

# Traffic Signal LED Module Specification Workshop and Informational Report for Snow Conditions



U.S. Department of Transportation  
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<b>16. Abstract</b> <p>The primary objective of this research was to identify significant environmental (i.e., weather) variables that may contribute to snow and ice buildup on LED traffic signal lenses. If a subset of variables can be identified that may predict the potential occurrence of snow and/or ice buildup on LED traffic signal lenses, then it may be possible for traffic engineers to take a more proactive approach to eliminating or minimizing the potential negative effects.</p> <p>One of the unintended consequences of the transition to LED traffic signals lenses/indications is the fact that LEDs do not produce heat to the traffic signal lens or face of the traffic signal display. Therefore, LEDs do not provide a “melting” element to traffic signals in the northern climates that experience snow and ice conditions.</p> <p>The U.S. Department of Transportation (USDOT) has worked with ITE in determining the issues related to the snow and ice conditions on LED traffic signal lenses. ITE and USDOT conducted a stakeholder workshop on December 14–15, 2010 that created a set of proceedings documenting the issues, findings, and potential next steps in addressing the snow and ice-covered LED traffic signal lens issue. One of the outcomes of the workshop was the initiation of a small research task to further explore the environmental conditions (i.e., weather) upon which the snow and ice problem occurs. This report summarizes the research effort completed to fulfill that outcome.</p>			
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# INTRODUCTION

## Background on LED Traffic Signals

Basic traffic signal requirements including the illumination of traffic signal lenses/indications are set forth in the *Manual on Uniform Traffic Control Devices* (MUTCD). The intensity and distribution of light from each illuminated signal lens should comply with the Institute of Transportation Engineers (ITE) standards publications titled "Vehicle Traffic Control Signal Heads" and "Traffic Signal Lamps" (see: [www.ite.org/standards/index.asp](http://www.ite.org/standards/index.asp)). References to signal lenses are no longer limited to incandescent lamps within optical assemblies that include lenses. Research has resulted in signal optical units that are light emitting diode (LED) traffic signal modules. ITE addressed the move to LED signal lenses by creating the "Vehicle Traffic Control Signal Heads: Light Emitting Diode (LED) Circular Signal Supplement" specification in 2005, followed by a supplement to include LED arrow indications in 2007.

LEDs are the new standard in traffic signals, largely due to the Energy Policy Act of 2005 which set minimum standards for energy efficiency in traffic signal and pedestrian modules. The "Vehicle Traffic Control Signal Heads: Light Emitting Diode (LED) Circular Signal Supplement" specification effectively addresses the physical, mechanical, photometric, and electrical requirements for LEDs, including environmental requirements for protecting LEDs from dust and moisture intrusion, including blowing rain. One of the unintended consequences of the transition to LED traffic signals lenses/indications is the fact that LEDs do not produce heat to the traffic signal lens or face of the traffic signal display. Therefore, LEDs do not provide a "melting" element to traffic signals in the northern climates that experience snow and ice conditions.

Incandescent lenses typically provide sufficient heat from the light source such that snow and ice melt on contact with signal lenses. Nevertheless, incandescent technology is not foolproof, as some traffic engineers have experienced significant snow events where lenses associated with incandescent traffic signals become partially snow covered. Additionally, in situations where traffic signals rest in phase for long periods of time, snow and ice buildup on dark incandescent lenses has been observed. However, these lenses tend to be self-cleaning by the heat generated when illuminated. Current LED traffic signal specifications do not address a requirement to prevent snow and ice from accumulating on traffic signal lenses.

Traffic engineers in northern locations that experience winter weather have reported instances in which traffic signal lenses have become snow and/or ice covered during storm events, partially or completely obstructing the

view of the signal indication from drivers. Numerous property damage-only crashes and at least one fatality have been attributed to snow-covered LED traffic signal lenses. Therefore, a potential safety issue exists with LED traffic signals in locations that experience winter storm events.

The U.S. Department of Transportation (USDOT) has worked with ITE in determining the issues related to the snow and ice conditions on LED traffic signal lenses. ITE and USDOT conducted a stakeholder workshop December 14–15, 2010 that created a set of proceedings documenting the issues, findings, and potential next steps in addressing the snow and ice-covered LED traffic signal lens issue. One of the outcomes of the workshop was the initiation of a small research task to further explore the environmental conditions (i.e., weather), which cause the snow and ice problem to occur. This report summarizes the research effort completed to fulfill that outcome. The primary objective of this research was to identify significant environmental (i.e., weather) variables that may contribute to snow and ice buildup on LED traffic signal lenses. If a subset of variables can be identified that may predict the potential occurrence of snow and/or ice buildup on LED traffic signal lenses, then it may be possible for traffic engineers to take a more proactive approach to eliminating or minimizing the potential negative effects.

The research study design included several tasks, focused on the objective of identifying winter storm variables that lead to snow or ice-covered LED traffic signal lenses. Through a “request for information” process, researchers identified a number of winter storm events in both the United States and Canada in which traffic engineers reported snow and/or ice-covered LED traffic signal lenses. Weather data were located and tabulated with each winter storm event, both during the storm and at least one day prior, to help identify weather attributes that are common to the LED traffic signal lens covering storm events. In some locations, winter storm events in which snow-covered LED traffic signal lenses were compared to winter storm events in which snow did not cover LED traffic signal lenses to again analyze and search for weather attributes associated with the LED lens-covering storms.

This report summarizes the research activities completed within each research task, along with comments pertaining to technologies, specifications, and future research. Appendix A provides information on each study site as well as the weather data information for the reader’s reference.

## Background Information on Responding Agencies

The first task in the research was to identify sites in which a specific date and time of a winter storm event that led to snow and/or ice buildup on LED traffic signal lenses could be identified. A “Request for Information” document was created and circulated among ITE members in the traffic engineering community, along with the participants in the initial workshop, to identify these storms and some of the basic attributes of the locations. A copy of the “Request for Information” document is included in Appendix B.

The objective of this data collection exercise was to identify locations which have experienced problems with snow and/or ice buildup on LED traffic signal lenses and transportation agencies that were willing to participate in this research. Nine complete responses to the “Request for Information” were received in November 2011. The responding agencies included:

1. City of Green Bay, Wisconsin;
2. City of Thornton, Colorado;
3. Virginia Department of Transportation;
4. City of Winnipeg, Manitoba, Canada;
5. Michigan Department of Transportation;
6. City of Helena, Montana;
7. Utah Department of Transportation;
8. Regional Municipality of York (RMOY), Town of Newmarket, Ontario, Canada; and
9. Wisconsin Department of Transportation.

To be included in the research analysis, responding agencies were required to provide specific dates and times of the referenced winter storm events that led to snow and/or ice buildup on LED traffic signal lenses, and they had to be able to identify the intersections affected. Researchers were most interested in storm events in which at least 50 percent of the LED traffic signal lenses were covered by snow and/or ice and occluded from the traveling public.

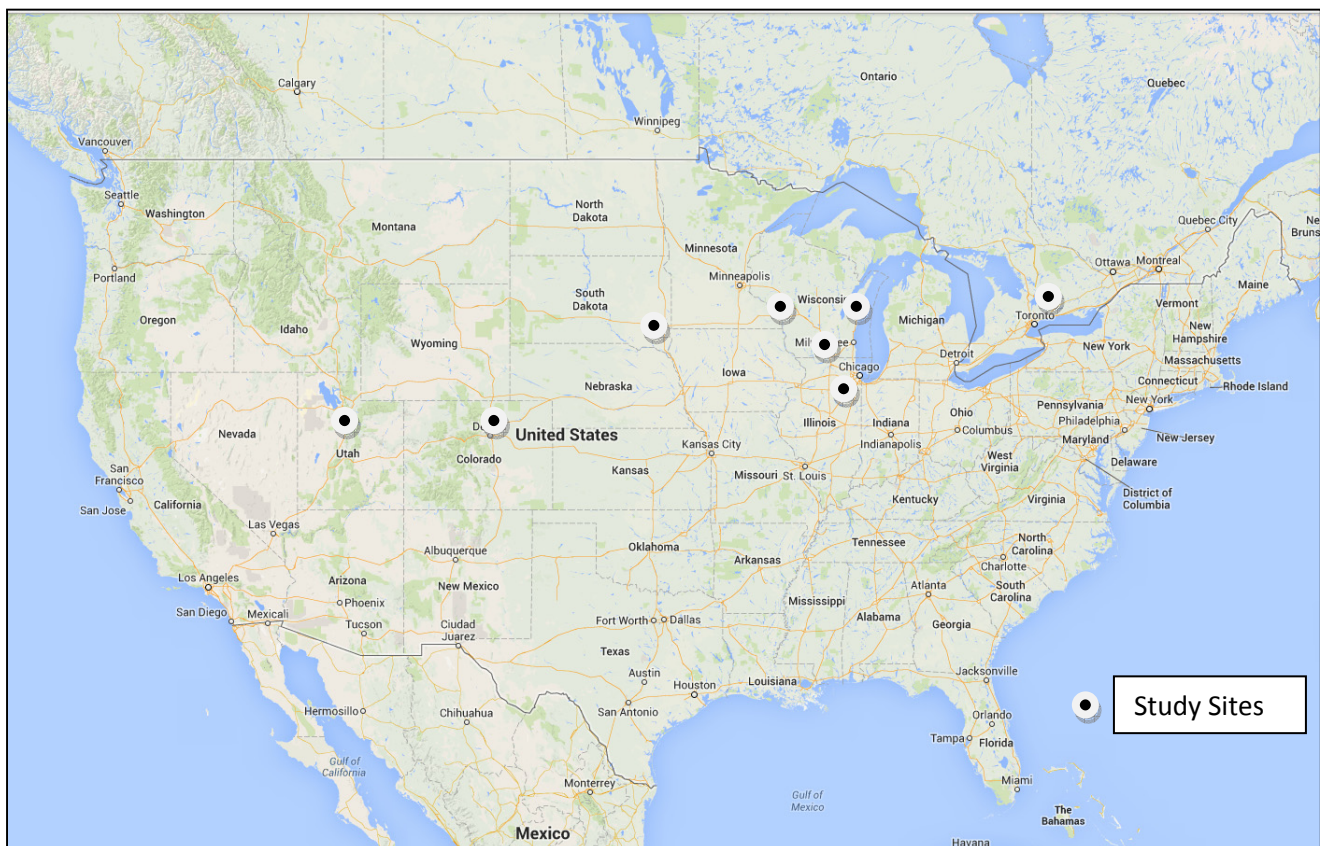
While having experienced snow and/or ice-covered LED traffic signal winter storm events, the Virginia Department of Transportation, City of Winnipeg, Michigan Department of Transportation, and City of Helena were unable to provide specific storm event date data. Each of these locations were not included in this analysis



as a result. Therefore, the “Request for Information” produced five agencies with the necessary data to be included in this research. Since it was desirable to include as many agencies as possible, researchers contacted several additional agencies who did not respond to the initial data request but were known to have experienced snow and/or ice on LED traffic signal lenses. This process led to three additional sites that had the necessary data and were subsequently included in this research. They were:

1. City of Madison, Wisconsin;
2. City of Sioux Falls, South Dakota; and
3. Village of Oswego, Illinois.

Therefore, a total of eight agencies were included in the final analysis, with several providing more than one study site or storm event. The geographical location of each agency location is highlighted in Figure 1. Note that the sites generally represent the upper Midwest of the United States along with one southeastern Canadian site.



**Figure 1. United States and Canada Map Showing Locations of Study Sites**

Source: Map data ©2013 Google, INEGI, Maplink

To complete the preliminary data collection process, additional information was obtained and included with each of the study sites and storm events considered. A review of Appendix A shows that each site description generally contains:

- Date(s) of storm events considered;
- Approximate number of intersections affected;
- Maps and/or photographs of the site(s) and traffic signals;
- Weather data tables; and
- Contact information for person with local knowledge of the events.

A summary of the 8 sites and 12 storm events considered are presented in Table 1.

**Table 1. Information on the 12 Storm Events Evaluated**

Location	Date	Approximate Number of Intersections Affected	Total Number of Signalized Intersections in Jurisdiction	Percentage of Storm Affected Signalized Intersections
Green Bay, WI	December 8-9, 2009	107	107	100%
Green Bay, WI	April 9, 2010	Multiple	105	N/A
Green Bay, WI	March 23, 2011	105	105	100%
Thornton, CO	March 26, 2009	Multiple	142	N/A
Thornton, CO	March 19, 2010	Multiple	142	N/A
Saratoga Springs, UT <sup>1</sup>	February 8, 2011	12	15 <sup>2</sup>	80%
LaCrosse, WI <sup>3</sup>	April 19, 2011	18	950 <sup>4</sup>	2%
Wausau, WI <sup>3</sup>	March 23-25, 2011	39	950 <sup>4</sup>	4%
RMOY, Newmarket, Ontario	March 6, 2011	25-50	812	~5%
Oswego, IL	April 6, 2009	Multiple	N/A	N/A
Sioux Fall, SD	February 23, 2012	Multiple	248	N/A
Madison, WI	March 2, 2012	Multiple	240	N/A

<sup>1</sup> Provided by Utah DOT.

<sup>2</sup> Estimate for Saratoga Springs. Utah DOT maintains 1,121 signalized intersections.

<sup>3</sup> Provided by Wisconsin DOT.

<sup>4</sup> Total Wisconsin DOT signalized intersections statewide.

## Weather Data Collection

The second task involved an extensive data collection effort to capture all of the pertinent and available weather data for the storm events identified. Weather data collection was completed for the 8 agencies, 9 sites, and 12 storm events presented in Table 1. Four Internet-based public sources were considered to obtain the necessary weather data. Each is listed below with their corresponding Internet link:

1. Weather Underground – <http://wunderground.com>
2. Quality Controlled Local Climatological Data (from the National Oceanic & Atmospheric Administration (NOAA)) - <http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N>
3. National Environmental Satellite, Data, and Information Services (NESDIS), National Climatic Data Center (NCDC), [www.ncdc.noaa.gov](http://www.ncdc.noaa.gov)
4. Road Weather Information systems (RWIS) – state DOTs (where available)

Fortunately, weather data for all U.S. study sites were available at the NCDC and Weather Underground sites; hence, these two sites were used exclusively. Weather data for the RMOY, Newmarket, Ontario site was obtained from a Canadian National Weather Data source: [www.climate.weatheroffice.gc.ca/climateData/canada\\_e.html](http://www.climate.weatheroffice.gc.ca/climateData/canada_e.html).

A review of Appendix A will show numerous data tables containing weather data. In all National Climatic Weather Center (NCWC) data tables presented in Appendix A, and described hereafter, a number of codes are used to describe weather data that may not be common to the transportation engineering community. The following list of weather attributes and codes (presented by typical NCWC column number) is intended to provide an initial description of the data terms used. Some of these attributes are further defined later in this report. A similar description is presented at the beginning of Appendix A.

Commonly used codes include:

1. DATE
2. TIME: TIME IN LST (LOCAL STANDARD TIME)
3. STATION TYPE (type of weather station reporting)
4. Sky Conditions
  - a. SKY CONDITIONS BELOW 12,000 FEET AGL (ABOVE GROUND LEVEL)
  - b. SKY CONDITIONS CONTRACTIONS ARE FOR EACH LAYER IN ASCENDING ORDER
  - c. NUMBERS FOLLOWING CONTRACTIONS ARE BASE HEIGHT IN HUNDREDS OF FEET ABOVE GROUND LEVEL (AGL)
  - d. CLR: CLEAR BELOW 12,000 FT
  - e. FEW: > 0/8 - 2/8 SKY COVER
  - f. SCT SCATTERED: 3/8 - 4/8 SKY COVER
  - g. BKN BROKEN: 5/8 - 7/8 SKY COVER
  - h. OVC OVERCAST: 8/8 SKY COVER
  - i. VVXXX INDICATES INDEFINITE CEILING WITH THE VERTICAL VISIBILITY (XXX) LISTED IN HUNDREDS OF FEET
  - j. WHEN CLOUDS ARE COMPOSED OF TOWERING CUMULUS OR CUMULONIMBUS, TCU OR CB (RESPECTIVELY) FOLLOW CLOUD HEIGHT.
  - k. SOME STATIONS REPORT CLOUDS ABOVE 12,000 FEET.
5. VISIBILITY IN STATUTE MILES (SM)
6. WEATHER TYPES (codes found elsewhere)
7. DRY BULB TEMPERATURE (DEGREES F) (Air temperature without humidity)
8. DRY BULB TEMPERATURE (DEGREES C)
9. WET BULB TEMPERATURE (DEGREES F) (Air temperature plus humidity)
10. WET BULB TEMPERATURE (DEGREES C)
11. DEW POINT TEMPERATURE (DEGREES F)
12. DEW POINT TEMPERATURE (DEGREES C)
13. RELATIVE HUMIDITY (PERCENT)
14. WIND SPEED (MPH)
15. WIND DIRECTION (TENS OF DEGREES FROM TRUE NORTH)
  - a. VRB = VARIABLE WITH SPEED EQUAL TO OR LESS THAN 6 KNOTS
16. WIND CHARACTERISTIC GUSTS (MPH)
17. STATION PRESSURE (INCHES OF MERCURY)
18. PRESSURE TENDENCY
19. NET 3 HOUR CHANGE (MILLIBARS)
20. SEA LEVEL PRESSURE (INCHES OF MERCURY)
21. REPORT TYPE:
  - a. AA - METAR (AVIATION ROUTINE WEATHER REPORT) – HOURLY
  - b. SP - METAR SPECIAL REPORT
22. PRECIPITATION TOTALS (INCHES AND HUNDREDTHS)
  - a. HOURLY TOTALS IF COLUMN 20 IS "AA" (HOURLY METAR REPORT)
23. ALTIMETER (INCHES OF MERCURY)

Appendix A also contains a description of each study site along with photos and relevant information provided.

## Weather and Location Data Analysis

The primary objective of this analysis task is to analyze the large amount of weather data obtained in an effort to identify weather attributes that may be empirically and/or statistically correlated to the weather events leading to snow and ice-covered LED traffic signal lenses. Three approaches were taken to complete this analysis: (1) an anecdotal approach; (2) a statistical approach; and (3) a meteorological evaluation.

### ***Anecdotal Approach***

An anecdotal approach was used based on a detailed review of all of the weather data obtained. Weather attributes that were consistently recorded with each of the 12 storm events were identified and compared across data sets included in Appendix A. The objective was to identify weather variables and their associated values that were consistent in each of the LED traffic signal lens-covering weather events considered. Weather variables considered included:

- Winter storm date;
- Temperature and temperature change;
- Humidity;
- Dew point;
- Atmospheric pressure;
- Wind direction;
- Wind speed;
- Wind gust;
- Wet bulb temperature; and
- Dry bulb temperature.

These weather variables with quantitative or qualitative commonality were recorded and further analyzed.

A summary of the conclusions include:

- *Date* – All storms were late in the winter—February, March, or April—except for the December 2009 storm in Green Bay, WI.
- *Temperature* – In all storms, the temperature was between 30 and 32 degrees Fahrenheit. In each storm except the December 2009 storm in Green Bay, WI, temperature was falling and had been significantly above freezing prior to the main snow event. Wet bulb and dry bulb temperatures were within 2 degrees Fahrenheit.

- *Humidity* – Humidity was typically recorded between 88 and 93 percent.
- *Atmospheric pressure* – Atmospheric pressure ranged from 29.3 to 30.0 inches but varied in whether the pressure was rising or falling. In eight of the storms, pressure was falling (high to low pressure storm). In four of the storms, pressure was rising.
- *Wind* – In each storm, sustained wind speeds were at least 10 mph and ranged between 10 and 38 mph. Wind gusts ranged from 17 to 48 mph. Wind was generally from a northerly direction.

Clearly, a common requirement for snow and ice-covered LED traffic signal lenses is a wind of sufficient speeds to blow the snow at an angle towards the signal lens and below the visor, usually aided by strong wind gusts. All storms had at least 10 mph sustained winds with gusts generally exceeding 20 mph. Another extremely consistent variable is air temperatures very near freezing, falling from higher temperatures above freezing shortly before the snow storm. Humidity is high and moisture is high, increasing the water content of the snow and the snow's ability to adhere to the LED lenses.

### ***Statistical Analysis***

The primary focus of the statistical analysis was to determine if it was statistically possible to compare storm events that produced snow-covered signal lenses to storm events that did not, and to identify weather attributes that were significant to the differences. Furthermore, a statistical analysis was also attempted to determine if the change in weather variables within a specific storm had statistically identifiable changes in variable values.

To consider the differences in weather attributes between storms that led to snow-covered LED traffic signal lenses and storms that did not, three of the sites with the most robust and direct weather data were selected. These locations included:

1. Madison, WI;
2. Green Bay, WI; and
3. Sioux Falls, SD.

Specifically, each of these three locations had abundant weather data; storm durations that were well documented; weather data from more than one reporting source; and perhaps most importantly, a reporting weather station located directly within the jurisdiction reporting. Note that in some of the jurisdictions, the reporting weather station was some distance from the jurisdiction.

The statistical procedures attempted to model the relationship between the explanatory and response weather variables included in the data sets. Since the data set contained both quantitative and qualitative measures and multiple response variables, a binary response statistical model was considered and used in the generalized linear models methodology. This methodology can be easily repeated using one of several off-the-shelf or Internet-based statistical modeling software packages.

The discrete nature of the responses required a special function, usually referred to as a “link function,” to serve as a bridge between the linear predictors and the mean of the distribution we use in the analysis. For the binary responses in the analysis, the logistic or “logit” link was used. Logistic regression improves the analysis when categorical dependent variables are also part of the analysis. The results of the climatological modeling of Green Bay, WI, Madison, WI, and Sioux Falls, SD, data are presented in Table 2.

**Table 2. Statistical Results**

<b>Coefficients</b>	<b>Estimate</b>	<b>Standard Error</b>	<b>Z value</b>	<b>Pr(&gt; z )</b>	<b>Significant?</b>
(Intercept)	14.3705207	4.5455073	3.161	0.001570	Yes
Wet Bulb	0.0804709	0.0101068	7.962	<0.0001	Yes
Relative Humidity	-0.0247351	0.0056458	-4.379	<0.0001	Yes
Wind Speed	0.0562571	0.0104013	5.409	<0.0001	Yes
Wind Direction	0.0015179	0.0005614	2.704	0.006852	Yes
Station Pressure	-0.5674953	0.1518244	-3.738	0.000186	Yes

The results of the statistical analysis suggest that the variables in Table 2, at a 95 percent level of confidence, are statistically significant predictors of snow-covered LED lenses in the winter storm events considered. Detailed descriptions of each of the Table 2 variables include:

- *Wet bulb temperature* – the lowest temperature that can be obtained by evaporating water into the air. This is the temperature indicated by a moistened thermometer bulb exposed to the air flow. Wet bulb temperature can be measured by using a thermometer with the bulb wrapped in wet muslin. The rate of evaporation from the wet bandage on the bulb, and the temperature difference between the dry bulb and wet bulb, depends on the humidity of the air. The evaporation is reduced when the air contains more water vapor. The wet bulb temperature is always lower than the dry bulb temperature but will be identical with 100% relative humidity.
- *Relative humidity* – amount of moisture in the air compared to what the air can "hold" at that temperature. When the air can't "hold" all the moisture, then it condenses as dew. Relative humidity is a



function of both moisture content and temperature. As such, relative humidity by itself does not directly indicate the actual amount of atmospheric moisture present (dew point is used).

- *Wind speed and direction* – speed of the wind, measured in miles per hour (MPH), along with the direction from which the wind originated.
- *Station pressure* – the absolute air pressure at a given reporting station. The air pressure is directly proportional to the combined weight of all air in the atmosphere located in a column directly above the reporting site.

Using the four statistically significant variables reported above and the associated coefficients in Table 2, it is possible to create a statistical model such that future data can be used to predict the probability of a storm event that leads to snow and ice-covered LED traffic signal displays. Nevertheless, as described in the next section, the model predictability will likely have little practical significance. In other words, it is possible to model past storm events, but unlikely that the attributes of a future storm event will be holistically consistent with past events, with or without the buildup of snow and/or ice on LED traffic signals lenses.

### ***Meteorological Evaluation***

Two meteorologists were consulted to assist in the analysis, given their direct expertise on the primary consideration in this research. A meteorological researcher with expertise in winter storm events provided insight and expert recommendations during the analysis process. Also, a professional meteorologist who forecasts weather for local television and radio media outlets, and analyzes and provides daily weather data throughout the United States, was retained to complete a thorough review of the data. Additionally, he looked more formally at professional weather databases and historical models to help identify weather attributes that may not be captured in the public weather data sites used. The results of each of these analysis steps are provided below.

First, both weather experts agreed that the databases considered from NCWC and Weather Underground contained the necessary variables important to this analysis. There was nothing additional in their local databases that would add to this research. Although meteorologists consider the same variables identified in this research, most weather forecasting is completed by computer weather models which may not directly report the variables pertaining to this research. Nevertheless, all weather variables are considered and reported as necessary.

The meteorologists concluded that the major factors in these winter storm events that lead to snow and/or ice buildup on LED traffic signal lenses are simply wind speed and temperature (wet bulb). The fact that most of the storms identified occurred in late winter or early spring is expected as these warmer-type storms tend to occur



later in the winter as the typical storm tracks brings the storms from the southwest more often (as opposed to clipper-type systems from the northwest that tend to be colder). Nevertheless, it is possible for storms moving in from the northwest or other directions to produce the same conditions, i.e., wet snow and wind, although it may be less probable.

Humidity is always fairly high in any precipitation situation, even with colder storms which will not produce wet snow. This is because there is an abundance of moisture in the atmosphere due to the precipitation, and that moisture will evaporate into the atmosphere. Atmospheric pressure *tendency* may not be a significant predictor, as pressure will always fall as a weather front approaches and rise after it passes. Precipitation can occur on both sides of the front, though the wet snow is much more common ahead of the front (when pressure is falling). The actual minimum pressure could be an indicator variable.

The question remains as to what types of storms produce the type of conditions described above such that snow and ice-covered LED traffic signal lenses can be predicted. Unfortunately, meteorologists agree that the simple answer is *all* types. Nevertheless, the key variable appears to be the temperature (wet bulb) as the storm approaches. If the temperatures are above freezing at the surface before the storm moves through, chances are there will be at least some wet snow. Storms that produce more wet snow generally move in from the southwest, although some parts of the United States and Canada can experience storms from most any direction. Southwest storms also tend to be stronger storms, which mean stronger winds (note that the strength of storms is typically determined by the atmospheric pressure). As a general rule, the lower the atmospheric pressure, the stronger the wind.

In the opinion of the meteorologists, a specific set of weather variables that are a perfect predictor of snow and/or ice-covered LED traffic signal lenses is not practical. The meteorologists often consider statistical modeling and evaluations of previous storms, which is part of their forecasting methodology, but through experience, they know that models of previous storm are often imperfect predictors. The fact that models are not always good predictors is why weather professionals often have extreme variability in weather forecasts.

Considering typical weather data and generalizing the results, it is likely that stronger storms with minimum pressures under 29.8 inches of mercury (wind producing), moving into an area with above freezing temperatures, is a good indicator of the need to be aware of the potential for snow and/or ice buildup on LED traffic signal

lenses. The storm would most likely have to be several hours in duration to provide time for the temperatures to move through the above to below freezing range. The potential for snow and/or ice-covered LED traffic signal lenses also increases if the forecast snow totals are higher, as this often associates with the snow-to-liquid equivalent ratio. The snow-to-liquid equivalent ratio is the predictor of how many inches of snow is produced as compared to an inch of liquid (rain) water. The ratio for wet snow that is commonly consistent with snow-covered LED signal lenses is 10:1 or less.

Both meteorologists suggested that from a forecast standpoint, it could be reasonably predicted that an upcoming winter storm had *no* potential for causing problems with LED traffic signal lenses as well as that an upcoming winter storm had a *reasonable* potential to cause snow and/or ice buildup on LED traffic signal displays. Unfortunately, more specific predictions are not possible since every storm is different and would need to be considered individually to determine the potential risk.

### **Results of the Anecdotal, Statistical, and Meteorological Analyses**

The results of the combined analyses, including consideration of weather data in both the anecdotal and statistical methods, along with the evaluation, analyses, and opinions of the meteorologists, suggest that near freezing temperatures (typically wet bulb temperatures starting above freezing or dropping below freezing) and sufficient wind speed (associated with atmospheric pressure) are the two key attributes of the winter storm events that produce snow and/or ice-covered LED traffic signal lenses. These conditions are more common in late winter storms, which are consistent with the dates of the storms described in this research. Moisture conditions leading to predicted snow-to-water equivalency ratios of 10:1 (or less) is common. Results of the data analysis and meteorologist's opinions also agree that these weather attributes are potential predictors, and may or may not lead to snow and/or ice-covered LED traffic signal lenses. Nevertheless, winter storms with the following attributes have a highly probable potential for snow/ice covered LED traffic signals displays: predicted temperatures near or passing through 32 degrees Fahrenheit; humidity levels at approximately 90 percent; atmospheric pressures at or below 29.9 inches of Mercury (i.e., less than average sea level pressure); and wind speeds greater than 10 mph with northerly high speed gusts.

### **Countermeasures**

Several reactive and proactive countermeasures to solve snow and ice-covered LED traffic signal lens problems have been employed by traffic engineers around the country. The following example focuses on the City of Green

Bay, Wisconsin, which provided details on the countermeasures it has considered. A summary of attempted countermeasures from other locations included in this research is also provided.

Reactive countermeasures employed include manual brush cleaning, compressed air spraying, and antifreeze or deicing spraying. Each of these countermeasures requires manual labor and staff to be in the field during or immediately after the storm event to clear the affected traffic signal lenses. Figure 2 depicts a long handled brush commonly used. Figure 3 shows a lens cleaning operation in Utah.



**Figure 2. Brush with Telescoping Pole**

Source: ©Dave Hansen/City of Green Bay



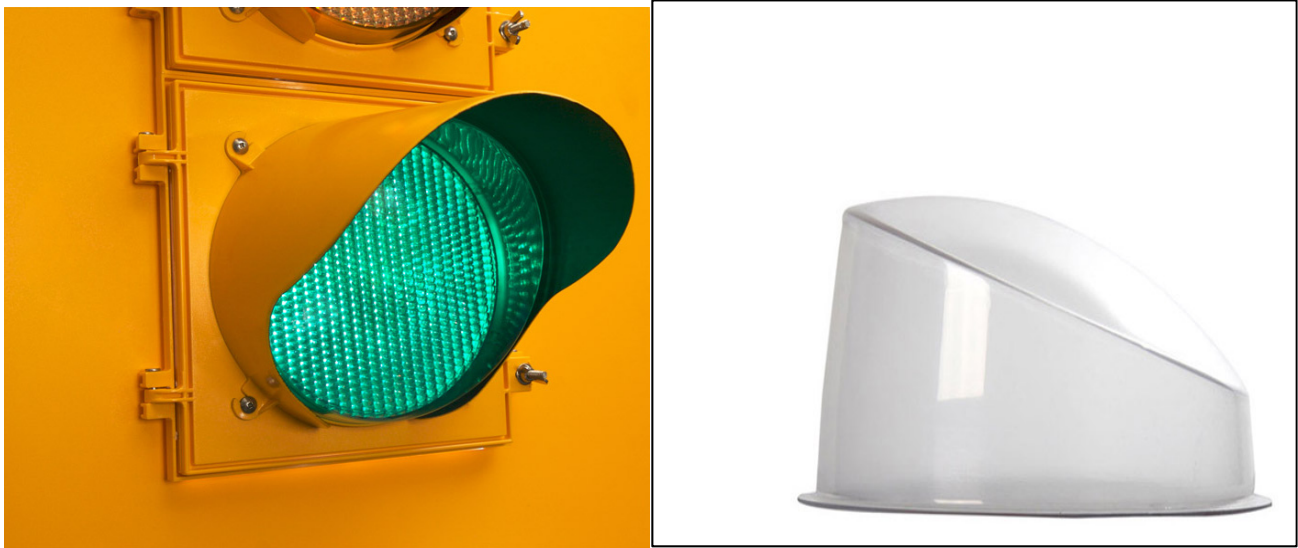
**Figure 3. Cleaning Lenses with Telescoping Pole**

Proactive countermeasures include the Fortran Snow Sentry,<sup>TM</sup> the McCain Snow Scoop visor, and the before-storm application of chemical deicers. The Fortran Snow Sentry<sup>TM</sup> was a product developed after multiple experiments with lens heating elements (see [www.ite.org/standards/led/files/13\\_%20Fortran.ppt](http://www.ite.org/standards/led/files/13_%20Fortran.ppt)). Heating elements were evaluated in both environmental chambers and field installations. Results showed that the heating elements were not successful in eliminating the snow and ice buildup on lenses, and may also lead to discoloration and deformation of the lens. These issues were in addition to the cost and complexity of adding power to operate the heating elements.

The Fortran Snow Sentry<sup>TM</sup> is a lens cover designed to guard the signal lens from snow and ice buildup. As shown in Figure 4, the slope of the lens cover generally matches the signal visor, sloping down and towards the signal head. The shape is believed to minimize the ability for snow and ice to stick to the lens cover, and the clear acrylic material used to make the Snow Sentry<sup>TM</sup> was independently tested and shown to have no impact on the transmission of light from the signal indication.

The McCain Snow Scoop visor was designed with a louvered vent at the top that funnels wind across the signal face. As shown in Figure 5, the wind funnel air speed across the signal lens decreases the probability of snow and ice adhering to the signal lens.

Several traffic agencies in the U.S. have experimented with one or both of these devices. Green Bay, Wisconsin reported improvements with the Snow Scoop visor and the Snow Sentry,<sup>TM</sup> although neither was reported to completely prevent snow and ice buildup on the lenses. Figure 4 provides an example of the Snow Sentry<sup>TM</sup> and Figure 5 shows the Snow Scoop. Figure 6 depicts the results of an in-field comparison test of the two devices. Although Figure 6 does not show a comparative signal display without the Snow Scoop visor or Snow Sentry<sup>TM</sup>, both devices reportedly provided improvement in preventing snow and ice buildup on the LED traffic signal lens from occluding the indication.



**Figure 4. Fortran Snow Sentry<sup>TM</sup> Lens Cover**

Source: Fortran Traffic Systems Ltd.





**Figure 5. McCain Snow Scoop Visor**  
Source: McCain Inc.



**Figure 6. Snow Sentry vs. Snow Scoop**

Source: ©Dave Hansen/City of Green Bay

Pre-storm spraying with deicer was also shown to reduce the amount of snow and ice buildup, although the application life of the deicer is undetermined. Figure 7 shows a commonly used deicer product and the empirical results of an in-field test.

The Wisconsin Department of Transportation (WisDOT) reported an experiment with Intelight's Automatic Lens Defrosters. This device includes a flexible heating element to thermodynamically heat the inside of the LED's signal casing, providing heat to melt snow and ice buildup. A heating unit sits inside the door of the LED signal lens and consumes 34 Watts as part of a 120-V AC connection. WisDOT reported difficulty with this device in non-Intelight products. The devices were never field installed.

A review of the countermeasures identified found no device or application that proved to be completely effective at preventing snow and/or ice buildup on LED traffic signal lenses. Nevertheless, each method provided some reduction in the snow and ice buildup and improvement in traffic signal indication visibility.



**Figure 7. Chemical Deicer Fluid for Lens Application**

Source: ©Dave Hansen/City of Green Bay

Table 3 provides a summary of the primary countermeasures and their reported uses by the agencies included in this research. In discussing countermeasures with traffic engineers who are part of the National Committee on Uniform Traffic Control Devices (NCUTCD) and participate in the Transportation Research Board's Traffic Control Devices Committee (AHB50), most suggest that brush cleaning is the only countermeasure employed, and only when self-cleaning through melting is not timely.

**Table 3. Countermeasures Attempted by Responding Agencies**

Location	Reactive	Proactive		
	Brush Cleaning	Chemical Deicer	Snow Sentry™	Snow Scoop
Green Bay, WI	Yes	Yes	Yes	Yes
Thornton, CO <sup>2</sup>	Yes	Yes	No	Yes
Utah DOT	Yes <sup>1</sup>	No	No	Yes
Wisconsin DOT <sup>2</sup>	Yes	No	Yes	Yes
RMOY, Newmarket, Ontario	Yes	No	Yes	No
Oswego, IL	Yes	No	No	No
Sioux Fall, SD	Yes	No	No	No
Madison, WI	Yes	No	No	No

<sup>1</sup> With hot steam spray

<sup>2</sup> Has also experimented with Automatic Lens Defrosters

### ***Federal Aviation Administration Countermeasure***

As a final note on countermeasures, other transportation-based agencies were explored for related information on their use of LED lighting and signals. Perhaps not surprisingly, the Federal Aviation Administration (FAA) has addressed the issue of snow and ice-covered LED runway and taxiway lighting through a specification referred to as an “arctic kit” or “heating kit.” FAA Engineering Brief 67D, dated March 6, 2012, section 2.13 states:

2.13 Optional Arctic Kits - Any fixture (includes in-pavement fixtures), may have an optional arctic kit and/or an appropriate addressing of potential icing conditions to no less extent than present fixtures. An arctic kit may be an optional feature and may be specified by the customer at the time of purchase. The arctic kit, if present, must be self-activating.

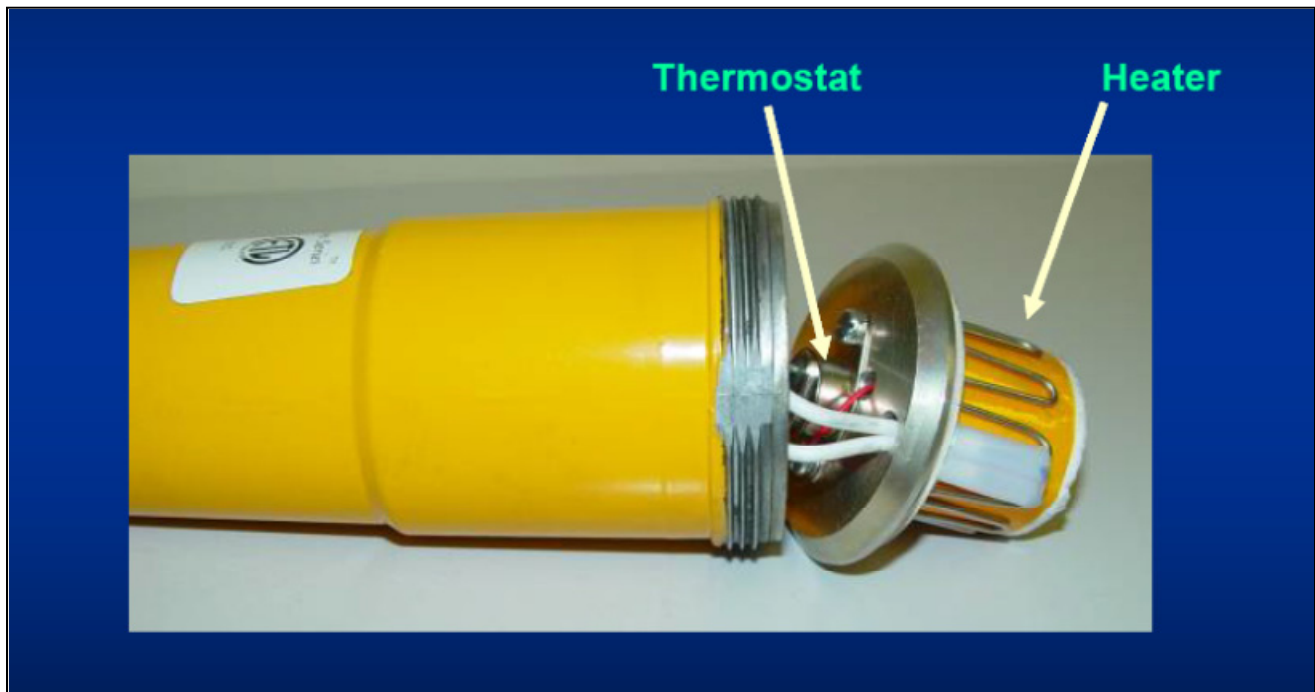
2.13.1 Arctic Kit Testing Requirements. The arctic kit must be tested as follows:

- a. With light source and arctic kit off, the light fixture must be stabilized for 4 hours at - 20°C.
- b. Then, in still air and with the light source activated at the highest intensity setting, the main beam light emitting surface temperature must rise a minimum of 15°C after 30 minutes operation.
- c. For elevated fixtures, this test is run in open-air conditions.

The kit is a thermostatically controlled heater, designed to replicate an incandescent bulb, activated automatically when temperatures fall below 41 degrees Fahrenheit. The device uses a 20 to 45 Watt isolation transformer connected to heating elements, as shown in Figure 8. This device could be applicable to traffic signal LEDs with minor modifications and provide a heat source to prevent snow and ice buildup on the lenses. However, experimentation with existing LED traffic signal products is required to determine the trade-off in energy consumption and accelerated degradation and deformation of the LED signal lens with this potential



countermeasure. Additionally, the impact and feasibility of operating a series of heater elements on battery backup power should be considered.



**Figure 8. FAA LED Heating Element**

Source: Courtesy ADB Airfield Solutions

### Recommendations

The research results have led to the following recommendations:

1. Develop formal relationships with local meteorologists. The most effective way of predicting a storm event that may lead to snow and/or ice-covered LED traffic signal lenses is to establish a formal relationship with a local meteorologist. Many states and cities have staff meteorologists or contract with local meteorologists to provide weather data. In most cases, weather data is used to determine snow plowing and general winter maintenance needs. However, consideration of the weather attributes identified in this research, in advance of the storm, can also help traffic engineers prepare for the potential of snow and ice buildup on the LED traffic signal lenses. The findings of this research suggest that meteorologists and the weather models used can be good predictors of potential winter storm events that may lead to snow and ice on the LED traffic signal lenses.

2. Manual and Specification Changes. A presentation was made to the Signals Technical Committee, part of the National Committee on Uniform Traffic Control Devices (NCUTCD), describing the problem and soliciting their input on potential solutions. A query was also presented as to whether this issue should be addressed in the Manual on Uniform Traffic Control Devices (MUTCD) or similar document. The response was unanimous—there is no interest by the national committee in trying to address this issue in the MUTCD, or suggest in the MUTCD the minimum requirements for traffic signal indication visibility during storm events. Perhaps a minimum standard should be considered in an attempt to maintain some level of minimum visibility, even if it only considers the red indication. Committee members suggested that technology be considered to provide a heating element of some sort in traffic signal lenses that would prevent the snow and ice from adhering to the signal lens. An example of this type of technology was described in the countermeasures section of this report. If an acceptable solution were to be found, a specification for LED traffic signal lenses for locations susceptible to winter storm events should be created as a supplement to the current ITE specification.

### Needed Research

1. It does not appear that a weather-based simulation (i.e., creating snow events in a lab to determine the attributes of the snow that stick to traffic signal lenses) would provide any additional information beyond what is gleaned from the historical weather data reported. There are simply too many weather variables that would not be replicable in a laboratory environment, nor would it be possible to predict every possible storm type.
2. Additional research should be more appropriately focused on developing technologies to minimize or eliminate the snow/ice problem. Several prototype heating elements have been developed for LED traffic signal lenses. At least one of these devices was patented in 2007 under the title “De-Icing System for Traffic Signals” ([www.google.com/patents/US7211771](http://www.google.com/patents/US7211771)). Intelight has produced a defroster heating element that can be added to the LED signal lens housing. Other prototypes have been produced as part of university experiments, which include a number of sensors to measure precipitation and wind speed such that the heater only turns on when a weather event is sensed. Previous tests with heating elements led to degradation of the signal lenses and insufficient snow melt. New technologies should be considered that do not impact the quality of the signal lenses. More exploration is required before a deicer element could be specified and used within the traffic signal LED marketplace. The evaluation of heating

technologies could be the basis of future laboratory experiments to test its effectiveness under varying weather conditions.

3. A new technology currently being used in the clothing and electronics industry has the potential to be an effective solution for the snow/ice buildup problem on traffic signal lenses. An ultrathin layer of polymer is applied to the surface of devices to lower the surface energy ([www.p2i.com/](http://www.p2i.com/)). This polymer layer acts to reduce the disruption of intermolecular bonds within a liquid, essentially “waterproofing” the device, and allowing liquids to remain in droplet formation to easily move away. This liquid repellent nano-coating technology applied to traffic signal lenses would prevent water from adhering to the lenses and may prevent snow and ice from adhering to the lenses. This technology would require testing in freezing climates and varying winter weather conditions, along with economic considerations.
4. A final potential solution proposed by some would be to include a small incandescent bulb in combination with LEDs, in the red indication only, such that the red indication would produce enough heat to prevent snow and ice adhering to the lens. Most transportation professionals would agree that in the unfortunate storm event where traffic signals are lost or covered, if only one indication could be saved, it would be the red indication. The red indication would continue to provide the stop message to drivers necessary to maintain safety. Therefore, it is most critical that drivers can determine when the red indication is illuminated. This potential solution of modifying only the red indication to create heat during winter months certainly has its drawbacks, adding additional energy consumption, and signal maintenance, and lense degradation that would offset some of the financial and energy benefits of LEDs. Nevertheless, the safety benefits may be worth this cost tradeoff. An LED traffic signal lens or traffic signal head manufacturer, or someone with a general understanding of the operating conditions of traffic signals in winter weather, would need to experiment with this change.