AN INVESTIGATION INTO THE EFFECTIVENESS OF ICE WARNING SIGN PLACEMENT PRACTICES
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This study was undertaken to assist WSDOT traffic engineers understand the effectiveness of ice warning signs.

16. ABSTRACT

Road surface conditions, particularly ice and snow, are not a permanent feature of the roadway. This lack of permanence in hazard formation, location, and duration makes effective signing difficult. To compensate for this difficulty in predicting ice warning signing requirements, two practices have emerged: oversigning and standard sign placement. The purpose of the project was to provide (1) insight into the effectiveness of current ice warning signing placement practices based on other state practices, ice-related accident locations and frequencies, and public attitudes toward the warning signs; (2) insight into driver behavior related to ice warning signs based on public response and observed driver behavior; and (3) possible recommendations for ice-related accident "trouble spots" not currently signed.

The research approach comprised four primary tasks: (1) conducting a national review to learn of previous ice warning sign experiences, (2) identifying current placement practices for ice warning signs in Washington, (3) considering public attitudes about and responsiveness to Washington's ice warning signs, and (4) examining problems related to public safety and state liability in Washington.

On the basis of positive public support for ice warning signs, WSDOT's perceived liability in the event of an ice warning sign accident, and the terms required to escape or minimize liability damages (i.e., proof of a reasonable and systematic process for placing signs), the continued use of ice warning signs is recommended. However, signs should be placed not at standard, sometimes irrelevant locations (e.g., entrances to state routes) but rather at high-risk areas (e.g. at bridges or locations identified by motorists) or locations with a history of ice-related accidents.

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VOLUME I

by

Jodi L. Carson	Jennifer Nee	Ed McCormack
Research Engineer, TRAC	Research Assistant, UW	Research Engineer, TRAC

Washington State Transportation Center (TRAC)
University of Washington, Box 354802
University District Building
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transportation
Technical Monitor
Ms. Jennene Ring
Traffic Engineer

Prepared for

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and in cooperation with
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AN INVESTIGATION INTO THE EFFECTIVENESS OF ICE WARNING SIGN PLACEMENT PRACTICES

Introduction

Road surface conditions, particularly ice and snow, are not a permanent feature of the roadway. This lack of permanence in hazard formation, location, and duration makes effective signing difficult. To compensate for this difficulty in predicting ice warning signing requirements, two practices have emerged: (1) oversigning, and (2) standard sign placement. Oversigning, or placing more signs than are necessary, is intended to improve the level of safety on the facility and to protect the Washington State Department of Transportation (WSDOT) from unnecessary liability. The placement of signs on *all* bridges, regional boundaries, or other standard roadway features is again intended to improve the level of safety on the facility and to protect WSDOT from unnecessary liability.

This summary describes the key findings of a study of current ice warning sign placement practices in Washington that is documented more fully in "An Investigation into the Effectiveness of Ice Warning Sign Placement Practices." The purpose of the project was to provide (1) insight into the effectiveness of current ice warning signing placement practices based on other state practices, ice-related accident locations and frequencies, and public attitudes toward the warning signs; (2) insight into driver behavior related to ice warning signs based on public response and observed driver behavior; and (3) possible recommendations for ice-related accident "trouble spots" not currently signed.

Research Approach

The research approach comprised four primary tasks: (1) conducting a national review to learn of previous ice warning sign experiences, (2) identifying current placement practices for ice warning signs in Washington, (3) considering public attitudes about and responsiveness to Washington's ice warning signs, and (4) examining problems related to public safety and state liability in Washington.

Conclusions and Recommendations

On the basis of positive public support for ice warning signs, WSDOT's perceived liability in the event of an ice warning sign accident, and the terms required to escape or minimize liability damages (i.e., proof of a reasonable and systematic process for placing signs), the continued use of ice warning signs is recommended. However, signs should be placed not at standard, sometimes irrelevant locations (e.g., entrances to state routes) but rather at high-risk areas (e.g., at bridges or locations identified by motorists) or locations with a history of ice-related accidents. Accident history maps are provided in the Appendix of the report to assist in ice warning sign placement.

Technical Contacts/Project Personnel

Name	Bill B. Legg	Jodi L. Carson
Organization	Washington State Dept. of Transportation	Washington State Transportation Center
Address	1107 NE 45th Street, Suite 535 University District Building Seattle, Washington 98105-4631	1107 NE 45th Street, Suite 535 University District Building Seattle, Washington 98105-4631
Phone	206-543-3332	206-543-8690
Fax	206-685-0767	206-685-0767

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Transportation Commission, Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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CHAPTER 1
INTRODUCTION

Road signs provide the traveling public with three types of information: regulatory, guidance, and warning. Warning signs are used to alert drivers to potential hazards such as unexpected

- changes in horizontal alignment
- intersections
- traffic control devices
- converging traffic lanes
- narrow roadways
- grades
- railroad crossings
- entrances and crossings (i.e., hidden driveways)

and usually advise the driver to perform an action such as reducing speed or being particularly alert.

In addition to the reasons cited above, warning signs are used to alert drivers to potentially hazardous road surface conditions. Unlike the instances listed above, road surface conditions, particularly ice and snow, are not a permanent feature of the roadway. This lack of permanence in hazard formation, location, and duration makes effective signing difficult.

To compensate for the difficulty in predicting the need for ice warning signage, two practices have emerged: oversigning and standard sign placement. Oversigning, or placing more signs than are necessary, is intended to improve the level of safety on the facility and to protect the Washington State Department of Transportation (WSDOT) from unnecessary liability. The standard placement of signs on *all* bridges, regional boundaries, or other specified roadway features is again intended to improve the level of safety on the facility and to protect WSDOT from unnecessary liability.

However, contrary to the intent of these two practices, too many warning signs or the inappropriate posting of warning signs (i.e., at locations where hazards are rarely present) can desensitize drivers to the actual hazard, reducing the likelihood that they will take appropriate action. This casual driver attitude toward warning signs may be carried over to other hazardous situations in which a driver's reaction (e.g., reducing travel speed) to the cautionary message is more critical.

Currently, little guidance exists to help WSDOT traffic engineers determine the effectiveness of current sign placement practices. This lack of guidance potentially results in inconsistency among WSDOT regions or areas, a lower level of service to the traveling public, a lower level of safety, higher signing costs incurred by WSDOT, and a higher risk of liability for WSDOT.

This project was meant to help provide better guidance by providing the following:

- insight into the effectiveness of current ice waring sign placement practices based on other state practices, ice-related accident locations and frequences, an dpublic attitudes toward the warning signs
- insight into driver behavior related to ice warning signs based on pbulic response and observed driver behavior
- possible recommendations for ice-related accident "trouble spots" not currently signed.

CURRENT GUIDELINES

Currently, three main sources provide traffic engineers and maintenance personnel with guidance related to warning signs: (1) *Manual on Uniform Traffic Control Devices (MUTCD)*, (2) *WSDOT Maintenance Manual*, and (3) *WSDOT Sign Fabrication Manual.*

The *MUTCD* recommends both sign design and placement. The recommended design of warning signs, as described in the MUTCD, is as follows:

- diamond shaped square
- black legend and border
- yellow background
- fully reflectorized for night conditions.

The *MUTCD* recommends larger signs for particularly hazardous areas.

The sign placement recommended by the *MUTCD* is based on driver processing and reaction times; specifically, time to perceive, identify, decide on necessary maneuvers, and perform them (referred to as Perception/Identification/Emotion/Volition or PIEV time). PIEV times typically range from 3 to 10 seconds, depending on the level of driver processing and reaction required. The *MUTCD* defines three levels of hazard conditions:

Condition A - highest hazard condition, driver requires extra time to make a decision and execute reactions because of a complex driving situation (i.e., changing lanes, passing, merging)

Condition B - hazard condition in which driver will likely be required to stop his or her vehicle

Condition C - hazard condition in which driver will likely be required to decelerate to a specific speed.

Ice warning signs could be categorized as Condition C; drivers are advised to decelerate, although a reduced speed is typically not posted. On this basis, warning sign placement preceding hazard locations ranges from 198.2 meters at 104.8 kilometers per hour (650 feet at 65 miles per hour) to 30.5 meters at 40.3 kilometers per hour (100 feet at 25 miles per hour). For speeds of 32.3 kilometers per hour (20 miles per hour) or lower, shorter signing distances may be used. Methods for determining sign placement on a larger scale (e.g., routes, bridges, etc.) are not described.

The *MUTCD* recommends that the effectiveness of any warning sign should be tested periodically under both day and night conditions. Methods for determining sign effectiveness are not described.

The *WSDOT Maintenance Manual* describes signing responsibility, but it gives little guidance on sign placement and management.

As described in the *WSDOT Maintenance Manual,* the regional traffic engineer has authority for determining the design, location, height, and other features associated with the installation of all signs, including warning signs. Regional maintenance personnel are responsible for the maintenance and erection/removal of all signs, including warning signs.

Much emphasis is placed on snow and ice control in the *WSDOT Maintenance Manual.* While snow and ice control is recognized by WSDOT as a high priority (taking precedence over all other non-emergency work), ice warning signs seem to be a minor measure for keeping the roadways safe during freezing conditions. Efforts focus on preventing the formation of snow and ice on the roadways (i.e., snowplowing, sanding, ice blading, and applying abrasives or chemicals) rather than preventing accidents once the ice has formed.

The *WSDOT Sign Fabrication Manual*, like the *MUTCD*, recommends that the design of ice warning signs include

- diamond shaped square
- black non-reflectorized legend and border
- yellow reflectorized background for night conditions.

The ice warning sign message in Washington reads "Watch for Ice."

CORRELATING ICE, SIGNING, AND ACCIDENT DATA

The deceptively simple task of identifying potentially unsafe roadway segments and comparing those to current ice warning sign locations is in fact quite complex. With public safety and agency liability of highest concern, these questions must be asked:

(1) What roadway segments or features in the state of Washington are most likely to result in an ice-related accident?

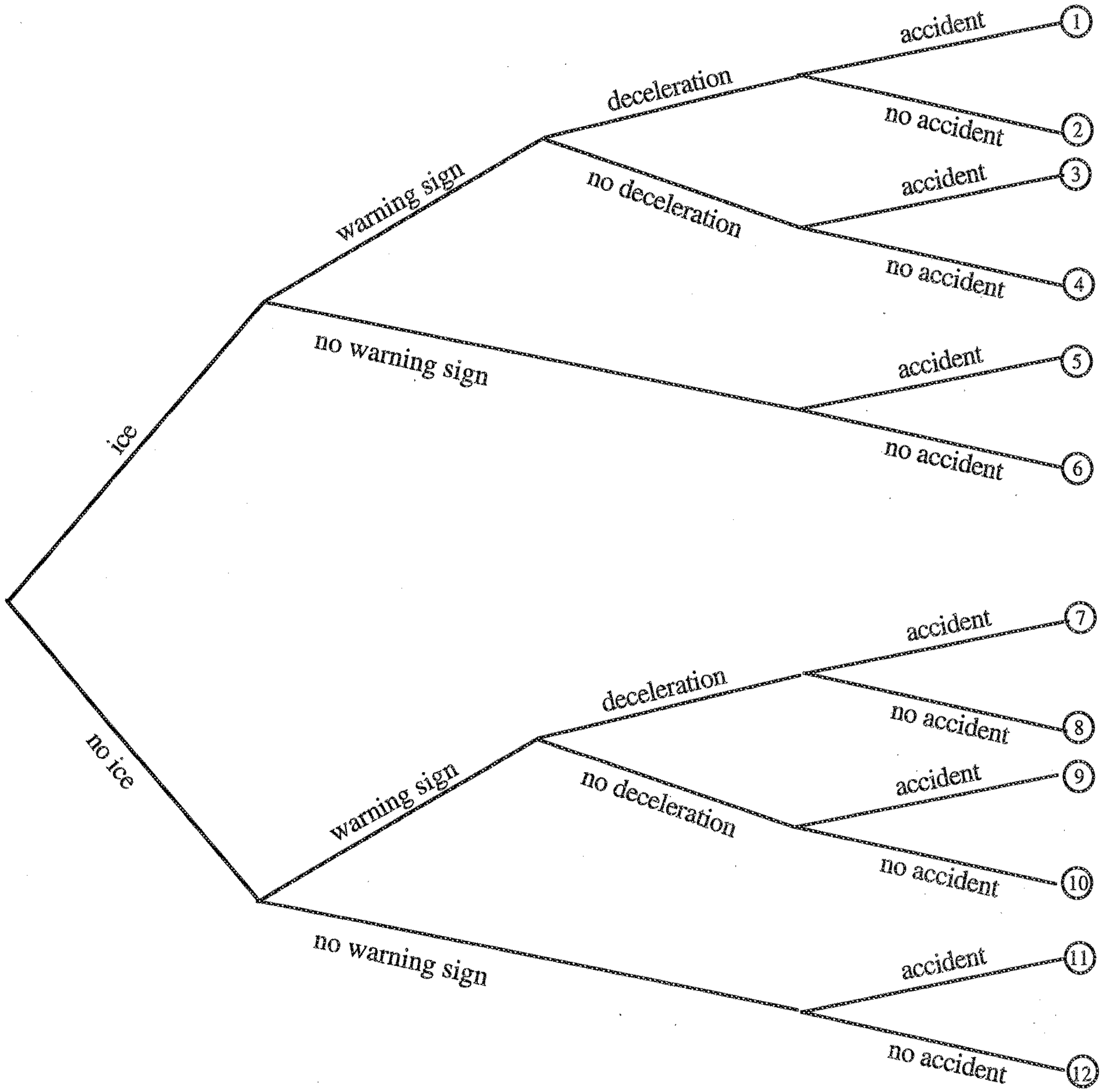
(2) If an ice-related accident occurs, how likely is it that an ice warning sign was in place?

(3) If an ice warning sign was in place, how likely was it that the driver reacted appropriately (i.e., decelerated)?

To adequately answer these related questions, probabilistic methods could be used to determine route segments in the state of Washington with the highest likelihood for safety and liability problems related to ice (see Figure 1). Geographic Information Systems (GIS) could be used to display and spatially correlate the icing, signing, and accident data. Unfortunately, a number of problems make this type of analysis difficult to perform.

The first relates to defining the probability of ice forming along particular route segments. Ice formation is both location and time dependent. Ice can form over vast stretches of roadway or in localized areas such as bridges or shaded areas. Ice can persist for many months or for only a few hours in early morning or late evening. In addition, the conditions that constitute "ice" are not well defined. At what point is compact snow considered to be ice? Historical surface

PROBABILITY PATH



CONSEQUENCE

1 appropriate signing and driver response, may indicate non-ice-related safety problem, potentially high risk of non-ice-related liability

2 appropriate signing and driver response, adequate safety level and low risk of liability

3 appropriate signing but inappropriate driver response, ice-related safety problem but low risk of liability

4 appropriate signing but inappropriate driver response, potential ice-related safety problem but low risk of liability

5 inappropriate signing, inadequate safety level and high risk of liability

6 inappropriate signing, potential ice-related safety problem and high risk of liability

7 inappropriate signing but appropriate driver response, may indicate non-ice-related safety problem, potentially high risk of non-ice-related liability

8 inappropriate signing but appropriate driver response, adequate safety level and low risk of liability, may desensitize driver to warning sign

9 inappropriate signing and driver response, may indicate non-ice-related safety problem, potentially high risk of non-ice-related liability

10 inappropriate signing and driver response, adequate safety level and low risk of liability, may indicate desensitized driver to warning sign

11 appropriate signing, may indicate non-ice-related safety problem, potentially high risk of non-ice-related liability

12 appropriate signing, adequate safety level and low risk of liability

Figure 1. Safety and Liability Risks Related To Ice Warning Signs

climatic data, including minimum temperature, precipitation, snowfall, freezing elevations, hours of sunshine, and dew point isare provided macroscopically and do not show promise for predicting localized icing. Additionally, proven relationships between climatic data and roadway surface conditions appear to be lacking (i.e., although the temperature and precipitation measurements suggest the formation of ice, no ice may form on the roadway surface).

Ice and weather prediction technologies have been investigated in Washington. Current ice or weather prediction technologies attempt to predict weather timing at a fixed location (e.g., predict the start of snowfall at a mountain pass) with the intent of deploying short-term, immediate control measures (e.g., snowplow and sand spreader fleets). Because ice warning signs are a semi-permanent control measure, location rather than time is critical.

A second difficulty in effectively identifying proper ice warning sign placement lies in the examination of ice-related accidents. Accidents are unpredictable events; not all vehicles that traverse an icy road segment will get in an accident. Factors such as vehicle speed, tire traction, and vehicle weight influence the probability of an accident occurring. In addition, the majority of ice-related accidents likely occur along rural routes, result in only minor property damage, and are not formally reported. A historical examination of statewide ice-related accidents is likely to underestimate the probability of occurrence.

Driver reaction further confounds the problem of accurately quantifying the probability of ice-related accident occurrence. If the driver heeds the warning sign and decelerates the vehicle, the probability of having an accident decreases.

Because of these complications to effectively comparing potentially unsafe roadway segments with current sign placement, the effort proposed here will serve as an introductory investigation into potential indicators of sign placement effectiveness. If ice-related accident locations are not correlated with sign placement, this may indicate that the current methods for determinging sign locations should be reassessed. If ice-related accident locations are highly correlated with sign placement, possibly indicating that signs are being placed in the appropriate locations yet drivers are reacting inappropriately, the answer might be to abandon large-scale attempts to improve sign placement practices and instead to adopt efforts to improve public education about winter driving.

REPORT ORGANIZATION

In the next chapters, this report contains a description of the project's reseach approach, a summary of national ice warning sign experiences reported both in the literature and through a survey, a description of current ice warning sign placement practices in Washington, an examination of public attitudes about and responsiveness to ice warning signs in Washington, an examination of safety and liability issues in Washington, and conclusions and recommendations for improving Washington's ice warning sign placement practices.

CHAPTER 2
RESEARCH APPROACH

The research comprised four primary tasks: (1) conducting a national review to learn about others' ice warning sign experiences, (2) identifying the current practices for placing ice warning signs in Washington, (3) considering public attitudes about and responsiveness to Washington's ice warning signs, and (4) examining problems related to public safety and state liability in Washington. Each of these primary tasks is described below.

NATIONAL REVIEW

Insight into other area ice warning sign practices, as well as literature related to the effectiveness of ice warning signs, directly benefited this effort. A review of previous research served to (1) identify factors in need of consideration and (2) provide a baseline against which the current research findings could be compared. The survey of national experience related to ice warning signs also identified factors that should be considered. In addition, researchers looked to the national survey to discover any consensus in ice warning sign practices nationally. A consensus, based on judgment or other more substantive factors, would imply agreement on the most effective use of ice warning signs. Information learned as part of the national review is contained in Chapter 3.

Literature Review

Literature specifically related to ice warning sign placement and effectiveness was initially sought ,but few formal ice warning sign-related studies were found. Expanding the scope of the literature review to include findings related to all types of warning signs (i.e., general warning signs) resulted in

- few studies related to the effectiveness of warning sign *placement*
- several studies related to warning sign *recognition* and driver *reaction*.

Because of the dearth of literature related to the effectiveness of ice warning signs and their placement, information related to (1) the effectiveness of general warning signs, specifically the motorist's comprehension of warning signs (i.e., sign recognition and driver reaction), and (2) ice-related liability issues was collected. Information related to sign recognition and driver reaction was considered in the development of the current public opinion survey. Do the motorist's reactions to the warning sign stem from sign placement or from other factors such as personal experience? Information regarding ice-related liability helped in an assessment of the importance of sign placement in relation to other factors such as highway geometrics or vegetation.

National Survey

A national survey was conducted to collect information related to other states' practices for ice warning signs. The purpose of the survey was to identify (1) the use of ice warning signs among states, (2) consistency in ice warning sign use, both among states and within states, (3) factors that influence sign placement and erection/removal, and (4) possible safety and liability issues related to ice warning signs.

Primary survey questions included the following:

- Do you use ice warning signs anywhere in your state?

If yes:

- Are ice warning sign practices consistent statewide?
- How are ice warning sign locations determined?
- When are ice warning signs erected and removed?
- What triggers the ice warning sign erection or removal (e.g., set date, other work priorities, weather information)?
- What is the mechanism for ice warning sign erection or removal (e.g., removable sign with post, fold-up signs, sign covers)?
- Has your state experienced any problems with safety related to ice warning signs?
- Has your state experienced any problems with liability related to ice warning signs?

Secondary information that was collected included, for each state, the number of ice warning signs installed, the sign features (e.g., flashing lights, variable messages), and the message(s) displayed on the sign.

The survey was distributed, by fax, to a single person in each state who was deemed knowledgeable about ice warning sign practices statewide (signing practices differ not only among states but also within states at a more local level). A list of the people contacted, as well as a copy of the national survey, is contained in the Appendix. Typically, this person was employed by the state's transportation department at the headquarters level. All states responded to the survey with the exception of New Jersey and North Carolina. A summary of survey responses is provided in Chapter 3.

CURRENT PRACTICES IN WASHINGTON

As discovered through the national survey, signing practices typically differ from area to area within a state. Such is the case in Washington; ice warning sign practices are inconsistent statewide, from WSDOT region to region, and from WSDOT maintenance area to maintenance area. Therefore, to accurately assess the effectiveness of ice warning sign placement in Washington, information was gathered at the maintenance area level statewide (see Figure 2).

Similar to the national survey, the WSDOT maintenance area survey was distributed to a single person in each WSDOT maintenance area who was deemed to be knowledgeable about local ice warning sign practices. A list of the people contacted is included in the Appendix. Information similar to that collected through the national survey was solicited. This information included

- sign usage
- signing practice consistency
- the number of ice warning signs
- how ice warning sign locations are determined
- when ice warning signs are erected and removed
- what triggers the ice warning sign erection or removal
- what the mechanism is for ice warning sign erection or removal
- the sign features, if any
- the sign message

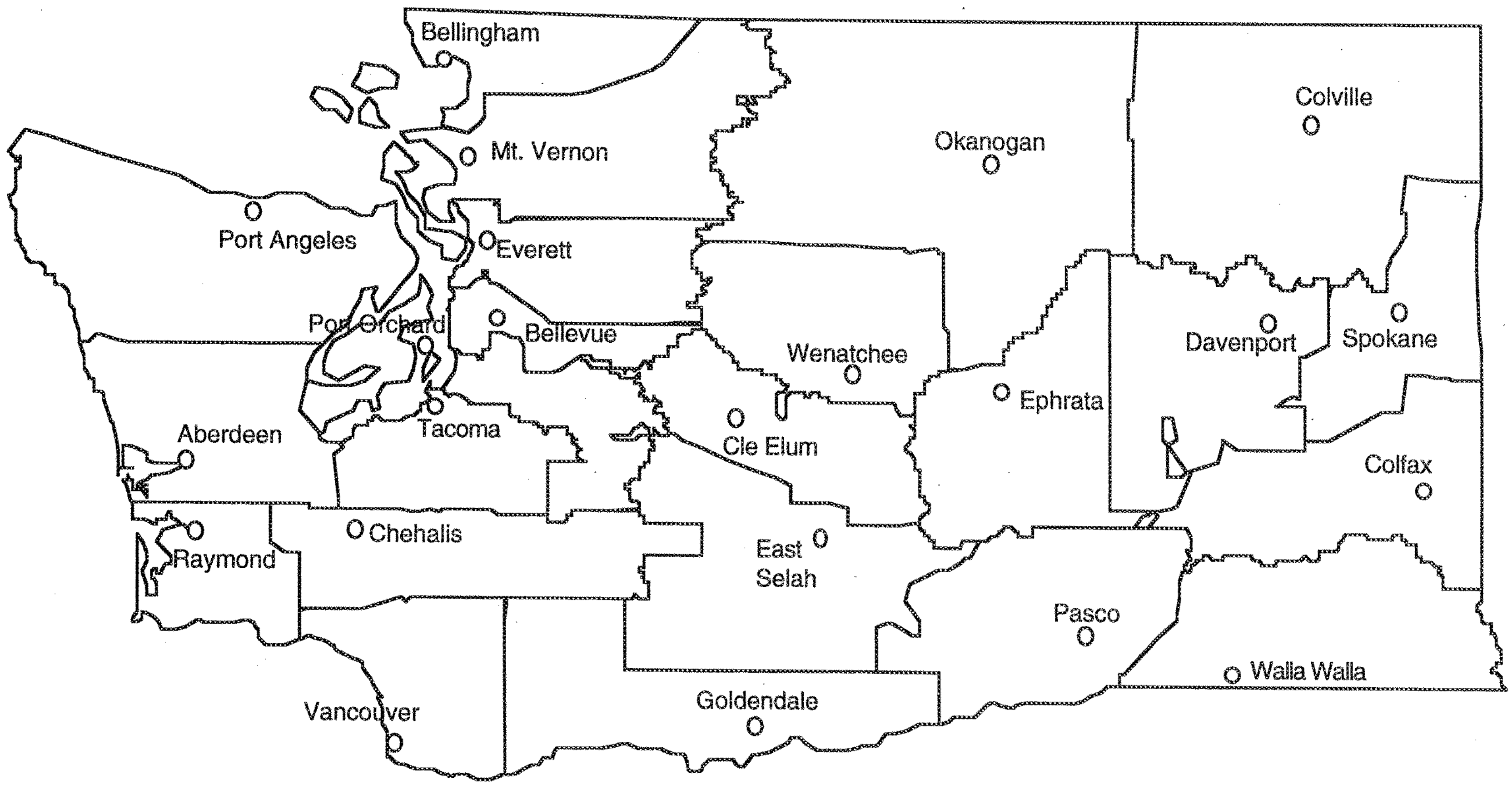


Figure 2. Washington State Department of Transportation Maintenance Areas

- problems with safety related to ice warning signs
- problems with liability related to ice warning signs (this information was supplemented with information collected from the Attorney General's Office).

Maintenance area representatives were also provided with a table listing the state routes and milepost locations of their area's ice warning signs. They were asked to indicate which ice warning signs were placed (1) as a general warning (i.e., at designated locations, such as all bridges, independent of road surface conditions) or (2) in response to a particular road surface problem (e.g., frequent icing). Area representatives were also asked to indicate their area's typical sanding routes and to estimate their ice control budget for fiscal year 1994, since other ice control measures are likely to influence the perceived effectiveness of ice warning signs. A copy of the maintenance area survey is included in the Appendix.

A description of the current ice warning sign practices in Washington is provided in Chapter 4. A clear identification of the current ice warning sign practices in Washington was necessary for a more accurate interpretation of public attitudes and responsiveness, and potential safety and liability problems.

PUBLIC ATTITUDES AND RESPONSIVENESS

An analysis of ice-related accidents could provide insight into the effect of sign placement on public safety. However, supplementary information related to drivers' reactions to warning signs (e.g., reducing speed) was necessary to more adequately describe sign effectiveness. Information related to drivers' attitudes about and responsiveness to ice warning signs was collected through a public opinion survey and an examination of historical vehicle speed data in the Puget Sound region where ice warning signs are placed.

Public Opinion Survey

Driver opinions, collected through a survey, helped to determine whether reactions to the warning sign stemmed from sign placement or from other factors such as personal experience. Questions were categorized into three groups: driving experience, opinions, and background.

In general, questions related to driving experience focused on

- vehicle type
- time of day during which most travel takes place
- average number of miles driven per day
- ice-related accident history
- reactionary measures taken on the basis of various cold weather stimuli (ice warning signs, temperatures below freezing).

In addition, survey respondents were asked to highlight on a regional map (provided) or textually describe their typical highway or interstate routes. This locational information was zonally coded to allow comparison with ice warning sign locations and ice-related accident locations.

Opinion-based questions included the following:

- Who is at fault if an ice-related accident occurs?
- How effective do you think ice warning signs are at improving safety and preventing accidents?
- Should ice warning sign usage be increased, decreased or abandoned?

Similar responses were prompted for not only ice warning signs but a variety of ice-related countermeasures. This provided insight into what ice-related actions or programs the public views as effective.

Typical background information was collected from the respondents, including sex, marital status, age, annual household income, and educational level. This information can be indicative of bias in the sample; sample proportions that are distinctly different from those proportions noted in the general or statewide population may lead to inaccurate findings related to public perceptions.

The sampling methods employed for this study were somewhat unique from previous survey methods. Typically, a survey sample is compiled from license plate numbers manually collected at site-specific locations. The license plate numbers are then submitted to the State of Washington Department of Licensing for processing. Addresses are provided after linking the license plate information with the residential information in the Department of Licensing database. This process is very convenient if the location of interest is fairly site-specific (e.g., Interstate 5 through downtown Seattle on Interstate 90). This study, because of varying population densities, climatic conditions, and ice warning sign practices, required information to be collected statewide. Because of limitations in the Department of Licensing database, a random list of addresses could not be produced without an initial list of license plates. Because it was not cost-effective to manually collect license plates at locations throughout the state, many of the addresses were obtained from a list of license plates randomly developed using an Excel spreadsheet. This method worked moderately well, although some additional license plate numbers were manually collected at site-specific locations. A copy of the public opinion survey is included in the Appendix.

Historical Vehicle Speed Data

The public opinion survey prompted people to self-report their behavior when passing an ice warning sign. Historical vehicle speed data allowed for a comparison of this self-reported behavior with actual observed behavior.

Speed data were examined to determine whether people actually change their behavior when an ice warning sign is displayed. Originally, vehicle spot speeds were to be collected with a radar device and recorded manually from a remote location, before and after an ice warning sign, allowing enough distance/time for a driver to react. However, drivers' likely detection of the radar device prompted concern over the attainment of accurate speed measurements. An alternative approach was therefore taken.

The historical speed analysis used speed data collected by two roadway data stations operated by the WSDOT as part of the Seattle area FLOW traffic control system. The data stations provided inductive loops to sample average vehicle speeds every 20 seconds and a database to store these data for 15-minute intervals throughout an entire year, from which they could later be extracted for analysis.

The location for this analysis was along Interstate 405 just south of SR 520. This site was selected because it was the only site within the FLOW system where two data stations bracketed several ice warning signs. The two data stations were 0.58 kilometers (0.36 miles) apart. Only information for northbound traffic was used. One northbound ice warning sign preceded the two data stations by 3.63 kilometers (2.25 miles); it was assumed that this distance was sufficient to reduce the influence of this sign through the study area. Between the two stations were two pairs of northbound ice warning signs (i.e., one on each side of the northbound road). The sign pairs were 243.9 meters (800 feet) and 597.3 meters (1900 feet) after the first station, respectively. The second sign pair was just 15.2 meters (50 feet) in front of the last data station. This configuration allowed motorists to travel for more than two miles without seeing an ice warning sign and then to view two signs within a 335.4-meter (1100-foot) section of roadway.

The difference in speeds between the first data station and the second data station were compared for times when the ice signs were up and after they had been removed for the season. Considering before and after speeds reduced the potential for attributing recurring deceleration patterns along the route to ice warning sign effectiveness (e.g., maybe vehicles always slow along this stretch of roadway). Because Washington State raised speed limits in March 1996, and the WSDOT instituted improved algorithms for the speed loops in June 1996, the data collection period for this analysis was constrained to the latter part of 1996. For travel with ice warning signs, mid-October through December 1996 was selected. For travel without ice warning signs, July through August 1996 was selected.

Within these months, a one-hour period for one lane during Sunday mornings was analyzed. Sunday traffic was used for several reasons. Because I-405 is a heavily used commuter route, speed fluctuations due to congestion were a concern. These speed changes might mask any effects of the ice warning signs. Sunday morning was a time when free flow conditions prevailed but was also a time with enough traffic to result in reasonable sample sizes.

The time used in the analysis was from 9:00AM to 10:00AM in the summer and from 10:00AM to 11:00AM in the winter. The hour difference between collection times was necessary to ensure similar traffic volumes. Because of the variability of sunrise times over the seasons, these staggered times had an additional advantage of ensuring similar levels of daylight.

Analysis of Variance (ANOVA) methods were used to determine whether changes in speed with and without ice warning signs were significant. Little or no change in vehicle spot speeds prior to and following the ice warning sign might indicate that the signs were ineffective in eliciting the appropriate driver response.

SAFETY AND LIABILITY

To explore the problems of safety and liability related to ice warning signs, an accident analysis and a liability review were performed.

Accident Analysis

An accident analysis explored the likelihood of ice warning signs being located where ice-related accidents occur. This is an important question from both the public safety and agency liability perspectives. Also of interest, more from an agency efficiency standpoint, is whether ice warning signs are located where no ice-related accidents have occurred (can unnecessary signs be removed?). However, a lack of ice-related accidents near an ice warning sign could mean that the sign is inappropriately placed or that the sign is effective in preventing ice-related accidents.

Current ice warning sign locations were identified from WSDOT's sign inventory. This information was supplemented through the area maintenance survey to ensure utmost accuracy. Large discrepancies in both the number of ice warning signs and their exact locations were discovered through this process, indicating a need for an improved sign inventory and record keeping system.

Accident locations and frequencies were identified from the WSDOT accident database. Only accidents related to "icy roads" were considered. The quality of ice-related accident data depended on the thoroughness with which the accident reports were filled out; often data fields are left blank. From January 1991 to December 1995, 12,091 ice-related accidents were reported in Washington. As described previously, it is likely that the accident records in the database underestimate the actual number of ice-related accidents. However, the database likely contains the most severe ice-related accidents, which are of the most concern in terms of public safety and liability. From January 1991 to December 1995, 4,663 accidents involving injuries or fatalities and ice were reported in Washington.

The two sets of information were combined. Injury and fatality ice-related accidents were spatially plotted statewide to depict route segments with the highest accident risk. The presence of ice warning signs in these areas was also noted. Statistical methods were used to determine the relationship between (1) ice-related accident frequency (i.e., the number of accidents per mile) and the presence of ice warning signs, and (2) ice-related accident severity (i.e., property damage only, injury or fatality) and the presence of ice warning signs.

Three unidirectional routes were considered in the statistical evaluation: state routes 2, 82, and 395 in the northbound or westbound directions. Because the data were ordinal rather than continuous, conventional correlation methods based on linear relationships could not be employed. Instead, the Spearman rank-correlation method was used. The Spearman rank-correlation coefficient is calculated from the ranks of the data rather than the actual data.

$$r_s = L_{xy} / (L_{xx} \times L_{yy})^{1/2}$$

where

- r_s is the Spearman rank-correlation coefficient
- L_{xy} is the cross product
- L_{xx} and L_{yy} are the corrected sum of squares.

One interprets the Spearman rank-correlation coefficient in the same way as a conventional correlation coefficient: as r_s approaches 1, correlation between the two variables of interest is higher. The statistical significance of the Spearman rank-correlation coefficient can then be tested using a t-test (see Rosner 1994).

Liability Review

Supplementary to the accident analysis, a review of liability issues related to ice warning signs was conducted. Within Washington, this search was conducted by the Attorney General's Office.

CHAPTER 3
NATIONAL REVIEW

In general, current research and related studies have focused on longer-term, more widespread snow and ice detection, control, and removal, similar to those that occur over mountain passes. Particularly, research has focused on technological advances for predicting snow and ice, and the cost effectiveness related to snow and ice management programs. New technologies that use real-time road weather information improve the predictability of road surface conditions. This, in turn, improves the effectiveness and efficiency of anti-icing, deicing, or snow removal activities. Although this type of prediction technology would, in theory, address the problems of isolated icing; it is unrealistic to expect the technology to be implemented at each potential problem location. Therefore, the applicability of such systems will not be further discussed in the context of this study.

The national review comprised both a review of related literature and a national survey. Findings from both are summarized topically below in the categories of sign design and placement, public attitudes and responsiveness, and safety and liability.

SIGN DESIGN AND PLACEMENT

The particular sign design and its placement may have a large impact on its effectiveness in improving public safety. This section describes various factors related to sign design and placement including sign usage, consistency in practice statewide, number, location determination, erection and removal methods, features, and messages. All states responded the survey except New Jersey and North Carolina.

Usage

Most states use ice warning signs. Only nine of the 48 responding states (19 percent) do not use ice warning signs: Connecticut, Delaware, Florida, Hawaii, Iowa, Kansas, Massachusetts, Missouri, and Rhode Island (see Figure 3). Year-round, above-freezing temperatures is one reason that signs are not used (e.g., in Florida and Hawaii). However, whereas some states that

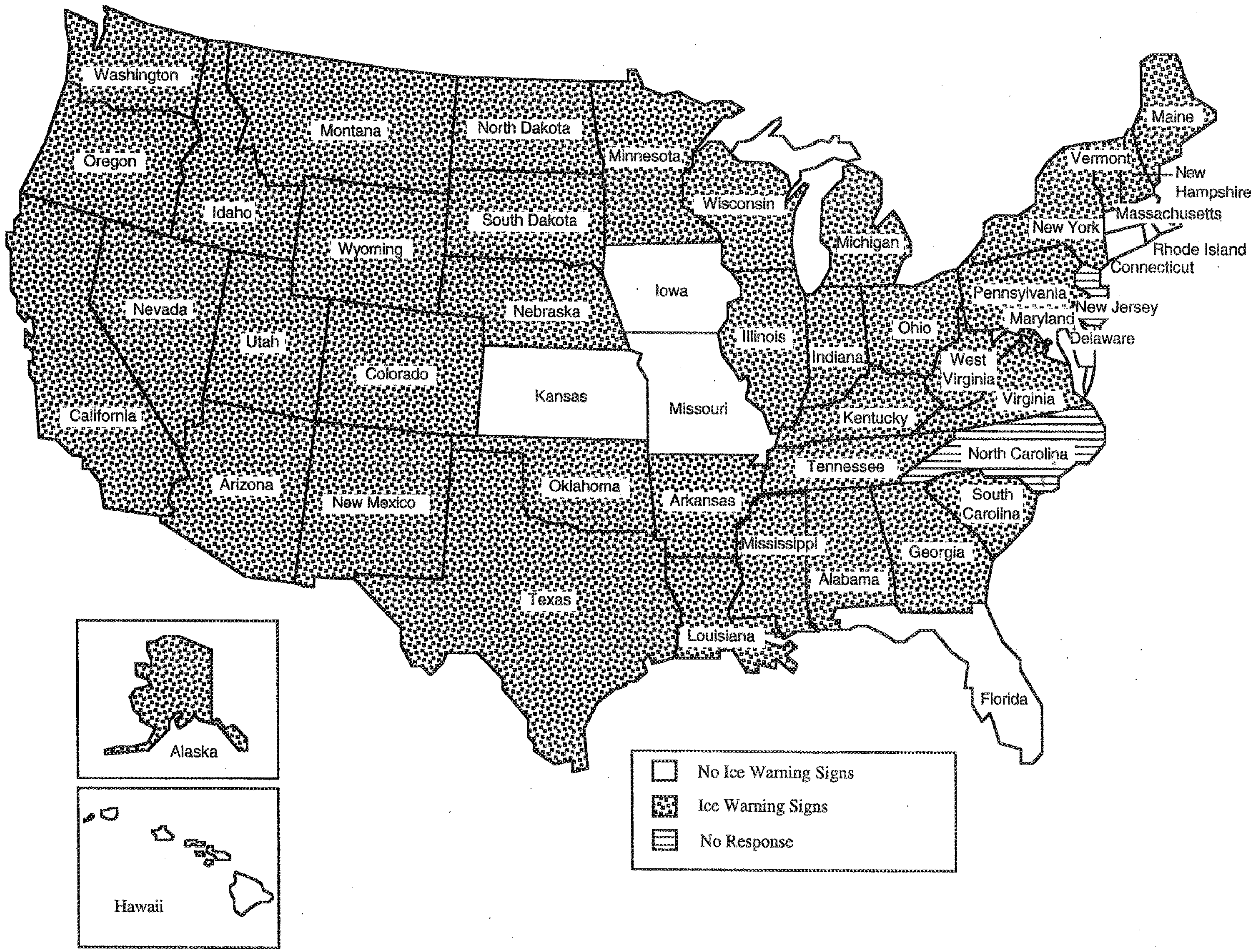


Figure 3. Ice Warning Sign Usage Nationally

reported no use of ice warning signs have comparatively colder climates (i.e., Iowa, Kansas, Missouri), other states that are relatively warm year-round do use ice warning signs. These findings suggest that factors other than climate may play a part in the decision to use ice warning signs.

For example, in Connecticut, signs used for ice-related warnings do not exist. Instead, variable message signs (VMS) are sometimes used to warn drivers of icy conditions.

Historically, WATCH FOR ICE ON BRIDGE signs were installed each year from mid-November to mid-April at all bridges 200 feet long or longer in Kansas. However, the Kansas Department of Transportation discontinued use of the ice warning signs nearly ten years ago. The decision to discontinue use was motivated by information contained in the *Manual on Uniform Traffic Control Devices (MUTCD)* that could not justify their use.

Vermont had 107 permanently installed, REDUCE SPEED DUE TO ICE AND SNOW signs at the end of Interstate on-ramps. These signs were turned to face traffic when weather conditions warranted. All have been removed because the signs were viewed as unnecessary and not cost effective. However, other types of ice-related warning signs placed site-specifically at known problem areas continue to be used.

Similarly, transportation personnel in Minnesota decided that it was neither practical nor prudent to attempt to sign for all the varying highway conditions that a motorist might encounter. Any existing ice warning signs will not be replaced at the end of their useful life unless an accident problem exists.

Consistency in Practice

Generally, the results of the survey showed consistency in the placement of ice warning signs within a given state but inconsistency among states. Some states use ice warning signs sparingly (e.g., sign placement sites are identified on the basis of accident histories). Conversely, some states place ice warning signs frequently (e.g., on every bridge). Rather than formal placement guidelines, ice warning sign placement practices are often based upon engineering judgment and existing conditions.

States with noted internal inconsistencies include California, Ohio, and Vermont. In California, the placement of ICY warning signs are consistent; the placement of BRIDGE MAY BE ICY and BRIDGES MAY BE ICY WHEN ROAD IS DRY—NEXT XX MILES is not consistent statewide.

In Ohio, ice warning sign locations are initially determined by reviewing accident data on bridges. Accident data are periodically reassessed. However this reassessment is neither consistent nor done with any regularity statewide.

Ice warning sign locations in Vermont are determined by the district transportation administrators' or traffic and safety personnel's judgment. Some signs are placed in response to public requests or complaints. Vermont uses several different ice-related text messages to relay cautionary information to motorists, including BRIDGES FREEZE BEFORE ROAD, WATCH FOR ICE, and REDUCED SPEED DUE TO ICE AND SNOW.

Among states, many inconsistencies related to sign numbers, location determination, erection and removal methods, features, and messages were noted. Many of these differences are discussed in the remainder of this section. A lack of formal guidance and a dependence on each state's discretion for signing is the likely cause.

Number of Ice Warning Signs

The exact number of ice warning signs was available from only a few of the states surveyed, making it difficult to draw any firm conclusions. As seen in Table 1, the number of ice warning signs in use varies drastically among states, ranging from 15 ice warning signs in Wisconsin to nearly 11,000 ice warning signs in Alabama. Note that several states with relatively warm climates (e.g., Louisiana, Mississippi, Alabama, and Georgia) have much higher numbers of ice warning signs than states that have considerably colder climates (e.g., Wisconsin, Maine, and North Dakota). Not all warm-weather states have significant numbers of ice warning signs; Nevada reported having only approximately 10 ice warning signs.

Table 1. Number of Ice Warning Signs in Use by State

STATE	NUMBER	STATE	NUMBER	STATE	NUMBER
Alabama	10,800	Maryland	na	Oklahoma	na
Alaska	na	Michigan	na	Oregon	na
Arizona	143 (Northern AZ)	Minnesota	na	Pennsylvania	na
Arkansas	na	Mississippi	~10,000	South Carolina	na
California	na	Montana	160	South Dakota	132
Colorado	na	Nebraska	500 folding/ 5 fiber optic	Tennessee	2
Georgia	~10,000			Texas	na
Idaho	331	Nevada	~10	Utah	50+
Illinois	na	New Hampshire	~30	Vermont	227
Indiana	na	New Mexico	70	Virginia	na
Kentucky	na	New York	na	West Virginia	100
Louisiana	5,000	North Dakota	36	Wisconsin	<15
Maine	50	Ohio	na	Wyoming	na

State size and number of roadway miles would normally account for differences in ice warning sign inventories. However, the number of ice warning signs noted in this national survey varied by several orders of magnitude from state to state. These sizable differences cannot easily be explained by differences in state size and roadway mileage.

Sign Placement Practices

The national survey results revealed that states take different approaches in determining the locations for ice warning signs. The locations of ice warning signs can be described as general (overall) coverage or site-specific. General coverage usually involves the installation of ice warning signs at set distances (e.g., every 10 miles), at specified boundaries (e.g., transportation department area boundaries), or near particular roadway features (e.g., near bridges over a certain length, near interstate on-ramps).

Site-specific placement practices attempt to target areas with high accident rates or that are deemed to have a high potential risk of accidents. Potential risk is usually determined by traffic and maintenance personnel on the basis of the roadway geometry and their experience. Sometimes, advice from the general public initiates the site-specific placement of ice warning signs.

Some states use a combination of general coverage and site-specific sign location practices. Figure 4 depicts the sign placement methods used in each state. Table 2 provides more detailed information related to the sign placement practices in each state.

General Coverage Sign Location Practices. Fifteen states (30 percent) reported using general coverage practices to locate ice warning signs. The most common general coverage practice for ice warning signs involves the installation of ice warning signs near bridges. Alabama, Arkansas, Georgia, Kentucky, Mississippi, New Mexico, South Carolina, and Wyoming all report ice warning signs near every bridge in the state. These findings explain the large sign inventories reported by many of these states.

Other states limit sign placement to bridges over a certain length. The following states report the following minimum bridge lengths for ice warning sign installation:

- Oklahoma—20-foot bridge span
- Michigan—50-foot bridge span
- Louisiana—100-foot bridge span

Illinois further limits the use of ice warning signs by placing them only near bridges that have open steel grid floors or filled steel grid floors, where exposed steel may interface with the vehicle.

Both California and Indiana install ice warning signs at bridge locations. However, this sign placement practice occurs in isolated regions of each state rather than statewide.

Site-Specific Sign Location Practices. Many states (18 states or 36 percent) place ice warning signs in response to either a noted safety problem (i.e., a history of accidents) or a suspected safety problem (i.e., complaints from the general public). Most often, site-specific sign placement practices are chosen over general coverage sign placement practices because of the concern that signs seen too often by the general public will lose their effectiveness.

In Alaska, ice warning signs are generally used in the northern region. The central region seldom uses ICY signs, perhaps because most people are accustomed to the highly variable weather conditions.

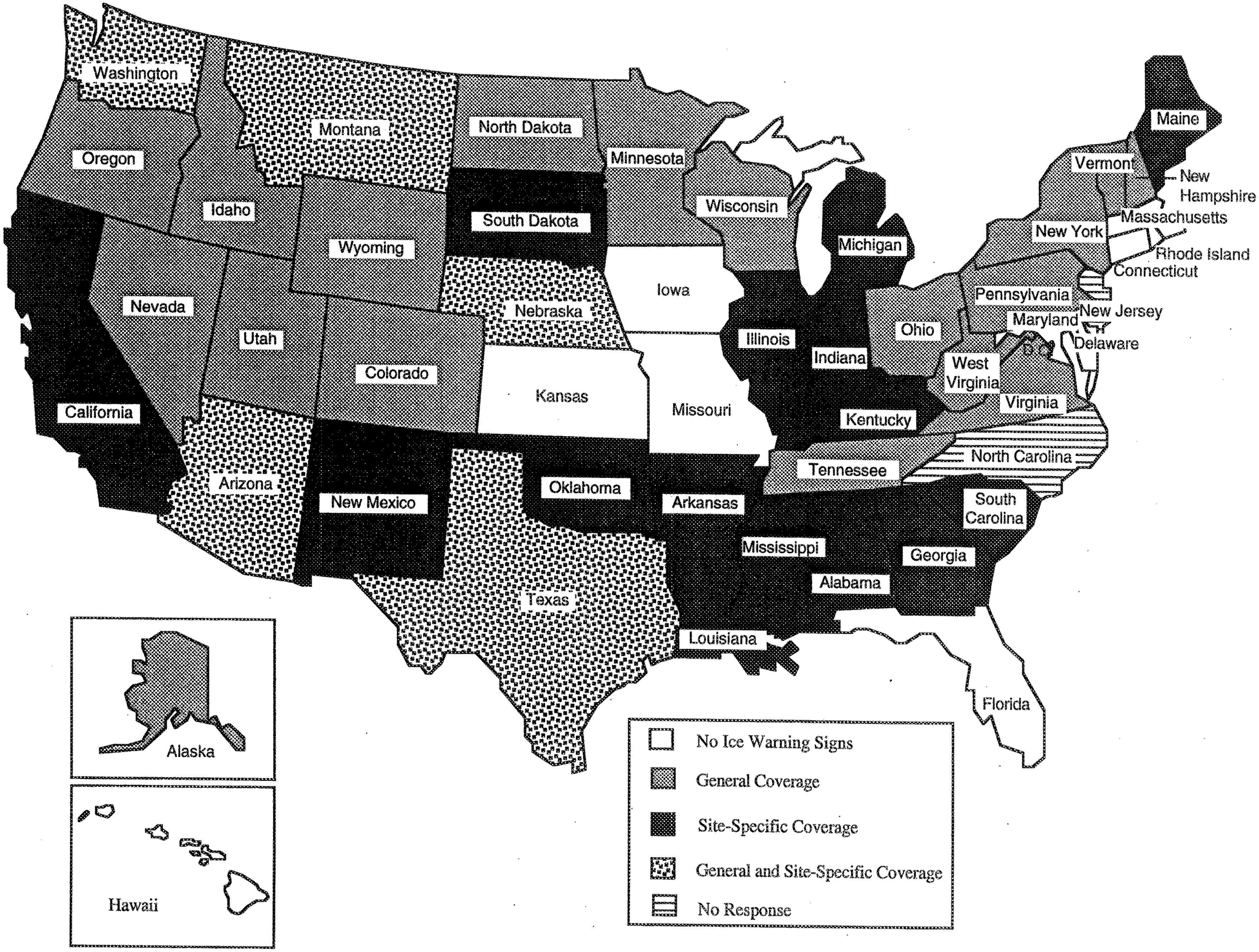


Figure 4. Ice Warning Sign Placement Practices Nationally

Table 2. Ice Warning Sign Placement Practices by State

STATE	PLACEMENT
Alabama	All bridge locations statewide on state and interstate routes
Alaska	Determined by historical records of problem areas
Arizona	Regional signs based on climatic regions (mountains), spot location signs based on documented instances of recurring icy conditions
Arkansas	All bridges statewide
California	Placed on mountain roads statewide, in advance of bridges in Northern Sierras, VMS used on Interstate 80
Colorado	Determined by maintenance superintendents and regional traffic engineers
Georgia	500-600 feet in advance of Interstate bridges, 200 feet in advance of all other bridges
Idaho	Determined by maintenance personnel and accident data with a priority for bridge decks
Illinois	On rural/high-speed urban highways near bridges having open steel grid floors
Indiana	All bridges in Northern Indiana are signed individually or in groups (i.e., ICE next 5 miles)
Kentucky	25-50 mile intervals on high speed, rural highways
Louisiana	All bridges over 100 feet
Maine	Only on Interstate (beyond entrance ramp)
Maryland	Determined by individual site reviews
Michigan	All rural bridges over 50 feet long.
Minnesota	Determined by accident problems related to icing on a bridge, existing ice warning signs will not be replaced at the end of its useful life, unless an accident problem exists
Mississippi	500 feet in advance of all bridges
Montana	Determined by district personnel and all bridges over 150 feet or within a curved section
Nebraska	All bridges and overpasses and determined by accident history
Nevada	All long span bridges and areas known to frequently ice
New Hampshire	Determined by accident history, citizen complaint, or maintenance district
New Mexico	All bridges
New York	Areas prone to ice up, follow MUTCD guidelines
North Dakota	Selected bridges where an accident problem has been identified
Ohio	Determined by accident history on bridges, periodic reassessment is supposed to occur, but is not consistently done
Oklahoma	All bridges over 20 feet
Oregon	Determined by accidents history
Pennsylvania	Determined by local engineering personnel
South Carolina	All bridges statewide
South Dakota	Determined by accident history for groups of Interstate bridges
Tennessee	Determined by accident history
Texas	All bridges on freeways and at known problem areas (steep grades, curves, etc.)
Utah	Determined by the regional traffic engineer and area maintenance foreman
Vermont	Determined by traffic and safety personnel, sometimes in response to public contact
Virginia	Determined by accident history and bridge geometrics
West Virginia	All lane-divided expressway bridges with curvature or potential icy surface problem area
Wisconsin	All areas where known ice conditions exist regardless of other measures (sand, salt) taken
Wyoming	All bridges that may ice up

Similarly, Wisconsin drivers are well conditioned to traveling on ice and snow. Ice warning signs are installed only at problem areas in Wisconsin, regardless of other snow and ice management methods such as sanding and salting. To increase the level of safety experienced by Wisconsin drivers, the Wisconsin Department of Transportation supplements signing with public awareness spots on TV, radio, and in newspapers, reminding motorists to be careful when temperatures are close to freezing.

Ice warning signs are used sparingly throughout Oregon. The Oregon Department of Transportation does not promote the use of ICE signs in the state unless it is absolutely necessary.

Combination of General Coverage and Site-Specific Sign Location Practices. States such as Arizona, Nebraska, Montana, and Texas both provide general ice warning sign coverage and locate signs on a site-specific basis.

Arizona has both regional and site-specific ice warning signs. Regional ice warning signs advise motorists of the potential for icy road conditions in a general driving area (e.g., mountain passes). Site-specific ice warning signs are used more conservatively. The locations of the site-specific ice warning signs are determined on the basis of historical accident data. The occurrence of at least one ice-related accident in three different winter seasons over the most recent five-year accident evaluation period warrants installation of an ice warning sign. Site-specific ice warning signs can also be placed where the regional traffic engineer deems necessary.

Nebraska, Montana, and Texas provide general ice warning sign coverage near bridges, as well as in problem areas. Again, problem area locations are determined by examining historical accident data, through input from the general public, or on the basis of traffic or maintenance personnel judgment.

Sign Erection and Removal

Many states (22 out of 50, or 44 percent) utilize ice warning signs during the winter season (October or November to March, April, or May) (see Figure 5). Long-term temporary signing mechanisms include the following:

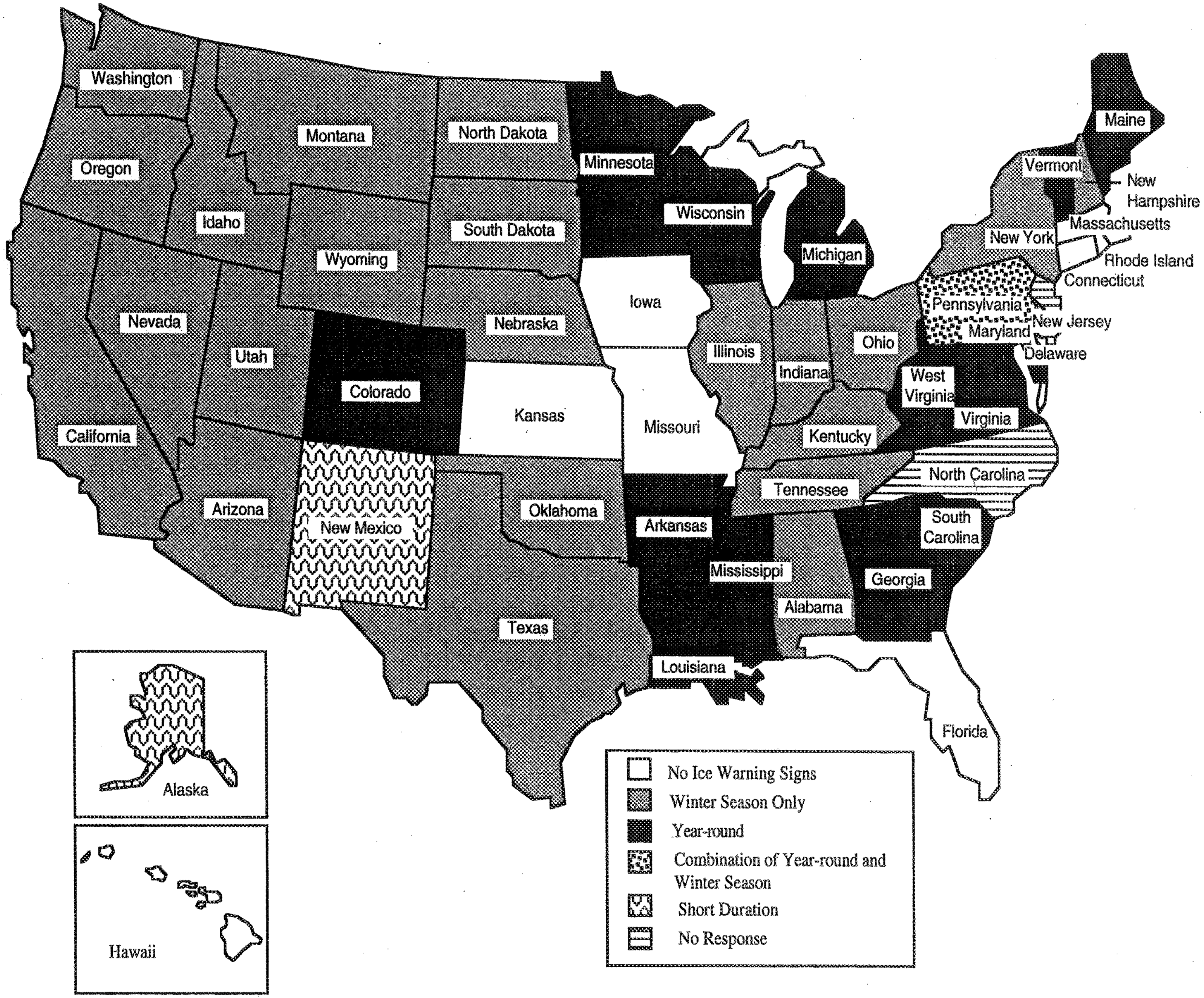


Figure 5. Ice Warning Sign Erection/Removal Practices Nationally

- permanently mounted sign posts with foldup signs
- permanently mounted sign posts with coverable signs
- swivel posts with standard signs (the sign face is turned away from traffic during warmer months).

Fourteen of the 50 states (28 percent) leave ice warning signs up year round. Pennsylvania reports a combination of signs used only during the winter season and year-round ice warning signs. Table 3 further describes ice warning sign erection and removal practices.

Both New Mexico and Alaska erect and remove ice warning signs for much shorter durations. The Alaska Traffic Manual reads,

> *The ICY (W16-3) sign is intended for use to alert the motorist driving at normal speeds on ice-free pavement of an isolated condition which is not readily apparent and shall not be used to define a general, overall road condition. ICY signs shall be removed or covered if the ice condition ceases to exist for a period of time in excess of 48 hours.*

This method is of course more labor-intensive but may increase the motoring public's trust in the warning sign.

Sign Features

The most common type of ice warning sign is the diamond-shaped square, with a black non-reflectorized legend and border, and a yellow reflectorized background for nighttime conditions. Only a few of the states reported using any type of additional sign feature to enhance the effectiveness of the sign (see Table 4). Most common sign features include

- flashing amber beacons (used by Colorado, Maine, New Mexico, North Dakota, Oregon and Pennsylvania)
- supplemental plaques providing reduced speed or other information (used by Montana and New Hampshire).

The effectiveness of supplemental plaques was discussed in the literature. The most common supplemental plaque used with warning signs is the Advisory Speed Plate. Current MUTCD descriptions of the uses of supplemental plaques are limited but restrictive. In research focused solely on driver comprehension of supplemental plaques with standard warning signs

Table 3. Ice Warning Sign Erection/Removal Practices by State

STATE	MECHANISM	TIME FRAME
Alabama	Fold-up signs	Through cold weather season
Alaska		Erected when unexpected, isolated conditions exist, removed when the ice condition abates
Arizona	Permanently installed, fold-up signs	October 1st to April 15th
Arkansas	Permanently installed	
California		November 1 to May 1, generally
Colorado	Permanently installed	Portable message signs are moved in the fall
Georgia	Permanently installed	
Idaho		From fall to spring, dates vary by area
Illinois	Permanently post-mounted, may be covered or folded	
Indiana		Most remain up all year; some fall to spring
Kentucky		Through winter months only
Louisiana	Permanently installed	
Maine	Permanently installed	
Maryland	Permanently installed	
Michigan	Permanently installed	Left up year round
Minnesota		Left up year round typically
Mississippi	Permanently installed	
Montana	Hinged fold-up signs	Based on seasonal conditions
Nebraska		November to March
Nevada	Turnaround posts	Turned towards traffic as needed
New Hampshire		Late fall to spring
New Mexico	Permanent fold-up signs	During inclement weather
New York		During winter weather conditions
North Dakota	Fold-up signs mounted permanently	Fall to spring
Ohio		November 1 to May 1
Oklahoma	Hinged fold-up signs	October to April
Oregon	Posted as fold-up signs	Fall to spring
Pennsylvania	Permanently installed (BRIDGE MAY BE ICY)	November 1 to April 1 (WATCH FOR ICE)
South Carolina	Permanently installed	
South Dakota		Fall to spring
Tennessee		Fall to spring
Texas	Fold-up signs	November to March
Utah		Fall to spring.
Vermont		As requested
Virginia		Left in place year round
West Virginia		Left in place year round
Wisconsin	Permanently installed	
Wyoming	Fold-up signs	September 15th through April 1st

Table 4. Ice Warning Sign Features by State

STATE	NONE	FLASHING BEACONS	EXTRA PLAQUES	VARIABLE MESSAGES	COMMENTS
Alabama	√				
Alaska	√				
Arizona	√				
Arkansas	na	na	na	na	na
California				√	on major mountain routes
Colorado		√		√	Fixed VMS, ground/overhead Portable VMS on trailer
Georgia	na	na	na	na	na
Idaho	√				
Illinois	na	na	na	na	na
Indiana	√				
Kentucky	na	na	na	na	na
Louisiana	na	na	na	na	na
Maine		√			
Maryland				√	
Michigan	√				
Minnesota	√				
Mississippi	√				
Montana			√		Variable legends
Nebraska	na	na	na	na	na
Nevada	√				
New Hampshire			√		
New Mexico		√		√	
New York	√				
North Dakota		√			
Ohio	√				
Oklahoma	√				
Oregon		√		√	
Pennsylvania		√			Few "Bridge may be icy" signs installed with flashing lights
South Carolina	√				
South Dakota				√	Portable VMS for blizzards
Tennessee	√				
Texas				√	Portable VMS for blizzards
Utah	√				
Vermont				√	
Virginia	√				
West Virginia	√				
Wisconsin	√				
Wyoming				√	

(specifically Railroad Crossing and Pedestrian Crossing warning signs), the results suggested that supplemental plaques are effective for conveying unique and site-specific information about a potential hazard (Hawkins 1994). Supplemental plaques can be used to convey not only speed related information but also (1) the distance to a hazard, (2) the length of the hazard area, (3) the appropriate driving responses for the hazard, and (4) other miscellaneous information. The researchers recommended a wider use of supplemental plaques with warning signs. Note, however, that this evaluation only considered driver comprehension and did not evaluate driver response, reaction time, cost, or other factors.

Variable message signs are used in many states in place of ice warning signs for shorter duration, more severe icing conditions. Portable variable message signs (usually trailer-mounted) are most appropriate for this application.

<u>Sign Messages</u>

Surprisingly, a variety of ice warning sign messages exist both among the various states and within certain states (see Table 5). Some states utilize a single ice warning message statewide, whereas others use multiple messages according to a specific need. Table 6 lists the ice warning sign messages alphabetically to emphasize the variety. In California, ICY signs are generally placed on mountain roads. Signs preceding bridges in the Northern Sierras read BRIDGE MAY BE ICY. Variable message signs (VMS) displaying BRIDGES MAY BE ICY WHEN ROAD IS DRY - NEXT _ MILES are used on Interstate 80 during winter conditions. Multiple messages may be confusing to motorists. Between the Arizona and New Mexico border, Arizona's ice warning signs read BRIDGES FREEZE FIRST, New Mexico's signs read CAUTION ICY BRIDGE.

Massachusetts has a "bare pavement" policy for snow and ice control; plowing, sanding, and salting are performed to maintain ice free pavement. Instead of utilizing ice warning signs to warn motorists of potentially hazardous situations, Massachusett's signs read LOW SALT AREAS. In Oklahoma, the current message WATCH FOR ICE ON BRIDGE is displayed during the winter seasons (from October to April). To reduce labor requirements of the

Table 5. Ice Warning Sign Messages by State

STATE	MESSAGE	STATE	MESSAGE
Alabama	WATCH FOR ICE ON BRIDGE	Nevada	BRIDGE MAY BE ICY ICY
Alaska	ICY	New Hampshire	W8-5 (slippery symbol)
Arizona	REGIONAL ALERT - ICE MAY BE PRESENT ON ROADWAY WATCH FOR ICE	New Mexico	CAUTION ICY BRIDGES
Arkansas	BRIDGE MAY ICE IN COLD WEATHER	New York	ICY PAVEMENT ZONE
California	ICY BRIDGE MAY BE ICY BRIDGES MAY BE ICY WHEN ROAD IS DRY - NEXT _ MILES	North Dakota	MUTCD Sign No. W5-2M
Colorado	ICY ROADS	Ohio	WATCH FOR ICE ON BRIDGE
Georgia	CAUTION BRIDGE MAY ICE IN WINTER	Oklahoma	WATCH FOR ICE ON BRIDGE
Idaho	WATCH FOR ICE BRIDGE MAY BE ICY ROADWAY ICY, CHAINS ADVISED ROADWAY ICY IN SHADED AREAS WATCH ICE IN SHADED AREAS	Oregon	Varies
Illinois	ICE ON PAVEMENT WATCH FOR ICE ON BRIDGE SLIPPERY WHEN WET OR ICY	Pennsylvania	WATCH FOR ICE BRIDGES MAY BE ICY SLIPPERY WINTER CONDITIONS
Indiana	WATCH FOR ICE ON BRIDGE	South Carolina	BRIDGE ICES BEFORE ROAD
Kentucky	BRIDGES FREEZE BEFORE ROADWAY	South Dakota	WATCH FOR ICE ON BRIDGES
Louisiana	BRIDGE MAY ICE IN COLD WEATHER	Tennessee	WATCH FOR ICE ON BRIDGE
Maine	REDUCE SPEED (SPEED LIMIT) WHEN FLASHING	Texas	WATCH FOR ICE ON ROAD - BRIDGE
Maryland	BRIDGE DECK FREEZES BEFORE ROAD SURFACE	Utah	ICY ROAD
Michigan	BRIDGE MAY BE ICY	Vermont	BRIDGES FREEZE BEFORE ROAD WATCH FOR ICE REDUCED SPEED DUE TO ICE AND SNOW REDUCE SPEED DUE TO ICE AND SNOW OR "DUE TO ACCIDENT"
Minnesota	BRIDGE MAY BE ICY	Virginia	BRIDGES FREEZE BEFORE ROADWAY
Mississippi	BRIDGE MAY ICE IN COLD WEATHER	West Virginia	WATCH FOR ICE ON BRIDGE
Montana	ICY ROAD ICY SPOTS NEXT _ MILES WATCH FOR ICE ON BRIDGE	Wisconsin	BRIDGE MAY BE ICY W8-64
Nebraska	BRIDGES MAY BE ICY ICY ROAD	Wyoming	BRIDGES MAY BE ICY

Table 6. Ice Warning Sign Messages Alphabetically

MESSAGES
BRIDGE DECK FREEZES BEFORE ROAD SURFACE
BRIDGE ICES BEFORE ROAD
BRIDGE MAY BE ICY
BRIDGE MAY ICE IN COLD WEATHER
BRIDGES FREEZE BEFORE ROAD
BRIDGES FREEZE BEFORE ROADWAY
BRIDGES MAY BE ICY
BRIDGES MAY BE ICY WHEN ROAD IS DRY - NEXT _ MILES
CAUTION BRIDGE MAY ICE IN WINTER
CAUTION ICY BRIDGES
ICE ON PAVEMENT
ICY
ICY PAVEMENT ZONE
ICY ROAD
ICY ROADS
ICY SPOTS NEXT _ MILES
REDUCE SPEED (SPEED LIMIT) WHEN FLASHING
REDUCE SPEED DUE TO ICE AND SNOW OR "DUE TO ACCIDENT"
REDUCED SPEED DUE TO ICE AND SNOW
REGIONAL ALERT - ICE MAY BE PRESENT ON ROADWAY (W4-6Z)
ROADWAY ICY IN SHADED AREAS
ROADWAY ICY, CHAINS ADVISED
SLIPPERY WHEN WET OR ICY
SLIPPERY WINTER CONDITIONS
WATCH FOR ICE
WATCH FOR ICE ON BRIDGE
WATCH FOR ICE ON BRIDGES
WATCH FOR ICE ON ROAD - BRIDGE
WATCH ICE IN SHADED AREAS

temporary signs, ice warning signs that can be left up all year round are being considered. The new message would read BRIDGE MAY BE ICY IN COLD WEATHER.

PUBLIC ATTITUDES AND RESPONSIVENESS

Ice warning signs are intended to warn motorists of ice-related, potentially hazardous driving conditions, especially on bridges and through shaded areas. Motorists' responsibilities are to recognize the warning sign and take appropriate precautions.

Drivers' comprehension was also examined in the literature with respect to warning signs rather than supplemental plaques. In Texas, 1,745 motorists were surveyed to determine their comprehension of regulatory signs, warning signs, and pavement markings (Hawkins, et al. 1993). One of the warning signs evaluated in the survey read WATCH FOR ICE ON BRIDGE. The results of the survey indicated that the majority (84 percent) of motorists know the correct actions to take when they see an ice warning sign (i.e., slow down, don't brake or make sudden turning movements). Another 11 percent described correct actions as slowing down and gently applying the brakes. Motorists surveyed who did not speak English as their primary language were most apt to misinterpret the sign. Note that this study focused on a motorists' understanding of the sign and did not consider actual motorist reactions in the roadway environment.

A second study, sponsored by the U.S. Department of Transportation and conducted in Missouri in 1971, considered the effectiveness of warning signs for icy bridges (Glauz, et al. 1971). An ICY BRIDGE AHEAD warning sign with a top-mounted, flashing amber beacon was erected on Interstate 435 south of Kansas City, Missouri, preceding the Blue River bridge by a quarter-mile. Field data, including vehicle speed, traffic flow rates by lane, lane-change frequencies, and brake light occurrences, were collected at various locations upstream and downstream of the warning sign. A sample of motorists were also interviewed on an exit ramp downstream of the bridge.

The ice warning sign was found to have a statistically significant effect on traffic speed (7 mph reduction) after it was erected. With the flashing beacon activated, an increase in the amount of lane-change activity near the bridge was noted. Braking activity approaching the bridge increased under widespread icing conditions, but braking activity did not increase when the icing conditions were localized (i.e., if the bridge was icy but the roadway was clear).

Of the motorists interviewed, only slightly more than half recalled seeing the ice warning sign. Others seemed to recall seeing some sort of sign but could not remember the subject matter. Three out of five school bus drivers who were interviewed either did not recall seeing the sign or remembered seeing a sign concerning "workmen ahead."

This study concluded that most motorists do not respond to ice warning signs in the manner desired. Some important contributory factors included (1) failure to see or mentally register the sign, (2) intuitive selection of a response other than the one recommended by the sign, (3) disbelief that a hazard exists, (4) uncertainty about the necessary response, and (5) willful disregard of the sign.

The report suggested that "signs incorporating some form of alternation (such as a flashing light) are more conspicuous than static signs" and "signs which include an explicit recommendation are more likely to produce a favorable response than one which simply gives a general warning" (Glauz, et al. 1971). Some of the recommendations were as follows:

> Most hazardous situations are ones which the driver cannot anticipate on his own, which means he must accept the message on faith. It follows that warning systems should be used only when absolutely necessary. The practice of posting permanent signs which are relevant only infrequently (such as SLIPPERY WHEN WET) should be avoided whenever possible, because they probably tend to instill an indifference toward all warning signs.
>
> The warning sign should specify an explicit recommended action. When a driver reads and comprehends a sign, he makes a decision about how to respond. An explicit recommendation will reduce the amount of time to make the decision as well as influence the driver toward a favorable response.

Concerns were especially voiced about signs that are seen year round, regardless of weather, such as WATCH FOR ICE ON BRIDGE. Whereas these signs may offer agencies some legal protection in some instances of litigation, their value to motorist safety is highly questionable at best (Glauz, et al. 1971). As indicated in the 1976 Maintenance Manual of the American Association of Highway and Transportation Officials,

> The first parts of a roadway to become slippery under ice and frost conditions are bridges and overpasses. Static signs such as WATCH FOR ICE ON BRIDGE: can become an accustomed feature of the landscape and not alert a driver at the necessary time. Flashing lights are recommended that turn on at or near freezing temperatures or ice detection systems that will result not only in a warning to motorists but will notify maintenance personnel.

SAFETY AND LIABILITY

Little information related to the safety benefits of ice warning signs was available. One study, conducted in Monroe, Michigan, found that accident rates were reduced by over 50 percent as a result of additional signing (Elachkar and Suboski 1992). However, the study focused on local streets and considered permanently installed signs, including stop ahead, curve, chevrons/arrows, and side-road signs.

Significantly more information was available concerning liability. A government agency may be held liable if actions taken (or not taken) by the agency are deemed negligent. Negligence can result in two ways: (1) doing something that a reasonable person would not do (e.g., driving drunk, excessive speed) or (2) neglecting to do something that a reasonable person would do (e.g., putting up a warning sign).

Four key elements are required to prove negligence:

- a duty or standard to perform or maintain
- a breach of that duty, either through some action or omission
- an actual loss or harm to involved parties
- a connection between the breach of duty and the resulting harm.

States operate under what is called a "Duty of Care," which places the responsibility to maintain reasonably safe travel under ordinary travel conditions on state agencies. An example "Duty of Care" statement is provided below:

> WPI 140.01 Sidewalks, Streets and Roads - Duty of Municipality (Revision)
>
> A [county] [city] [town] [state] has a duty to exercise ordinary care in the [construction] [maintenance] [repair] of its public [roads] [streets] [sidewalks] to [keep] [construct] them in a [manner] [condition] that is reasonably safe for ordinary travel by persons using them in a proper manner and exercising ordinary care for their own safety.
>
> - Washington Pattern Jury Instruction

This duty is typically divided into two areas: periodic repair and response to unpredictable natural and unnatural events (e.g., ice, accidents). Fulfillment of this duty requires notification of the existence of a problem and a reasonable amount of time to correct the problem.

In the following discussion of liability in the context of ice warning signs, two issues are explored: actions taken by states to protect themselves from liability, and specific case illustrations.

Legal Protection for Government Agencies

Fear of liability is often the motivator behind the deployment of warning signs. However, some states are reluctant to rely only on warning signs for legal protection. Historically, legal protection for state governments was achieved through the Doctrine of Sovereign Immunity. Simply put, a public agency was immune from lawsuits without its (the involved government agency's) consent. Today, more than half of the states have enacted Tort Claims Acts that waive the Doctrine of Sovereign Immunity and expose government agencies to tort-related lawsuits. ("Tort" refers to any wrongful act, injury, or damage, not including a breach of a contract.)

Until 1965, tort-related lawsuits against the state of Michigan were effectively discouraged; lawsuits could only be initiated with prior approval of the state (because of sovereign immunity). However, Michigan's *Public Acts of 1964*, which defined the state's responsibility to construct, maintain, and operate safe roadways, was modified to provide opportunities for tort litigation against the state:

> Each governmental agency having jurisdiction over any highway shall maintain the highway in reasonable repair so that it is reasonably safe and convenient for public travel. Any person sustaining bodily injury or damage to his property by

> reason of failure of any governmental agency to keep any highway under its jurisdiction in reasonable repair and in condition reasonably safe and fit for travel, may recover the damages suffered by him from such governmental agencies (Orme 1976).

In retaliation to the Tort Claims Acts, some states have enacted "weather immunity" laws. Such laws exist in Illinois, Minnesota, Kansas, and New Jersey.

The weather immunity statute of Illinois (*Illinois Revised Statute 1985, Chapter 85, paragraph 3-105*) states that "neither a local public entity nor a public employee is liable for an injury caused by the effect on the use of streets, highways of weather conditions."

The Minnesota Municipal Tort Liability Act (*Minnesota Statutes, Sections 466.01-466.15*) retains immunity for any "claims based on snow or ice conditions on any highway except when the condition is *affirmatively* caused by the negligent acts of the municipality."

Similarly, Kansas' statute (*Kansas Statutes Annotated, Section 75-6104 (k)*) exempts government agencies from liability for incidents involving "snow or ice conditions or other temporary or natural conditions on any public way or other public place due to weather conditions unless the condition is affirmatively caused by the negligent act of the governmental entity."

New Jersey's weather immunity statute (*New Jersey Statutes Annotated 59:4-7*) provides governmental immunity in cases where personal injury is caused solely by the effect on the use of streets and highways of weather conditions.

Weather immunity statutes do not always exempt a state from liability, as was discovered in New Jersey. The case of *Horan v. State (1986)* involved an accident that occurred when a vehicle skidded on an icy bridge (no ice had formed on the roadways). During this case, the weather immunity statute was considered, as was a second New Jersey statute (*New Jersey Statute Annotated 59:4-2*) that imposes a duty on governmental agencies to warn of known dangerous conditions. No warning sign had been posted to warn of ice forming on bridges. The Court stated:

> The substance of the plaintiff's argument is that the injury was not caused solely by the weather, but that the failure of defendants to warn of the likelihood of this

> potential contributed as a causal event. He (the plaintiff) embellishes this argument by insisting that *New Jersey Statute Annotated 59:4-2* imposes a duty when there is a dangerous condition to warn of that condition. As the trial judge recognized and as we agree, if these arguments were thought to be sound, the weather immunity statute would, in effect, be written out of the books. It is apparent that weather contributes to the occurrence of injury from an accident only when that weather creates a dangerous condition If the weather does not create a dangerous condition, then there is nothing with which to charge government in any event.

Thus, the "weather conditions" statute provides immunity in the case of icy conditions notwithstanding the provisions of the companion statute requiring that warning be given of known dangerous conditions (NCHRP 1976). More case illustrations are provided below.

<u>**Case Illustrations**</u>

The following cases illustrate different scenarios of ice related liability in tort claims, and how each case has been interpreted by the courts. Specific cases are grouped by topic:

- duty of the state to provide or install highway warning signs
- duty of the state to warn about known dangerous conditions
- compliance with the *Manual on Uniform Traffic Control Devices*
- icing due to tree shelter
- preferential icing on bridges
- highway defects.

Duty of the State to Provide or Install Highway Warning Signs. Because the fall of snow and the formation of ice is a natural act that cannot be controlled or prevented, government agencies are often exempted from taking action. In the case of *Koehler V. State, (Iowa 1978)*, the State was found to have no duty to place warning signs at or near snow drifts on the highways. Similar reasoning was illustrated in *Lansing V. County of McLean, (1978)*; the county was found to have no duty to warn motorists of natural accumulations of ice on the streets or highways (Vance 1991).

Duty of the State to Warn about Known Dangerous Conditions. In the case *State Department of Highway and Public Transportation V. Bacon (Texas, 1988)*, personal injury and death resulted from a vehicular collision on an icy bridge. The state of Texas was found negligent for failing to provide warning of the icy condition of the bridge.

In the case *States v. Abbott, 498 P.2d 712,726 (Alaska 1972)*, the court found the state's duty to exercise reasonable care in maintaining highways included the duty to warn the traveling public of conditions that endanger travel.

Compliance with the Manual on Uniform Traffic Control Devices. In some states, but not all, the Manual on Uniform Traffic Control Devices (MUTCD) is recognized as a state standard. Compliance with the MUTCD may not be sufficient to avoid a charge of negligence in traffic signing, as illustrated in the case of *Sweetman v. State Highway Department, (Michigan 1984).* The Michigan State Highway Department was deemed negligent for an accident involving ice on an overpass. A permanently posted MUTCD-compliant sign warned of possible icy conditions on the overpass. However, according to the court, the value of the sign as a warning device was eroded because it was posted year round.

Icing Due to Tree Shelter. In *Shepard v. State Department of Roads (Nebraska 1983)*, the plaintiff's automobile skidded on icy pavement and collided with an oncoming truck. The accident site was bordered by a belt of trees whose shadow resulted in the icy conditions. Recognizing these conditions, the state had scraped the accumulated ice and repeatedly applied a heavy mixture of sand, salt, and calcium chloride before the accident. According to the court, the state had performed duties of reasonable care (NCHRP 1990).

Preferential Icing on Bridges. In the case *Salvati V. Department of State Highways (Michigan 1982)*, a person lost control of his automobile on a bridge that had iced over suddenly. The preferential icing created a thin layer of ice that was not readily visible; the highway was otherwise clear and dry. A warning sign that read WATCH FOR ICE ON BRIDGE was posted at the accident location. In spite of this, the court found the state negligent because the warning sign was not illuminated and because the message, WATCH FOR ICE ON BRIDGE, did not adequately warn motorists of the threat of preferential icing. The Michigan Department of State Highways was found guilty of failing to keep the highway in reasonable repair and in a condition reasonably safe and fit for travel. This example illustrates the importance of accuracy in messaging (NCHRP 1990). Michigan changed the wording from WATCH FOR ICE ON BRIDGE to BRIDGE MAY BE ICY because of this court decision.

Highway Defect. Under Connecticut law, the presence of snow or ice on highways constitutes a "highway defect" when a dangerous condition results, or the roadway is not rendered reasonably safe for public travel.

As stated in the case of *Patrick V. Burns (Connecticut 1985)*, according to law, a highway is defective when ice makes it not reasonably safe for public travel. The mere fact that there is ice on the surface of the highway does not render the highway defective. Ice is a defect only when its presence on the highway creates a condition that is not "reasonably safe.". The law does not require that a highway be kept "perfectly" or "absolutely safe" for public use (NCHRP 1990).

SUMMARY

A survey of other states' ice warning sign practices and a review of the literature produced some interesting findings. A summary of major findings is as follows:

- Little consistency exists among and within states regarding ice warning sign usage, numbers, placement practices, erection and removal mechanisms and time frames, features, and messages.
- Findings reported in the literature related to public attitudes and responsiveness were conflicting. Ice warning signs were reported to have a statistically significant effect on traffic speeds, lane change activity, and braking activity (under certain conditions), yet few surveyed drivers recalled seeing signs (Glauz et al. 1971).
- No significant literature was found that investigated increased levels of safety attributable to ice warning signs.
- Ice warning signs do appear to provide some protection against liability as long as transportation departments continue to fulfill their "duty of care" responsibilities and sign placement determination can be justified as a systematic and reasonable process.

The lack of consistency in ice warning sign practices within and among states is likely a direct result of the lack of consistent and substantive findings in the literature, so that traffic and maintenance personnel have little evidence to guide or support their decisions.

CHAPTER 4
CURRENT PRACTICES IN WASHINGTON

In this section, current signing practices in Washington for ice-related warning signs are described. Signing practices vary among the six WSDOT regions and even among WSDOT's 24 maintenance areas. To gain a better understanding of the current signing practices in Washington for ice-related warning signs, superintendents of the 24 maintenance areas in the six WSDOT regions were asked to participate in a maintenance survey. All maintenance areas responded to the survey. Information similar to that collected through the national survey was solicited. This information included

- sign usage
- signing practice consistency
- the number of ice warning signs
- how ice warning sign locations are determined
- when ice warning signs are erected and removed
- what triggers the ice warning sign erection or removal
- what the mechanism is for ice warning sign erection or removal
- the sign features, if any
- the sign message
- problems with safety related to ice warning signs
- problems with liability related to ice warning signs (this information was supplemented with information collected from the Attorney General's Office).

Results of the maintenance area survey are described below.

SIGN DESIGN AND PLACEMENT

As mentioned previously, the particular sign design and its placement may have a large impact on its effectiveness at improving public safety. This section describes various factors related to sign design and placement in Washington.

Usage

As seen in Figure 6, 23 of the 24 WSDOT maintenance areas use ice warning signs. The exception is the Walla Walla maintenance area in the South Central Region. Ice warning signs in this area were permanently removed in the spring of 1994 because they were deemed ineffective at improving public safety.

Consistency in Practice

As observed in the national survey results, consistency among states is not only a problem; consistency within states is also a problem. Such inconsistencies in ice warning sign practices were noted in Washington.

Some areas in Washington use ice warning signs sparingly (i.e., sign placement sites are identified on the basis of accident histories). Conversely, some areas place ice warning signs frequently (i.e., on every bridge or jurisdictional boundary). Methods for determining proper placement of ice warning signs varies greatly from area to area. Sign placement coincides with (1) jurisdictional or geographic boundaries, (2) engineering or maintenance personnel judgment, (3) requests from the motoring public, (4) accident histories, or (5) roadway features (e.g., bridges, junctions).

Consistencies noted among the various maintenance areas include the messaging for ice warning signs (most read WATCH FOR ICE) and the sign erection/removal time frames (ice warning signs in all areas remain up only through the winter season). Inconsistencies in sign erection/removal methods (e.g., foldup signs, swivel posts, etc.) were noted, however.

Number of Ice Warning Signs

The number of ice warning signs used in each maintenance area ranges from zero to nearly 100 (see Table 7). The actual number of signs in each area was difficult to obtain. Initially, the sign logs maintained in each area were thought to be a good source of this information. However, information contained in the sign logs differed from the information reported by the maintenance personnel. In some instances, the number of signs reported by area maintenance personnel was more than four times the number of signs reported in the sign logs.

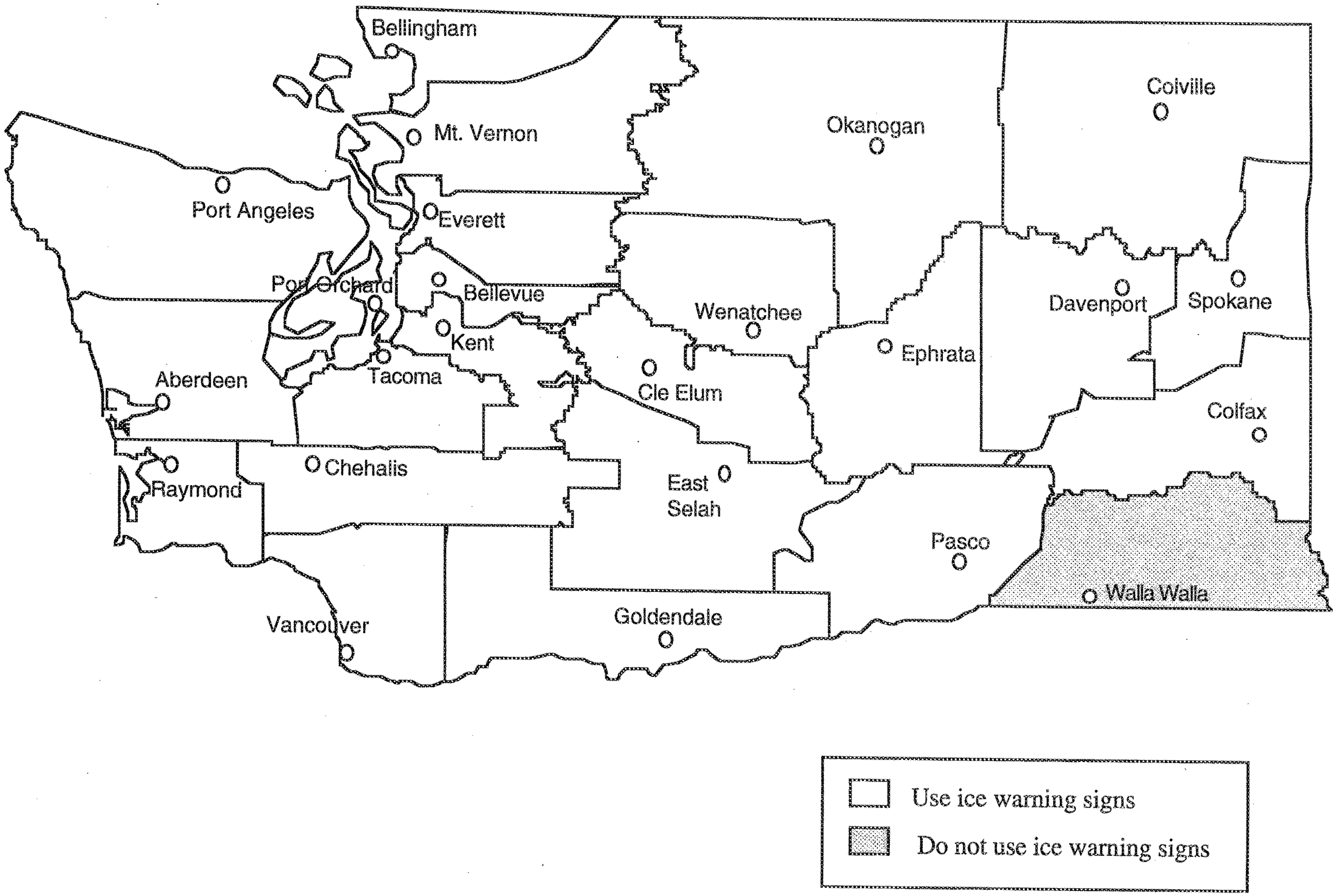


Figure 6. Ice Warning Sign Usage in Washington

Table 7. Number of Ice Warning Signs in Use in Washington

REGION AND AREA	NUMBER	REGION AND AREA	NUMBER	REGION AND AREA	NUMBER
EASTERN		**NORTHWEST**		**SOUTH CENTRAL**	
Colfax	100	Bellingham	38	Cle Elum	44
Colville	55	Mount Vernon	83	East Selah	61
Davenport	33	Everett	75	Pasco	85
Spokane	26	Kent	56	Walla Walla	0
		Bellevue	24		
NORTH CENTRAL		**OLYMPIA**		**SOUTHWEST**	
Wenatchee	36	Tacoma	42	Vancouver	66
Ephrata	17	Port Orchard	36	Chehalis	57
Okanogan	34	Port Angeles	60	Goldendale	29
		Aberdeen	51	Raymond	45

Sign Placement Practices

To collect information related to ice warning sign placement practices, each maintenance area representative was provided with a table listing the state routes and milepost locations of their area's ice warning signs. Area representatives were asked to indicate which ice warning signs were placed (1) as a general warning (i.e., at designated locations, such as all bridges, independent of road surface conditions) or (2) in response to a particular road surface problem. Results are summarized in Table 8. General warning signs are placed at locations such as city boundaries, state highway junctions, beginnings of state routes, or county intersections. Site-specific warning signs target problem areas such as shady areas, hills, places that hold moisture and frost easily, and areas with documented accident problems due to ice.

Figure 7 better depicts the inconsistencies in ice warning sign placement practices in Washington. Nine of the 24 maintenance areas follow general warning placement practices ,although the exact locations for placement vary. The following locations were reported:

- all state route entrances
- all state route entrances, mountain passes, state highway junctions, local jurisdiction boundaries
- state highway junctions, maintenance area boundaries, between local jurisdictions

Table 8. Ice Warning Sign Placement Practices in Washington

REGION AND AREA	PLACEMENT
EASTERN	
Colfax	Entrances to state roadway system
Colville	Determined by lead maintenance technician, supervisor, and traffic engineers and accident history. New seal coat, overlay, tree removal can change needed ice signs locations.
Davenport	Problem areas such as bridges, shady areas, hills, draws where fog lays
Spokane	Determined by observation, submitted to traffic engineer for approval
NORTH CENTRAL	
Wenatchee	Entrances to state roadway system, state roadway junctions, mountain passes, and town boundaries
Ephrata	Between cities, state roadway junctions, and maintenance area boundaries
Okanogan	Determined by traffic office
NORTHWEST	
Bellingham	Traditional locations
Mount Vernon	Problem areas, city boundaries
Everett	Major state route intersections
Kent	Entrances to state roadway system
Bellevue	All bridges, entrances to state roadway system
OLYMPIA	
Tacoma	Entrances to state roadway system
Port Orchard	Maintenance area boundaries, major state route intersections, and problem areas
Port Angeles	Entrances to state roadway system every 5-10 miles
Aberdeen	Entrances to state roadway system, problem areas (hills, bridges)
SOUTH CENTRAL	
Cle Elum	Determined by traffic office
East Selah	Maintenance area boundaries, section breaks within an area, old control section breaks, leaving urban areas, urban areas where traffic enters the highway system, problem areas
Pasco	Section boundaries, major state route interchanges/intersections
Walla Walla	(No signs)
SOUTHWEST	
Vancouver	Determined by accident history
Chehalis	Bridges, hills with accident history
Goldendale	Problem areas that are shaded, hold moisture, frost easily, and have numerous curves
Raymond	Section boundaries and problem areas

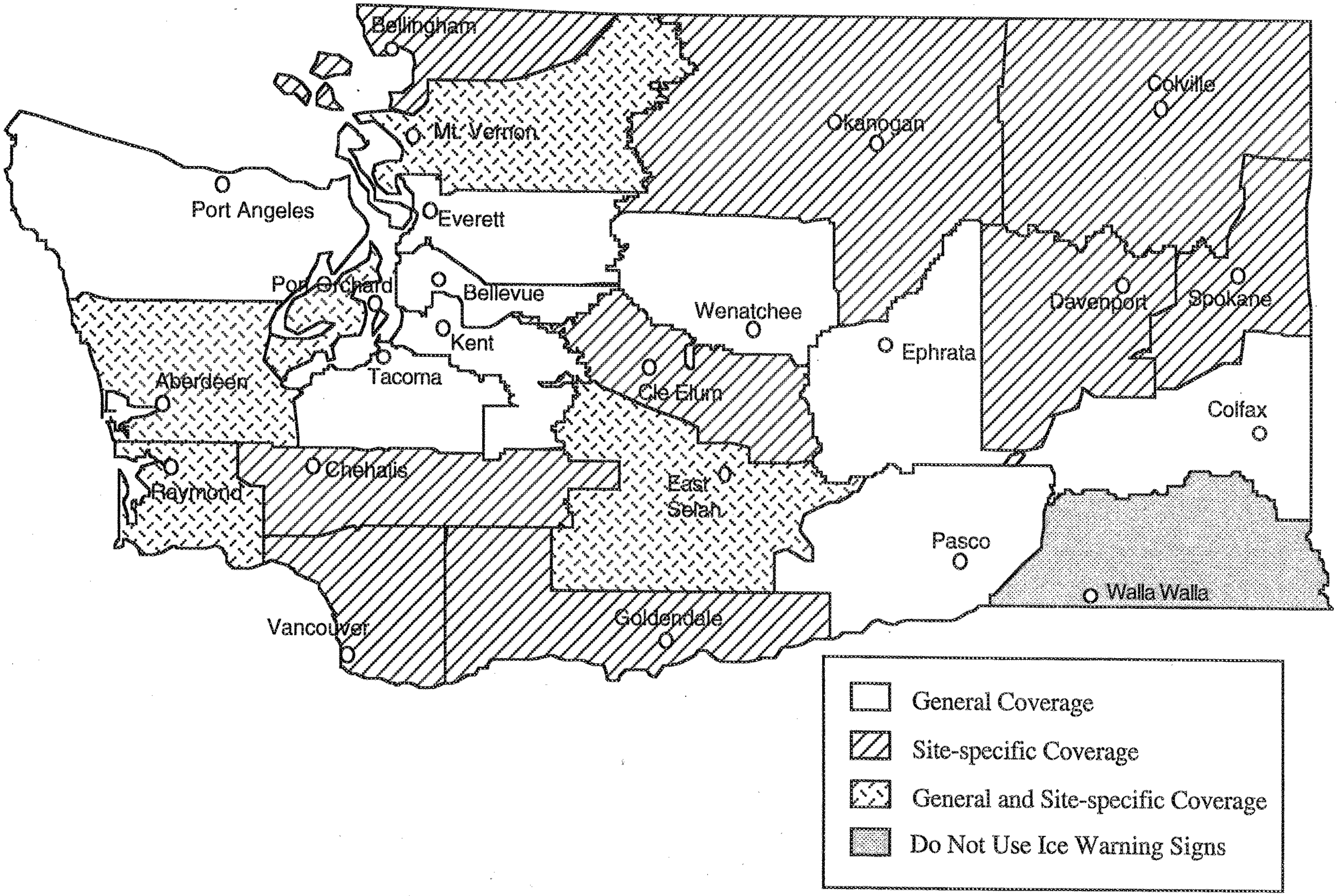


Figure 7. Ice Warning Sign Placement Practices in Washington

- general vicinity of bridges, maintenance area boundaries
- all state route entrances, every 5 to 10 miles.

An equal number of maintenance areas (nine) follow site-specific ice warning placement practices. Some areas report that approval is required from the region's Traffic Engineering Office before an ice warning location can be added or removed.

Some of the maintenance areas follow a combination of general and site-specific ice warning sign placement practices.

Sign Erection and Removal

All of the ice warning signs in Washington are installed only through the winter season, typically from October/November to March/April (see Table 9). The mechanisms for installing/displaying the ice warning signs vary both among the maintenance areas and within some of the maintenance areas (see Figure 8). Mechanisms include fold-up signs, sign covers, turnable post mounts (signs are mounted on square brackets that fit down over post so that signs can easily be turned 90 degrees), or removable posts with signs (require reinstallation every fall).

Sign Features

Most of the ice warning signs used in Washington are static signs with black lettering and border on a yellow reflective background, as specified by the MUTCD. In a few isolated instances (in Colfax, Spokane, Wenatchee, and Tacoma), the static signs are supplemented with flashing amber beacons (see Table 10). In Spokane, the flashing beacons are remotely controlled and can be activated when weather conditions warrant. Variable message signs in Spokane and Everett are available to warn motorists of icy conditions but are not specifically dedicated for that purpose.

Sign Messages

Nearly all of the ice warning signs in Washington read WATCH FOR ICE (see Table 11). The Davenport maintenance area deviates from this message slightly by displaying signs reading WATCH FOR FOG-ICE. Mount Vernon uses more specific ICE IN TUNNEL signs in addition to the WATCH FOR ICE signs.

Table 9. Ice Warning Sign Erection/Removal Practices in Washington

REGION AND AREA	MECHANISM	TIME FRAME
EASTERN		
Colfax	Fold-up signs	Fall to spring
Colville	Posts and signs erected/removed	Fall to spring
Davenport	Posts and signs erected/removed and sign covers	Mid-November to mid-April
Spokane	Posts and signs erected/removed	November to April.
NORTH CENTRAL		
Wenatchee	Turnable signs on posts	October to April
Ephrata	Turnable signs on posts	October to March
Okanogan	Turnable signs on posts and fold-up signs	Fall to spring
NORTHWEST		
Bellingham	Posts and signs erected/removed	October to mid-April
Mount Vernon	Posts and signs erected/removed	Oct. 15 to March 15th.
Everett	Turnable signs on posts	Mid-October to mid-April
Kent	Turnable signs on posts, luminaires	Through winter season
Bellevue	Turnable signs on posts	Late October to late March
OLYMPIA		
Tacoma	Fold-up signs and sign covers	Mid-October to March
Port Orchard	Fold-up and turnable signs on posts	October to April
Port Angeles	Turnable signs on posts	November to mid-April
Aberdeen	Posts and signs erected/removed	Mid-October to mid-April
SOUTH CENTRAL		
Cle Elum	Fold-up signs	Mid-October to mid-April or first of May
East Selah	Fold-up and turnable signs on posts	October to April
Pasco	Fold-up signs	Late October to mid-March
Walla Walla	(No signs)	
SOUTHWEST		
Vancouver	Fold-up and turnable signs on posts	November to March
Chehalis	Fold-up and turnable signs on posts	Mid-October to April 15th
Goldendale	Fold-up signs	November to April
Raymond	Posts and signs erected/removed	September to mid-April

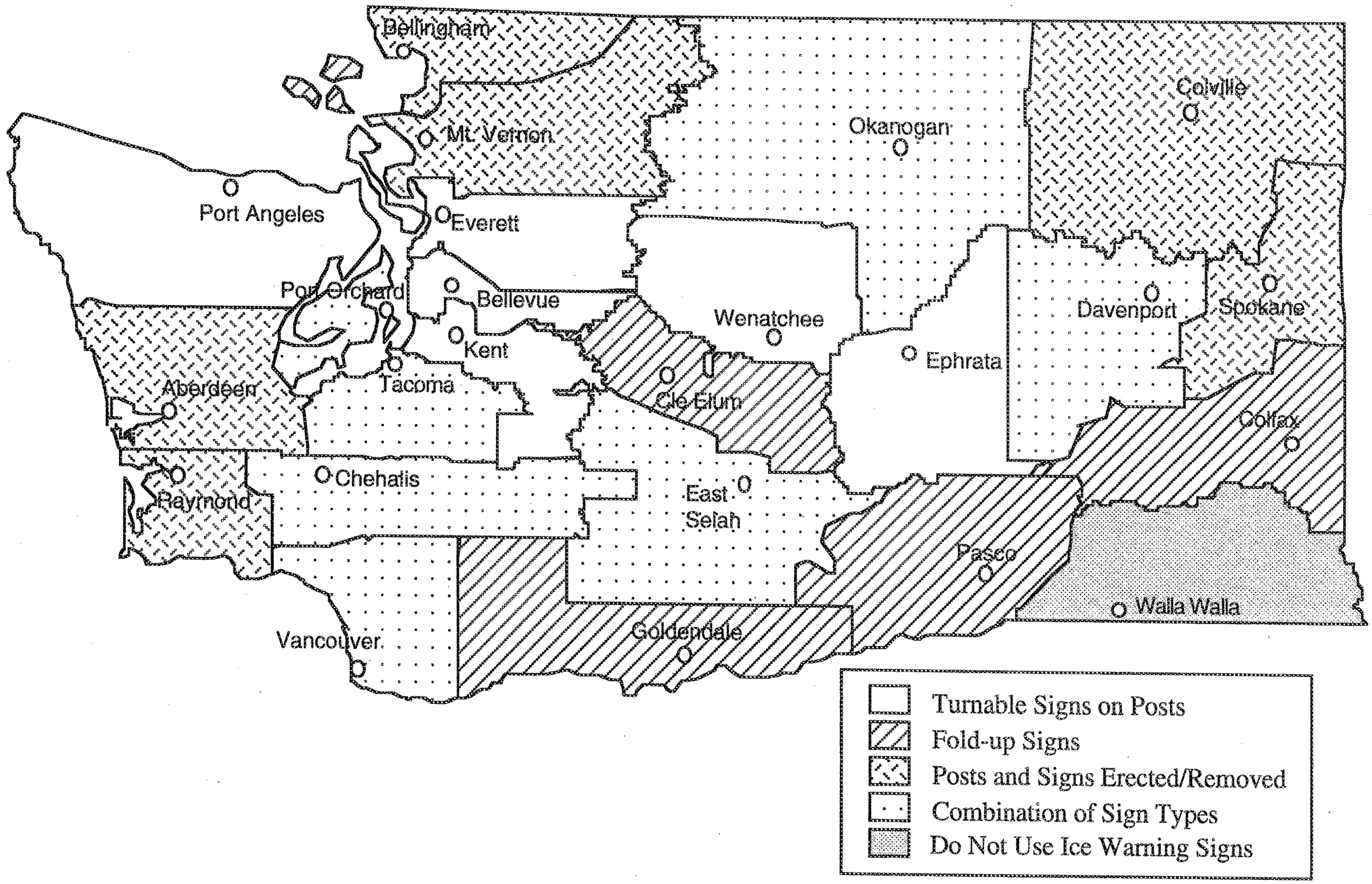


Figure 8. Ice Warning Sign Erection/Removal Practices in Washington

Table 10. Ice Warning Sign Features

REGION AND AREA	NONE	FLASHING BEACONS	EXTRA PLAQUES	VARIABLE MESSAGES	COMMENTS
EASTERN					
Colfax		√			
Colville	√				
Davenport	√				
Spokane		√		√	Remotely-controlled flashers VMS not specifically dedicated to ice warning
NORTH CENTRAL					
Wenatchee		√			
Ephrata	√				
Okanogan	√				
NORTHWEST					
Bellingham	√				
Mount Vernon	√				
Everett				√	
Kent	√				
Bellevue	√				
OLYMPIA					
Tacoma		√			
Port Orchard	√				
Port Angeles	√				
Aberdeen	√				
SOUTH CENTRAL					
Cle Elum	√				
East Selah	√				
Pasco	√				
Walla Walla	na	na	na	na	(No signs)
SOUTHWEST					
Vancouver	√				
Chehalis		√			
Goldendale	√				
Raymond	√				

Table 11. Ice Warning Sign Messages in Washington

REGION AND AREA	MESSAGE	REGION AND AREA	MESSAGE
EASTERN		**OLYMPIA**	
Colfax	WATCH FOR ICE	Tacoma	WATCH FOR ICE
Colville	WATCH FOR ICE	Port Orchard	WATCH FOR ICE
Davenport	WATCH FOR FOG-ICE	Port Angeles	WATCH FOR ICE
Spokane	na	Aberdeen	WATCH FOR ICE
NORTH CENTRAL		**SOUTH CENTRAL**	
Wenatchee	WATCH FOR ICE	Cle Elum	na
Ephrata	WATCH FOR ICE	East Selah	WATCH FOR ICE
Okanogan	WATCH FOR ICE	Pasco	WATCH FOR ICE
		Walla Walla	(No signs)
NORTHWEST		**SOUTHWEST**	
Bellingham	WATCH FOR ICE	Vancouver	WATCH FOR ICE
Mount Vernon	WATCH FOR ICE	Chehalis	na
	ICE IN TUNNEL		
Everett	WATCH FOR ICE	Goldendale	na
Kent	WATCH FOR ICE	Raymond	na
Bellevue	WATCH FOR ICE		

PUBLIC ATTITUDES AND RESPONSIVENESS

Maintenance area representatives were not asked questions directly related to public attitudes about and responsiveness tow ice warning signs, but many expressed opinions related to this topic. In general, maintenance representatives questioned the value of ice warning signs for improving public safety. Motorists' confidence in the warning signs may be compromised if WATCH FOR ICE signs are not relevant to road conditions (i.e., if they are left up all year round). Some of the maintenance area representatives suggested that the effectiveness of ice warning signs could be improved if flashing beacons were activated as weather conditions warranted. Motorists would also benefit from driver education and more radio and television coverage when icy conditions exists.

SAFETY AND LIABILITY

The effectiveness of ice warning signs in improving public safety was evaluated in WSDOT's Southwest Region along the Interstate-5 corridor in 1993. The study compared, route-by-route and mile-by-mile, ice-related accidents and ice warning signs. No correlation was found between signed and unsigned areas. In addition, the frequency of ice-related accidents on bridges was no higher than ice-related accidents elsewhere on the highway. The study recommended the removal of all WATCH FOR ICE signs, except for known problem areas including, but not limited to, (1) the air reduction plant in Tacoma that produces a vapor or fog and (2) the waterfalls or springs along the road near Spokane that mist or spray onto the pavement when the wind is blowing. In colder temperatures, ice frequently forms in these locations. Only short-term installation of ice warning signs is recommended at these problem locations.

No specific examples of liability-related problems and ice warning signs were provided by the maintenance area representatives. However, some representatives indicated that they thought ice warning signs do provide some protection against liability in tort claims.

SUMMARY

Similar to those noted at a national level among states, ice warning sign-related inconsistencies were noted within Washington state among maintenance areas. Most inconsistencies involve sign placement practices (i.e., general coverage, site-specific coverage, or a combination of both) and consequently, the number of signs used in each maintenance area. Maintenance areas are relatively consistent in their

- usage of ice warning signs (only the Walla Walla maintenance area does not use ice warning signs)
- erection/removal times (typically erected from fall to spring)
- sign messages (WATCH FOR ICE).

The examination of ice warning sign practices in Washington was complicated because of inaccuracies in WSDOT's sign inventories/logs. In some cases, the number of signs reported by maintenance personnel and the number of signs reported in the sign inventories/logs differed by a factor of four.

CHAPTER 5
PUBLIC ATTITUDES AND RESPONSIVENESS

Whereas an accident analysis provides information related to the effectiveness of sign placement, it does not provide information about whether drivers react appropriately to the warning sign. Driver opinions, collected through a survey, helped to determine whether reactions to ice warning signs stem from sign effectiveness or from other factors such as personal experience. These self-reported reactions to ice warning signs were then compared to historical speed observations to determine if the self-reported reactions were in fact occurring.

PUBLIC OPINION SURVEY

A total of 1500 mail-in surveys were distributed to six different zones statewide (see Figure 9). This zonal breakdown helped to ensure that an adequate representation of responses was received statewide from a variety of climatic and geographic regions. The overall survey response rate was 16.3 percent (254 surveys). Response rates for the individual zones ranged from 13 percent to 18.7 percent. Survey response rates for each of the six individual zones are listed in Table 12.

The specific characteristics of the sample are summarized in Table 13. In every zone except Zone 3, the majority of respondents were male (the statewide average was 62 percent). Zone 3 also reported, for the majority, a lower household income than the other zones. The majority of the respondents in Zones 1, 2, 4, 5, and 6 reported households incomes ranging from $30,001 to $50,000. Zone 3's majority reported household incomes ranging from $10,001 to $30,000. In each of the zones, most of the respondents were married (the statewide average was 72 percent). The age group of the respondents ranged primarily from 31 to 60 (statewide, 34 percent were 31 to 45, and 33 percent were 45 to 60). On average, statewide, 36 percent of the respondents reported college or university as their highest level of education, 19 percent had only attended a community college, and 24 percent had only finished high school.

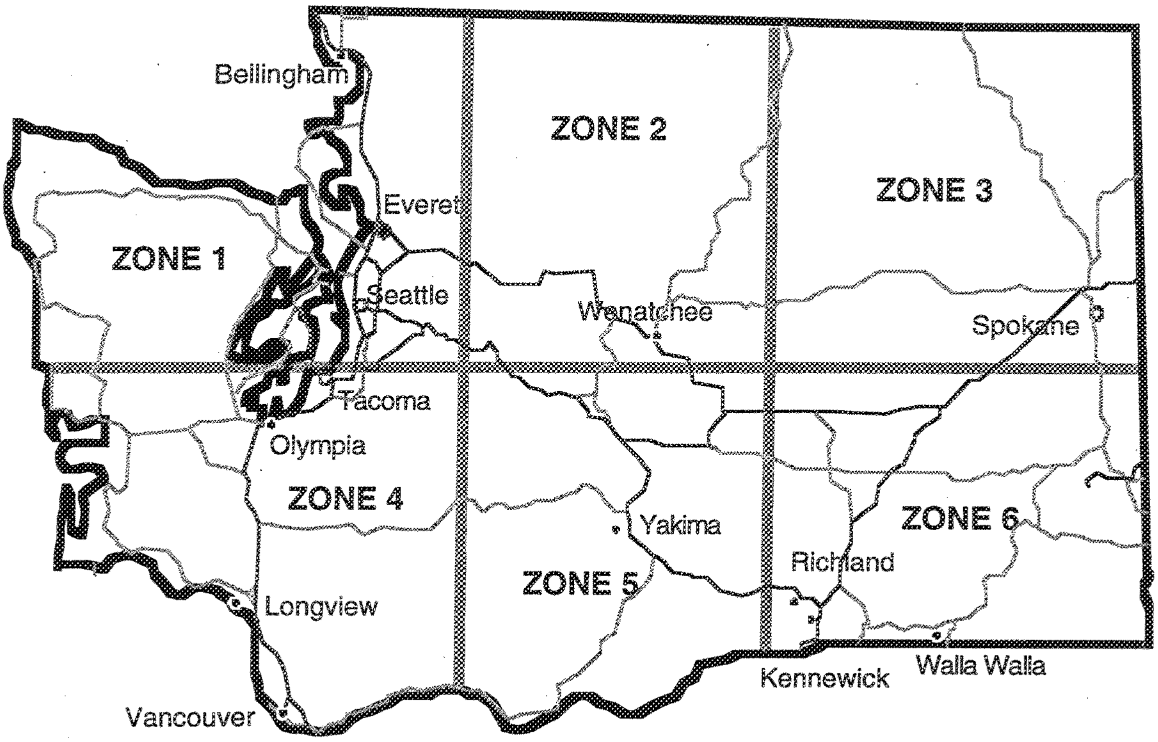


Figure 9. Survey Zone Map

Table 12. Survey Distribution

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Statewide
Survey Response Rate	18.7% (56/300)	15.0% (30/200)	18.3% (55/300)	13.0% (39/300)	18.5% 37/200)	14% (28/200)	16.3% (254/1,500)

Table 13. Sample Characteristics

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Statewide
SEX							
Male	60.7%	71.4%	47.2%	60.6%	73.0%	67.9%	61.7%
Female	39.3%	28.6%	52.8%	39.4%	27.0%	32.1%	38.3%
MARITAL STATUS							
Married	64.7%	89.3%	65.2%	77.4%	67.7%	78.3%	71.9%
Single	35.3%	10.7%	34.8%	22.6%	32.3%	21.7%	28.1%
AGE							
16 to 30	13.0%	11.1%	11.1%	7.9%	13.9%	7.1%	11.0%
31 to 45	31.5%	44.4%	27.8%	28.9%	36.1%	42.9%	33.8%
46 to 60	37.0%	37.0%	33.3%	36.8%	22.2%	32.1%	33.3%
Over 60	18.5%	7.4%	27.8%	26.3%	27.8%	17.9%	21.9%
HOUSEHOLD INCOME							
Less than $10,000	0.0%	4.2%	10.2%	8.3%	14.7%	4.0%	7.1%
$10,001 to $30,000	18.2%	8.3%	32.7%	16.7%	20.6%	8.0%	19.3%
$30,001 to $50,000	29.5%	41.7%	20.4%	30.6%	38.2%	44.0%	32.1%
$50,001 to $70,000	25.0%	33.3%	18.4%	16.7%	17.6%	36.0%	23.1%
$70,001 to $90,000	9.1%	8.3%	6.1%	5.6%	5.9%	4.0%	6.6%
Over $90,000	18.2%	4.2%	12.2%	22.2%	2.9%	4.0%	11.8%
EDUCATION							
Did not finish high school	0.0%	0.0%	2.0%	5.1%	8.3%	3.7%	3.1%
High school	13.7%	26.9%	30.0%	7.7%	41.7%	33.3%	24.5%
Community college	11.8%	26.9%	10.0%	30.8%	19.4%	22.2%	18.8%
College or university	51.0%	26.9%	28.0%	43.6%	25.0%	37.0%	36.2%
Post graduate work	23.5%	19.2%	30.0%	12.8%	5.6%	3.7%	17.5%

Driving Characteristics

Respondents in each zone were asked to describe their driving habits, including

- the type of vehicle that they most often drive
- the time of day that they most often drive
- the average number of miles that they typically drive on weekdays and weekends
- their frequent travel routes
- how they typically react to various cold weather stimuli (e.g., visible snow or ice, vehicles slowing)
- whether they had ever been in an ice-related accident.

In addition, respondents in each zone were asked to predict their driving behavior under certain conditions.

Vehicle Type. Table 14 summarizes responses to the question, "What type of vehicle do you typically drive?" Over half of all respondents reported typically driving a passenger car; of these, the majority are front-wheel drive. Note the zonal variation in the percentage of respondents who typically drive all-wheel drive vehicles (including sport utility vehicles and pickup trucks). This variation is likely a result of some combination of climatic and geographic conditions in each area. For example, in Zone 4 (southwestern Washington), which experiences a warmer climate than the rest of the state but is mountainous, a relatively high percentage of respondents drive all-wheel drive vehicles. Conversely, in Zone 6 (southeastern Washington), which experiences a colder climate but has relatively flat terrain, an unusually low percentage of respondents drive all-wheel drive vehicles.

Time of Day of Travel. The time of day of typical travel is relatively consistent among the six zones (see Figure 10). Most respondents reported traveling between 6AM and 9AM and between 3PM to 6PM. This is consistent with typical work commute times. An almost equal percentage of motorists reported traveling midday (from 9AM to 3PM). In addition, a higher than expected number of respondents reported traveling between 6PM and midnight.

Table 14. What Type of Vehicle Do You Typically Drive?

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Statewide
MOTORCYCLE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PASSENGER CAR							
Front-wheel Drive	41.8%	34.5%	50.9%	39.0%	24.3%	42.9%	40.0%
Rear-wheel Drive	10.9%	3.4%	9.1%	2.4%	13.5%	14.3%	9.0%
All-wheel Drive	5.5%	3.4%	1.8%	9.8%	0.0%	3.6%	4.1%
FULL-SIZE VAN/MINIVAN							
Front-wheel Drive	7.3%	13.8%	9.1%	12.2%	2.7%	0.0%	7.8%
Rear-wheel Drive	3.6%	3.4%	3.6%	4.9%	13.5%	10.7%	6.1%
All-wheel Drive	1.8%	3.4%	1.8%	2.4%	0.0%	3.6%	2.0%
SPORT UTILITY VEHICLE							
Front-wheel Drive	3.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%
Rear-wheel Drive	0.0%	3.4%	1.8%	0.0%	2.7%	0.0%	1.2%
All-wheel Drive	10.9%	13.8%	12.7%	9.8%	5.4%	0.0%	9.4%
PICKUP TRUCK							
Front-wheel Drive	1.8%	0.0%	0.0%	4.9%	2.7%	10.7%	2.9%
Rear-wheel Drive	7.3%	10.3%	3.6%	2.4%	8.1%	10.7%	6.5%
All-wheel Drive	5.5%	10.3%	5.5%	12.2%	24.3%	3.6%	9.8%
HEAVY TRUCK	0.0%	0.0%	0.0%	0.0%	2.7%	0.0%	0.4%

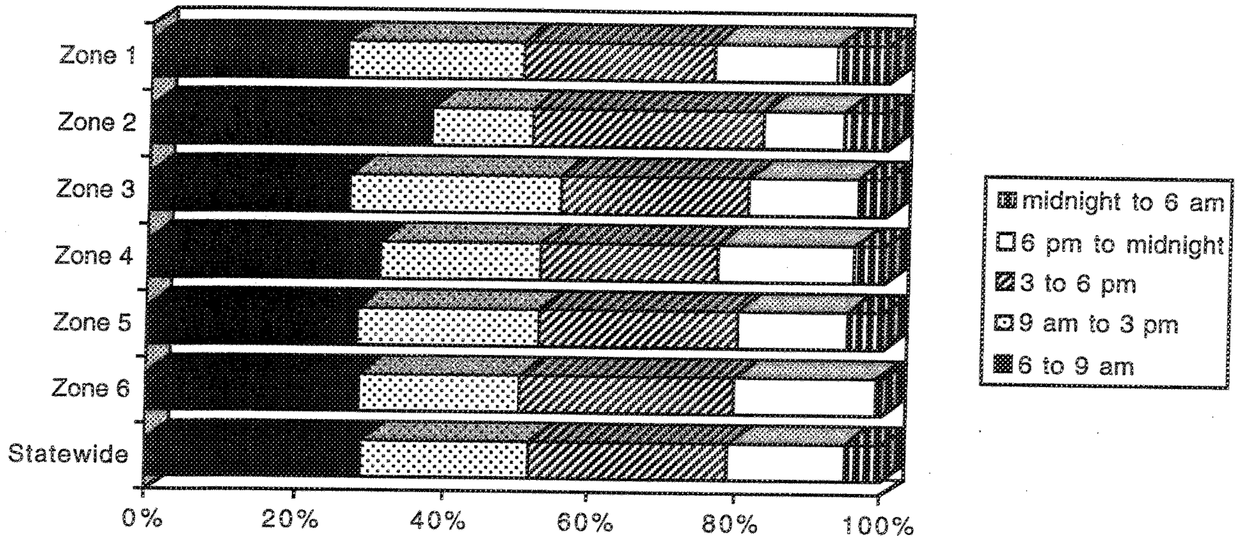


Figure 10. When Do You Typically Drive?

Miles Traveled. The total number of miles that respondents reported driving on a weekday and a weekend day are depicted in Figure 11 by zone. Respondents in Zones 2, 4, 5, and 6 reported higher miles traveled than the statewide average. These zones make up much of the rural areas of the state; longer driving distances between work or other activities and home are expected. Comparable miles traveled were reported for weekdays and weekend days. In fact, when averaged statewide, the total miles traveled per day on weekdays and weekend days were identical.

Frequent Travel Routes. The most frequently traveled routes reported by the survey sample are depicted in Figure 12. In general, approximately half of the respondents reported frequently traveling on

- Interstate 5 near Bellevue, Bellingham, Chehalis, Everett, Kent, Mount Vernon, Tacoma and Vancouver
- Interstate 90 near Bellevue, Cle Elum, Ephrata, and Spokane.

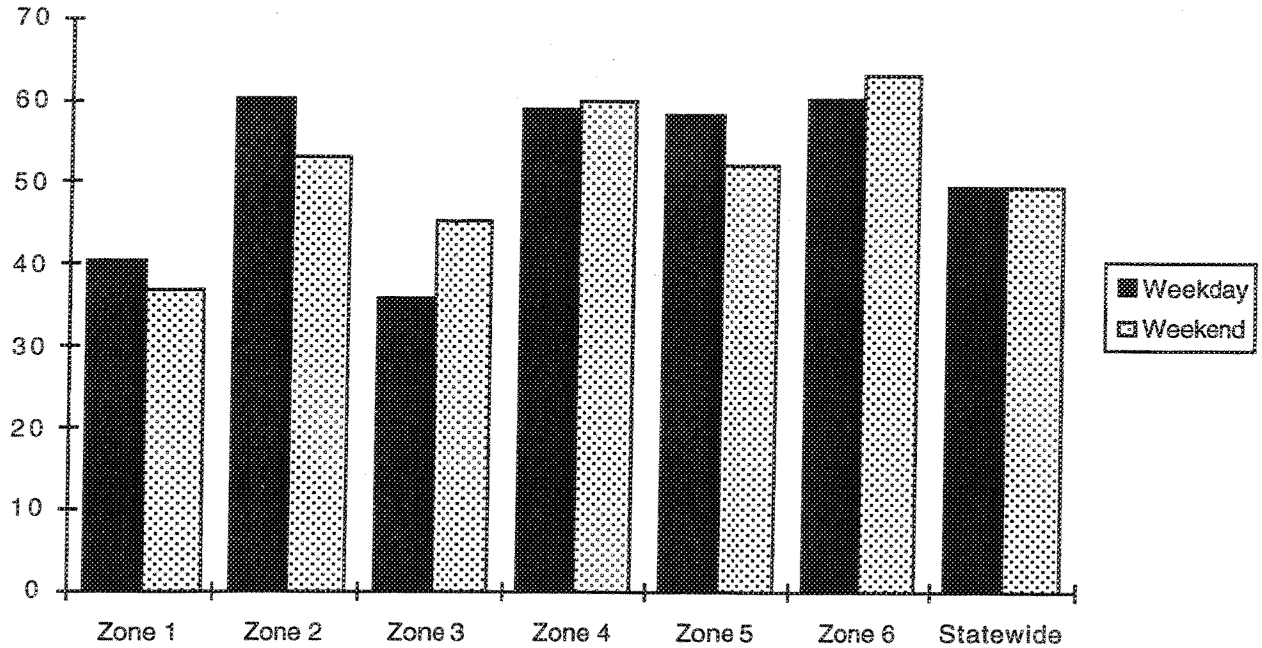


Figure 11. What Is the Total Number of Miles You Drive in a Weekday and Weekend Day?

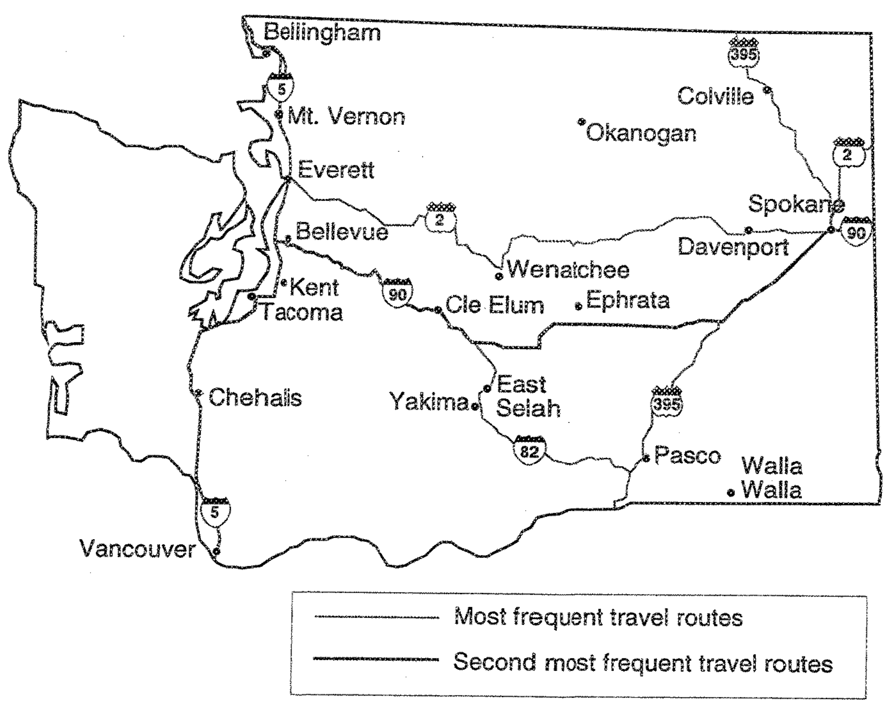


Figure 12. What are Your Most Frequently Traveled Routes?

Approximately 20 percent of the respondents reported frequently traveling on

- State Route 82 near Cle Elum, East Selah, Pasco, and Walla Walla
- State Route 395 near Colville, Davenport, Pasco, and Spokane
- State Route 2 near Bellevue, Davenport, Ephrata, Everett, Okanogan, Spokane and Wenatchee.

Less traveled routes included State Routes 821, 97, 18, 405, 12, 17, and 195. Only 5 to 10 percent of the survey respondents reported travel on these routes.

Cold Weather Driving Habits. To investigate their cold weather driving habits, motorists were asked to respond to the following question with the following choices: "How often do you slow down and exercise caution when the following cold weather conditions exist?"

- visible snow or ice
- ice warning signs
- slowing vehicles
- sand on the road
- vehicles off the road
- freezing temperatures
- radio and television warnings

Surprisingly, the majority of motorists reported "always" slowing down and exercising caution when seeing visible snow or ice, ice warning signs, other slowing vehicles, and vehicles off the road (see Table 15). With the exception of Zone 6, the majority of motorists reported "always" slowing down and exercising caution when temperatures dropped below freezing and when radio and television warnings were aired. The majority of motorists in Zone 6 reported "sometimes" slowing and exercising caution under these conditions. The majority of motorists in Zones 1, 5, and 6 reported "always" slowing if the road has been sanded. The majority of motorists in Zones 2, 3, and 4 reported only "sometimes" slowing.

Table 15. How Often Do You Slow Down and Exercise Caution When the Following Cold Weather Conditions Exist?

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Statewide
VISIBLE SNOW OR ICE							
Always	98.2%	100%	96.2%	100%	97.3%	88.9%	97.1%
Sometimes	1.8%	0.0%	3.8%	0.0%	2.7%	11.1%	2.9%
Seldom	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Never	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ICE WARNING SIGNS							
Always	50.0%	51.7%	76.9%	59.5%	77.1%	69.2%	63.9%
Sometimes	42.6%	34.5%	21.2%	32.4%	20.0%	26.9%	30.0%
Seldom	5.6%	13.8%	1.9%	8.1%	2.9%	3.8%	5.6%
Never	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
SLOWING VEHICLES							
Always	79.6%	75.9%	96.2%	81.6%	88.6%	88.9%	85.6%
Sometimes	18.5%	24.1%	3.8%	18.4%	11.4%	11.1%	14.0%
Seldom	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Never	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SAND ON THE ROAD							
Always	51.9%	41.4%	47.2%	42.1%	47.2%	68.4%	50.0%
Sometimes	40.7%	51.7%	52.8%	52.6%	44.4%	28.9%	45.2%
Seldom	7.4%	6.9%	0.0%	5.3%	8.3%	2.6%	4.8%
Never	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
VEHICLES OFF THE ROAD							
Always	65.5%	70.0%	69.2%	62.2%	67.6%	78.6%	68.2%
Sometimes	32.7%	30.0%	25.0%	35.1%	29.7%	17.9%	28.9%
Seldom	1.8%	0.0%	5.8%	2.7%	2.7%	3.6%	2.9%
Never	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FREEZING TEMPERATURE							
Always	58.2%	60.0%	52.8%	47.4%	66.7%	29.6%	53.6%
Sometimes	36.4%	40.0%	37.7%	47.4%	19.4%	55.6%	38.5%
Seldom	5.5%	0.0%	7.5%	5.3%	13.9%	7.4%	6.7%
Never	0.0%	0.0%	1.9%	0.0%	0.0%	7.4%	1.3%
RADIO/TV WARNINGS							
Always	49.1%	44.8%	55.1%	51.4%	51.5%	40.7%	49.6%
Sometimes	35.8%	41.4%	40.8%	45.9%	30.3%	51.9%	40.4%
Seldom	13.2%	13.8%	2.0%	2.7%	18.2%	7.4%	9.2%
Never	1.9%	0.0%	2.0%	0.0%	0.0%	0.0%	0.9%

Ice-Related Accident History. Statewide, 19 percent of the survey respondents indicated that they had been involved in an ice-related accident. Surprisingly, the percentage of respondents reporting involvement in an ice-related accident is relatively equal among the six zones (see Figure 13). The majority of accidents were reported to have occurred at mountain passes (17 percent), shaded areas (15 percent), and on roadways with curvature (15 percent). However, in Figure 14, note the variation in accident locations among the various zones. On a statewide basis, about 32 percent of the these motorists were less 10 miles from their home, and 38 percent were more than 50 miles from home when the accident occured (see Figure 15). Again, however, note the variation among zones. Most accidents involved rear-wheel drive vehicles (probably because front-wheel drive vehicles typically have better tractive capabilities) (see Table 16). A surprising number of accidents were reported to have involved four-wheel drive vehicles. Four-wheel drive vehicle owners may have an elevated sense of security and, hence, may be less cautious when driving in adverse roadway conditions.

Predicted Driving Behavior. When asked at what locations they are most likely to slow down and exercise caution, motorists responded nearly equally to the alternatives provided and nearly identically from zone to zone (see Figure 16). Potential locations for caution included bridges or overpasses, known trouble spots, mountain passes, shaded areas, and roadway curves. This response may indicate a high level of public awareness regarding higher risk, ice-related accident locations. However, note that public awareness regarding potential hazards is not equivalent to proper reaction to the hazard.

When asked at what hours of the day or night they are most likely to slow down and exercise caution during potentially icy conditions, the majority of motorists reported between 6AM and 9AM and between 6PM and midnight (see Figure 17). Responses were relatively consistent among the zones. Typically, ambient temperatures are lowest between midnight and 6AM; the threat of ice may be greater during these times.

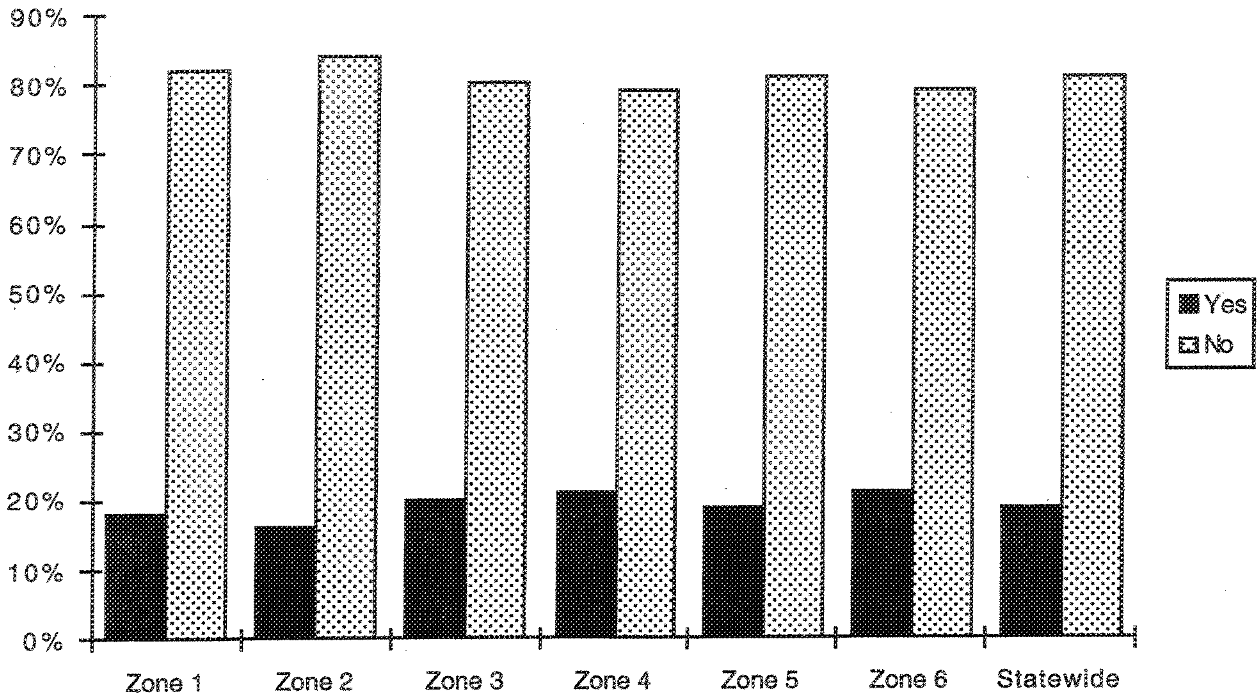


Figure 13. Have You Ever Been Involved in an Ice-Related Accident?

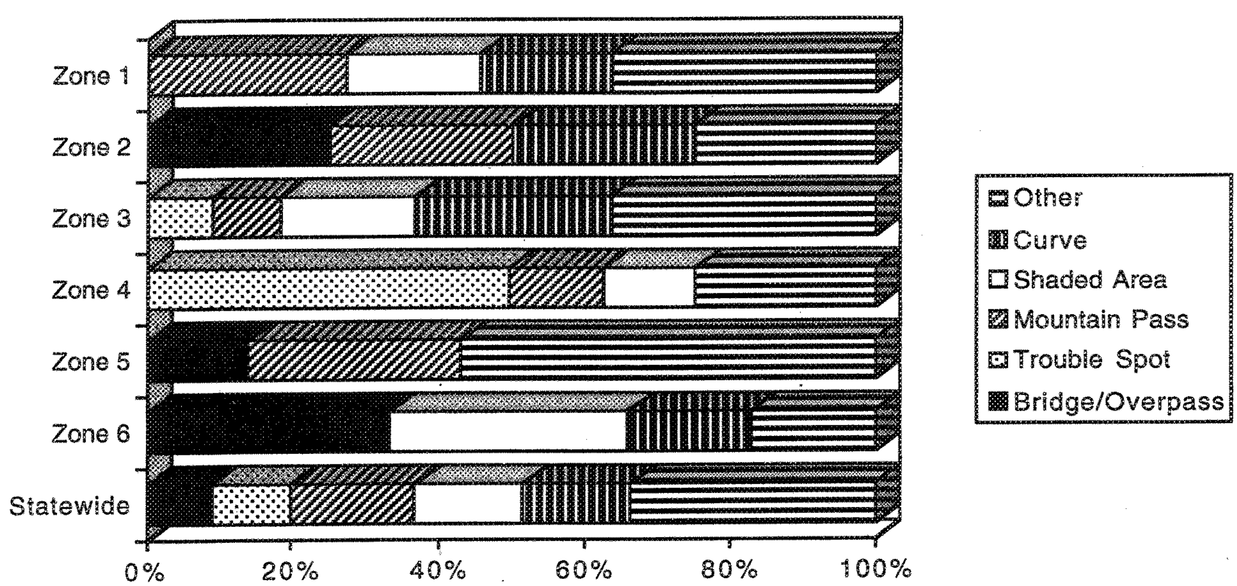


Figure 14. Where Did Your Most Recent Ice-Related Accident Occur?

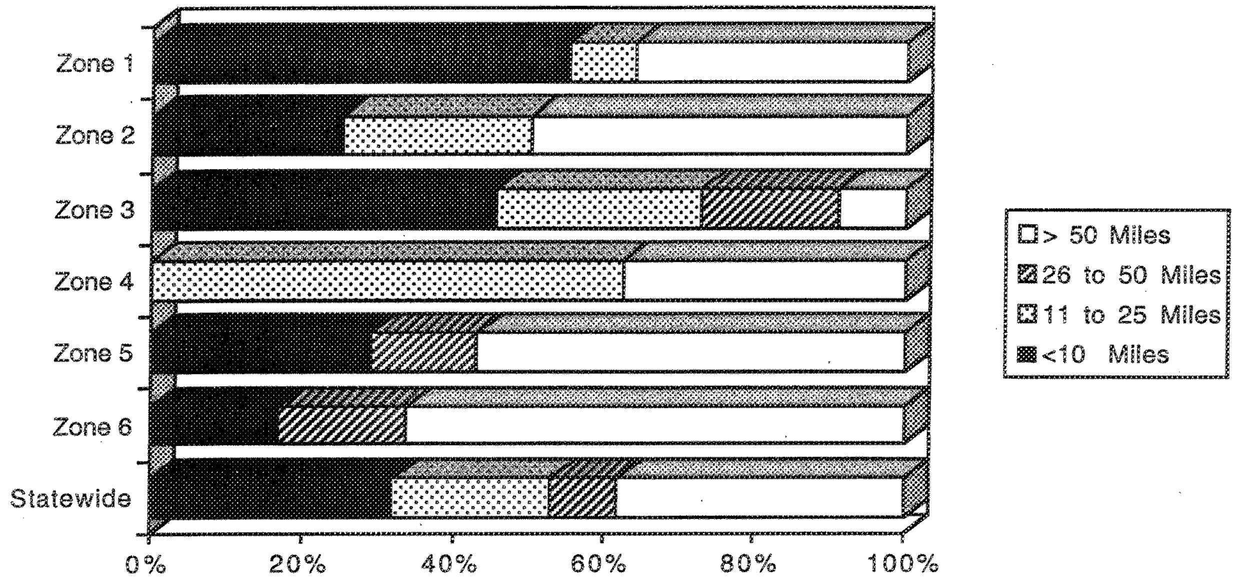


Figure 14. How Far from Your Home Did Your Most Recent Ice-Related Accident Occur?

Table 16. What Type of Vehicle Were You Driving or Riding in?

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Statewide
MOTORCYCLE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PASSENGER CAR							
Front-wheel Drive	27.3%	0.0%	45.5%	50.0%	0.0%	16.7%	27.7%
Rear-wheel Drive	45.5%	25.0%	9.1%	37.5%	42.9%	83.3%	38.3%
All-wheel Drive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FULL-SIZE VAN/MINIVAN							
Front-wheel Drive	0.0%	0.0%	18.2%	0.0%	0.0%	0.0%	4.3%
Rear-wheel Drive	9.1%	25.0%	9.1%	12.5%	0.0%	0.0%	8.5%
All-wheel Drive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SPORT UTILITY VEHICLE							
Front-wheel Drive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rear-wheel Drive	0.0%	0.0%	9.1%	0.0%	0.0%	0.0%	2.1%
All-wheel Drive	18.2%	0.0%	9.1%	0.0%	14.3%	0.0%	8.5%
PICKUP TRUCK							
Front-wheel Drive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rear-wheel Drive	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	4.3%
All-wheel Drive	0.0%	0.0%	0.0%	0.0%	42.9%	0.0%	6.4%
HEAVY TRUCK	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

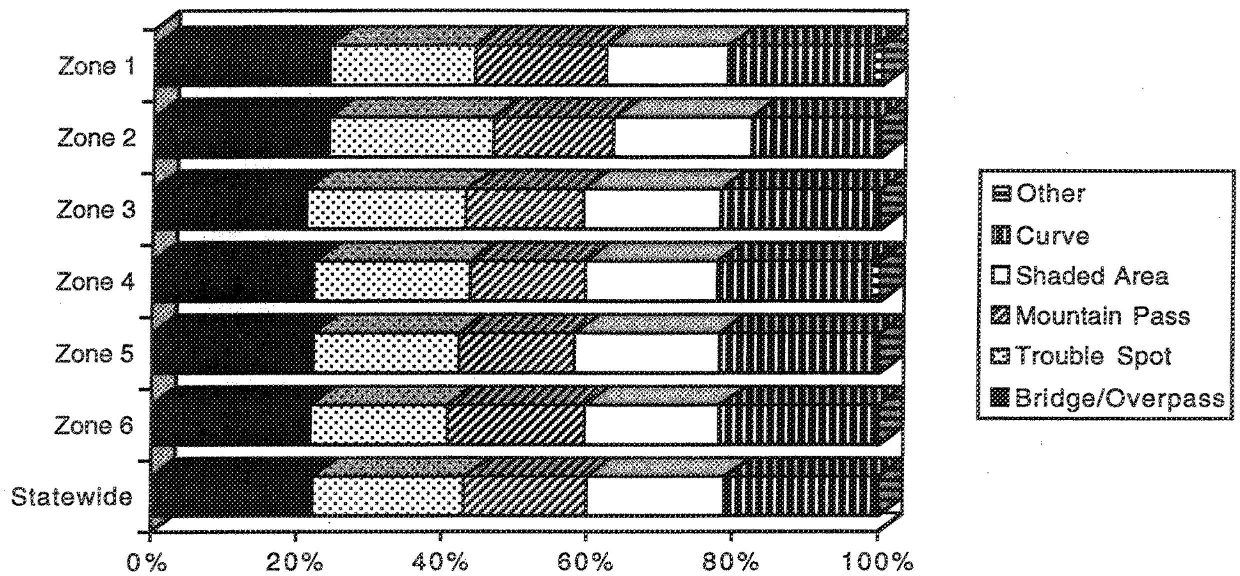


Figure 16. At What Locations Are You Most Likely to Slow Down During Icy Conditions?

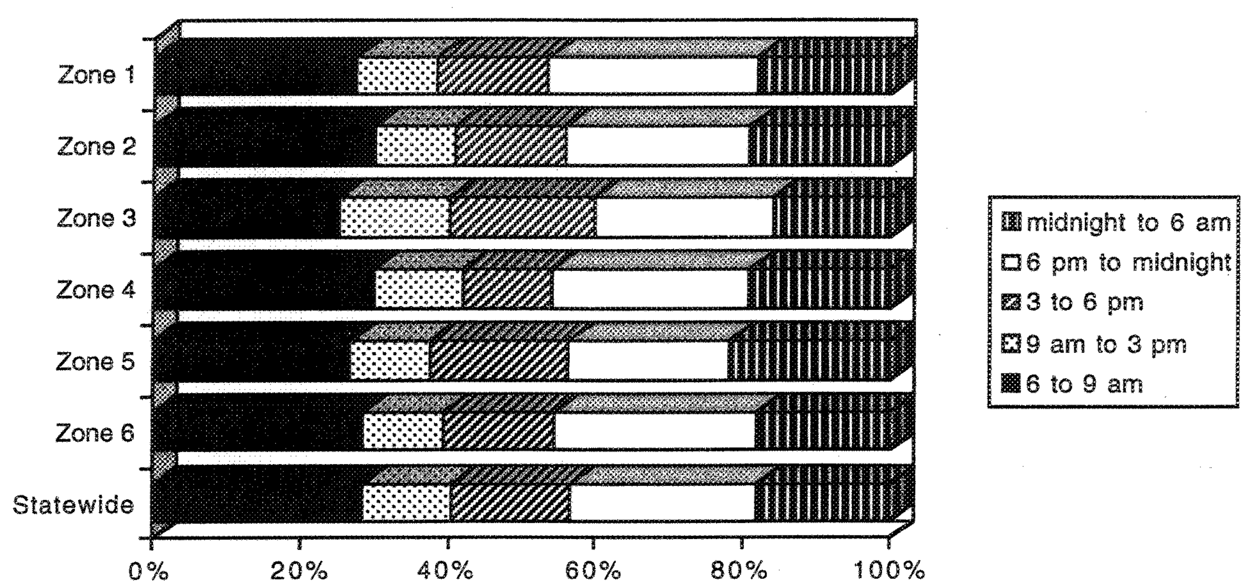


Figure 17. At What Hours of the Day or Night Are You Most Likely to Slow Down During Icy Conditions?

Motorist Opinions

In addition to questions related to driving characteristics, motorists were asked opinion-based questions. Questions of primary interest related to the party at fault in an ice-related accident, the effectiveness of ice warning signs, and their continued use.

Accident Fault. In each of the six zones, the majority of survey respondents indicated that the driver(s) involved in an ice-related accident were most at fault (see Figure 18). Involved drivers may be likely to travel too fast for conditions. Statewide, approximately 20 percent of the survey respondents placed fault with the roadway maintenance department should an ice-related accident occur. This is alarming from a liability standpoint. If an injury or fatality results from an ice-related accident, and the two primary parties thought to be at fault are the driver(s) involved and the roadway department, certainly the liability suit will be brought against the roadway maintenance department. Roadway maintenance departments have the funds to support typically large monetary damage awards; individual drivers usually do not.

Ice Warning Sign Effectiveness. When asked to describe ice warning sign effectiveness, the majority of survey respondents indicated that they are "somewhat effective" and "very effective" (50.6 percent statewide and 26.4 percent statewide, respectively). Figure 19 depicts the survey responses by zone and statewide. Note the variation in response by zone. Motorists in Zones 1, 3, 4, and 5 find ice warning signs most effective, while motorists in Zones 2 and 6 find them least effective. These variations are seemingly unrelated to either climatic patterns or sign placement practices.

Some motorists offered suggestions to improve the effectiveness of ice warning signs. Some felt that providing ice-related warnings via variable message signs would draw much more attention. Others suggested using "active" rather than passive signs and recommended signs that would change color when temperatures dropped below freezing. Some motorists admitted paying little attention to ice warning signs left up year-round. Interestingly, many motorists emphasized driver awareness and recommended education related to driving in hazardous conditions, black ice formation, the effect of vehicle speed, and appropriate distances between vehicles.

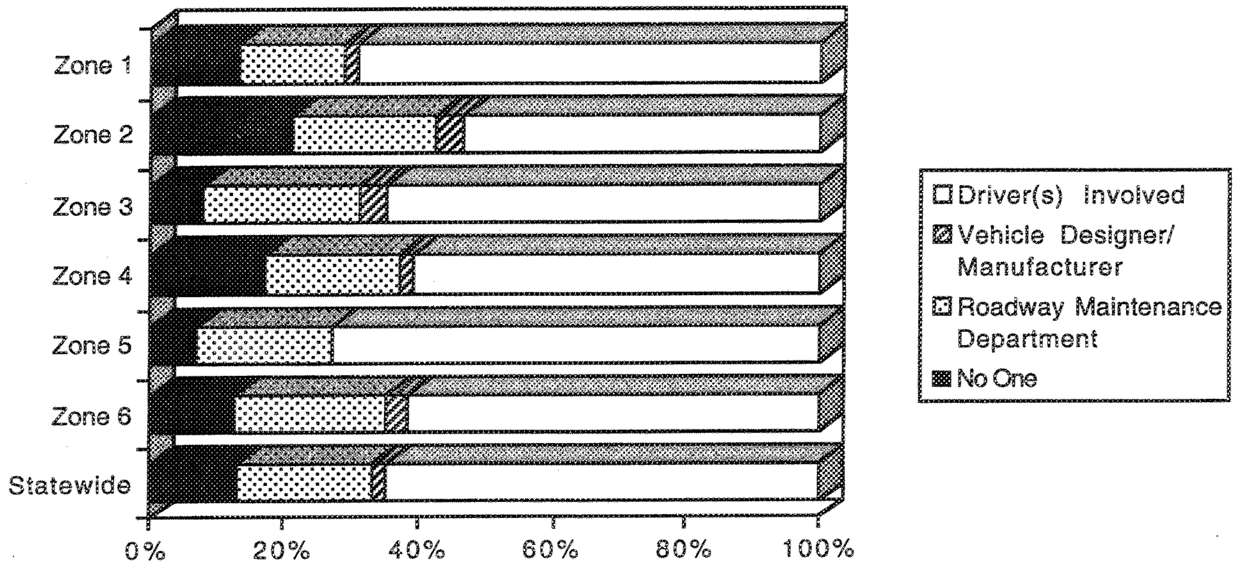


Figure 18. Who Is at Fault If an Ice-Related Accident Occurs?

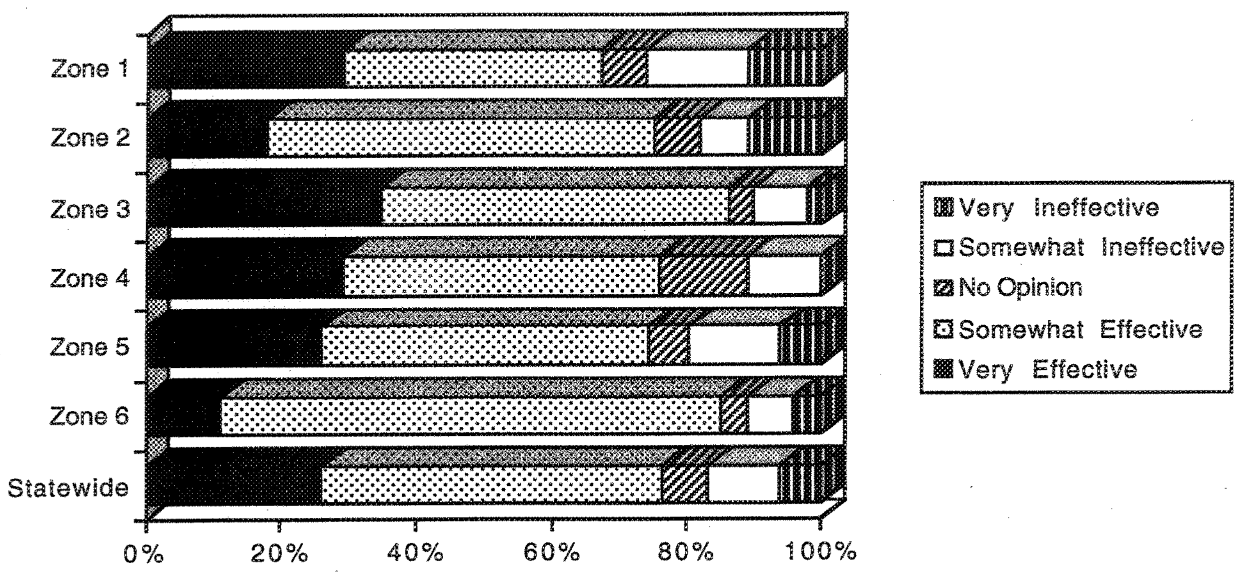


Figure 19. How Effective Are Ice Warning Signs for Improving Safety and Preventing Accidents During Icy Conditions?

Effectiveness of Other Accident Prevention Tools or Strategies. When asked about how effective other accident prevention tools or strategies are in improving safety and preventing accidents, the majority of respondents rated reduced vehicle speeds and sanding the road (particularly in Zones 5 and 6) as "very effective" (see Table 17). Vehicle traction devices are thought to be very and somewhat effective, depending on locale. Radio and television warnings are perceived to be "somewhat effective" in improving safety and preventing accidents by the majority of respondents in each of the six zones.

Ice Warning Sign Usage. Motorists were asked whether they think the use of ice warning signs should be increased, decreased, or abandoned. An overwhelming majority of motorists in each of the six zones reported that they would like to see the use of ice warning signs increased (see Figure 20).

Use of Other Accident Prevention Tools or Strategies. When asked about the continued use of other accident prevention strategies, including sanding the road and radio/television warnings, the overwhelming majority of motorists in each of the six zones sid they would like to see use increased. Table 18 summarizes the results. Note from this table that the number of motorists who favor increased use of sand on the road is larger than the number of motorists who favor either increased use of ice warning signs or increased radio or television broadcasts.

HISTORICAL SPEED OBSERVATIONS

The public opinion survey described earlier in this chapter asked people to self-report their behavior when passing an ice warning sign. Recall that the majority of motorists (63.9 percent statewide) reported "always" slowing down and exercising caution upon seeing icewarning signs. The observation of historical speed data allows this self-reported behavior to be compared with actual observed behavior.

Table 17. How Effective Are the Following for Improving Safety and Preventing Accidents During Icy Conditions?

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Statewide
ICE WARNING SIGNS							
Very Effective	29.1%	17.9%	34.6%	28.9%	25.7%	11.1%	26.4%
Somewhat Effective	38.2%	57.1%	51.9%	47.4%	48.6%	74.1%	50.6%
No Opinion	7.3%	7.1%	3.8%	13.2%	5.7%	3.7%	6.8%
Somewhat Ineffective	14.5%	7.1%	7.7%	10.5%	14.3%	7.4%	10.6%
Very Ineffective	10.9%	10.7%	1.9%	0.0%	5.7%	3.7%	5.5%
SANDING THE ROAD							
Very Effective	62.5%	62.1%	53.1%	51.4%	81.1%	81.5%	63.9%
Somewhat Effective	37.5%	31.0%	44.9%	42.9%	18.9%	18.5%	33.9%
No Opinion	0.0%	0.0%	2.0%	5.7%	0.0%	0.0%	1.3%
Somewhat Ineffective	0.0%	6.9%	0.0%	0.0%	0.0%	0.0%	0.9%
Very Ineffective	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRACTION DEVICES							
Very Effective	48.1%	37.9%	55.6%	35.3%	59.5%	40.7%	47.6%
Somewhat Effective	40.4%	37.9%	38.9%	52.9%	29.7%	55.6%	41.6%
No Opinion	1.9%	10.3%	3.7%	8.8%	2.7%	3.7%	4.7%
Somewhat Ineffective	9.6%	10.3%	1.9%	2.9%	5.4%	0.0%	5.2%
Very Ineffective	0.0%	3.4%	0.0%	0.0%	2.7%	0.0%	0.9%
VEHICLE FEATURES							
Very Effective	21.6%	10.3%	22.9%	22.2%	41.2%	15.4%	22.8%
Somewhat Effective	49.0%	37.9%	52.1%	55.6%	41.2%	69.2%	50.4%
No Opinion	7.8%	3.4%	18.8%	16.7%	2.9%	11.5%	10.7%
Somewhat Ineffective	15.7%	41.4%	6.3%	5.6%	8.8%	3.8%	12.9%
Very Ineffective	5.9%	6.9%	0.0%	0.0%	5.9%	0.0%	3.1%
REDUCED SPEEDS							
Very Effective	72.7%	67.9%	80.0%	71.1%	75.7%	77.8%	74.6%
Somewhat Effective	27.3%	25.0%	16.4%	26.3%	18.9%	22.2%	22.5%
No Opinion	0.0%	0.0%	1.8%	2.6%	0.0%	0.0%	0.8%
Somewhat Ineffective	0.0%	7.1%	1.8%	0.0%	5.4%	0.0%	2.1%
Very Ineffective	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RADIO/TV WARNINGS							
Very Effective	22.2%	34.5%	23.6%	28.6%	31.4%	22.2%	26.8%
Somewhat Effective	44.4%	37.9%	50.9%	54.3%	54.3%	55.6%	50.2%
No Opinion	20.4%	3.4%	7.3%	5.7%	11.4%	14.8%	11.3%
Somewhat Ineffective	7.4%	24.1%	12.7%	5.7%	0.0%	7.4%	9.5%
Very Ineffective	3.7%	0.0%	1.8%	2.9%	2.9%	0.0%	2.2%

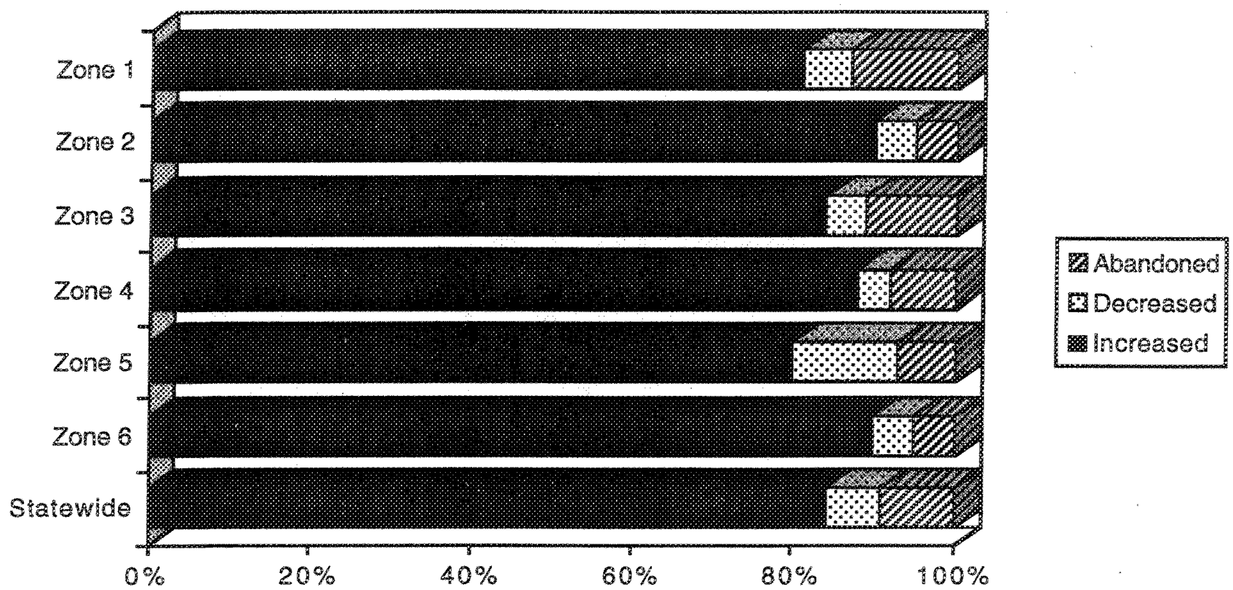


Figure 20. Should the Use of Ice Warning Signs Be Increased, Decreased, or Abandoned?

Table 18. Should the Use of the Following Be Increased, Decreased, or Abandoned?

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Statewide
ICE WARNING SIGNS							
Increased	81.3%	89.5%	84.2%	87.5%	80.0%	89.5%	84.6%
Decreased	6.3%	5.3%	5.3%	4.2%	13.3%	5.3%	6.8%
Abandoned	12.5%	5.3%	10.5%	8.3%	6.7%	5.3%	8.6%
SANDING THE ROAD							
Increased	100%	100%	98.0%	100%	97.3%	95.7%	98.6%
Decreased	0.0%	0.0%	2.0%	0.0%	2.7%	4.3%	1.4%
Abandoned	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RADIO/TV WARNINGS							
Increased	87.5%	76.5%	87.9%	96.2%	86.2%	95.0%	88.5%
Decreased	10.0%	17.6%	6.1%	3.8%	3.4%	0.0%	6.7%
Abandoned	2.5%	5.9%	6.1%	0.0%	10.3%	5.0%	4.8%

The intent of the historical speed analysis was to confirm a meaningful reduction in speeds immediately after motorists passed an ice warning sign. The location used for this analysis was on Interstate 405 just south of SR 520. This site was selected because it was the only site within the FLOW system where two data stations bracketed several ice warning signs. This location allowed motorists to travel for more than two miles without seeing an ice warning sign and then to view two signs within a 1100-foot section of roadway.

Speed data were analyzed for times when the ice signs were up and after they had been removed for the season. For travel with ice warning signs, mid-October through December 1996 was selected. For travel without ice warning signs, July through August 1996 was selected. Within these months, a one-hour period (9:00AM to 10:00AM in the summer and from 10:00AM to 11:00AM in the winter) for one lane during Sunday mornings was analyzed. Sunday morning was a time when free flow conditions prevailed but was also a time with enough traffic to result in reasonable sample sizes.

To determine whether the difference in speed with and without ice warning signs was significant, an analysis of variance (ANOVA) was performed. The ANOVA is a statistical tool used to test statements of the following form:

> The difference in speed between the time with and without ice signs is the same (i.e., variability in speed differences is simply due to chance).

Table 19 summarizes the descriptive statistics for the two data collection time periods (i.e., with ice warning signs in place and without ice warning signs in place).

The results of the ANOVA (F-Ratio = 0007, F Probability = .9784) do not allow the above statement to be rejected. The results suggest that there is a 98 percent probability that the difference in vehicle speeds with the ice warning signs and without the ice warning signs is due solely to chance and cannot be statistically linked to the presence of the ice warning signs. In other words, the results of this analysis suggest that motorists do not change speeds when passing ice warning signs, in contradiction to their self-reported behavior.

Table 19. Descriptive Statistics for Historical Speed Data

	With Ice Warning Sign October - December		Without Ice Warning Sign July - August	
	Mean	Standard Deviation	Mean	Standard Deviation
Traffic Volumes	565	46	556	34
Speeds Before Ice Warning Sign	59.9	0.45	59.4	0.53
Speeds After Ice Warning Sign	61.7	0.59	61.2	0.68
Speed Differential	1.82	0.50	1.82	0.31
Number of Days	12		12	

SUMMARY

Responses to many of the survey questions were similar among the six zones, in spite of differing climatic and geographic conditions. Some of the more interesting survey findings are summarized below.

- Nearly consistently statewide, 19 percent of respondents reported ever having been involved in an ice-related accident.
- A relatively small proportion of ice-related accidents had occurred on bridges or overpasses. Many reportedly occurred at known troublespots, mountain passes, or shaded areas.
- When considering who is at fault, the majority of motorists feel that the driver involved is at fault. However, the second highest majority of respondents indicated that the roadway maintenance department is at fault. This is alarming from a liability standpoint; suits are rarely raised against individuals because of the low potential for monetary payout. The roadway maintenance department would thus be the first party considered in a potential liability suit.
- A majority of respondents feel that ice warning signs are either very or somewhat effective at improving safety and preventing accidents.
- An overwhelming majority of respondents feel that the use of ice warning signs should be increased.
- The majority of motorists report always slowing down and exercising caution when they see an ice warning sign. This conflicts with the historical speed analysis, which found that ice warning signs had no significant effect on vehicle speeds.

Such high public support for ice warning signs is surprising, especially given that most motorists seem to take no precautionary action when passing a sign. Positive public support in combination with the fact that the top two parties named at fault in an ice-related accident are the driver and the roadway maintenance department indicate a need for continued ice warning sign use from a liability standpoint. From both a liability and a public safety standpoint, improved targeting of potential or known problem areas is needed. The next chapter discusses this further.

CHAPTER 6
SAFETY AND LIABILITY

The previous chapter describes the benefits the motoring public attributes to ice warning signs. In this section, quantified benefits related to safety and liability are discussed. More specifically, this section describes

- characteristics of ice-related accidents including time-related, environmental, locational, and vehicle and driver characteristics
- relationships between ice-related accident frequency and severity and the presence of ice warning signs
- specific cases of ice-related liability in Washington state, their circumstances and outcomes.

ICE-RELATED ACCIDENT CHARACTERISTICS

Ice-related accident data spanning four years (January 1991 to December 1995) were considered in this analysis. In all, police recorded 12,091 ice-related accidents in this four-year period; many more were likely never reported. Of these accidents, the majority resulted in property damage only (i.e., to the vehicle or to the adjacent infrastructure), many resulted in injuries, and a small percentage resulted in a fatality (see Figure 21). With respect to public safety and liability, ice-related accidents resulting in an injury or fatality are of most concern.

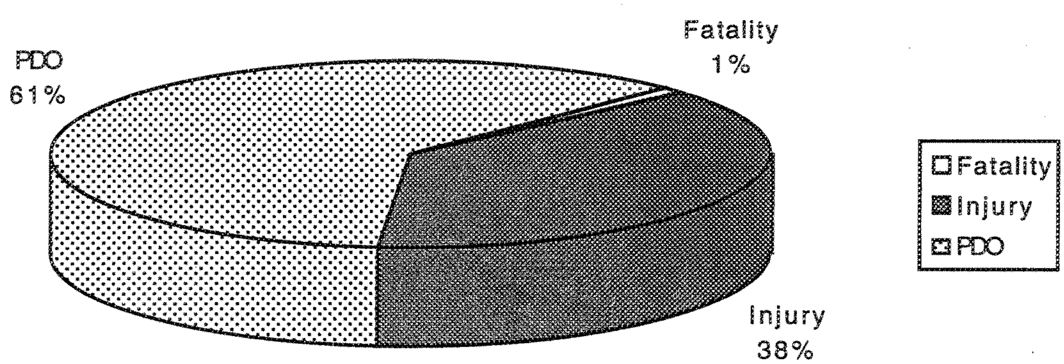


Figure 21. Ice-Related Accident Severity

Time-related Characteristics

The frequency of ice-related accidents fluctuated throughout the four-year time span (see Figure 22). This fluctuation likely resulted from differences in climatic conditions over the same period (i.e., some years may have had longer, harsher winters). Note in Figure 23 that the frequency of ice-related accidents is negligible in May, June, July, August, and September. Ice-related accident frequency dramatically increases in November, peaks in December, and gradually declines in January, February, and March. Colder temperatures during these months result in a greater propensity for ice formation on the roadway surface. Friday, Saturday, Sunday, and Monday experience the highest frequency of ice-related accidents (see Figure 24). Recreational travel—during which motorists may be unfamiliar with local conditions, driving on more rural routes, or crossing a mountain pass—is likely highest on these days. Figure 25 depicts ice-related accidents by time of day. Note the obvious peak in ice-related accident frequency between 6AM and 9AM. The combination of high traffic volumes and lower temperatures likely increase accident frequencies during this time period.

Environmental Characteristics

Surprisingly few ice-related accidents occurred during dawn and dusk (see Figure 26). At these times, temperatures are typically low, lighting conditions are not optimal, and traffic volumes are lighter (i.e., uncongested conditions allow for higher travel speeds, and a vehicle may not be warned of danger by other slowing vehicles). Instead, the majority of ice-related accidents occurred during daylight hours. Also surprising, most ice-related accidents occrured when weather conditions were dry rather than snowy or icy (see Figure 27).

Locational Characteristics

Most ice-related accidents occurred in rural rather than urban areas and along level or graded, straight or curved sections of the roadway (see Figures 28 and 29). These statistics may reflect the higher proportion of roadway mileage in rural areas with level or graded characteristics, rather than a higher likelihood of an ice-related accident occurring in these

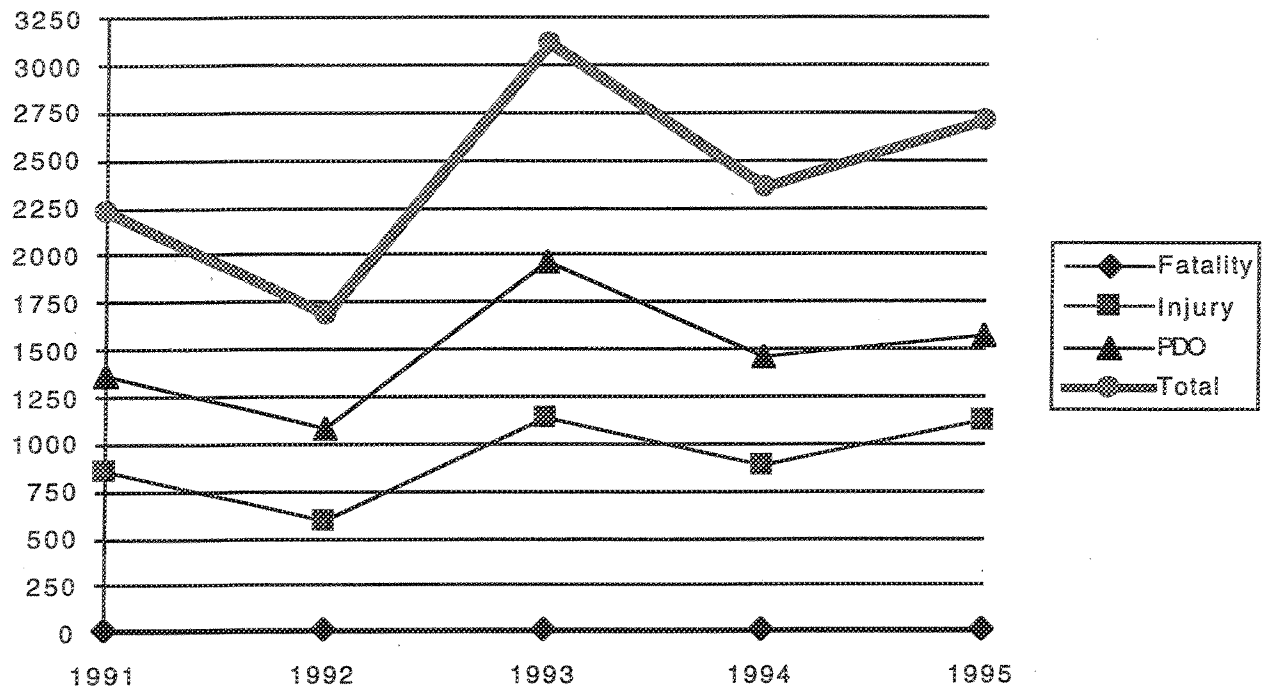


Figure 22. Ice-Related Accidents by Year

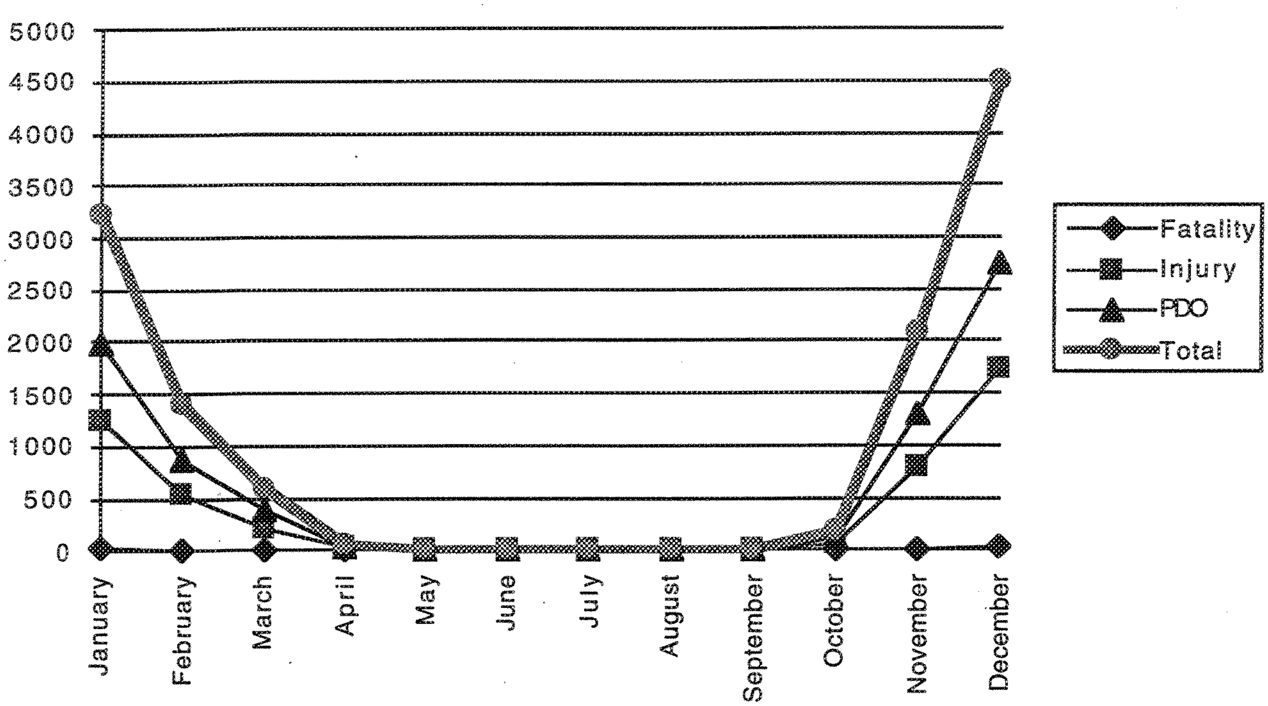


Figure 23. Ice-Related Accidents by Month

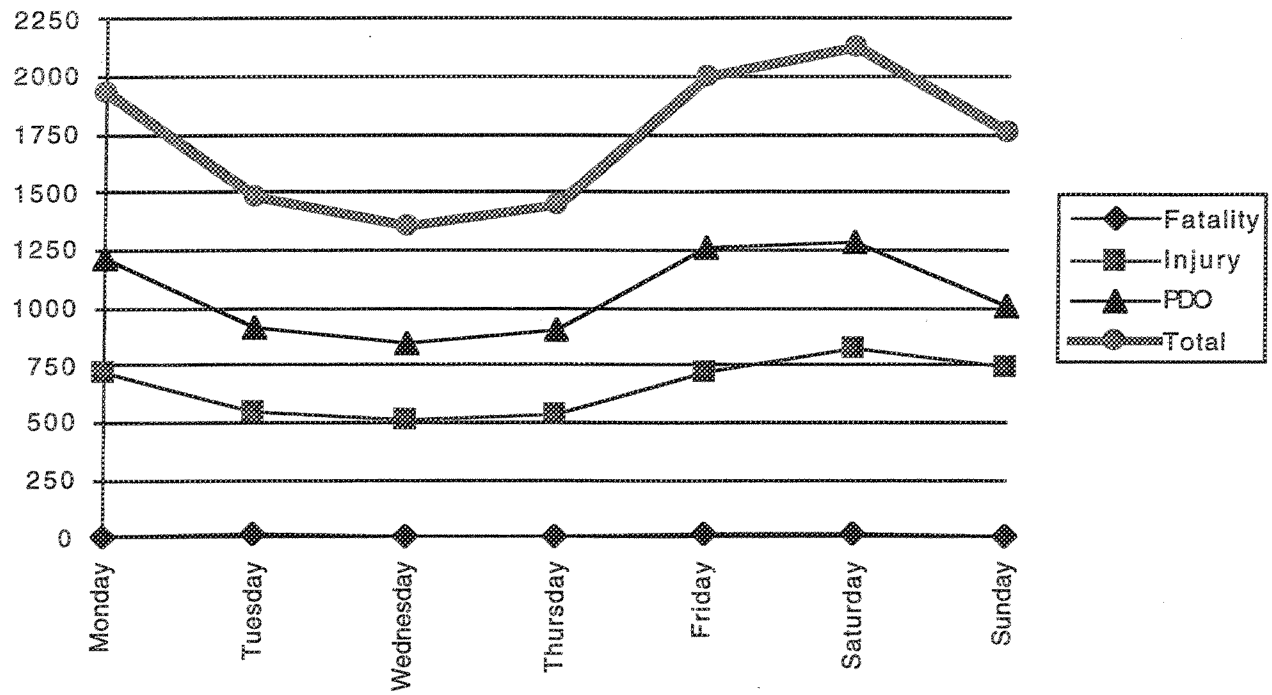


Figure 24. Ice-Related Accidents by Day of Week

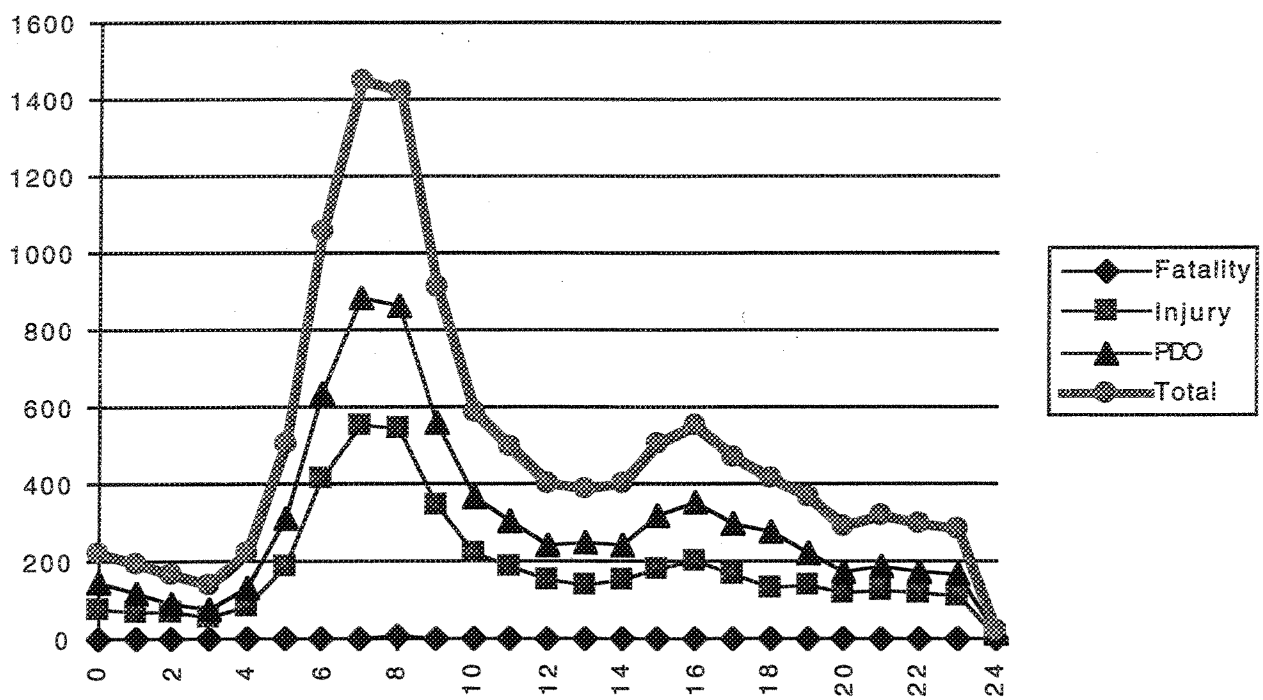


Figure 25. Ice-Related Accidents by Time of Day

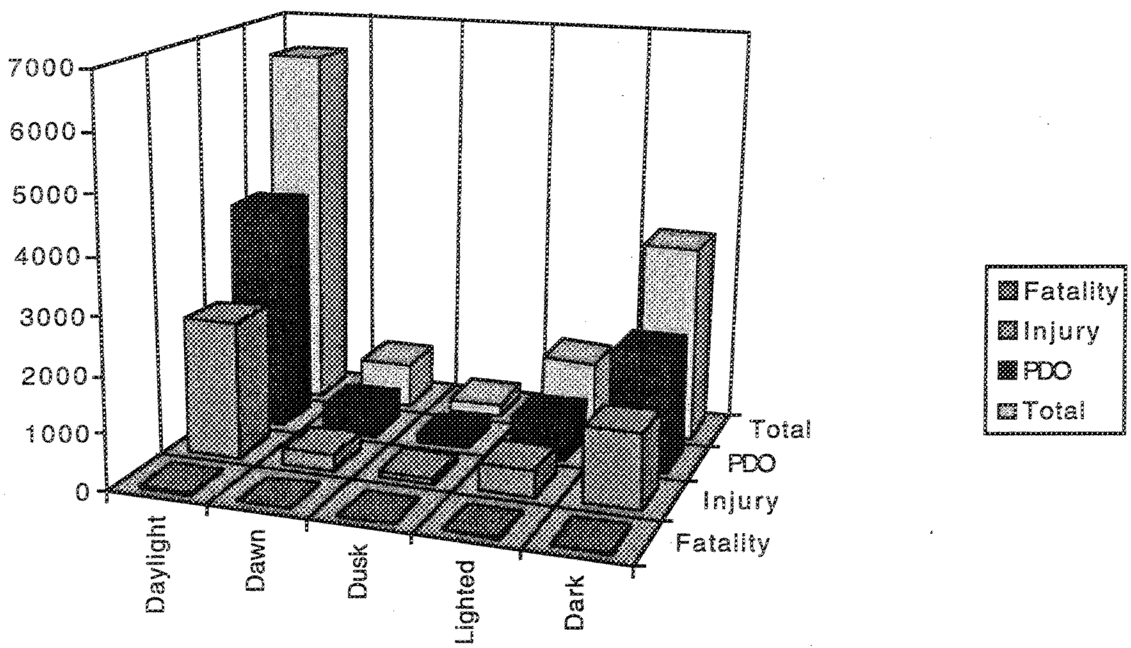


Figure 26. Ice-Related Accidents by Light Conditions

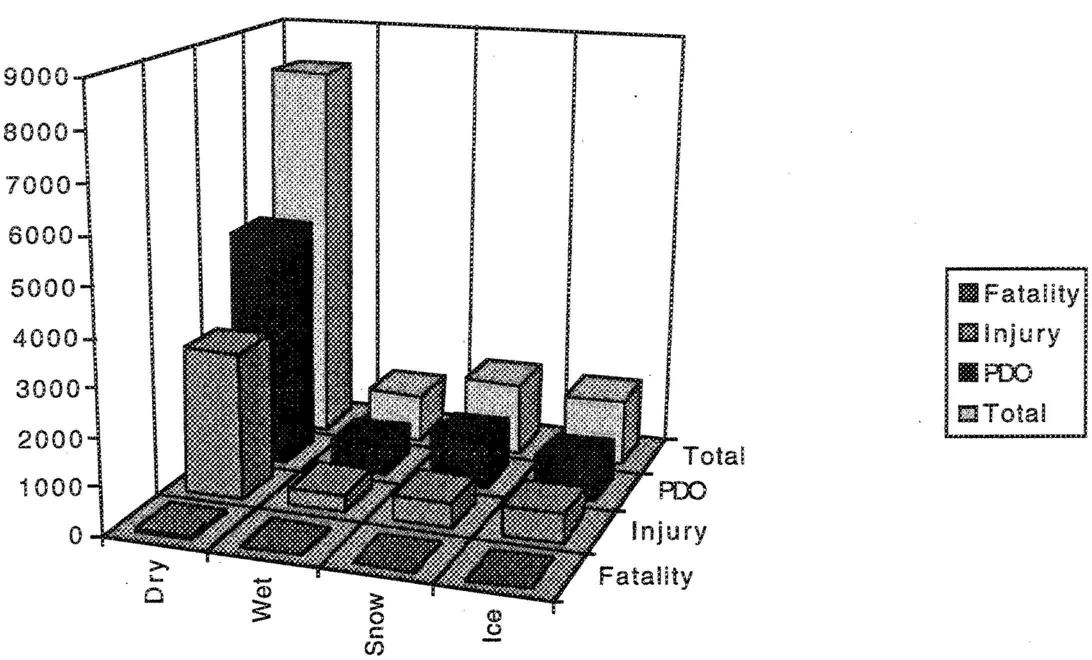


Figure 27. Ice-Related Accidents by Weather Conditions

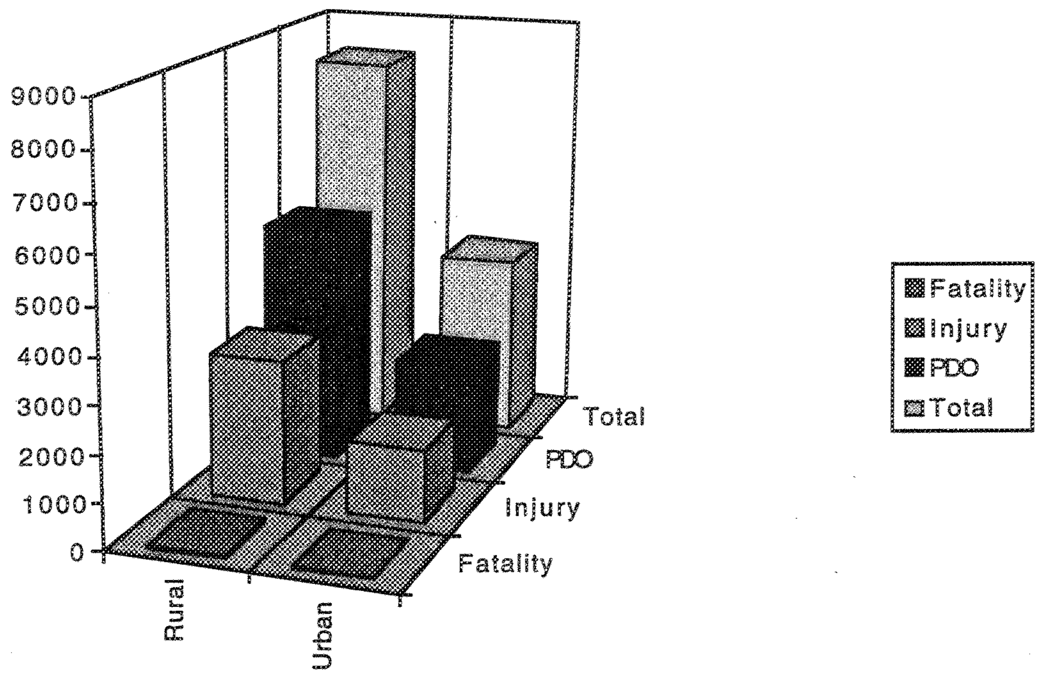


Figure 28. Ice-Related Accidents by Rural/Urban

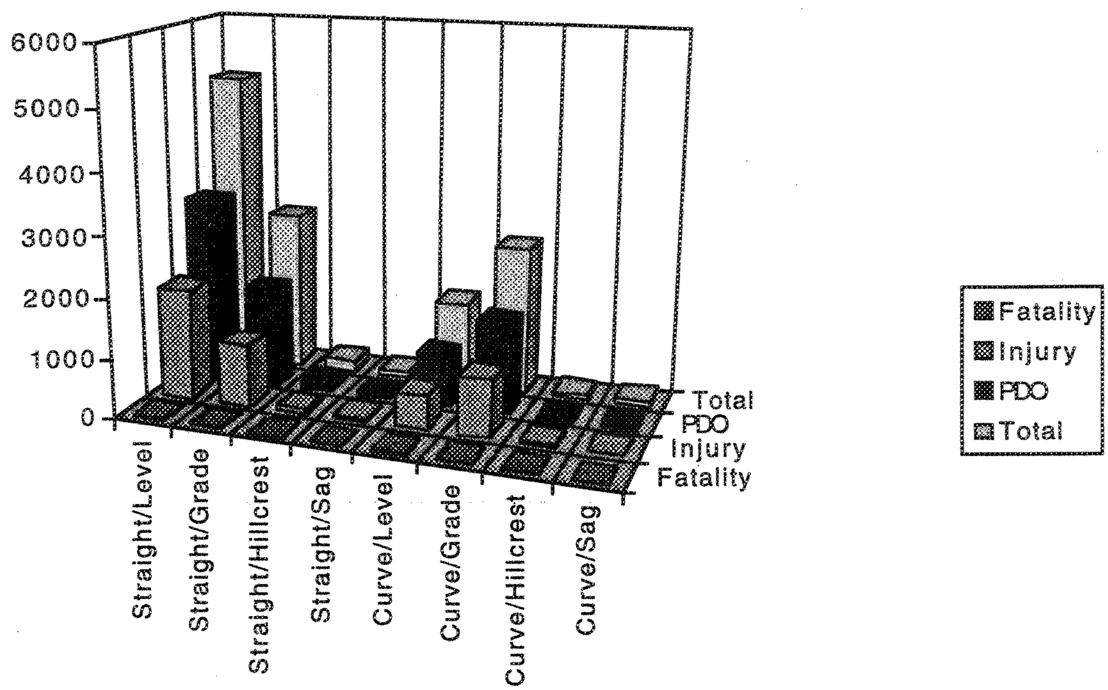


Figure 29. Ice-Related Accidents by Roadway Characteristic

areas. Similarly deceptive, the data show that few ice-related accidents occurred at intersections or driveways, bridges or overpasses, underpasses or tunnels, and rest areas or weigh stations (see Figure 30). If the data are normalized to reflect the proportion of roadway mileage covered by these features, the data may indicate an abnormally high number of ice-related accidents occurring at these locations.

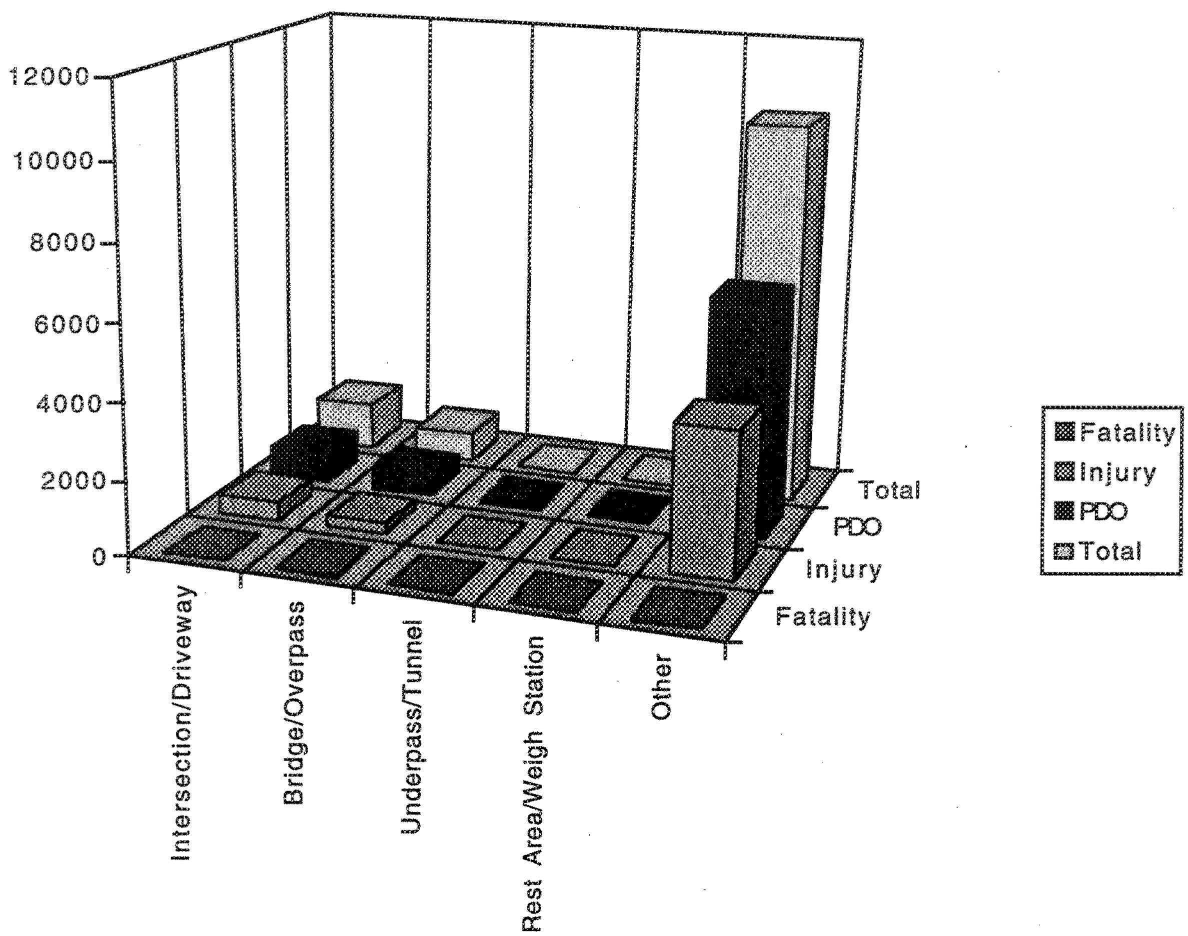


Figure 30. Ice-Related Accidents by Roadway Feature

Vehicle and Driver Characteristics

Figure 31 depicts the various vehicle types involved in ice-related accidents. Most involved passenger cars, pickups, light trucks, or vans. Again, these statistics likely reflect the higher proportion of these vehicles in the traffic stream. Surprisingly, pickups, light trucks, and vans had a higher occurrence of ice-related accidents than passenger cars. Many of these vehicles may be equipped with four-wheel drive, and vehicle drivers may be overconfident in their vehicles' ability to maintain control in icy conditions. Drivers between the ages of 16 and 30 had the highest frequency of ice-related accident involvement, likely because of their more limited driving experience. As driver age increases, their frequency of ice-related accident involvement gradually decreases (see Figure 32).

ICE WARNING SIGNS AND ICE-RELATED ACCIDENTS

To explore the relationship between ice-related accidents and the placement of ice warning signs, Spearman rank-correlation methods were used. Because the ice-related accident characteristics of interest, namely accident frequency and severity, are ordinal rather than continuous, use of the Spearman rank-correlation coefficient ensured that significant tests would be valid (Rosner 1994).

Three sample routes were considered in this analysis: SR 2, SR 82, and SR 395. Tables 20 and 21 summarize the results of the analysis for accident frequency and severity, respectively. The supposition or hypothesis was that no relationship ($r_s = 0$) existed between either accident frequency or accident severity and ice warning signs. A p-value of greater than 0.05 would support this hypothesis; a p-value of less than 0.05 would contradict this hypothesis. Note in Table 20 that no statistically significant relationship exists between ice-related accident frequency and ice warning signs. A significant relationship between ice-related accident frequency and signs is noted for SR 395, although the correlation is not that strong (i.e., r_s = 0.1863). This inconsistency may be the result of different ice warning sign placement methods. For example, if a high proportion of the maintenance areas responsible for SR 395 place ice

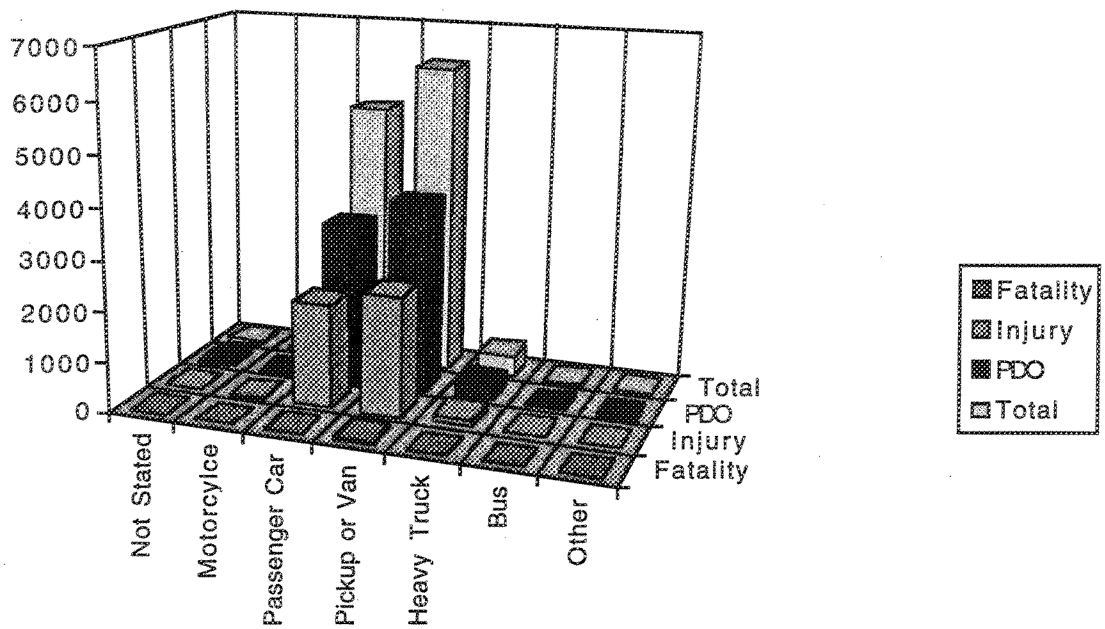


Figure 31. Ice-Related Accidents by Vehicle Type

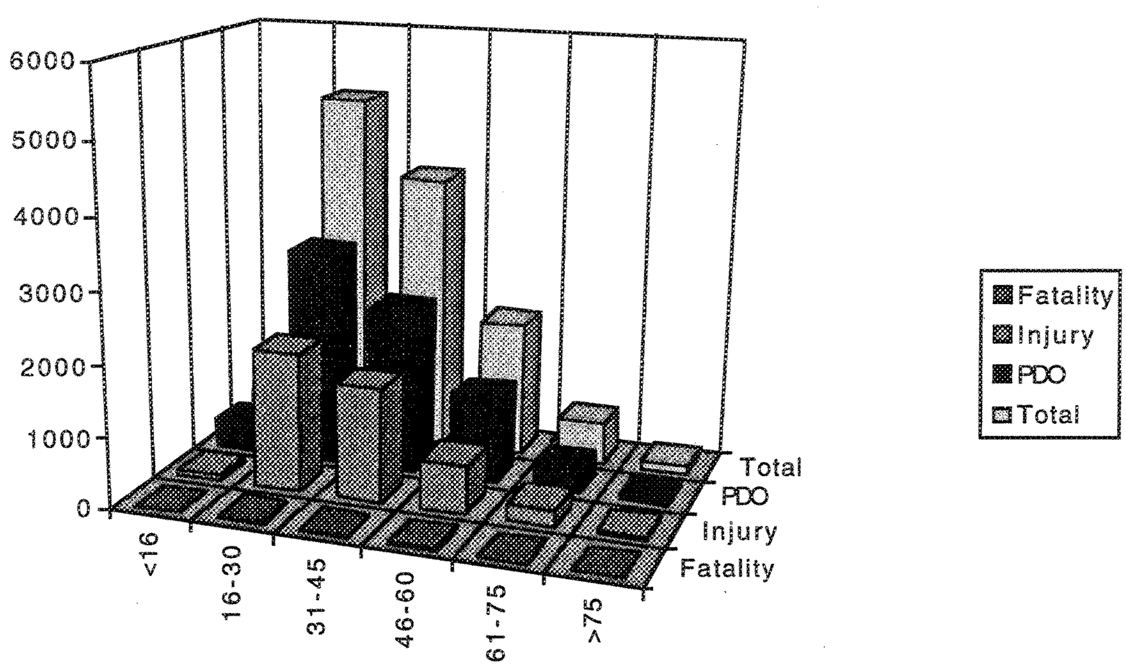


Figure 32. Ice-Related Accidents by Driver Age

Table 20. Correlation Between Ice-Related Accident Frequency and Ice Warning Sign Presence

State Route	Spearman Correlation Coefficient r_s	Sample Size N	Statistical Significance p-value
SR 2	0.0417	335	0.447
SR 82	0.1033	133	0.237
SR 395	0.1863	258	0.003
SR 395 injury/fatality only	0.0944	180	0.208

Table 21. Correlation Between Ice-Related Accident Severity and Ice Warning Sign Presence

State Route	Spearman Correlation Coefficient r_s	Sample Size N	Statistical Significance p-value
SR 2	-0.0740	436	0.123
SR 82	-0.0353	366	0.501
SR 395	0.1028	134	0.237

warning signs in response to trouble spots, the correlation between ice-related accidents and ice warning signs will obviously be higher. When ice-related accidents involving property damage only are ignored along SR 395, the relationship between ice-related accident frequency and ice warning signs is not significant. None of the state routes showed a significant relationship between ice-related accident severity and ice warning signs, although the discrepancy among SR 395, SR 2, and SR 82 is interesting to note. Data from SR 2 and SR 82 showed a negative correlation between ice-related accident severity and ice warning signs, whereas data from SR 395 showed a positive correlation.

This cursory examination of the relationship between ice-related accident frequency and severity and ice warning signs does not appear to indicate that ice warning signs prevent the occurrence of or reduce the severity levels of ice-related accidents. It is difficult to determine whether the fault lies in the sign placement practices or in inappropriate driver reaction (i.e., not deceleration).

To ensure effective ice warning sign placement on the basis of historical accident data, a series of maps are provided in the Appendix. These maps depict historical injury and fatality ice-related accidents as well as ice warning sign locations (determined from a combination of the sign inventory/log and maintenance personnel). Two unidirectional maps were drawn per maintenance area for a total of 48 maps (i.e., one map depicts accidents and signs northbound and eastbound, the other map depicts accidents and signs southbound and westbound). These maps should clearly identify the following:

- existing ice-related trouble spots that are already signed with an ice warning sign
- existing ice-related trouble spots that are in need of an ice warning sign
- ice warning signs whose placement should be reconsidered (either they were placed at a standard junction or boundary or they are acting successfully as a warning device).

LIABILITY REVIEW

Supplementary to the accident analysis, a review of liability issues related to ice warning signs was conducted. Within Washington, this search was conducted by the Attorney General's Office. A representative from the Attorney General's Office reported finding no cases of liability involving the Washington State Department of Transportation and an ice-related accident.

While no cases have been reported in Washington, ice-related liability problems have arisen in other states. Recall that there are two primary ways of protecting the state from ice-related accident liability:

(1) implement weather immunity statutes

(2) prove that signs were placed in a reasonable and systematic manner and that no prior knowledge of the danger existed.

Ice warning signs placed at standard locations (i.e., entrances to state routes, maintenance area boundaries, etc.) will likely not protect against liability unless an accident coincidentally occurs at one of these standard locations. Instead, ice warning sign placement methods that offer the most promise for liability protection include

- ice warning signs placed at bridges or overpasses because it is well known that these locations have a higher ice-related accident risk
- ice warning signs placed at locations with a high incidence of ice-related accidents
- ice warning signs placed in response to a motorist request.

In each of these three cases, it can easily be shown that WSDOT had or should have had prior knowledge of the ice-related hazard. If no action is taken to warn the public of the hazard within a reasonable amount of time, WSDOT can be found negligent in fulfilling its "duty of care" commitment and may be liable for resulting damages.

SUMMARY

This chapter explored the safety- and liability-related aspects of ice warning signs. Below are some of the more important findings.

- Of the routes considered, no relationship was found to exist between ice-related accident frequency and ice warning signs with the exception of SR 395. However, when only injury and fatality accidents along SR 395 were considered, no relationship was found to exist between ice-related accident frequency and ice warning signs.
- Of the routes considered, no relationship was found to exist between ice-related accident severity and ice warning signs.
- No liability problems related to ice warning signs were found to have come up in Washington to date.
- To protect from future liability problems, ice warning signs should be placed at bridges and overpasses, at locations with a high incidence of ice-related accidents, and in response to motorist requests. Ice warning sign removal at standard locations should be considered.

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

This effort resulted in

- insight into the effectiveness of current ice warning sign placement practices based on other state practices, ice-related accident locations and frequencies, and public attitudes toward the warning signs
- insight into driver behavior related to ice warning signs based on public response and observed driver behavior
- possible recommendations for ice-related accident "trouble spots" not currently signed.

Key findings are summarized below.

NATIONAL REVIEW

A survey of other states' ice warning sign practices and a review of the literature produced some interesting findings.

- Little consistency exists among and within states regarding ice warning sign usage, numbers, placement practices, erection and removal mechanisms and time frames, features, and messages.
- Findings reported in the literature related to public attitudes and responsiveness were conflicting. Ice warning signs were reported to have a statistically significant effect on traffic speeds, lane change activity, and braking activity (under certain conditions), yet few drivers recalled seeing a sign.
- No literature was found that investigated increased levels of safety attributable to ice warning signs.
- Ice warning signs do appear to provide some protection against liability as long as transportation departments continue to fulfill their "duty of care" responsibilities.

The lack of consistency in ice warning sign practices within and among states is likely a direct result of the lack of consistent and substantive findings in the literature, which leaves traffic and maintenance personnel with little evidence to support their decisions.

CURRENT PRACTICES IN WASHINGTON

Similar to those noted at a national level among states, ice warning sign-related inconsistencies were noted within Washington state among maintenance areas. Most inconsistencies involve sign placement practices (i.e., general coverage, site-specific coverage, or a combination of both) and consequently, the number of signs used in each maintenance area. Maintenance areas are relatively consistent in their

- usage of ice warning signs (only the Walla Walla maintenance area does not use ice warning signs)
- erection/removal times (typically erected from fall to spring)
- sign messages (WATCH FOR ICE).

The examination of ice warning sign practices in Washington was complicated because of inaccuracies in WSDOT's sign inventories/logs. In some cases, the number of signs reported by maintenance personnel and the number of signs reported in the sign inventories/logs differed by a factor of four.

PUBLIC ATTITUDES AND RESPONSIVENESS

Responses to many of the survey questions were very similar among the six zones in spite of differing climatic and geographic conditions.

- The majority of motorists reported always slowing down and exercising caution when they see an ice warning sign. This conflicts with the historical speed analysis, which found that ice warning signs had no significant effect on vehicle speeds.
- Nearly consistently statewide, 19 percent of respondents reported ever having been involved in an ice-related accident.
- A relatively small proportion of ice-related accidents occurred on bridges or overpasses, many reportedly occurred at known troublespots, mountain passes, or shaded areas.
- When considering who is at fault, the majority of motorists feel that the driver involved is at fault. However, the second highest majority of respondents indicated that the roadway maintenance department is at fault. This is alarming from a liability standpoint; suits are rarely raised against individuals because of the low potential for monetary payout. The roadway maintenance department would thus be the first party considered in a potential liability suit.
- The majority of respondents feel that ice warning signs are either very or somewhat effective at improving safety and preventing accidents.
- An overwhelming majority of respondents feel that the use of ice warning signs should be increased.

- In spite of self-reported behavior, no significant change in travel speed was observed when motorists encountered a WATCH FOR ICE sign.

SAFETY AND LIABILITY

This chapter explored the safety- and liability-related aspects of ice warning signs.

- Of the routes considered, no relationship was found to exist between ice-related accident frequency and ice warning signs, with the exception of SR 395. However, when only injury and fatality accidents along SR 395 were considered, no relationship was found to exist between ice-related accident frequency and ice warning signs.
- Of the routes considered, no relationship was found to exist between ice-related accident severity and ice warning signs.
- No liability problems related to ice warning signs have arisen in Washington to date.
- To protect from future liability problems, ice warning signs should be placed at bridges and overpasses, at locations with a high incidence of ice-related accidents, and in response to motorist requests. Ice warning sign removal at standard locations should be considered.

RECOMMENDATIONS

On the basis of positive public support for ice warning signs, WSDOT's perceived liability in the event of an ice-related accident, and the terms required to escape or minimize liability damages (i.e., proof of a reasonable and systematic process for placing signs), the continued use of ice warning signs is recommended. However, signs should be placed not at standard, sometimes irrelevant locations but rather at high-risk areas (e.g., at bridges or locations identified by motorists) or at locations with a history of ice related accidents. Accident history maps are provided in the Appendix to assist in ice warning sign placement.

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