contains the number of miles above cumulative snowfall totals for a selection of snowstorms including the 6-9 January 1996 storm mapped in Figure 2. For example, there were over 7,900 miles of interstate highways that received more than 15" of snowfall during this event. Of these, there were about 130 miles that experienced over 30" of snowfall. These are large snowfall totals over large stretches of America's primary highway transportation network which resulted in numerous negative impacts to society. In terms of heavy snow and transportation, this storm appears to have had more of an impact then the 12-15 March 1993 "Super Storm". The 1993 storm had more than 17,000 miles of interstate affected by greater than 4" of snowfall compared to about 16,000 in the 1996 storm (Table 1). However, for snowfall amounts greater than 15", the 1996 storm had more negative impacts. The cumulative miles of interstate greater than 15", 20", and 30" for the 1996 storm are 7,946, 4,557, and 130 miles respectively. The corresponding amounts for the 1993 "Super Storm" are, 7,034, 2,873, and 198 miles. Thus, for the larger snowfall amounts and their effect on the interstate highway system, the 1996 storm had more of an impact then the 1993 "Super Storm". This example shows how the GSDB is able to characterize the societal impacts of a snowstorm in both a qualitative and quantitative manner. It also shows how the GSDB can be used to differentiate the societal impacts between different storms. It becomes clear that societal impacts from snowstorms are a multidimensional function of the area of snowfall, the amount of snowfall, the location of infrastructure, and the spatial juxtaposition of all these elements. On a local level (city and county), the temporal progression of the storm becomes important. However, the GSDB is really intended to describe and explore the regional (state and multi-state areas) impacts of a storm.

Example of Using GSDB With an External Forecast Application St. Louis University and the National Weather Service are developing an Analog Snowfall Guidance product (Graville et al., 2009). The purpose is to identify historical snowstorms that are similar to the 48 hour or 72 hour GFS forecast. The North American Regional Reanalysis (NARR) is searched using various statistical techniques to identify the top 15 analogs. The goal is not to produce a deterministic forecast but rather give guidance about the magnitude and scale of impending snowstorms.

The Analog Forecast Guidance can be used with the GIS Snowstorm Database to give an indication of the societal impacts the storm will produce. Figure 3 shows analogs that are identified for a forecast valid at Dec 19, 2008. The top four analogs are listed. The fourth rated storm is an event that occurred in February of 1993, which has an entry in GSDB. Tables 2-5 show the societal impact for interstate highways, airports, hospitals, and schools from snowfall with the 20-24 February 1993 storm highlighted. The tables are the same format as Table 1, however the values for airports, hospitals, and schools indicate the number of facilities experiencing snowfall greater than the threshold defined for that column. For example, Table 4 shows that approximately 150 hospitals experienced over 10” of snowfall during the storm. There were over 28,000 schools that experienced over 4” of snowfall during the storm (Table 5). Recall, GSDB attempts to quantify the regional impacts from a snowstorm but is not as useful for local effects. Whether a school district makes the decision to close schools is a function of the timing of the storm locally and the community’s ability to respond to the forecast amount of snowfall. Call (2008) describes how snowstorms affect communities on this local scale. If the forecaster has confidence in the forecast, it is reasonable to assume that there will be similar impacts for this storm. Of course the actual spatial distribution of heavy snow in relationship to the transportation network and infrastructure locations will determine the resulting societal impacts.

4. Summary and Conclusion

This note has described the development and possible uses for the GIS Snowstorm Database. Its primary purpose is to serve as input for regional and national snowfall indices being developed at NCDC. The snowstorms in GSDB will be made available to the public and other researchers. Since demographic data is part of GSDB, it serves as an excellent tool for the analysis and exploration of the relationship between snowstorms and societal impacts.

5. References

Call, D. A., 2005: Rethinking snowstorms as snow events, a regional case study from upstate New York. *Bull. Amer. Meteor. Soc.*, **86**, 1783-1793.

Durre, I., M. J. Menne, and R. S. Vose, 2008: Strategies for evaluating quality-control procedures. *Journal of Climate and Applied Meteorology*, **47**, 1785-1791.

Gravelle, C. M., C. E. Graves, J. P. Gagan, F. H. Glass, and M. S. Evans, 2009: Winter weather guidance from regional historical analogs. *23rd Conf. on Weather Analysis and Forecasting*, Omaha, NE.

Habermann, T., 2005: What is GIS (for UNIDATA)?. *Bull. Amer. Meteor. Soc*., **86**, 174-175.

Kocin, P. J. and L. W. Uccellini, 2004: A snowfall impact scale derived from northeast storm snowfall distributions. *Bull. Amer. Meteor. Soc*., **85**, 177-194

Squires, M. F. and J. H. Lawrimore, 2006: Development of an operational snowfall impact scale. *22nd IIPS*, Atlanta, GA.

Squires, M. F., J. H. Lawrimore, R. R. Heim Jr., D. A. Robinson, M. R. Gerbush, and T. W. Estilow, 2010: Development of regional snowfall indices. *18th Conference on Applied Climatology*, Atlanta, GA.

Shipley, S. T., 2005: GIS Applications in Meteorology, or Adventures in a Parallel Universe. *Bull. Amer. Meteor. Soc*., **86**, 171-173.

Wilhelmi, O. V., and T. L. Betancourt, 2005: Evolution of NCAR’s GIS initiative. *Bull. Amer. Meteor. Soc*., **86**, 176-178.

Yuan, M., 2005: Beyond Mapping in GIS Applications to Environmental Analysis. *Bull. Amer. Meteor. Soc*., **86**, 169-170.

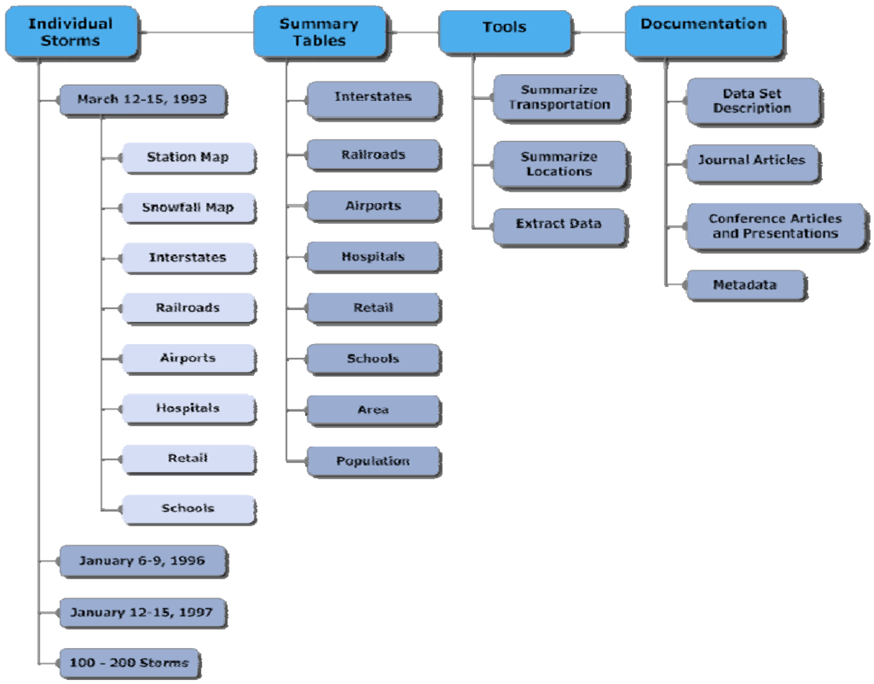

Figure 1. Conceptual design of the GIS Snowstorm Database.

Storm Date	Year	Month	>4"	> 10"	> 15"	> 20"	> 30"
19820111_19820115	1982	1	17,228	1,163	0	0	0
19820404_19820408	1982	4	12,578	3,036	608	43	0
19830210_19830213	1983	2	10,388	7,796	4,871	1,266	6
19850129_19850203	1985	1	16,165	705	5	0	0
19870121_19870124	1987	1	14,544	6,737	734	28	0
19880105_19880109	1988	1	17,445	2,605	128	7	0
19880209_19880214	1988	2	13,224	2,696	354	4	0
19921209_19921213	1992	12	10,336	3,336	1,237	416	1
19930214_19930218	1993	2	14,782	1,216	44	0	0
19930220_19930224	1993	2	12,965	1,632	321	40	0
19930312_19930315	1993	3	17,174	12,353	7,034	2,873	198
19940116_19940119	1994	1	14,858	4,228	911	32	0
19940222_19940225	1994	2	10,987	681	0	0	0
19940222_19940225	1994	2	10,987	681	0	0	0
19950202_19950207	1995	2	11,028	3,746	284	28	0
19951218_19951222	1995	12	11,140	3,297	322	15	0
19960106_19960109	**1996**	**1**	**15,926**	**11,102**	**7,946**	**4,557**	**130**
19990101_19990104	1999	1	11,766	4,950	1,311	221	1
20001228_20010101	2000	12	9,518	824	107	5	0
20021222_20021226	2002	12	13,229	2,211	709	288	8
20030214_20030218	2003	2	14,945	8,786	6,658	2,543	9
20031204_20031208	2003	12	9,836	4,581	2,006	255	0
20040124_20040129	2004	1	18,738	2,266	122	33	0
20050121_20050124	2005	1	15,583	5,697	1,233	674	0

Table 1. Interstate Highway table from the GIS Snowstorm Database.

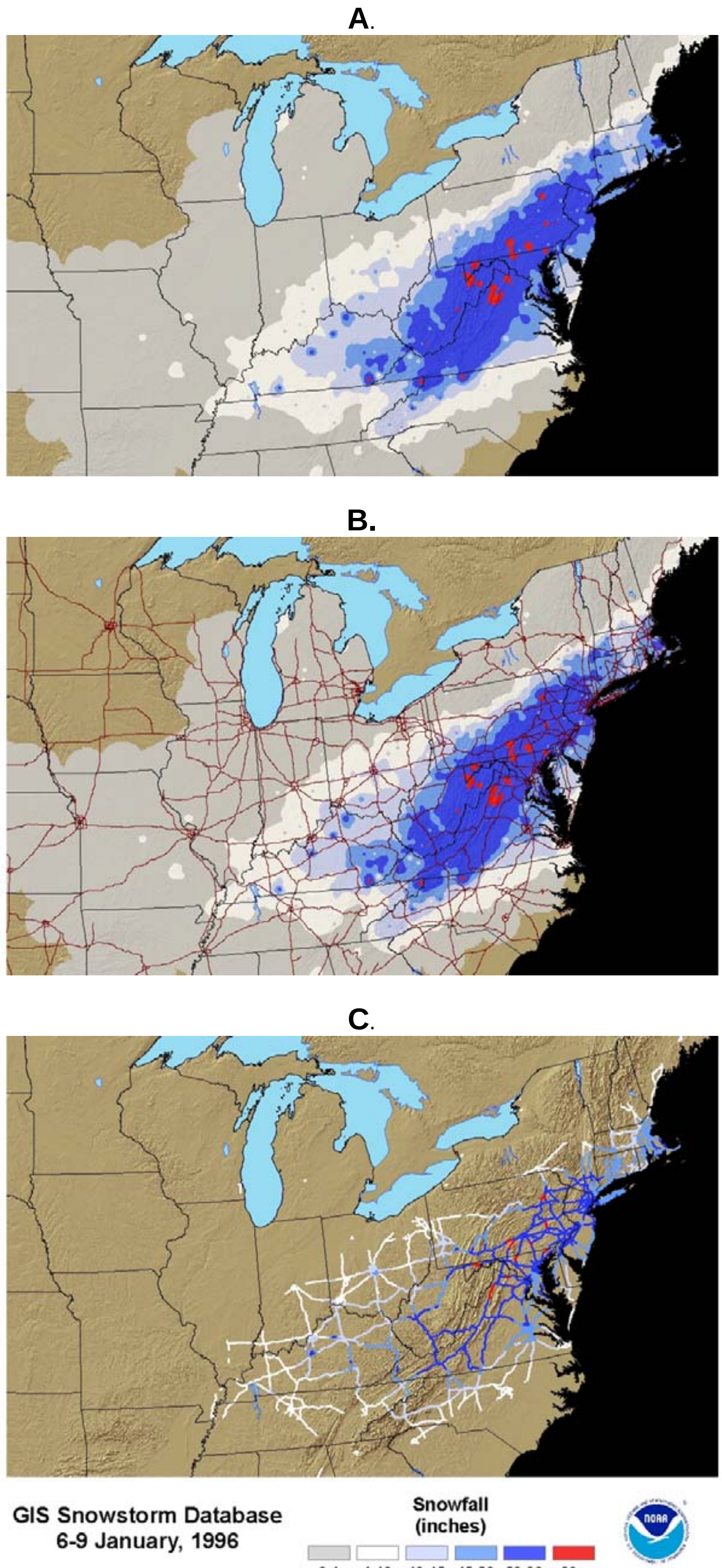

Figure 2. A. Snowstorm map for the 6-9 January snowstorm. B. Interstate highway system superimposed over the storm. C. Interstates categorized and color-coded by snowfall amount.

St Louis University & National Weather Service
Analog Snowfall Guidance

Analogs for 2008/12/19		
Rank	Date	Score
1	1994 12 07	7.741
2	1990 12 15	6.859
3	2000 02 18	6.813
4	1993 02 21	6.758

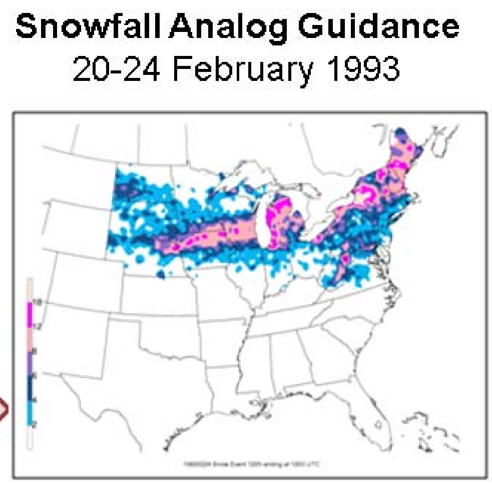

Figure 3. Analog forecasts for 19 December 2008.

Storm Date	Year	Month	>4"	> 10"	> 15"	> 20"	> 30"
19820111_19820115	1982	1	36,075	3,287	0	0	0
19820404_19820408	1982	4	27,447	7,216	1,543	106	0
19830210_19830213	1983	2	4,676	5,256	13,364	3,760	14
19850129_19850203	1985	1	34,249	1,058	0	0	0
19870121_19870124	1987	1	20,867	13,679	937	101	2
19880105_19880109	1988	1	33,334	4,604	172	51	0
19880209_19880214	1988	2	27,512	5,441	626	51	0
19921209_19921213	1992	12	17,762	5,665	1,869	705	20
19930214_19930218	1993	2	27,699	2,265	168	3	0
19930220_19930224	**1993**	**2**	**28,398**	**4,060**	**538**	**92**	**2**
19930312_19930315	1993	3	9,622	17,332	8,572	4,287	349
19940116_19940119	1994	1	24,641	5,392	1,353	118	0
19940222_19940225	1994	2	25,396	1,925	105	9	0
19950202_19950207	1995	2	19,621	10,421	636	100	2
19951218_19951222	1995	12	22,688	7,212	702	31	0
19960106_19960109	1996	1	8,970	5,230	7,940	14,144	284
19990101_19990104	1999	1	15,654	9,079	4,907	404	4
20001228_20010101	2000	12	26,113	1,575	166	18	0
20021222_20021226	2002	12	27,578	3,554	763	358	11
20030214_20030218	2003	2	11,713	4,776	13,622	7,397	34
20031204_20031208	2003	12	12,363	9,563	4,328	995	45
20040124_20040129	2004	1	42,177	4,816	223	118	0
20050121_20050124	2005	1	24,455	17,036	1,404	2,484	19
20051207_20051210	2005	12	29,731	3,919	95	0	0

Table 2. Interstate highway miles affected by more than 4", 10", 15", 20", and 30" of snowfall.

Storm Date	Year	Month	>4"	> 10"	> 15"	> 20"	> 30"
19820111_19820115	1982	1	145	8	0	0	0
19820404_19820408	1982	4	94	23	6	1	0
19830210_19830213	1983	2	24	19	34	11	0
19850129_19850203	1985	1	139	9	0	0	0
19870121_19870124	1987	1	75	46	6	0	0
19880105_19880109	1988	1	132	21	0	1	0
19880209_19880214	1988	2	98	23	5	1	0
19921209_19921213	1992	12	74	11	8	6	0
19930214_19930218	1993	2	136	13	2	0	0
19930220_19930224	**1993**	**2**	**115**	**16**	**6**	**3**	**0**
19930312_19930315	1993	3	39	37	40	26	2
19940116_19940119	1994	1	97	28	7	1	0
19940222_19940225	1994	2	104	16	2	0	0
19950202_19950207	1995	2	70	34	9	1	0
19951218_19951222	1995	12	80	29	7	0	0
19960106_19960109	1996	1	34	26	23	37	3
19990101_19990104	1999	1	76	35	17	7	0
20001228_20010101	2000	12	90	8	2	0	0
20021222_20021226	2002	12	94	20	4	1	0
20030214_20030218	2003	2	50	22	35	20	0
20031204_20031208	2003	12	45	31	15	1	0
20040124_20040129	2004	1	158	34	1	2	0
20050121_20050124	2005	1	98	45	7	8	0

Table 3. Number of airports affected by more than 4", 10", 15", 20", and 30" of snowfall.

Storm Date	Year	Month	>4"	> 10"	> 15"	> 20"	> 30"
19820111_19820115	1982	1	1,418	123	0	0	0
19820404_19820408	1982	4	923	264	53	4	0
19830210_19830213	1983	2	218	205	428	110	2
19850129_19850203	1985	1	1,463	66	0	0	0
19870121_19870124	1987	1	790	503	39	9	0
19880105_19880109	1988	1	1,395	282	8	5	0
19880209_19880214	1988	2	1,061	183	27	1	0
19921209_19921213	1992	12	606	232	72	27	1
19930214_19930218	1993	2	1,238	98	7	0	0
19930220_19930224	**1993**	**2**	**1,082**	**152**	**30**	**2**	**0**
19930312_19930315	1993	3	394	608	365	210	14
19940116_19940119	1994	1	986	242	63	8	0
19940222_19940225	1994	2	1,023	91	8	0	0
19950202_19950207	1995	2	703	372	22	6	0
19951218_19951222	1995	12	810	274	31	1	0
19960106_19960109	1996	1	396	235	319	464	12
19990101_19990104	1999	1	697	298	160	14	0
20001228_20010101	2000	12	942	56	7	0	0
20021222_20021226	2002	12	1,040	137	38	14	2
20030214_20030218	2003	2	520	179	445	242	4
20031204_20031208	2003	12	461	302	144	36	3
20040124_20040129	2004	1	1,566	210	11	7	0
20050121_20050124	2005	1	900	552	42	90	2

Table 4. Number of hospitals affected by more than 4", 10", 15", 20", and 30" of snowfall.

Storm Date	Year	Month	>4"	> 10"	> 15"	> 20"	> 30"
19820111_19820115	1982	1	36,075	3,287	0	0	0
19820404_19820408	1982	4	27,447	7,216	1,543	106	0
19830210_19830213	1983	2	4,676	5,256	13,364	3,760	14
19850129_19850203	1985	1	34,249	1,058	0	0	0
19870121_19870124	1987	1	20,867	13,679	937	101	2
19880105_19880109	1988	1	33,334	4,604	172	51	0
19880209_19880214	1988	2	27,512	5,441	626	51	0
19921209_19921213	1992	12	17,762	5,665	1,869	705	20
19930214_19930218	1993	2	27,699	2,265	168	3	0
19930220_19930224	**1993**	**2**	**28,398**	**4,060**	**538**	**92**	**2**
19930312_19930315	1993	3	9,622	17,332	8,572	4,287	349
19940116_19940119	1994	1	24,641	5,392	1,353	118	0
19940222_19940225	1994	2	25,396	1,925	105	9	0
19950202_19950207	1995	2	19,621	10,421	636	100	2
19951218_19951222	1995	12	22,688	7,212	702	31	0
19960106_19960109	1996	1	8,970	5,230	7,940	14,144	284
19990101_19990104	1999	1	15,654	9,079	4,907	404	4
20001228_20010101	2000	12	26,113	1,575	166	18	0
20021222_20021226	2002	12	27,578	3,554	763	358	11
20030214_20030218	2003	2	11,713	4,776	13,622	7,397	34
20031204_20031208	2003	12	12,363	9,563	4,328	995	45
20040124_20040129	2004	1	42,177	4,816	223	118	0
20050121_20050124	2005	1	24,455	17,036	1,404	2,484	19
20051207_20051210	2005	12	29,731	3,919	95	0	0

Table 5. Number of schools affected by more than 4”, 10”, 15”, 20”, and 30” of snowfall.