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Implementation and Evaluation of the Sacramento Regional Transportation Management Center Weather Alert Notification System

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This report presents the results of an evaluation of Caltrans District 3 Regional Transportation Management Center's (RTMC) implementation of a weather alert notification system. This alert system was selected for implementation from among several weather information integration strategies identified by the RTMC through a self-evaluation process supported by the FHWA Road Weather Management Program. The weather types of particular interest to RTMC operations are fog, wind and frost. These weather conditions have potential consequences for the operation of their transportation system and the safety of the traveling public. The RTMC desired to more effectively and proactively manage their system and keep their traveling public well informed when faced with these weather conditions. They implemented a system that automatically generates adverse weather warnings and alerts to the RTMC operators to help them make more timely and effective decisions regarding posting advisory messages to the public on electronic roadside message signs. Quantitative and qualitative data were collected to support evaluation measures in both the baseline and post-deployment periods. The evaluation focused on several significant weather events (fog, wind and frost), documenting the alerts, the progress of the event, and operator messaging responses to the event. It identified a need for operator training and for clear procedures to guide the use of the alert system, and these improvements were implemented on an on-going basis during the course of the evaluation over the 2009-2010 winter period. Management intends to fine tune their alert system, including adding additional sensors when their budgets will allow that, based on the evaluation findings, to further enhance the alert system's effectiveness.</td></tr>
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List of Acronyms

ASCII	American Standard Code for Information Interchange
CAD	Computer Aided Dispatch
CCTV	Closed Circuit Television
CHIN	California Highway Information Network
CHIRP	Caltrans Highway Internet Reporting Program
CHP	California Highway Patrol
CMS	Changeable Message Sign
CT	Caltrans
DMS	Dynamic Message Sign
DRI	Caltrans Division of Research and Innovation
EB	East Bound
EMS	Extinguishable Message Sign
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
FOT	Field Operational Test
FSP	Freeway Service Patrols
HAR	Highway Advisory Radio
LED	Light Emitting Diode
MPH	Miles per Hour
N/A	Not Available
NB	North Bound
NWS	National Weather Service
Postmile	Distance a route travels through individual counties in California
RTMC	Regional Transportation Management Center
RWIS	Road Weather Information System
RWMP	Road Weather Management Program
SAC	Sacramento
SB	South Bound
SHOPP	State Highway Operation and Protection Program
TMC	Transportation Management Center
TMT	Traffic Management Teams
USDOT	U.S. Department of Transportation
VMS	Variable Message Sign
WB	West Bound
Wx	Weather

Executive Summary

Background

The Caltrans District 3 Regional Transportation Management Center (RTMC) has been participating for the past three years in a U.S. Department of Transportation (USDOT) Federal Highway Administration (FHWA) sponsored study to identify strategies to enhance TMC weather integration in support of operations, to implement selected strategies, and to participate in an evaluation of the results of their strategy implementation. The RTMC has followed a FHWA TMC Weather Integration Self-Evaluation and Planning process and prepared a weather integration plan. The intent of this project is to integrate road-weather information into the RTMC operational advisory functions by implementing an automated weather alert notification system. This system is expected to provide timely traveler and road weather information to the public, particularly regarding fog, wind and frost conditions that can severely affect travel safety and mobility. This report describes a weather alert notification system implemented by the RTMC, describes the steps taken to implement that system, and evaluates the results and benefits achieved to date. Lessons are identified that may be helpful in the future to Caltrans and other TMCs throughout the country.

Alert Notification System Implementation Objectives

In order to enhance their operational performance, particularly during severe winter weather events in the Sacramento Valley, the RTMC implemented a series of activities in 2009 to achieve the following five main objectives:

1. Improved coordination of operator response and decision making regarding the posting of traveler advisories during severe weather conditions;

2. Enhanced weather information coming into the RTMC;

3. Implementation of an automated alert notification system that would improve operational awareness of, and response to, severe weather;

4. Refined operational procedures to guide efficient and appropriate operator response to weather conditions; and,

5. Development and implementation of a training program to enhance awareness and strengthen the capability of operators to proactively use weather information, weather warnings and alerts in RTMC operations and in posting and removing advisory messages.

Evaluation Approach

Quantitative and qualitative data were collected to support evaluation measures in both the baseline (“before”) and post-deployment (“after”) periods. The quantitative data included weather condition readings from a set of RWIS sensors, records of warnings and alerts issued before and during weather events, information on messages posted on electronic signs in the valley, and operator entries in the Computer Aided Dispatch (CAD) TMC logs. The qualitative data were obtained through interviews with operators and managers of the RTMC, and they included observations and perceptions of changes and benefits being derived from the implementation of the weather alert notification system, and also institutional and organizational benefits received as a result of using this system. Data were collected throughout the baseline period of the implementation, and again after the strategies had been implemented and were operational for a period of time.

The evaluation focused on a few significant weather events during which the alert notification system was active. These events were analyzed in detail to understand how well the warnings and alerts tracked the actual weather conditions and how well the operators were able to use those warnings and alerts in supporting their decisions to post messages for the public. The evaluation also addressed the institutional process by which management sought to implement the system, make adjustments based on their real-time experiences with the system, and incorporate feedback from the operators.

The evaluation analysis compared outcomes between the “before” and “after” periods as bases for identifying changes and benefits that could be attributed to the new integration strategies. Lessons learned were derived from the total implementation experience for the benefit of Caltrans and other TMCs that are considering enhancing their own level of weather integration.

Alert System Implementation Tasks

The RTMC management committed to implement the weather alert notification system through a series of tasks to be carried out between May and December of 2009, as follows:

1. Identify and assign an RTMC weather coordinator.
2. Identify weather information sources (observations and forecasts) and determine what is needed in addition to sources already available and access by the RTMC.
3. Properly calibrate and maintain Caltrans-owned road weather observation sensor sites.
4. Identify, procure and install additional weather observation systems.
5. Define alert mechanisms and thresholds, procedures, and timing.
6. Implement the weather alert notification system.
7. Define and implement a training program for operators and others.

Responsibilities were assigned, a schedule was established, and by December 2009 automated weather warnings and alerts were being delivered to operators 24/7 in the RTMC.

Baseline Conditions and Challenges

The information collected during the baseline evaluation period identified shortcomings and needs that are closely aligned with the selection of weather integration strategies the RTMC intended to pursue and the tasks identified in their Implementation Plan. Table ES-1 below summarizes the primary baseline condition findings and corresponding implementation plan tasks that address the issues.

Table ES-1. Summary of Baseline Conditions and the Relationship to Implementation Plan Tasks

Baseline Conditions and Challenges	Implementation Tasks
1. General lack of focused and coordinated use of weather information.	Task 1: Identify and assign a RTMC weather coordinator.
2. RWIS sensors inaccurate and unreliable. No confidence in sensor data.	Task 3: Properly maintain/calibrate Caltrans RWIS data stations.
3. Lack of knowledge of all possible weather information sources that could be used to identify or confirm weather events.	Task 2: Identify weather information sources (observations and forecasts) available or accessible.
4. Lack of coverage of sensor data, mostly in areas that experience dense fog.	Task 4: Identify, procure, and install additional weather observation systems.
5. Too much dependency on field personnel to determine when a weather event begins and ends – their input is not always accurate or timely.	Task 5: Define alert mechanisms, thresholds, and procedures. Task 6: Implement weather alert system.
6. Lack of procedures or guidance regarding operations during inclement weather events.	Task 5: Define alert mechanisms, thresholds, and procedures.
7. Inconsistent response by the various RTMC operators during weather events.	Task 7: Define and implement training program.
8. Difficult to know when a weather event is beginning.	Task 6: Implement weather alert system.
9. Difficult to know when a weather event has ended.	Task 6: Implement weather alert system. (Note: future enhancements to the alert system are planned to address the issue of when events end.)
10. Significant delays between when an event begins and when signs are activated.	All Tasks: Implementation of a weather alert system, operator training, and consistent use of operational procedures.

Alert Notification System Implementation

The RTMC management decided to build their automated alert notification system by activating a feature of the SCAN Web[1] system (called SCAN Sentry) that issues email alerts when certain conditions (weather data thresholds) are met. This approach is limited to the six RWIS station locations in the Sacramento Valley and was selected as the easiest and least costly way to get an alert system up and running. The RTMC management saw this as a way to test and demonstrate how an alert system might help the operators, with the thought that it could be expanded in the future if it proved successful. The results of this evaluation will help the RTMC management decide if an expanded alert system is required to continue improving weather responsive operations.

[1] SCAN Web® is a registered trade mark of Surface Systems, Inc.

The following is a summary of how the implemented alert system is currently working:

1. Weather data from the six RWIS stations identified in Task 2 are posted every 10 minutes to the SCAN Web database. This includes all sensor data available at each location.
2. The SCAN Sentry system (software routine with access to the SCAN Web database) compares the weather measurements to the established warnings and alerts. The warnings and alerts identified above were incorporated in the SCAN Sentry system by RTMC management.
3. When the warning or alert conditions are met based on established thresholds, an email is sent to RTMC management and operators.
4. The SCAN Sentry system allows the manager to limit the number of alerts issued if the conditions persist. The maximum time (suspend time) between alerts is 3 hours. If a wind event continues to exceed (or repeatedly fluctuates through) the threshold for several hours, or even days, the operator will continue to receive alerts every 3 hours (but, not every 10 minutes).
5. The SCAN Sentry system does not have the capability of issuing an alert when the thresholds are no longer met, or not met for a given period of time, so operators are not alerted when weather conditions drop below thresholds. This is a limitation that the RTMC management would like to rectify with a new alert system in the future (second approach above).

The SCAN Sentry alert system was activated in the fall of 2009 and began issuing warnings and alerts based on the established weather data thresholds.

Alert Notification System Performance

Four significant fog and wind events that occurred between December 2009 and April 2010 were selected for a careful assessment, as case studies, of the performance of the weather alert notification system. These included:

1. A fog event that occurred December 17-18, 2009. While fog persisted throughout the valley over these two days, visibility conditions actually dropped below the indicated threshold in two distinct periods such that, for the purposes of assessing messaging performance, this can be interpreted as two separate fog events over this period of time.

2. A particularly severe and persistent wind event that occurred January 17-21, 2010, resulting in 176 alerts being issued.

3. A wind event that occurred March 12-13, 2010.

4. A wind event that occurred April 27-28, 2010.

Each event was evaluated with regard to 1) the timing and duration of the event, trends in the weather measure (sight distance for fog, average sustained speed and gust speed for wind, and temperature for frost) and when those measures crossed their pre-defined threshold, 2) the timing of issuance of automatically generated warnings and alerts that were received by RTMC operators via email, and 3) the timing of traveler advisory message activation and deactivation by the operators during the event. In assessing the RTMC operator responses to these weather events, several indicators were considered:

- Were the warnings and alerts issued appropriately and according to the designated thresholds?
- To what extent was the event covered by messaging to the public?
- Were the appropriate message signs activated based on receipt of alerts and readings from the various sensor sites?
- Were signs deactivated in an appropriate and reasonably timely way?
- Did the operators record information about the event and their decisions in the TMC log?

Follow-up interviews were conducted with four of the RTMC operators in June 2010 after they had experience with the weather alert notification system. The purpose of these interviews was to learn how the alert system has been working from the operators' perspective. Some of the same questions were addressed for these interviews as had been covered in the baseline interviews conducted a year earlier. Operators in the follow-up interviews were asked to describe how they used the new alert system and whether it was helpful to them in improving the efficiency of their messaging decisions. The new procedures were discussed along with the factors operators consider when making advisory decisions. The analyses of some of the weather events from this evaluation were shared with the operators.

Evaluation Findings and Lessons Learned

The evaluation of the Sacramento RTMC weather alert notification system examined several adverse weather events in some detail in order to assess quantitatively how the alert system was performing and how the operators were able to use it in supporting their operational decisions regarding posting of advisory messages. The quantitative analysis focused primarily on the post-implementation data obtained from the RWIS sensors, the alert system records, and message sign records. Qualitative findings are based on interviews with selected operators before and after the implementation of the alert notification system.

The quantitative findings include the following:

- **Timeliness of Alerts**. Alerts should be issued to coincide with the start of an event, when conditions exceed the defined threshold. Across the four event periods analyzed, alerts were issued for the most part in a timely and accurate way; that is, 16 out of 18 times (for individual RWIS sensors) they were issued within +/- an average of 10 minutes of the time when the weather condition broke its defined threshold value at the beginning of the event. This is virtually right on time, given measurement error. **Interpretation:** The alerts were mostly well timed, indicating the alert notification system was working as planned.
- **Timeliness of Message Activation.** The RTMC aims to have messages posted on appropriate message signs for the duration of a weather event that exceeds the defined threshold. Fifteen individual sensor-reported weather events that exceeded threshold

and/or lasted longer than 16 minutes should properly have had weather warning messages posted throughout those events; 13 of them did and two had no messages posted. For those event segments with some message coverage, coverage ranged between 27% and 100% of the duration of the event. Out of the 13 events with message coverage, 11 had coverage over 75% of the duration of the event. **Interpretation:** Messaging coverage was generally good but not complete. However, coverage improved over the duration of the evaluation from December 2009 to April 2010, suggesting that the alerts were helping operators post messages more appropriately.

- **Adequacy of Messaging Coverage.** Another dimension of messaging adequacy is related to the posting of messages triggered by sensor alerts on the primary signs near the sensor site. As discussed in this report, there are a number of mitigating circumstances that might reasonably prevent posting weather messages on some of these signs. For example, during road emergencies the signs may be needed for traveler alerts, and during mountain snow events, some valley signs may be used for chain control advisories. Nevertheless, across all these case study events, the number of CMS, EMS and LED signs used was significantly less than the number of signs recommended in the RTMC policy guidelines. For the December fog event, out of 8 opportunities to activate primary signs for significant events, only 2 were used, along with 2 out of 8 secondary signs. For the three wind events taken together, out of 43 opportunities to activate the primary signs for significant events, 12 were used (28%). However, the ratio of messaging on primary signs improved over time, with 7 out of 17 (41%) used in the April wind event. **Interpretation:** A low number of primary message signs had messages posted during the weather event case studies examined, but coverage improved over the course of the evaluation period, presumably due to the operators' increasing familiarity with and understanding of the new procedures.

- **Timeliness of Message Deactivation.** Once a message has been posted advising the traveling public about an existing severe weather condition (e.g., dense fog, high winds, frost on road), the operators need to periodically monitor conditions. They need to remove the message after the weather condition has abated and it is reasonable to assume it is not about to return to threshold conditions soon. This is a judgment call, as the alert notification system does not provide explicit guidance regarding when a weather event is over. The alert notification system will continue to provide warnings and alerts in three hours or longer intervals as long as the weather conditions persist, which is helpful to the operators in maintaining their awareness of the status of these conditions. It is considered prudent to leave a message active for a while as conditions are improving in order to avoid frequently activating and deactivating messages. On the other hand, leaving a weather warning message posted long after the event is over may lead to a loss of public trust in the messages. The RTMC management is considering how their alert notification system might be able to issue an "all clear" signal based either on the length of time that passes after last crossing the threshold with an improving trend or the time when conditions reach a designated level after last crossing the threshold.

  For 14 sensor-covered event segments for which messages were activated among the four case studies, the period from the end of the event to message deactivation ranged from 18 minutes to 8 hours and 44 minutes. This extended period of message activation equaled an average lag time of 4 hours and 14 minutes. This is the average period of time during which a message was posted on a roadside message sign indicating an adverse weather condition after that condition no longer exceeded the defined threshold. Without knowing the detailed circumstances associated with each of these events, it is not appropriate to make a definitive judgment about them. For example, operators often rely on CHP in the field to verify conditions for activating messages, but after the weather has improved, CHP is usually no longer available at those locations to advise the operators to deactivate the message. **Interpretation:** While the RTMC has not specified an appropriate amount of time to leave a message actively displaying an advisory about weather that has since subsided, nor implemented alerts to signal that time for the operators, the experience with many of these sensor-covered event segments shows there were a number of periods during which messages were left active much longer than needed or desired.

Findings from the qualitative interviews conducted in the baseline and post-alert periods included the following:

- In the baseline period the operators reported they would like to have more frequent weather updates. They also said they lacked adequate weather readings for some important locations in the valley.
- In both the before and after periods, operators expressed less than high confidence in the quality and accuracy of the weather data they were receiving in the RTMC. They uniformly said it was critical to confirm either data from sensors with human observations or readings from other sensors, or human observations with sensor readings. This follows management guidance that all weather data be verified with one or more additional sources before making a decision to post a travel advisory message. They did, however, perceive that sensor data quality had improved over this period.
- Operators in both periods felt that operating procedures and guidelines for making decisions based on reported weather conditions were less than adequate. Some said they desired additional training and consistent information on how to respond to the weather data (observations and forecasts) that they receive in the RTMC. Other experienced operators felt they knew how best to perform their job responsibilities without need for additional management oversight.
- RTMC operators want to be proactive with regard to weather. They want to be aware of impending weather conditions likely to affect traffic in advance if possible so that they are well prepared to respond in an appropriate and timely way. However, they feel that in practice they tend to primarily be reactive to weather, and as long as they receive the information they need in a clear and timely way, they respond appropriately.
- In the baseline period the operations floor was staffed most of the time with two operators who then could share the workload. In the later period after furloughs and staff reductions, there was typically only one operator. This meant responses to weather events had to take second priority to higher priority safety matters, and there would be response delays due to very busy shift activity.
- The operators valued the warnings and alerts that were available to them in the post-implementation period, though they felt it necessary to verify their accuracy before taking

any actions based on them. They said the automated alert system has made them more aware and allowed them to be more responsive to events as they unfold.

Several lessons can be drawn from this evaluation of the experience of the Caltrans District 3 RTMC and their efforts to establish and refine an automated weather alert notification system. What has been learned, and continues to be learned, as this system matures and becomes more a part of the operating procedures of the RTMC, can be helpful to both Caltrans and other TMCs across the country as they explore ways they can integrate weather information into their operations. These lessons include the following:

- **Operator training is essential for successful weather integration.** Both the RTMC management and the operators recognize the importance of training to help assure a well informed and consistent use of the new weather alert notification system. Providing this training to all the operators as a group has been a challenge in the face of the recent staff reductions and furlough policy enacted by the State of California. The training content should include clear operational policy guidance along with conveying to the operators an understanding of the system upgrades and changes, how and why they have been made, and how these affect the weather information flowing into the RTMC. A challenge is to strike an appropriate balance between the level of specificity in operational guidance for taking action in response to weather, and providing flexibility for the operators to use their experience and judgment in making decisions about their advisory and control actions.
- **Alert notification procedures need to be clearly and consistently specified.** It is important that the thresholds for issuing warnings and alerts that are programmed into the notification system be consistent with the specifications communicated to operators in the written procedures and training content, and that the operators understand and follow these procedures. The Caltrans District 3 procedures call for operators to verify an alert with information from adjacent RWIS sensors, available third party weather services (NWS, AccuWeather, local weather reports, etc.), and/or field observers (typically CHP, sometimes general public calling in). Reconciling differences among these information sources about a particular weather event condition takes experience and judgment on the part of operators. Procedures and training must account for the complexity of operator decision making based on information of varying accuracy, reliability and geographic focus.
- **A successful demonstration of an alert system depends on a well-integrated system.** The Caltrans District 3 system is built off of their existing SCAN Web software that monitors data from RWIS sensors and can be programmed to issue warnings and alerts when pre-defined weather condition thresholds are reached. The success of this system depends on accurate and reliable weather data from the sensors, appropriately defined threshold conditions, clear communications of alerts to the operators, procedures in place that guide operator responses, and operator training and buy-in to assure effective use of the information. The RTMC management has remained flexible and responsive throughout this demonstration period to understanding where their alert notification system could be fine-tuned and improved as they experienced its use under various weather events. This has provided a foundational experience upon which they can consider a more robust alert system for the future that adds features and capabilities that

are not currently available with existing hardware and software. For example, adding new strategically located sensors, upgrading the weather detection capabilities of the sensors, adding better detection and notification of the end of a weather event, adding possible visual and auditory notification in the RTMC, and refining their procedures, are all candidate improvements that have been identified in the course of operating the current system through this weather integration demonstration.

- **Time and resource constraints affect the performance of an alert notification system.** The State of California is experiencing a severe economic downturn that has resulted in reduced staffing and furloughs among TMC management and operators. This has raised the stresses associated with getting the day-to-day work done and made it more difficult to integrate the weather alert notification system into TMC operations. Operators have competing priorities and fewer operators to meet these responsibilities. Management faces similar constraints, resulting is less time to focus on new weather integration initiatives such as the alert notification system. TMC management also is constrained by time consuming procedural requirements of Caltrans associated with the implementation of new projects. These kinds of constraints need to be anticipated and understood when implementing new systems like this and contingency plans developed to overcome the constraints. There were several planned activities that were not accomplished due to funding or time constraints, including installing new RWIS sites and developing a more sophisticated alert system with enhanced capabilities. Based on the progress made to date, the RTMC management intends to improve their alert system as new funding can be secured.

In implementing the weather alert notification system, management developed a good step-by-step implementation plan that has guided them through the process. A critical task early in this process was to engage a contractor to calibrate the RTMC's field sensors. In the baseline period the operators reported having very little confidence in the data they were receiving from the sensors. After sensor recalibration and implementation of the alert notification system, operator confidence improved, though there remained some carryover of the perception that these data were still suspect. Operator training can help overcome such skepticism by explaining clearly what has been done to improve the data quality in the system and providing evidence that shows these improvements.

The use of the TMC logs offers a good example of how operators are learning to work with the alert notification system. The new procedures have emphasized the importance of making log entries that document and explain the actions operators have taken in response to receipt of the alerts, and the operators' logging performance has improved over this period. RTMC management also has made good progress implementing this system and responding in real time to the need for mid-course adjustments, refinement of procedures, and oversight of the operators. The evaluation process has served to identify ways the notification system, and the institutional support for the system, could be refined, and the result of this collaborative interaction with the RTMC is reflected in the benefits being derived from the alert notification system. Ultimately, it is the traveling public that is the beneficiary of these RTMC system innovations in terms of enhanced mobility and safety during periods of inclement weather and dangerous road conditions.

Conclusions and Recommendations

The Sacramento RTMC has experienced a number of benefits from the implementation of their weather alert notification system, and as they are able to make improvements in the system in the future, further benefit can be expected. Two key benefits include:

- Awareness of the important role that weather plays in the operation of the region's traffic systems, from management to the floor operators, has been enhanced throughout the process of evaluating the RTMC's need for greater weather information integration and through the implementation of a basic alert notification system. Enhanced recognition of the need to manage the effects of weather on traffic, to be more proactive in preparing operators and the traveling public to deal safely with weather impacts, and experience integrating a weather warning system into the RTMC operations has created a foundation upon which the RTMC can make effective future improvements.

- Going through a step-by-step process of calibrating sensors, verifying alerts (timeliness and accuracy), instituting revised procedures in support of operational decisions, and becoming increasingly efficient and comfortable managing the system supported by warnings and alerts have increased confidence in decision making throughout the RTMC. It is expected that the traveling public finds the information increasingly useful and trustworthy as well, though that could not be directly assessed within the scope and timing of this evaluation.

Although Caltrans faces difficult economic challenges at this time, the Sacramento RTMC intends to upgrade their alert notification system as their budget and staffing constraints will allow. Recommendations from this evaluation that could help guide such improvements include the following:

- The current alert notification system has been built off an existing system that is not capable of providing the level of performance that is desired. A more refined system is anticipated to have the capability of alerting operators when weather conditions drop below threshold and no longer represent a danger and will encompass enhanced weather information in order to be able to produce more effective alerts.

- Installation of new RWIS ESS in critical weather locations, with enhanced capabilities for detecting fog and wind conditions. Existing and new RWIS will need to be closely monitored to assure they are properly calibrated and functioning appropriately.

- Continued attention to training and oversight of the operators to assure full understanding of the weather alert notification system, adherence to consistent procedures for making decisions under adverse weather conditions, uniform protocols for verifying alerts, and an effective feedback system that supports a process of continuous improvement in operator performance.

1 Introduction and Background

1.1 Project History

The Caltrans District 3 Regional Transportation Management Center (RTMC) has been participating for the past three years in a U.S. Department of Transportation (USDOT) Federal Highway Administration (FHWA) sponsored study to identify strategies to enhance TMC weather integration in support of operations, to implement selected strategies, and to participate in an evaluation of the results of their strategy implementation. The RTMC has followed a FHWA TMC Weather Integration Self-Evaluation and Planning process[2] and prepared a weather integration plan.[3] This report describes the weather alert notification system that has been implemented by the RTMC in the Sacramento Valley region (see map, Figure 1), describes the implementation of that system, and evaluates the results and benefits achieved to date.

Source: Composite map created by authors from two Google maps.

Figure 1. Map of the Sacramento, CA Area

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[2] Guide available from the FHWA Road Weather Management Program website at: *http://www.ops.fhwa.dot.gov/weather/tmctool/registration.htm.*

[3] *Caltrans District 3 Weather Integration Plan*. April 2, 2008. Prepared by Marcus E. Heiman, PE, Office Chief, Transportation Management Center.

Caltrans District 3 covers a large and geographically varied area that experiences a range of weather events from snow and ice in their mountainous areas to fog, frost, and high winds in the low lying valley areas. The Caltrans RTMC in Sacramento operationally focuses on the management of roads and traffic in the valley portion of their district. Winter weather operations and road maintenance activities in the mountains are addressed primarily by a separate satellite TMC located in Kingvale. A decision was made to focus the RTMC's weather integration activities on the implementation of the strategies in their integration plan that were related to the implementation of an alert notification system in the valley. The intent of this weather integration project is to integrate road-weather information into the key RTMC operational advisory functions associated with providing timely traveler and road weather information to the public.

1.2 Sacramento RTMC Weather Alert Notification System Goals

RTMC management worked with their operators and members of the California Highway Patrol (CHP) to clearly understand the types of weather encountered in the Sacramento Valley. The weather types of particular interest to RTMC operations are fog, wind and frost. These weather conditions have potential consequences for the operation of their transportation system and the safety of the traveling public. The RTMC desired to more effectively and proactively manage their system and keep their traveling public well informed when faced with these weather conditions in the valley. The specific weather information integration strategies originally identified from the self-evaluation and incorporated in their weather integration plan were reassessed in terms of their relevance to the refined list of needs and potential to enhance operational integration.

The RTMC initially identified 12 tasks, described in the RTMC's Implementation Plan, that they wanted to implement in support of a weather alert notification system that could improve their operational performance. The main goals associated with these tasks are indicated below, and the tasks are described in detail in Chapter 2 and accomplishments on these tasks in Chapter 4.

1. Identification of a weather coordinator in the RTMC who would oversee the integration of weather information in their operations.

2. Enhancement of the type, quality and integration of available weather information coming into the RTMC.

3. Implementation of an alert system that would improve the RTMC's awareness of severe weather conditions (or forecast conditions) that may affect travel in the Sacramento Valley.

4. Establishment of well-defined procedures to support more timely and accurate RTMC decision making, primarily related to advisory messaging to the traveling public.

5. Development and implementation of a training program to enhance awareness and strengthen the capability of operators to proactively use weather information, weather warnings and alerts in RTMC operations and in posting and removing advisory messages.

1.3 Evaluation Objectives

The evaluation of the Sacramento RTMC's weather alert notification system seeks to assess how well it is achieving the following outputs and outcomes:

- Effective standardized procedures and training to guide the RTMC operators in their decision making regarding providing advisory messages to the traveling public during weather events;
- Accurate notification to RTMC operators of weather conditions through implementation of warnings and alerts from Road Weather Information System (RWIS) sensor sites, presented to operators in a timely way that is both helpful and not interfering with their many other responsibilities;
- More proactive use of weather information in support of RTMC operations;
- More timely and effective decision making by RTMC operators communicating weather advisories to the traveling public; and
- Enhanced operational coordination with regard to weather and its potential impacts on travel and road conditions, both internally and with other key agencies.

1.4 Evaluation Approach

The evaluation approach identified the data collection and analysis requirements needed to understand the extent to which the expected benefits noted above had been achieved as a result of the RTMC's weather integration activities over the 2008-2010 period. Quantitative and qualitative data were collected to support evaluation measures in both the baseline and post-deployment periods. The quantitative data included weather condition readings from a set of RWIS sensors, records of warnings and alerts issued before and during weather events, information on messages posted on electronic signs in the valley, and operator entries in the TMC logs. The qualitative data were obtained through interviews with operators and managers of the RTMC, and they included observations and perceptions of changes and benefits being derived from the implementation of the weather alert notification system, and also institutional and organizational benefits received as a result of using this system. Data were collected throughout the baseline period of the implementation, and again after the strategies had been implemented and were operational for a period of time.

The evaluation focused on a few significant weather events during which the alert notification system was active. These events were analyzed in detail as case studies to understand how well the warnings and alerts tracked the actual weather conditions and how well the operators were able to use those warnings and alerts in supporting their decisions to post messages for the public. The evaluation also addressed the institutional process by which management sought to implement the system, make adjustments based on their real-time experiences with the system, and incorporate feedback from the operators.

In addition to the post-implementation case study approach, the evaluation analysis also sought to compare outcomes between the "before" and "after" periods, to the extent the available data would allow, as a basis for identifying changes and benefits that could be attributed to the new integration strategies. Lessons learned were derived from the total implementation experience for the benefit of Caltrans and other TMCs that are considering enhancing their own level of weather integration.

1.5 Document Contents

This evaluation report describes the weather alert system implementation in Chapter 2, the baseline conditions in both quantitative and qualitative terms in Chapter 3, the RTMC's accomplishments in implementing the weather alert notification system in Chapter 4, the analysis and results from the weather event case studies in Chapter 5, and findings and lessons learned in Chapter 6.

2 Weather Alert Notification System

The first step to implement the Sacramento RTMC weather integration strategies was to develop a plan that addressed the required tasks. The Sacramento RTMC staff drafted an implementation plan, with detailed task descriptions and a schedule, in early 2009. This was a "working plan" that was modified based on experience with task implementation. This chapter provides background information on integration strategies and needs, uses of weather information, and then describes the tasks that were undertaken to implement their weather alert notification system.

2.1 Weather Integration Strategies

The Sacramento RTMC identified the following weather integration strategies (using the FHWA Self-Evaluation and Planning Guide process).

1. **Frequency of road weather observations –** identify the time intervals for collection of environmental sensor station data. This will reflect the level of information detail that is required by the RTMC for decision making.
2. **Extent of coverage –** identify additional observations beyond the present environmental sensor station coverage that are required to provide the needed weather information for various road weather conditions informing RTMC decision making.
3. **Weather information coordination** – assign responsibility to an RTMC staff member for coordination of weather information/integration related activities, including training.
4. **Alert notification –** provide automatic alerts to RTMC personnel (and potentially others) when certain weather condition thresholds are exceeded.
5. **Road weather data acquisition –** identify the road weather data, including forecasted road weather conditions, needed to support RTMC decisions. Additionally, identify the level of technological sophistication used to process and manage weather data.
6. **Use of external weather information sources –** identify the appropriate weather information sources, observed and predicted, not owned by the RTMC or other state agencies. Additionally, identify the integration techniques to incorporate these information sources into the RTMC decision making processes.
7. **Decision support** – identify procedures and tools to integrate road weather information into the RTMC decision making processes.

There are overlaps among each of these strategies, and these interrelationships are an important consideration when planning implementation tasks. It was decided early in the implementation planning steps that the Sacramento RTMC's primary goal was to provide alert notification to their operators regarding existing weather conditions so that more effective public advisory notification actions could be taken in a more timely manner. The other strategies listed became supportive of that goal. It was also decided to focus the weather integration strategies on operations associated with the Sacramento Valley.

2.2 Current Use of Weather Information

The Sacramento RTMC performs the following operations:

- Activate changeable message signs to alert motorists
- Activate highway advisory radio to provide additional traveler information
- Issue media advisories (e.g., fog advisory, wind advisory)
- Place conditions into the Caltrans Highway Internet Reporting Program (CHIRP) to broadcast chain requirements in mountainous areas
- Dispatch maintenance forces and Traffic Management Teams (TMTs) to assist with traffic or clean up operations
- Request traveler information be displayed on CHIN (California Highway Information Network)
- Coordinate with CHP to dispatch Freeway Service Patrols (FSP tow trucks)

Forecast and current weather condition data and information are accessed at low levels by the RTMC personnel in support of their operational decisions and activities. Most of their operational functions are advisory in nature; that is, they involve issuing advisories and keeping the public well informed through the use of various information dissemination technologies available to the RTMC. Only a few of their weather-related operational functions can be considered control functions. These include the last two listed above that involve dispatching activities.

The RTMC has identified the following weather events that impact their operations, listed in the order of their level of impact and operational priority:

a. Dense fog – reduced visibility leading to impaired driving conditions.
b. Strong winds – swerving and overturned commercial and recreational vehicles.
c. Heavy rains/flooding – ranges from standing water (hydroplaning) to road closures due to flooding.
d. Ice or frost on bridge decks – slippery conditions increasing accident risk, often due to freezing fog.

The Sacramento Valley has 6 RWIS Environmental Sensor Stations (ESS) that would be applicable to provide information. The weather and road condition data from these sites are collected every 15 minutes by the Statewide Weather Data Server located at the District 3 RTMC. Table 1 shows a list of those sites. The data are stored locally at the RTMC. An ASCII flat file version of the data is sent to a HQ server where the atmospheric data can be publicly accessed through the Internet. The data set varies by site but usually consists of the following: air temperature, wind speed and direction, visibility, precipitation (type and rate), humidity, pavement temperature, subsurface temperature, pavement chemical concentration, and pavement ice detection. The server has the capability of generating alarm notifications and this was the method used to provide operators with warnings and alerts, as discussed later in the report.

Table 1. RWIS Sites in the Sacramento Valley

County	Route	Postmile	Location
Sac	5	24.80	North of American River Bridge
Sac	51	3.00	North of American River Bridge
Sac	80	0.40	East of Sacramento River Bridge
Sac	99	8.80	McConnell (at rail overpass)
Yolo	5	0.40	West of Sacramento River
Yolo	80	8.90	East end of Yolo Causeway

There are additional weather data resources outside of State owned systems. WeatherShare, a research-based effort led by the Caltrans Division of Research and Innovation (DRI), is an example. It is a web-based application that fuses data from various sources to provide a comprehensive real-time view of weather conditions in the northern part of the state (http://www.weathershare.org). There are also various other weather data sources that are utilized (e.g., National Weather Service and Weather.com).

2.3 Need for Enhanced Weather Information Integration

There are several unmet needs for enhanced weather information integration in the RTMC that result in a lack of, or inefficient, decisions being made when weather conditions dictate quick action. They include:

- Awareness of, and access to, readily available or contracted weather information sources with road weather forecast and road condition tailored to the needs of the region.
- Properly maintained and/or calibrated road weather information systems (RWIS/ESS stations) that are currently out of service due to lack of maintenance.
- Lack of specific procedures to assemble and coordinate the use of weather information.
- Lack of RWIS stations positioned in appropriate locations to support fog and/or flood detection.
- No road weather information consolidation or alert notification system.
- Lack of defined, documented procedures to identify and direct actions when specific weather and/or road conditions exist.
- Lack of training for RTMC personnel on the understanding and use of road weather information supporting operational decision making.

2.4 Alert System Implementation Tasks

The following specific tasks were conducted to implement the weather alert notification system in support of the Sacramento RTMC operations.

1. **Identify and assign an RTMC weather coordinator.**

   Responsibility: Barry Pavan, RTMC Operations

   Weather integration strategies:[4]

   3. Weather Information Coordination

   Approach

   Develop a description of the desired attributes of an RTMC weather coordinator who would provide support and maintenance of the weather integration implementation plan. This should include a Duty Statement defining the roles of the weather coordinator. Due to the need to cover different shifts, more than one coordinator may need to be selected. Select and/or recruit an individual, or individuals, who either have the desired attributes or can be trained to attain these attributes. Establish the RTMC weather coordinator, or coordinators, within the RTMC organizational chart and assign the appropriate responsibilities, including providing training to other operators, and authority for the position to be successful.

   Priority

   While this is identified as a high priority, it is unlikely and potentially not feasible to have a dedicated weather coordinator due to the 24-hour operation and the limited staffing resources. This would mean that operators are all trained on the various weather functions. There may be a lead worker or operator who may function in this roll in each shift.

2. **Identify weather information sources (observations and forecasts); determine what is needed, in addition to sources already available and accessed by the RTMC.**

   Responsibility: Brian Simi, RTMC Electrical Systems Support

   Weather integration strategies

   5. Road weather data acquisition
   6. Use of external weather information sources

   Approach

   RTMC Staff will explore and investigate all available weather sources. They will look at both internal and external web-based sources. They will identify available sources of weather information from existing Caltrans owned weather sites. An external search will be performed to look at Internet web sites to determine what sites provide the necessary information that may be helpful to operations. Some examples include the National Weather

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[4] Numbering of strategies follows list in Section 2.1 above.

Service (www.nws.noaa.gov/) and local media (www.kcra.com/weather/). This task also includes reviewing private road weather forecast providers and locating potential external data sources.

Priority

This effort is the cornerstone for the further use of weather data for operational support. It was completed as the first order of work to provide the foundation for the subsequent activities.

3. **Properly maintain/calibrate Caltrans-owned RWIS/ESS.**

Responsibility: Brian Simi, RTMC Electrical Systems Support

Weather integration strategies

5. Road weather data acquisition

Approach

Staff first will identify specific sensors failing to meet desired performance levels. The goal of this task is to obtain enough data from these sensors to support a "workable" alert system. They investigate using any available quality checking sources that are available presently from the FHWA *Clarus* System to assist in the determination of poorly performing sensors. Once this step is completed, the cost for calibration or repair will be determined. A comprehensive look will also be made to determine if those sites in need of repair are critical to this plan, given other sources of data both internal and external. Maintenance personnel will be directed to repair the out of compliance sites or a service contract will be generated. A long-term maintenance program will be developed that can be executed through maintenance forces or under a service contract.

Priority

The initial evaluation of the available data is critical and should be done immediately. However further steps to calibrate or repair the sites rely on resources available and as such will be accomplished later during the implementation.

4. **Identify, procure, and install additional weather observation systems.**

Responsibility: Bob Mcnew, RTMC Operations / Brian Simi, Electrical Systems Support

Weather integration strategies

2. Extent of coverage
5. Road weather data acquisition

Approach

Conduct a needs assessment to identify the types of data required and the locations where the observations can provide the best decision making support. Conduct a site survey utilizing the FHWA ESS Siting Guidelines to determine best locations to obtain quality observations that meet the RTMC needs. Construct an ESS procurement plan to detail the types of sensors required to optimize the coverage while minimizing costs. Procure and install additional sites.

Priority

This activity is medium priority. There are sufficient existing sites to at least begin the implementation process but additional information will increase reliability over time.

5. Define alert mechanisms and thresholds, procedures, and timing (initial, critical, and after weather conditions improve).

Responsibility: Bob Mcnew, RTMC Operations / Brian Simi, Electrical Systems Support

Weather integration strategies

1. Frequency of road weather observations
3. Weather information coordination
4. Alert notification
5. Road weather data acquisition
6. Use of external weather information sources

Approach

Develop a process that directs the operator to collect weather data and provide an output action. Conduct a review of existing data management procedures and evaluate the appropriate level to which current and additional data should be managed. Document the format of the data being received, and determine whether the data can be maintained in a consistent format for interpretation. Where data are collected manually, establish and define a data collection protocol to ensure that sufficient detail is available in the data and unambiguous descriptors are used to describe the weather conditions. Prepare a data flow diagram that shows how the data will be assembled, consolidated and processed to ensure data quality and to present the data in a useable format.

Using various data points from multiple sources, construct appropriate alerting schemas that provide desired levels of notification for corresponding thresholds of weather impacts. Establish organizational hierarchies to which information alerts escalate as road weather conditions evolve.

Establish functional procedures required to implement the alert notification process that include an identification of levels of notification required and the desired time intervals for notification between threshold being met and notification completion. Activities would be tracked in the RTMC log.

Construct standard operating procedures that incorporate weather decision making actions associated with the issuance of advisories. Describe what will be accomplished by the decision making actions, how the procedures will be monitored and managed, the outcomes or deliverables, and how the procedures support or fit with the other RTMC tasks. Include how each group will be advised and what content will be included. Evaluate additional advisory tools such as Highway Advisory Radio (HAR) and 511 that may aid in issuing advisories.

Priority

This is a high priority item that will provide critical notification to the operators.

6. Implement alert system.

Responsibility: Bob Mcnew, RTMC Operations / Brian Simi, Electrical Systems Support

Weather integration strategies

4. Alert notification

Approach

For existing Caltrans RWIS sites, an automated alert system will be put into place using thresholds defined in Task 5. Additional software development may be needed to incorporate other data sources. Systems may exist that perform some of these functions with existing Caltrans RWIS management networks, and those will be investigated. Necessary alert mechanisms will be configured and activated. Automated feeds will be generated through existing applications or a new application may need to be developed.

Future activities will investigate a sophisticated alert system to gather a more varied group of weather sources to be used as a basis of a more comprehensive alert system. These activities are not anticipated to be completed as part of the initial alert system.

Priority

This is a high priority task needed to increase efficiency for the operations staff.

7. Define and implement training program for operators and others.

Responsibility: Bob Mcnew, RTMC Operations

Weather integration strategies

3. Weather information coordination

Approach

Construct a survey instrument to measure the level of understanding of road weather management strategies and road weather concepts relating to the advisory effort of the RTMC. Administer this survey to RTMC staff to determine level of comprehension of the aspects within the survey instrument. Determine the desired level of comprehension that should exist by RTMC staff and measure this against the survey results. Design an appropriate training program that addresses the gap between the desired and actual comprehension levels of road weather by RTMC staff. Establish a recurrent training program that is measurable and repeatable and include this in an annual staff training program.

Priority

This is a high priority task that needs to be implemented immediately after the operating procedures have been developed.

2.5 Alert System Implementation Task Schedule

The following schedule reflects the relative timing of the implementation of the tasks.

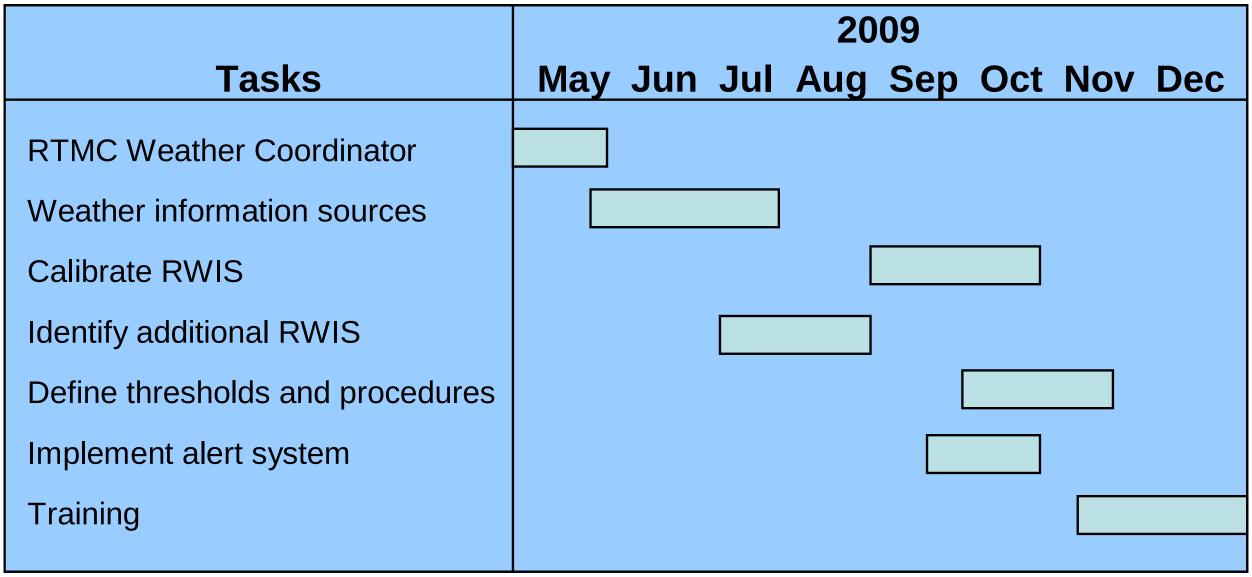


Figure 2. Schedule for Weather Alert System Implementation

3 Baseline Conditions

The research design for this evaluation called for a before-after evaluation of the weather alert notification system that included the collection of baseline data before the implementation of the alert system that could be compared with comparable data collected after system implementation. The evaluation team, working closely with the Sacramento RTMC management and staff, identified the needed baseline data elements and collected these data prior to the deployment of the RTMC's weather alert system. The data included weather events, weather data sources and uses, and RTMC operator activities. This chapter documents these baseline conditions.

The baseline period was from October 2008 through April 2009 and focused on fog, wind, and frost events during that time. Data collection included RWIS sensor readings for various locations, message sign logs, TMC activity logs, and other notes from TMC operators.

Quantitative data provided by the RTMC management were analyzed and interviews conducted with the RTMC operators. This quantitative and qualitative information formed the basis for establishing the baseline conditions.

This chapter is divided into three main sections. First, the weather events and RTMC operational responses to these event conditions are addressed. Second, a summary of the RTMC operator interviews is provided. The chapter concludes with a summary of the observed baseline conditions.

3.1 Weather Events and Analysis

The RTMC staff collected weather data and operator response actions for a variety of events during the baseline evaluation period. The data sources included RWIS data (visibility, wind speed and gusts, and surface temperature), field reports (primarily by CHP Officers) recorded in the RTMC log system, and operator actions also recorded in the RTMC log system. The data were compiled by an RTMC staff person in an Excel spreadsheet with a separate worksheet created for each month in the baseline period. During that compilation of data and assembly in the Excel spreadsheet, the RTMC staff made judgments about what the data were telling them, namely actions needed based on sensor data and other comments to help understand what was happening during the events. A sample page from the 32 page report is shown in Table 2.

Table 2. Sample of RTMC Weather Event Data and Operator Response

Date	Time	Sensor Location	Visibility	Wind (MPH)		Surface Temp	Action Taken Per Tmc Logs	Action Needed (wind gusts >25 mph visib <500 ft)	Comments
				Speed	Gusts				
4/1/2009									Sensor at Richards not reporting data for month of April 2009
	00:00	Airport	N/A	calm	4	N/A			
	06:40	Exposition	315 ft	9	15			Fog up	
	06:50	Exposition	499 ft	8	14				
	07:50	Exposition	1.2 mi	9	16			Fog down	
	09:50	Airport	N/A	17	24	N/A			
	10:00	***Wind Msg***					Wind Adv up		Schp L463
	10:00	Airport	N/A	16	26	N/A			
	10:04	Bryte Bend	N/A	17	26	N/A			
	11:10	Exposition	1.2 mi	15	25				
	13:00	Exposition	246 ft	15	26			Fog up	
	14:00	Exposition	1.2 mi	16	25			Fog down	
	18:40	Airport	N/A	13	19	N/A		Winds down	
	18:49	Bryte Bend	N/A	12	18	N/A			
	19:00	Exposition	1.2 mi	10	17				
	20:19	Bryte Bend	N/A	calm	4	N/A			
	21:50	Airport	N/A	calm	4	N/A			
	21:55	***Wind Msg***	N/A				Wind Adv down		ScanWeb
4/3/2009									
	04:30	Exposition	308 ft	9	16			Fog up	
	05:00	Exposition	1.2 mi	6	12			Fog down	
	09:00	Airport	N/A	16	26	N/A		Winds up	
	09:04	Bryte Bend	N/A	15	25	N/A			
	09:40	Exposition	1.2 mi	14	25				
	10:31	Mcconnell	1.2 mi	N/A	N/A	71.8			this sensor started receiving data again at 1500 hrs on 4/2/2009
	11:50	Airport	N/A	21	32	N/A			
	11:52	***Wind Msg***	N/A				Wind Adv up		Schp L675
	12:49	Bryte Bend	N/A	25	43	N/A			
	13:30	Exposition	1.2 mi	21	35				
	15:01	Mcconnell	1.2 mi	N/A	N/A	92.8			
	16:10	Exposition	1.2 mi	19	40				
	19:30	Airport	N/A	12	19	N/A		Winds down	
	19:34	Bryte Bend	N/A	12	18	N/A			
	19:40	Exposition	1.2 mi	9	15				
4/4/2009									
	00:00	Airport	N/A	15	24	N/A			
	02:49	Bryte Bend	N/A	10	16	N/A			
	03:31	Mcconnell	1.2 mi	N/A	N/A	43.9			
	04:00	Exposition	167 ft	9	14	43.2		Fog up	
	04:10	Airport	N/A	15	21	N/A			
	04:11	***Wind Msg***	N/A				Wind Adv down		
	04:19	Bryte Bend	N/A	14	21	N/A			
	04:51	Mcconnell	1.2 mi	N/A	N/A	41.9		Fog down	
	05:00	Airport	N/A	11	15	N/A			
	05:00	Exposition	1.2 mi	6	11	41.5			
	06:49	Bryte Bend	N/A	4	8	N/A			
	08:40	Exposition	394 ft	7	12	47.1		Fog up	
	09:00	Exposition	1.2 mi	6	12			Fog down	
	10:20	Exposition	495 ft	6	14	67.3		Fog up	
	11:50	Exposition	180 ft	7	14	82.9			
	12:40	Exposition	1.2 mi	5	11			Fog down	
	13:30	Exposition	495 ft	4	10	92.7		Fog up	
	16:40	Exposition	587 ft	calm	6	89.4			
	18:00	Exposition	1.2 mi	calm	calm	81.1		Fog down	
	19:50	Exposition	522 ft	calm	6	67.6			

Findings based on an analysis of these data include the following:

- It is difficult to accurately determine when weather events occurred or what their duration was due to a lack of reliable RWIS stations and a lack of continuity between the RWIS data and reports from the field.
- There were several cases when signs were activated based on field observations and the RWIS data did not appear to support the action. Therefore, in reviewing the data months after the event it was difficult to determine when events actually occurred. In spite of these problems, the data seemed to indicate the following:
  - Approximately 28 high wind events occurred.
  - Approximately 37 dense fog events occurred.
  - Approximately 2 frost events occurred.
- The RTMC operators believed the RWIS data were inaccurate. They made comparisons between sensor sites and with other weather data sources.
- The RTMC operators relied heavily on field observations primarily from CHP officers. It was the policy that if a CHP officer requested the signs be used to alert motorist of a weather condition, the RTMC operators complied (even if the RWIS data did not support the field report of conditions).
- The data indicate when message signs were used for high winds or dense fog events, but not which specific signs or their locations.
- Significant delays occurred between when an event began and when signs were activated. Also, delays existed between when the event appeared to end and when the signs were turned off. From a review of the information contained in the spreadsheet, it was not possible to calculate an average delay time for each; however, sign activation delays ranged from 40 minutes to several hours. The delay in sign deactivation after the weather event ended was as much as 18 hours.

The next section presents the results of RTMC operator interviews. This information helps to explain how operators respond to inclement weather events, what information they used, and their decision process for posting traveler advisories.

3.2 RTMC Operator Interviews

The purpose of the interviews was to learn more about RTMC operator activities before, during and after weather events and to gain their perspective and insights based on their experiences. Four operators were interviewed at the same time in an office away from the RTMC operations floor. The interview questions addressed traffic operations during weather events over the 7-month period covering the past winter (2008-2009). The following questions (and paraphrased responses) document what was learned during the interview.

1. During the past winter period, please describe the data available to the RTMC from field sensors. Discuss the sources of data. Discuss data type and quality.

   Reliability is always a question. The main data (reports of strong winds or fog) we get from a person in the field (CHP, sign trucks, or maintenance crews). SCAN Web is not accurate or up to date. We also get weather information from NWS, or from CHP or maintenance personnel in the field. Data come in on the CAD system regarding weather and chain control. Someone from the field sends it in. Sometimes a log is created for weather, usually for chain control. The Weather Channel is mostly for upcoming and current weather, and SCAN Web is used to check current weather observations – wind and visibility, but it often is not working or not reliable or doesn't match up with what the field personnel say or with what Weather Channel says – there is a lot of inconsistency.

2. How did you use these data in the RTMC, in support of operational decisions or to advise travelers, for example?

   We put out traffic advisories through the CAD and from there to the media, or put information out as HAR messages or on electronic message signs (extinguishable, fixed and changeable message signs). The Extinguishable Message Signs (EMS) have on/off fixed messages pre-installed to cover only weather events. LED CMS are smaller signs (3 lines by 8 characters) specifically located and configured for weather events but they can display other kinds of information as well. Traditional DMS (large CMS) are not typically used for weather-related incidents (though they could be), mainly because they tend to not be located where needed. There is a standard library of messages preprogrammed for the two HAR stations. They are only used for wind advisories, not for fog. Fog is not a standard practice, and there are no standard messages for fog events. HARs are already in the main fog areas. Control action used in RTMC: Notify maintenance dispatchers (Caltrans) and they contact HQ on the phone, who then type into CHIN a description of the location (route #), beginning and end location of weather. CHIN goes onto Internet and 800 number. RTMC also does messaging for chain control.

3. Was available weather information adequate to support travel advisories? Do you have any evidence regarding the benefits that were experienced by travelers? For example, safety or customer satisfaction?

   We don't do surveys. We only get complaints when something is not working. Weather information is not frequent enough. Also, information (particularly as provided by field personnel) is not always available in the location needed by operators, or provided in a timely manner. We don't know when to take down messages. We need updates on conditions more often. We have to ask observers to go to places, and they are busy. It is not their first priority. Sign trucks driven by maintenance are on call, but mostly they are assigned to their own maintenance tasks and not available for helping us with updates (our service patrols are not used as a source for Wx information). We also contact maintenance supervisors to send a crew member out. We can request the maintenance dispatcher to contact the supervisor. Also, cameras are not typically used to confirm information. Most of the time a camera is not close enough to the event and is not useful during the night. Cameras cannot confirm wind conditions.

4. How confident were you and other operators in the RTMC in the road-weather data available to you over the past winter period, both observational and forecast data?

   We are not confident at all in what people in the field are telling us so we look at SCAN Web to see if it confirms field reports or if it says something different, and we look to see if we are getting consistent and confirming reports from more than one person in the field. We are more likely to activate in the face of consistent information from more than one source. This can raise a liability issue, and we tend to err on the cautious side. This compromises our credibility. Operators consider the information source in determining their sense of the reliability of that information source. We try to use multiple sources to confirm what we're told.

5. How timely and effective do you think the RTMC was at dispatching resources in response to weather events? Discuss the time between the onset of a weather event and the dispatch of resources.

   We don't dispatch resources at this time. We used to dispatch sign trucks to put up fog messages, but quit doing that because it was too dangerous in a fog event. For a while maintenance used their personnel to go out in the trucks to check on weather events. We used to have roving trucks to help assess intensity and location of fog. Now sign truck drivers are less accessible and operators don't have primary jurisdiction over them. The TMC should have more to say about construction closures (lane, road, shoulder).

6. Do you have procedures in place in the RTMC that provide guidance about responding to weather events? If not, what do you think is needed, if anything? If yes, are those procedures adequate, standardized, and effective in supporting your operations?

   We really don't have procedures, and we need clear guidance on what to do during weather events. We have conflicting information, and operators may not be consistent in their actions for certain weather events. We have threshold levels for fog: Level 1 = <500 feet visibility. Level 3 = <200 feet. CHP will escort traffic in very bad fog. CHP will request TMC regarding posting messages. We also have thresholds for wind speed and gusts: 15-20 = wind advisory. But there are conflicting procedures in the TMC. If the temperature is less than 32 degrees we contact maintenance dispatch. They will call the supervisor in the area. Some may use pavement sensors. "We don't manage anything – we just pass along information."

7. Over the past winter, which of the following choices would you say best described RTMC operations? *(Listen to all the options before responding.)*
   a. We would only take advisory or operational control actions in response to weather if we observed a direct impact on traffic.
   b. We would initiate actions (advisory or control) as soon as we received information about a weather event we thought would impact traffic operations.
   c. We would take action in response to a weather event when we learned of a specific weather-related problem occurring in our jurisdiction.
   d. Describe any other operational response to knowledge of weather events that you think best describes your operations this past winter.

We try to do “b” and “c” together – that is how we operate. We don’t base decisions on what’s going on in other districts. If we think something is coming up, we do try to get ready. For example, we are proactive about issuing advisories for motorists to carry chains. But in the valley we pretty much act after an event occurs, and that approach is more like “a” than the others. This is largely because our predominant weather events, fog and wind, are very hard to anticipate or forecast.

8. Overall, would you describe your RTMC as proactive or reactive in handling weather events this past winter? Explain your response. Describe how the RTMC responded to weather events.

   We are reactive. The information is not that reliable. There is no procedure for high winds that we can do anything with. We wait until heavy fog or high winds materialize, and then we put up signs. We have no procedures saying this is what you need to do in advance. We believe the response of the RTMC is good and appropriate, once the data are available for us to act upon.

9. How would you describe the quality and timeliness of decision making in the RTMC with regard to weather response?

   As long as we get the information, we respond. We are as good as the information we receive.

10. Please describe the type of weather information exchanged among operators in the RTMC. Would you say the exchange of weather information enhanced overall operational performance this past winter? If so, describe how.

    If there is an event coming in, operators on the floor agree on who will track the event on the CAD and who will work with the messaging. We always have discussion and agreement regarding who will do what. People take events as they come if there are not too many. If there is a lot of stuff happening, we focus on geographic areas of responsibility. In the daytime there are mostly two operators. Also, one operator on grave shift and two on swings on Tuesday and Thursday.

11. Finally, can you briefly describe operational coordination with regard to weather and the RTMC’s responses to weather, both within the RTMC and with other agencies or stakeholders?

    CHP is the only other agency we deal with on regular basis regarding weather events. Also we work with District 1 and 2 adjacent to our District 3. We deal with the fire department during fire season (July-Sept). What about the Office of Emergency Services? We work with Sacramento County Transportation when there is a major crash and we have to divert traffic onto local roads. However, we don’t work with them for weather events.

3.3 Summary of Findings from the Baseline

Generally, the information collected during the baseline evaluation period identified shortcomings and needs that are closely related to the original selection of weather integration strategies (from the Guide) and the tasks identified in the Implementation Plan (see Chapter 2). Table 3 below summarizes the primary baseline condition findings and corresponding implementation plan tasks that address the issues.

Table 3. Summary of Baseline Conditions and the Relationship to Implementation Plan Tasks

Baseline Conditions	Implementation Plan Task to Address
1. General lack of focused and coordinated use of weather information.	Task 1: Identify and assign a RTMC weather coordinator.
2. RWIS sensors inaccurate and unreliable. No confidence in sensor data.	Task 3: Properly maintain/calibrate Caltrans RWIS data stations.
3. Lack of knowledge of all possible weather information sources that could be used to identify or confirm weather events.	Task 2: Identify weather information sources (observations and forecasts) available or accessible.
4. Lack of coverage of sensor data, mostly in areas that experience dense fog.	Task 4: Identify, procure, and install additional weather observation systems.
5. Too much dependency on field personnel to determine when a weather event begins and ends – their input is not always accurate or timely.	Task 5: Define alert mechanisms, thresholds, and procedures. Task 6: Implement weather alert system.
6. Lack of procedures or guidance regarding operations during inclement weather events.	Task 5: Define alert mechanisms, thresholds, and procedures.
7. Inconsistent response by the various RTMC operators during weather events.	Task 7: Define and implement training program.
8. Difficult to know when a weather event is beginning.	Task 6: Implement weather alert system.
9. Difficult to know when a weather event has ended.	Task 6: Implement weather alert system. (Note: future enhancements to the alert system are planned to address the issue of when events end.)
10. Significant delays between when an event begins and when signs are activated.	All Tasks: Implementation of a weather alert system, operator training, and consistent use of operational procedures.

4 Weather Alert System Implementation Accomplishments

The Sacramento RTMC weather alert system implementation plan, described in Chapter 2, identified seven key tasks that were conducted to implement their weather alert system. This chapter describes the accomplishments achieved under each task.

4.1 Alert System Implementation Accomplishments

The following accomplishments under each of the implementation tasks were made by RTMC staff to implement the weather alert system in support of Sacramento RTMC operations.

1. Identify and assign a RTMC weather coordinator.

The primary RTMC weather coordinator responsibility was assigned to Barry Pavan, Lead Engineer. Mr. Pavan is responsible for all weather related activities in the RTMC. This may at a minimum include: providing updated weather information sources; coordinating with other agencies regarding weather related activities or events; developing procedures regarding weather data collection, assessment, and relevant RTMC actions; and training of RTMC operators regarding proper collection and use of weather information during weather events. Due to the need to cover different shifts, Mr. Pavan may delegate some of these responsibilities to other operators for certain periods during RTMC operation.

2. Identify weather information sources (observations and forecasts); determine what is needed, in addition to sources already available and accessed by the RTMC.

The Sacramento RTMC staff identified a variety of weather information sources available to operators. These sources are listed in Table 4. Two types of weather information sources were identified as the two Tiers in Table 4: Tier 1) free weather information consisting of current observations and forecast services; and, 2) fee based road weather forecast services that are usually staffed 24 hours a day by meteorologists and provide a specific forecast and weather analysis for a very specific region.

The SCAN Web data source (highlighted in Table 4) consists of a database of current observations (and histories) from Caltrans-owned RWIS sites. The relevant Sacramento Valley RWIS, and the information provided for each, are shown in Table 5.

The discrete data sets of current interest are air and pavement temperature, wind speed, wind gust and direction, humidity, visibility and precipitation type and rate. This information is available to the RTMC operators via a CT Intranet website.

Figure 3 illustrates the location of the state owned RWIS throughout the Sacramento Valley. The white hexagonal symbols on the map indicate the location of each of the six RWIS stations. Each RWIS station is numbered to identify it, and they are close to the corresponding highway in order to provide conditions reflective of what the motorist would be experiencing. The information for each location is provided to the RTMC operators through the SCAN Web system. The sign location, also provided on the map, will be discussed later in this chapter.

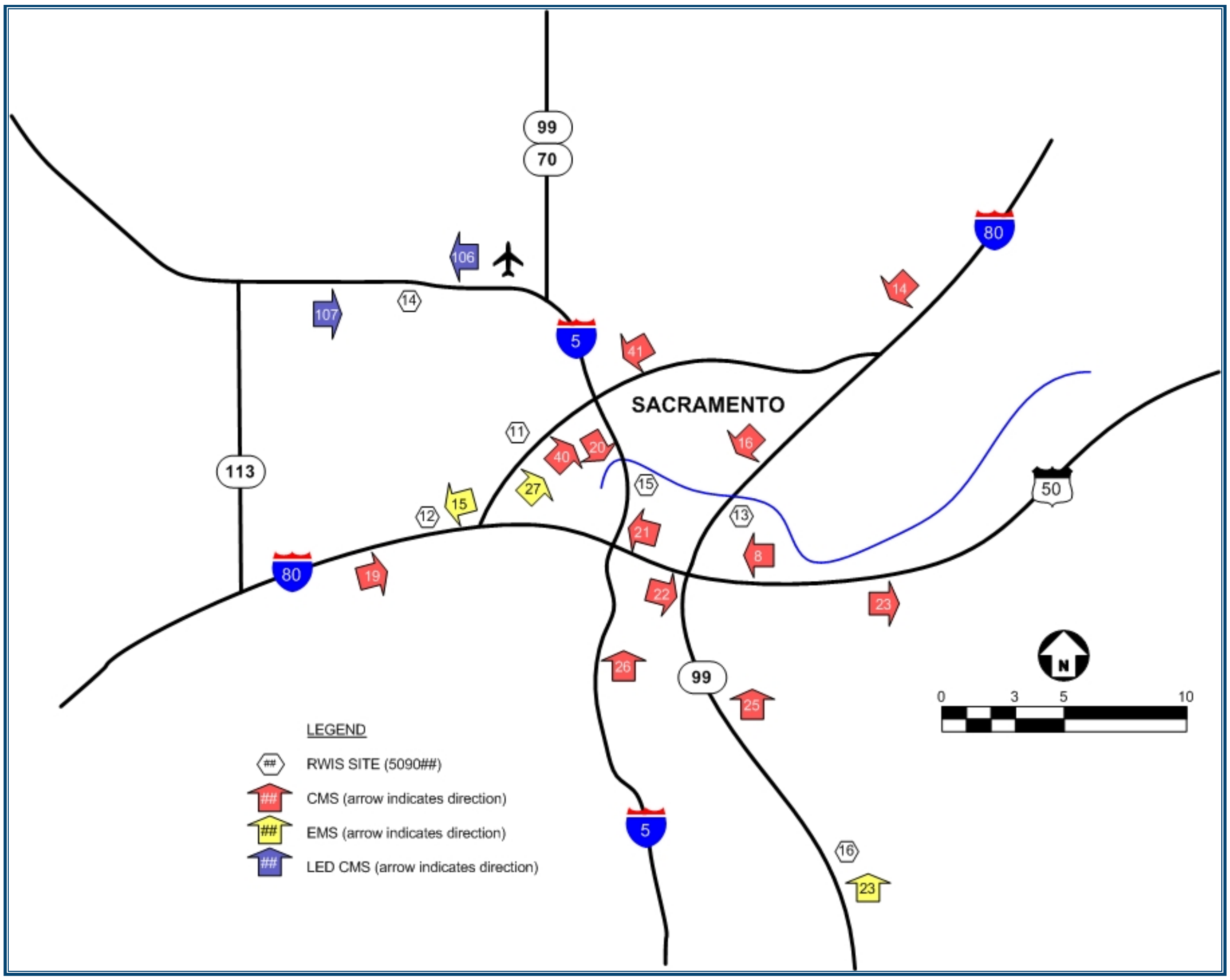
Table 4. Weather Data Services

Tier	Title Data Source	Data Location Web Address	Update Interval (H = hours M = minutes D = days)	Forecast Project Period	Data Available (A = Air Temp W = Wind Speed)	Comments	Alarm Notification Available
Tier I	National Weather Service	www.weather.gov	H	up to 7 days	Radar, Satellite, Vis, W, A, Humidity, Precip, River forecasts /Observ		No
	AccuWeather	www.accuweather.com	-	up to 15 days	Radar, A, Precip, Precip type		Yes
	SCAN Web	Internal Caltrans Website	10 M	none	A, W, Precip, Dew, Vis, SurfTemp,	Caltrans RWIS GUI	Yes
	The Weather Channel	www.weather.com	20 M	up to 10 days	Radar, A, Precip, W		Yes
	Intellicast	www.intellicast.com	H	up to 10 days	Radar, A, Precip, W, Vis, Humidity,		Yes
	WeatherShare	www.weathershare.org	var	up to 2 days	A, W, Humidity,Precip, Precip Type	Utilizes RWIS, MesoWest and MADIS sites	Yes
	Clarus	www.clarus-system.com/	var	-	A, W, Humidity,Precip, Precip Type		No
	CBS13 weather	http://weather.cbs13.com/us/ca/sacramento.html	Varies	up to 7 days	A, W, Vis, Humidity, Precip, Radar, River conditions		No
	KCRA weather	www.kcra.com/weather	H	up to 7 days	Radar, A, W, Humidity		Yes
Tier II	Northwest Weathernet	www.nw-weathernet.com	12 H	-	A, W, RWIS	Radar links w/ Intellicast,	Yes
	DTN Meteorlogix	www.dtnmeteorlogix.com	N/A	-	Radar, Precip, Snow, Rain amount, W, A		Yes
	Meridian Environmental Technology	http://meridian-enviro.com	N/A	up to 24 hrs	SurfTemp, A, W, Humidity, Dew, Precip,		Yes

Table 5. Caltrans RWIS sites in the Sacramento Metropolitan area

County	Route	Postmile	Location Name	Vendor	Air Temp	Wind (sp,dir,gust)	Precip	Precip rate	Surface Temp	Sub Surface Temp	Visibility	Humidity
Sac	5	24.8	Richards	Vaisala	Y	Y	Y	Y			Y	Y
Yol	5	0.4	Airport	Vaisala	Y	Y	Y	Y	Y	Y	Y	Y
Sac	51	3	Exposition	Vaisala	Y	Y	Y	Y	Y	Y	Y	Y
Yol	80	8.9	Enterprise	Vaisala	Y	Y	Y	Y	Y	Y	Y	Y
Sac	80	0.4	Bryte Bend	Vaisala	Y	Y	Y	Y			Y	Y
Sac	99	8.8	McConnell	Vaisala	Y	Y	Y	Y	Y	Y	Y	Y

Note: The surface data set includes pavement temperature, ice presence, and chemical presence and concentration.

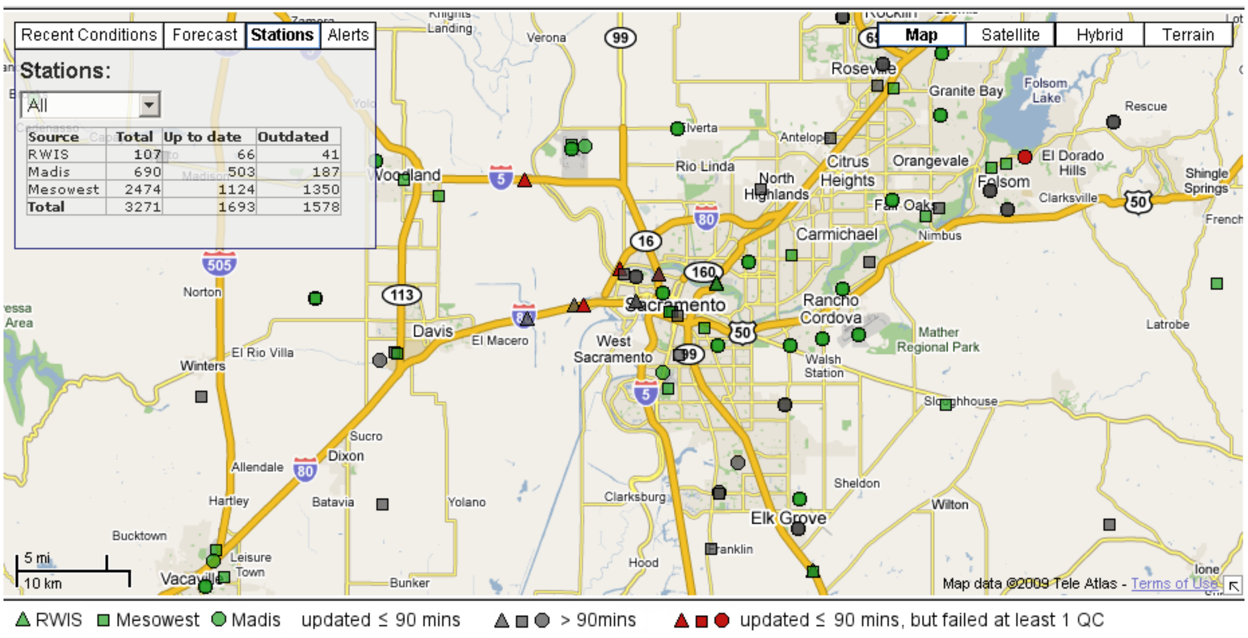


Source: Map created by the Sacramento RTMC for this report.

Figure 3. Map of Sacramento Valley Major Routes, RWIS Sites, and Message Signs

WeatherShare was developed by Western Transportation Institute at Montana State University, and it is sponsored by Caltrans, Division of Research and Innovation to improve weather-related situation assessment, incident recognition, and response by providing streamlined access to surface weather data from multiple sources.[5] There is a follow-up phase of WeatherShare that will enhance the data quality and alarm capability. Recommended enhancements to WeatherShare will be provided based on the preliminary work of this project.

Figure 4 below shows the various sites providing weather information on the WeatherShare display map. Also shown are the areas of interest for high wind conditions. There appears to be adequate coverage for wind sensors within the areas of interest.



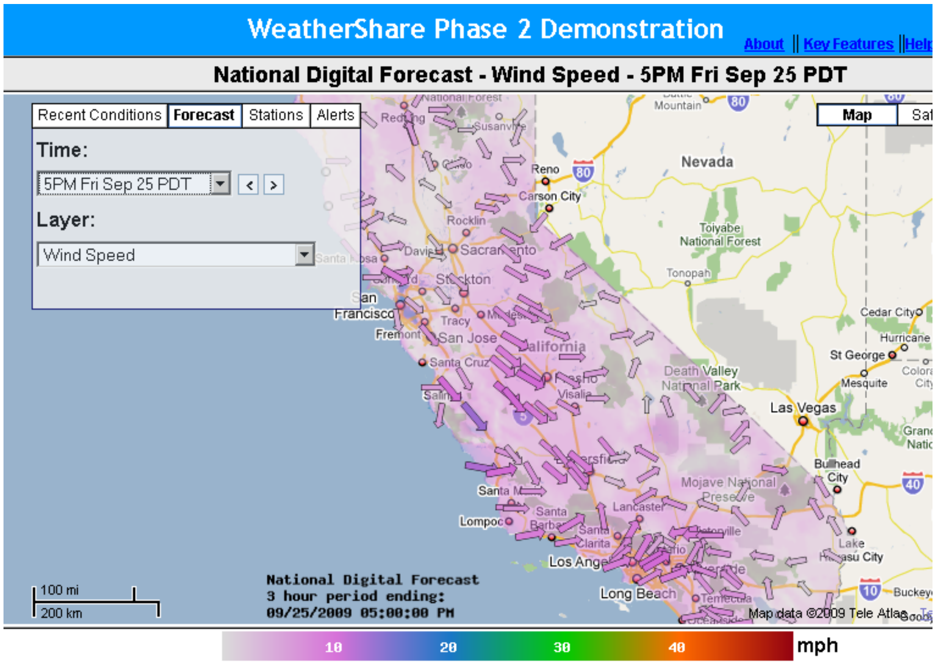
Source: WeatherShare, developed by Western Transportation Institute – www.WeatherShare.org (select "Stations" and zoom on Sacramento).

Figure 4. WeatherShare.org Display

The areas affected by low visibility or fog are the low elevations on the valley floor, mainly I-5 and SR 99 from the Sacramento County / San Joaquin County line and into Sutter and Yuba Counties. Although there are sites that collect visibility data, these existing sites are insufficient to adequately record conditions in the key areas that are subject to degraded visibility. Fog can be site specific, and if there is no sensor in that area, poor visibility conditions may go undetected. Not included in the previous RWIS list are existing visibility sensors that were installed in Sutter County as part of a federally funded Field Operational Test (FOT) in 1998. A future follow-up project in 2002 installed an additional 13 RWIS sites in the surrounding counties. The sensors are fundamentally different than the RWIS visibility sensors. The RWIS sensors use a forward scatter measurement technique that is an industry standard used for aviation. The FOT sensors use a back-scatter technique that does not provide the same output but does indicate low visibility. These sensors are currently not operational and have fallen into disrepair. The data are not currently being used.

[5] http://www.weathershare.org/about.html

The WeatherShare web tool also provides forecasting in a graphical format as shown below in Figure 5.



Source: www.WeatherShare.org (select "Forecast" and set Layer to "Wind Speed")

Figure 5. Example of WeatherShare Forecast in Graphical Format

For the purposes of this implementation the primary sources for real-time and forecast data will be the NWS, WeatherShare, and SCAN Web.

Tasks 5 and 6 below will more clearly define how the data derived from these sources will be used by the RTMC in monitoring weather conditions.

3. Properly maintain/calibrate Caltrans-owned road weather observation stations.

Baseline interviews with RTMC operators revealed a lack of confidence in data being provided by the SCAN Web system that tracks data from the state owned RWIS sites. It was vitally important to RTMC management that the real-time weather data being monitored and collected be reliable, timely, and accurate.

In order to ensure more accurate observations from the RWIS stations, a statewide contract was initiated to evaluate the condition of the Caltrans-owned RWIS sites. The contract allowed for evaluation of the sites listed in Table 3 above during the first week of November 2009. The evaluation and calibration was completed within that week. The main focus was an effort to independently verify the data being provided along with any minor calibrations that might be required. The contract did not provide for the replacement of weather sensors. These efforts were successful and the RTMC operators (and management) reported a significant improvement in both reliability and accuracy of the RWIS readings.

Additionally as part of this Task, Caltrans Operations and Maintenance personnel met to discuss the long-term maintenance effort required to keep the sites up and running.

4. Identify, procure, and install additional weather observation systems.

The Sacramento RTMC staff conducted an evaluation of data needs versus data availability. The two weather conditions of primary interest were high winds and low visibility due to dense fog. In the case of wind, work under this task determined that the current weather information sources (public and private) were sufficient to provide operators with accurate data for decision making. This was not the case for areas of dense fog. Fog is very difficult to forecast and to measure accurately when it exists. The location and number of the current RWIS, although able to measure low visibility conditions were determined to be not fully adequate to support RTMC operations for dense fog conditions. The RTMC management determined future RWIS locations that would be helpful in detecting fog conditions and providing the operators with the information necessary to enhance decision making regarding media alerts and sign activation. These locations are presented in Table 6 below. The list below includes some of the previously mentioned existing sites that are currently not operational and in need of upgrades.

Table 6. Future RWIS Locations for Enhanced Fog Detection

County	Route	Postmile	Location Name
Butte	99	21.81	Jct. 99/149, S/O 149
Sacramento	5	3.20	Twin Cities Road
Sacramento	5	8.20	Hood Franklin Road
Sacramento	5	30.20	5/99 Junction
Sacramento	50	20.67	West of Scott Road
Sacramento	80	11.80	Myrtle Avenue
Sacramento	99	5.88	Arno Road
Sutter	70	6.00	N/O Nicolaus
Sutter	99	4.00	Sankey Road
Sutter	99	8.07	Junction 99/70
Sutter	99	14.10	Sacramento Avenue
Sutter	99	24.10	Messick Road
Yolo	5	5.50	County Road 102
Yolo	80	3.00	Mace Boulevard

This task was able to evaluate and determine future RWIS location needs for fog detection to augment the six existing RWIS stations identified in Task 2. However, sufficient funding was not available to install new, or update existing, weather observation systems during the project period of performance. It is the intent of Sacramento RTMC to procure and install these new sensors as funding can be identified and secured. The next 10 Year State Highway Operation and Protection Program (SHOPP) Plan will include a project to upgrade all existing RWIS sites and add new ones where needed.

5. **Define alert mechanisms and thresholds, procedures, and timing (initial, critical, and after weather conditions improve).**

The first step of this task was to establish alert thresholds for certain weather conditions. Thresholds were established for three different weather conditions: 1) dense fog, 2) high winds, and 3) frost (pavement temperature). Two levels of alerts were developed. First, a warning would be issued when conditions approached the defined threshold. Second, an alert would be issued indicating when the threshold was exceeded.

For dense fog conditions, the following thresholds were set:

- Warning – visibility readings between 500 and 700 feet
- Alert – visibility readings below 500 feet

For high wind conditions, the following thresholds were set:

- Warning – sustained wind speeds between 10-15 mph and [6]wind gusts above 15 mph
- Alert – sustained wind speeds above 15 mph and wind gusts above 25 mph

For low pavement temperatures, the following threshold was set:

- Alert – pavement temperature readings below 34 degrees Fahrenheit

Note: no warning was set for this weather condition.

These warnings and alerts were provided to the RTMC operators through their emails. Further discussion on how the alert system was implemented is discussed in the next task description.

The next step was to establish procedures to assist the RTMC operators in knowing what actions to take when they receive a warning or alert. Figure 6, on the following page, was developed by RTMC management and provided to the operators to establish a protocol for their response. The primary duty of the operators during inclement weather events is to provide information to the traveling public regarding the conditions in an effort to maintain safety. This is accomplished in two ways – issuing a media advisory (similar to the press release describing the weather conditions and possible impacts to travel), and placing messages on the many large and medium-sized electronic highway message signs.

The protocol describes response actions following receipt of a warning or alert. It addresses responses including how to confirm the alert, what actions to take in response to the alert, decisions to issue advisories or activate message signs, and monitoring to know when to remove advisories or deactivate message signs. These protocols are being used by the RTMC operators in an effort to increase awareness and take action in a more timely manner (than before the alert system was operational).

[6] Note that the "and" condition reflects the defined sensor criterion for issuing warnings and alerts, but the operator protocol indicates an "and/or" condition for guiding advisory messaging decisions. This has resulted in some confusion for the operators. The evaluation data presented in this report reflect the "and" condition.

Protocol for Operator Response to Weather Alerts

Upon receiving a weather-related Alert, the Operator will key the following information, in the order as listed, to the TMC Log of the day:

A. ALERT RECEIVED:

1. **Note the Source:**
   a. Email via SCAN Sentry
   b. Audible text to dispatch Cell Phone
   c. Field personnel, either CHP unit or CT employee, i.e., Maintenance, Construction or other Department personnel

2. **Note threshold achieved and content of the Alert:**
   a. high winds: >15 mph sustained and/or > 25 mph gusts.
   b. ice/frost: temperature at or below 33 deg. F.
   c. fog/dust: Level 1 (Light Fog) = visibility at 500 ft. or below
      Level 2 (Moderate Fog) = visibility > 200 ft. but < 500 ft.
      Level 3 (Dense For) = visibility < 200 ft.

B. RESPONSE ACTION:

1. **What action was taken to confirm the Alert?**
   a. Were field personnel available to detect and verify alert warning?
   b. What other sources confirmed or conflicted with the alert warning? (NOAA, AccuWeather, weathershare.org, etc.)

2. **What action was taken in response to the Alert?**
   a. More information gathered about weather event?
   b. What other sources confirmed or conflicted with the Alert?
   c. Verify 2 or more sensors, by location, confirm cause for alert.
   d. Watch for trends from sensors.

3. **Decision: No action necessary - monitor or do nothing until next Alert update**.
   Conflicting information from separate sources requires field personnel to verify before taking action.

4. **Decision: Deploy message to any of following**:
   a. Media Advisory via CAD
   b. Deploy message to field element such as CMS, LED, EMS, HAR or TMT Sign Truck for traveling motorists.
   c. Contact Field Personnel, CHP, Maintenance, Construction

5. **Decision to take message down or revise to new message**:
   a. How often is Operator checking/monitoring weather event status?
   b. Weather event dropped below threshold. (How long was weather event below threshold (trend) before dropping sign and Media Advisory messages?)
   c. Additional information acquired to support next decision.
   d. Record time message was blanked or taken down.

Figure 6. Protocol for Operator Response to Weather Alerts

Also to assist the operators, RTMC management developed a matrix of possible message signs that could be activated based on alerts for various weather conditions at different locations around the Sacramento Valley. This matrix, shown in Table 7, has been provided to each RTMC operator as a guidance document to inform them which message sign or signs should be considered for activation when a weather alert is received in the RTMC from one or more of the specified weather stations. The following three sign types are identified:

- Extinguishable Message Signs (EMS) – a total of 9 fixed message, on/off signs indicating fog or wind conditions.
- Changeable Message Signs (CMS) – a total of 13 variable message sign (operator determines appropriate message for the conditions). These signs are used for a variety of possible messages, including but not limited to, weather conditions.
- Light Emitting Diode (LED) signs – a total of 5 fixed message, on/off signs indicating fog or wind conditions. These are newer signs.

Table 7. Protocol for Preferred Sign Usage for Various Weather Station Locations

		WEATHER STATIONS (RWIS #'s)						
SIGNS	LOCATION	80@Byte Bend 509011	80@Enterprise 509012	51@Exposition 509013	5@Airport 509014	5@Richards 509015	99@McConnell 509016	Sutter Co. Chico CHP
EMS #								
60	Sut NB 99 PM 0.2							F
61	Sut NB 99 PM 9.1							F
13	Sut SB 99 PM 7.2							F
15	Yol WB 80 PM 9.2		W					
19	Yub SB 99 PM 11.4							F
22	Sut NB 70 jno 99 jct							F
23	Sac NB 99 PM 7.4						F	
24	Sut NB 99 jno 70 jct							F
27	Sac EB 80 PM 11.6	W						
CMS #								
8	WB 50 @ 48th St	F / W ❷	F / W ❶			F / W ❷		
14	WB 80 @ Madison	F / W ❷	F / W ❷	F / W ❶				
16	SB 51 @ El Camino	I / F / W ❷		I / F / W ❶		I / F / W ❷		
19	EB 80 @ Chiles	I / F / W ❷	I / F / W ❶			I / F / W ❷		
20	SB 5 @ W El Camino	I / F / W ❷		I / F / W❷		I / F / W ❶		
21	WB 50 @ 8th St	I ❷	I ❶			I ❷		
22	EB 50 @ 18 th St			W ❶		W ❷		
23	EB 50 @ Howe			W ❶		W ❷		
25	NB 99 @ MLK			F / W ❶		F / W ❷		
26	NB 5 @ 35th Ave	I / F / W ❷	I / F / W ❷	I / F / W ❷		I / F / W ❶		
39	NB 51 @ Elvas			I / F / W ❶		I / F / W ❶		
40	EB 80 @ W El Camino	F / W ❶				F / W ❷		
41	WB 80 @ Truxel	I / F / W ❶	I / F / W ❷			I / F / W ❶		
LED CMS #								
105	NB 5 @ Richards	F / W ❷		F / W ❷		F / W ❶		
106	NB 5 @ Airport				F / W ❶			
107	SB 5 @ Co Rd 102				F / W ❶			
108	EB 50 @ Jefferson	F / W ❷	F / W ❶			F / W ❷		
109	NB 51 @ Tribute			F / W ❶		F / W ❷		

Legend:
I = Ice (Frost)
F = Fog
W = Wind
I / F / W = Ice, Fog or Wind

Notes:
❶ Primary RWIS Station nearest to Sign or Corridor of Sign.
❷ Secondary RWIS Station, near Primary RWIS Station, for verification purposes.
❸ Assumes all elements are operational.
❹ Weather Alert Info. is not necessarily first priority for CMS use.
❺ Refer to maps for field element geographic locations.

For each sensor location, primary and secondary sign activation possibilities are provided (indicated by the “1” and “2” notations in the matrix). The operators use their judgment to determine the best location and information to post the messages to best reflect the conditions. This matrix is not meant to be prescriptive in directing operators to post messages on all relevant signs, but rather to provide options for the operators to consider based on the situation.

Figure 3 above illustrates the location of each message sign (EMS, CMS, and LED). The signs are strategically located to provide information to motorists for key sections of highway. Some, but not all, were located and designed to specifically address weather issues. The signs are numbered for identification purposes. The arrow symbols for each sign indicate the direction of travel from which a motorist could read the sign. For example, LED sign 106 (facing westbound traffic) and 107 (facing eastbound traffic), near the airport on I-5 can alert motorists to high winds or dense fog (both of which can occur during different times of the year at this location). These signs are used by the RTMC operators (as they judge appropriate) to alert motorist to potentially dangerous conditions.

6. Implement alert system.

Two possible alert system approaches were investigated. The first approach involved activating a feature of the SCAN Web system (called SCAN Sentry) that issues email alerts when certain conditions (weather data thresholds) are met. This approach is limited to the six RWIS station locations (identified in Task 2) because those are the only relevant weather data in the SCAN Web database. The second approach was more comprehensive and included developing a new system to collect weather data from a variety of sources (see Task 2), building a database of relevant weather information, and creating algorithms to issue alerts based on the same weather data thresholds (see Task 5).

The first approach was chosen to be implemented for the evaluation period because it was a no-cost solution that was fairly easy to get working within the time constraints. The RTMC management also thought this was a way to test how an alert system might assist the operators, with the thought that it could be expanded in the future if it proved successful. The second option was much more involved and would have required both additional time and a specific budget to accomplish. Funding was not available to attempt the second approach. The results of this evaluation will help the RTMC management decide if an expanded alert system is required to continue improving weather responsive operations.

The following is a summary of how the implemented alert system is working:

1. Weather data from the six RWIS stations identified in Task 2 are posted every 10 minutes to the SCAN Web database. This includes all sensor data available at each location.
2. The SCAN Sentry system (software routine with access to the SCAN Web database) compares the weather measurements to the established warnings and alerts. The warnings and alerts identified above were incorporated in the SCAN Sentry system by RTMC management.
3. When the warning or alert conditions are met based on established thresholds, an email is sent to whomever is identified in the SCAN Sentry system – in this case RTMC management and operators.

4. The SCAN Sentry system allows the manager to limit the number of alerts issued if the conditions persist. The maximum time (suspend time) between alerts was adjusted from 2 hours to 3 hours on May 10, 2010. If a wind event continues to exceed (or repeatedly fluctuate through) the threshold for several hours, or even days, the operator will continue to receive alerts every 3 hours (but, not every 10 minutes).[7]
5. The SCAN Sentry system does not have the capability of issuing an alert when the thresholds are no long met, or not met for a given period of time, so operators are not alerted when weather conditions drop below thresholds. This is a limitation that the RTMC management would like to rectify with a new alert system in the future (second approach above).

The SCAN Sentry alert system was activated in the fall of 2009 and issued relevant alerts based on the established weather data thresholds. The results of the system performance and operator responses are described in the Chapter 5.

7. Define and implement training program for operators and others.

The RTMC management trained the operators on the use of the new alert system and response protocols. This training proved challenging because the operators were trained separately and not as a group. This was necessary due to recent staffing reductions and the three furlough days per month imposed by the State of California in response to the current economic downturn. In order to maintain operator coverage 24/7, it was not possible to assemble everyone for training.

[7] Warnings and alerts were issued with a suspend time of 2 hours for each of the events included in this evaluation.

5 Alert Notification System Performance

Chapter 4 described the implementation of the weather alert notification system by the Sacramento RTMC, and this chapter presents the performance of the implementation of the alert system during the winter of 2009-2010. Selected weather events are described in detail, including times during the event when designated thresholds were exceeded, the timing of receipt by operators of warnings and alerts, and the operators' responses to the alerts and observed weather conditions with regard to posting of advisory messages for motorists. Events are selected for analysis that cover a five month period (December 2009 through April 2010), offering an opportunity to assess changes in system output and operator response over that time period.

5.1 Weather Events

In order to evaluate the performance of the RTMC's weather alert notification system and operator responses to the alerts, one visibility and three wind events were selected out of a list of 13 weather events. Table 8 lists these events, with those selected for analysis shown in shaded rows and bold type. The selected events were significant enough to activate the alert system (that is, weather intensity exceeded the defined threshold levels that warranted, and resulted in, TMC messaging actions), they lasted for a long enough duration to warrant analysis, and they covered a sufficient period of time to allow an opportunity to identify changes in performance.

Table 8. Selected Weather Events in Sacramento Area: October 2009 to April 2010

Event Type	Start Date/Time	End Date/Time	Number of Warnings / Alerts	TMC Messaging Actions
Wind	10/13 – 02:20	10/13 – 17:50	0/43	None
Wind	10/27 – 00:31	10/27 – 23:16	0/36	Activated 1 signs
Wind	11/27 – 21:20	11/28 – 20:40	0/40	None
Frost	12/07 – 16:14	12/10 – 07:30	0/41	None
Visibility	**12/17 – 06:24**	**12/18 – 08:15**	**15/9**	**Activated 4 signs**
Visibility	01/03 – 01:35	01/03 – 09:01	6/6	Activated 2 signs
Visibility	01/05 – 00:00	01/05 – 10:31	7/4	Activated 1 sign
Wind	**01/17 – 18:00**	**01/21 – 04:10**	**36/176**	**Activated 2 signs**
Wind	02/04 – 15:10	02/05 – 01:40	8/19	Activated 1 sign
Wind	02/23 – 17:30	02/24 – 06:30	10/32	Activated 1 sign
Wind	02/26 – 06:00	02/26 – 16:40	8/17	Activated 4 signs
Wind	**03/12 – 11:40**	**03/13 – 16:30**	**13/8**	**Activated 5 signs**
Wind	**04/27 – 01:37**	**04/27 – 18:23**	**8/14**	**Activated 6 signs**

(shaded) = Event selected for evaluation.

The evaluation of this system's performance focuses substantially on the timing of posting messages, the distribution of messages relative to the locations where these particular weather types have exceeded the designated thresholds, and the effectiveness of the system in promoting an effective, proactive response on the part of the RTMC operations.

5.2 Evaluation Approach

The Evaluation Plan described an approach that called for collecting both quantitative and qualitative data during the baseline period over the winter of 2008-2009 and then assessing performance changes in comparison with the winter period of 2009-2010, after the alert notification system had been implemented, including calibration and maintenance of the field weather data sensors. Chapter 3 provided a description of the baseline conditions. Unfortunately, the data available on weather events in the baseline period and the RTMC response to those events was very incomplete, compared with the extent and quality of data available after the implementation of the alert notification system. As a result, the quantitative component of the evaluation approach has been adjusted to focus on a careful analysis of the performance of the alert system in the post-implementation period during a number of representative weather events or case studies. In addition, with regard to the qualitative assessment, interviews with operators conducted both pre- and post-implementation are available for comparison and analysis of potential changes in operator perspective on the system and their ability to offer the public improved weather advisory services due to the new alert system.

As shown in Table 8, four weather events were selected for more detailed analysis. These include a fog event over two days in December 2009, a severe wind event that occurred over a five day period in January, 2010, and two more wind events that occurred in March and April, 2010. These were selected from among 13 weather events that were identified as significant and potentially worth assessing, based primarily on the number of warnings and alerts they generated. There were many more wind, fog and frost events that took place over the winter of 2009-2010 but this subset seems to warrant further investigation and were more likely to illustrate the performance of the alert notification system and operator response. Selecting only four events does not fully represent all possible events, but the four that are analyzed in detail in this chapter offer useful insight into how the alert system worked, how the operators' job was affected by having these warnings and alerts, and the impact on advisory messaging that could be attributed to the alert system. Thus, these four events serve as case studies of the alert system performance, while the interviews with the operators offers insights into the alert system that enrich an understanding of the quantitative data illustrated by these four events.

5.3 Quantitative Data Elements

For each of the four events included in this assessment, the following data elements are examined in order to assess and understand how well the alert notification system performed and how the operators responded to the alerts, along with other available information, in making their decisions regarding posting of advisory messages. Data examined for each of these weather events fall into three main categories as follows:

Event timing and duration. A weather event, such as fog, wind or frost, typically does not affect the Sacramento Valley uniformly across all its geography. As shown in Figure 3 in Chapter 4, the Sacramento RTMC has access to selected RWIS ESS sensor sites located at key points along their major road network in proximity to message signs. These sensors record localized weather condition data and transmit those data to the RTMC. In this way the RTMC operators can see a variety of weather condition information for each of these sites, including atmospheric temperature, wind speed, visibility, and related data. In addition, operators have access to Closed Circuit Television (CCTV) cameras that help them to confirm readings from their distributed sensors, particularly snow, rain and fog, along with traffic conditions.

In each of the weather event case studies, reports from the sensor sites were reviewed to identify the start and end times for the events. The data were compiled for a few hours prior to the actual start of the event, defined as the time when conditions first crossed the defined threshold for that event type, and a few hours after the end of the event. In every event, conditions fluctuated throughout the event period above and below the threshold, and may have persisted in either of those states for a long period of time. Also, because of the non-uniformity of weather condition across the region, the characteristics of the event at each sensor site could vary significantly. Thus, the defined start and end times were based on the earliest start and latest end for the collection of sensor sites for which records were available.

Within this timeframe for an event, the event duration was defined separately for each sensor site as the time when conditions first crossed the threshold to the time conditions dropped below the threshold and persisted under threshold for several hours. The event duration is calculated as the difference between these start and end times. The data illustrate the actual times during the event period when conditions present serious challenges for the traveling public, such as when fog is below the 500 foot threshold or wind is sustained above 15 mph and gusting above 25 mph. These are the times when it is critical that the public have access to information through the media or on the roadside message signs warning them of these adverse weather conditions.

Warning and alert notification timing. The issuance of warnings and alerts is under the control of the RTMC supervisor who can decide which sensor sites issue either or both of these notifications to the operators, the threshold levels at which they are issued, and the intervals (suspend times) at which these notifications are given. Because the alert system is new for the RTMC, several of these parameters have been adjusted during the course of the evaluation of the system. The supervisor has sought to balance the benefits of warnings and alerts with the potential annoyance that could be caused to busy operators who may be receiving too many warnings and alerts. The supervisor activated warnings selectively at several of the sensor sites and, based on experience through April 2010, decided to extend the suspend time interval between successive notifications from two hours to three hours as of May 10, 2010.

The different threshold settings for warnings and alerts for the three different weather events were described in detail in Chapter 4. As conditions approach the alert threshold, a warning is issued, and when the condition threshold is crossed, an alert is issued in the form of an email to the operators. Alerts will continue to be issued every three hours as long as the condition exceeds the threshold value. Both warnings and alerts may be issued as conditions fluctuate above and below the threshold values, but no more often than every three hours. Thus, these notifications serve not only to alert the operators to an impending or critical weather condition but also to maintain their awareness that these conditions may continue to affect traffic conditions and require on-going vigilance.

An objective of the evaluation of the system is to verify the timeliness of the issuance of both the warnings and alerts with regard to the measured weather conditions at each sensor site and their utility in prompting timely messaging by the operators.

Traveler message activation and deactivation. The purpose of the weather alert notification system is to facilitate the timely issuance by the RTMC of travel advisories for the public. In order to evaluate the system's performance in meeting this objective, data were collected on the timing of message sign activation and deactivation, and these data were then compared with the timing of the start and end of the weather event. The evaluation sought to measure the extent to which messages were appropriately posted throughout the duration of the event.

The goal is to have the timing of the first alert coincide with the start of the event and the initial posting of an advisory message. Furthermore, these messages would need to be posted in those areas throughout the valley where motorists would be expected to encounter the adverse weather conditions. Then the expectation would be that the proper message signs would continue to be active throughout the event and not be deactivated until after the weather conditions had improved (above or below threshold, depending on the event type). In reality, and from a practical operational standpoint, it makes sense that the message signs remain active until it is no longer plausible that the weather conditions will worsen again to the point of requiring a message. This is a judgment call and, for analysis purposes, it was assumed that conditions should remain below threshold for no more than 2-3 hours before deactivating a message, and sooner if field reports indicate the weather condition has passed.

Thus, the evaluation will look at each weather event and determine the percent of the duration of the weather event for which messages were activated, how timely the activation was (lag time after the start to posting of the message), the amount of time after the end of the event during which the advisory message remained active, and the extent to which the proper signs were used during the event, according to the RTMC protocol guidance. In making this assessment, it will be important to take account of other factors that can affect messaging decisions, such as high priority traffic safety events that must be managed before weather messaging is considered, or the use of a message sign for other higher priority purposes (e.g., chain control messaging). Finally, the evaluation will seek to determine whether the messaging performance improved over the winter test period from the earlier events to the most recent events.

5.4 Analysis of Weather Events

As noted above, four events have been selected for more thorough assessment to help evaluate the performance of the weather alert notification system. These include:

1. A fog event that occurred December 17-18, 2009. While fog persisted throughout the valley over these two days, visibility conditions actually dropped below the indicated threshold in two distinct periods such that, for the purposes of assessing messaging performance, this can be interpreted as two separate fog events over this period of time.
2. A particularly severe and persistent wind event that occurred January 17-21, 2010, resulting in 176 alerts being issued.
3. A wind event that occurred March 12-13, 2010.

4. A wind event that occurred April 27-28, 2010.

Each of these events is presented in this section with separate graphs of the weather data that are available from each of the sensor stations that are linked to the various message signs. Each sensor site-based graph of the weather condition also displays the timing of warnings and alerts that were issued through the period, along with the message signs that were activated and the timing of activation and deactivation.

Below the graphics a table shows which message signs were activated, the timing of activation and deactivation, the duration of each message, and the message content displayed on the sign.

Finally a table summarizes this information for the entire event. At the bottom of the table for each of the events are selected statistics that indicate the timing of alerts, messaging and the extensiveness of coverage of messaging during the event. A common table format is used for each of the four events, with all message signs listed. The shaded cells in the table indicate the potential for sign activation, and the blank cells don't apply in that case (i.e., only message signs pertinent to particular sensor sites and weather type are candidates for placing messages during a weather event).

A discussion is provided along with each event, and the overall performance of the weather alert notification system is evaluated and discussed in terms of the objectives for this system and as illustrated by each event.

In assessing the TMC response to these weather events, several indicators are considered:

- Were the warnings and alerts issued appropriately and according to the designated thresholds?
- To what extent was the event covered by messaging to the public?
- Were the appropriate message signs activated based on readings from the various sensor sites?
- Were signs deactivated in an appropriate and reasonably timely way?
- Did the operators record information about the event and their decisions in the TMC log?

Analysis of Fog Event, December 17-18, 2009. The Enterprise and Airport sensor sites provided data in 10 minute intervals to the RTMC on a fog event that occurred in December 2009 in the Sacramento Valley. Figure 7 and Figure 8 illustrate the changes in visibility over this period as reported to the RTMC operators via SCAN Web. Visibility was significantly reduced on the morning of December 17th and again from early morning the following day. The rest of this period was less foggy, with visibility remaining well above the threshold for triggering messaging by the operators. Message sign activation related to this fog event is illustrated in Table 9, and additional details are presented in Table 10. These findings are discussed below:

- Warnings were issued prior to the issuance of an alert for each of the components of the fog event at the two reporting sensor sites. The warnings mean that visibility is in the range of 500 to 700 feet, and the alert indicates that visibility has dropped below the 500 foot threshold that calls for messages to be posted on the appropriate message signs. This event occurred prior to management establishing the new messaging guidelines, so operators were making their messaging decisions with the benefit of the alert system but without the refined procedural guidelines. The timeliness of the alerts is shown at the bottom of Table 10 in the line titled: "1st Alert to Event Start." Three out of the four initial alerts were very timely.[8] The alert for the second fog episode detected by the Airport sensor was issued 3 hours and 5 minutes after visibility first fell below 500 feet. Although Figure 8 shows that two warnings had been issued before the threshold was breached, the alert was too late to prompt an appropriate messaging response by the operators.

- In spite of the very late alert issued by the Airport sensor on December 18th, evidently the warnings were sufficient to create an appropriate messaging response by the operators. As shown in Figure 8, messages were posted for the full duration of the December 18th event based on the information issued from both sensor sites. Message coverage was between 97% and 100% for this event at the two sites, as is shown in the bottom line of Table 10.

- Operator entries into the TMC log for this event confirm that the operators received alerts on December 18th of low visibility due to fog. Also the CHP in the area confirmed the low visibility conditions. Operators noted in the log the signs they had activated. However, the log indicates that CMS 25 was activated, but the sign logs do not confirm that action. There is no indication of fog conditions reflected in the TMC log for December 17th.

- Unfortunately, there were no messages posted for fog conditions experienced in the morning hours of December 17th. This outcome would appear appropriate for the first event detected by the Airport sensor, but not for the event as experienced at the Enterprise sensor. As shown in Figure 7 and Figure 8, both warnings and alerts were quite timely for this event at the two sensor sites. While at the Airport site visibility below the threshold level was brief and minimal in intensity, the visibility problems were much more pronounced at the Enterprise site, and an advisory message should have been issued in that case.

- For the messages that were posted, each was deactivated in a very timely way, even though the operators received additional warnings and alerts as conditions were improving. This indicated that the operators were being attentive during this part of the event, and that they likely were accessing other information about visibility conditions that helped them make these appropriate decisions.

- As shown in Table 10, there were other primary and secondary message signs that could have been activated during this event. While the reasons other message signs were not used is unknown, only a few were. The sign priorities indicated in Table 10 reflect a protocol developed in 2010 after this event and therefore were not available to the operators to guide their messaging decisions for this event.

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[8] Note that Figure 7 and Table 9 show a message posted on CMS 15, a sign that was not included in the refined messaging protocol. This message is not shown in Table 10.

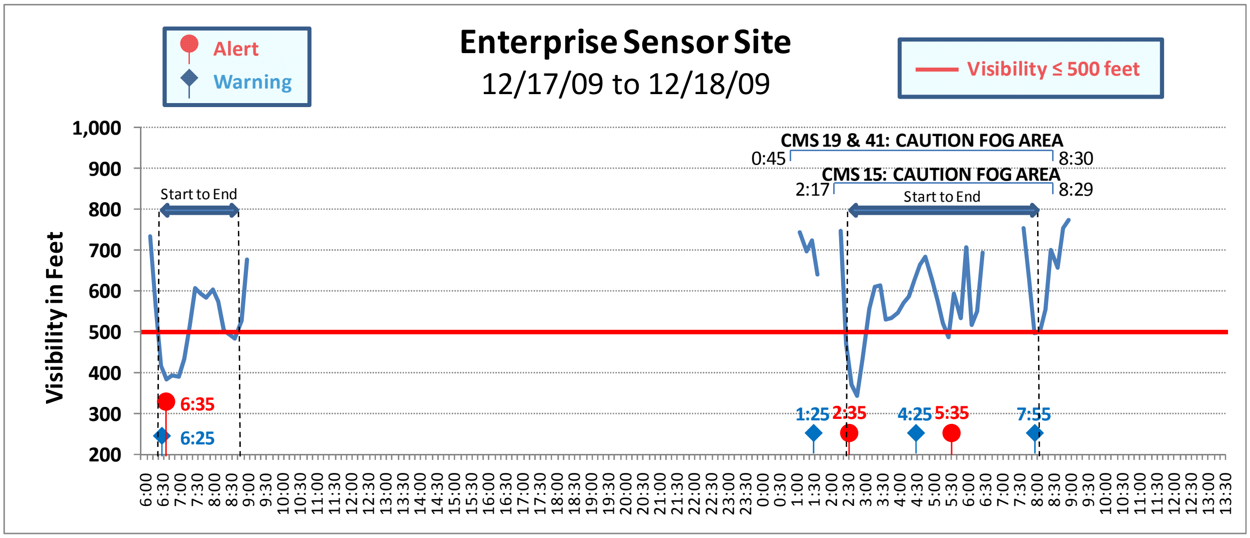

Figure 7. Fog Event, December 17-18, 2009, Enterprise Sensor

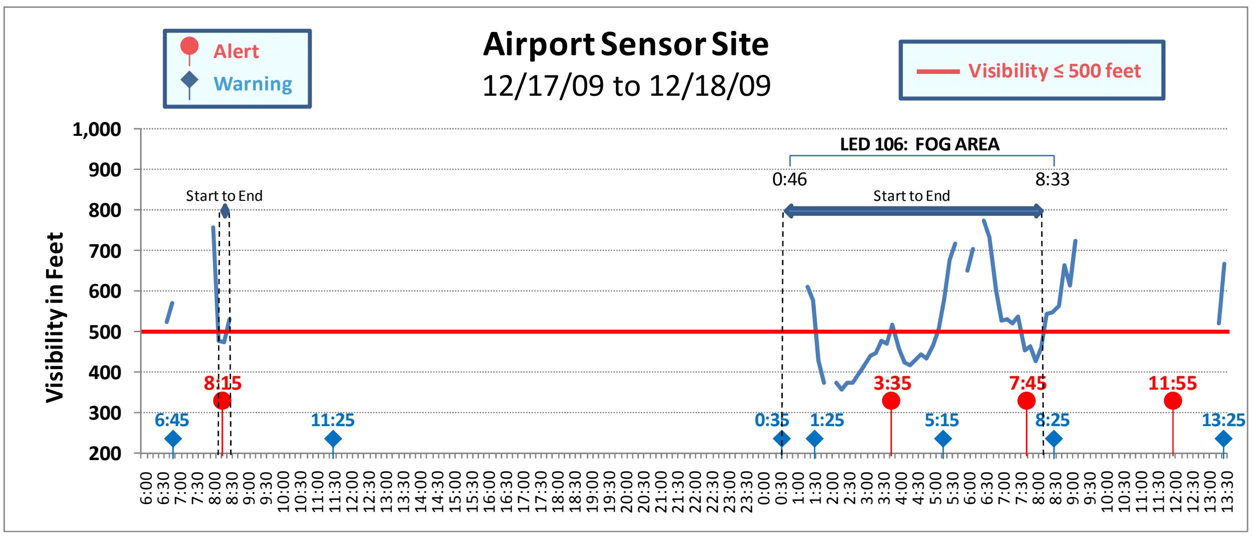

Figure 8. Fog Event, December 17-18, 2009, Airport Sensor

Table 9. Message Signs Activated During Event

CMS ID	Activation Time	Deactivation Time	Duration	Line 1	Line 2
15	12/18/2009 2:17	12/18/2009 8:29	6:11:36	CAUTION	FOG AREA
19	12/18/2009 0:45	12/18/2009 8:29	7:43:54	CAUTION	FOG AREA
41	12/18/2009 0:46	12/18/2009 8:30	7:43:44	CAUTION	FOG AREA
LED 106	12/18/2009 0:46	12/18/2009 8:33	7:47:00	CAUTION	FOG AREA

Note: CMS 15 is shown here and in Figure 8, but it is no longer in the RTMC protocol.

Table 10. Summary Statistics for Fog Event on December 17-18, 2009

		Enterprise1	Enterprise2	Airport-1	Airport2
Date		12/17/2009	12/18/2009	12/17/2009	12/18/2009
Event Start Time		6:24	2:29	8:09	0:30
Event End Time		8:44	8:10	8:25	8:15
First Alert Time		6:35	2:35	8:15	3:35
CMS-8	On				
	Off				
CMS-14	On				
	Off				
CMS-16	On				
	Off				
CMS-19	On		0:45		
	Off		8:29		
CMS-20	On				
	Off				
CMS-22	On				
	Off				
CMS-23	On				
	Off				
CMS-25	On				
	Off				
CMS-26	On				
	Off				
CMS-39	On				
	Off				
CMS-40	On				
	Off				
CMS-41	On		0:46		
	Off		8:30		
LED-105	On				
	Off				
LED-106	On				0:46
	Off				8:33
LED-107	On				
	Off				
LED-108	On				
	Off				
LED-109	On				
	Off				
EMS-15	On				
	Off				
1st Alert to Event Start		-0:11	-0.06	-0.20	-3.05
Event Start to Activate		No Msg	-1:44	No Msg	0:16
Event End to Deactivate		No Msg	0:20	No Msg	0:18
Event Duration		2:20	5:41	0:16	7:45
Message Duration		0:00	7:45	0:00	7:47
Message During Event		0:00	5:41	0:00	7:29
% of Event Messaged		0.0%	100.0%	0.0%	96.6%

(orange) = Primary RWIS Near Sign; (yellow) = Secondary RWIS

Analysis of Wind Event, January 17-21, 2010. A major wind event occurred from January 17 to 21, 2010, reaching wind gusts as high as 60 miles per hour. Winds were substantial during this period and remained above the designated wind thresholds (wind gusts above 25 mph and sustained average wind speeds above 15 mph) for most of this time.

Data are available from five sensor stations for this wind event, as shown on the accompanying graphs (Figure 9 – Figure 13). Each graph shows sustained average wind speeds in miles per hour (mph) above 15 mph (the lower horizontal blue line) and wind gusts above 25 mph (the upper horizontal red line), the designated threshold for issuing a high wind alert. When both of these conditions are met, the system issues an alert to the RTMC operator. Prior to reaching this threshold, the system is supposed to issue warnings when winds are between 10 and 15 mph and gusts are over 15 mph, although warnings were only issued during this event from the Richards sensor site. Alerts are not supposed to be issued more frequently than every two hours.

The results for this event can be summarized as follows:

- The alerts were for the most part very well timed for the start of the event (see Figure 9 – Figure 13 and Table 12). However, the first alert from the Exposition sensor site was issued about 34 minutes after the winds first exceeded the designated threshold.

- Wind warnings were set by management to be issued only by the Richards sensor site (Figure 13). The first warning was issued at 11:08 on January 19, 2010, slightly over 38 hours after the event began on January 17th. Then 20 additional warnings were issued at this site during the height of the event, along with additional alerts. These warnings continued to be issued for more than 9 hours after the end of the event.

- The few messages that were posted generally covered the majority of the wind event (between 78% and 99% of the event duration). However, no messaging was posted based on information from the Exposition sensor site, and only two message signs were used at all (CMS-19 and LED-106 – See Figure 10 and Table 12).

- Message coverage of this event was spotty but mostly for good reason. While the LED-107 message was posted an hour after the start of the event, a long delay in posting the CMS-19 message (10 to 13 hours after the event start, depending on which sensor site was being used by the operators to inform their messaging decision) occurred because CMS-19 was also used to post a chain control message (which takes priority) on January 17-18 right up to the time the sign was switched over to show high winds (see attached table showing message signs activated during event). There was significant snowing in the mountains during the wind event in the valley.

- The wind message on CMS-19 was deactivated for a four and a half hour period late on January 20th when winds were under the threshold but then rose back above the threshold several hours before the messaging was re-established on the sign. This created a gap in messaging that, with the benefit of hindsight, should have been avoided (See Figure 9, Figure 12, and Figure 13).

- Messages were kept active for a period of time after the end of the event, ranging from 1 hour and 45 minutes to 5 hours and 29 minutes longer than required. The extended messaging calculation for the Bryte Bend sensor was affected by a significant loss of sensor data on January 20th so much of the apparent extra messaging was likely justified by actual conditions (Figure 12). It is difficult to determine the actual end of an event, and it is prudent to leave messages active until wind levels have abated. However, leaving messages up too long after an event has ended risks public trust in the messaging.

- A high wind message was posted on CMS-21 from January 18 to 20 during this event; however, CMS-21 is not included in the operators' protocol for use during wind events.

- The TMC log entries indicate a strong winter storm in the mountain region, and this was likely taking a lot of the operators' time and attention. Chain controls and extensive signage was being used in the mountain region during this time. Also, the wind event was causing other problems, such as trees blown over on or near the roadways, along with power outages. While the logs also indicate that wind advisories were issued, very little information was provided in the TMC log regarding receipt of warnings or alerts of the wind event or the decisions regarding advisory messaging on the signs.

- The TMC log entries do not indicate whether LED-106 or LED-107 was used, or possibly both, during this event. The attached graphic (Figure 11) for the Airport sensor site show LED-106 to illustrate the messaging triggered by that sensor site.

- Many signs that could have been activated during this event (based on operator guidelines) were not (Table 12). While these decisions may have been fully appropriate, or guided by other contingencies, it is unclear from these data alone how the decision to activate or not activate a particular message sign is being made.

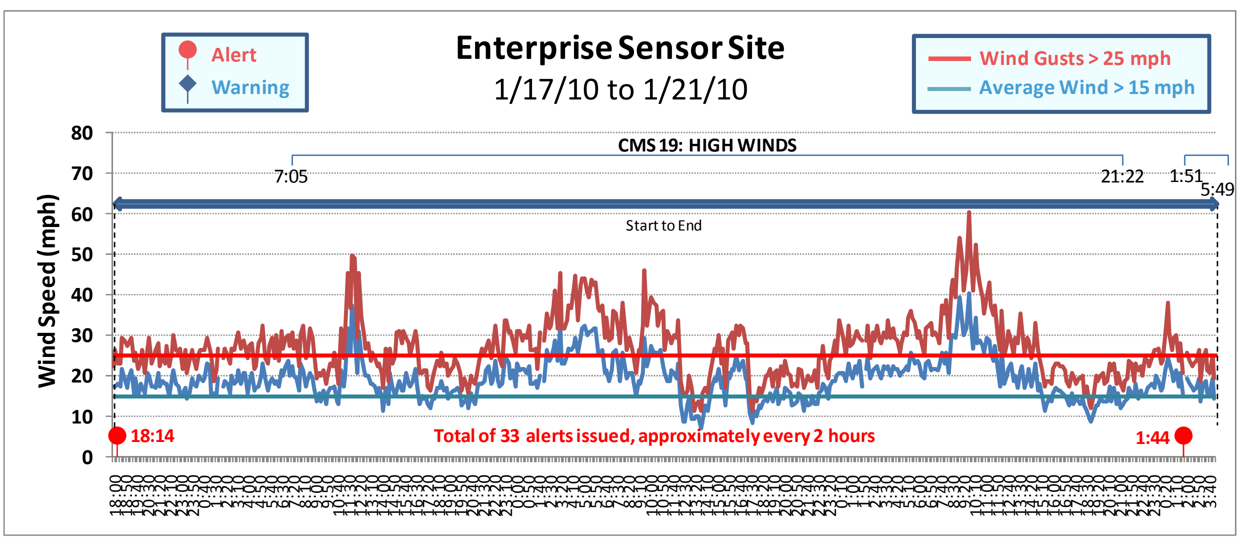

Figure 9. Wind Event, January 17-21, 2010, Enterprise Sensor

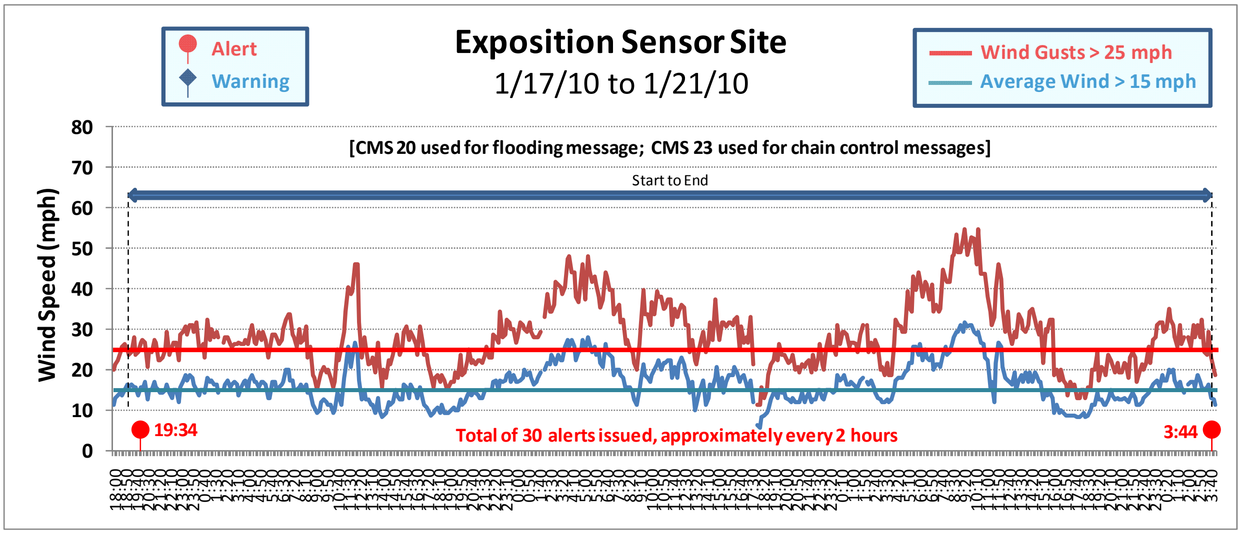

Figure 10. Wind Event, January 17-21, 2010, Exposition Sensor

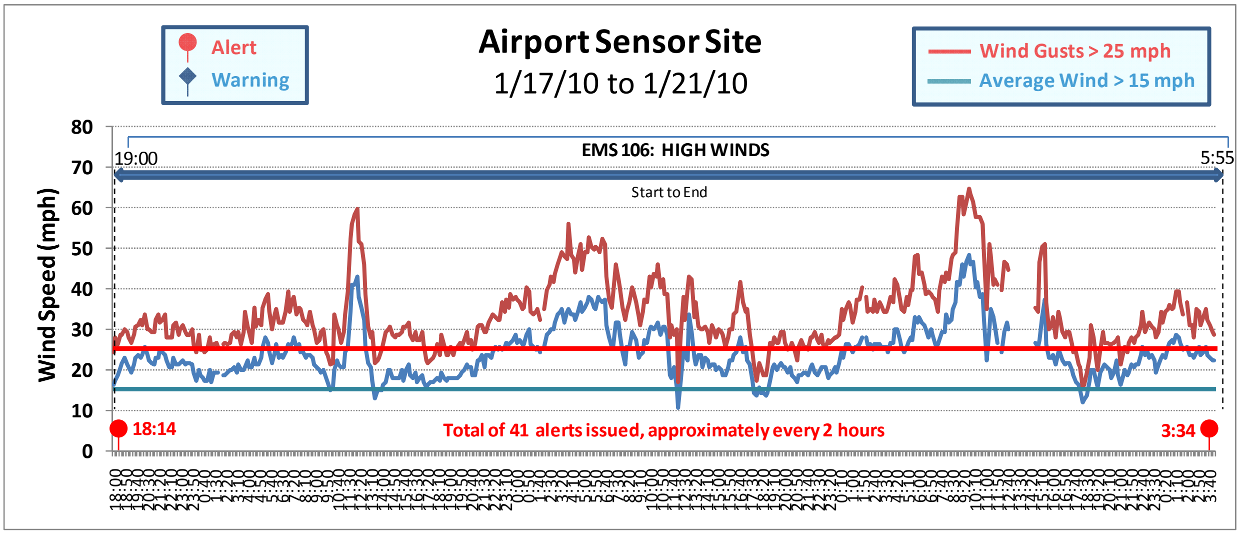

Figure 11. Wind Event, January 17-21, 2010, Airport Sensor

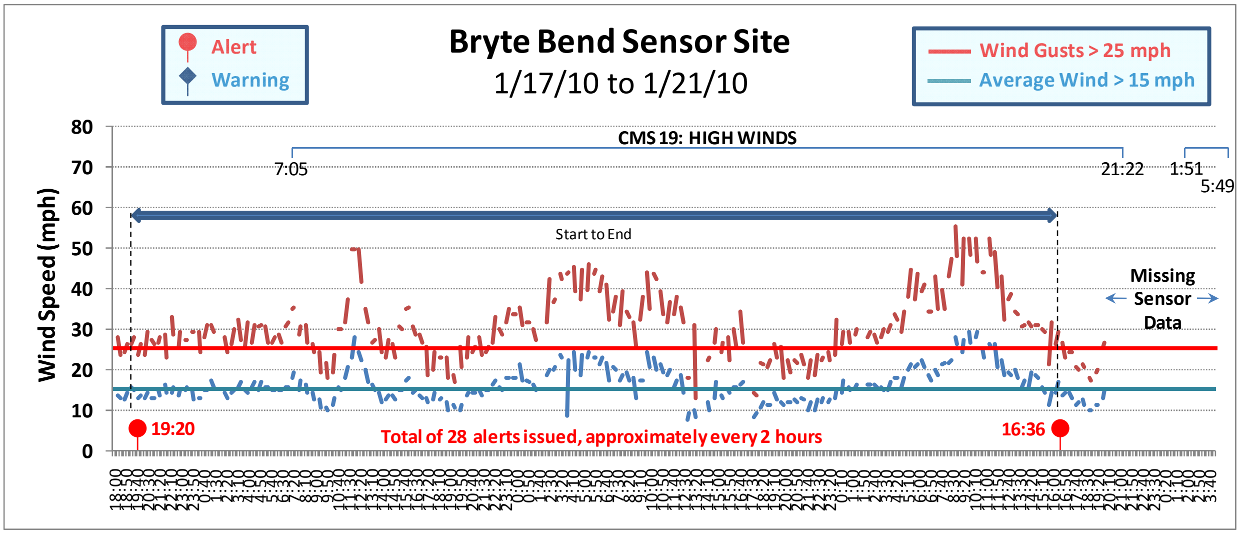

Figure 12. Wind Event, January 17-21, 2010, Bryte Bend Sensor

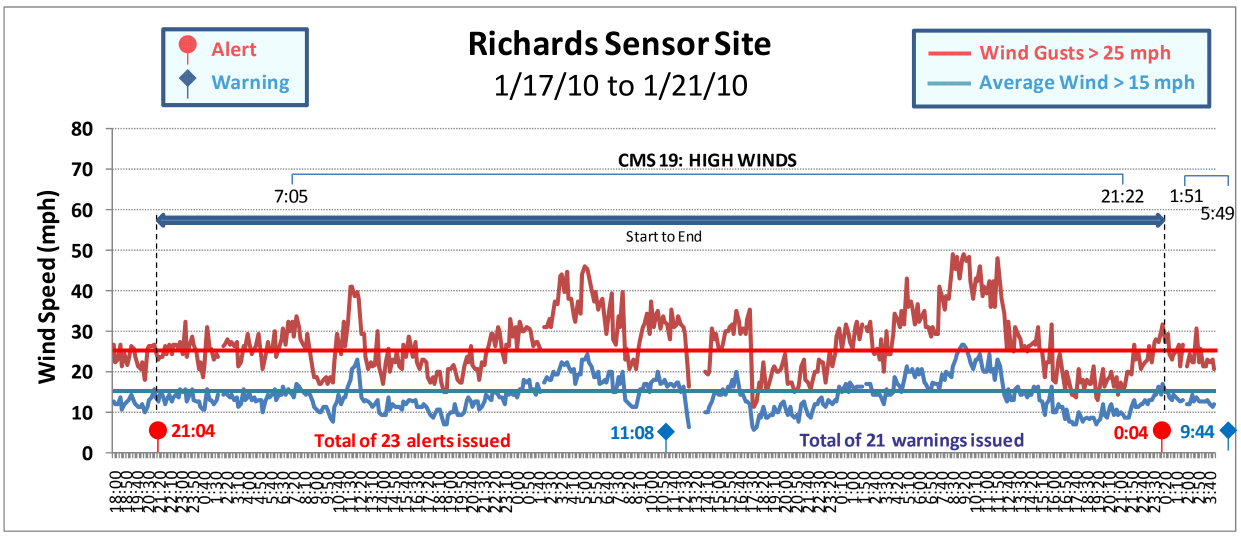

Figure 13. Fog Event, December 17-18, 2009, Richards Sensor

Table 11. Message Signs Activated During Event

CMS ID	Activation Time	Deactivation Time	Duration	Line 1	Line 2	Line 3
8	1/19/2010 14:29	1/19/2010 14:48	00:18:58	TRAFFIC	CONGESTED	PREPARE TO STOP
16	1/20/2010 08:07	1/20/2010 08:11	00:03:36	ACCIDENT	CCF AT E ST	LEFT LANES BLKD
19	1/17/2010 15:37	1/18/2010 07:05	15:27:34	US50 / I-80	CHAIN CONTROL	OVER SUMMIT
19	1/18/2010 07:05	1/202010 21:21	38:17:07	CAUTION	HIGH WINDS	
19	1/21/2010 01:51	1/21/2010 05:49	03:57:35	CAUTION	HIGH WINDS	
LED 106	1/17/2010 19:00	1/21/2010 05:55	10:55:00	CAUTION	HIGH WINDS	

Table 12. Summary Statistics for Wind Event on January 17-21, 2010

		Enterprise	Exposition	Airport	Bryte Bend	Richards
Date		1/17-21/2010	1/17-21/2010	1/17-21/2010	1/17-20/2010	1/17-21/2010
Event Start Time		18:00	19:00	18:00	19:20	21:00
Event End Time		4:00	3:40	4:10	16:30	0:20
First Alert Time		18:14	19:34	18:14	19:20	21:04
CMS-8	On					
	Off					
CMS-14	On					
	Off					
CMS-16	On					
	Off					
CMS-19	On	7:05			7:05	7:05
	Off	5:49			5:49	5:49
CMS-20	On					
	Off					
CMS-22	On					
	Off					
CMS-23	On					
	Off					
CMS-25	On					
	Off					
CMS-26	On					
	Off					
CMS-39	On					
	Off					
CMS-40	On					
	Off					
CMS-41	On					
	Off					
LED-105	On					
	Off					
LED-106	On			19:00		
	Off			5:55		
LED-107	On					
	Off					
LED-108	On					
	Off					
LED-109	On					
	Off					
EMS-15	On					
	Off					
1st Alert to Event Start		-0:14	-0:34	-0:14	0:00	-0.04
Event Start to Activate		-13:05	no signs	-1:00	-11:45	-10:05
Event End to Deactivate		1:49	no signs	1:45	13:19	5:29
Event Duration		82:00	80:40	82:10	72:06	75:20
Message Duration		66:15	no signs	82:55	82:55	82:55
Message During Event		64:26	no signs	81:10	57:25	62:18
% of Event Messaged		78.6%	0.0%	98.8%	79.6%	82.7%
		= Primary RWIS Near Sign		= Secondary RWIS		

Analysis of Wind Event, March 12-13, 2010. High winds were experienced March 12-13 in the Sacramento Valley, and this wind event is tracked by five sensor stations, as shown on the accompanying graphs (Figure 14 – Figure 17). Each graph shows sustained average wind speeds in miles per hour (mph) above 15 mph (horizontal blue line) and wind gusts above 25 mph (horizontal red line). The designated threshold for issuing a high wind alert is average wind speed at or above 15 mph and wind gusts at or above 25 mph. When both of these conditions are met, the system issues an alert to the TMC operator. Prior to reaching this threshold, the system is set up to issue a warning when winds are between 10 and 15 mph with gusts over 15 mph. Alerts are not issued more frequently than every two hours.

The graphs of wind conditions at each sensor site show when the combination of average wind speed and wind gusts exceeded the threshold and later dropped below the threshold. The start-to-end period of each wind "event" is measured from the time the threshold is first exceeded to the time it goes below the threshold. This definition is arbitrarily set for this evaluation, as there is no RTMC policy that defines when an event is officially over nor when a posted advisory message should be deactivated after the end of the event. Each graph also shows the timing of message sign activation. The signs that are linked to each sensor site are shown on the graph if they were activated during this event. Table 14 shows which signs could potentially be activated when conditions at each sensor site warrant activation (shaded to show primary and secondary message signs for each sensor site). In this event only some of the possible signs were activated.

Each graph provides a visual image of how message activation was timed relative to the timing of the wind event and the issuance of alerts. Table 14 shows the duration of each event at each sensor site, the timing of alerts, timing of sign activation and deactivation, and a calculation of how long it took from both the start of the event and the issuance of an alert to activate the sign. Also calculated is how long it took after the wind event ended to deactivate the sign. The RTMC's objective is to have a message sign active for the public throughout the event. The results for the event on March 12th can be summarized as follows:

- The alerts were all well timed for the start of the event, except no alert was issued by the event detected at Exposition (Figure 15).

- Message activation was delayed on each sign after the event began on March 12th by from 59 minutes (Richards, Figure 17) to 3 hours and 50 minutes (Airport, Figure 16).

- Messages uniformly were kept active a long time after the end of the event, ranging from 3 hours and 36 minutes to 5 hours and 59 minutes too long (Table 14).

- The proportion of the event when a message was active ranged from 0% (there was no message posted during the event) to 28.1% (only about a quarter of the time during the event was there a message up).

The wind event on March 13th only exceeded the threshold at the Airport site (Figure 16). Response to that event was much better than on March 12th. The alert was timely (though a little late), the message sign was activated 51 minutes after the start of the event (later than it could have been activated but better performance than on March 12th), and although the sign was kept active almost three hours after the end of the event, the message was active for 82% of the actual event (much better performance than on March 12th).

Some additional observations:

- There are many factors that affect the operator's decision to post a message, and the timing of their decision needs to be better understood in evaluating the final outcomes. Interpretation of the results of each decision is limited because it was not possible to identify and interview each operator that made each messaging decision, and information provided in the TMC Log system is too sparse to support clear inferences.

- The decision regarding which signs to activate when a sensor indicates wind has exceeded the threshold also needs to be better understood. Note in Table 14 that many other signs linked to the various sensor sites were not activated during this event (see shaded cells in Table 14).

- Operator entries in the March 12th TMC log did not indicate receipt of warnings or alerts for high wind. However, the log did indicate that CHP called in high wind conditions, the operator checked the sensors and put messages up n the signs. The log also showed evidence of monitoring the wind event by checking sensors and asking CHP to check it out and report back to the RTMC.

- Entries in the March 13th log indicated that the operator received an alert, checked various sensors, and activated signs. Later that day (at 8:30 pm), CHP requested signs be activated for wind, and the operator checked the sensor readings, which showed the wind threshold had not been met but the operator activated the signs anyway per the CHP request.

- There were no wind warnings issued at three of the sensor sites.

- The McConnell site did not show excessive winds on these days and is not linked to any of the message signs; hence, a figure is not included for McConnell here. Nevertheless, McConnell had 8 wind warnings, more than any of the other sites.

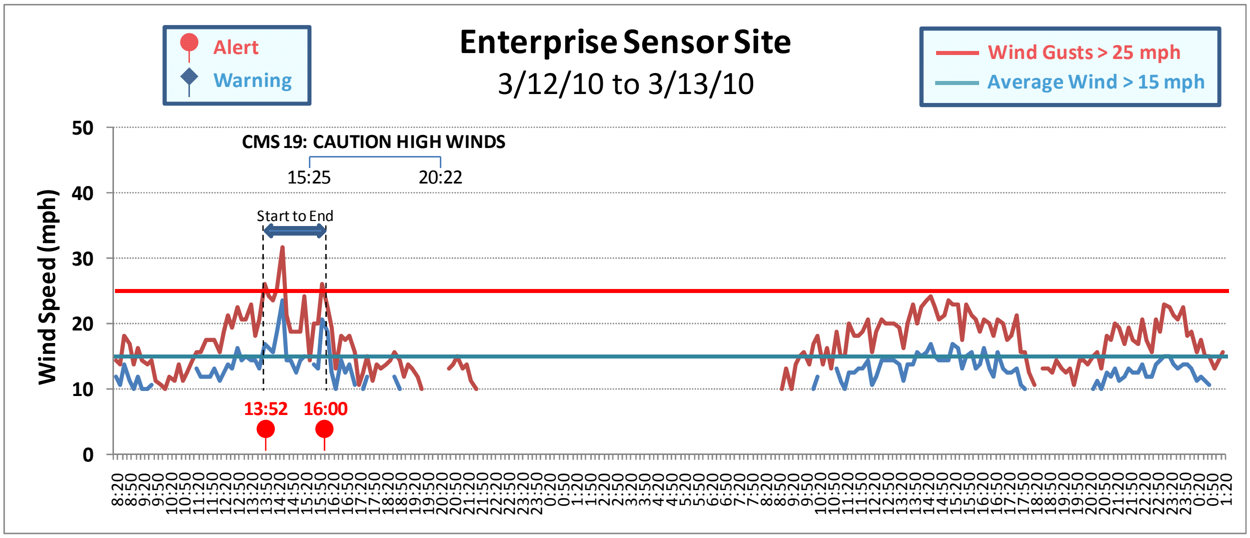

Figure 14. Wind Event, March 12-13, 2010, Enterprise Sensor

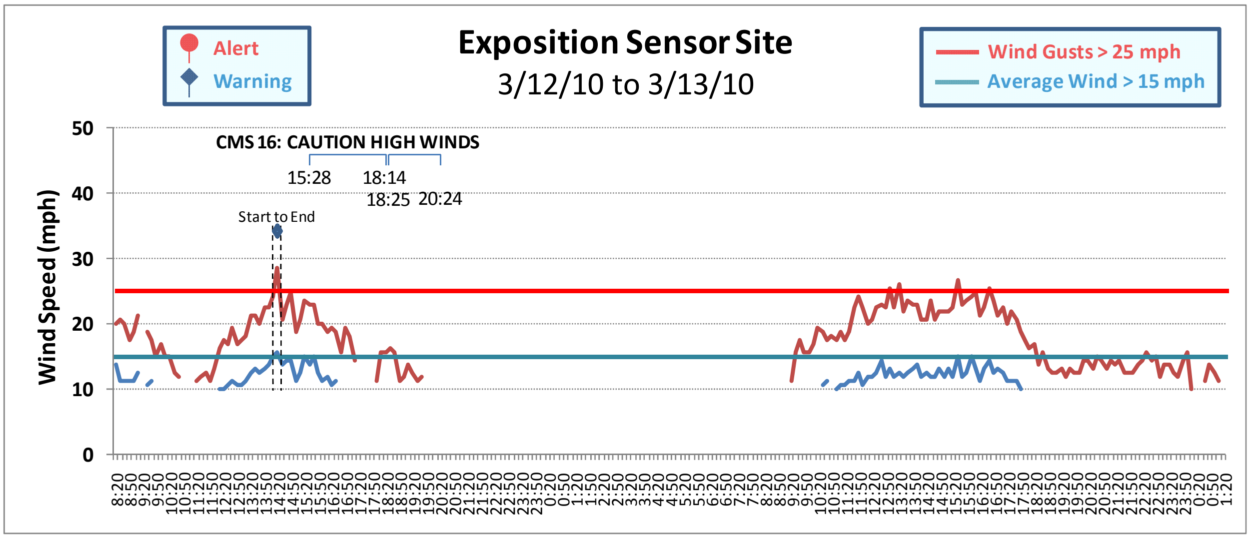

Figure 15. Wind Event, March 12-13, 2010, Exposition Sensor

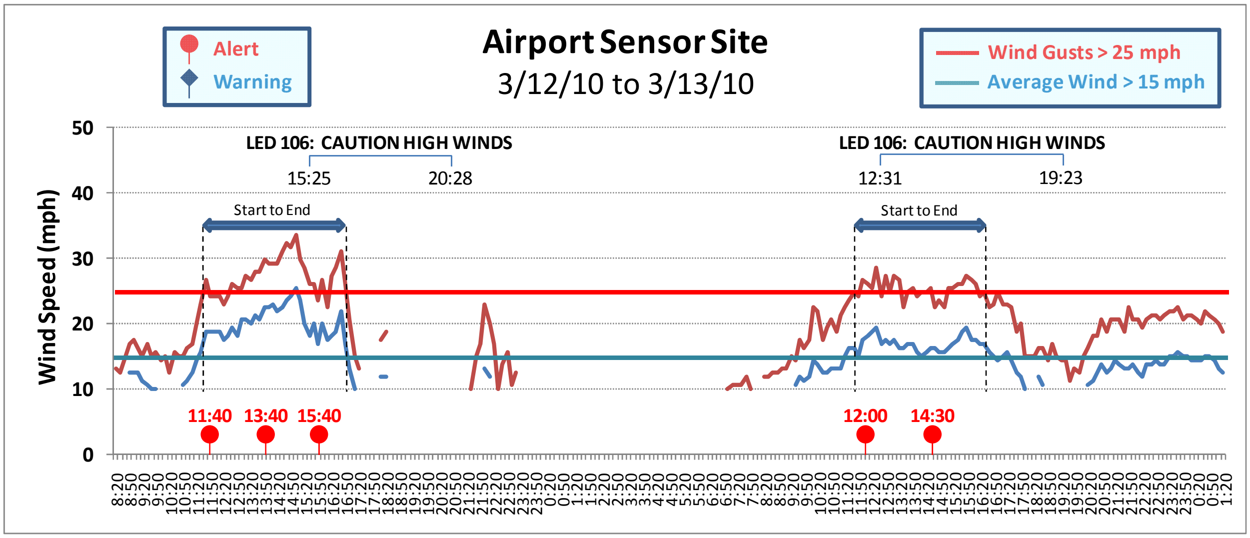

Figure 16. Wind Event, March 12-13, 2010, Airport Sensor

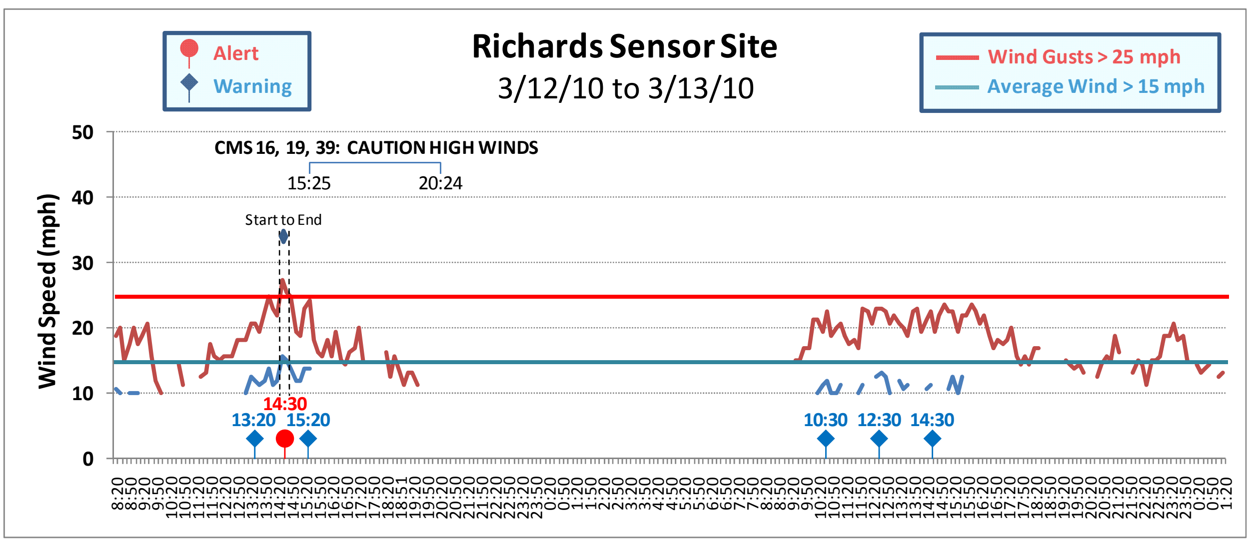

Figure 17. Wind Event, March 12-13, 2010, Richards Sensor

Table 13. Message Signs Activated During Event

CMS ID	Activation Time	Deactivation Time	Duration	Line 1	Line 2
16	3/12/2010 15:28	3/12/2010 18:14	2:46:41	CAUTION	HIGH WINDS
16	3/12/2010 18:25	3/12/2010 18:25	0:00:11	CAUTION	HIGH WINDS
16	3/12/2010 18:25	3/12/2010 20:24	1:59:27	CAUTION	HIGH WINDS
19	3/12/2010 15:25	3/12/2010 20:22	4:56:49	CAUTION	HIGH WINDS
21	3/12/2010 15:28	3/12/2010 20:24	4:56:09	CAUTION	HIGH WINDS
39	3/12/2010 15:28	3/12/2010 20:24	4:56:35	CAUTION	HIGH WINDS
LED 106	3/12/2010 15:25	3/12/2010 20:28	5:03:00	CAUTION	HIGH WINDS
LED 106	3/13/2010 12:31	3/13/2010 19:23	6:52:00	CAUTION	HIGH WINDS

Table 14. Summary Statistics for Wind Event on March 12-13, 2010

		Enterprise	Exposition	Airport-1	Airport-2	Richards
Date		3/12/2010	3/12/2010	3/12/2010	3/13/2010	3/12/2010
Event Start Time		13:48	14:12	11:35	11:40	14:26
Event End Time		16:03	14:25	16:52	16:30	14:40
First Alert Time		13:52		11:40	12:00	14:30
CMS-8	On					
	Off					
CMS-14	On					
	Off					
CMS-16	On		15:28			15:28
	Off		20:24			18:14
CMS-19	On	15:25				15:25
	Off	20:22				20:22
CMS-20	On					
	Off					
CMS-22	On					
	Off					
CMS-23	On					
	Off					
CMS-25	On					
	Off					
CMS-26	On					
	Off					
CMS-39	On					15:28
	Off					20:24
CMS-40	On					
	Off					
CMS-41	On					
	Off					
LED-105	On					
	Off					
LED-106	On			15:25	12:31	
	Off			20:28	19:23	
LED-107	On					
	Off					
LED-108	On					
	Off					
LED-109	On					
	Off					
EMS-15	On					
	Off					
1st Alert to Event Start		-0:04	no alerts	-0:05	-0.20	-0.04
Event Start to Activate		1:37	1:16	3:50	0:51	0:59
Event End to Deactivate		4:19	5:59	3:36	2:53	5:44
Event Duration		2:15	0:13	5:17	4:50	0:14
Message Duration		4:57	4:56	5:03	6:52	4:59
Message During Event		0:38	0:00	1:27	3:59	0:00
% of Event Messaged		28.1%	0.0%	27.4%	82.4%	0.0%
		= Primary RWIS Near Sign		= Secondary RWIS		

Analysis of Wind Event, April 26-28, 2010. A wind event that reached its peak intensity on April 27, 2010 is summarized in terms of the performance of the new alert notification system and the TMC responses to the event. Data are available from four sensor stations for this wind event, as shown on the accompanying graphs shown as Figure 18 - Figure 21 (there were technical problems with the Bryte Bend sensor site). Each graph shows sustained average wind speeds in miles per hour (mph) at or above 15 mph (horizontal blue line) and wind gusts at or above 25 mph (horizontal red line), the designated threshold for issuing a high wind alert. When both of these conditions are met, the system issues an alert to the RTMC operator. Prior to reaching this threshold, the system is supposed to issue warnings when winds are between 10 and 15 mph and gusts are over 15 mph. Warnings and alerts are not supposed to be issued more frequently than every two hours.

The results for the event on April 27th can be summarized as follows:

- The alerts were all very well timed for the start of the event (Table 16).

- Warnings apparently were issued only by the Richards sensor site (Figure 20), beginning approximately 17 hours before the event actually exceeded the defined threshold.

- Message coverage of this event was excellent, and in most cases the messages were activated prior to the start of the event and remained active well past the end of the event (Table 16).

- Messages uniformly were kept active a long time after the end of the event, ranging from 5 hours and 1 minute to 8 hours and 44 minutes longer than required (Table 16). It is difficult to determine the actual end of an event, and it is prudent to leave messages active until wind levels have abated. However, leaving messages up too long after an event has ceased risks public trust in the messaging.

- It appears that operators activated messages generally early, prior to the start of the event. In the case of the Richards sensor site, there were many warnings issued prior to the start of this event, which would have alerted the operator to check other sources of information and could have prompted an early advisory posting. For the other site where no warnings were issued, the early message posting may be due to confusion regarding the threshold criteria. Examination of the attached charts suggest that messages were posted when either average wind speed, or wind gust speed independently exceeded its threshold (the “or” condition). The fact that, in most cases, signs were activated before alerts were issued (in some cases by several hours) suggests a limited value of the alert system for triggering actions. However, operators report a value in subsequent alerts to maintain their awareness of the event condition.

- The TMC log for this event indicated the operators were more attentive to posting weather-related information than in the other events. Good information was posted in the log regarding receipt of alerts, verification with other weather sources and sensor data, sign activation decisions, and event monitoring.

- While many signs were activated for this event, many that could have been activated (based on operator guidelines) were not (see shaded cells in Table 16). While these decisions may have been fully appropriate, or guided by other contingencies, it is unclear from these data alone how the decision to activate or not activate a particular message sign is being made.

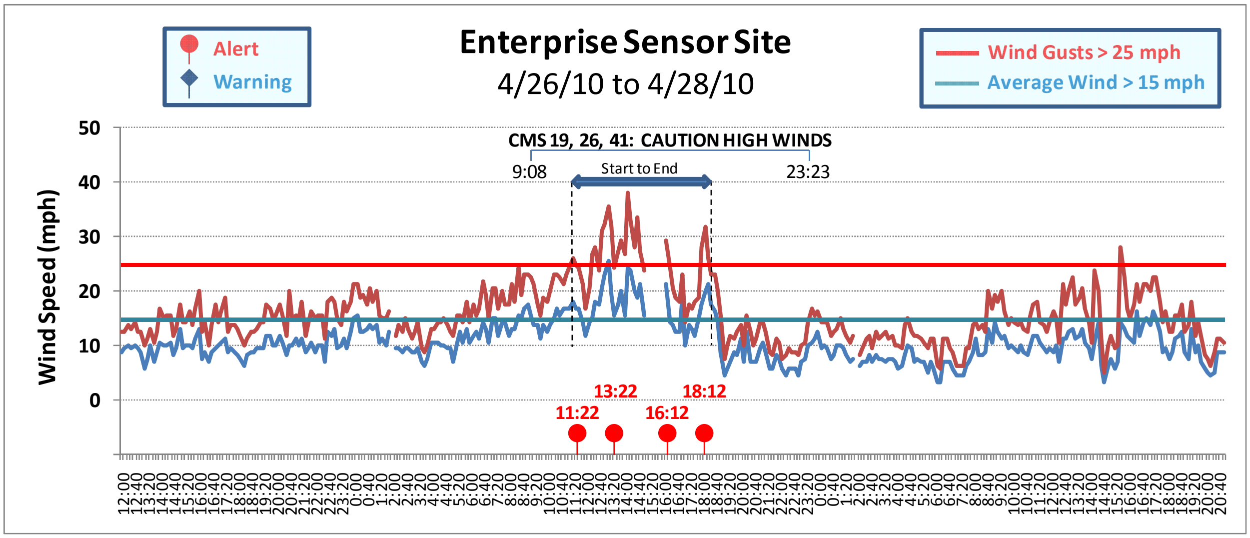

Figure 18. Wind Event, April 26-28, 2010, Enterprise Sensor

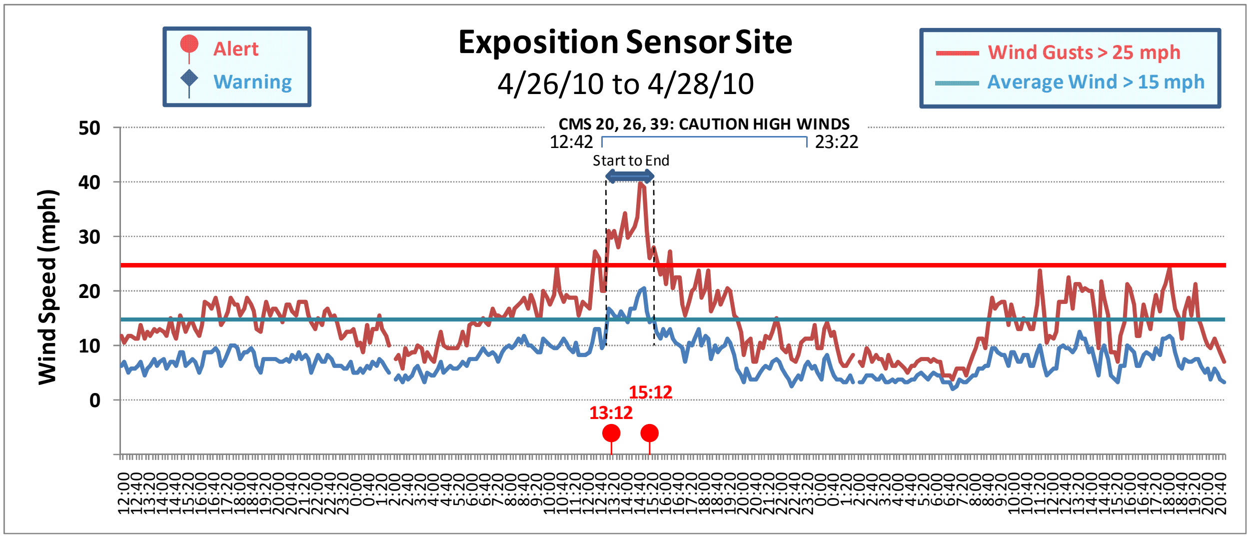

Figure 19. Wind Event, April 26-28, 2010, Exposition Sensor

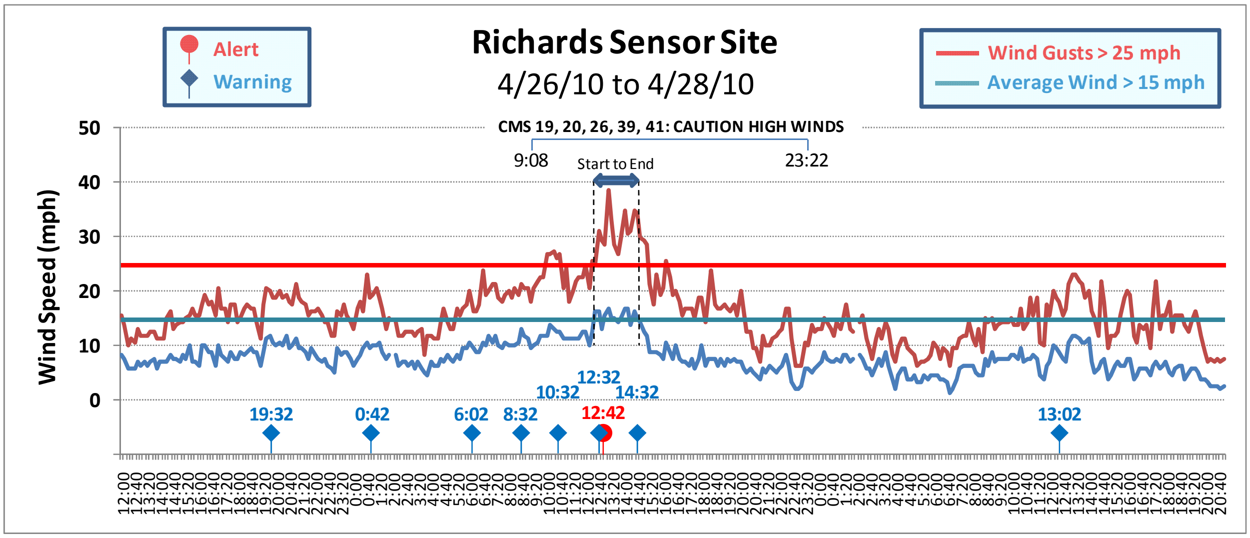

Figure 20. Wind Event, April 26-28, 2010, Richards Sensor

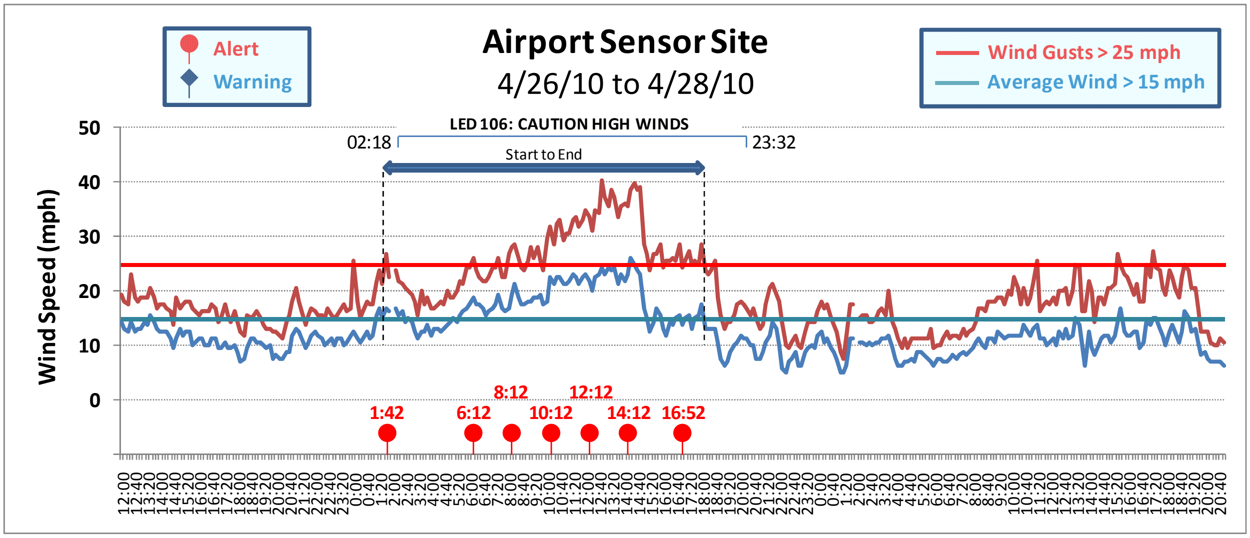

Figure 21. Wind Event, April 26-28, 2010, Airport Sensor

Table 15. Message Signs Activated During Event

CMS ID	Activation Time	Deactivation Time	Duration	Line 1	Line 2
19	4/27/2010 09:08	4/27/2010 23:23	14:14:05	CAUTION	HIGH WINDS
20	4/27/2010 12:42	4/27/2010 15:20	02:37:56	CAUTION	HIGH WINDS
20	4/27/2010 15:30	4/27/2010 23:22	07:52:43	CAUTION	HIGH WINDS
26	4/27/2010 12:43	4/27/2010 23:24	10:41:06	CAUTION	HIGH WINDS
39	4/27/2010 12:44	4/27/2010 14:52	02:08:20	CAUTION	HIGH WINDS
39	4/27/2010 15:01	4/27/2010 23:23	08:22:01	CAUTION	HIGH WINDS
41	4/27/2010 09:10	4/27/2010 23:22	14:12:49	CAUTION	HIGH WINDS
LED 106	4/27/2010 02:18	4/27/2010 23:32	21:14:00	CAUTION	HIGH WINDS

Table 16. Summary Statistics for Wind Event on April 26-28, 2010

		Enterprise	Exposition	Richards	Airport
Date		4/27/2010	4/27/2010	4/27/2010	4/27/2010
Event Start Time		11:15	13:05	12:28	1:37
Event End Time		18:23	15:30	14:40	18:05
First Alert Time		11:22	13:12	12:42	1:42
CMS-8	On				
	Off				
CMS-14	On				
	Off				
CMS-16	On				
	Off				
CMS-19	On	9:08		9:08	
	Off	23:23		23:23	
CMS-20	On		12:42	12:42	
	Off		23:22	23:22	
CMS-22	On				
	Off				
CMS-23	On				
	Off				
CMS-25	On				
	Off				
CMS-26	On	12:43	12:43	12:43	
	Off	23:24	23:24	23:24	
CMS-39	On		12:44	12:44	
	Off		23:23	23:23	
CMS-40	On				
	Off				
CMS-41	On	9:08		9:08	
	Off	23:22		23:22	
LED-105	On				
	Off				
LED-106	On				2:18
	Off				23:32
LED-107	On				
	Off				
LED-108	On				
	Off				
LED-109	On				
	Off				
EMS-15	On				
	Off				
1st Alert to Event Start		-0:07	-0:07	0:14	-0.05
Event Start to Activate		-2:07	-0:22	-3:36	0:41
Event End to Deactivate		5:01	7:54	8:44	5:27
Event Duration		7:08	2:25	2:12	16:28
Message Duration		14:15	10:40	14:15	21:14
Message During Event		7:08	2:25	2:12	15:47
% of Event Messaged		100.0%	100.0%	100.0%	95.9%

= Primary RWIS Near Sign; = Secondary RWIS

5.5 RTMC Operator Post-Implementation Interviews

Follow-up interviews were conducted with four of the RTMC operators in June 2010 after they had experience with the weather alert notification system. It was not possible to arrange for interviews with all of the operators, given their schedules and furloughs. However, two of the four operators interviewed in this period had been interviewed in the baseline a year earlier. The purpose of this interview was to learn how the alert system has been working from the operators' perspective. Some of the same questions were addressed for this interview as had been covered in the baseline interviews in order to assess any changes over this period of time. Also, some new questions were added to more specifically probe the operators' use of and perspectives on the alert system. The following questions (and paraphrased responses integrated across the four respondents) document what was learned during the interview.

1. Tell us about the weather alert system in the TMC. How does it work? And how do you respond to warnings and alerts? [Probe: Are the alerts accurate? Do they help improve the efficiency of your decisions?]

   Before we had this alert system, someone would call in from the field to inform us about the weather conditions. We could go to the NWS and other sources to verify the reported condition. We could call CHP to see if the winds are high, for example. It has been somewhat difficult to learn the new alert system. We get alerts via email from Ray Patron (ray_patron@dot.ca.gov). We try to verify the alert information too. A problem is that the sensor data are not or are only partly correct, and they are not accurate enough to rely upon them alone. We look at that sensor to see if it matches up with the alert information. We also check other sources, such as the NWS and AccuWeather, and we always try to use common sense. It seems that half the time the sensor readings may not be correct. Before we can trust the alert system, we need to verify it with a field representative. A sensor may detect low visibility, but that may just be due to a random cloud blowing through. Alerts say "pay attention" and be more proactive to watch sensors more frequently, and this is helpful to us. Sometimes it is hard to see the distinction between warnings and alerts. We start activating signs when the threshold is broken and we can verify the condition. Some of us send CHP out to verify a reading. Others who been here a number of years as operators rely on gut feeling.

   Some operators would like more detailed explanation of this new alert system and how these systems work (for example, how the sensors measure fog). Our computer screen sometimes cuts off critical data, such as the last digit of the wind speed or visibility, so it would show for example visibility greater than 50 feet when it really meant 500 feet. When the system goes down, we aren't getting warnings, so as a result we may be late taking messages down. It would be helpful for us to know when the system is down.

   In spite of some issues, operators say they have more confidence in the data now compared with last year. From their perspective it has been more accurate on average, allowing them to respond more quickly with the warnings and alerts.

2. We understand you have new operational procedures for handling weather events in the valley (wind, fog). Can you describe those? Are they helpful and effective? Do they need further improvements?

In the past, once wind hit a certain speed, we activated certain CMS on the roads to and from that sensor area (CMS or EMS). Or if one sign is used for chain control, we will try to use another appropriately located one for the wind message (chain control has priority). The recently provided messaging protocol guidelines are sometimes hard to use because they don't say specifically what you should do in response to an alert, or when to take an action or not take an action. When we have to train a new operator, it would be helpful to have this more specific guidance. There is turnover especially on the graveyard shift. Also, if a decision is made for the dispatchers to work more closely with the operators, they will have to know our procedures too. As far as fog is concerned we activate messages a few dozen times, so we need guidelines about what level to put on a sign, etc. Otherwise, we have to search through our old protocols for that guidance. There has been some confusion among the operators regarding the use of "or" rather than "and" for wind (sustained and gusts). The latest guidance is "or." For fog, we have three levels, but the guidance doesn't say how we deal with these levels differently. A fog advisory is a media message, versus sign "Fog Area." We put advisories in the CAD, and that goes out to the media. Media advisories are the first order of providing information to the public. Messages go up on the CMS when fog is intense.

We don't have clear standard operating procedures for the TMC operators. Everyone has their own way of doing things. Some seek to verify an alert, some actively post entries into the TMC log, some ask field personnel, such as CGP to verify a reported condition. Each operator does things a little differently. Some operators don't agree with verifying with two or more sensors because you can have a real event at one and not at another. Operators are generally complying with the new procedures and the need to document events and their decisions in the TMC log.

3. A number of factors go into a decision to post a weather warning message, such as warnings and alerts, and your need to confirm the observation with other sources. Please describe the factors you consider, including warnings, alerts and any other factors. [Probe: traffic conditions, CHP observations, Motorists Assist Trucks, other?]

   Operators don't post messages based on just one sensor reading and often will send CHP out to verify an alert or sensor reading or consult the CCTV if images are available in the weather area. I look out the window. I also look at AccuWeather and the NWS, but all those services tend not to be consistent with each other. They are a tool I use but I don't believe in them totally. I trust what I can see or what other human observers say. SCAN Web is good but it goes down a lot. We used to be taught that if one sign goes up, they all go up. But that's not the policy now. We figure out what signs seem to make sense, taking into account directions of travel with respect to the event location, and using judgment based on experience.

   We have to consider the sensor reported conditions carefully. The sensors can show wet in some places and dry in others within a 10 mile radius when we know everything should be dry. If CHP calls in, that's quite reliable, because they are trained observers and we trust them, and are more confident to act on what CHP says.

4. Have the data you get from field sensors via SCANWEB that trigger the warnings and alerts improved in quality/accuracy? Have there been changes in the sources of weather data you

are now receiving (number, location, etc.)? Are you using the information differently than in prior years? Are you more confident in the data now than you were last year?

Sensors (SCAN Web) are working more often than not, so they are better than before. But some operators still don't have a lot of confidence in the accuracy of the data. For example, we saw high winds from most sensors, and SCAN Web confirmed that also. So we activated signs, then notified CHP. But another CHP officer at the airport said nothing was happening and to take the message down. Then a different CHP officer in the field called back and said there was a big wind storm. We have been told to go with the person in the field. When one of our operators was hired several years ago, she was told you can be personally liable if someone's life is lost. Most operators try to cover themselves by entering their decisions in the TMC log, though some operators still don't put much information into the TMC log.

Sometimes the SCAN Web information doesn't match what the cameras show. This reduced confidence in the system. Many operators compare the National Weather Service and Weather Channel information with SCAN Web in addition to looking at cameras. Then, based on all the available information, they decide whether and when to put up a wind advisory.

5. The warnings and alerts help with posting messages on signs (EMS, CMS, LED), but what about deactivating the messages? Is this system providing any better help with that than last year? How do you determine when to remove a fog or wind message?

The operators are teaching each other how to read the information off SCAN Web. The operators said they would like more training on how best to use this equipment. They check SCAN Web for when it goes down below threshold. One of the experienced operators says let's wait a half hour because it might go above again. Now that there is only one operator on the floor during a shift, their attention to weather may be diverted to other higher priority responsibilities so they can't focus solely on weather. When they were double staffed day and swing they could cover weather events better, but now they only have one person on the floor at a time. This is especially a problem in the winter operations when everything happens at once. Sometimes an operator's ability to place an entry in the TMC log is an hour late due to other higher priority activities.

In deciding when to deactivate a message, operators generally wait for the winds to drop, but they realize the system won't tell them when that happens. Some go to AccuWeather and check weather first thing at the beginning of their shift so they know what to expect. Some will ask CHP if it is still windy in the field. Operators recognize they need to monitor these conditions themselves.

Some CHP officers will call in if a sign is still active when the fog is actually gone. Operators then check other sources to try to verify conditions, then take down the sign. They don't want to leave fog advisories up if the event is over because people will ignore the signs.

6. Overall, do you think the improvements made to the weather sensors in the field and the alert system in the TMC have led to more timely and effective posting of messages for the traveling public? If yes, describe how. If not, discuss why not. [Probe: Has the economic downturn had an impact on your ability to get your job done in the TMC?]

We have something to start with now. We have something to bring our attention on to events. Messages are getting up sooner, and that is our goal. I am aware of events I might have otherwise missed. I believe I can post messages more quickly now than prior to the alert system.

7. Please describe how the operators in the TMC handle and exchange weather information among each other. Would you say the exchange of weather information enhanced overall operational performance this past winter? If so, describe how.

   We want to be responsive. All we want is to be clearly instructed about what we should be doing and care about us, and we'll be supportive. Some operators feel that they don't receive the attention and recognition they would like: "We're like mushrooms." They want consistency and clarity in the procedures they are expected to follow.

8. We would like to show you a couple of examples of wind and fog events that have occurred in the past few months and discuss how the system worked in these particular events (let us know if you were among the operators on duty during any of these events). Please help us understand the details of the event and decisions made.

   Operators were shown some of the event analyses from this evaluation. They said this was a helpful way to show where they can improve their performance based on data from actual past events. They are concerned when priority events prevent them from providing optimal advisory timing to motorists. Sometimes they can't get messages up or down when they know they should because of accidents or chain control for which they are responsible. One operator said they thought they are not as proactive now as they used to be or as they should be. This is partly due to staffing reductions and partly due to feeling unclear about the procedures for posting and removing messages.

9. Are there any other things you would like to discuss that might help us better understand the value or benefit provided by the weather warning and alert system in the TMC?

   In Sacramento we are quite careful about selecting which signs to activate. We tend not to trust weather information called into the TMC by citizens but to trust CHP or emergency assist people.

   It would be helpful to know who put a message up, particularly when there is overlap in shifts. We're a little unclear about the distinctions between warnings and alerts and the intervals at which those are provided. But it is worth having warnings ahead of time. The alerting system would be really good if SCAN Web worked perfectly. Periodic alerts remind us that the condition is still out there. We wouldn't change that.

6 Evaluation Findings and Lessons Learned

The evaluation of the Sacramento RTMC weather alert notification system examined several adverse weather events in detail in order to assess quantitatively how the alert system was performing and how the operators were able to use it in supporting their operational decisions regarding posting of advisory messages. While the initial objective was to collect data before the alert system was implemented (baseline) and then again after implementation, the data in the baseline were sparse and not comparable in completeness and quality with the data available in the post-implementation period. Therefore, the quantitative analysis focused primarily on the post-implementation data obtained from the RWIS sensors, the alert system records, and message sign records. Quantitative findings are examined for three main measures of performance: 1) the timeliness of issuance of warnings and alerts, 2) timeliness of operator activation and deactivation of messages, and 3) the adequacy of use of available message signs in the valley relative to those sensor sites that were reporting adverse weather conditions.

These results are interpreted within the limitations of the information available, recognizing that many factors influence operator decisions and opportunity to take timely actions. Where possible these factors are identified and caution advised in drawing unwarranted conclusions from these available data. The evaluation lacked data on many of these relevant factors; hence, the data on the event cases are interpreted with these limitations in mind, and the reader must be cautious in inferring anything further regarding operational performance.

Qualitative findings are based on interviews with selected operators. It was not possible, given conflicting schedules, to interview every operator. Interviews were conducted in the baseline period, and follow-up interviews were conducted a year later after the alert system was in place. These conversations were paraphrased and reported in a way to maintain the anonymity of the participants while seeking to retain the flavor and nuance of their observations.

Finally, considering both the data collected over the evaluation period and observations of the process while working with the management team and RTMC operators, some lessons that may be of value to the larger transportation community from the Sacramento RTMC experiences are discussed.

6.1 Quantitative Findings from the Weather Event Case Studies

- **Timeliness of Alerts**. Alerts should be issued to coincide with the start of an event, when conditions exceed the defined threshold. Across the four event periods analyzed, alerts were issued for the most part in a timely and accurate way; that is, 16 out of 18 times (for individual RWIS sensors) they were issued within +/- an average of 10 minutes of the time when the weather condition broke its defined threshold value at the beginning of the event. This is virtually right on time, given measurement error, particularly in the timing of the threshold crossing (an interpolated value between two adjacent readings). In the other two cases, one alert was issued a half-hour after the start of the event and in the other case, no alert was apparently issued. **Interpretation:** The alerts were mostly accurate, indicating the alert notification system was working as planned.

- **<u>Timeliness of Message Activation</u>.** The RTMC aims to have messages posted on appropriate message signs for the duration of a weather event that exceeds the defined threshold. There were 6 discrete event periods covered by the four event case studies presented in this evaluation that offered an opportunity to assess how much of the defined event period was messaged. Figure 7, Figure 8 and Figure 16 illustrate how two discrete events were identified in the case studies. Each of these discrete events involved different sensors providing weather data and issuing warnings and alerts. Fifteen individual sensor-reported weather events that exceeded threshold and/or lasted longer than 16 minutes should properly have had weather warning messages posted throughout those events; 13 of them did and two had no messages posted. For those event segments with some message coverage, coverage ranged between 27% and 100% of the duration of the event. Out of the 13 events with message coverage, 11 had coverage over 75% of the duration of the event. **Interpretation:** Messaging coverage was fair but not complete. However, coverage improved over the duration of the evaluation from December 2009 to April 2010, suggesting that the alerts were helping operators post messages more appropriately.

  <u>Adequacy of Messaging Coverage</u>. The second dimension of messaging adequacy related to the posting of messages triggered by sensor alerts on the primary signs near the sensor site. As discussed in this report, there are a number of mitigating circumstances that might reasonably prevent posting weather messages on some of these signs. For example, during road emergencies the signs may be needed for traveler alerts, and during mountain snow events, some valley signs may be used for chain control advisories. Nevertheless, across all these case study events, the number of CMS, EMS and LED signs used was significantly less than the number of signs recommended in the RTMC policy guidelines. For the December fog event, out of 8 opportunities to activate primary signs for significant events, only 2 were used, along with 2 out of 8 secondary signs. For the three wind events taken together, out of 43 opportunities to activate the primary signs for significant events, 12 were used (28%). However, the ratio of messaging on primary signs improved over time, with 7 out of 17 (41%) used in the April wind event. **Interpretation:** A low number of primary message signs had messages posted during the weather event case studies examined, but coverage improved over the course of the evaluation period, presumably due to the operators' increasing familiarity with and understanding of the new procedures.

- **<u>Timeliness of Message Deactivation</u>.** Once a message has been posted advising the traveling public about an existing severe weather condition (e.g., dense fog, high winds, frost on road), the operators need to periodically monitor conditions to remove the message after the weather condition has abated and it is reasonable to assume it is not about to return to threshold conditions soon. This is a judgment call, as the alert notification system does not provide explicit guidance regarding when a weather event is over. The alert notification system will continue to provide warnings and alerts in three hours or longer intervals as long as the weather conditions persist, which is helpful to the operators in maintaining their awareness of the status of these conditions. It is considered prudent to leave a message active for a while as conditions are improving in order to avoid frequently activating and deactivating messages. On the other hand, leaving a weather warning message posted long after the event is over may lead to a loss of public trust in the messages. The events examined in Chapter 5 illustrate the difficulty presented to the operators, as every event period as defined involved fluctuations in conditions above and below the designated threshold for messaging. The RTMC management is considering how their alert notification system might be able to issue an “all clear” signal based either on the length of time that passes after last crossing the threshold with an improving trend or the time when conditions reach a designated level after last crossing the threshold.

For 14 sensor-covered event segments for which messages were activated among the four case studies, the period from the end of the event to message deactivation ranged from 18 minutes (see Figure 7) to 8 hours and 44 minutes (see Figure 20). This extended period of message activation equaled an average lag time of 4 hours and 14 minutes. This is the average period of time during which a message was posted on a roadside message sign indicating an adverse weather condition after that condition no longer exceeded the defined threshold. Without knowing the detailed circumstances associated with each of these events, it is not appropriate to make a definitive judgment about them. For example, operators often rely on CHP in the field to verify conditions for activating messages, but after the weather has improved, CHP is usually no longer available at those locations to advise the operators to deactivate the message. **Interpretation:** While the RTMC has not specified an appropriate amount of time to leave a message actively displaying an advisory about weather that has since subsided, nor implemented alerts to signal that time for the operators, the experience with many of these sensor-covered event segments shows there were a number of periods during which messages were left active much longer than needed or desired.

6.2 Qualitative Findings from the RTMC Operator Interviews

The operator interviews from the baseline period, as reported in Section 3.2, and from the post-implementation period a year later, as reported in Section 5.4, were reviewed for comparative findings as summarized below. Where the same or very similar questions were asked of the operators in each period, results of those comparisons for changes in operator perspective over this period are also summarized.

- In the baseline period the operators reported they would like to have more frequent weather updates. They also said they lacked adequate weather readings for some important locations in the valley.

- In both the before and after periods, operators expressed less than high confidence in the quality and accuracy of the weather data they were receiving in the RTMC. They uniformly said it was critical to confirm either data from sensors with human observations or readings from other sensors, or human observations with sensor readings. This follows management guidance that all weather data be verified with one or more additional sources before making a decision to post a travel advisory message. They did, however, perceive that sensor data quality had improved over this period.

- Operators in both periods felt that operating procedures and guidelines for making decisions based on reported weather conditions were less than adequate. Some said they desired additional training and consistent information on how to respond to the weather data (observations and forecasts) that they receive in the RTMC. Other experienced operators felt they knew how best to perform their job responsibilities without need for additional management oversight.

- RTMC operators want to be proactive with regard to weather. They want to be aware of impending weather conditions likely to affect traffic in advance if possible so that they are well prepared to respond in an appropriate and timely way. However, they feel that in practice they tend to primarily be reactive to weather, and as long as they receive the information they need in a clear and timely way, they respond appropriately.

- In the baseline period the operations floor was staffed most of the time with two operators who then could share the workload. In the later period after furloughs and staff reductions, there was typically only one operator. This meant responses to weather events had to take second priority to higher priority safety matters, and there would be response delays due to very busy shift activity.

- The operators valued the warnings and alerts that were available to them in the post-implementation period, though they felt it necessary to verify their accuracy before taking any actions based on them. They said the automated alert system has made them more aware and allowed them to be more responsive to events as they unfold.

6.3 Lessons Learned from the Experience Developing the Alert Notification System

Several lessons can be drawn from this evaluation of the experience of the Caltrans District 3 RTMC and their efforts to establish and refine an automated weather alert notification system. What has been learned, and continues to be learned, as this system matures and becomes more a part of the operating procedures of the RTMC, can be helpful to both Caltrans and other TMCs across the country as they explore ways they can integrate weather information into their operations. These lessons include the following:

- **Operator training is essential for successful weather integration.** Both the RTMC management and the operators recognize the importance of training to help assure a well informed and consistent use of the new weather alert notification system. Providing this training to all the operators as a group has been a challenge in the face of the recent staff reductions and furlough policy enacted by the State of California. The training content should include clear operational policy guidance along with conveying to the operators an understanding of the system upgrades and changes, how and why they have been made, and how these affect the weather information flowing into the RTMC. A challenge is to strike an appropriate balance between the level of specificity in operational guidance for taking action in response to weather, and providing flexibility for the operators to use their experience and judgment in making decisions about their advisory and control actions.

- **Alert notification procedures need to be clearly and consistently specified.** It is important that the thresholds for issuing warnings and alerts that are programmed into the notification system be consistent with the specifications communicated to operators in the written procedures and training content, and that the operators understand and follow these procedures. The Caltrans District 3 procedures call for operators to verify an alert with information from adjacent RWIS sensors, available third party weather services (NWS, AccuWeather, local weather reports, etc.), and/or field observers (typically CHP, sometimes general public calling in). Reconciling differences among these information sources about a particular weather event condition takes experience and judgment on the part of operators. Procedures and training must account for the complexity of operator decision making based on information of varying accuracy, reliability and geographic focus.

- **A successful demonstration of an alert system depends on a well-integrated system.** The Caltrans District 3 system is built off their existing SCAN Web software that monitors data from RWIS sensors and can be programmed to issue warnings and alerts when pre-defined weather condition thresholds are reached. The success of this system depends on accurate and reliable weather data from the sensors, appropriately defined threshold conditions, clear communications of alerts to the operators, procedures in place that guide operator responses, and operator training and buy-in to assure effective use of the information. The RTMC management has remained flexible and responsive throughout this demonstration period to understanding where their alert notification system could be fine-tuned and improved as they experienced its use under various weather events. This has provided a foundational experience upon which they can consider a more robust alert system for the future that adds features and capabilities that are not currently available with existing hardware and software. For example, adding new strategically located sensors, upgrading the weather detection capabilities of the sensors, adding better detection and notification of the end of a weather event, adding possible visual and auditory notification in the RTMC, and refining their procedures, are all candidate improvements that have been identified in the course of operating the current system through this weather integration demonstration.

- **Time and resource constraints affect the performance of an alert notification system.** The State of California is experiencing a severe economic downturn that has resulted in reduced staffing and furloughs among TMC management and operators. This has raised the stresses associated with getting the day-to-day work done and made it more difficult to integrate the weather alert notification system into TMC operations. Operators have competing priorities and fewer operators to meet these responsibilities. Management faces similar constraints, resulting is less time to focus on new weather integration initiatives such as the alert notification system. TMC management also is constrained by time consuming procedural requirements of Caltrans associated with the implementation of new projects. These kinds of constraints need to be anticipated and understood when implementing new systems like this and contingency plans developed to overcome the constraints. There were several planned activities that were not accomplished due to funding or time constraints, including installing new RWIS sites and developing a more sophisticated alert system with enhanced capabilities. Based on the progress made to date, the RTMC management intends to improve their alert system as new funding can be secured.

In implementing the weather alert notification system, management developed a good step-by-step implementation plan that has guided them through the process. A critical task early in this process was to engage a contractor to calibrate the RTMC's field sensors. In the baseline period the operators reported having very little confidence in the data they were receiving from the sensors. After sensor recalibration and implementation of the alert notification system, operator confidence improved, though there remained some carryover of the perception that these data were still suspect. Operator training can help overcome such skepticism by explaining clearly what has been done to improve the data quality in the system and providing evidence that shows these improvements.

The use of the TMC logs offers a good example of how operators are learning to work with the alert notification system. The new procedures have emphasized the importance of making log entries that document and explain the actions operators have taken in response to receipt of the alerts, and the operators' logging performance has improved over this period. RTMC management also has made good progress implementing this system and responding in real time to the need for mid-course adjustments, refinement of procedures, and oversight of the operators. The evaluation process has served to identify ways the notification system, and the institutional support for the system, could be refined, and the result of this collaborative interaction with the RTMC is reflected in the benefits being derived from the alert notification system. Ultimately, it is the traveling public that is the beneficiary of these RTMC system innovations in terms of enhanced mobility and safety during periods of inclement weather and dangerous road conditions.

6.4 Conclusions and Recommendations

The Sacramento RTMC has experienced a number of benefits from the implementation of their weather alert notification system, and as they are able to make improvements in the system in the future, further benefit can be expected. Two key benefits include:

- Awareness of the important role that weather plays in the operation of the region's traffic systems, from management to the floor operators, has been enhanced throughout the process of evaluating the RTMC's need for greater weather information integration and through the implementation of a basic alert notification system. Enhanced recognition of the need to manage the effects of weather on traffic, to be more proactive in preparing operators and the traveling public to deal safely with weather impacts, and experience integrating a weather warning system into the RTMC operations has created a foundation upon which the RTMC can make effective future improvements.

- Going through a step-by-step process of calibrating sensors, verifying alerts (timeliness and accuracy), instituting revised procedures in support of operational decisions, and becoming increasingly efficient and comfortable managing the system supported by warnings and alerts have increased confidence in decision making throughout the RTMC. It is expected that the traveling public finds the information increasingly useful and trustworthy as well, though that could not be directly assessed within the scope and timing of this evaluation.

Although Caltrans faces difficult economic challenges at this time, the Sacramento RTMC intends to upgrade their alert notification system as their budget and staffing constraints will allow. Recommendations from this evaluation that could help guide such improvements include the following:

- The current alert notification system has been built off an existing system that is not capable of providing the level of performance that is desired. A more refined system is anticipated to have the capability of alerting operators when weather conditions drop below threshold and no longer represent a danger and will encompass enhanced weather information in order to be able to produce more effective alerts.

- Installation of new RWIS ESS in critical weather locations, with enhanced capabilities for detecting fog and wind conditions. Existing and new RWIS will need to be closely monitored to assure they are properly calibrated and functioning appropriately.

- Continued attention to training and oversight of the operators to assure full understanding of the weather alert notification system, adherence to consistent procedures for making decisions under adverse weather conditions, uniform protocols for verifying alerts, and an effective feedback system that supports a process of continuous improvement in operator performance.

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