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Communication Plan for Windblown Dust

Arizona Department of Transportation Research Center

ADOT

Communication Plan for Windblown Dust

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16. Abstract

Windblown dust events occur in Arizona, and blowing dust has been considered a contributing factor to serious crashes on the segment of Interstate 10 (I-10) between Phoenix and Tucson, as well as on other Arizona roadways. Arizona's dust events can be regional or localized in scope. Regional events often originate with the influx of monsoonal moisture during the mid- to late-summer period. Localized events can occur when the passage of cold fronts produces strong pressure gradients that drive high winds across the fronts. Such winds can drive dust "channels" that are difficult to predict or remotely detect.

Currently, the Arizona Department of Transportation (ADOT) acquires information about predicted or in-progress dust events through National Weather Service forecasts and advisories and through field reports from motorists and ADOT personnel. ADOT then communicates this information to the public using a variety of methods, including roadway message signs, e-mail blasts, and social media outlets (e.g., Twitter). In addition, ADOT has developed the "Pull Aside, Stay Alive" public outreach campaign, which is focused on increasing safe driver behavior during dust events. ADOT has also recently implemented a pilot dust monitoring system on a 26-mile stretch of I-10 in the Safford District.

During this project, researchers developed a set of recommendations that ADOT can implement to identify the most effective means for acquiring data about windblown dust events, communicating information about these events to the public, and influencing driver behavior during dust storms in the future.

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List of Acronyms

Term	Definition
ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
ALDOT	Alabama Department of Transportation
Caltrans	California Department of Transportation
CCTV	closed-circuit television
CHP	California Highway Patrol
DMS	dynamic message signs
DOT	department of transportation
DPS	Department of Public Safety
DREAM	Dust REgional Atmosphere Model
DUST	Dual Use Safety Technology
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FLIR	forward-looking infrared
GDOT	Georgia Department of Transportation
GFS	Global Forecast System
GTRI	Georgia Tech Research Institute
HAR	highway advisory radio
ITD	Idaho Transportation Department
ITS	intelligent transportation system
LaDOTD	Louisiana Department of Transportation and Development
MCAQD	Maricopa County Air Quality Department
MIST	Management Information System for Transportation
MSHA	Maryland State Highway Administration
msl	Mean sea level
MVD	Motor Vehicle Division
NASA	National Aeronautics and Space Administration
NCDOT	North Carolina Department of Transportation
NDOT	Nevada Department of Transportation
NMDOT	New Mexico Department of Transportation
NMM	Non-Hydrostatic Mesoscale Model
NWS	National Weather Service
ODOT	Ohio Department of Transportation
PCAQCD	Pinal County Air Quality Control District
PennDOT	Pennsylvania Department of Transportation
PIO	Public Information Officer
PM	particulate matter
PSA	public service announcement
RWIS	Road Weather Information System
TDOT	Tennessee Department of Transportation
TMC	Traffic Management Center
TOC	Traffic Operations Center

Term	Definition
TRID	Transportation Research International Documentation
UCF	University of Central Florida
UDOT	Utah Department of Transportation
VDOT	Virginia Department of Transportation
VMS	variable message signs
VSL	variable speed limit
WRF	Weather Research and Forecast

EXECUTIVE SUMMARY

SUMMARY

Windblown dust events occur in Arizona, and blowing dust has been considered a contributing factor to serious crashes on the segment of Interstate 10 (I-10) between Phoenix and Tucson, as well as on other Arizona roadways. Arizona's dust events can be regional or localized in scope, with regional events often originating with the influx of monsoonal moisture during the mid- to late-summer, producing high winds along the outflow boundary of thunderstorms. Localized events can occur when the passage of cold fronts produces strong pressure gradients that drive high winds across the fronts. Such winds can drive dust "channels" that are difficult to predict or remotely detect.

Currently, the Arizona Department of Transportation (ADOT) acquires information about predicted or in-progress dust events through National Weather Service (NWS) forecasts and advisories and through field reports from motorists or ADOT personnel. ADOT then communicates this information to the public using a variety of methods, including roadway message signs, e-mail blasts, and social media outlets (e.g., Twitter). In addition, ADOT has developed the "Pull Aside, Stay Alive" public outreach campaign, which is focused on increasing safe driver behavior during dust events. ADOT has also implemented a pilot dust monitoring system on a 26-mile stretch of I-10 in ADOT's Safford engineering district.

This project developed a set of recommendations that ADOT could implement to identify the most effective means for acquiring data about windblown dust events, alerting the public to these events, and influencing driver behavior during dust storms in the future. To do this, the project team:

- Identified and documented ADOT practices for receiving and communicating information to travelers about approaching and existing windblown dust to travelers.
- Identified how other transportation agencies across the United States acquire information for reduced-visibility events on roadways and to disseminate that information to the public.
- Performed a literature review on visibility detection warning systems and on effective methods for improving safe driver behavior.
- Conducted a survey and two focus group events to collect information from Arizona travelers on their experiences with driving in dust storm events and with ADOT's efforts to communicate information about these events.

RECOMMENDATIONS

ADOT's current practices for acquiring and disseminating information about dust events and dust safety can be categorized as: (1) dust detection and forecasting; (2) event-based communication; and (3) public education and outreach. Each recommendation is designated as a step to be considered for short-, mid-, or long-term implementation, with definitions of these classifications provided below:

- **Short-term** – actions that can likely be implemented within the next year with existing ADOT resources and staff
- **Mid-term** – actions likely to require one to three years to implement and that may involve the participation of external partners or financial resources

- **Long-term** – actions likely to require more than three years to implement and that may require extensive cooperation and coordination with external partners

Dust Detection and Forecasting

ADOT can benefit from improving the timeliness and accuracy of dust detection and forecasting methods, particularly in regard to localized dust channels, which are harder to predict and detect than large-scale events. Key findings and recommendations for this area of focus include:

- Due to the widespread occurrence of dust storms in Arizona and the difficulties associated with detecting localized dust events, a dense network of sensors, deployed as part of a comprehensive communication plan, could be beneficial in some regions. Because of the expense and maintenance issues identified with optical sensors used in the Safford pilot project and in other states, pilot studies aimed at evaluating alternative small-sensor technologies are recommended. [***Mid-term:*** *requires partnerships with NWS, universities, air quality agencies, or other organizations familiar with implementing available technologies.*]
- Due to the importance of providing accurate and timely information to drivers, additional sensor deployment should be augmented with human verification through closed circuit television (CCTV) cameras or field observations where possible. [***Mid-term:*** *can be implemented once appropriate sensor technologies are identified.*]
- Because current meteorological modeling and observational techniques do not adequately capture localized dust events, research aimed at improving existing modeling approaches is recommended. [***Long-term:*** *ADOT does not perform meteorological research, but the agency's continued partnership with NWS and the University of Arizona could help to promote and inform such research.*]

Event-Based Communication

When disseminating information about Arizona weather events and driving conditions, ADOT can benefit from communication strategies using the tools and media channels that drivers of various age groups prefer. Key findings and recommendations for this area of focus include:

- Due to the preference of younger (age 16 to 34) survey respondents for online and social media tools, ADOT should aggressively market the agency's existing suite of communication tools (e.g., the ADOT Twitter account, the AZ 511 website, and the ADOT Facebook page) and investigate other innovative ways to disseminate real-time weather information across smart media and any promising social media channels that may develop in the future. [***Short-term:*** *this step primarily involves the expanded use of existing ADOT tools.*]
- Because nearly half of survey respondents reported receiving weather information through mobile applications ("apps"), ADOT should examine the feasibility of developing a free ADOT mobile app to take advantage of this shift in consumer media consumption. [***Mid-term:*** *requires an assessment of potential conflicts with ADOT's messaging on distracted driving and would be based on funding availability for app development and maintenance.*]
- Due to the significant number of survey respondents (59 percent) who reported obtaining weather information from highway message boards and the concerns expressed about the

distribution and messaging of such signs, ADOT should consider expanding the number of dynamic message signs (DMS) in identified dust "hot-spots" (e.g., the Picacho Peak area on I-10) and adding instructional information (e.g., "During limited visibility, pull off road, turn off lights") to existing warning messages. [***Long-term:*** *may require significant infrastructure investment in some areas and additional research into appropriate action-directed messaging.*]

Public Education and Outreach

Project findings suggest the need to fine-tune ADOT's "Pull Aside, Stay Alive" campaign and to explore opportunities to communicate with professional truckers and other pass-through drivers who may be unfamiliar with the campaign. Key findings and recommendations for this area of focus include:

- Due to confusion expressed by survey and focus group participants, ADOT should update the "Pull Aside, Stay Alive" website and other campaign materials to include information on the rationale behind driving tips; in particular, the tips related to pulling off the roadway, turning off lights, and setting the emergency brake appear to be sources of confusion. [***Short-term:*** *may require additional focus groups to test potential messaging.*]
- Though survey participants commended ADOT's "Dust on the Horizon" public service announcement (PSA) for its vivid portrayal of rapidly deteriorating visibility conditions, many felt that the piece should link the decision to drive in dust to the harsh consequences of doing so. ADOT should consider updating this PSA accordingly. [***Mid-term:*** *may be implementable in the short term, depending on resource and approval requirements.*]
- The survey, which targeted 44,000 ADOT e-mail subscribers and was promoted in ADOT media channels, produced only 49 non-Arizona residents as participants. This result may indicate that ADOT communications are not reaching out-of-state drivers, and that additional approaches should be developed to target this portion of Arizona travelers. ADOT should consider providing dust-related educational materials at rest stops, port-of-entry locations, visitor centers, and truck stops, as well as partnering with Department of Public Safety (DPS) to coordinate activities for contacting truckers and trucking industry groups. [***Mid-term:*** *may require significant planning and coordination.*]

ANALYSIS AND JUSTIFICATION

Reduced visibility from roadway dust has long been a concern in Arizona and has been the subject of previous research efforts over the past 40 years (e.g., Marcus 1976, Cowherd et al. 1997). In part, this issue is related to land-use patterns and other factors over which ADOT has limited direct jurisdiction. Nevertheless, ADOT seeks to do its part in communicating useful information to the public about this important safety issue. ADOT's current efforts, including the "Pull Aside, Stay Alive" campaign, go well beyond efforts identified in other states with roadway visibility issues, which are largely limited to providing warnings to drivers in the field.

Going forward, ADOT seeks to build on its current efforts and develop improved methods for communicating dust-related information to drivers in the field and through education and outreach programs. This research has identified several actionable recommendations that ADOT could implement to achieve this objective. Some of these recommendations are readily implementable in the short term with existing resources, while others require significant investments or collaborations with partner agencies.

CHAPTER 1. REVIEW OF CURRENT PRACTICES

BACKGROUND

Windblown dust events occur in Arizona, and blowing dust has been considered a contributing factor to serious crashes on the segment of Interstate 10 (I-10) between Phoenix and Tucson, as well as on other Arizona roadways. Arizona's dust events can be regional or localized in scope. Regional events often originate with the influx of monsoonal moisture during the mid- to late-summer, resulting in high winds along the outflow boundary of thunderstorms. Localized events can occur when the passage of cold fronts produces strong pressure gradients that drive high winds across the fronts. Such winds can drive dust "channels" that are difficult to predict or remotely detect.

The Arizona Department of Transportation (ADOT) has previously used a variety of methods to communicate information about dust storms to motorists, including the "Pull Aside, Stay Alive" campaign. That campaign focuses on improving safe driver behavior during dust events. ADOT has also implemented a pilot dust monitoring system on a 26-mile stretch of I-10 in the Safford engineering district (see Figure 1).

Figure 1. Location of ADOT Safford District Pilot Project (Blue Box)

The goal of this project was to develop a set of recommendations that ADOT can implement to identify the most effective means for acquiring data about windblown dust events, communicating information about these events to the public, and influencing driver behavior during dust storms. As a first step toward achieving this goal, the project team identified and reviewed practices used by transportation agencies to detect and respond to windblown dust and other reduced-visibility events on roadways. Specifically, the project team:

1. Identified and documented ADOT practices for receiving and communicating information about approaching and existing windblown dust to travelers.
2. Identified practices employed by other transportation agencies across the United States to facilitate intra-agency communication and to disseminate information to the public about reduced-visibility events on roadways.

This chapter documents the methods used to complete this research and summarizes key findings. Chapter 2 of this report documents findings from a needs assessment performed to evaluate the extent to which current ADOT practices meet the need for windblown dust detection and communication along I-10 and other impacted roadways in Arizona. This needs assessment included the gathering of information from Arizona travelers through a survey and two focus groups. Chapter 3 provides a synthesis of overall project findings and a set of recommendations that ADOT might implement to effectively acquire and disseminate information about approaching and existing windblown dust events.

Technical Approach

To identify past and current research on roadway visibility issues, the project team conducted a comprehensive literature review to identify journal articles, government agency reports, and other publications on this topic. This literature review was conducted using a variety of sources, including the Transportation Research International Documentation (TRID) database, Google Scholar, and Engineering Village.

To identify practices in Arizona related to windblown dust events, the project team contacted numerous ADOT staff members who have worked on dust-related issues, including staff from the ADOT Research Center, Communications Office, Emergency Preparedness and Management Group, Air Quality Program, and Traffic Safety Section, as well as engineering district offices in Phoenix, Tucson, Safford, and Holbrook. The project team interviewed these individuals and acquired reports, presentations, and other materials related to windblown dust. In addition, the project team interviewed staff members from other Arizona agencies and organizations that work with ADOT to detect and respond to windblown dust events, including the Arizona Department of Public Safety (DPS), the NWS, the University of Arizona, Pinal County, and Maricopa County. Interviews focused on each individual's role and experiences with predicting, detecting, and responding to windblown dust events in Arizona and were tailored to the individual's organizational affiliation. Following each interview, a summary of the discussion was written, and any materials gathered from the individual being interviewed were reviewed. A complete list of individuals interviewed is provided in Appendix A.

Recognizing that agencies in other states also face roadway visibility issues due to windblown dust and other weather phenomena such as fog and windblown snow, the project team interviewed staff at agencies that have deployed various types of systems and approaches to detect reduced visibility on roadways and provide warnings to travelers. A hybrid approach was taken to identify and document the warning systems used by different states. First, results of the literature review described above were used to identify visibility warning systems that had previously been documented and to develop a list of prospective contacts for gathering information about these systems. In addition, through past work, the project team was aware of other systems that have not been documented in literature, and agencies deploying these systems were also identified and contacted. A complete list of individuals from outside Arizona who were interviewed (including their respective agencies) is provided in Appendix B.

Once the agencies, systems, and prospective contacts had been identified, the project team conducted telephone interviews to obtain the information of interest. This information included the nature of the problem being addressed, its frequency and scope, the approach(es) taken to address it, and an overview of the system(s) employed. For the non-Arizona agencies, the project team used a specific set of questions during each telephone interview to ensure that uniform data would be obtained from each contact; the list of questions is presented in Appendix C.

Historical Background

Windblown dust associated with thunderstorms or frontal passages has long been considered a contributing factor to visibility impairment and motor vehicle crashes on Arizona roadways. Such crashes have frequently occurred on the portion of I-10 between Phoenix and Tucson (mileposts 160 to 250). A 1976 study evaluated the frequency of dust-related crashes between I-10 mileposts 170 and 240 from the years 1968 through 1975 (Marcus 1976). A total of 32 such crashes were identified during that eight-year period, with 18 crashes (56 percent) occurring between mileposts 200 and 220 near Picacho Peak, as shown in Figure 2. In addition, 27 of the 32 crashes (84 percent) occurred during the summer months of May through September. This 1976 study also found that a wind speed of at least 10 mph was required to raise dust in the I-10 study area; however, the frequency of blowing dust occurrences by month did not correlate to monthly mean wind speeds due to the influence of other factors such as wind direction and land use (Marcus 1976).

A 1997 study examined dust-related crashes from 1985 through 1996 along the entire span of I-10 from the California state line to the New Mexico state line (Cowherd et al. 1997). The researchers identified 46 dust-related crashes on I-10 during that time period, with 35 of those crashes (76 percent) occurring during the summer months of July and August. Only 14 of the crashes (30 percent) occurred between mileposts 170 and 240, the section of I-10 examined in the 1976 study. During the 1997 study, wind direction analyses were performed for each of the 46 dust-related crashes identified, and it was determined that blowing dust originated from a variety of land use types, including active and abandoned farmland, disturbed desert areas, unpaved parking lots, and construction sites (Cowherd et al. 1997).

An NWS analysis of dust-related crashes identified 100 traffic fatalities associated with dust storms from 1955 to 2004. These incidents were distributed almost equally between two distinct dust “seasons”: (1) monsoonal events during the summer months; and (2) synoptic systems during the fall, winter, and spring that may have very localized impacts (Shoemaker and Davis 2008). More recently, the ADOT Dust Task Force (2011) found that 302 dust-related crashes occurred on I-10 during the 10-year period from 2001 through 2010, with 13 of these incidents resulting in fatalities. A total of 141 crashes (47 percent) occurred between mileposts 170 and 240, and 65 crashes (22 percent) occurred in the Picacho Peak area between mileposts 200 and 220, as shown in Figure 3.

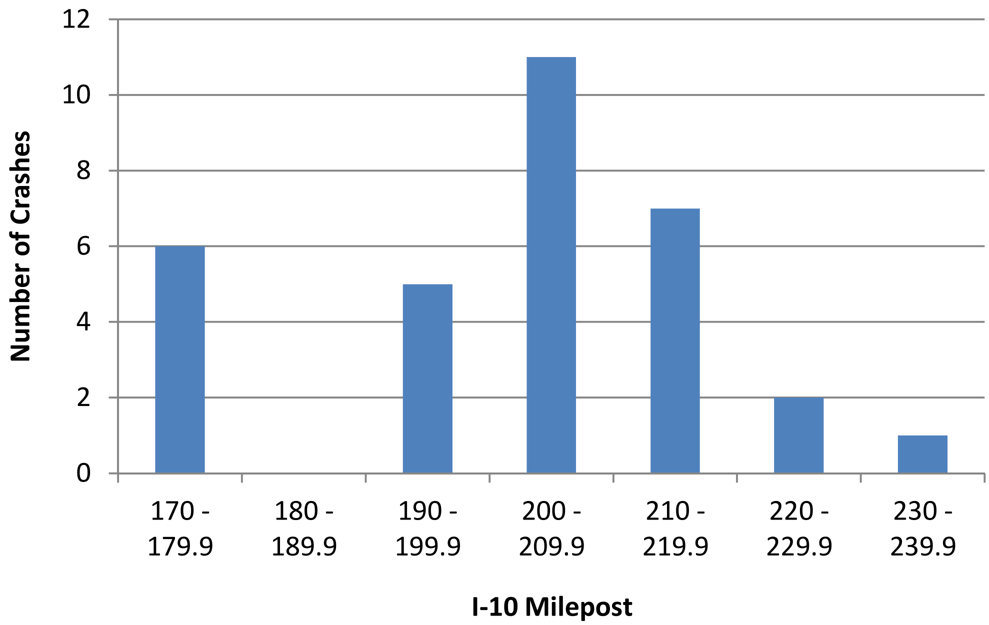

Figure 2. Number of Dust-Related Crashes on I-10 by Milepost, 1968-1975

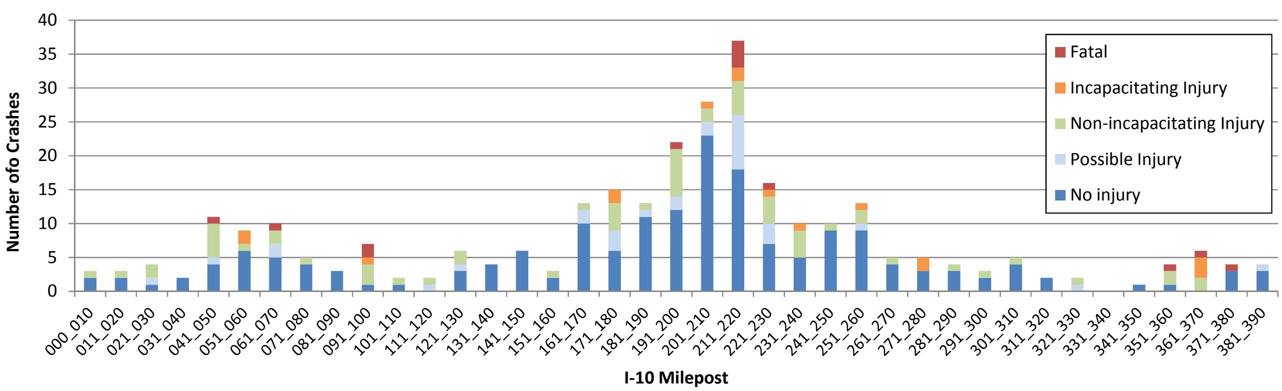

Figure 3. Number of Dust-Related Crashes on I-10 by Milepost, 2001-2010

All of these studies do not define "dust-related crashes" in the same way, which may confound comparisons between them. For example, during the 1997 study, researchers obtained traffic accident reports from DPS and used two report elements to identify dust-related crashes: (1) the "Weather Conditions" element, with dust noted; and (2) the "Vision Obscurement" element, with bad weather noted (Cowherd et al. 1997). However, during the more recent ADOT Dust Task Force investigation, crashes that were reported to occur under "severe crosswinds" or "blowing sand/soil" were treated as dust-related. But despite differences in methods for identifying dust-related crashes, these studies indicate that dust-related crashes on I-10 have been a concern for the past three decades, and that the portion of I-10 between mile markers 200 and 220 has been an identifiable area of concern for dust-related crashes.

ADOT is currently updating the land use evaluation conducted during the 1997 study by using aerial imagery to identify consistent land attributes associated with dust hot-spots along I-10 between Phoenix and Tucson (Daniel Brilliant and Mark Poppe, ADOT staff members, personal communication, March 13, 2014). In addition, the Pinal County Air Quality Control District (PCAQCD) developed land use shapefiles for the years 2008 and 2011 that cover much of Pinal County, information that may be useful for similar analyses. Land use evaluations may help the private sector and public agencies identify potential mitigation strategies that could be used to reduce quantities of windblown dust (note that ADOT has a limited right-of-way along the I-10 corridor and, therefore, has limited authority to act independently to implement specific dust mitigation steps).

Previous Research: Literature Review

Previous research on roadway visibility detection and warning systems is limited, and existing systems are not well documented. Typically, such systems have been deployed by state transportation departments to address specific, localized issues and have not been treated as research projects. In addition, these systems are generally integrated into larger Intelligent Transportation Systems (ITS) as part of Road Weather Information Systems (RWIS).[1] However, previous research efforts were identified during the literature review, as summarized below.

Day (1993) reviewed crashes on interstates caused by blowing dust and found that five factors contributed to the development of dust storms: wind, soil type, vegetation, soil moisture, and soil density. Silt, which erodes at a moisture content of less than 10 percent, was determined to be the predominant soil type in dust storms. This research did not address driver behavior or roadway warning systems, but did identify grooved pavements and barrier construction as means to improve traction and reduce the impact of dust on roadways.

The Enterprise Pooled Fund, a U.S. Federal Highway Administration (FHWA) research program focused on ITS, sponsored work that identified information on low-visibility warning systems and made recommendations on site selection for the deployment of such systems (Castle Rock Consultants 2002). This work identified forward scatter optical sensors, traffic sensors, and closed-circuit television (CCTV) as available technologies for identifying reduced visibility conditions on roadways. Technologies recommended for communicating warnings, speed advisories, and road closure information to drivers included DMS, variable speed limit signs, highway advisory radio (HAR), and fixed signs with flashing beacons.

Syntheses of visibility detection and warning systems deployed by various agencies in the United States have been performed by Abdel-Aty et al. (2012), Murphy et al. (2012), and Shahabi et al. (2012). These

[1] An RWIS consists of environmental sensors that measure real-time meteorological, pavement, and visibility conditions and a communication system that transfers data to a central system, where it is used to support decision making by roadway managers.

studies found that visibility detection systems are not widely implemented but identified several such systems in Alabama, California, New Mexico, Tennessee, and other states (each of these systems are discussed in detail in subsequent sections of this document). Abdel-Aty et al. (2012) also reviewed crash data records for the state of Florida for 2003 through 2010 to identify crashes resulting from adverse visibility conditions. The researchers found that visibility-related crashes tended to involve more vehicles and result in more severe injuries than crashes occurring under clear conditions. Also, recent research by the AAA Foundation for Traffic Safety has shown that the proportion of fatal crashes involving fog or smoke is highest for drivers aged 20 to 29 and lowest for drivers aged 70 and older (Hamilton et al. 2014).

Other publications focused on visibility issues and detection and warning systems in individual states. Lynn et al. (2002) evaluated approaches for addressing fog-related crashes on I-64 and I-77 in Virginia and recommended the installation of DMS immediately prior to the most fog-prone areas, the use of HAR, and increased police patrols in the affected areas. Ozbay et al. (2002) researched sensor and ITS component integration for a fog detection system in New Jersey. The researchers designed and deployed a test system on the Wanaque Bridge on Route 287, a fog-prone area in which several fog-related crashes had occurred. An RWIS station was installed to collect and archive meteorological and visibility data and testing was performed on the data-transfer mechanisms and surveillance capabilities of the system. CCTV monitoring and site visits were used to verify visibility conditions, and the system was judged to be accurate. However, the system was never fully implemented in a real-time advisory capacity due to issues with long-term maintenance requirements and the availability of DMS.

Results of the literature review indicate that little has been done in the area of public outreach regarding low-visibility events on roadways. However, researchers at the Center for Urban Transportation Research (1997) recommended that a driver education campaign be initiated before and during the fog season to help address fog-related traffic incidents in Florida’s Tampa Bay area. The recommended campaign would provide tips on driving in foggy conditions and consist of public service announcements, brochures, and enhanced traffic reporting on radio and television. The project team could find no evidence that the recommended campaign was ever implemented.

CURRENT PRACTICES IN ARIZONA

Overview

This section documents current ADOT practices for detecting windblown dust, providing dust-related information to the public, and fostering intra-agency and interagency communication on dust-related events.

Figure 4 provides an overview of ADOT’s current dust detection and communication practices. These practices can be categorized as: (1) dust detection and forecasting (orange elements), (2) event-based communication (green elements), and (3) public education and outreach (blue element). When NWS forecasts weather conditions that could lead to dust storms in a given area, a blowing dust advisory or dust storm warning is issued through the NWS website; via e-mail through the NWS EWARN system; through InteractiveNWS (iNWS), a text messaging service for public agencies; and through NWSChat, an instant messaging program used by NWS to share warnings and other critical weather information with the media and emergency responders. ADOT's Traffic Operations Center (TOC) has access to NWSChat, which is monitored at the TOC by the on-duty public information officer (PIO). The ADOT PIO distributes NWS dust storm information through parallel channels, including e-mail blasts and social media outlets.[2] In addition, the ADOT TOC communicates weather- and dust-related information to media outlets and is also in close communication with DPS.

DPS also receives warnings and advisories for blowing dust through the EWARN and iNWS systems. In addition, each DPS district monitors NWS forecasts independently to determine whether dust is likely to be an issue on a given day. These forecasts are obtained from the NWS website. If high winds are predicted, DPS patrol officers are dispatched to known problem areas to monitor dust and visibility levels. Depending on dust severity and officer availability, DPS officers have set up traffic breaks on I-10 and led small groups of vehicles through dusty areas or metered traffic in those areas (i.e., let small groups of vehicles through at a time after cautioning drivers to proceed slowly). In addition, DPS officers report to NWS on weather events in the field through a 24-hour emergency phone number.

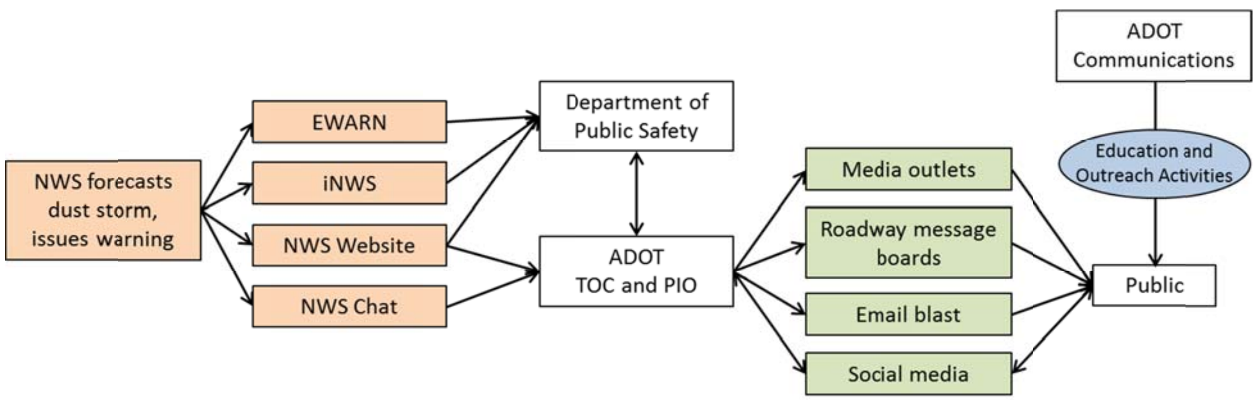

Figure 4. Flow Chart of ADOT's Current Dust Detection and Communication Practices

The sub-sections that follow provide background material on meteorological conditions leading to windblown dust in Arizona, more detailed information on the dust detection and communication practices described above, and a discussion of ADOT communication strategies for windblown dust events. In addition, the final sub-section addresses other issues that are relevant to dust-related roadway safety (e.g., land use and driver behavior). A pilot dust warning system implemented in ADOT's Safford District in 2011 is discussed later in the District-Specific Responses section of this paper.

Conceptual Model for Windblown Dust

As previously stated, dust storms routinely impact communities throughout Arizona. Dust storms in the southwestern United States typically occur during one of two meteorological regimes: convectively driven dust storms during the summer monsoon season, and dust storms associated with frontal

[2] In some cases, ADOT may also become aware of dusty conditions through social media channels (e.g., a driver posts a photo via Twitter).

passages during the fall, winter, and spring seasons. These two regimes are described in more detail below, combining information from previous studies of dust storms, the interviews conducted by the project team, and recent work by the Arizona Department of Environmental Quality (ADEQ) and the project team on case studies of high particulate matter (PM) concentrations due to dust storms.

Convectively Driven Dust Storms

Convectively driven dust storms, also known as haboobs, are formed by the lofting of dust by intense winds associated with outflow boundaries from thunderstorms. While thunderstorms are possible at any time of the year in Arizona, they are most common during the monsoon season from June 15 to September 30. During this season, humid air moves northward from the Gulf of California and the Gulf of Mexico, and large thunderstorm complexes form over northwestern Mexico. The influx of moisture associated with the monsoon, combined with strong solar heating, can result in unstable atmospheric conditions that are favorable for the development of thunderstorms. Heavy precipitation associated with thunderstorms, and the eventual collapse or dissipation of thunderstorms, can generate downbursts, which are the rapid descent of rain-cooled air in a thunderstorm. Upon reaching the surface, this descending air rapidly disperses horizontally away from the storm as an outflow boundary (also called a gust front), as shown in Figure 5. Winds associated with strong outflow boundaries can exceed 60 mph. These winds can efficiently loft dust into the air and transport the dust over long distances, causing low visibilities and high particulate concentrations. Anecdotally, the ground-level visibility reductions are not as severe as they are during the synoptically driven dust storms discussed below.

Dust storms generated by thunderstorms are most common during the early part of the monsoon season, when soil moisture levels typically are lowest. Later in the monsoon season, assuming widespread thunderstorm activity has occurred, higher soil moisture levels can reduce lofting of surface soils by high winds. Specific dust source regions are difficult to determine during convectively driven dust storms because the thunderstorm outflow can carry dust over long distances that encompass many possible sources of dust. In addition, wind speeds and directions during convectively driven dust storms are often erratic, both within the parent thunderstorm and at outflow boundaries due to interactions and mergers between individual outflow boundaries from different parent thunderstorms. However, the convectively driven dust storms can be easier to predict and monitor (compared to smaller-scale dust storms described below) because of the relatively large spatial scale of these dust storms and the ability to track the parent thunderstorms via conventional means (e.g., weather radar and satellite).

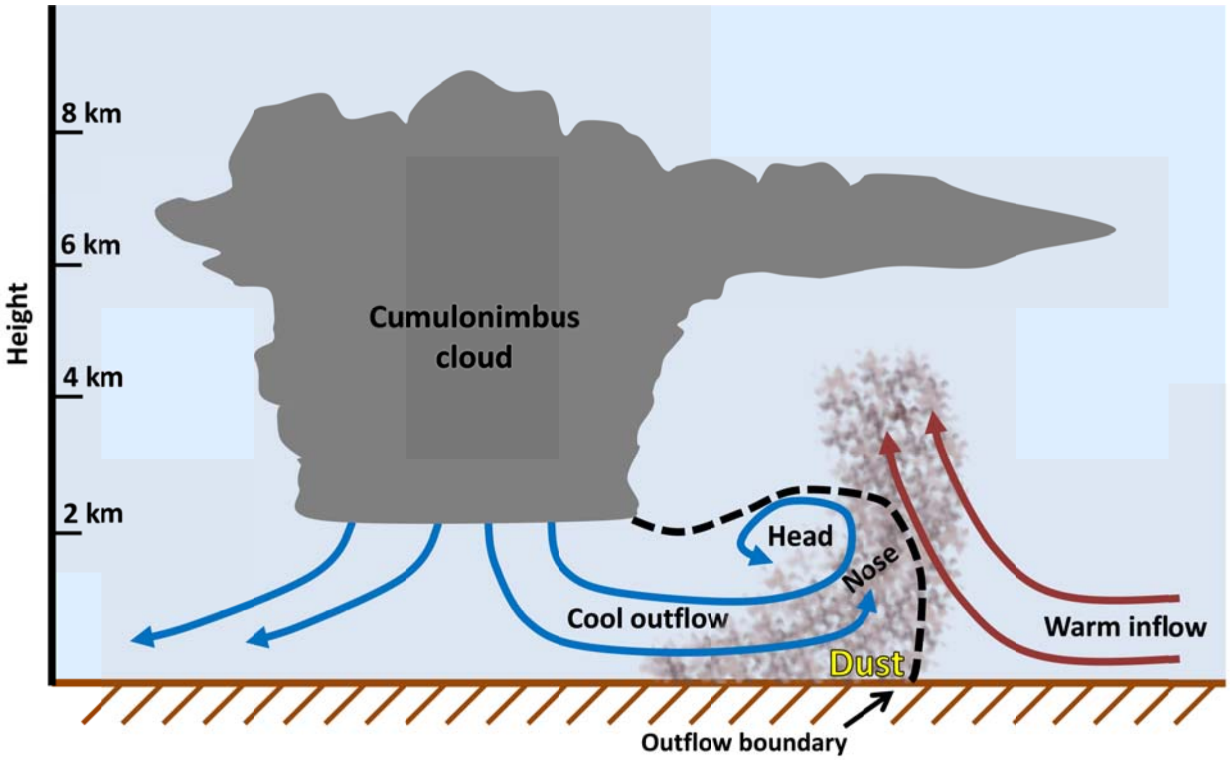

Figure 5. Cross-Section of a Thunderstorm Creating an Outflow Boundary (Black Dotted Line) and Haboob (Brown Shaded Area)[3]

Synoptically Driven Dust Storms

Windblown dust events in Arizona during the fall, winter, and spring are usually due to strong winds associated with synoptic-scale weather features, such as passing low-pressure systems or cold fronts moving eastward from the Pacific Ocean or southeastward from the Great Basin. These winds are the result of strong surface pressure gradients between the approaching low-pressure system (or cold front) and higher pressure ahead of it. As the low-pressure system (or cold front) approaches and passes, gusty southwesterly winds typically shift to northwesterly. In addition, locally gusty easterly or northeasterly winds can develop in Arizona when a strong surface high-pressure system builds southward over the Rocky Mountains behind the front; this localized scenario has been documented by ADEQ in case studies of high particle concentration episodes in Rillito, Arizona (located along I-10 northwest of Tucson) (Alrick et al. 2013). Synoptically driven dust storm events can range widely in severity. Winds associated with particularly strong storm systems can cause widespread dust storm conditions, while winds associated with weaker storm systems may result in more localized dust storm conditions, especially in areas with particularly loose soils and/or areas where nearby topographic features can locally enhance wind speeds. These favored areas for localized dust storm activity are sometimes termed dust channels. Dust storm events are particularly difficult to predict and track due to their brevity and small spatial scale.

[3] Image adapted from Warner T.T. 2004. *Desert Meteorology*. Cambridge: Cambridge University Press.

Dust Forecasting and Detection

Dust Forecasting

The NWS forecasts dust events out to 48 hours in advance and issues Blowing Dust Advisories when blowing dust is expected to reduce visibility to between 0.25 to 1 mi with winds of 25 mph or greater, and a Dust Storm Warning when blowing dust is expected to reduce visibility frequently to 0.25 mi or less with winds of 25 mph or greater. For some short-term events (less than 1 hour), such as small thunderstorm outflows, the NWS may issue a Short Term Forecast (also referred to as a NowCast) or a Special Weather Statement. For the 6- to 48-hr forecast window, trained NWS meteorologists primarily rely on three-dimensional, grid-based models such as the Weather Research and Forecast (WRF) and the Global Forecast System (GFS), and especially higher-resolution local mesoscale models. For the zero- to six-hour forecast window, the NWS typically uses short-term models that incorporate fine-scale terrain along with real-time observations of winds, thunderstorms, and dust detected by satellites and Doppler radar as well as storm spotter reports from the field. For synoptic-scale events, NWS meteorologists review the large-scale (hundreds to thousands of kilometers) surface pressure patterns and the movement and strength of frontal systems, and focus on predictions of winds at ground level and of winds in the lower levels of the atmosphere (e.g., less than 3,000 m msl). Assessing the winds aloft is important because vertical momentum transfer can often lead to gusty winds near the surface as winds mix down in the atmosphere. For thunderstorm outflow events, the NWS reviews predictions of aloft moisture and atmospheric stability to determine the likelihood of thunderstorms, and monitors for thunderstorms and outflow boundaries (especially colliding boundaries) using satellites and weather radar. The NWS noted that the prediction of localized dust events that lie close to the ground is one of their biggest forecast challenges because these events are transient, difficult to detect, and short-lived.

ADEQ also issues dust forecasts as part of its daily air quality forecasting, and issues an Air Quality Health Watch or Air Quality Health Warning when high particle concentrations due to widespread dust are expected to occur or are occurring. Similarly, PCAQCD issues air quality forecasts that include health watches and high pollution advisories. Determining whether wind speeds will be above or below a threshold at which dust will be lofted is particularly important for dust forecasting, and this wind speed threshold may vary depending on soil moisture and soil type.

The University of Arizona developed a mobile app that warns users of dust-related alerts issued by the NWS. The app uses GPS to track a phone's location and displays a notification message when the user is located within the geographic boundaries (usually county boundaries) of the NWS alert.

The University of Arizona also runs an operational WRF modeling system that provides weather forecasts that are used by ADEQ and PCAQCD, as well as a model called the Dust REgional Atmosphere Model (DREAM), which uses the Non-Hydrostatic Mesoscale Model (NMM) to predict weather conditions and simulate dust emissions, transport in three dimensions, deposition, and near-ground-level concentrations. DREAM uses land cover data sets and contemporaneous National Aeronautics and Space Administration (NASA) satellite observations to identify dust source regions and these datasets are updated every two weeks. When operating, DREAM's PM forecasts are updated twice per day and provide hourly PM forecasts out to 48 hours. The original development of DREAM was funded by the

University of Malta, and additional development of the model was funded by a grant from NASA; however, DREAM is not currently in operation due to lack of ongoing funding. The forecast domain covers the southwestern United States and the spatial resolution of the model is 3.5 x 3.5 km, which may be increased in the near future to 2-km resolution. The dust forecasts have been validated through comparison to particle concentration data from monitors operated by state and local air quality agencies, satellite imagery, and visibility data from ground-based optical sensors. In general, the model is able to capture the shape, duration, and magnitude of larger-scale dust events (Vukovic et al. 2014). Future improvements to the model will focus on predicting thunderstorm outflow boundaries, localized wind events, and localized dust sources.

Dust Detection

The general consensus among the interviews conducted with staff at ADOT, NWS, and the University of Arizona is that gathering more observations of small-scale dust events using a denser network of meteorological, visibility, soil moisture, and particle concentration monitors will be critical to improving both the detection and forecasting of these events.

The basic meteorological conditions conducive to widespread dust storm activity in Arizona are well known (described in the conceptual model), but detecting and predicting smaller-scale dust storms and local dust channels present much greater challenges. Windblown or suspended dust can be detected directly and indirectly using several methods, including satellite, radar, visibility sensors, visibility cameras, particle ($PM_{2.5}$ and PM_{10}) monitors, and visual reports from weather observers, public safety officers, or the general public. These detection methods are useful for detecting large-scale events, but often miss small-scale events because of a lack of observations in both time and space. Per interviews with ADOT and NWS staff, visibility is typically at its worst during the initial onset of local dust channel events, and thus, detection, observation, and public notification of these events may not occur until after the event has already occurred or is diminishing. Satellite data, for example, are useful for detecting large-scale dust events on otherwise clear days (Figure 6), but the usefulness of satellite data are limited during cloudy conditions and due to poor temporal resolution. High-resolution MODIS satellite images, such as the image shown in Figure 6, are usually not available until at least an hour after the image was taken, and these images are unlikely to depict small, low-level dust channels. Doppler radar data are particularly useful at identifying outflow boundaries and the associated windblown dust (Figure 7); however, radars have limited range and are cost prohibitive to build and maintain. Parts of the I-10 corridor between Phoenix and Tucson that are particularly susceptible to windblown dust have very limited radar coverage. For example, the Phoenix NWS radar is blocked to its south by mountains, which severely limits radar coverage along I-10 in Pinal County. In addition, the radar beam is too high off the ground to detect low-level dust channels.

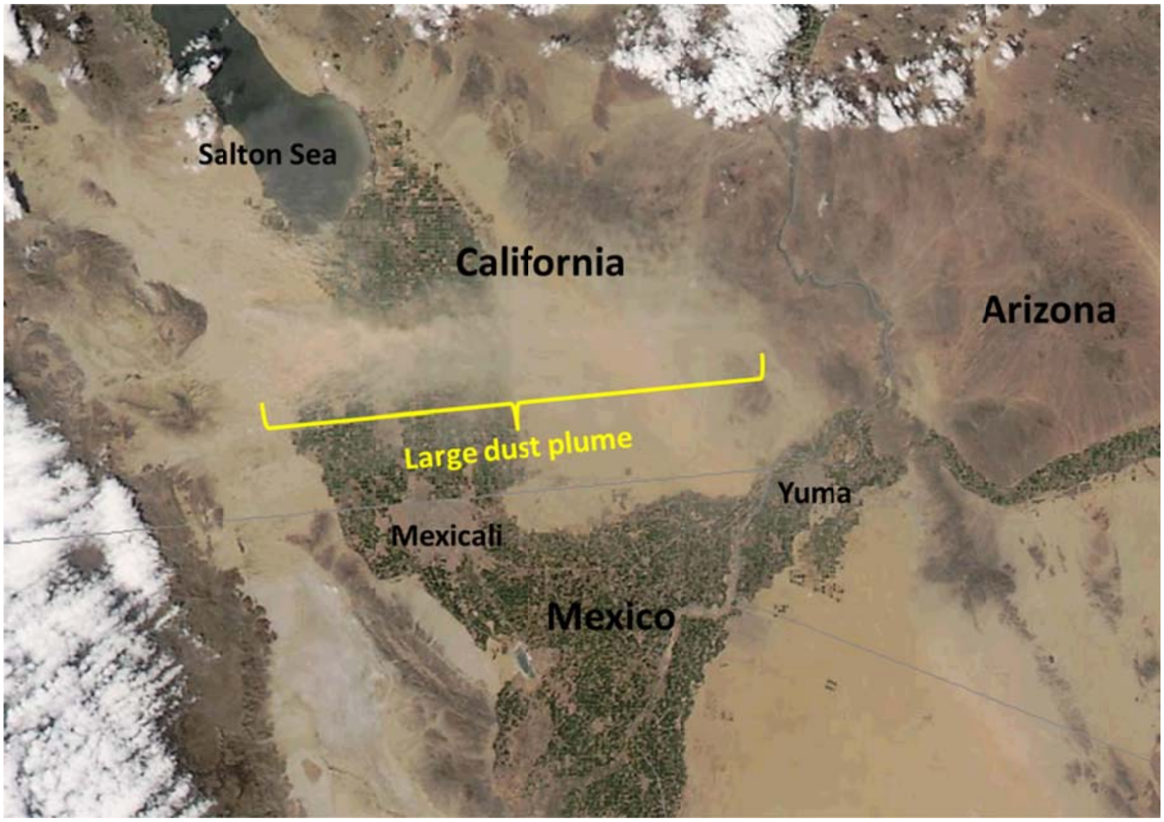

Figure 6. Large Dust Plume over Southeastern California on April 8, 2013 (NASA Image from MODIS Satellite)

Visibility sensors, CCTV visibility cameras, and surface meteorological monitors measuring wind speed, pressure, temperature, relative humidity, dew point, and precipitation are currently in place along a section of I-10 east of Willcox, Arizona, as part of an ongoing study project to detect dust events, communicate road conditions to drivers, and reduce dust-related traffic crashes (see the Dust Detection Technologies section for additional details). As of the time of publication, no dust-related visibility events have been detected during the study along this monitored section of I-10. A presentation on this study given at the 2014 Dust Workshop noted that the visibility sensors had limited detection range, a tendency to fail or give false readings, and a high replacement cost.

ADEQ operates several visibility cameras in the Phoenix and Yuma areas that are useful in detecting approaching dust storms (Figure 8); the real-time video feeds from these cameras are available online.[4] However, detecting small-scale dust events using these video feeds would require constant monitoring by personnel. ADEQ and local air quality agencies, such as Maricopa County Air Quality Department (MCAQD) and PCAQCD also operate PM monitors across Arizona. Some of these monitors are in urban areas, and many are positioned too high off the ground (e.g., on rooftops at a 30-ft elevation) to detect low-level dust channel events. However, PCAQCD operates several monitors in rural or semi-rural areas that generally have inlet heights well below 30 ft, and that agency has found that dust-related roadway

[4] ADEQ's visibility camera video feeds: http://www.phoenixvis.net.

incidents and high PM_{10} measurements are somewhat correlated. But localized dust events do not always correspond to monitored episodes of elevated PM_{10}; in addition, PM monitors typically used by air monitoring agencies are expensive, making them cost prohibitive for creating a dense monitoring network along roadways.

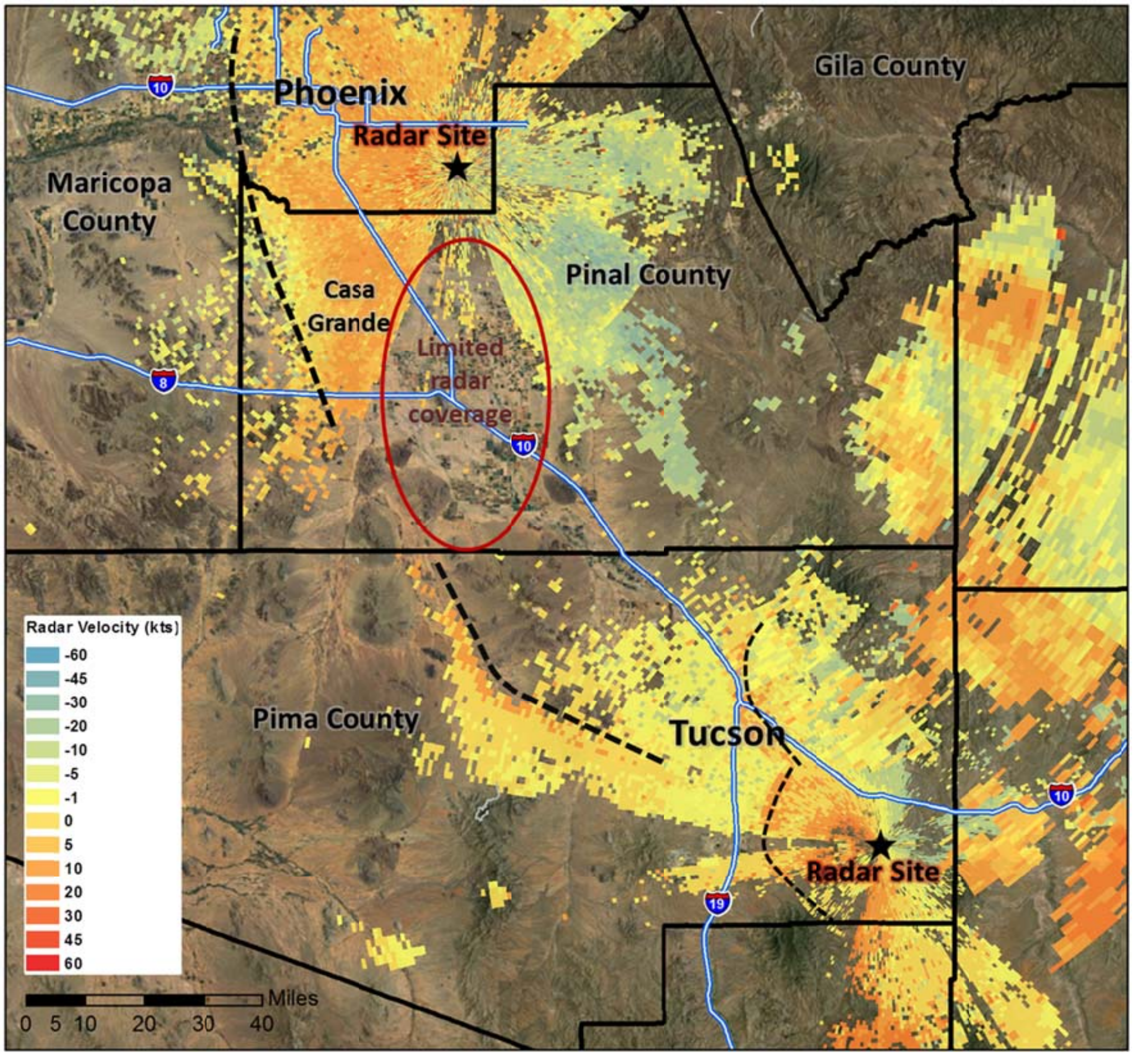

Figure 7. Radar Velocity Data from the Phoenix and Tucson NWS Radars on the Evening of July 2, 2013 (Alrick et al. 2014)

Figure 7 shows several well-defined thunderstorm outflow boundaries (dashed lines) that were detected over southern Arizona.

Figure 8. Central Phoenix Dust Storm Due to Thunderstorm Outflow on August 18, 2011 (From ADEQ Visibility Camera on North Mountain)

ADOT Communication Strategies

Incident Response

ADOT has a multi-faceted strategy for communicating information about windblown dust events. When ADOT receives advance notice of potential dust storm activity from the NWS or field reports from maintenance crews, DPS officers, or drivers, warning messages (e.g., "Dust storm possible – low visibility") are displayed on the ADOT system of overhead DMS, which typically have three text rows consisting of 18 characters each. The characters measure 18 inches in height (see Figure 9). ADOT has deployed about 180 DMS across the state; seven of the signs are located on I-10 between Phoenix and Tucson, with two on westbound I-10 near Tucson, one on eastbound I-10 near Phoenix, and four others in between those cities. In addition, three of the signs are located on I-10 between Willcox and the New Mexico state line, with two on eastbound I-10 and one on westbound I-10.

When active dust storms are observed in the area between Phoenix and Tucson, ADOT deploys portable message boards in the affected area that warn of "Blowing Dust Ahead."

Figure 9. An ADOT Overhead DMS[5]

In addition, ADOT sends e-mail messages with dust-related information to a subscription list of about 35,000 individuals. These messages reference the NWS advisories or warnings that have been issued, describe anticipated weather conditions in affected parts of the state, and provide driving tips on staying safe in a low-visibility dust storm. The e-mail messages also contain links to ADOT's "Pull Aside, Stay Alive" website, which contains additional information on driving during dust storms, and to ADOT's 511 website, which provides current information on Arizona roadways (e.g., road closures, crashes, and lane restrictions). Sample e-mail messages from ADOT are provided in Appendix D.

ADOT also provides dust-related information via social media outlets, including Facebook and Twitter (see Figure 10). ADOT's Twitter feed currently has over 65,000 followers. Formal news releases are provided to media outlets in the Phoenix and Tucson markets, and ADOT public information officers provide live updates to reporters to help them track the storm and communicate information to their audience. Updates are made to both the 511 phone system and website.

[5] Source: http://www.azdot.gov/media/blog/posts/2012/09/26/transportation-defined-dynamic-message-signs.

Figure 10. Sample Dust-Related Tweet from ADOT's Twitter Feed

District-Specific Responses

Beyond the overarching incident responses described above, individual ADOT districts have developed strategies for responding to windblown dust events. Most notably, a pilot dust warning system was implemented in ADOT's Safford District in 2011; this system is discussed in detail in a subsequent section of this chapter. Also, ADOT's Tucson District has experimented with placing human observers on hilltops to watch for dust on days when windy conditions are predicted. However, the localized nature of dust events on I-10 has made it difficult to know where to place spotters on a given day, and this method of dust detection has proven ineffective.

In addition, staff at ADOT's Holbrook District closely monitors a 7- to 8-mi stretch on I-40 between Winslow and Flagstaff that, like the stretch of I-10 between Phoenix and Tucson, is an area of concern for windblown dust. The ADOT Winslow Maintenance Office is located on this portion of I-40, so staff at this office can usually see dust storms beginning to form. The worst dust events tend to occur in the spring, when winds above 35 mph come out of the south-southeast, and the Holbrook District staff monitors NWS forecasts to prepare for such events. When active dust is predicted or observed on the roadway, DMS are activated and departments of transportation (DOT) in California and New Mexico are asked to activate signs at the state lines to warn drivers of potential windblown dust ahead. When motorists on I-40 are clearly affected by dust (e.g., braking as they enter the dust storm), ADOT works with DPS and the Winslow Police Department to close I-40, a process that can typically be completed in about 15 minutes.

During closures of I-40, ADOT informs local radio stations so that information on alternate routes can be provided to the public. In the past, closures of I-40 have lasted from two hours to over 20 hours, and have occurred five or six times per year. However, no road closures have been necessary over the past two years. Road closures for dust events in Arizona have not occurred on I-10, though the Safford District has closed I-10 at the junction with U.S. Route 191 for dust events occurring in New Mexico. However, during severe dust storms, DPS has stopped and metered traffic on I-10. In addition, closures of I-10 have occurred in New Mexico due to windblown dust in the area between the Arizona border and Lordsburg, New Mexico.

Public Outreach and Education

In addition to providing information on individual windblown dust events, ADOT has made significant efforts to change driver behavior during dust storms by educating the public about these storms and the proper way to respond when encountering dust while driving. Most notably, ADOT launched the “Pull Aside, Stay Alive” campaign in 2012, which instructs drivers to:

- Check surrounding traffic and begin slowing down when encountering a dust storm
- Completely exit the highway if possible (do not stop in a travel lane or the emergency lane)
- Turn off all vehicle lights and take their foot off the brake (to prevent other motorists from attempting to follow their lights)
- Stay in the vehicle with seat belts buckled until the storm passes

This information has been disseminated to the public in a variety of ways, including ADOT’s “Pull Aside, Stay Alive” website (see Figure 11), public service announcements on television and radio, videos posted on ADOT’s YouTube channel, and posts to ADOT’s blog and Facebook page. As part of this campaign, ADOT also sponsored the “Haboob Haiku Challenge” in 2012 and 2013, which encouraged individuals to write a haiku (17-syllable poem) to help educate the public about the dangers of driving in dust storms. Haiku entries were submitted through ADOT’s Twitter feed. The campaign generated over 500 media stories and was covered by a wide variety of news outlets, including CNN, MSNBC, BBC, NPR, the *New York Times*, and *The Washington Post* (Tait 2013).

Figure 11. Screenshot of ADOT's "Pull Aside, Stay Alive" Website[6]

ADOT is in the process of developing a dust awareness communication plan, which will be informed by findings from the research described in this paper. Elements of this plan will include efforts to educate commercial truck drivers and visitors from outside Arizona about dust-related safety, increase the visibility of the "Pull Aside, Stay Alive" campaign during non-monsoon season (i.e., October to May), and provide new educational content on the "Pull Aside, Stay Alive" website.

Other Relevant Issues

Though the focus of this paper and the related project is the detection of windblown dust events and the communication of information about those events, it is important to include a brief discussion of other key issues that consistently arose during our discussions with staff from ADOT and other Arizona agencies.

First, it is clear that the type of land cover adjoining a roadway is a key factor in the generation of windblown dust. Cowherd et al. (1997) identified conditions creating potential dust sources along I-10, including large unvegetated areas (especially those with soil that had been recently tilled or disturbed), long distances for winds to blow unobstructed, and dry soils with large erodible fractions. More recently,

[6] Available online: http://www.pullasidestayalive.org.

the ADOT Dust Task Force identified large tracts of undisturbed dry land with little vegetation, cultivated farmland with loose dirt, and dry river beds as land cover types contributing to windblown dust along I-10 between Phoenix and Tucson. From a roadway engineering perspective, there is little ADOT can directly do to mitigate dust that originates from land beyond the ADOT right-of-way.

Also, driver behavior is another key factor impacting roadway safety during windblown dust storms. DPS staff noted that drivers often proceed at high speeds through dusty conditions with severely reduced visibility. Localized dust channels that occur under otherwise clear conditions may create a false sense of security for drivers, and out-of-state motorists may not have been exposed to ADOT's "Pull Aside, Stay Alive" campaign and thus may take the wrong actions during a dust storm. Driver perceptions and behaviors during dust storms will be investigated during the next phase of this project.

Summary of Key Findings

In summary, this review of the conceptual model for windblown dust and current dust-related practices in Arizona produced several key findings:

- Windblown dust events primarily occur as a result of two types of meteorological conditions: (1) thunderstorms associated with the summer monsoon season and (2) cold front passages in the spring, winter, and fall.
- Dust associated with thunderstorms is easier to predict because of the large spatial scale of these events, while cold front passages produce localized dust channels that are harder to predict because they occur over small areas, are shallow in height, and typically have a brief duration.
- Similarly, available dust detection technologies are more useful for detecting large-scale events and may miss small-scale events because of a lack of observations in both time and space.
- A general consensus among the individuals interviewed was that more observations of small-scale dust events using a denser network of meteorological, visibility, soil moisture, and particle concentration monitors will be critical in both the detection and forecasting of these events.
- ADOT currently relies on a variety of methods for communicating information about windblown dust events, including DMS, portable message boards, e-mail messages, professional news media, and social media.
- ADOT has also made significant efforts to educate the public about dust storms through the "Pull Aside, Stay Alive" campaign.

The sections that follow provide information on visibility detection and warning systems in other states and additional information on dust detection technologies.

CURRENT PRACTICES IN OTHER STATES

A number of states and regions across the United States are faced with weather events that reduce visibility and impact traveler safety. These events include not only dust storms, but also fog, smoke, and windblown snow. To address these conditions, state DOTs and other agencies have deployed various types of systems and approaches to detect reduced visibility on roadways and provide warnings to travelers. Some of these systems and approaches may warrant consideration by ADOT for use in addressing reduced visibility from dust storms; therefore, the project team surveyed agencies that currently implement or previously implemented visibility warning systems and documented the range of approaches used to provide visibility warning information to drivers and to communicate about such events with the public.

To complete this task, the project team first conducted a high-level literature review to identify visibility warning systems that had previously been documented. For example, researchers from the University of Central Florida (UCF) developed a synthesis of visibility detection systems for the Florida Department of Transportation (Abdel-Aty et al. 2012). The UCF report provided a high-level documentation of the various visibility warning systems that have been deployed in the United States, which the project team then used to identify prospective contacts within each respective agency. In addition, through past work the project team was aware of other systems that have not been documented in literature, and contacted the agencies that deployed those systems. A complete list of individuals and agencies interviewed is provided in Appendix B.

Once the agencies, systems, and prospective contacts had been identified, the project team conducted telephone interviews to obtain the information of interest. This information included the nature of the problem being addressed, its frequency and scope, the approach(es) taken to address it, and an overview of the system(s) employed. In addition, the project team inquired about approaches to intra-agency communication as well as communication with drivers and the general public. The project team used a specific set of questions during each telephone interview to ensure that uniform data would be obtained from each contact, and the list of questions is presented in Appendix C. At the conclusion of each interview, the project team asked the contacts to recommend other individuals who would be useful to contact for follow-up interviews, and whether they knew of similar systems at other agencies that should be investigated.

The following sections summarize information related to low-visibility detection and warning systems deployed by various agencies throughout the United States, some of which remain active, while others have been decommissioned. Additional technical details on each of the individual systems identified, including system costs, are provided in Appendix E.

Forecasting and Detection

The identified systems were largely implemented to address fog-related events, though systems in Idaho, Montana, and New Mexico were primarily deployed due to windblown dust issues. The use of visibility sensors in these systems to monitor roadway conditions is almost universal; cameras or field observations are commonly used to verify visibility sensor readings. Reliance on weather forecasts to provide advanced warning of deteriorating visibility conditions is very limited, though the Idaho Transportation Department (ITD) does rely on NWS forecasts to determine when high winds are expected along a 40-mile stretch of Interstate 84 that is impacted by blowing dust, fog, smoke from fires, and blowing snow. Other agencies, such as the Maryland State Highway Administration (MSHA) rely on Internet weather forecasts from sites such as Accuweather or weather.com to identify conditions that may lead to fog and reduced visibility. In many cases, the visibility problems addressed were quite localized (e.g., blowing dust from a dry lake bed or fog along a river bottom), making accurate forecasts of reduced visibility difficult.

In general, the identified systems are deployed along roadway segments ranging from 1 to 40 miles in length and make use of forward-scatter visibility sensors to detect reduced visibility conditions on these roadways. The forward-scatter measurement technology features an infrared transmitter that projects light into a sample volume of air, and a receiver detects light scattered in the forward direction by particles of dust, moisture, or snow. The amount of scattered light is then used to calculate a visual range (e.g., objects are discernible at a distance of 1,000 m). Visibility sensors commonly used in the identified systems include the Optical Scientific OWI 650, the Vaisala family of Present Weather Detectors (e.g., the PWD10, PWD11, and PWD12), and the Envirotech Sentry. These sensors are generally deployed at intervals ranging from 0.5 to 1 mi. For example, the California Department of Transportation (Caltrans) has deployed a fog detection and warning system along a 12-mi stretch of State Route 99 that is impacted by the thick “tule fog” that occurs in California’s Central Valley each year from November through February. This system uses about 24 Vaisala PWD10 sensors deployed at half-mile intervals to detect the presence of fog.

In some cases, however, visibility sensors were deployed at existing RWIS stations, providing less highly resolved spatial coverage. For example, ITD deployed Vaisala’s PWD11 visibility sensors and DRD11A rain sensors at four RWIS stations along the 40-mi stretch of I-84 in Idaho referenced above, providing an average spacing of 10 mi per sensor. Concerns about spatial coverage were expressed by some of the agencies interviewed, including the Alabama Department of Transportation (ALDOT), the North Carolina Department of Transportation (NCDOT), and the Georgia Department of Transportation (GDOT). In response to a 196-vehicle crash in 1995, ALDOT implemented a fog warning system along an 8-mi stretch of I-10 spanning the Bay Bridge in Mobile. The system includes Optical Scientific visibility sensors spaced one mile apart, which does not always provide an accurate representation of conditions between sensors. Therefore, ALDOT is investigating less expensive sensors that could be deployed in the gaps between the existing Optical Scientific sensors. Previously, ALDOT experimented with the use of infrared and thermal imaging technologies, but the cameras proved unable to resolve visibility distances when the fog was thick. However, ALDOT suggested that forward-looking infrared (FLIR) cameras may be more suitable for dust-related events.

NCDOT also stressed the importance of good sensor placement and noted that obtaining field data prior to system deployment would help to ensure the proper distribution of sensors. NCDOT has installed two systems for fog warnings in the Great Smoky Mountains near Ashville: one covers a 6-mi section of I-40 and the other covers an 11-mi section of I-26. Combined, the systems include three full RWIS stations (including visibility sensors) and seven additional sites with visibility sensors. Similarly, GDOT has deployed a fog and smoke warning system along a 14-mi segment of I-75 in the southern portion of the state. The system includes 19 Vaisala visibility sensors, but 15 of those sensors are concentrated along a 2-mi segment that is particularly fog-prone.

Many of the systems identified augmented the visibility sensors with CCTV cameras. The primary purpose of the CCTV cameras was to provide verification for the visibility sensor readings, as the sensors can be impacted by dirt, insects, and other elements of the environment. For example, when fog is detected by the I-75 warning system deployed by GDOT, the system triggers fog warning and speed advisory messages on four DMS, and CCTV cameras are used to verify visibility conditions and confirm that DMS messages are being displayed properly. The ALDOT fog warning system deployed on I-10 in Alabama also uses CCTV cameras to provide verification when fog alerts are triggered and ALDOT stressed the importance of the "human element" in the system. The CCTV camera feeds are on the state's website and local TV stations have direct access to the camera feeds so they can monitor and report on road conditions.

In general, the agencies contacted reported that the visibility sensors were accurate when verified with human observations of roadway conditions, though limited efforts have been made to formally assess the performance of the warning systems (the Georgia Tech Research Institute [GTRI] evaluated the GDOT system on I-75 but has not yet released results of that study). The New Mexico Department of Transportation (NMDOT) reported occasional false warning triggers from their dust storm warning system, which features Vaisala PWD12 visibility sensors and Vaisala WMT52 ultrasonic wind sensors. It is believed that these issues are due to system voltage issues, and NMDOT has generally been pleased with system performance. The Ohio Department of Transportation (ODOT) reported accuracy issues with Vaisala's PWD11 and PWD12 visibility sensors placed at RWIS stations throughout the state. However, ODOT made significant investments in maintenance contracts for their RWIS network, and the visibility sensors reported correct data when properly maintained. Other agencies, including Caltrans and the Pennsylvania Department of Transportation (PennDOT), stressed the importance of maintaining visibility sensors, replacing the sensors as technology improves, and accounting for these costs in system budgets.

Infrastructure and Communications

The systems identified almost universally include DMS, which are typically activated when visibility or wind speeds reach some threshold value. Other common system components include variable speed limit (VSL) signs, flashing beacons, HAR stations, and 511 websites.

For example, the Louisiana Department of Transportation and Development (LaDOTD) deployed a visibility warning system in 1999 and 2000 that covered a 10-mi stretch of I-10 and a 15-mi stretch of I-55 in an area frequently impacted by fog. When data from visibility and humidity sensors reached determined thresholds, notifications were sent to the Traffic Management Center (TMC) through wireless communication. TMC staff then manually posted messages to DMS and adjusted speed limits on VSL signs. This system was destroyed by Hurricane Katrina in 2005 and was never reinstalled.

The ALDOT system on I-10 uses fiber optic communication to collect visibility data and send warnings to the TMC when fog is detected. TMC operators verify visibility conditions using CCTV cameras, post warnings on 9 Daktronics DMS, and activate 24 Daktronics VSL signs. When speed limits are reduced, the state highway patrol and local law enforcement agencies are automatically notified via fax. In addition, two HAR stations begin to broadcast warning messages and flat panel signs with beacons alert drivers to tune to the proper frequency when the beacons are flashing.

Caltrans uses a similar approach for the SR 99 fog warning system. Data from visibility sensors is transmitted to the local TMC for processing and review, and then TMC staff determine which warning message should be posted to the 33 DMS that are spaced at approximately one-mile intervals along the SR 99 corridor. TMC staff also contact the California Highway Patrol (CHP) when traffic is detected as moving at less than 45 mph, and information on corridor conditions are posted to the Caltrans 511 system.

In some cases, DMS messages or flashing beacons are automatically activated when decreased visibility conditions are detected, though there is usually still a human component to the system. The Tennessee Department of Transportation (TDOT) has implemented a fog warning system on a section of I-75 in southeastern Tennessee that is prone to foggy conditions. The system features 10 Envirotech Sentry SVS1 visibility sensors, 10 DMS, and 10 VSL signs, which are linked using Management Information System for Transportation (MIST) software. When the visibility sensors detect fog, messages are automatically posted to DMS. And while the MIST software could run the entire system automatically, human operators follow a graduated response plan once the initial DMS messages are posted. Responses include speed limit adjustments and road closures, depending on the severity of the fog. The Florida Department of Transportation (FDOT) is following a similar approach for a low-visibility warning system that is currently being implemented on a section of I-75 that is impacted by smoke and fog. The system will incorporate eight to 12 Optical Scientific OWI 650 visibility sensors, CCTV cameras, vehicle detectors, and FLIR cameras. Data from these instruments will be processed by FDOT's Sunguide software, which will automatically activate warning messages on five DMS when a low-visibility event is detected. In addition, FDOT's 511 telephone message will be updated to include visibility information for the site, and an alert will be posted to FDOT's SmartTraffic website.

The Virginia Department of Transportation (VDOT) has encountered infrastructure difficulties in deploying a VSL system along a remote stretch of I-77 near Fancy Gap. Much of the traffic on this route is from out of state and unfamiliar with the area and its tendency for fog, leading to crashes that are often severe and involve multiple vehicles. The affected segment of I-77 is approximately 14 mi in length and does not have access to power and communications. As a result, VDOT has taken a piecemeal approach to implementing the system, starting with the installation of a power and communications conduit. At present, work is underway to complete the power network, install a communication network, and deploy a total of 13 RWIS sites that include visibility sensors.

The Nevada Department of Transportation (NDOT) also encountered infrastructure issues with a fog warning system designed to cover a 4-mi stretch of I-80 occasionally impacted by fog. The system featured a Vaisala RWIS station with a visibility sensor and DMS and was intended to be fully automated. However, the stand-alone communications services used in the system did not function properly and the system was never fully activated. NDOT plans to integrate any future visibility warning systems into their existing congestion management system.

In terms of public outreach, few of the agencies contacted go beyond providing warnings in the field (e.g., through DMS and HAR) or through 511 systems and traffic websites. However, Caltrans Districts 3, 4, 5, and 10, along with the California Highway Patrol, have produced a pamphlet on fog (presented in

Appendix F) and a "Fog University" website (http://www.foguniversity.com/) that provides safe driving tips and an overview of the different technologies used to detect and warn of fog on roadways.

In addition, prior to the development of the I-75 low-visibility warning system described above, FDOT has been active in providing warnings to motorists through Twitter. This medium is used when a complete road closure has occurred so that motorists can be notified of the closure and available detour routes. FDOT reports that these Twitter alerts have frequently been retweeted by both ordinary users and the media. FDOT also sends e-mail alerts to trucking companies when visibility is compromised.

Finally, the NMDOT dust system features automated e-mail and text alerts when visibility and wind speeds reach user-defined thresholds, as shown in Figure 12. At present, those notifications are provided to stakeholder agencies (e.g., NMDOT maintenance staff and law enforcement), who confirm low-visibility conditions and then issue advisories or warnings through HAR, DMS, 511, and flashing beacons on static metal signs.

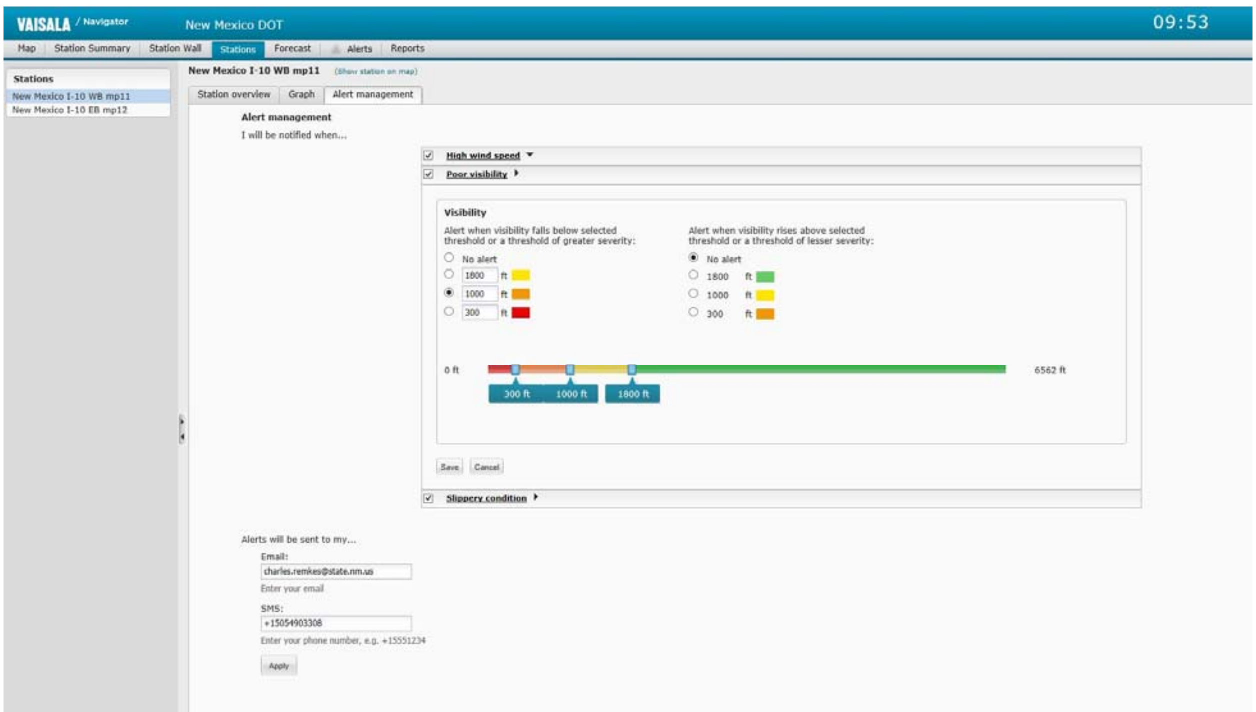

Figure 12. Interface for Setting User-Defined Thresholds for E-mail and Text Alerts in the NMDOT System

Performance Measures

Few agencies have undertaken data collection and analysis to formally evaluate visibility detection and warning systems, though some anecdotal information was provided on system performance. In general, the agencies contacted felt that the systems were working well and successfully reducing crashes. ALDOT reported that the fog warning system on I-10 has served its intended purpose, and that there have been no multi-vehicle crashes since it was installed almost 20 years ago. ALDOT also noted that feedback from the public and other DOTs has been overwhelmingly positive. Similarly, Caltrans reported that no major visibility-related crashes have occurred on SR 99 since the fog detection and warning system was deployed in 2009; however, it should be noted that such major crashes had previously occurred every 5 to 10 years, so the true effectiveness of the system may not be evident for some time.

The ITD has conducted informal analysis of general crash rates along the I-84 corridor since the current storm warning system was deployed in 2008 and noted that crash rates have fallen since that time, though this decline in crashes may not be due to the system alone. TDOT reports that over the past five years, the fog warning system on I-75 has been activated five to seven times per year on average, and that no major crashes have occurred since the system was installed.

The Utah Department of Transportation (UDOT) used vehicle speed as a performance metric for a visibility warning system deployed in 1999-2000 on I-215 along a river bottom impacted by fog. The system featured multiple forward-scatter sensors, vehicle detection sensors, and DMS that posted a recommended speed for the current visibility conditions. For example, a message saying "Dense Fog – Advise 40 mph" was posted when the detected visibility ranged from 328 to 492 ft. UDOT staff reported that overly cautious drivers (those already driving below the posted speed limit) increased their speeds when the system was active, and the overall speed variance between drivers decreased by 22 percent, enhancing mobility and reducing the risk of crashes. However, the system was deemed ineffective due to the low accuracy of the visibility sensors available at the time and was ultimately deactivated in 2003.

NMDOT is in the process of having its dust storm mitigation system on I-10 evaluated by New Mexico State University (Jiang and Cooper 2013) and reports that the system seems to be performing well overall. NMDOT has established specific performance measures so that post-deployment conditions can be compared to pre-deployment conditions. A concept of operations plan (New Mexico Department of Transportation 2009) stated that these measures include:

- The number of dust storms detected
- The time from detection to the beginning of management activities (e.g., diverting motorists, notifying other organizations)
- Number of dust storm-related crashes
- Severity of dust storm-related crashes

Also, as previously noted, the GTRI evaluated the GDOT fog and smoke warning system on I-75 but has not yet released results of this study.

Summary of Key Findings

In summary, this review of available literature and visibility warning systems in other states produced several key findings:

- A significant number of states have deployed or are in the process of deploying systems to address roadway visibility issues.
- The use of forward-scatter visibility sensors in these systems is nearly universal, and these sensors have generally proven accurate when properly maintained.

- Reliance on human operators to verify low-visibility conditions is a common and crucial element of visibility detection systems.
- Reliance on staff meteorologists or weather forecasts is very limited among the agencies contacted.
- Visibility sensors and related system components require regular maintenance (e.g., cleaning, calibration, etc.) and periodic replacement, which should be accounted for in system budgets.
- Good field data for visibility conditions is needed before a system is deployed, so that sensors are placed in correct locations to detect occurrences of reduced visibility.
- The identified systems almost universally include DMS and commonly include VSL signs, flashing beacons, HAR stations, and 511 systems.
- The general focus of the identified systems was to provide warnings to drivers in the field, including out-of-state drivers, so little effort was expended on public education and outreach.
- The challenges presented by some areas experiencing low-visibility conditions can be extensive and require significant engineering and financial resources to properly address.

Table 1 provides an overview of each of the individual systems identified, and additional technical details on each of these systems are provided in Appendix E.

Table 1. Summary of Visibility Warning Systems Deployed in the United States

State	System	Roadway Length Covered	Visibility Issue(s)	System Components	System Actions	Status
Alabama	I-10 Bay Bridge Fog Warning System	8 miles	Fog	• Visibility sensors • DMS signs • RWIS stations • VSL signs	• Driver warnings via DMS • VSLs posted	Active
California	District 10 Fog Warning System	Districtwide	Fog Smoke (ag burns) Inclement weather	• Visibility sensors • RWIS stations • DMS signs	• Driver warnings via DMS • DMS message posted to Caltrans Quickmap traveler information website	Active
California	SR 99 Fog Detection and Warning System	12 miles	Tule fog (Nov. - Feb.)	• Visibility sensors • Radar speed sensors • CCTV cameras • DMS signs	• Driver warnings via DMS • DMS message posted to Caltrans Quickmap traveler information website • Vehicle guidance from highway patrol cars (when warranted)	Active
California	SR 18 and SR 138 Visibility Warning Systems	800 feet	Fog	• Visibility sensors • DMS signs	• DMS warn of low visibility and signalized intersection ahead	Active
Florida	Paynes Prairie Low Visibility Warning System	2.5 miles	Smoke Fog	• Visibility sensors • CCTV • Forward-looking infrared cameras • DMS signs	• Driver warnings via DMS • Warnings issued through 511 system and SmartTraffic website • Alerts sent out via Twitter • Email alerts sent to trucking	Under const.
Georgia	I-75 Fog and Smoke Warning System	14 miles	Fog Smog/smoke	• Visibility sensors • Loop detectors • CCTV • DMS signs	• Fog warning and speed advisories issued via DMS	Active
Idaho	I-84 Storm Warning System	40 miles	Blowing dust Fog Smoke Blowing snow	• Visibility sensors • RWIS stations • DMS signs • NWS forecasts	•Driver warning via DMS • Warnings issued through 511 system and traveler information website	Active
Louisiana	Reduced Visibility Enhancement System	25 miles	Fog	• Visibility sensors • VSL signs • DMS signs • RWIS stations • CCTV	• Driver warnings via DMS • VSLs posted	Inactive
Maryland	I-68 Fog Warning System	20 miles	Fog (transition between seasons)	• DMS signs • Weather reports and field observations of conditions	• Driver warnings via DMS	Active
Montana	I-15 Dust Warning System	1 mile	Alkali dust	• Infrared sensor • Flashing beacons on metal signs	• Driver warnings via flashing beacons and static signs	Active
Nevada	I-80 Fog-based VSL system	4 miles	Fog	• VSL signs • RWIS stations	• VSL signs activated	Inactive
New Jersey	I-287 Fog Sensor / ITS Integration	< 1 mile	Fog Hazardous weather	• Visibility sensors • CCTV • RWIS stations • DMS signs • Pavement temperature and traffic sensors	• Driver warnings via DMS • VSLs posted	Inactive

511 – system for providing travel information through a 511 telephone number or website
CCTV – closed-circuit television
DMS – dynamic message signs
HAR – highway advisory radio
NWS – National Weather Service
RWIS – road weather information system
SR – state route
VSL – variable speed limit

Table 1. Summary of Visibility Warning Systems Deployed in the United States (continued)

State	System	Roadway Length Covered	Visibility Issue(s)	System Components	System Actions	Status
New Mexico	I-10 Dust Control System	1 mile	Dust	• Visibility sensors • CCTV • Speed indicator sensors • RWIS stations	• Driver warnings via DMS • Warnings broadcast on HAR • Flashing beacons activated • Warnings issued through 511 system and traveler information website	Active
North Carolina	I-40, I-26 Fog Warning Systems	17 miles	Fog Snow	• RWIS stations • CCTV • Flashing beacons on metal signs	• Driver warnings via flashing beacons and static signs • Email alerts sent to emergency responders	Active
Ohio	Statewide Visibility System	Statewide	Winter weather	• Visibility sensors • RWIS stations	• Conditions monitored • Intra-agency phone calls as needed	Active
Pennsylvania	Route 22 Fog Warning System	5 miles	Fog	• Visibility sensor • CCTV camera • RWIS station • VMS signs	• Driver warnings via DMS • TMC operators notified via paging system	Active
Pennsylvania	Turnpike Fog Warning System	10 miles	Fog	• Visibility sensors • CCTV • RWIS stations • Microwave traffic sensors • DMS signs	• Driver warnings and speed guidance via DMS • Warnings issued through 511 system and traveler information website	Active
Tennessee	I-75 Fog Warning System	17 miles	Fog	• Visibility sensors • DMS signs • VSL signs • Radar detectors • HAR • Closure gates • Flashing beacons on metal signs	• Driver warnings via DMS • VSLs posted • Flashing beacons activated • Road closures as conditions warrant	Active
Utah	I-215 Low Visibility Warning System	1 mile	Tule fog	• Forward-scatter visibility sensors • Vehicle detectors • DMS signs	• Driver warnings and speed guidance via DMS	Inactive
Virginia	I-64 Afton Mountain Fog Warning System	8 miles	Fog	• Visibility sensors • RWIS stations • CCTV • DMS signs	• Driver warnings via DMS • In-pavement lighting activated • Warnings issued through 511 system	Active
Virginia	I-77 Fancy Gap VSL System	14 miles	Fog	• Visibility sensors • RWIS stations • VMS signs • VSL signs	• Driver warnings via DMS • VSLs posted	Under const.

511 – system for providing travel information through a 511 telephone number or website
CCTV – closed-circuit television
DMS – dynamic message signs
HAR – highway advisory radio
NWS – National Weather Service
RWIS – road weather information system
SR – state route
VSL – variable speed limit

DUST DETECTION TECHNOLOGIES

This section provides a more in-depth review of available technologies for detecting windblown dust and reduced visibility, including a review of technologies currently in use on a pilot project in ADOT's Safford District.

The Safford District Pilot Project

In 2011, ADOT implemented the Dual Use Safety Technology (DUST) Warning System to detect weather conditions and poor visibility and to reduce the number of dust- and weather-related crashes on a 26-mi stretch of I-10 in Cochise County near the New Mexico state line. This location was selected, in part, because of multiple fatalities in a dust-related crash that occurred on I-10 near Bowie on April 9, 1995. The $600,000 DUST project was partially funded by a $480,000 grant from the FHWA and was implemented at existing RWIS sites near Bowie (milepost 364) and San Simon (milepost 380), as well as at one other location near Olga Road at milepost 372. Each of these three monitoring locations serves as the center point of a warning zone that spans 4 to 6 mi (Engel 2014).

Previously, ADOT placed tower-mounted, passive systems at the Bowie and San Simon sites that measured wind speed and temperature and that allowed authorized users to log in to receive updates on these parameters, as well as still images from fixed focus cameras. When the DUST system was implemented in 2011, visibility and wind speed instruments and CCTV cameras were installed at the Bowie, Olga Road, and San Simon sites and at the new site near milepost 372. The Belfort Visibility Sensor Model 6000, which is designed to monitor visibility conditions over a range of 20 ft to 50 mi, was selected for visibility detection. This sensor includes an infrared LED transmitter that projects light into a sample volume; light scattered in a forward direction is detected by a receiver. Visibility sensors are mounted on a lattice tower at a height of 12 ft, with wind speed anemometers placed at the top of the tower, as shown in Figure 13.

Static signs are placed at both ends of the project (near mileposts 361 and 387) that read, "During limited visibility, pull off road, turn off lights." In addition, the system's dynamic warnings are triggered by specific wind speed and visibility thresholds, causing it to send an e-mail message to ADOT responders, activate DMS, and issue warnings through HAR. When wind speeds exceed 38 mph, flashing signs instruct drivers to tune to the HAR frequency, where they hear a message that warns about high winds and the potential for reduced visibility. In addition, 12 beacons that indicate "Limited Visibility When Flashing" are activated; these beacons are distributed across the three warning zones described above. Lastly, overhead DMS near mileposts 362 (eastbound) and 385 (westbound) display a message saying "Caution – High Winds." When visibility is reduced to 1,100 ft or less, a more strident HAR script is activated that instructs drivers to pull over. In addition, the overhead DMS messages are changed to "Caution – Blowing Dust."

The structure and components of the Safford District DUST system are similar to the visibility detection and warning systems of other states as described previously; these systems generally consist of forward-scatter visibility detectors, CCTV cameras, DMS, and HAR. However, while many of the systems in other states have proven to be reasonably reliable and effective at detecting conditions of reduced visibility, it has been difficult to evaluate the effectiveness of the DUST system. One key issue is that, since the DUST system was installed in 2011, the visibility sensors have never been triggered by dust, and no dust-related low-visibility incidents have been reported on this section of I-10. In addition, a number of potential issues have been identified with the system since its installation, including the following:

- The durability of the computer interfaces and visibility sensors may be problematic, as the devices have lost function after about 18 months and have required frequent maintenance to ensure functionality.
- The sample of air read by the visibility sensor is only about 18 inches in diameter, and these readings are used to represent variable conditions over 4 to 6 mi of roadway.
- A single sensor placed with a dust detection zone spanning several miles may miss localized dust events, such as narrow dust channels, that may be less than half a mile wide.

For these reasons, it is unclear whether or not the DUST system is workable on a large scale, and ADOT continues to evaluate the viability of extending this type of system to other sections of I-10.

Summary of Available Technologies

As previously described, organizations in Arizona and other states have identified detecting the onset of conditions that result in reduced visibility as a means of providing real-time warnings to motorists and reducing dust-related crashes. Table 2 contains several dust detection methods that are currently used by meteorologists, transportation agencies, and air quality management agencies. Overall, these methods are more useful for detecting large-scale dust events and less useful for detecting localized events. In addition, the instrumentation may be too cost-prohibitive to create a dense enough network to be useful in detecting small-scale dust channel events that can occur anywhere over a broad area. Other benefits and limitations of each instrument are provided.

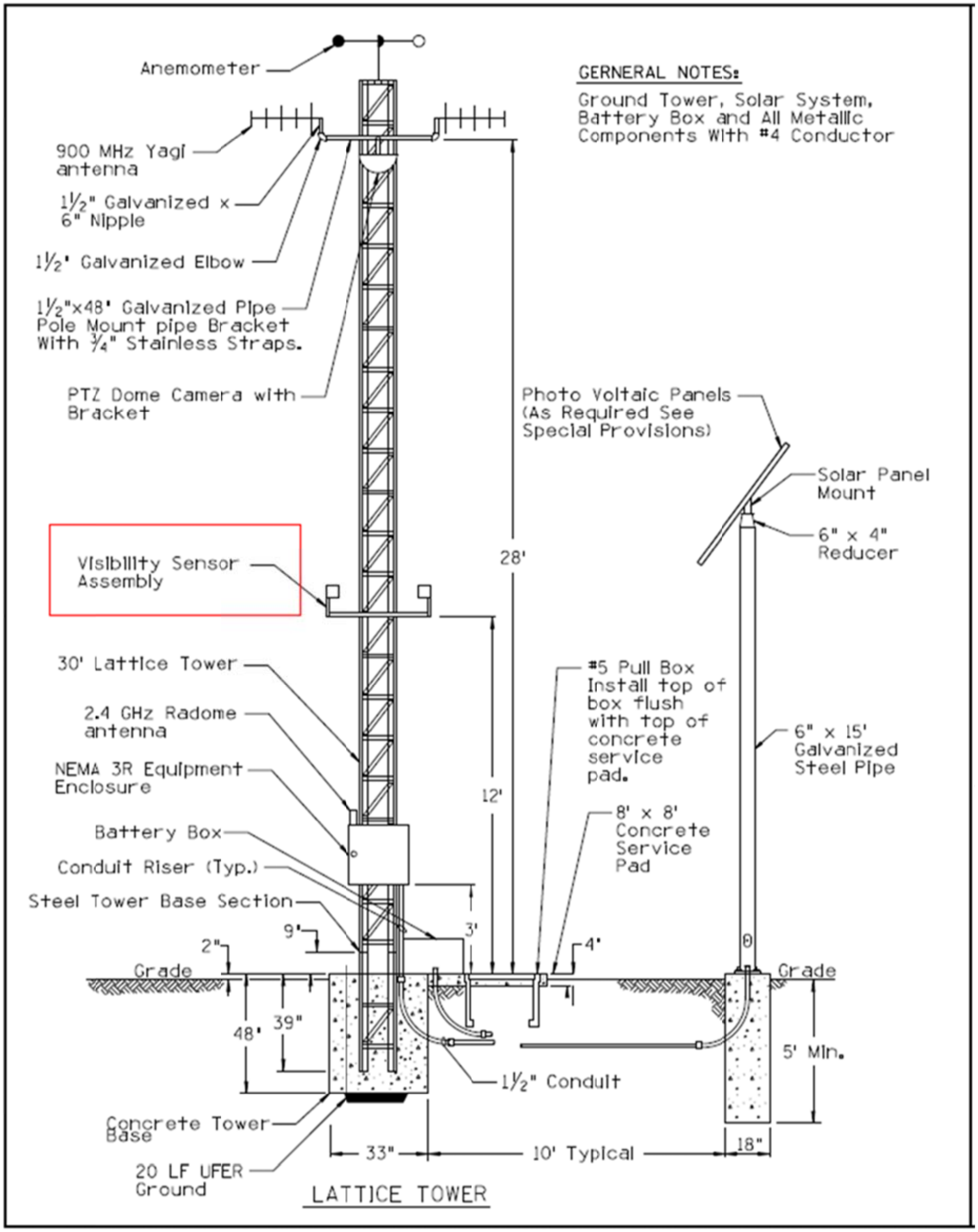

Figure 13. Schematic of the Safford District DUST Tower Installations (Source: ADOT)

Table 2. Summary of Technologies Currently Used to Detect Windblown Dust

Instrument	Benefits	Limitations
Visible satellite	• Covers a large area • Images are easily accessible online	• Dust may be obscured by cloud cover • Poor temporal resolution • Spatial resolution does not capture low-level dust channels • Onset of events may be missed
Doppler radar	• Near-real-time data • Very useful for detecting and tracking outflow boundaries of thunderstorms	• Limited coverage along the I-10 corridor between Phoenix and Tucson • Radar beam overshoots low-level dust channels
"High-end" visibility sensors	• Can be placed near-road as part of dust warning systems • Provide continuous measurements of visibility	• Sensors may be too costly to cover a broad area.
Visibility cameras	• Real-time data via video feeds • Can view a large area depending on siting • Reliable and relatively inexpensive	• Video feeds may require constant monitoring to identify dust
Regulatory air quality monitors	• Tested, accurate measurements of near-real-time particle concentrations	• Current network is not dense enough to capture localized dust events • Monitors may be too high above the surface in some cases • New sites require extensive infrastructure • Expensive to install and maintain

As indicated by the interviews and other research, a monitoring system capable of detecting small-scale dust channel events will be most useful, as larger-scale dust events are already relatively well detected and predicted. Table 3 contains several examples of lower-cost commercially available particle monitors that could be useful for detecting PM associated with reduced visibility. This list represents a range of monitor costs, detection methods, uses, technologies, power requirements, and level of monitor precision and accuracy. This list does not include all available sensors, but provides a sense of the types of instruments available and their relative cost. Some of these sensors have been used more extensively to measure particles (rows 1 through 7), though not in situations requiring long-term deployment, while others are relatively new sensors (rows 8 and 9) that have a very limited track record for PM measurements, but cost less. Note that factors other than purchase cost should be considered for each instrument, including power requirements, instrument life span, operations and maintenance, reliability, replacement costs, and data acquisition (i.e., mechanisms for downloading or monitoring data feeds).

Table 3. Examples of Available Particle Monitors

	Name	Sensor Type	Approximate Purchase Cost
1	E-BAM (Environmental Beta Attenuation Monitor)	Particle mass	$8,000
2	Thermo Scientific ADR-1500	Particle counter	$7,000
3	TSI DustTrak Model 8530	Particle counter	$5,000
4	Thermo PDR-1500	Particle counter	$5,000
5	MetOne E-Sampler	Particle mass	$5,000
6	MetOne-212 Particle Profiler	Particle counter	$4,000
7	Sensit	Particle momentum	$2,000
8	Dylos DC1100 Pro Air Quality Monitor	Particle counter	$300
9	Shinyei PPD60	Particle counter	$300

ISSUES FOR FURTHER RESEARCH

During this background research for designing a communication plan on windblown dust, the project team identified several issues that might benefit from future research. These issues are noted below:

- A lack of current information exists on specific sources of fugitive dust that lead to windblown dust storms on I-10 between Phoenix and Tucson. A better understanding of land-use types that contribute to the dust problem could be used to design long-term mitigation strategies.
- The windblown dust events most difficult to predict and detect are localized dust channels. More research is needed on meteorological models to accurately forecast these local events.
- Though areas of concern for windblown dust have been identified on specific portions of I-10 between Phoenix and Tucson, dust storms can occur in a number of areas along this 100-mi stretch. Such storms can be relatively small in scale, so research regarding a network of sensors along critical roadway segments may be worthwhile. Research that explores a broad range of new “small sensor” technologies might identify cost-effective solutions.
- Driver behavior is a contributing factor to dust-related crashes in Arizona, and little is known about how drivers typically react in conditions of reduced visibility.

The next phase of this project primarily focused on the last issue identified above: providing information on driver perceptions and behaviors by conducting a survey of Arizona travelers and convening two focus groups with selected drivers. Chapter 2 of this report documents findings from the survey and focus groups.

CHAPTER 2. ASSESSMENT OF ADOT COMMUNICATION NEEDS

BACKGROUND

Following the review of current practices in Arizona and other states documented in Chapter 1, the project team next performed a needs assessment to evaluate the extent to which current ADOT practices meet the need for windblown dust detection and communication along I-10 and other impacted roadways in Arizona. This chapter reports on that needs assessment, which consisted of (1) a literature review examining efforts to change driver behavior and (2) the collection of information from Arizona travelers related to driving in dust storm events, such as personal experiences, usage and influence of weather information, preferred information sources and media, and similar topics.

LITERATURE REVIEW

Road safety campaigns, such as ADOT's "Pull Aside, Stay Alive" campaign communicating the dangers of windblown dust events, have commonly been used to influence driver behavior related to safety issues, such as driving while intoxicated, seat belt use, and aggressive driving patterns. In addition, ITS technologies such as variable message signs (VMS) have been used to improve roadway safety by providing information on road conditions and suggested driving practices. Several studies have been conducted on the effectiveness of these efforts to increase safe driver behavior and reduce the number of motor vehicle crashes. This section provides a high-level overview of key findings from this research.

Phillips et al. (2011) performed a meta-analysis of 67 studies that contained at least one estimate of the impact of a road safety campaign, and extracted a total of 119 such estimates from these studies. Based on this meta-analysis, road safety campaigns reduce crashes by 9 percent, on average. Higher crash reduction rates were associated with campaigns that use personal communication techniques, such as in-person seminars, two-way discussions with a safety expert or distributor of campaign media, group discussions, or personally addressed letters. In addition, campaigns determined to be more effective at reducing crash rates included: (a) campaigns focused on the drinking-driving theme, (b) campaigns accompanied by enforcement, and (c) short-term campaigns that were proximal in time and space to targeted behaviors.

The Phillips et al. results are consistent with an earlier meta-analysis of 87 studies that evaluated the effectiveness of mass media campaigns related to road safety (Elliott 1993). The Elliot study evaluated campaigns that spanned 20 years, occurred mostly in English-speaking countries, and focused on seat belt use, drinking and driving, and other driver behaviors. Researchers identified a variety of campaign effects, including increased knowledge, changed attitudes, and changed behaviors, and found that the average effect size was 7.5 percent. In other words, a road safety campaign typically brought about a 7.5-percent increase in post-campaign measures of a given effect relative to pre-campaign measures of that effect. However, campaign impacts were highly dependent on the base level of knowledge or behavior measured before the campaign began. Campaigns starting with a base level below 40 percent had greater effects than campaigns starting with higher base levels. In addition, campaigns featuring emotional or negative (e.g., fear-based) approaches were more effective when base levels were below

40 percent, while positive, rational approaches were more effective when base levels were over 40 percent. Delhomme and Forward (2009) noted that the effectiveness of emotional or fear-based appeals was also increased when the messaging vividly described a threat and offered a specific plan for avoiding the threat. The members of the target audience must also believe themselves capable of executing the recommended plan.

Delaney et al. (2004) developed a synthesis of international literature related to road safety campaigns and identified a number of characteristics that helped determine a campaign's effectiveness in reducing crash rates. In particular, the researchers found that campaign effectiveness is increased when development of the campaign is informed by explicit theoretical models of human behavior. Also, the use of campaign supports, such as enforcement, public relations, and unpaid media coverage, can improve campaign results. Lastly, message characteristics and media mix play a key role in the campaign's success; specifically, messages should be credible, realistic, and include a consistent slogan.

Wundersitz et al. (2010) reviewed international road safety literature published from 2001 to 2009 and identified best practices for mass media campaigns. The researchers recommended the use of new technologies such as short message service (SMS; i.e., text messaging) to disseminate information, noting that three exposures are generally needed to effectively convey the campaign message. This study also identified a need for further research into the effectiveness of media campaigns for a variety of behaviors, as most research has focused on speeding or drinking and driving.

MacCarley et al. (2006) evaluated an automated fog detection and warning system in California's Central Valley, which is subject to seasonal tule fog from October through April. The researchers monitored vehicle speeds before and after drivers were exposed to VMS in the warning system area, and found that warning messages resulted in an average speed reduction of only 1.1 mph. In addition, mean speeds averaged 61 mph when warning messages advised drivers to reduce speeds to 30 mph due to reduced visibility.

Regarding VMS, this technology is widely used to manage transportation networks, and several studies have evaluated the effectiveness of VMS in influencing driver route decisions (Peeta et al. 2000; Peng et al. 2004). However, limited research has been conducted on the effectiveness of VMS for improving driver safety during reduced visibility conditions. Hassan et al. (2012) studied drivers' responses to VMS during various visibility and traffic conditions, noting that although the number of crashes occurring due to poor visibility is small compared to the number of crashes occurring in clear conditions, visibility-related crashes tend to be more severe. This research was conducted by surveying 566 drivers in Florida, where reduced visibility due to fog and smoke on roadways is common. Survey participants were exposed to several scenarios designed with driving simulation software and asked to report on their responses. Survey results showed that both the use of the simple message "Caution—fog ahead—reduce speed" and the placement of two successive VMS prior to the reduced visibility zone increased the effectiveness of the warning system. In addition, based on study findings, the researchers also emphasized the importance of accurate, real-time detection of visibility conditions so that warning messages match current conditions, as well as the use of educational campaigns to enhance drivers' awareness of the importance of responding to warning messages.

Rodier et al. (2010) conducted driver surveys and two focus groups to evaluate the public safety benefit of using VMS to display roadway safety campaign messages in California. Study results indicated that driver behavior changes were connected to VMS message comprehension rates. For example, only 61 percent of drivers surveyed understood a "Click It or Ticket" message related to seat belt use, and over half of drivers who took no action after viewing the VMS reported that they did not fully comprehend the message.

DATA COLLECTION FROM ARIZONA TRAVELERS REGARDING DUST STORM EVENTS

To examine whether ADOT's current communication methods meet drivers' needs for dust event information, as well as identify information sources and communication methods preferred by Arizona drivers, information was gathered from Arizona drivers. Quantitative data were obtained through an online survey of drivers statewide, and qualitative data were gathered through two focus groups; one held in Phoenix and the other in Tucson.

Three Arizona counties—Maricopa, Pima, and Pinal—were designated by ADOT as target areas for this study due to their propensity toward dust storms. Individuals who completed the survey and lived in one of the three targeted counties were considered potential focus group participants and, at the end of the survey, were asked if they were interested in participating in a follow-up focus group discussion to be held in August. Those who responded affirmatively comprised the pool of potential focus group participants. Additional information on the selection of focus group participants is provided later in this paper.

SURVEY METHODOLOGY

The online survey was launched on June 10, 2014, and remained available online through July 20, 2014. To reach the goal of at least 300 completed surveys, a recruitment e-mail was sent to 44,000 ADOT e-mail subscribers, using a list provided by the agency. The e-mail included a link to access the survey. Additionally, ADOT promoted the survey on its website and in media releases.

The survey was open to both residents and non-residents of Arizona. The sole eligibility requirement for participation was being a licensed driver age 16 or older, which was determined by the first survey question. When the final data were collected and the survey terminated, 2,551 questionnaires had been completed. Of the total, 57 percent had accessed the survey in response to the e-mail invitation; these individuals are subsequently referred to as *ADOT subscribers*. The remaining 43 percent had accessed the survey in response to other promotional efforts by ADOT, and are referred to as *ADOT non-subscribers*. Where statistically significant, differences between subscriber and non-subscriber responses are noted.

Respondents were identified as either residents or non-residents of Arizona by means of a survey question, with residents including those who live in the state year-round as well as those who identified themselves as living in Arizona part of the year, such as winter visitors. The vast majority of respondents (98 percent) were Arizona residents, and the majority of those individuals (96 percent) live in the state year-round. The 2 percent of respondents who were non-residents of Arizona represent only

49 individuals. Each respondent living in Arizona was also identified as a resident of either one of the three target counties—Maricopa, Pima, and Pinal—or as a resident of “all other counties.” Throughout this paper, charts that present data by county of residence exclude the 49 individuals who do not live in Arizona.

Additional demographic data were also collected from survey participants:

- Gender – Males composed 53 percent of respondents and females 47 percent.
- Age – Survey participants ranged from age 16 to 65 and older, with 54 percent in the age range of 45 to 64. Specific representation in each age group is as follows:
    - 10 percent were ages 16 to 34 (N = 271)
    - 70 percent were ages 35 to 64 (N = 1,779)
    - 20 percent were ages 65+ (N = 501)
- Number of years living in Arizona (year-round and seasonal residents) – The majority (82 percent, or 2,056) of respondents living in Arizona, either full-time or part of the year, reported living in the state for 10 or more years. Additionally, 7 percent have lived in Arizona for one to four years, and another 11 percent, five to nine years.
- Length of time holding a driver’s license – The vast majority (93 percent, or 2,366) of respondents have had a driver’s license for 15 years or longer.

Detailed demographic information on the survey participants is provided at the end of the section discussing survey findings. In addition, additional summary information on survey results is provided in Appendix G.

SURVEY FINDINGS

Primary Reason for Driving in Arizona

Respondents were asked to identify their primary reason for driving on Arizona highways. Among Arizona residents, the two primary reasons for driving Arizona highways were to get to and from work or business (50 percent) and to engage in activities of daily life, such as shopping and doing errands (30 percent). As would be expected, driving related to work and business was significantly higher among individuals under age 65 than those 65 and older (57 percent and 20 percent, respectively). Also as would be expected, non-residents’ primary reasons for visiting the state were to visit Arizona landmarks or travel destinations, and to visit with family and friends.

Seeking Out Weather Information Related to Driving Conditions Prior to Trip

As seen in Figure 14, nearly one-third of respondents (32 percent, or 794 of 2,551) reported that they often seek out weather information related to Arizona driving conditions before their trip. *Often* is defined as selecting 6 or 7 on a scale of 1 to 7, where 1 represented *never seek out information* and 7 represented *frequently seek out information*.

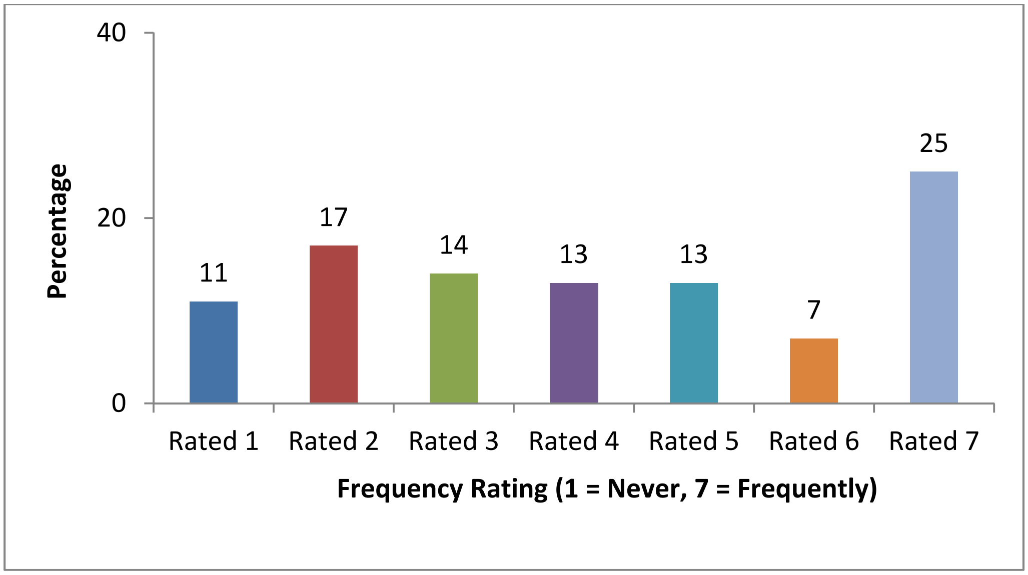

Figure 14. Frequency of Seeking out Weather Information Before Trip (N = 2,551)

It is noteworthy that, as seen in Figure 15, respondents in the three target counties of Maricopa, Pima, and Pinal sought out weather information significantly less often than the collective group of respondents in all other counties, with collective rates of 30 and 37 percent, respectively.

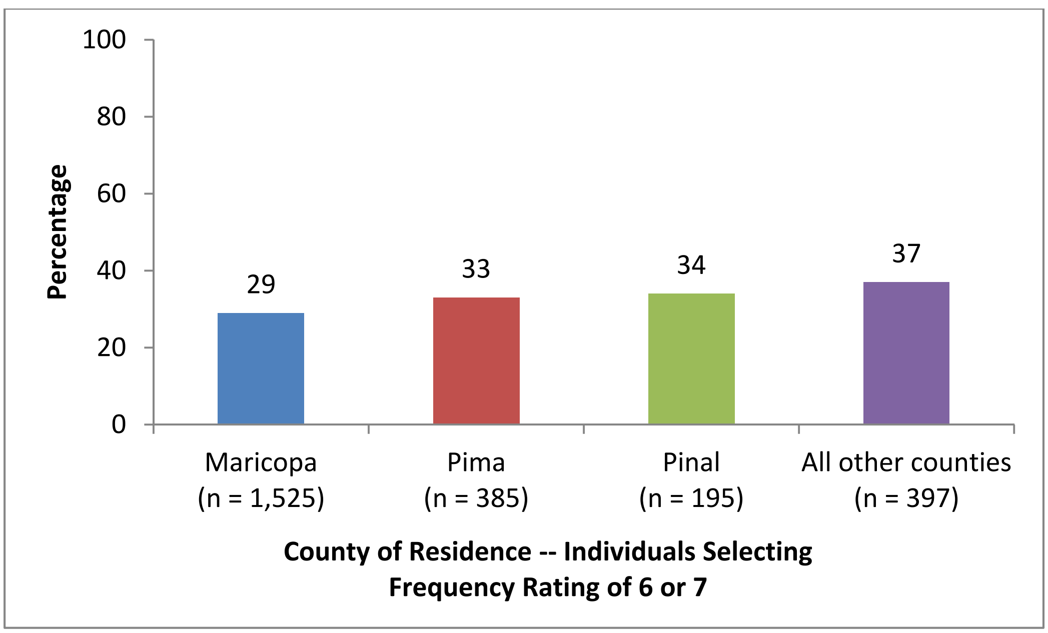

Figure 15. Respondents Who Often Seek Weather Information Before Trip, by County of Residence (N = 2,502)

On the scale of 1 to 7 used for responses, the mean response for all respondents and across all age groups was 4.2. Figure 16 shows that the likelihood of seeking out weather information prior to a driving trip directly corresponded with age, growing from a rate of 19 percent among respondents ages 16 to 34 to a rate of 41 percent among those 65 and older.

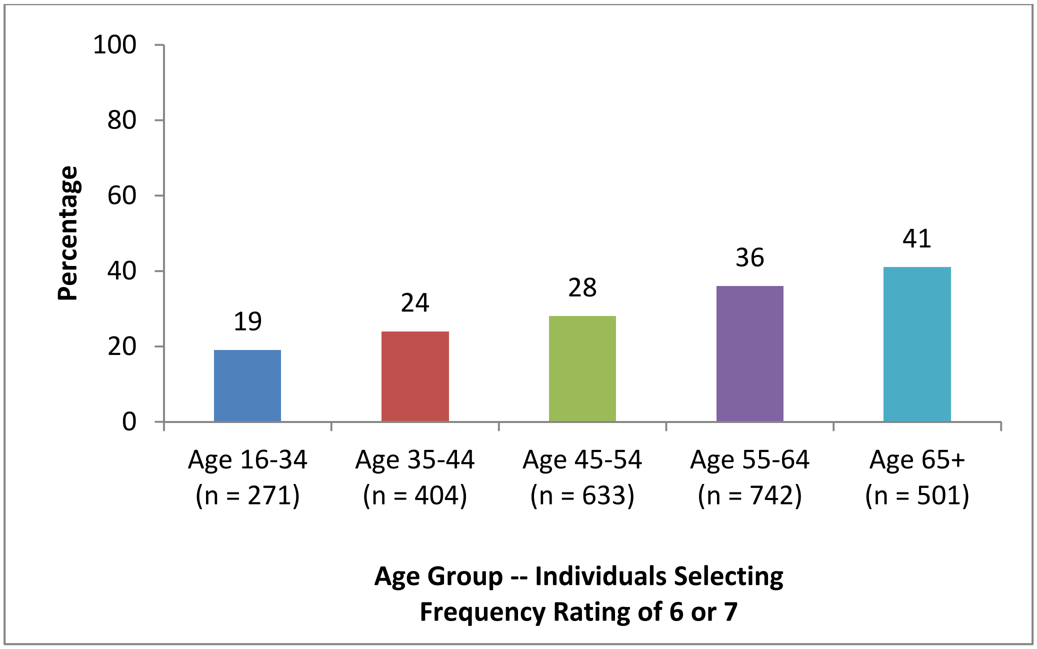

Figure 16. Respondents Who Often Seek Weather Information Before Trip, by Age Group (N = 2,551)

Sources Used to Obtain Weather Information

All respondents who reported that they seek out information about weather conditions (N = 2,265), regardless of how often they do so, were asked to identify the sources they have used to obtain that information. In a series of three questions, respondents were presented lists of potential sources: agencies and organizations, media sources, and personal contacts.

Agencies and Organizations as Sources of Weather Information

In response to the question about which agencies and organizations were used as weather information sources, 87 percent of the respondents reported using one or more of the sources that had been provided as answer choices. As shown in Figure 17, the top three agencies and organizations used by respondents were the NWS, cited by 70 percent of respondents; ADOT, cited by 51 percent; and Arizona 511 (defined in the survey as the AZ511.gov website as well as the 511 phone system), cited by 29 percent of respondents. Interestingly, individuals ages 16 to 34 and those 65 and older had the highest and second highest rates among all age groups for consulting the NWS, at 76 percent and 73 percent, respectively. Agencies and organizations that were least used by respondents included roadside assistance clubs, the Arizona Office of Tourism, and the Arizona Trucking Association.

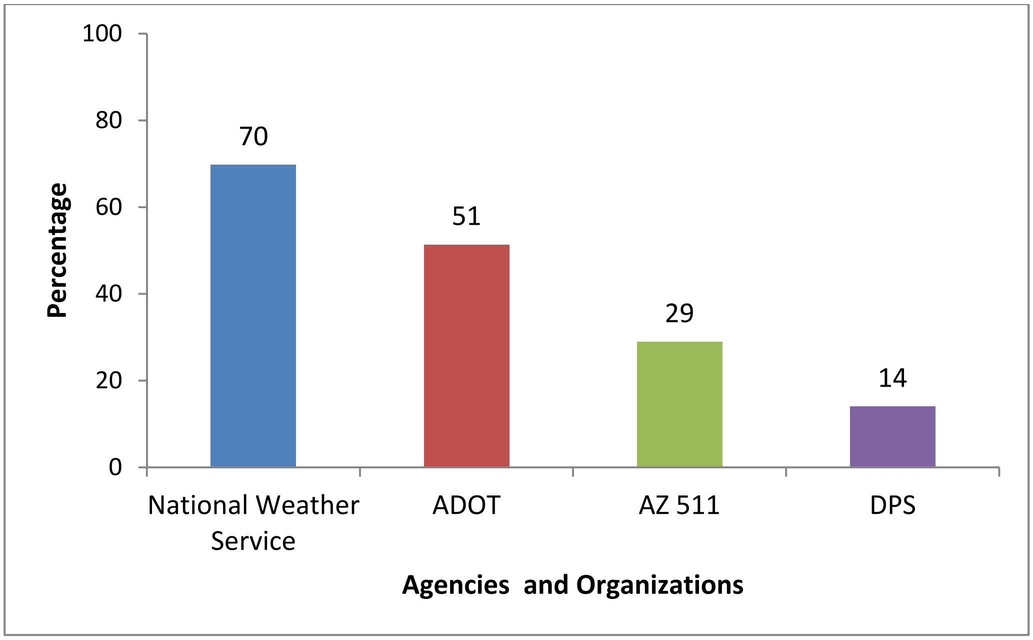

Figure 17. Agencies and Organizations Most Frequently Used for Weather Information by Respondents Overall (N = 2,265)

Use of ADOT and Arizona 511 as Information Sources. As might be expected, both ADOT and Arizona 511 were cited as information sources more frequently by ADOT subscribers than by non-subscribers (58 and 43 percent, respectively, for ADOT; 32 and 25 percent, respectively, for Arizona 511). Additionally, as seen in Figure 18, the use of ADOT as an information source was significantly higher among respondents living in Maricopa County (55 percent) than among those living in Pima County (44 percent), Pinal County (48 percent), and all other (non-target) counties (48 percent). In contrast, Figure 19 shows that usage of Arizona 511 was highest among respondents living in non-target counties (35 percent) than respondents living in Maricopa County (31 percent), Pima County (20 percent), and Pinal County (24 percent). A greater percentage of women than men reported using ADOT (53 percent and 50 percent, respectively), while a greater percentage of men than women used Arizona 511 (31 percent and 27 percent, respectively).

ADOT Tools or Services Used. Individuals who reported using ADOT and/or Arizona 511 as an information source (N = 1,395) were asked a follow-up question about the specific tools or services used to obtain the information. As seen in Figure 20, the top three tools used by respondents overall were the ADOT website (65 percent), travel advisories received via e-mail (34 percent), and the AZ 511 phone line (32 percent).

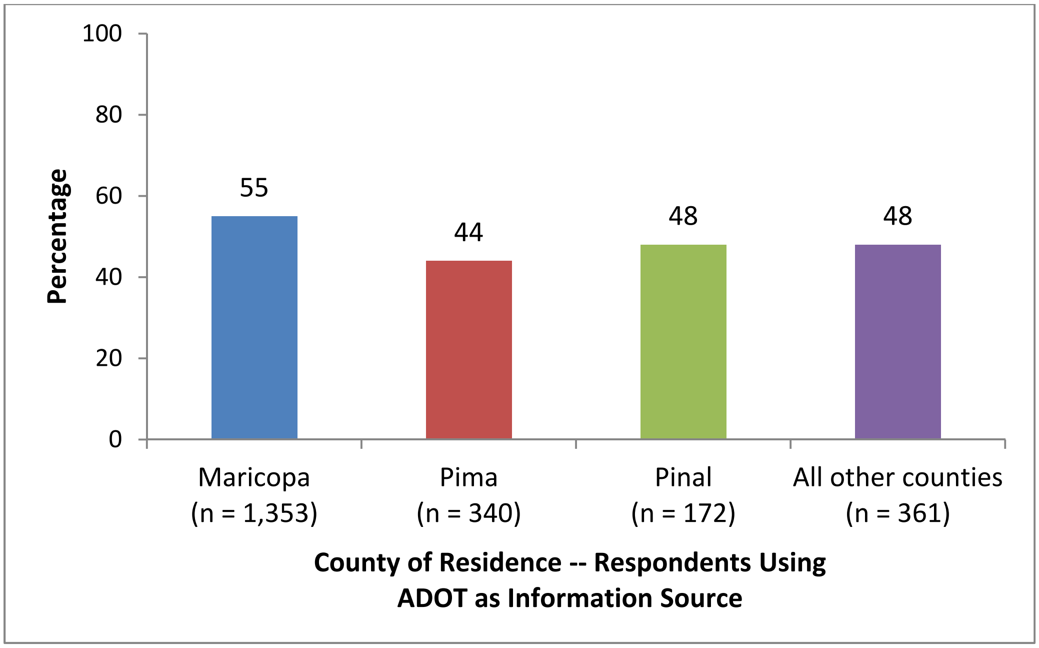

Figure 18. Use of ADOT for Weather Information, by Respondent's County of Residence (N = 2,265)

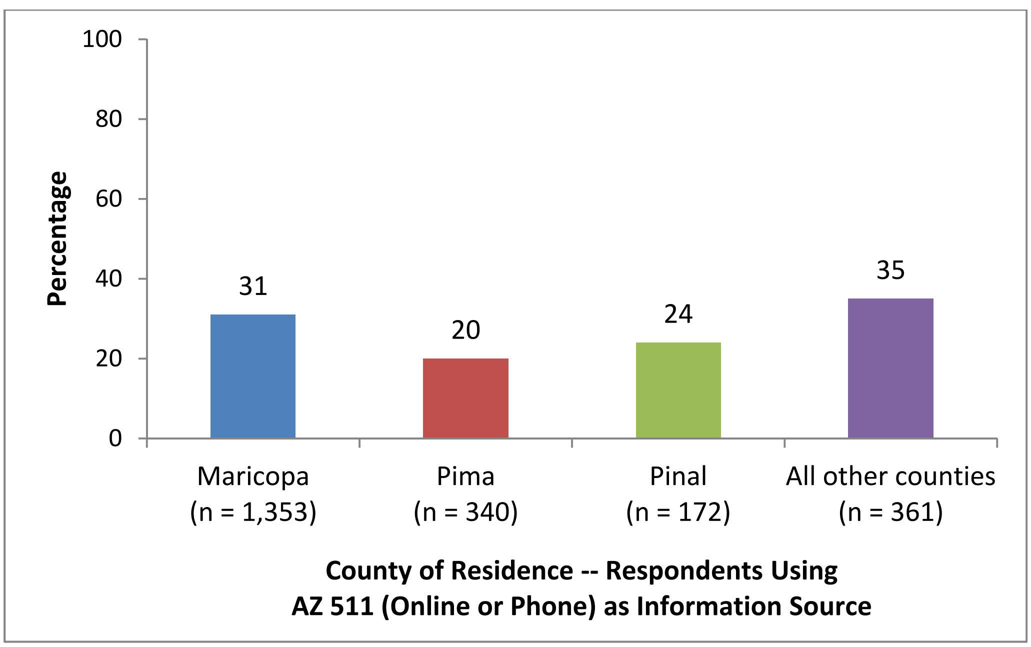

Figure 19. Use of AZ 511 for Weather Information, by Respondent's County of Residence (N = 2,265)

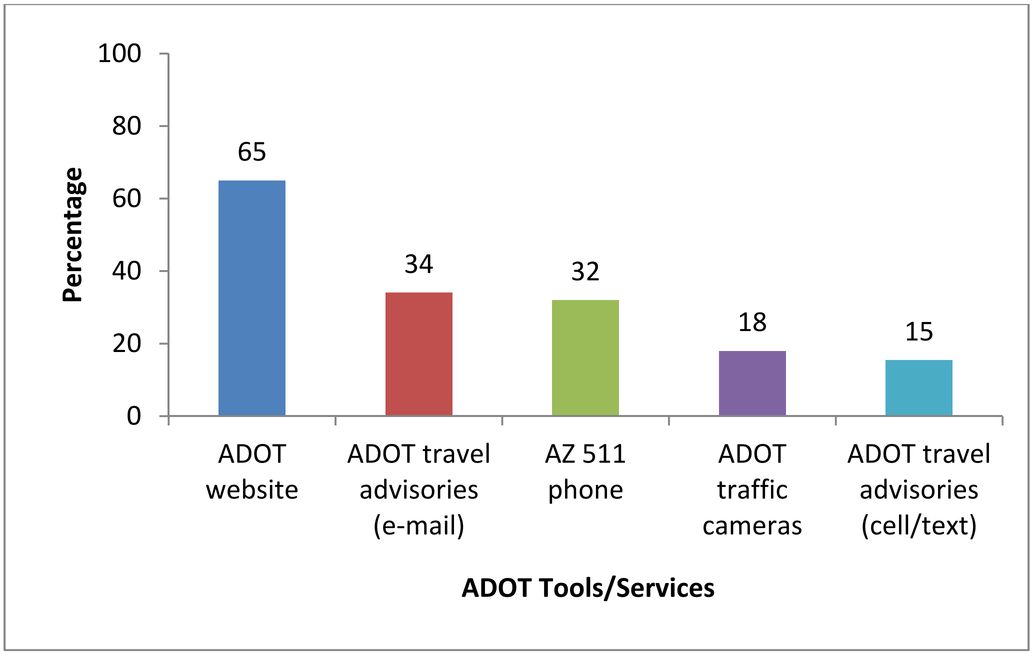

Figure 20. ADOT Tools/Services Most Frequently Used for Weather Information by Respondents (N = 1,395)

An examination of the usage of ADOT tools and services by age group, as seen in Figure 21, showed that the youngest respondents, those in the 16 to 34 age group, reported the highest usage of social media to obtain information, with 21 percent using ADOT's Twitter account and 16 percent using ADOT's Facebook page. At the other end of the age spectrum, respondents age 65 and older reported the highest usage of ADOT travel advisories via e-mail (42 percent), second highest usage of the AZ 511 phone line (29 percent), and the lowest usage of all social media channels among the three age groups.

Additionally, statistically significant differences were seen between subscriber and non-subscriber usage of three specific ADOT tools and services. Non-subscribers reported significantly greater use of the ADOT website than did subscribers (70 and 62 percent, respectively), as well as use of the ADOT Facebook page (7 and 4 percent, respectively). Conversely, subscribers reported significantly greater use of ADOT travel advisories (by e-mail) than did non-subscribers (43 and 19 percent, respectively).

Media as Sources of Weather Information

In response to the question about which media were used as weather information sources, respondents overall (N = 2,265) most frequently selected the following four, as seen in Figure 22: websites (64 percent), electronic highway message boards or signs (59 percent), radio (55 percent), and television (53 percent). Mobile devices were the next most frequently used media, with mobile apps and wireless alerts selected by 44 and 43 percent of respondents, respectively.

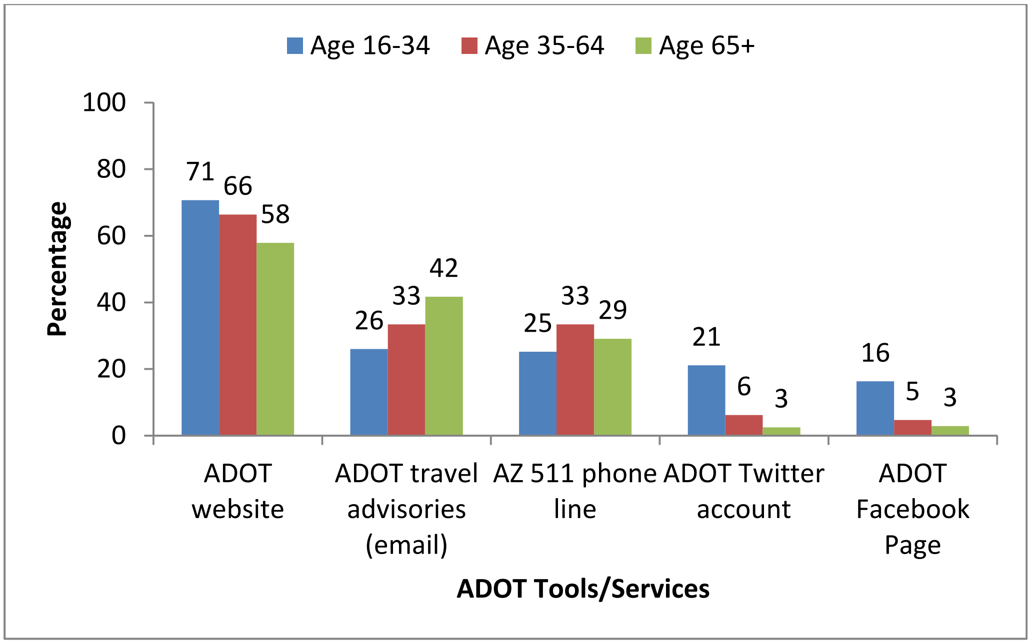

Figure 21. ADOT Tools/Services Most Frequently Used for Weather Information, by Respondent's Age Group (N = 1,395)

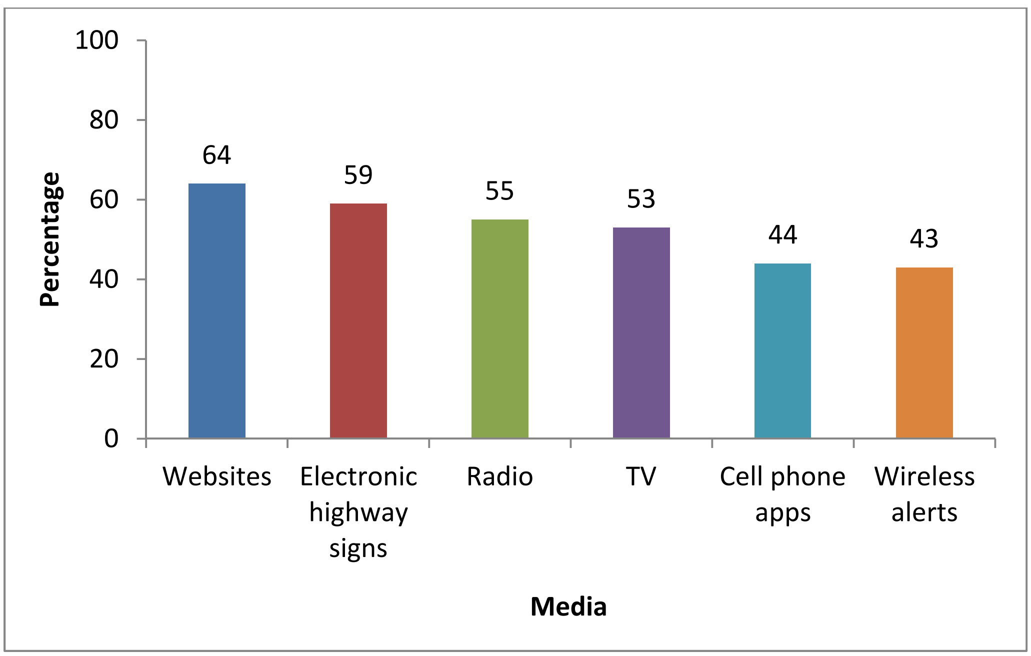

Figure 22. Media Most Frequently Used for Weather Information by Respondents Overall (N = 2,265)

Significant differences in media usage were seen between the younger demographic of respondents and those 65 and older. As seen in Figure 23, respondents in the age group of 16 to 34 reported high usage of mobile apps (56 percent) and social media (51 percent), while usage of these tools by respondents ages 65 and older was far lower (31 percent for mobile apps and 10 percent for social media). Usage of wireless alerts sent to mobile devices was more prevalent among respondents ages 16 to 34 and 35 to 64 (50 and 45 percent, respectively) than those ages 65 and older (34 percent). In contrast, respondents age 65 and older reported high usage of television (64 percent) for information.

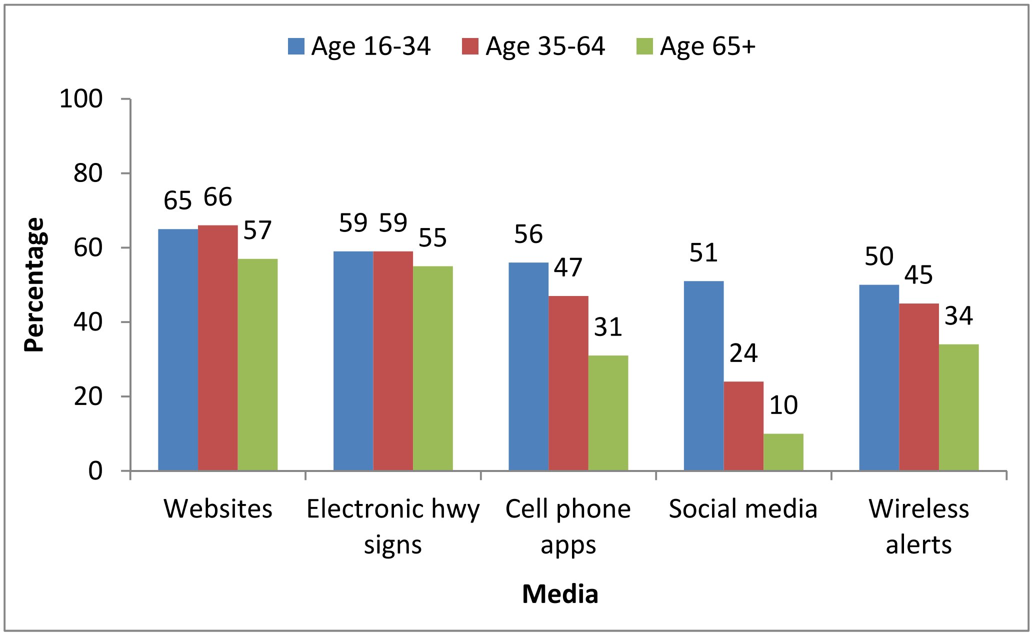

Figure 23. Media Most Frequently Used for Weather Information, by Respondent's Age Group (N = 2,265)

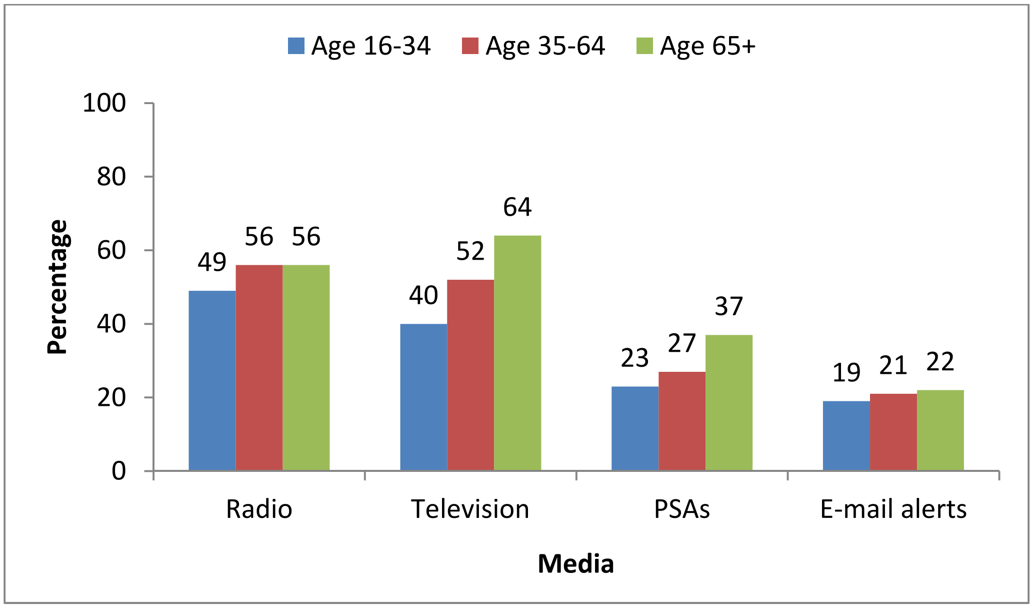

Figure 23. Media Most Frequently Used for Weather Information, by Respondent's Age Group (N = 2,265) (Continued)

Usage of media also differed by gender. A significantly higher percentage of women than men used wireless alerts sent to their mobile devices (47 and 39 percent, respectively), social media (32 and 17 percent, respectively), and public service announcements (30 and 27 percent, respectively). Conversely, a significantly higher percentage of men than women used websites (67 and 61 percent, respectively), and HAR channels (5 and 3 percent, respectively).

An analysis of the usage of media sources by target county (Maricopa, Pima, and Pinal) and all other counties also revealed significant differences. A significantly higher percentage of respondents in the three target counties than those in non-target counties used information obtained via wireless alerts received on mobile devices (45 and 34 percent, respectively), radio (57 and 51 percent, respectively), and television (55 and 46 percent, respectively). In contrast, a significantly higher percentage of respondents in the non-target counties than those in the three target counties used information obtained via websites (71 and 63 percent, respectively).

Additionally, statistically significant differences were seen between subscriber and non-subscriber usage of two specific media. Non-subscribers reported significantly greater use of social media than did subscribers (31 and 18 percent, respectively). Conversely, subscribers reported significantly greater use of e-mail than did non-subscribers (24 and 17 percent, respectively).

Personal Contacts as Sources of Weather Information

Among the respondents who seek out weather information (N = 2,265), 60 percent reported using personal contacts as a source. Slightly more than half (52 percent) of all respondents reported using co-workers, friends, or family as a source for information. Another 18 percent used employer-provided alerts, and less than 3 percent reported use of citizens band radio communications with other drivers and/or information obtained from a dispatch office. Women were significantly greater users of personal contacts than men (66 and 54 percent, respectively).

Other Weather Information Sources

After completing the series of questions regarding the use of agencies and organizations, media sources, and personal contacts as information sources, respondents were asked whether they use any other sources to obtain weather information related to Arizona driving conditions. Slightly less than one-fifth (19 percent) reported the use of other sources, which included self-observation, word of mouth, highway signage, references to specific TV and radio stations, references to specific mobile apps and websites, and information provided through other agencies or counties (e.g., Pinal County Air Quality EnviroFlash e-mail, Mohave County ALERT Flood Warning System, Pima County Sheriff's road conditions hotline, and DPS text alerts).

Preferred Means of Receiving Weather Information

Respondents who reported that they seek out information about weather conditions (N = 2,265) were then asked to select their preferred ways of receiving that information. As seen in Figure 24, among respondents overall, the top six preferred means of obtaining or receiving weather information related to Arizona driving conditions were wireless alerts received on mobile devices (51 percent), radio

(49 percent), mobile apps (42 percent), e-mail alerts (37 percent), websites (36 percent), and TV (35 percent).

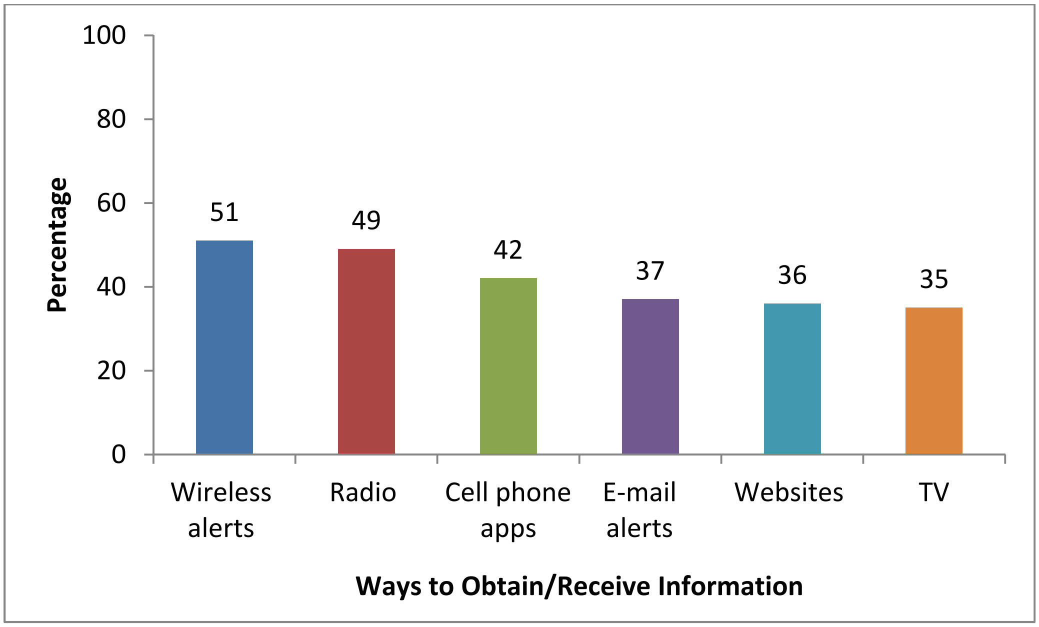

Figure 24. Preferred Means of Obtaining/Receiving Weather Information Among Respondents Overall (N = 2,265)

As seen in Figure 25, an examination of preferred means of receiving information by age group shows that respondents under the age of 65 preferred the use of smart media tools, including wireless alerts on mobile devices, mobile apps, and social media. Conversely, respondents ages 65 and older preferred to use traditional sources and media channels, including radio and television.

Preferences in means of obtaining weather information also differed by gender, mirroring the data reported earlier for usage of media. A significantly higher percentage of women than men preferred wireless alerts sent to their mobile devices (56 and 47 percent, respectively), social media (27 and 12 percent, respectively), and public service announcements (29 and 23 percent, respectively). Conversely, a significantly higher percentage of men than women preferred websites (40 and 32 percent, respectively), and HAR channels (5 and 3 percent, respectively).

An analysis of preferences by target county (Maricopa, Pima, and Pinal) and all other counties also mirrored the data reported for usage of media. A significantly higher percentage of respondents in the three target counties than those in non-target counties preferred the use of wireless alerts received on mobile devices (53 and 44 percent, respectively), while a significantly higher percentage of respondents in the non-target counties than target counties preferred the use of websites (34 and 46 percent, respectively).

Additionally, statistically significant differences were seen between subscriber and non-subscriber preferences related to two specific means of receiving information, which also mirrored the data for usage of media. Non-subscribers reported significantly greater preference for social media than did subscribers (25 and 14 percent, respectively). Conversely, subscribers reported significantly greater preference for e-mail than did non-subscribers (43 and 28 percent, respectively).

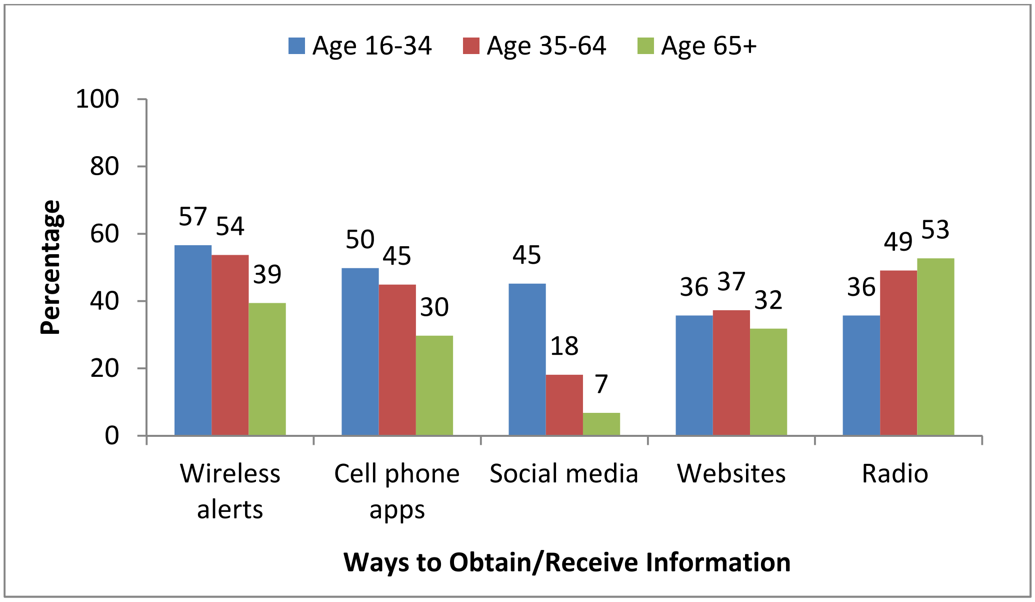

Figure 25. Preferred Means of Obtaining/Receiving Weather Information, by Respondent's Age Group (N = 2,265)

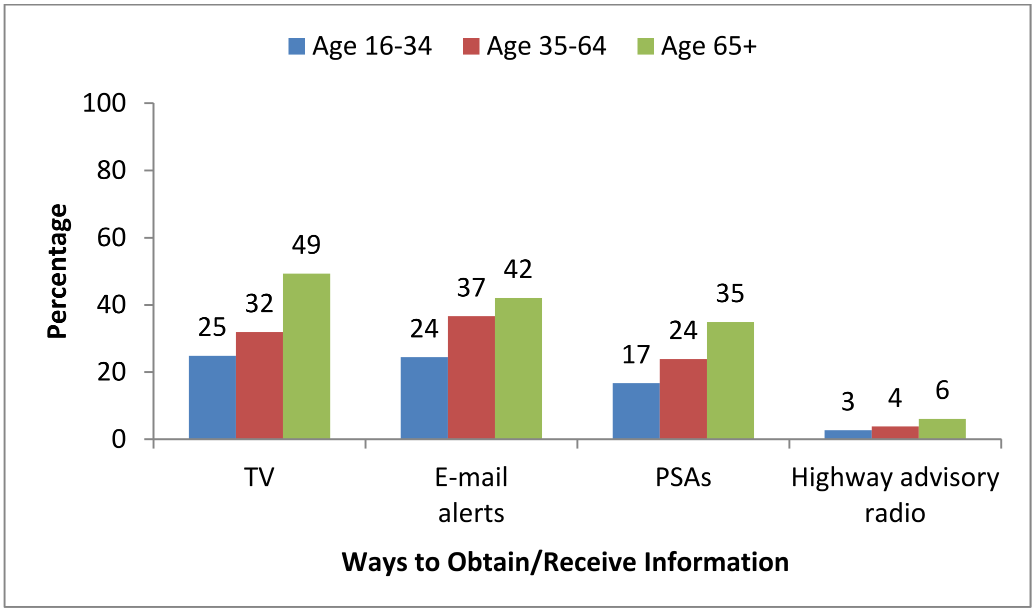

Figure 25. Preferred Means of Obtaining/Receiving Weather Information, by Respondent's Age Group (N = 2,265) (Continued)

Influence of Dust Storm Alerts on Driving Plans or Travel Decisions

A particularly noteworthy finding, and one that highlights the challenge of changing driver behavior, is seen in the degree of influence that weather information has on drivers' travel plans. Among respondents who actively seek out weather information prior to a trip (N = 2,265), slightly less than half (48 percent) report that this information has heavy influence on their driving plans or travel decisions, as seen in Figure 26. *Heavy influence* is defined as selecting 6 or 7 on a scale of 1 to 7, where 1 represented *information has no influence* and 7 represented *information has significant influence.*

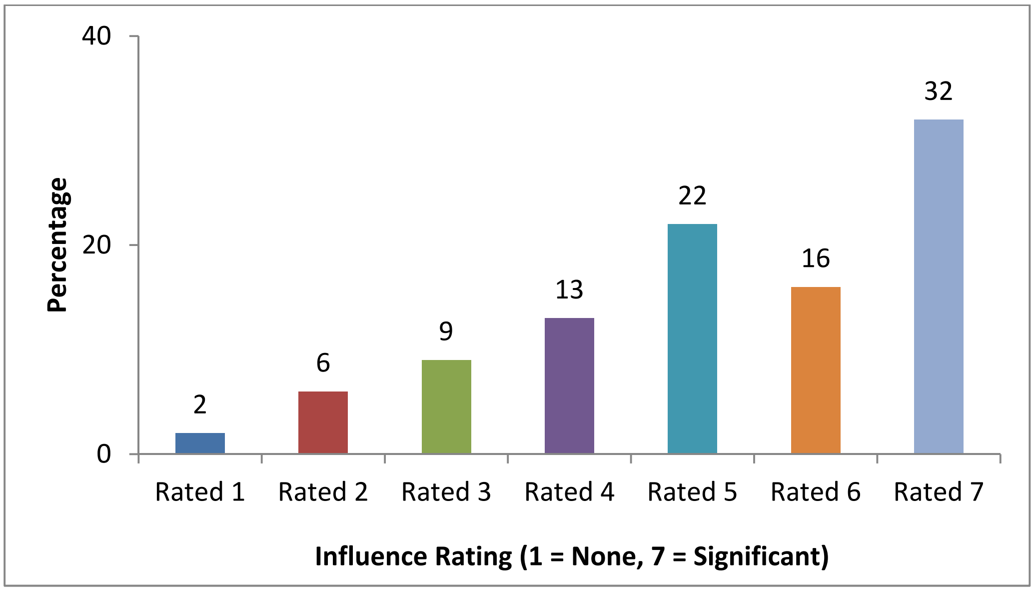

Figure 26. Degree of Influence of Weather Information on Travel Plans Among All Respondents (N = 2,265)

As seen in Figure 27, the degree to which weather information influences driving plans varies significantly by age, with 59 percent of respondents ages 65 and older reporting a heavy influence, as compared with 30 percent of respondents ages 16 to 34 and 47 percent of those ages 35 to 64. The extent to which weather information influences driving plans also varies by gender, with a significantly higher percentage of women than men (52 and 43 percent, respectively) reporting that this information heavily influences their driving plans or travel decisions.

No significant differences were seen between the collective responses from participants in the target counties and those of the non-target counties (48 and 47 percent, respectively). However, a higher percentage of respondents living in Pinal County (62 percent) reported that weather information heavily influences their driving plans, as compared with the percentages of Maricopa County respondents (46 percent) and Pima County respondents (47 percent) reporting the same.

Awareness of Dust Storms and Knowledge about Appropriate Driving Practices

As seen in Figure 28, a significant majority (83 percent) of respondents overall (N = 2,551) reported that their awareness of Arizona dust storms prior to taking the survey was high. *High awareness* is defined as selecting 6 or 7 on a scale of 1 to 7, where 1 represented *not at all aware* and 7 represented *very aware.*

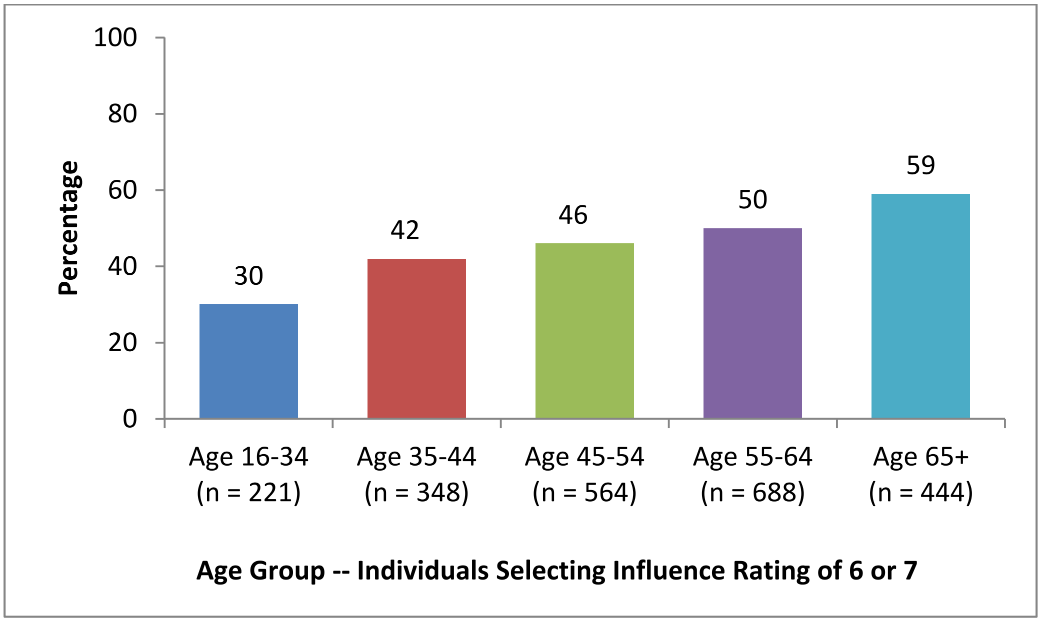

Figure 27. Respondents Reporting Heavy Influence of Weather Information on Travel Plans, by Age Group (N = 2,265)

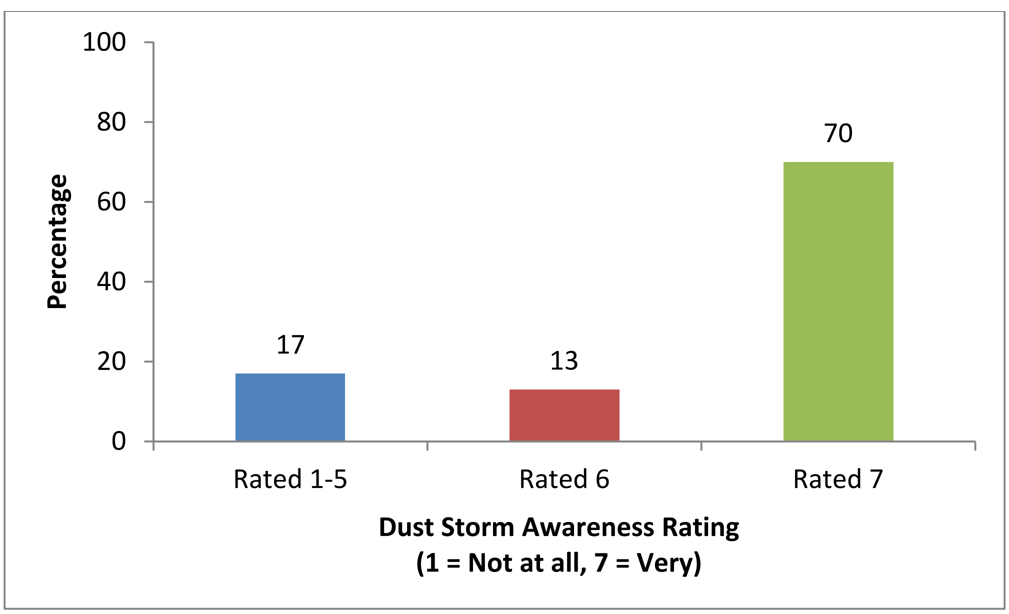

Figure 28. Awareness of Arizona Dust Storms Among All Respondents Prior to Survey (N = 2,551)

Figure 29 shows that respondents' awareness of dust storms increased with age through age 64, when it decreased significantly. Analysis of responses by county showed no significant differences among responses from residents of the three target counties, but respondents residing in the three target counties reported significantly higher awareness levels than those living in all other counties (85 and 78 percent, respectively).

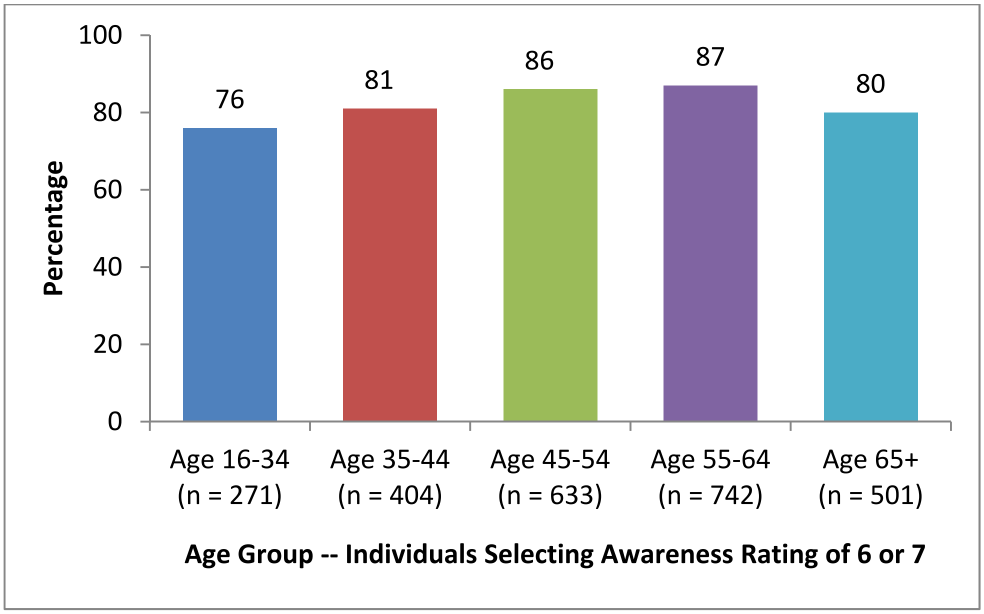

Figure 29. Respondents with High Awareness of Arizona Dust Storms Prior to Survey, by Age Group (N = 2,551)

As seen in Figure 30, when asked how knowledgeable they feel about what to do if they see a dust storm approaching or suddenly find themselves driving in one, over half of all survey respondents (63 percent) reported they were highly knowledgeable about what to do. *Highly knowledgeable* is defined as selecting 6 or 7 on a scale of 1 to 7, where 1 represented *not at all knowledgeable* and 7 represented *very knowledgeable*. It is noteworthy that this figure of 63 percent is significantly lower than the 83 percent who considered themselves highly aware of dust storms.

As was noted with regard to awareness of dust storms, the percentage of respondents who considered themselves knowledgeable about what to do in a dust storm increased with age through age 64, when it dropped considerably, as seen in Figure 31. An analysis of responses by gender showed that it was also related to respondents' reported knowledge of what to do in a dust storm, with 71 percent of men and 53 percent of women considering themselves highly knowledgeable.

No significant difference was seen in degree of knowledge between respondents living in the target counties and those living in all other counties (collectively 64 and 59 percent, respectively). However, as seen in Figure 32, a significantly greater percentage of respondents in Pinal County (69 percent) considered themselves highly knowledgeable about what to do than respondents in Maricopa and Pima Counties (64 and 61 percent, respectively).

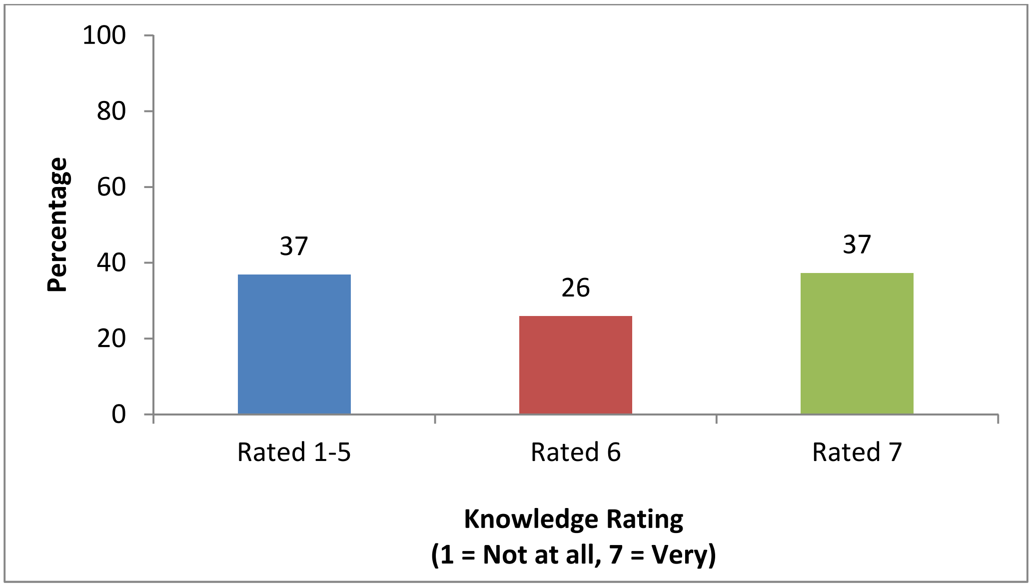

Figure 30. Knowledge of What to Do in Arizona Dust Storms Among All Respondents (N = 2,551)

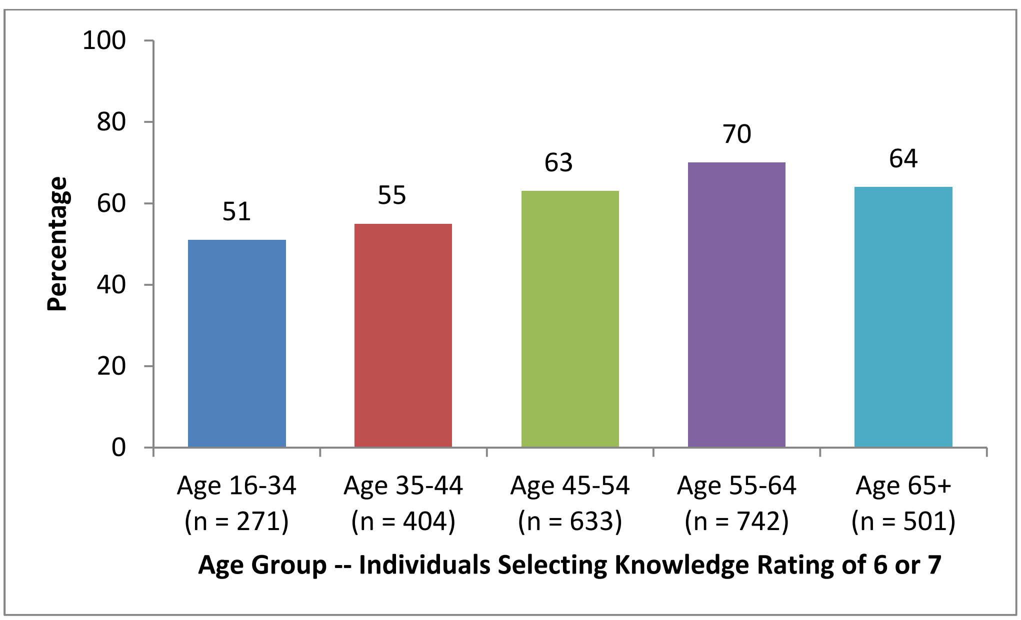

Figure 31. Respondents Who Considered Themselves Highly Knowledgeable About What to Do in a Dust Storm, by Age Group (N = 2,551)

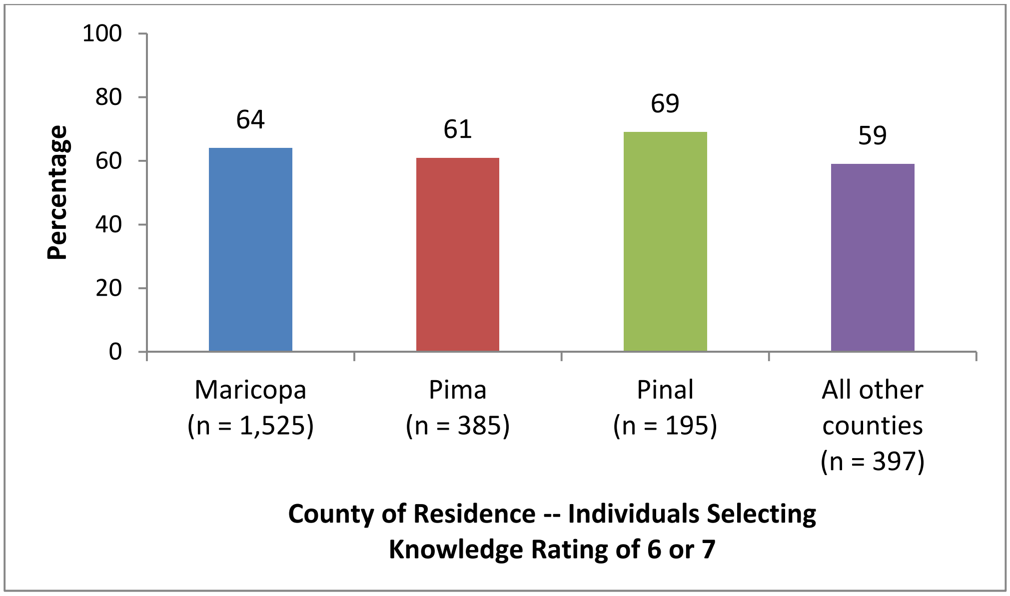

Figure 32. Respondents Who Considered Themselves Highly Knowledgeable About What to Do in a Dust Storm, by County of Residence (N = 2,551)

Frequency of Travel and Experience with Dust Storms on Target Corridors

A key objective of the needs assessment was to obtain feedback from drivers who travel four target corridors where dust storms regularly occur and are considered to be contributing factors in serious crashes:

- I-10 between Tucson and Phoenix
- I-10 between Bowie and San Simon
- I-8 between Casa Grande and Yuma
- I-40 between Flagstaff and Holbrook

This objective was achieved, with 97 percent of all survey respondents reporting that they traveled one or more of the target corridors. By location of residence, 97 percent of Maricopa County respondents, 100 percent of Pima County respondents, and 98 percent of Pinal County respondents reported traveling one or more of these corridors. Among respondents in all other Arizona counties, the figure was 97 percent, and among non-residents of Arizona, 86 percent.

Respondents were asked about their frequency of travel and their experience with dust storm conditions on these four corridors. To describe their frequency of travel on each corridor, respondents could select from the following choices: daily, weekly, monthly (at least once a month), every few months, rarely, and not traveled. For each of the four target corridors, Figure 33 presents the percentage of survey respondents (N = 2,551) who reported traveling on it, and Figure 34 presents the percentage who reported traveling on it at least once a month.

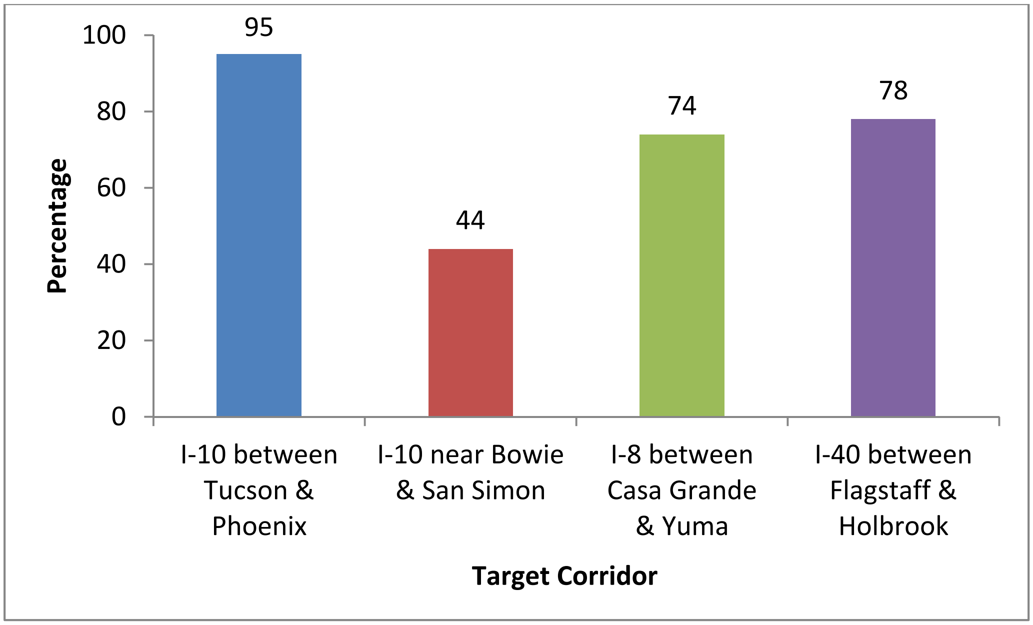

Figure 33. Respondents Who Travel Each of the Target Corridors (N = 2,551)

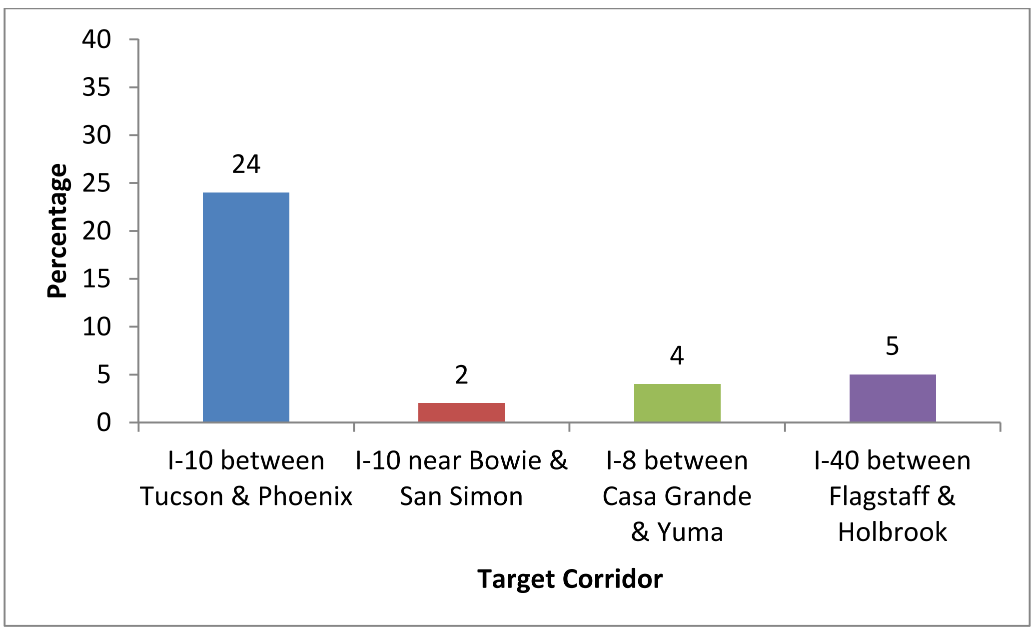

Figure 34. Respondents Who Travel Each of the Target Corridors at Least Once a Month (N = 2,551)

For each corridor, the following data are presented below:

- Percentage of all survey respondents who have traveled the corridor
- Percentage of all survey respondents who travel the corridor at least once a month

- Mean number of times per month traveled on this corridor (calculation based only on those who reported traveling at least one of the corridors, regardless of how often; excludes the 69 respondents who reported not traveling any of the target corridors)
- Percentage of corridor travelers who have experienced dust storm conditions while driving

I-10 between Tucson and Phoenix

- Among all survey respondents (N = 2,551), 95 percent (2,419) have traveled this corridor.
- Among all survey respondents (N = 2,551), 24 percent (602) travel this corridor at least once a month.
- The mean number of times per month traveled on this corridor was 1.7.
- Among survey respondents who travel this corridor (N = 2,419), 61 percent (1,482) have experienced dust storm conditions while driving.

I-10 between Bowie and Sam Simon

- Among all survey respondents (N = 2,551), 44 percent (1,117) have traveled this corridor.
- Among all survey respondents (N = 2,551), 2 percent (43) travel this corridor at least once a month.
- The mean number of times per month traveled on this corridor was 0.2.
- Among survey respondents who travel this corridor (N = 1,117), 12 percent (130) have experienced dust storm conditions while driving.

I-8 between Case Grande and Yuma

- Among all survey respondents (N = 2,551), 74 percent (1,877) have traveled this corridor.
- Among all survey respondents (N = 2,551), 4 percent (101) travel this corridor at least once a month.
- The mean number of times per month traveled on this corridor was 0.3.
- Among survey respondents who travel this corridor (N = 1,877), 22 percent (414) have experienced dust storm conditions while driving.
- Among all survey respondents (N = 2,551), 78 percent (2,001) have traveled this corridor.
- Among all survey respondents (N = 2,551), 5 percent (121) travel this corridor at least once a month.
- The mean number of times per month traveled on this corridor was 0.4.
- Among survey respondents who travel this corridor (N = 2,001), 10 percent have experienced dust storm conditions while driving.

A review of the travel frequency data by target county and corridor produced the findings outlined below.

Pinal County Respondents

- Respondents residing in Pinal County reported significantly more frequent travel on the I-10 Tucson-to-Phoenix corridor than respondents residing in Maricopa and Pima Counties, as well as the non-target counties. Over half (57 percent) of the Pinal County respondents travel this corridor at least once a month, compared with 16 percent of Maricopa respondents, 50 percent of Pima respondents, and 11 percent of respondents residing in the other, non-target counties.

- Respondents residing in Pinal County also reported driving the I-8 Casa Grande-to-Yuma corridor more frequently than respondents residing in Maricopa, Pima, and the non-target counties. The corridor is driven at least once a month by 10 percent of Pinal County respondents, compared with 3 percent of Maricopa County respondents, 5 percent of Pima County respondents, and 6 percent of respondents residing in the other, non-target counties.

Pima County Respondents

- Respondents residing in Pima County reported significantly more frequent travel on the I-10 Bowie-to-San Simon corridor than respondents residing in Maricopa and Pinal Counties. Approximately 4 percent of Pima County respondents travel this corridor at least once a month, compared with 1 percent of respondents each in Maricopa and Pinal Counties. Among respondents from the other, non-target counties, 4 percent reported traveling this corridor at least once a month, the same rate of frequency as Pima County respondents.

Maricopa County Respondents

- Respondents residing in Maricopa County reported significantly more frequent travel on the I-40 Flagstaff-to-Holbrook corridor than respondents residing in Pima and Pinal Counties.
- Approximately 4 percent of Maricopa County respondents travel this corridor at least once a month, compared with 1 percent of respondents each in Pima and Pinal Counties. However, the percentage of respondents from the other, non-target counties that reported driving this corridor at least once a month was significantly higher (14 percent) than for any of the target counties.

Experience with Dust Storm Events Anywhere in Arizona

Among all survey respondents, 84 percent (2,138) reported having encountered an approaching dust storm or having been caught in a dust storm while driving, 15 percent (385) had not, and 1 percent (28) did not recall. Among the respondents who had experienced a dust storm:

- 1,597 experienced these conditions driving on at least one of the target corridors; this figure represents 64 percent of the 2,482 respondents who reported traveling any of these corridors.
- 541 experienced these conditions driving in other areas of the state; this figure represents 57 percent of the 954 respondents who do not travel any of the target corridors or had not experienced dust storm conditions on any of those corridors.

Of the 2,138 respondents who had experienced a dust storm, nearly half (49 percent) reported that they had not received information about the likelihood of dust storms in the area before departing or during their trip, 32 percent reported they had received information, and 19 percent did not recall.

Survey respondents who had encountered a dust storm were asked to describe their most recent storm experience in terms of the characteristics listed below:

- Size of dust storm – On a 5-point scale, where 1 is s*mall localized event* and 5 is *large regional event,* the mean for all responses is 3.3.
- How quickly the storm appeared – On a 5-point scale, where 1 is *visible in distance* and 5 is *suddenly appeared,* the mean for all responses is 2.3.
- Speed at which the storm was moving – On a 5-point scale, where 1 is *very slow moving* and 5 is *extremely fast moving,* the mean for all responses is 3.3.
- Decline in visibility – On a 5-point scale, where 1 is *not impacted* and 5 is *declined quickly to near-zero,* the mean for all responses is 3.6.

Driving Behavior in Dust Storm Events

Respondents who had experienced driving in dust storm conditions were asked to describe their own driving behavior (i.e., "How did you react and what did you do?") and the behavior of other drivers during the dust storm event:

- In describing their own behavior, respondents commonly cited two actions: slowing down and continuing to drive with headlights on, or pulling to the side of the road to wait out the storm, either with headlights turned off or with headlights or emergency flashers turned on.
- Respondents tended to describe the behavior of other drivers as either cautious or reckless, and their descriptions of cautious behaviors were very similar to their descriptions of their own behaviors, such as turning their lights on, slowing down, or pulling off to the side of the road. Reckless behaviors included speeding or not slowing down, making abrupt lane changes, and applying the brakes erratically or inconsistently.

Respondents were also asked if, looking back, there was anything about their own driving behavior that they wish they had done differently. Less than one-fifth (16 percent) of respondents overall answered affirmatively. However, a difference was seen between the percentage of affirmative responses from ADOT subscribers and from non-subscribers (15 and 18 percent, respectively). It is possible that subscribers were less likely to think they should have acted differently because they had been better informed and prepared for the storm due to travel advisories or alerts warning of the storm. Among respondents who would have changed their behavior, typical responses focused on taking such actions as getting weather information before starting the trip, changing travel plans, and exiting the highway when the storm was first seen.

When asked whether they had ever received formal or professional training or instruction about driving in dust storms, a significant majority (86 percent) of respondents answered they had not. Respondents who reported that they had received training or instruction referenced such sources as ADOT-provided training, instruction, and information (PSAs, communication, and web tools); defensive driving or driver education courses that they had taken; work-related training; training received through the military; and training courses provided through organizations such as AARP.

Perceived Reasons That Drivers Do Not Change Behavior

All survey respondents (including those who had not experienced driving in dust storm conditions) were presented a list of statements and asked to select those that might explain why people do not change their driving behaviors or travel routes when they see a dust storm approaching or when they find themselves driving in a dust storm. The following statements were selected by more than half of all respondents (N = 2,551), as shown in Figure 35:

- Drivers underestimate the hazardous driving conditions caused by low-visibility dust storms (85 percent).
- Drivers overestimate their driving skill (59 percent).
- Drivers tend to go along with the flow of traffic and will continue to drive through the storm (55 percent).
- Drivers don't know what to do when they get caught in a dust storm (55 percent).
- Drivers don't take warnings or forecasts of dust storm conditions seriously (51 percent).

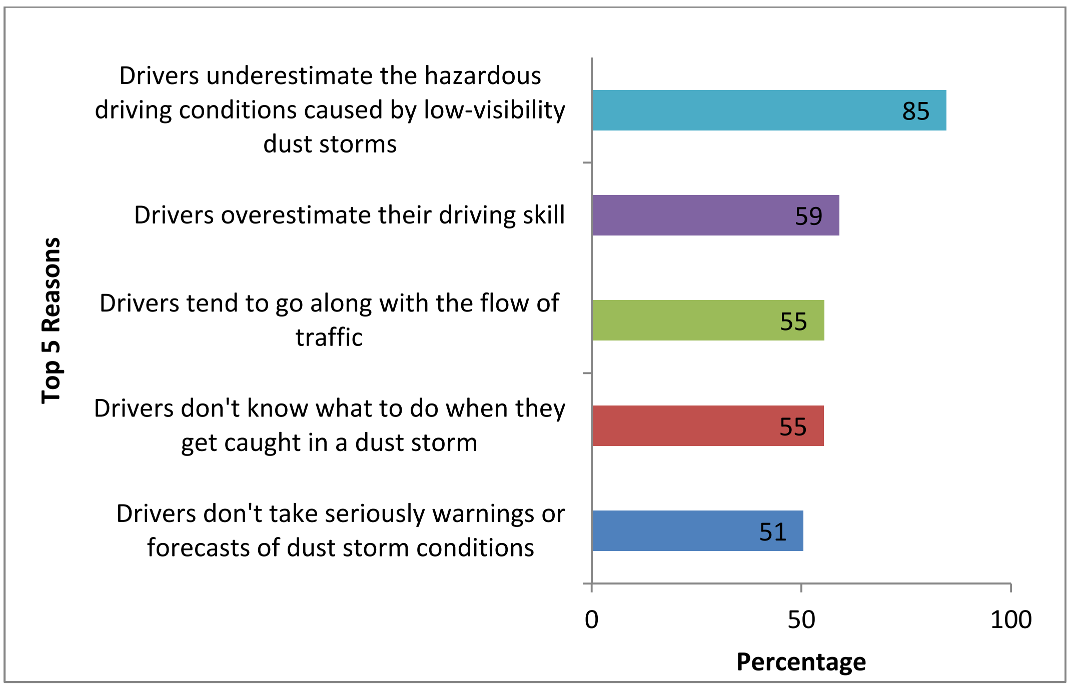

Figure 35. Respondents' Top Five Reasons Why Drivers Do Not Change Behavior in Response to Dust Storms (N = 2,551)

The statement "Drivers underestimate the hazardous driving conditions caused by low-visibility dust storms" was selected by a significantly greater percentage of respondents from Pima County (90 percent) than from Maricopa, Pinal, and the other, non-target counties (84, 79, and 86 percent, respectively).

Respondents also had the option to provide other reasons not included in the list of response choices. Reasons provided by respondents centered on the following themes:

- Driver's need to reach destination
- Storm not that severe
- Danger of stopping, fear for safety
- Warnings not specific enough
- Out-of-state drivers not familiar with protocol and dangers of dust storms
- No alternative routes
- Do what other drivers are doing
- Drivers not familiar with storms' unpredictability, duration, or impairment of vision

Unique Dust Storm Challenges for Commercial Drivers

The number of survey respondents self-identifying as commercial truckers or fleet drivers was too small to support statistical analysis as a group (39, or 2 percent). Nevertheless, insights were gleaned from their responses to an open-ended question regarding the unique challenges that commercial drivers experience when caught in a dust storm. These respondents identified the following challenges that they encountered as commercial truckers and fleet drivers:

- Visibility and navigating around cars stopped on the roadway (instead of pulling off to the side of the road)
- Erratic drivers who create hazardous driving conditions for everyone on the road
- Dangers of high winds and wind shear effects
- Lack of available safe locations to pull over
- The need to complete their assignments despite the storm

Awareness of "Pull Aside, Stay Alive" Campaign

All survey respondents (N = 2,551) were asked if they had ever heard of this particular safety campaign. Their responses are summarized below and in Figure 36:

- A significant majority (70 percent, or 1,778) of respondents had heard of the campaign.
- A statistically significant higher percentage of males than females had heard of the campaign (72 and 67 percent, respectively).
- A statistically significant higher percentage of respondents ages 35 to 64 and ages 65 and older (71 and 72 percent, respectively) had heard of the campaign than had those respondents ages 16 to 34 (63 percent).
- A statistically significant higher percentage of respondents from Pima County (77 percent) and Pinal County (76 percent) had heard of the campaign than had respondents from Maricopa and the non-target counties (70 and 65 percent, respectively).
- Among respondents from the three target counties (Maricopa, Pima, and Pinal), awareness was lowest among Maricopa respondents (70 percent) versus Pima (77 percent) and Pinal (76 percent).
- A statistically significant higher percentage of ADOT subscribers (72 percent) than non-subscribers (66 percent) had heard of the campaign.

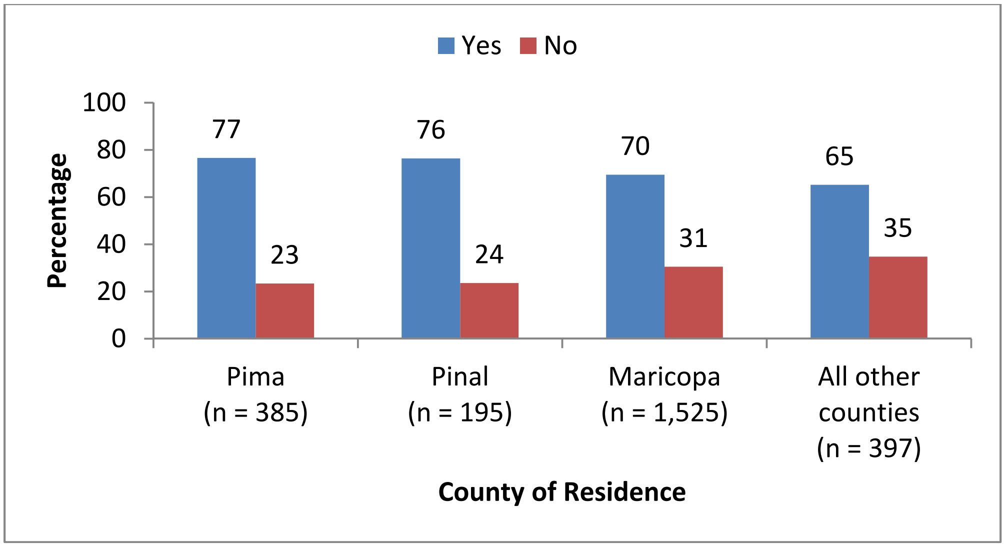

Figure 36. Respondents' Awareness of "Pull Aside, Stay Alive" Campaign, by County of Residence (N = 2,551)

As seen in Figure 37, the majority of the 1,778 survey respondents who had heard of the campaign learned about it from the following sources (respondents were permitted to select multiple responses):

1. TV public service announcements (52 percent)
2. Coverage in the news media (37 percent)
3. ADOT website (34 percent)
4. Radio public service announcements (32 percent)
5. Electronic highway message boards or signs (26 percent)

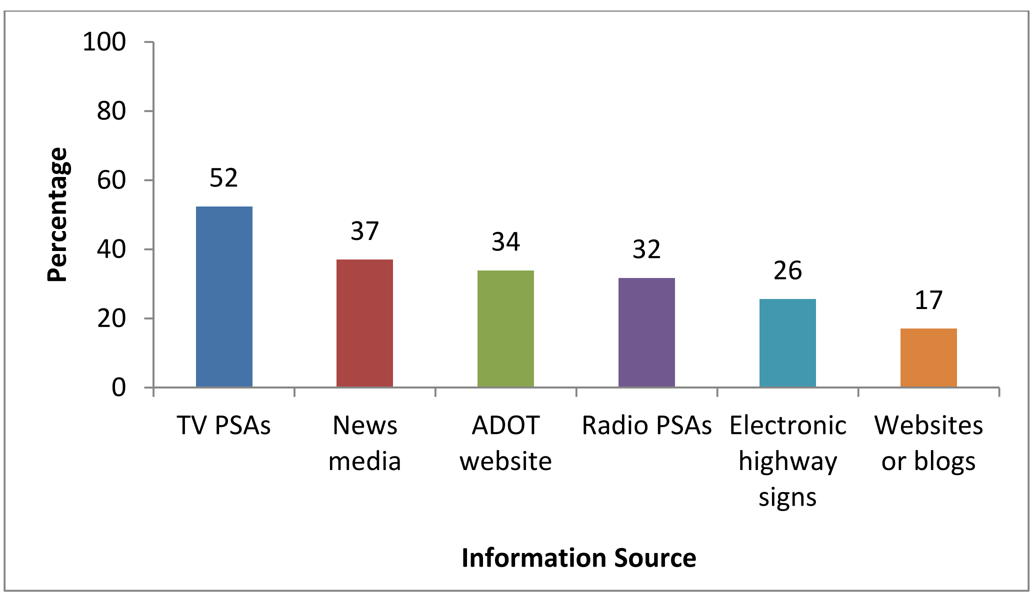

Figure 37. Information Sources for Learning of "Pull Aside, Stay Alive" Campaign (N = 1,778)

As seen in Figure 38, a statistically significant higher percentage of Maricopa County respondents (37 percent) than Pima and Pinal County residents (24 and 26 percent, respectively) had heard about the campaign through the ADOT website. Additionally, a statistically significant greater percentage of Maricopa County respondents (28 percent) than respondents from non-target counties (19 percent) had heard of the campaign through electronic highway message boards or signs. The figure for respondents from Pima County was 24 percent and 21 percent from Pinal County.

Additionally, statistically significant differences were seen between subscribers and non-subscribers with regard to three specific sources for learning about the campaign. A significantly greater percentage of non-subscribers than subscribers had learned of the campaign through social media (16 and 9 percent, respectively). Conversely, greater percentages of subscribers than non-subscribers had learned of the campaign through the ADOT website (40 and 25 percent, respectively) and through their employer (14 and 9 percent, respectively).

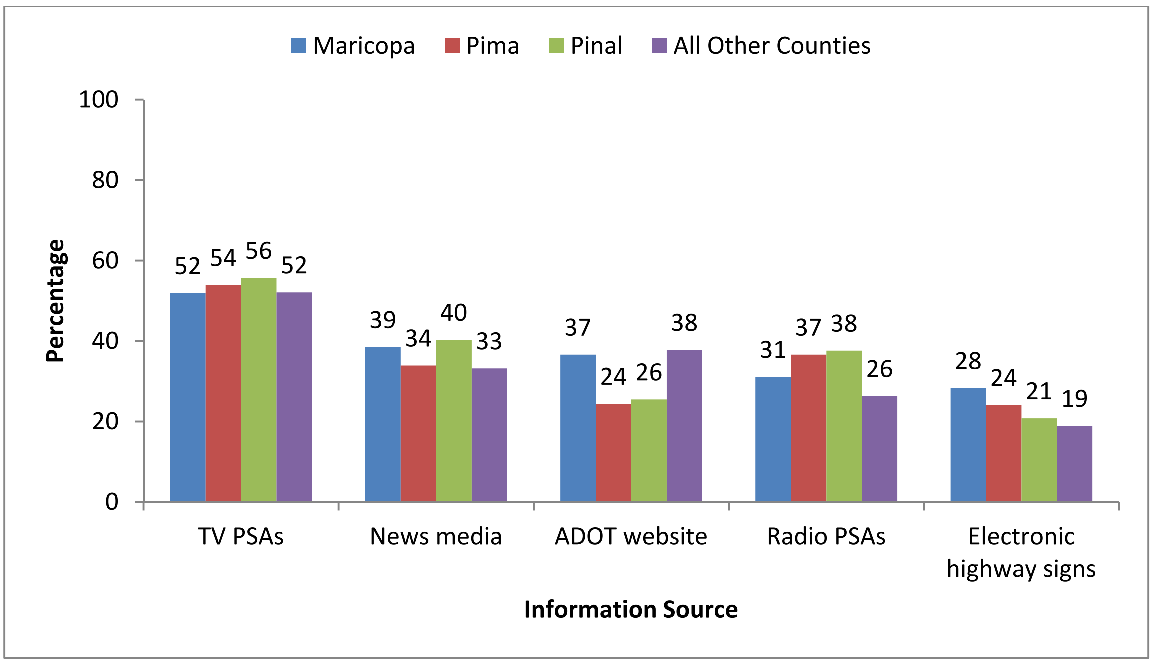

Figure 38. Information Sources for Learning of "Pull Aside, Stay Alive" Campaign, by County of Residence (N = 1,778)

Perceived Meaning of "Pull Aside, Stay Alive" Campaign

When asked about the meaning of the "Pull Aside, Stay Alive" slogan, the majority of responses centered on the following themes:

- Leave the roadway, pull over to stay alive because of bad weather, and don't try to drive in it
- Pull to the side of the road, turn off lights
- Be alert; watch out for the dust storm and other drivers
- Dust storms and dust storm safety

Respondents who were unsure of the meaning had the following comments:

- "I thought it was about pulling over to the side of the road because emergency crews were coming."
- "The slogan is meaningless; a driver needs more information on what to do. The slogan says nothing about wind or dust, it communicates nothing to visitors unfamiliar with the dust problem, and it gives too little information."
- "Not aware of it."
- "I know I am supposed to pull off but am scared to; [it] might help if you can put action to this, if I could see this slogan work."

ADOT Driving Tips for Dust Storm Conditions

Likelihood of Following All Tips

All respondents (N = 2,551) were asked to read through the ADOT list of tips about driving in dust storm conditions and were then asked, "How likely are you to follow all these tips when driving in dust storm conditions?" Responses were based on a 7-point scale where 1 is *not at all likely* and 7 is *very likely.* In the discussion below, the percentages represent the individuals who were highly likely, or who selected 6 or 7 on the scale:

- As seen in Figure 39, 71 percent of respondents reported they are highly likely to follow all the tips. The percentage steadily increased by age group, from 59 percent of respondents ages 16 to 34 to 80 percent of respondents ages 65 and older, as seen in **Figure 40**.
- As seen in Figure 41, a greater percentage of women than men reported that they are highly likely to follow the driving tips (74 and 68 percent, respectively).
- No significant difference was seen between the percentages ADOT subscribers and non-subscribers who reported that they are highly likely to follow the driving tips (70 and 72 percent, respectively).
- With regard to the target counties, no statistically significant difference was seen among respondents living in Maricopa, Pima, and Pinal Counties regarding their reported likelihood of following the driving tips (70, 73, and 71 percent, respectively), as seen in Figure 42. Additionally, no difference was seen between respondents living in the target counties and the other, non-target counties (collectively 71 and 73 percent, respectively).

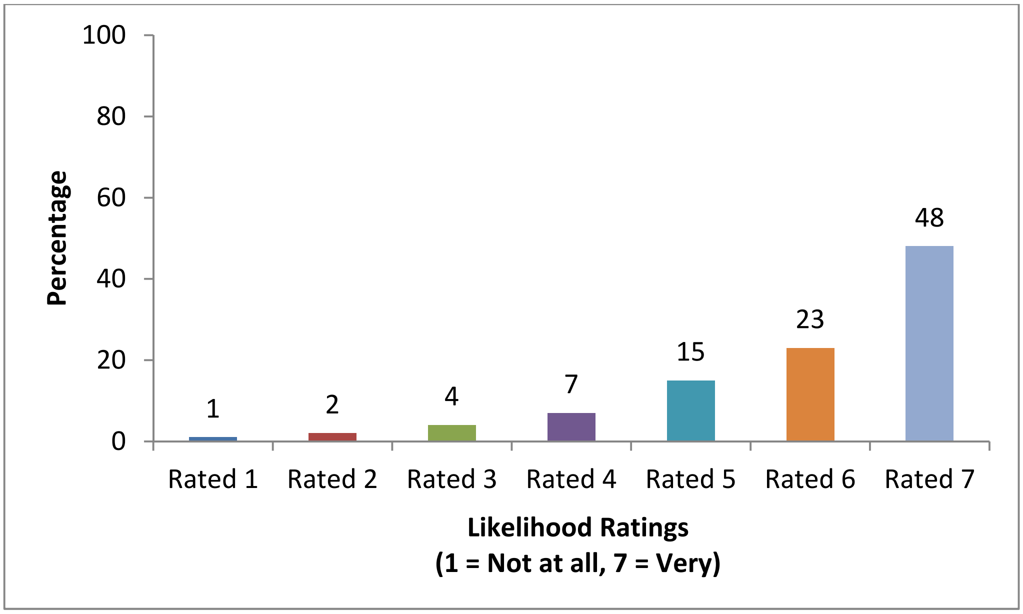

Figure 39. Respondents' Reported Likelihood of Following All Tips for Driving in Dust Storm (N = 2,551)

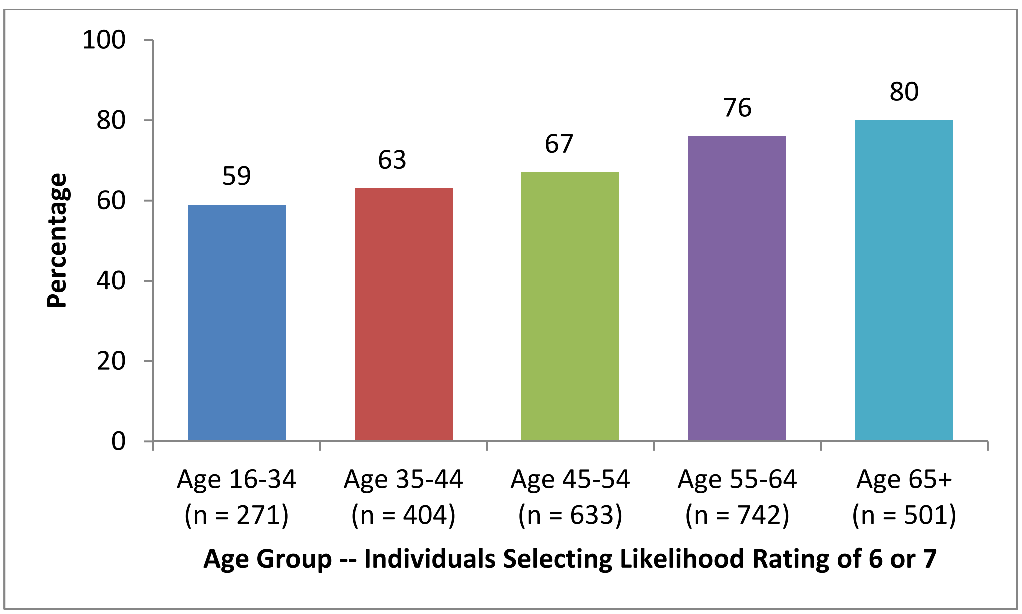

Figure 40. Respondents Who Reported Being Highly Likely to Follow All Tips for Driving in Dust Storm, by Age Group (N = 2,551)

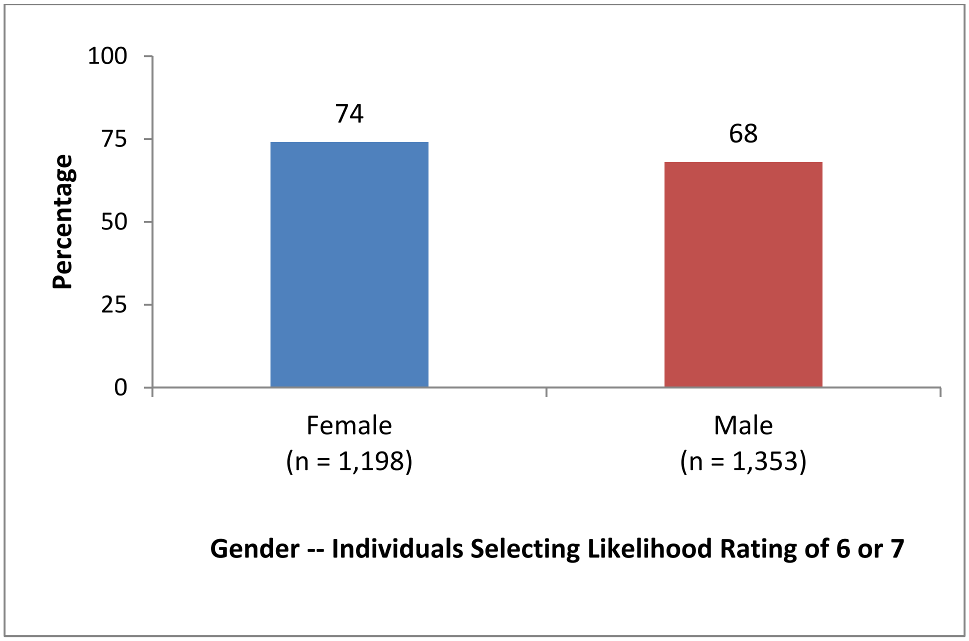

Figure 41. Respondents Who Reported Being Highly Likely to Follow All Tips for Driving in Dust Storm, by Gender (N = 2,551)

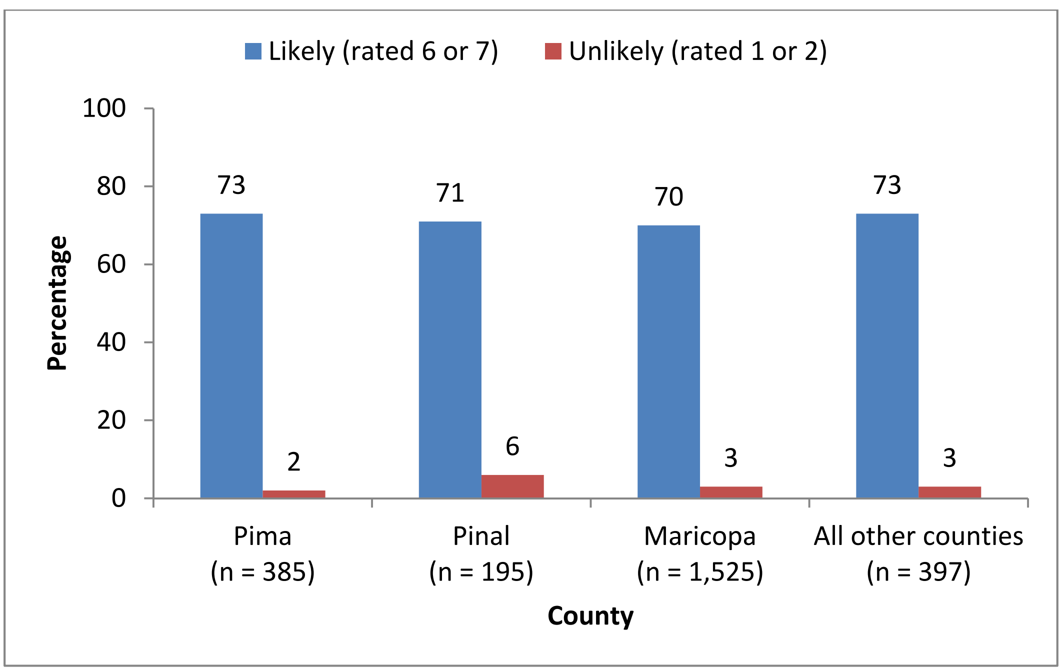

Figure 42. Respondents Who Reported Being Highly Likely and Highly Unlikely to Follow All Tips for Driving in Dust Storms (N = 2,551)

Reasons for Not Following All Tips

An open-ended follow-up question was asked of the 364 respondents who selected 4 or below in the previous question, requesting that they briefly explain why they were unlikely (or somewhat unlikely) to follow the "Pull Aside, Stay Alive" driving tips. These individuals represented 14 percent of all survey respondents (N =2,551). Their most frequently cited reasons are quantified below. Because this was an open-ended question, respondents could provide multiple reasons; thus the total of the figures is much greater than 364:

- 135 (37 percent) were confident in their driving skills, would proceed with caution, and believed that "every storm is different"; that is, their likelihood of following the driving tips was dependent on the severity of the dust storm.
- 72 (20 percent) expressed concern about there not being adequate space to pull over/pull off the roadway, and/or were confused about where to pull over (i.e., dangers of trying to pull over when visibility is low).
- 69 (19 percent) did not understand and/or agree with the instruction to turn off all lights (headlights, flashers), reporting that they felt it was unsafe to do so.
- 66 (18 percent) reported that they did not understand or were confused about the safe driving tips in general, not understanding the rationale behind one or more of the safe driving tips.
- 51 (14 percent) expressed the view that most dust events result in dusty conditions or dust devils that do not warrant such extreme reactions such as pulling over, exiting the highway, etc.
- 49 (13 percent) expressed concern that by pulling over and/or turning off their lights they would be "sitting ducks" and vulnerable to being hit by other vehicles (rear-end collision).
- Less than 10 percent of respondents offered comments that (a) did not address the question or was left blank, (b) expressed concern that there is too much information to remember, (c) expressed disagreement with the safe driving tips because they thought it put people in danger (these respondents also did not understand the rationale behind the driving tips), and (d) expressed concern about the instruction to put on their emergency brake.
- 52 (14 percent) provided "other" comments (e.g., fear that pulling off the road in dry dusty conditions could cause a fire, driving tips are not at the forefront of their thoughts when encountering a storm, not sure as to what they will do, feel pressured to make appointments and be on time, etc.).

An additional question was then asked of all respondents (N = 2,551) to determine whether they disagreed with or had questions about any of the "Pull Aside, Stay Alive" safe driving tips. A total of 636 survey respondents, representing 25 percent of all survey respondents, reported that they did have questions and/or disagreed with the safe driving tips. Analysis of comments from these respondents is quantified below. Because this was an open-ended question, respondents could provide multiple reasons; thus the total of the figures is much larger than 636:

- 288 (45 percent) did not understand and/or agree with the instruction to turn off all lights (headlights, flashers), reporting that they felt it was unsafe to do so.
- 208 (33 percent) reported that they did not understand or were confused about the safe driving tips in general, not understanding the rationale behind one or more of the safe driving tips.

- 176 (28 percent) expressed concern about there not being adequate space to pull over/pull off the roadway, and/or were confused about where to pull over (and the dangers of trying to pull over when visibility is low).
- 130 (20 percent) expressed concern that by pulling over and/or turning off their lights they would be “sitting ducks” and vulnerable to being hit by other vehicles (rear-end collision).
- 62 (10 percent) were confident in their driving skills, would proceed with caution, and believed that “every storm is different”; that is, their likelihood of following the driving tips was dependent on the severity of the dust storm.
- Less than 10 percent of respondents offered comments that (a) expressed concerns about the instruction to put on their emergency brake, (b) did not address the question or left the comment box blank, (c) expressed concern that there is too much information to remember, (d) expressed disagreement with the safe driving tips because they thought it put people in danger (these respondents also did not understand the rationale behind the driving tips), (e) expressed concern about the instruction to put on their emergency brake, (f) expressed the view that most dust events result in dusty conditions or dust devils that do not warrant such extreme reactions such as pulling over or exiting the highway, and (g) there were no tips for motorcyclists.
- 92 (14 percent) provided “other” comments (e.g., not understanding why drivers should fasten seat belts while parked).

It is interesting to note that among the group of 636 respondents who reported having a question about or disagreeing with the safe driving tips, 80 percent (510) had also reported in a previous question that they were somewhat to very likely to follow all the safe driving tips (provided a response of 5, 6, or 7 on a seven-point scale, where 7 is *very likely*). Further, responses to questions soliciting feedback on the safe driving tips were analyzed, and it was determined that slightly more than one-third (834) of all survey respondents (N = 2,551) indicated that drivers need to be informed of the reasons for taking the actions identified in the “Pull Aside, Stay Alive” driving tips.

Suggestions and Ideas for ADOT

Respondents were asked to share their suggestions and ideas with ADOT by responding to two additional open-ended questions. The first of these questions asked respondents for ideas to help ADOT spread the word to drivers about what to do when a dust storm is approaching, or if suddenly caught in a dust storm. Feedback primarily centered on four common themes:

- Expand the use of media to provide information, including traditional media (primarily radio and TV); smart media such as mobile apps, wireless alerts, and e-mail and text alerts; and social media such as Twitter, Facebook, and others.
- Expand the use of signage, including placing more signs along highway corridors and in rural areas known for a high incidence of collisions and fatal crashes. Survey participants also suggested use of electronic highway message boards, billboards, and roadside signage with warning and instructional messaging, attention-grabbing features such as flashing lights and visuals, and use of successive signage, such as placing a series of signs, each displaying one simple and easy-to-read instruction that informs drivers of what to do, in successive order along the designated stretch of highway.

- Improve public education and outreach by leveraging the Motor Vehicle Division (MVD) as a resource to raise awareness and inform and educate drivers. Suggestions included ensuring that information on safe driving tips for dust storm and other hazardous driving conditions is included in the *Arizona Driver License Manual* and in the curriculum for driver-offender safety and training courses; updating the driver's license test to include questions about the "Pull Aside, Stay Alive" driver safety tips; inserting information into MVD communications with drivers (e.g., mailings and online communications regarding driver's license and vehicle registration); and posting information at MVD locations and showing instructional videos while individuals are waiting in line for MVD services.
- Improve outreach by bringing the "Pull Aside, Stay Alive: Will You Know What to Do?" message to college campuses and schools (high school and middle grades), locations that the public frequently visits (e.g., shopping centers, gas stations, convenience stores), and tourist attractions and hospitality centers. Use a variety of collateral materials such as posters, pamphlets, and wallet insert cards.

Additionally, survey participants commented on anticipated benefits of repetitive messaging, support from news outlets to expand coverage to include warnings, a review of the "Pull Aside, Stay Alive" driver safety tips, and improvements to ADOT's advisories and alerts. The latter included suggestions to have ADOT (a) include both warning and instructional messages in its advisories or alerts; (b) inform the public of the reasons for the prescribed safe driver tips to address concerns that some of the "Pull Aside, Stay Alive" driving tips appear to be counterintuitive, thus prompting drivers to state that they would not likely follow these tips or change their driving behaviors; (c) provide drivers with localized and targeted e-mail, cell phone, and text communications using information provided by consumers (preference or profile information) and GPS data; and (d) develop an ADOT mobile app.

Other noteworthy comments and suggestions focused on (a) DPS presence and enforcement of speed limits and highway closure options, (b) outreach to provide educational materials and training to groups such as truckers and businesses that employ a fleet of drivers, and (c) outreach to employers throughout the state (including state and local government entities). It was also suggested that ADOT (a) coordinate with port-of-entry operators to distribute flyers printed in English and Spanish to drivers and motorists entering the state; (b) work with the tribal communities to promote radio broadcasts of dust storm warnings and safe driving tips in native languages, such as Hopi and Navajo; and (c) work in collaboration with border and ring states to ensure motorists entering the state are provided information about hazardous driving conditions and safe driving tips. In addition, a small number of survey participants raised concerns about land owner responsibility and offered suggestions regarding land use and environmental solutions (e.g., planting vegetation and trees and exploring the feasibility of installing fencing to block blowing dust and sand—similar in concept to wind and snow fencing in northern Arizona); and providing education and training on dust mitigation strategies to farmers and construction company employees (onsite workers).

The second open-ended question asked respondents for ideas on how to reduce the number of crashes related to dust storm events. A summary of responses[7] is presented below:

- Continue promotion and education of safety steps using social media, text alerts, PSAs, website, blog, TV, radio, news print, signage, billboards. Increase efforts within younger generation and in schools.
- Add dust storm safety to driver education.
- Increase traffic enforcement of violations, increase patrol in these areas.
- Seek help from agricultural specialists and USDA.
- Increase occurrence of informative signs on the highways; engage some alert system with lighting.
- Close the road.
- Ensure there is space to pull off the road, create safety pull-out areas. Let people know how much they should pull over; provide more information on this topic.
- Make travelers aware of the tips for safety, as well as out of state commercial drivers.
- Make information about what to do, more standard and clear. I don't understand some of the messaging.
- Reduce speed limits in storm prone areas.
- Create a safety zone or dust storm prone area in which the local businesses and residents partake in promoting awareness and safety tips.
- Create a rating system so people know the severity.
- Turn on lights when pulled over.
- Build commuter rail.

Perceptions of "Pull Aside, Stay Alive" PSAs

The last section of the online survey solicited respondent feedback about two ADOT PSAs on the dangers of dust storms. Respondents were required to watch the PSA videos to answer the questions, and all survey participants were given the option to either conclude the survey without completing the PSA section or to continue. Of the original 2,551 respondents, 1,618 elected to continue, and the following data are based on that universe of 1,618 respondents. The key respondent perceptions of the "Pull Aside, Stay Alive" PSAs were as follows:

- Nearly three-fourths (71 percent) of drivers reported that they had not seen either the "Dust on the Horizon" or "9-1-1 Call" PSA on TV over the past two years.
- Drivers appeared nearly evenly split on which PSA they like better.
- Drivers tend to consider "9-1-1 Call" as more impactful and more likely to change driver behavior when driving in dust storm conditions.

[7] In this list of responses and subsequent such lists in this chapter, the text shown represents paraphrased summaries of common responses.

Message

Respondents watched the first PSA, “Dust on the Horizon,” and were then asked, “What is the message that ADOT is trying to convey?” Presented below is a summary of the most common responses:

- Dust storms can occur quickly and without any notice.
- Drivers need to pull safely off of the road.
- Do not underestimate the storm.
- Pull aside, stay alive.
- Things happen quickly, so know what to do.
- Don’t drive into a wall of dust or into the storm.
- Be educated about what to do in a dust storm.
- Pull aside as you see the dust storm is approaching, get off the road.

A very small number of respondent comments indicated confusion about the PSA’s message:

- I do not know; there was not much information in regard to “what to do.”
- The visibility doesn’t seem that bad.

After watching the second PSA, “9-1-1 Call,” respondents were asked the same question regarding its message. Following are the most common responses:

- Dust storms are dangerous; serious crashes can occur.
- Don’t drive into a dust storm.
- Consequences will be great if you ignore the warning signs.
- Pull aside.
- Contact 911, stay in your car.

As with “Dust on the Horizon,” a few respondents reported confusion about the message of “9-1-1 Call”:

- There is not enough information showing “what to do.”
- Not clear.

Recollection of Having Seen PSAs Prior to Survey

When asked whether they recalled seeing one or both of the PSAs on TV over the past two years, a significant majority of respondents (70 percent) reported that they had not seen either of the PSAs on TV over the past two years:

- 13 percent (215) reported having only seen “Dust on the Horizon” on TV over the past two years.
- 6 percent (89) reported having only seen “9-1-1 Call” on TV over the past two years.
- 11 percent (175) reported having seen both PSAs on TV over the past two years.

The final survey questions about the ADOT PSAs asked respondents which PSA they liked best, which they thought had the greatest impact, and which is more likely to change their own driving behavior.

PSA That Respondents Liked Best

Respondents were asked which of the two PSAs they liked best and to briefly explain why. Respondents were equally divided, with 50 percent (805 respondents) preferring Video A, "Dust on the Horizon," and 50 percent (813) favoring Video B, "9-1-1 Call."

Respondents' most common reasons for preferring "Dust on the Horizon" included the following comments:

- It depicts a "real life" visual that shows what it's like to drive into the storm.
- Shows the actual conditions.
- Tells how unpredictable the storms are and how they can suddenly appear.
- Video A is a warning and focused on prevention.
- Message is clearer than the other video.
- Visually, it's impactful.
- I really like it because it conveys (a) risk and (b) potential.
- This video is more proactive.
- I am able to relate and place myself in the situation better.
- I liked this video because it gives you the idea of how large these storms can be, how fast moving they are, and you see the actual lack of visibility once you're in the thick of the storm.
- It's not as graphic and morbid.
- More specific about what you see as a storm approaches and how quickly visibility conditions deteriorate. Everyone assumes someone else will be the one to wreck.
- I felt like it could really happen to me... I was really in the storm. Video B felt somewhat removed from reality... I see that kind of thing on TV all the time and I could easily brush it off and think "it will never really happen to me."
- It confronts the idea, "it will not happen to me."
- I think it is more useful to see how bad the visibility does get.
- Preventative rather than reactive.

Respondents' reasons for preferring "9-1-1 Call" included the following comments:

- This video shows the viewer the dangers of driving into a dust storm and what "could happen" by making poor judgment.
- Does a better job of capturing the chaos, confusion, and ensuing destruction that can accompany severe dust storms.
- People pay more attention to the graphic nature of the accident.
- It shows the reality of what can happen and how serious these storms are.
- Clarifies the consequences and ominous reality.
- More serious, you see the results of the dust storm.
- Captures the severity of the storm.
- More vivid and leaves a lasting impression.
- It gets to the point faster and with greater force.

- I think it sends a strong message as to the dangers of driving into a dust storm with graphic and realistic pictures of the results. I believe people are more affected by actual footage of what really happens more so than hypothetically what could happen.

A few respondents offered feedback regarding both videos and what they perceived to be missing. This same feedback was subsequently echoed by focus group participants.

- Neither video addresses how you are actually supposed to navigate the road.
- Wish they both showed what to do during a dust storm.
- The videos should be combined, to show what a dust storm looks like and the results of what could happen if you drive into a storm.

PSA That Respondents Perceived as Having the Greatest Impact

Respondents were asked which of the two PSAs they perceived as having the most impact and to briefly explain why. A significant majority of respondents (73 percent) thought that “9-1-1 Call” had the greatest impact.

Respondents’ most common reasons for perceiving “9-1-1 Call” as more impactful included the following comments:

- The video is more graphic and leaves a lasting image.
- The images are harsher and more dramatic.
- The reality of the whole thing and how it could’ve been avoided if the drivers had done what they were supposed to do.
- Drivers need to equate dust storms with danger and develop appropriate response habits.
- Has more scare factor; motorists take fewer risks if they have been exposed to an aftermath of a risk-taking situation.
- More scary.
- It has more of an impact, because it shows the dangers of driving into a storm.
- Elicits fear and more of an emotional reaction.

Respondents’ reasons for perceiving “Dust on the Horizon” as more impactful included the following comments:

- Shows the deterioration of visibility and the quick approach of the storm.
- This PSA depicts a generic weather event, reminding people that it happens frequently. I believe that is more effective at arming people with knowledge they will understand and use, versus the “worst case’ illustration that some people will discount because they perceive that to be rare, less likely it would happen to them.
- If you have never been in a storm before, you instantly get the gist of the experience by watching this.
- Gives you a first-hand feel of what it would be like to be in the storm.
- It has more impact because it shows the driver what to do.
- No one ever thinks they will be involved in an accident, people are arrogant when it comes to their driving skills so “9-1-1 Call” may not have such an impact as “Dust on the Horizon.”

- I think they are both effective. I chose "Dust on the Horizon" because "9-1-1 Call" makes me think about how horrible the collisions are rather than what I need to do when in the situation.

PSA That Respondents Perceived as Most Likely to Change Their Behavior

Respondents were asked which of the two PSAs was most likely to change the actions they take when driving in dust storm conditions and to briefly explain why. The ratio of respondents reporting "9-1-1 Call" (Video B) as most likely to influence and change their driving behaviors to those reporting the same for "Dust on the Horizon" (Video A) was 3:2. That is, 58 percent of respondents selected "9-1-1 Call" as more likely to influence and change their driving behavior, compared with 42 percent who selected "Dust on the Horizon."

Following are some of the explanatory comments from the 58 percent of respondents choosing "9-1-1 Call" as most likely to influence their behavior:

- Realization of the severity of the storms and "demonstrates the dangers"; will proceed with caution.
- Want to avoid a similar action, will proceed with caution.
- I will slow down or exit the highway.
- I would check the weather report first.
- Pull aside, stay alive.
- It gets your attention and makes you realize there is a chance you can be involved in an accident like that if you drive into a dust storm.
- I will not drive into the storm, I will exit the highway.
- I will not change my driving behavior.

Following are some of the explanatory comments from the 42 percent of respondents choosing "Dust on the Horizon" as most likely to influence their behavior:

- Paints the picture of what it looks like, helps to be prepared.
- Not having experienced a dust storm personally, it would certainly influence my decision to pull over.
- If I had never seen a dust storm, it would have prepared me for one.
- Do not drive into the storm.
- I will look ahead and be prepared.
- Be more aware.
- Pull aside when encountering a storm.
- I can picture myself in this situation, but not in the other ("9-1-1 Call").
- For me, this is more impactful because it allows me to experience the storm. The other video ("9-1-1 Call") just seems like scare tactics.
- Causes the viewer to pull over.
- Provides a very clear example of why dust storms are dangerous. It demonstrates how quickly visibility can drop and makes me want to be prepared for them.

Other responses to this series of questions regarding the PSAs speak to concerns regarding the preference for specific information about what to do in dust storm conditions—concerns that were subsequently raised by focus group participants:

- Neither are going to make me change my habits until I learn more about specifically what to do when involved in a serious dust storm.

Respondent Demographics

Participants by Recruitment Source

Individuals responding to a personalized e-mail invitation to participate in the survey represented 57 percent (1,459) of all respondents. This group was composed of individuals who had registered with ADOT to receive travel advisory or other types of ADOT communications via e-mail or SMS/text message (hereafter referred to as ADOT subscribers).

Gender and Age

As seen in Figure 43, males composed 53 percent of respondents and females 47 percent. Among ADOT subscribers, 56 percent were male, and among non-subscribers, 48 percent were male. Figure 44 shows the distribution of participants by age group. The mean age of all respondents was 53. Female representation was higher than male representation within the age groups of respondents under 54; ages 16 to 34 were 52 and 47 percent, respectively, and ages 35 to 44 were 55 and 45 percent, respectively. However, male representation was much higher among participants in the age groups of 55 to 64 (54 and 46 percent, respectively) and 65 and older (66 and 35 percent, respectively). Among participants ages 45 to 55, female and male representation were nearly equal (51 and 49 percent, respectively).

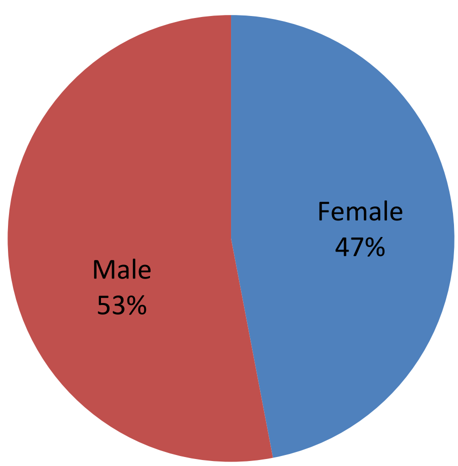

Figure 43. Respondents by Gender (N = 2,551)

Age

As seen in Figure 44, survey participants ranged from age 16 to 65 and older, with 54 percent in the age range of 45 to 64.

- 10 percent were ages 16 to 34 (N = 271)
- 70 percent were ages 35 to 64 (N = 1,779)
- 20 percent were ages 65+ (N = 501)

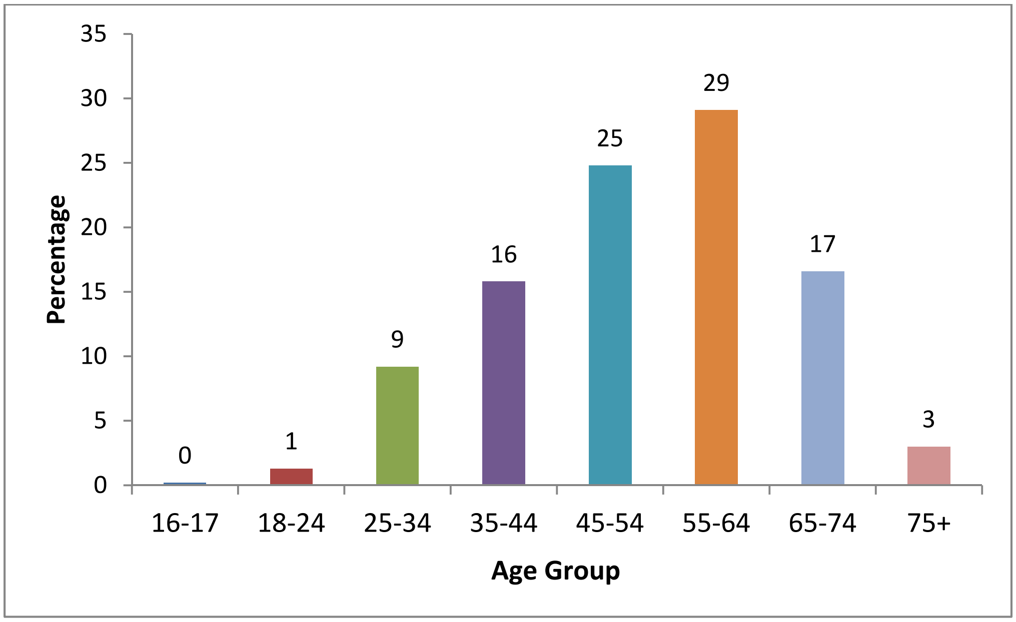

Figure 44. Respondents by Age Group (N = 2,551)

Within the 16 to 34 age group, a significantly greater percentage was of non-subscribers than subscribers (14 and 8 percent, respectively). Conversely, within the age group of 65 and older, a significantly greater percentage was of subscribers than non-subscribers (23 and 15 percent, respectively).

Place of Residence and Length of Time Living In Arizona

Nearly all respondents (98 percent) live in Arizona. As seen in Figure 45, 96 percent of these respondents live in the state full time, and 2 percent live in the state for part of the year. Among those living in the state either full or part time, 84 percent live in the three counties of specific interest to this study: Maricopa (61 percent), Pima (15 percent), and Pinal (8 percent), as seen in Figure 46. The mean number of years for living in Arizona either full or part time was 14.3. Among respondents in Maricopa, Pima, and Pinal counties, the mean number of years was 14.3, 14.6, and 13.2, respectively.

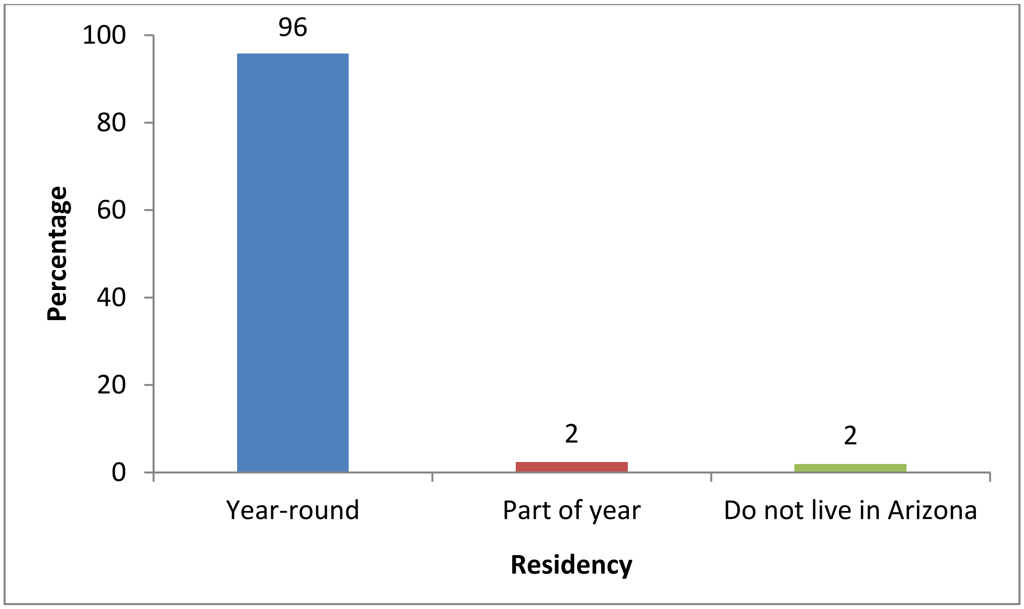

Figure 45. Respondents by Arizona Residency Status (N = 2,551)

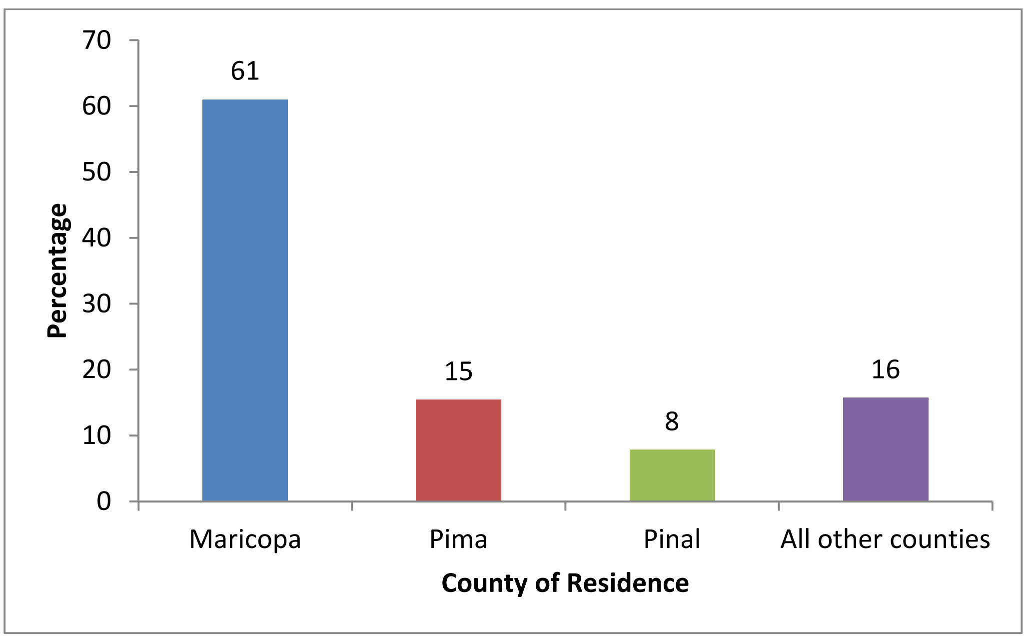

Figure 46. Respondents Living in Arizona, by County of Residence (N = 2,502)

As seen in Figure 47, a significant majority (82 percent, or 2,056) of respondents living in Arizona, either full time or part of the year, reported living in the state for 10 or more years. The mean number of years for living in Arizona either full or part time was 14.3. For respondents in Maricopa, Pima, and Pinal counties, the mean number of years was 14.3, 14.6, and 13.2, respectively.

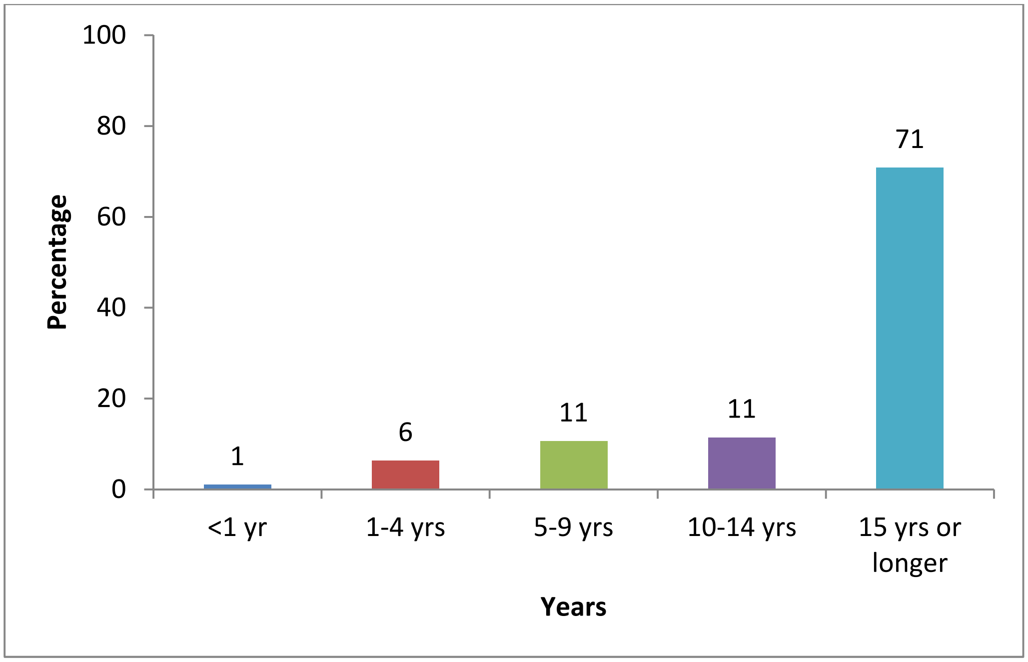

Figure 47. Respondents Living in Arizona, by Length of Residence (N = 2,502)

As seen in Figure 48, the vast majority of all respondents (93 percent, or 2,366) have had a driver's license for 15 years or longer.

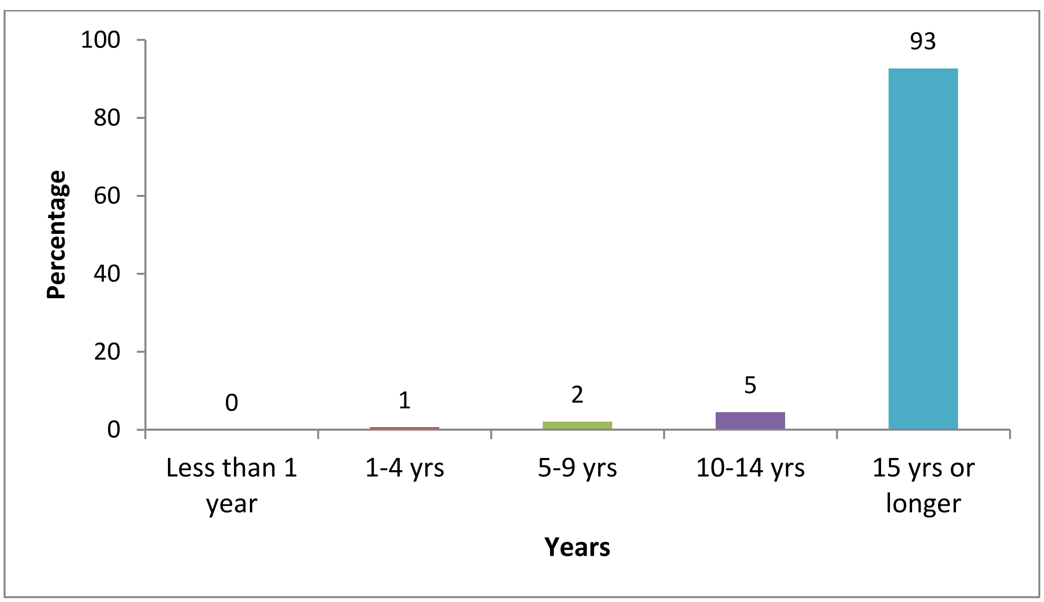

Figure 48. Length of Time Having a Driver's License (N = 2,551)

Non-Residents of Arizona

Two percent (49) of survey respondents reported that they do not live in Arizona, with nearly all (92 percent) residing in the United States. Among these non-residents participating in the survey:

- 28 individuals (57 percent) reported visiting or driving through Arizona in the past year.
- 45 individuals (92 percent) reported that they live in the United States:
  - Northeast: 7 percent (3) in New York
  - Midwest: 18 percent (8) in Illinois, Ohio, Wisconsin, Kansas, Minnesota, or North Dakota
  - South: 18 percent (8) in Florida, Georgia, Kentucky, Mississippi, Arkansas, or Texas
  - West: 56 percent (26) in Colorado, Idaho, Nevada, New Mexico, Utah, California, Oregon, or Washington
- Slightly less than half (19 of 45, or 42 percent) of those who reported not living in Arizona either full time or part of the year were from the following nearby states:
  - New Mexico (7)
  - Utah (6)
  - California (4)
  - Colorado (2)
- Four respondents reported that they do not live in the United States. These respondents were from Canada, England, and Mexico.

FOCUS GROUPS METHODOLOGY

Qualitative research was conducted with survey respondents who reported traveling the I-10 corridor between Tucson and Phoenix to more closely examine driver information regarding what to do when encountering hazardous driving conditions caused by low visibility dust storms in Arizona. The discussion group agenda was designed to complement the quantitative research component of the study by providing ADOT with a richer understanding of:

- Information sources and media channels used and preferred by drivers
- Public awareness of ADOT communication tools
- Driver response to ADOT's "Pull Aside, Stay Alive" public education and safety campaign
- Factors and dynamics likely influencing driver behaviors and motivation to heed dust storm alerts or warnings and to follow prescribed driver safety tips

Two in-person focus group discussions were conducted; one with drivers in the Phoenix metropolitan area who reported driving the I-10 corridor between Tucson and Phoenix and who self-identified as using and being familiar with ADOT information and communication tools, and the other with drivers in the Tucson area who were less familiar with ADOT communication tools. The groups met on Monday, August 11, 2014, and Wednesday, August 13, 2014, with each group meeting for approximately 90 minutes. To encourage participation, an incentive of $125 was offered.

Participant recruitment was initiated by means of the questionnaire for the online survey that had been implemented one month earlier. A series of questions placed near the end of the questionnaire asked respondents if they were interested in participating in a discussion group addressing topics similar to those in the survey as well as other ADOT transportation-related topics. Those who expressed interest were asked to provide contact information (i.e., preferred e-mail address, telephone number, and mailing address) that would be needed for follow-up. Additionally, participants residing in the target counties (Maricopa, Pima, and Pinal) were provided specific information regarding groups to be held in August 2014. Recruitment for these groups was primarily dependent upon ADOT's wish to structure the groups according to reported travel behavior (i.e., drivers who travel the I-10 corridor between Tucson and Phoenix), place of residence (i.e., metropolitan Phoenix and Tucson areas), and the use of ADOT information and communication tools, as well as such factors as the number of groups to be held (two) and the desired number of participants per group (ideally six to eight, with no more than 10 participants).

A total of 19 people participated; eight in Group 1 (Phoenix) and 11 in Group 2 (Tucson). Because travel behavior was identified as a key area of focus, emphasis was placed on recruiting from the survey respondent group that traveled the I-10 corridor between Tucson and Phoenix. All 19 participants reported driving this corridor. Additional demographics of the focus group participants were as follows:

- Age – Four participants were between the ages of 18 and 34; 12 were between the ages of 35 and 64; and three participants were age 65 and older, one of whom was age 75 or older. Representation by specific age group categories was as follows: ages 18 to 24 (2); 25 to 34 (2); 35 to 44 (4); 45 to 54 (3); 55 to 64 (5); 65 to 74 (2); and 75 and older (1).
- Gender – Nine women and 10 men. The Phoenix group consisted of four female and four male participants, and the Tucson group consisted of five female and six male participants.
- Place of residence – Participants in the Phoenix group resided in: Phoenix (4), Tempe (1), Scottsdale (1), Waddell (1), and Goodyear (1). Participants in the Tucson group resided in: Tucson (7), San Manuel (1), Red Rock (1), Green Valley (1), and Marana (1).
- Travel on the I-10 corridor between Tucson and Phoenix – Four participants reported traveling I-10 daily (in the Phoenix group, two of these participants were business owners with a fleet of drivers who travel this stretch of the highway daily); 10 reported monthly travel, with the number of trips ranging from once or twice a month to 10 to 15 trips per month; and five reported travel every other month or every few months.
- Experience with dust storm weather conditions – In the Phoenix group, five of the eight participants reported having driven in dust storm conditions on I-10 between Tucson and Phoenix, and two participants reported experiencing dust storm conditions in the metro Phoenix area (along I-10 in downtown Phoenix, traveling U.S. Route 60, and traveling State Loop 202 in the Mesa/Gilbert area). In the Tucson group, nine of the 11 participants reported having driven in dust storm conditions on I-10 between Tucson and Phoenix.

The goal of the discussion group was to solicit feedback regarding four key questions:

- How can ADOT spread the word to Arizona residents, tourists, and persons driving through the state about the hazardous driving conditions caused by low visibility dust storms?
- Which communication and media sources do drivers use and prefer to use? Which communication and media sources should be used to alert, inform, and educate drivers about

hazardous driving conditions and what to do when caught in low visibility dust storm conditions?
- How can ADOT improve or enhance the “Pull Aside, Stay Alive” campaign to more effectively influence and change driver behaviors—e.g., to aid understanding of what to do and why?
- How can ADOT raise awareness and improve or enhance the information available to drivers through the ADOT website and other ADOT communication and media channels or tools?

Other topics addressed in the discussion group focused on general viewpoints regarding Arizona dust storms and driver behaviors when experiencing hazardous driving conditions caused by low visibility dust storms. Emphasis was placed on examining in more detail how drivers use and perceive the effectiveness of electronic highway message boards or signage to provide meaningful and relevant information regarding dust storm warnings and safe driving tips. Specific topics discussed during the 90-minute focus group included:

- Participant perception of Arizona dust storm weather events (differences in types of storms, seasonality, and first-hand experiences; factors contributing to dust events).
- Communication and information channels participants use to obtain or receive weather-related information impacting driving conditions.
- Participant opinions regarding “Pull Aside, Stay Alive” messaging and the safe driving tips presented in ADOT PSAs and other media channels used to convey the “Pull Aside, Stay Alive” message.
- Participant views regarding overhead electronic highway messaging boards, signage, and VMS in aiding efforts to inform and alert motorists of hazardous driving conditions.
- Participant suggestions and ideas regarding information and communications likely to influence and impact driver behaviors and address highway safety concerns caused by low visibility dust storms.

FOCUS GROUPS TOPICS AND FINDINGS

Topic: Driver Use of Information and Media Sources and Preferred Sources for Obtaining and Receiving Information about Dust Storms

Participants were asked to identify and comment on their “go-to” resource for obtaining or receiving information about dust storms and other weather-related events likely to impact driving conditions. When asked to name the one communication channel or information source that they most frequently use and prefer to use, participants in both groups overwhelmingly identified their preference for online, web-based, and smart media tools over traditional media. Responses centered on the use of mobile apps (e.g., Weather Bug, Accuweather), wireless alerts sent to their mobile devices (e.g., NWS alerts), websites, and ADOT tools that included Twitter, e-mail alerts or advisories, and AZ511 (online and telephone system). Traditional media sources included commercial broadcast radio stations, public radio stations, and use of the AZ511 telephone system. Use of overhead electronic highway signs was cited by participants in both groups as a primary source for information about dust storm events.

Other Key Findings for Topic

- Participants in the Phoenix group reported a shift in their use and preference for traditional media (radio) to online, web-based, or smart media that provides real-time information and alerts or advisories regarding hazardous driving conditions.
  - o "I made the transition as well. Weather Channel was the big thing—and listening to the radio before. Since then, I also have signed up for the e-mails from ADOT, which they are great about sending out. I just recently really learned about the 511, so that's a new tool for me as well, which is pretty darn easy." (Phoenix)
- A number of participants in the Phoenix group reported using ADOT tools, most notably Twitter and AZ511, citing the advantages of having access to real-time information that they viewed as accurate and reliable. In addition, participants tended to view ADOT Twitter, ADOT e-mail, and text advisories or alerts, and AZ511 as their personal advance warning system.
  - o "Primarily, I use Twitter. If I'm going to hit the road, I'll set my phone to alert whenever ADOT tweets something. I wish I could make it specific. If I'm in Flagstaff, I don't want everything in Tucson, but it works. It seems to be more reliable than local radio or TV. It seems to be pretty immediate when something happens, and it's 24/7—at least it seems that way." (Phoenix)
- Among the few participants in the Phoenix group who reported not using social media tools such as Twitter, other tools such as websites (AZ511 and Weather Channel sites), ADOT e-mail and text advisories or alerts, and mobile apps were cited as their most frequently used and preferred means for obtaining or receiving information.
  - o "I don't do any social media, so that's kind of out. But when I'm in my car, I usually am listening to NPR, and they're very good about interrupting if they need to talk about exceptional weather conditions. If I'm getting ready to go on a trip and I want to know what the weather is, I will usually go online at one of the weather channels or to the ADOT511.com [sic] to see if there are any things that I need to know about before I go." (Phoenix)
- When referencing their use of AZ511, participants in the Phoenix group most often spoke about AZ511 online. In the Phoenix group, six of the eight participants reported using AZ511 as their primary "go-to" resource, with three reporting that they strictly use AZ511 online and three reporting that they use both AZ511 online and the AZ511 telephone system. The two participants who did not use AZ511 reported that they had forgotten about it or were not aware of AZ511. In the Tucson group, one participant reported using the AZ511 telephone system.
  - o "I'm plugged into ADOT AZ511. I have it on my cell phone, and I get the Amber Alerts and things like that. They're timely. Twitter, I don't do. Again, I have my drivers out there. I can send it to their tablets—that same information—just like that." (Phoenix)
  - o "I don't use my cell phone in my car, which is why I wouldn't dial up 511 on my phone. My attitude is, I checked (AZ511 online) before I left and if I see a dust storm—I know it when I see it. I get off and do what I have to do. But that's my explanation for why I don't use the phone number because I think that that's also kind of dangerous." (Tucson)

- Use of the ADOT Facebook page as a "go-to" resource for information about Arizona dust storms was limited to one or two participants in the Phoenix group. It is interesting to note that while these participants reported using the ADOT Facebook page, neither were avid Twitter users.
  - "I use Facebook. I don't use Twitter very much, but I have the ADOT Facebook page that I use. There's another—Weather Underground, the Weather Channel website. I don't drive very much during drive time, so I always check before I go out. So I use the internet a lot—the Facebook Page and the different websites. If I'm on the road, then I use just the radio, and it's always FM." (Phoenix)
- Participants in the Phoenix group preferred to use a mix of online, smart media, and traditional media that included websites, social media, mobile apps, radio, and electronic highway message boards. Participants in Tucson, while having similar responses regarding the use of online and smart media (absent the use of ADOT tools), expressed greater reliance on radio and electronic highway message signs, identifying these tools as "go-to" resources for information about dust storms and driving conditions.
  - "One of the things, and maybe this is just my personal feelings, I love the apps on the cell phones, and I love the computers. Because I drove so many times (I-10 between Tucson and Phoenix) and all the time my primary focus is to keep my eyes on the road. So I need to know something's wrong (dust storm warning) in a way that doesn't distract me." (Tucson participant's rationale for using radio as the primary and preferred source for information)
- Five participants in the Phoenix group reported using AM1510 when traveling between Tucson and Phoenix. However, these participants were quick to state that they have increasingly abandoned using AM1510 due to access-related issues (weak radio transmission signals and areas along the I-10 and in and around the Picacho Peak area where the signal fades in and out).
- ADOT received accolades from Phoenix focus group participants regarding administration of the ADOT Twitter account, which they viewed as providing accurate, timely, and consumer-responsive information.
  - "Can I add one thing about Twitter? They're really good about answering you. So if you say, 'Hey, I'm going to drive down the I-10 corridor today. Is there any wind conditions?' they'll answer you back. So you have communication with them, as opposed to a one way of you're waiting for the radio to tell you." (Phoenix)

Topic: Electronic Overhead Highway Message Boards or Signs

A key purpose of the focus group discussion was to gather in-depth information about driver attitudes and opinions regarding use of overhead electronic highway message boards or VMS. Findings from the online survey component of the research study indicated that nearly 60 percent (1,328) of drivers have used electronic highway message boards or signs to obtain weather information related to Arizona driving conditions, ranking them second in a list of 12 sources that included traditional media (e.g., radio, TV, telephone, newspapers) and new media (e.g., mobile apps, wireless alerts, social media, and e-mail). The focus group forum presented an ideal opportunity to engage drivers in discussion about the perceived value and effectiveness of electronic message boards and to solicit ideas regarding improvements that they feel will likely influence or impact driver behaviors and contribute to ADOT's efforts to improve highway safety.

When asked to rate their overall awareness of electronic highway message boards, nearly all participants were very aware of this type of signage, with participants in the Tucson group highlighting the value of this communication tool.

- "I definitely like the idea of the road signs. I think they reach a lot of people. You know, you can utilize one particular form of communication, but this is one that is kind of in your face. You'll pretty much see it regardless if you're paying attention driving. I think they're good too because there's a broad range of messages that they can convey on it. You know, it's not just for emergency purposes." (Tucson)

Focus group participants were then asked to comment on the effectiveness of this tool. A number of participants in both groups identified factors that they believe have contributed to the diminished effectiveness of overhead electronic highway message boards to influence driver behaviors—that is, to motivate drivers to be mindful of alerts or warnings and to follow prescribed actions, such as directives to reduce speed, switch lanes, or exit the highway. Participant responses centered on four key factors negatively impacting driver response to overhead electronic highway message boards: (1) distrust of the information presented (accuracy, timeliness, and reliability of information displayed); (2) overuse or non-judicious use of messaging that results in drivers being desensitized to alerts or warnings; (3) inadequate information to help drivers make informed decisions regarding alternate routes or to know exactly what it is they need to do in dust storm conditions; and (4) a limited number of signs along the I-10 corridor, particularly in the Picacho Peak area, to inform drivers of what to do in dust storm conditions. Discussion also touched on signage in general, such as options (i.e., type of signage, examples of progressive messaging, and placement) and best practice examples of effective signage from other states such as New Mexico:

- Based on personal experience, a number of participants stated that the lack of timeliness in providing drivers reliable real-time and consistently accurate information has resulted in mistrust regarding the information and warnings posted on overhead electronic highway message boards. Participants gave examples of what they felt to be the all-too-common experience of finding that the information posted on these signs was inaccurate, old (no longer a factor), or yet another false alarm. For many participants, this resulted in their minimizing or second guessing the accuracy of the information posted, opting to either delay action or ignore the warning or alert.
    - "It's kind of like the kid crying wolf. If what people get are always good, specific messages that mean something, and they're accurate, people will pay attention. But if you keep getting this message that's garbage, then I think people will stop giving it their attention." (Phoenix)
    - "I've actually seen a case, too, where the sign said that two miles down the road the left lane was closed. When I got there, it was the right lane that was closed. So it was just

wrong. And I made a change to be in the right place, and now I'm trying to get back to where I just left." (Phoenix)

- Participants expressed concern that overuse of messaging is contributing to lack of impact and effectiveness of electronic overhead signs to command attention and influence driver behaviors. A number of participants drew a distinction between the accuracy and the helpfulness of the messages posted on electronic highway message boards to provide drivers relevant and meaningful information that informs and motivates action. In addition, repetitive overuse of messages such as "Drive Hammered, Get Nailed" (referred to by participants as nonsense messaging) was identified as another factor impacting disregard of message postings.
    - "Accurate and helpful? Okay. Well, Drive Hammered, Get Nailed is accurate, but it's not at all helpful. It's up there all the time. If I see the sign, if it's generally blank and then I see something on it, then to me that means, okay, well, there's an alert. But if you're going to run Drive Hammered, Get Nailed on every sign all weekend long, then it just loses its impact. I don't even pay attention to it." (Phoenix)
- Participants believed that, in many instances, signage does not provide drivers adequate information regarding dust storms (meaning and consequence of "blowing dust" or "dust storm warning") and does not provide drivers enough information to make informed decisions about precisely what it is they should do when driving during dust storms.
    - "Dust storm warning? What am I? As an out-of-towner in 2008 when I saw this, what was I supposed to do? I wasn't really afraid because I drove in blizzards and white-outs. But not everybody's experienced that, so educate me, don't just tell me there's a dust storm." (Phoenix)
    - "I had a situation driving up to Phoenix and there was a chemical spill and they evacuated the highway. So you weren't going to be able to continue and you'd have to either wait, or if you knew how to get around it, you could take another route. But the sign didn't say where the spill was. So I took an alternate route and I popped back on the highway right where the darn thing was, and then there I was in the middle. They said it's ahead, but that's a pet peeve with mine about those warning signs. Where? Give me the location, the exit, whatever, the mile marker, where the thing is..." (Tucson)
- Participants believe that more signage—overhead electronic highway message signs as well as other types of signage—would be helpful along I-10 between Tucson and Phoenix.
    - "So now, knowing what the sign is, knowing what type of information could potentially be on there, I started becoming more aware of it and paying a lot of attention to it. And if says the right lane's closed because there was an accident up ahead I stay in the left hand lane. And they were pretty close and accurate, but they're too far apart." (Tucson)

Additionally, participants spoke about the types of signage used in other states, most notably New Mexico, and signage that presents a progressive series of messages that warn and inform drivers regarding what to do when caught in dust storm conditions. This type of signage was perceived as effective in raising awareness of hazardous travel conditions, reinforcing the seriousness of dust storm warnings, and in motivating drivers to be vigilant in heeding the warning and the instruction to slow down, etc. During this discussion, participants also commented on signage options that were perceived as providing a more cost-effective means for disseminating information, including signs with flashing lights. In the Tucson group, participants mentioned the possibility of including billboards. When describing billboards, Tucson participants stressed the importance of using large lettering and simple formats ("not those kind of billboards in Phoenix that change and morph and look like a television").

Signage

- "And they don't always have to be high tech. Probably the best you could see is when you cross Arizona to New Mexico, right? Before you hit the flats, there's like ten signs in a row, bright yellow, and the first one says dust storms possible, zero visibility, pull to right, turn off headlights, and they're just in a row about every–you know, they [say] everything except you will die, as the final, you know? It pretty much lets anyone know, wow, these signs, I've never seen signs like this, this must be really dangerous here, you know?" (Tucson)

Billboards

- "But these are informational signs; remember the big billboard, what is it called, the mystery, The Thing? Right. How many times have we seen that billboard sign? We already know what the thing is down there. You really could [not] care less. But every time you go by that billboard sign you look at it and you can kind of say something in your head about that thing."

Topic: ADOT's "Pull Aside, Stay Alive" Public Education and Safety Campaign

Another key purpose of the focus group was to enrich ADOT's understanding of driver response to the "Pull Aside, Stay Alive" driver safety tips, particularly what may have prompted approximately 30 percent of survey respondents to report that they were somewhat unlikely to follow all the prescribed driver safety tips. (The survey question used a seven-point scale where seven was "very likely"; 30 percent of respondents selected a rating between one and five, while 70 percent reported being very likely to follow all tips, selecting a rating of six or seven).

Participants were provided a handout titled, "Pull Aside, Stay Alive: Will You Know What to Do?" that included a list of the "Pull Aside, Stay Alive" driving tips. Each participant was asked to read through the list, circle those tips that they would tend to follow without question, place a question mark next to any tip(s) that they had a question about or didn't quite understand, and place an X through any tip(s) that they would not follow. Participants were given adequate time to complete this exercise, with follow-up discussion to identify those tips that they had questions about and/or would not follow. The most important aspect of this exercise was to gain insight into why participants were unlikely to follow all the "Pull Aside, Stay Alive" driver safety tips. For reference, the "Pull Aside, Stay Alive" driving tips are as follows:

- Avoid driving into or through a dust storm.
- If you encounter a dust storm, immediately check traffic around your vehicle (front, back and to the side) and begin slowing down.

- Do not wait until poor visibility makes it difficult to safely pull off the roadway—do it as soon as possible. Completely exit the highway if you can.
- Do not stop in a travel lane or in the emergency lane. Look for a safe place to pull completely off the paved portion of the roadway.
- Turn off all vehicle lights, including your emergency flashers.
- Set your emergency brake and take your foot off the brake.
- Stay in the vehicle with your seat belts buckled and wait for the storm to pass.
- Drivers of high-profile vehicles should be especially aware of changing weather conditions and travel at reduced speeds.

Key Findings on Topic

In the Phoenix group, seven of the eight participants raised questions about one or more of the driving tips, and in the Tucson group the number was eight of 11 participants. It is interesting to note that in each group, a few participants contributed to the discussion by offering explanation and the rationale for the prescribed course of action included in the safe driving tip, most notably the instruction to turn off all vehicle lights. It was clear, however, that participants who shared these concerns were unwavering in their hesitation to follow all of the driving tips because they did not fully understand the rationale or logic for doing so and the potential or probable consequence for not doing so.

The driving tips identified by participants as questionable or likely not to be followed included:

1. Turn off all vehicle lights, including your emergency flashers.
    - "I put question marks because we talk about this one and I've only been caught in one dust storm. But turning off your vehicle lights including your emergency flashers. I don't understand that. Nobody's ever told me why. To me, it's completely counterintuitive." (Phoenix)
2. Set your emergency brake and take your foot off the brake.
    - "I wanted to make a comment about one of the things it said about 'Set your emergency brake.' I'm quite sure that there are a lot of cars out there that when you set your emergency brake, it does the same thing as your brake pedal. It puts on the brake light. I would think it'd be better to say, 'Put your car in park,' or, 'Put your car in gear.' But don't put your emergency brake on because it's the same step." (Phoenix)
3. Do not stop in a travel lane or in the emergency lane. Look for a safe place to pull completely off the paved portion of the roadway.
    - "I can't see. Where am I supposed to look? And the other one. So it's kind of irrelevant to turn off all my vehicle lights, set my emergency brake or stay in my vehicle because I can't see where it's safe to pull off, and I don't know where the emergency lane is and where soft sand is. And then, 'Drivers with high profile vehicles should be especially aware of changing weather conditions and travel at reduced speeds.' Okay. You told me to pull off, but you're telling the drivers of high profile vehicles to drive at a reduced – travel at a reduced speed. It contradicts itself." (Phoenix)

4. Stay in the vehicle with your seat belts buckled and wait for the storm to pass.
    - "Same thing with staying with the vehicle. My husband and I have talked about that as well. I mean, there have been instances—we've seen on TV—where somebody decided to get out of the vehicle, and darn good thing that they did because if they had stayed in that vehicle, they would have been crushed. So those kinds of things make me uncomfortable." (Phoenix)

In wrapping up this portion of the group discussion, participants were also asked to briefly comment on whether the "Pull Aside, Stay Alive" public service announcements had top-of-mind presence as an educational tool or communication vehicle that they associate with dust storm weather events.

- "Well, a slogan like that is good because people remember it. But when would you say that people should hear that message? I think it should be in the PSA. I don't know when else somebody hears the slogan other than as a part of the PSA. There usually is more text with it and maybe some media images and things like that. But then they're going to remember the slogan. I think of that as being a piece of the PSA." (Phoenix)
- "The slogan can't be the message. The message has to be the detail, the education, and then have that slogan in there so when people—drivers, motorists—see it, then they kind of can remember the text of the message of what to do. Get into detail. Whether it's this state, whether it's the surrounding. Yeah. It has to be all of that." (Phoenix)
- "The thing for me is, every time I see the Pull Aside, Stay Alive, I always revert back to nobody in low visibility conditions from other states pulls aside, so they're not going to even know what it means." (Phoenix)

Topic: Acknowledging the Challenges of Influencing and Affecting Changes in Driver Behaviors

Participants spoke about the differences in the severity of dust events—ranging from dust devils and blowing dust events that quickly dissipate to massive haboobs that bring low visibility and brown-out conditions—and the difficulty in crafting a message that resonates with drivers and motivates them to be vigilant, heed warnings, and follow the safe driving tips. This was believed by many participants to be a root cause of driver confusion or hesitation to adhere to the "Pull Aside, Stay Alive" driving tips. The following exchange between participants in the Phoenix group highlights this point:

> "We keep saying, 'You always need to pull over. You always need to pull over.' There are levels of dust storms. I talked about this before. Some of them are not blackout conditions."
>
> "I think that's the point, though. You're not going to know. How many of us have started off in a dust storm going, 'Oh, it's going to not be that bad?' And then all of a sudden, it was."
>
> "ADOT has to be failsafe. They have to say, 'We're going to cover the condition which is best under all conditions, which is get off the road.'"
>
> "Right. So maybe that needs to be part of it: 'No matter what, you need to get off the road. Even if you think it's not going to be a bad dust storm, you need to get off the road.'"
>
> "But that's also like the whole crying wolf (thing)."

> "You know, it's been my experience with lots and lots of dust storms that you can tell when it's thick ahead of you. We've all been in dust storms where, you know; you can see that it never gets dark. I mean, you can see light at the other side of the dust storm. That's probably not what we're talking about here. We're talking about where you see a wall of brown up ahead. You're not in it, but you can't see through it, either. I think that that's when you need to say, 'That's really bad. Don't go in it.'"
>
> (Interviewer) "And as you look at Pull Aside, Stay Alive, what do you really feel they are referring to? Do you feel that they are referring to that wall of dust?"
>
> "Again, I think that they have to take a failsafe position, which is, 'We're not going to try to tell you the different degrees of dust storms. We're going to tell you don't drive into a dust storm. Period. We have to be (the) failsafe.'"

In the Tucson group, a few participants also expressed a need for the media to provide drivers information regarding the types of dust events and to provide a bit more clarification regarding how quickly dust storms can manifest and result in blackout driving conditions. These comments were somewhat akin to a comment made by a participant in the Phoenix group who, when asked about how best to warn and inform drivers to not drive into a dust storm, responded, "Very brown, slow down."

- "I think too that they don't make a distinction between, there's the dust storms from the quads (ATVs) where you're blind for about a second. And then I think a lot of people, when they actually get to a real dust storm, where it's black for like a mile and you can't do anything—I know they say to pull over, but you can't, because you're in the middle of the road or you're on the right but you're afraid to pull over, because you just can't see anything. And I think that the media or some of the media needs to be a bit clearer and give better examples." (Tucson)

Topic: Focus Group Participant Recommendations

Participants were asked, "If you had the opportunity to sit across the table from the Director of ADOT and tell him what you think needs to be done to ensure that ADOT is reaching people about the hazards of driving in low visibility dust storms, what you would tell him?" Additionally, participants were asked to provide feedback regarding ADOT communication tools and ADOT's "Pull Aside, Stay Alive" public education and safety campaign. Feedback and recommendations centered on the following themes:

- Educate drivers. Use the toolbox of communication tools at ADOT's disposal to inform, warn, and educate drivers about Arizona dust storms and the hazardous conditions caused by low visibility dust storms.
- Use messaging that addresses the broader topic of defensive driving.
- Don't just warn drivers about dust storms; tell them what to do and the potential consequences of not heeding warnings.
- Examine opportunities to improve, from a driver's perspective, the usefulness and perceived effectiveness of overhead electronic highway message boards or signs to increase motorist vigilance and influence and impact driver behaviors.
- Use impactful messages and images to motivate change driver behaviors.

- Enhance the impact of the "Dust on the Horizon" PSA by showing the consequences of driving into the dust storm as a real-time, real-video experience for the observer.
- If possible, fine-tune ADOT Twitter and ADOT e-mail advisories and mobile alerts to provide drivers localized alerts that utilize a network of coordinated media channels to deliver dust storm warnings.
- Improve signage and increase the number of signs along the I-10 corridor, following examples from other states (e.g., New Mexico and California).
- Use a series of frequently placed signs with progressive messaging that includes limited text, images, and simple warnings and instruction regarding what to do in dust storm conditions. Place these signs in areas prone to dust storm activity and that having a history as high-collision locations (including multiple fatal crashes involving local residents).
- Take the aggressive steps necessary to keep motorists safe—as conditions warrant, close the interstates.
- Work in unison with nearby states to disseminate information about the hazardous driving conditions caused by low visibility dust storms.
- Use the MVD as a resource to spread the word and help educate drivers. Place warnings on the back of the Arizona driver's license, create wallet-sized cards with emergency safe driving tips (English/Spanish), and include information in the Arizona Driver License Manual (print and online) regarding dust storms and safe driver tips.
- Spread the word to tourists, travelers, and Arizona residents by developing communication tools to place in strategic locations, such as airports, car rental agencies, travel information racks throughout the state, and MVD offices. In addition, expand use of ADOT social media tools and national media coverage of Arizona dust storms to inform and educate visitors and potential visitors about the hazards of driving in low visibility dust storm conditions.

Finally, it is also noteworthy that participants in the Tucson group offered feedback that touched on a holistic view of the issues associated with windblown dust events in Arizona, inquiring as to whether this was within the purview of ADOT's mission and charge. This included discussion regarding the manmade factors that have contributed to windblown dust events along I-10, public safety concerns that extend beyond highway safety to include environmental air quality and public health concerns, and expanding the discussion to include the responsibilities of land owners in mitigation efforts.

- "It seems to me as we face the drought it becomes hotter and drier. And because there's been a lot of excavation of land and clearing of land, and during the housing crisis, or the economic crisis, and the housing problems, there wasn't a lot, there was a lot of construction that didn't get completed, so we have a lot more dust to blow around."
- "There's other reasons why that these haboobs or these dust storms are being generated, not just necessarily by a thunderstorm collapsing or a funnel passage coming through. We have manmade things out there that are causing the same things are putting everybody in that exact same danger."
- "I'm just curious. I know that's not really the area that we're focusing on is like the prevention, and the human cause things, but is that something that ADOT is looking at and trying to address?"

- “Well, I just wanted to say that I heard a couple of people, several people, mentioned concerns about, I believe, health impacts, not only the acute health impacts of accidents, but also perhaps chronic health impacts, and a lot of people I talk to are very concerned about the fact that the dust is a health hazard for lung disease. I’ve worked in public health in my time. And the fact that we’re seeing a dramatically sharp increase in the incident of Valley Fever, in the Phoenix area, particularly where there’s even more dust blowing around than down here. And so stirring up the dust in whatever way releases the fungus into the atmosphere, and then we’re all at risk. So I think that’s something that I don’t know if that could be used in terms of the media, in terms of the press, whatever’s being given to safety in dust storms, or if that’s something that’s going to be addressed in how to deal with dust storms. There are also things that could hurt us even more, or put us in even greater risk.”
- “I don’t know how much we can expand on this conversation other than the four points we’re trying to meet. The land and the property owners of this land, and what they’re doing to this land, what responsibilities do they have in spreading the word and reducing the number of dust particles and sand in the air when a gust, a small dust, happens to sweep by. So I don’t know if that’s something we can expand on or not, but it’s something I’m very interested in.”

CHAPTER 3. COMMUNICATION PLAN RECOMMENDATIONS

INTRODUCTION

This chapter provides a synthesis of findings from the review of current practices documented in Chapter 1 and the needs assessment documented in Chapter 2. This chapter also presents a set of actionable recommendations that ADOT might implement to more effectively acquire information about windblown dust events, communicate information about these events to the public, and influence driver behavior during dust storms through education and outreach. These recommendations, which were formed on the basis of project findings, have also been organized into a plan that identifies steps to be considered for short-, mid-, and long-term implementation.

SYNTHESIS OF KEY FINDINGS

Chapter 1 provided an overview of ADOT's current practices for acquiring and disseminating information about predicted or in-progress dust events, as well as a description of efforts ADOT has made to educate the public about safety during dust events through its "Pull Aside, Stay Alive" campaign. As shown in Figure 4 on page 8, these practices can be categorized as: (1) dust detection and forecasting, (2) event-based communication, and (3) public education and outreach. A synthesis of key findings for each of these general categories is provided below.

Dust Detection and Forecasting

Blowing dust in Arizona is associated with both large-scale, convectively driven events during the summer monsoon season and synoptic-scale events (e.g., frontal passages) that can result in more localized dust storms. These localized events can occur when high winds impact areas with disturbed soils, conditions that may contribute to dust "hot-spots" (e.g., the portion of I-10 between mile markers 200 and 220) that have been identified during studies of dust-related crashes.

The NWS forecasts dust events on the basis of meteorological models and real-time observations from satellites and Doppler radar. These methods are effective for large-scale events that produce widespread dust but may fail to capture localized dust events that are transient and near to the ground.

ADOT relies on NWS dust warning information acquired through NWSChat, in conjunction with reports from drivers or ADOT personnel in the field. While 70 percent of survey respondents identified NWS as one of the agencies they rely on for weather information, only about one-third of survey respondents regularly check weather conditions prior to making a trip, which heightens the importance of information communicated in the field.

In general, other states with roadway visibility issues do not rely on weather forecasts, but on instruments deployed in the field, often as a part of RWIS installations. This approach generally consists of forward-scatter optical sensors, CCTV, and DMS with warning messages, which mirrors the pilot system implemented in ADOT's Safford District. However, staff from ADOT and other state DOTs reported durability and maintenance issues with optical sensors; in addition, visibility issues in other states are often small-scale (e.g., foggy river bottoms) in comparison with the widespread nature of dust issues in Arizona.

DOT staff from other states with visibility issues also recommended that CCTV or field observations be used to verify incidents of reduced visibility so that warning messages accurately reflect road conditions. This theme also emerged from the literature on roadway safety, which indicated that warning messages are more effective when proximal in time and space with occurrences of reduced visibility. Similarly, focus group participants from this project emphasized the importance of timely and accurate information so that warnings are not perceived as “crying wolf.”

Taken together, these findings suggest that a denser network of monitors may improve dust detection and forecasting and to deliver timely, accurate warning messages, particularly for localized dust channels. These findings also underscore the importance of DMS and other sources of public information provided in the field, as well as the need to continue to educate the public about the importance of monitoring weather conditions.

Event-Based Communication

When ADOT becomes aware of predicted or in-progress dust events, the agency communicates information to the public in a variety of ways, including DMS warning messages, e-mail messages distributed to about 35,000 subscribers, and the ADOT Twitter feed, which currently has over 65,000 followers.

More than half of survey respondents who reported having obtained weather information related to Arizona driving conditions relied on weather-based websites (64 percent), electronic message signs (59 percent), radio (55 percent), and television (53 percent). Because electronic message signs such as DMS are an important source of information, this topic was explored during the two focus group events. As noted previously, focus group participants emphasized the importance of displaying timely, reliable information on DMS. In addition, participants indicated that:

- Additional DMS would be helpful on the I-10 corridor between Phoenix and Tucson, especially in the Picacho Peak area.
- DMS should provide information not only on the presence of blowing dust, but on proper actions to take to stay safe.
- Progressive DMS messages would be effective at informing drivers what to do when caught in a dust storm (a recent study of drivers’ responses to DMS during reduced visibility events in Florida [Hassan et al. 2012] also found that successive signs prior to the reduced visibility area enhanced the effectiveness of the warning system).

Beyond electronic message signs, significant differences in media preferences by age were observed in the survey results. For example, survey respondents aged 16 to 34 reported high usage of mobile apps (56 percent), wireless alerts sent to mobile devices (50 percent), and social media (51 percent). In contrast, respondents aged 65 and older reported high usage of television (64 percent) and lower usage of mobile apps (31 percent) and social media (10 percent). These findings point to the importance of a diverse communication strategy that takes advantage of media channels preferred by drivers of various ages, as well as the need to further enhance and market existing ADOT communication tools.

Public Education and Outreach

ADOT's "Pull Aside, Stay Alive" campaign educates the public about dust storms and the proper way to respond when encountering dust while driving. The campaign has generated significant media coverage and appears to be unique among states dealing with roadway visibility issues (i.e., other states generally rely on real-time warning systems in the field and do little public outreach).

Project findings indicate that the campaign is well-known in Arizona, as 70 percent of survey respondents had heard of it. Respondents were most often exposed to "Pull Aside, Stay Alive" through televised public service announcements (52 percent), news coverage (37 percent), the ADOT website (34 percent), and radio public service announcements (32 percent). Fewer respondents aged 16 to 34 had heard of the campaign (63 percent) than respondents aged 35 to 64 (71 percent) and 65 and older (72 percent).

The respondents' reported likelihood of following all the driving tips provided in the "Pull Aside, Stay Alive" campaign also varied by age. Overall, 71 percent of respondents reported that they were highly likely to follow all the tips, but a much higher percentage of respondents in the 65 and older age group (80 percent) reported that they were likely to follow the tips than respondents in the 16 to 34 age group (59 percent). These findings indicate that younger drivers are less likely to be aware of the campaign and also less likely to follow campaign instructions when caught in a dust storm.

Respondents who reported being unlikely to follow all the tips were often confused about the meaning of one or more of the tips. For example, 20 percent expressed concern about where to pull over and 19 percent did not understand the need to turn off all lights. These concerns were echoed by focus group participants, as 15 of the 19 participants raised questions about one of more of the tips.

Survey participants were also given the opportunity to watch two public service announcements associated with the "Pull Aside, Stay Alive" campaign: "9-1-1 Call" and "Dust on the Horizon." Only 29 percent of participants reported that they had previously seen either PSA over the past two years, and they generally considered "9-1-1 Call" to be the more impactful of the two videos due to its graphic presentation of the consequences of dust-related crashes.

These findings indicate that while the "Pull Aside, Stay Alive" campaign is generally well-known among ADOT drivers, enhanced outreach to younger drivers and additional education on specific driving tips may make the campaign even more effective.

COMMUNICATION AND RESEARCH RECOMMENDATIONS

This section presents actionable recommendations for the design and implementation of an ADOT communication plan for windblown dust. These recommendations are based on the findings described above and are organized into the same general categories: (1) dust detection and forecasting, (2) event-based communication, and (3) public education and outreach. In the section that follows, these recommendations are considered from an implementation standpoint and further organized into actions that can be readily implemented in the short term versus actions that require additional research or infrastructure investments.

Recommendations for Dust Detection and Forecasting

Project findings suggest anticipated benefits from improving the timeliness and accuracy of dust detection and forecasting methods, particularly in regard to localized dust channels. Specific recommendations for this area of focus are as follows:

- Existing analyses of dust crash data on various roadway segments could be expanded to include an evaluation of land use types that contribute to fugitive dust "hot-spots." Though ADOT only has jurisdiction over a narrow right-of-way adjacent to Arizona highways, the agency could work with partner agencies to promote and design research into dust sources and mitigation strategies.
- Because current meteorological modeling and observational techniques do not adequately capture localized dust events, research aimed at improving existing modeling approaches is recommended. ADOT's continued work with partner organizations that focus on meteorological research and forecasting (e.g., the NWS and the University of Arizona) could help to promote and inform such research.
- Because of cost and reliability issues associated with optical visibility instruments (such as those used in the Safford District pilot project), such instruments may not be suitable for the dense network of sensors that would be required to detect small-scale dust events. Therefore, pilot studies are recommended to evaluate the usefulness of alternative small-sensor technologies (e.g., low-cost particle monitors) for roadway applications within the context of an effective communication system.
- Where possible, the deployment of additional visibility sensors should be augmented with human verification through CCTV or field observations to ensure the accuracy of dust-related information disseminated to the public.

Recommendations for Event-Based Communication

Project findings suggest that ADOT communication strategies should use the tools and media channels that drivers of various age groups prefer. Specific recommendations for this area of focus are as follows:

- Because more than half of survey respondents who sought weather information prior to a trip reported using television and radio, ADOT should continue to use mass media outlets that include these traditional communication channels. In addition, newspapers, which are used as a weather information source by slightly more than 25 percent of respondents age 65 and older, could be approached about presenting more in-depth reporting on ADOT efforts to promote driver safety during dust events.
- Due to the preference of younger (age 16 to 34) survey respondents for online and social media tools, ADOT should aggressively market the agency's existing suite of communication tools, including the ADOT Twitter account, AZ 511, the ADOT blog, and the ADOT Facebook page, as well as incentivize consumer signup for ADOT advisories distributed via e-mail or text message.

In addition, ADOT should consider other innovative ways to disseminate real-time weather information across smart media and any promising social media channels that may develop in the future.

- As ADOT promotes consumer signups for travel advisories, the agency should explore ways to expand options for tailoring information to customer needs and preferences (e.g., provide information that is specific to daily commute or travel destinations or that is targeted based on GPS location).
- Because 44 percent of survey respondents reported receiving weather information through mobile apps, ADOT should examine the feasibility of developing a free ADOT mobile app to take advantage of this shift in consumer media consumption. If this step is deemed at odds with ADOT communications on distracted driving, efforts could be made to collaborate with agencies and media outlets that offer related mobile apps to include information on roadway conditions.
- Due to the significant number of survey respondents (59 percent) who reporting obtaining weather information from highway message boards and the concerns expressed about the spatial distribution of such signs, ADOT could consider expanding the number of DMS, particularly along portions of the I-10 corridor between Phoenix and Tucson that have been identified as dust "hot-spots" (e.g., the Picacho Peak area).
- Regarding DMS, ADOT might also consider strategies (e.g., progressive signs) and messages that convey instructions from the "Pull Aside, Stay Alive" campaign on staying safe during dust events.[8] During this process, ADOT may benefit from collaborating with border states (e.g., California and New Mexico) on signage placement and messaging.

Recommendations for Public Education and Outreach

Project findings suggest fine-tuning ADOT's "Pull Aside, Stay Alive" campaign and exploring opportunities to communicate with professional truckers and other pass-through drivers who may be unfamiliar with the campaign. Specific recommendations for this area of focus are as follows:

- ADOT should consider updating the "Pull Aside, Stay Alive" website and other campaign materials to include information on the rationale behind driving tips that drivers find counterintuitive or contrary to their experience and training regarding driving in hazardous conditions other than dust. In particular, the tips related to pulling off the roadway, turning off lights, and setting the emergency brake appear to be sources of confusion.
- ADOT should explore further opportunities to highlight safety tips from the "Pull Aside, Stay Alive" campaign in conjunction with issuing dust warnings (e.g., through travel advisories, ADOT social media channels, the ADOT website, etc.).
- ADOT should share results from the drivers' survey with DPS and other partner agencies to ensure that consistent efforts are made to provide the public with dust safety information that addresses current questions and concerns.
- Though survey participants commended the "Dust on the Horizon" PSA for its vivid portrayal of rapidly deteriorating visibility conditions, many felt that the piece should link the decision to

[8] For example, additional signs could be deployed like those used at the Safford District pilot project, which read: "During limited visibility, pull off road, turn off lights."

drive in dust to the harsh consequences of doing so. ADOT should consider updating this PSA accordingly.

- The survey, which targeted 44,000 ADOT e-mail subscribers and was promoted in ADOT media channels, produced only 49 non-Arizona residents as participants. This result may indicate that ADOT communications may not be reaching out-of-state drivers, and that additional approaches may need to be developed to target this portion of Arizona travelers. ADOT should consider providing dust-related educational materials at rest stops, port-of-entry locations, visitor centers, and truck stops, as well as partnering with DPS to coordinate activities for contacting truckers and trucking industry groups.
- Based on survey and focus group responses, the MVD could be a key resource for educating drivers about dust safety. For example, MVD could include additional dust-related information in the Arizona Driver's Manual, update the license test to include questions on driving in dust storms, and display dust-related materials at MVD locations throughout the state.

Other Recommendations

The following recommendations were developed by the project team for ADOT's consideration, but did not emerge directly from the research findings presented in this report:

- ADOT could work with businesses that employ professional drivers to offer ADOT-sponsored workshops or instructional materials on driver safety during dust storms.
- ADOT could expand community-centered outreach, especially in rural areas of the state, to partner with agencies and organizations (e.g., faith-based organizations and tribal communities) that offer transportation services or work with underserved populations.
- ADOT could develop a youth-oriented public education and safety campaign that could be presented to middle schools, high schools, Boy Scout and Girl Scout Troops, and other youth groups.
- ADOT should develop strategies and tools to measure and assess the effectiveness of communication efforts related to windblown dust, using both quantitative measures and findings from qualitative research to identify opportunities for continuous improvement. For example, conducting additional focus groups with members of the public may be a useful way to periodically obtain feedback on specific strategies and materials that ADOT is using to communicate with the public about dust safety.

IMPLEMENTATION PLAN

The recommendations outlined above are extensive and diverse. To provide ADOT with guidance on implementing these recommendations, they have been organized into steps to be considered for short-, mid-, and long-term implementation, with definitions of these classifications provided as follows:

- **Short-term** – actions that can likely be implemented within the next year with existing ADOT resources and staff.
- **Mid-term** – actions likely to require one to three years to implement and that may involve the participation of external partners or financial resources.

- **Long-term** – actions likely to require more than three years to implement and that may require extensive cooperation and coordination with external partners.

Tables 4 through 6 list the recommendations that fall within each of these classifications in order of priority (i.e., steps with the highest priority within each classification are listed first).

Table 4. Short-Term Implementation Approach for Improving ADOT's Windblown Dust Communication Plan

Action Step	Focus Area	Comments
Short-Term Implementation		
Update "Pull Aside, Stay Alive" materials with rationale behind driving tips	Education and Outreach	Important for addressing driver confusion about dust responses
Aggressively market ADOT's online and social media tools	Event-Based Communication	Important for reaching a younger demographic
Continue to invest in traditional media outlets such as radio and television	Event-Based Communication	Many people, especially older age groups continue to obtain weather information from these sources
Develop strategies and tools to assess the effectiveness of communication efforts	Other	As action steps begin to be implemented, tracking their effectiveness is critical
Further explore opportunities to share tips from "Pull Aside, Stay Alive" when issuing dust advisories through e-mail or social media channels	Education and Outreach	Combines advisory information with safety tips
Share results from the drivers' survey with DPS and other partner agencies	Education and Outreach	This may happen naturally as study results are disseminated

Table 5. Mid-Term Implementation Approach for Improving ADOT's Windblown Dust Communication Plan

Action Step	Focus Area	Comments
Mid-Term Implementation		
Target truckers and other out-of-state drivers with dust safety materials	Education and Outreach	Important for reaching drivers that are not exposed to "Pull Aside, Stay Alive" messaging
Update the "Dust on the Horizon" PSA to reflect consequences of driving through low-visibility conditions	Education and Outreach	May be implementable in the short term, depending on the required resources and approvals
Examine the feasibility of developing an ADOT mobile app to better communicate dust-related warnings and information	Event-Based Communication	May conflict with ADOT messaging on distracted driving
Explore ways to tailor dust advisories to customer needs and preferences	Event-Based Communication	May require research into geo-targeting technologies
Support pilot studies to test small-sensor technologies aimed at detecting roadway dust as part of a comprehensive communication plan	Dust Detection and Forecasting	Would require partnerships with NWS, universities, and/or air quality agencies who are familiar with available sensor technologies
Augment additional visibility sensors with human verification where possible	Dust Detection and Forecasting	Important for ensuring that warnings reflect actual conditions
Expand or develop outreach efforts to professional drivers, community groups, and youth groups	Other	Many individuals in these groups may be reached through current ADOT outreach efforts

Table 6. Long-Term Implementation Approach for Improving ADOT's Windblown Dust Communication Plan

Long-Term Implementation		
Expand the number of DMS, particularly along the I-10 corridor between Phoenix and Tucson	Event-Based Communication	DMS is an important source of information for drivers, but significant resources would be required to implement this step
Explore progressive or alternative DMS messages that provide instructions on staying safe during dust events	Event-Based Communication	Should be done in tandem with the expansion of DMS recommended above
Work with MVD on incorporating dust safety information into drivers' education materials	Education and Outreach	May require a lengthy planning and approval process
Promote and cooperate with research efforts that evaluate land use and dust mitigation issues	Detection and Forecasting	ADOT has limited jurisdiction over land adjoining Arizona roadways and would need to work with other agencies on this issue
Promote and cooperate with efforts to improve the modeling and forecasting of dust events in Arizona	Detection and Forecasting	ADOT does not conduct meteorological research and would need to rely on the work of other agencies and organizations

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Appendix A

Individuals Interviewed from Arizona Agencies

Table A-1. Individuals Interviewed from Arizona Agencies

Agency	Name	Title
ADOT – Other	Daniel Brilliant	Budget Analyst
– Communications	Tim Tait	Assistant Communications Director
– Environmental Services	Darcy Anderson	Air Quality Program Coordinator
– Holbrook District	Lynn Johnson	District Engineer
– Phoenix Maintenance District	Mark Poppe	Regional Traffic Engineer
– Safford District	Tom Engle	Maintenance Engineer
	Bill Harmon	District Engineer
– Traffic Safety Section	Kohinoor Kar	Transportation Safety Engineer
	Richard Weeks	Road Safety Assessment Manager
– Tucson District	Rod Lane	District Engineer
– Winslow District	Rob Middleton	Supervisor
Arizona Department of Public Safety	Lee Bradshaw	Sergeant
	Larry Scarber	Major, Southern Patrol Bureau
Maricopa County – Air Quality Department	Beverly Chenausky	Air Quality Planner
National Weather Service – Tucson Office	Ken Drozd	Warning Coordination Meteorologist
Northern Arizona University	Pat Chavez	Adjunct Research Professor
Pinal County – Air Quality Control District	Scott DiBiase	Air Quality Planning Manager
University of Arizona Cooperative Extension	Kirk Astroth	Director, Arizona 4-H Youth Development
University of Arizona – Department of Atmospheric Sciences	William Sprigg	Research Professor

Appendix B

Individuals Interviewed from Out-of-State Agencies

Table B-1. Individuals Interviewed from Agencies in Other States (Continued)

State/Agency	Name	Title
Alabama DOT	David Johnson	Automated Transportation System Center Manager
Caltrans	John Castro	Senior Transportation Electrical Engineer
	Jose DeAlba	Electrical Engineer – Caltrans District 6
	Omar Perez	Electrical Engineer – Caltrans District 8
	Veronica Cipponeri	Electrical Engineer – District 10
Florida DOT	Craig Carnes	Office Manager/Project Manager – Metric Engineering
Florida – Atkins Consulting	Monica Reifeiss	Public Information Office
Georgia DOT	Mark Demidovich	Assistant State Traffic Engineer
Idaho Transportation Department	Bob Koeberlein	Mobility Services Engineer
Louisiana Department of Transportation and Development	Stephen Glascock	Director of Intelligent Transportation Systems (ITS)
Maryland State Highway Administration	John Wolford	Traffic Engineer
Montana DOT	Steve Keller	Chief - Communications Bureau
Nevada DOT	Jon Dickinson	Supervisor III
New Jersey DOT	Tim Bourne	Engineer, Traffic Operations
New Mexico DOT	Charles Remkes	ITS Bureau Chief
North Carolina DOT	C. Durwin Rice	Deputy Division Traffic Engineer
	Chad Franklin	Electronics Technician III
Ohio DOT	Abner Johnson	Statewide RWIS Coordinator
Pennsylvania DOT	Louis Cortelazzi	ITS Coordinator
	Tony Tanzi	Traffic Control Specialist
South Carolina DOT	Brian Holt	Traffic Management Center (TMC) Supervisor
Tennessee DOT	Bob VanHorn	Traffic Operations, TDOT TMC
	Said El Said	ITS Program Manager, Traffic Operations Division

State/Agency	Name	Title
Utah DOT	Ralph Patterson	Road Weather Operations Team Lead
Virginia DOT	Jason Bond	Salem District Public Relations and Marketing Specialist
	Fred Altizer	Assistant to the Chief Engineer (Retired/Consultant)
	Matthew Shiley	Regional Operations Director, Culpeper & Staunton Districts
West Virginia DOT	Steve Young	Design Engineer – District 1
	Rick Hazelwood	Mechanic – District 1

Appendix C

Interview Questions for Out-of-State Agencies

The following questions were the basis for telephone interviews conducted with agencies outside Arizona.

1. Please describe the nature of the roadway issue(s) your agency has addressed. What were the cause, frequency, and spatial scale of the issues?
2. Please briefly describe meteorological forecasting or reduced visibility detection that is incorporated into your current system or effort.
   - Purpose/intent
   - System components (sensors, etc.) including the vendor and product name(s)
   - Approximate cost of system (financial investment)
   - Active or decommissioned?
3. What actions are taken when a low-visibility event is detected?
   - How is information conveyed to the public during a low-visibility event?
   - Are intra-agency communications of information made during a low-visibility event? How are these communications made?
4. Has the system been successful in meeting its intended purpose(s)?
   - Accuracy and timeliness
   - Advantages and disadvantages
   - Key issues or problems (e.g., instrument reliability, data feeds)
   - Scope/level of deployment
   - Methods and metrics for tracking effectiveness
5. What improvements are needed to the detection and warning system (disregarding funding limitations)?
   - Components/infrastructure
   - Communication to the public or between agencies
6. Do you have any insights into public perceptions of the system and its effectiveness?
   - Has there been any public outreach on this issue? For example, ADOT has a "Pull Aside, Stay Alive" Campaign to inform the public what they should do when encountering a dust storm.
7. Do you have any literature/reports/documents that you could share with us for this work? If so, how can they be obtained (email, website link, etc.)?
8. Do you have any other thoughts you would like to share that may be of interest?
9. Are there other potential staff who work with aspects of the system, such as engineers, Public Information Officers, air quality experts, forecasters, emergency responders, etc., whose name and/or contact information you could provide that may have additional information to share?

Appendix D

Sample ADOT E-mail Message on Dust

ADOT

Strong winds, blowing dust could affect travel across Arizona today

Drivers urged to be alert, slow down, be prepared to pull off roadway

Strong winds predicted for today could lead to difficult driving conditions along with periods of blowing dust and low visibility on highways across much of the state, according to the Arizona Department of Transportation.

The National Weather Service in Phoenix has issued a blowing dust advisory until 6 p.m. for parts of central Arizona, including from Phoenix to Casa Grande. Areas of blowing dust and limited visibility have already been reported along Interstate 10 near Queen Creek Road.

ADOT warns drivers that breezy conditions could produce dust channels, which are localized areas of blowing dust where visibility can drop to nearly zero. This kind of wind and dust can occur in dust prone areas between Phoenix and Tucson, including I-10, I-8 and State Route 347.

Weather officials have also issued wind advisories for parts of northeast and southeast Arizona. One advisory in place until 7 p.m. includes most of I-40 between Flagstaff and New Mexico, while a second advisory also in place until 7 p.m. includes I-10 between Willcox and New Mexico.

The advisories forecast winds of 20 to 35 mph with gusts to 45 mph. Winds this strong can make driving difficult, especially for high profile vehicles.

Drivers are advised to stay alert and look out in all directions for blowing dust, especially in desert areas. ADOT urges drivers to avoid driving into a dust storm. Motorists play an important role in their own safety when driving during a dust storm. ADOT and the Arizona Department of Public Safety recommend the following driving tips when encountering a low-visibility dust storm:

- Avoid driving into or through a dust storm.
- If you encounter a dust storm, check traffic immediately around your vehicle (front, back and to the side) and begin slowing down.
- Do not wait until poor visibility makes it difficult to safely pull off the roadway — do it as soon as possible. Completely exit the highway if you can, away from where other vehicles may travel.
- Do not stop in a travel lane or in the emergency lane; look for a safe place to pull completely off the paved portion of the roadway.
- Turn off all vehicle lights, including your emergency flashers.
- Set your emergency brake and take your foot off the brake.
- Stay in the vehicle with your seatbelts buckled and wait for the storm to pass.
- Drivers of high-profile vehicles should be especially aware of changing weather conditions and travel at reduced speeds.
- Be aware that any storm can cause power outages to overhead roadway lighting and traffic signals. Drive with caution and treat all intersections without signals as having stop signs in all directions.

For more information and driving tips, please visit PullAsideStayAlive.org.

For the most current information about highway closures and restrictions statewide, visit ADOT's Travel Information Site at az511.gov or call 5-1-1.

Drivers reminded to 'Pull Aside, Stay Alive' during monsoon season

ADOT focuses on dust storm mindfulness as Monsoon Awareness Week begins

PHOENIX – Pull Aside, Stay Alive.

That's the familiar message to drivers from the Arizona Department of Transportation as another summer monsoon season approaches.

For the third year, ADOT continues its efforts to educate drivers about the threat of dust storms as monsoon season officially begins in Arizona on June 15. ADOT and its partners – the Governor's Office of Highway Safety, the Arizona Department of Public Safety and the National Weather Service – show motorists the real meaning of "Pull Aside, Stay Alive" with new television and radio public-education announcements that focus on the devastating outcomes for drivers who try to drive through dust storms.

The new public-education announcement focuses on a recent dust-related fatal crash along Interstate 10 between Phoenix and Tucson. The "911 Call" announcement illustrates what can happen to drivers who do not heed the "Pull Aside, Stay Alive" message. Audio of 911 calls from the crash are heard against visuals of emergency personnel moving among crushed vehicles and semi-trucks surrounded by blowing dust.

ADOT's mission is to provide valuable information to drivers before they get caught in a low-visibility dust storm. The agency's top recommendation is to avoid driving into a wall of dust at all costs.

"Driving into a dust storm is very dangerous, but the key is that oftentimes it can be avoided," said ADOT Director John Halikowski. "Drivers must be ready to alter their plans if there is a threat of a dust storm. It's better to change plans than try to power through dangerous conditions. But if you're on the road and a dust storm suddenly appears near you, pull off the highway as quickly and safely as possible. Never drive through a dust storm. It's not a risk worth taking."

Because dust storms can develop very quickly, particularly along the Interstate 10 corridor between Phoenix and Tucson, ADOT uses several methods to get information to drivers. These include electronic highway message boards, social and traditional media, communication with ADOT staff and law enforcement officers in the field, television and radio advertising, and close coordination with partnering agencies.

Throughout this week, which is Arizona Monsoon Awareness Week, ADOT will be using social media to engage Arizonans in spreading the word to "Pull Aside, Stay Alive." There will be posts on the ADOT Blog (azdot.gov/blog), Facebook page (facebook.com/AZDOT) and Twitter account (twitter.com/ArizonaDOT).

Please visit PullAsideStayAlive.org for the new public-education video along with videos from past years. The website also includes a tip sheet, which ADOT encourages drivers to print and keep handy in their vehicle.

Tips for drivers who encounter a dust storm:

- Avoid driving into or through a dust storm.
- If you encounter a dust storm, check traffic immediately around your vehicle (front, back and to the side) and begin slowing down.
- Do not wait until poor visibility makes it difficult to safely pull off the roadway — do it as soon as possible. Completely exit the highway if you can.
- Do not stop in a travel lane or in the emergency lane; look for a safe place to pull completely off the paved portion of the roadway.
- Stop the vehicle in a position ensuring it is a safe distance from the main roadway and away from where other vehicles may travel.
- Turn off all vehicle lights, including your emergency flashers.
- Set your emergency brake and take your foot off the brake.
- Stay in the vehicle with your seatbelts buckled and wait for the storm to pass.
- Drivers of high-profile vehicles should be especially aware of changing weather conditions and travel at reduced speeds.
- A driver's alertness and safe driving ability are always the top factors in preventing crashes.

Appendix E

Technical Details of Visibility Warning Systems Deployed by Other States

Table E-1. Technical Details on Visibility Warning Systems Deployed in the United States

State	System	Number of Meteorological and Visibility Sites	Visibility Sensor Make/Model	Cost Information
Alabama	I-10 Bay Bridge Fog Warning	• 2 RWIS stations • 6 visibility sensors	Optical Scientific	Visibility sensors cost $10,000 each
California	District 10 Fog Warning System	• 28 RWIS stations with visibility sensors	Various (Vaisala, RM Young, Envirotech, Texas Electronics, and Campbell Scientific)	RWIS stations cost $65,000 each
California	SR 99 Fog Detection and Warning System	• 24 visibility sensors	Vaisala PWD10	Entire system cost $12,000,000
California	SR 18 and State Route 138 Visibility Warning Systems	• 2 visibility sensors (one at each intersection impacted by fog)	Envirotech Sentry	Not available
Florida	Paynes Prairie Low Visibility Warning System	• 8 to 12 visibility sensors planned	Optical Scientific OWI 650	Entire system projected to cost $2,100,000
Georgia	I-75 Fog and Smoke Warning System	• 19 visibility sensors	Vaisala	Entire system cost between $2,000,000 and $2,500,000
Idaho	I-84 Storm Warning System	• 4 RWIS stations with visibility sensors	Vaisala PWD11 and DRD11A	System includes 4 RWIS stations costing from $60,000 to $120,000 each
Louisiana	Reduced Visibility Enhancement System	Unknown (system destroyed by Hurricane Katrina in 2005)	Vaisala	Entire system cost $4,000,000
Maryland	I-68 Fog Warning System	None	None	Not available
Montana	I-15 Dust Warning System	• 1 visibility sensor	Vaisala	Entire system cost $30,000
Nevada	I-80 Fog-based VSL system	• 1 RWIS station with a visibility sensor	Vaisala	Entire system cost $500,000
New Jersey	I-287 Fog Sensor / ITS Integration	• 1 RWIS station with a visibility sensor	Surface Systems, Inc. integrated weather and traffic sensor system	Entire system cost $100,000

DMS – dynamic message signs
RWIS – road weather information system
SR – state route
VSL – variable speed limit

Table E-1. Technical Details on Visibility Warning Systems Deployed in the United States (continued)

State	System	Number of Meteorological and Visibility Sites	Visibility Sensor Make/Model	Cost Information
New Mexico	I-10 Dust Control System	• 2 RWIS stations with visibility sensors	Vaisala PWD12	RWIS stations cost $80,000 each
North Carolina	I-40, I-26 Fog Warning Systems	• 3 RWIS stations • 7 visibility sensors (Numbers across both sites combined)	Vaisala	Total cost for both systems was $270,000 to $300,000
Ohio	Statewide Visibility System	• About 200 RWIS stations with visibility sensors statewide	Vaisala PWD11 and PWD12	Each RWIS site cost $50,000; entire network cost about $25,000,000
Pennsylvania	Route 22 Fog Warning System	• 1 RWIS station with a visibility sensor	Belfort Raven	Visibility sensor cost $7,000
Pennsylvania	Turnpike Fog Warning System	• 3 RWIS stations • 9 visibility sensors	Vaisala	Original deployment cost $5,300,000; a subsequent upgrade including new DMS and removal of VSL signs cost $1,400,000
Tennessee	I-75 Fog Warning System	• 10 visibility sensors	Envirotech Sentry	Original deployment cost $3,000,000; a subsequent upgrade including new DMS and sensors cost $1,300,000
Utah	I-215 Low Visibility Warning System	Unknown	Forward-scatter visibility sensors (make and model unknown)	Not available
Virginia	I-64 Afton Mountain Fog Warning System	• 5 visibility sensors	Vaisala PWD12	Original deployment of fog detection system in 1974 cost $2,000,000; a major system upgrade in 1997 cost $5,300,000; additional upgrades (including additional cameras, signs, and sensors) to be completed in 2015 for $4,600,000
Virginia	I-77 Fancy Gap Variable Speed Limit System	• 13 RWIS stations with visibility sensors	Not known	System is under construction and projected to cost $7,000,000

DMS – dynamic message signs
RWIS – road weather information system
SR – state route
VSL – variable speed limit

Appendix F

Caltrans and California Highway Patrol Fog Warning Pamphlet

Facts and Tips

It's not a Race!

The Dangers of Fog

- Driving in fog is comparable to driving while wearing a blindfold.
- Fog creates the most dangerous driving condition: *Zero Visibility!*
- Statistically, fog-related accidents carry the highest fatality rates.
- Unsafe driving speeds in foggy conditions drastically reduce stopping distances and reaction times.

Stay safe. Slow down while driving in fog.

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Governor

Dale E. Bonner
Secretary Business, Transportation And Housing Agency

Will Kempton
Director
Department Of Transportation

Joe Farrow
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Slow your Pace

Fog Driving Tips

1. Reduce your speed to allow for safe stopping distance.
2. Drive with your headlights on low-beam. NEVER drive using only your parking or fog lights.
3. Use extreme caution when crossing traffic or busy intersections during dense fog conditions.
4. Lower your window and listen for traffic you cannot see.
5. Use windshield wipers and your defroster to improve visibility.
6. Be patient! Don't pass long lines of traffic in fog.
7. If visibility diminishes to the point that you no longer feel safe driving, don't stop in the traffic lanes.
8. Attempt to utilize the closest off-ramp so you can stop at a safe location and wait for the fog to clear.
9. Call the Caltrans Highway Information Network at 1-800-427-ROAD for the latest information on highway driving conditions.

Caltrans®
CALIFORNIA DEPARTMENT OF TRANSPORTATION

visit our website at:

Current Technology

Changeable Message Signs

LOW YOUR PACE

Changeable Message Signs

These signs are programmed from the Transportation Management Center (TMC) to alert motorists regarding highway construction, maintenance work and adverse weather conditions.

Visibility Sensors

Visibility Sensors

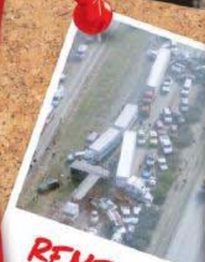
New technology also gives TMC workers the ability to "read" environmental conditions with the use of roadside weather stations, visibility sensors and closed circuit television cameras. The stations and sensors measure visibility, wind speed and direction, humidity, precipitation and pavement temperature.

Visibility Signs

Visibility Signs

These signs can assist motorists in determining Sight Distance in low-visibility locations. Motorists can then adjust their speed and the distance between the vehicles in front of them depending on the visibility.

For more info on current TECH visit our website ★



REMEMBER!

Fog KILLS!

California Fog Programs

Central California's Operation Fog Program

Whether you're traveling south to enjoy the warmer climate, heading north to walk among the majestic redwoods, or if you live in the fertile Central Valley, you need to always be aware of winter driving conditions. Especially when dense fog blankets the highways.

Fog can catch you by surprise. One minute you're driving along at 65 mph with a clear view of the road and the next minute your visibility drops to less than 200 feet and the traffic ahead of you slows to a crawl. This dramatic change in visibility and the speed of traffic can lead to multiple-car pileups, severe injury, or even death. It is difficult for motorists to perceive speed in dense fog conditions.

Caltrans and the CHP began "Operation Fog" in 1991 in an effort to help make you aware of this unique winter driving condition in Central California and to reduce the number of fog-related accidents.

This program not only relies on educational information like this brochure, but it also uses high-tech equipment to help you find your way when visibility drops on state highways in Central California. There are roadside weather stations and visibility sensors that gather information as well as electronic message sings and low-powered AM radio stations that alert you in advance of foggy conditions. Also, signs are posted in low-visibility areas that estimate Sight Distance. And as you approach off-ramps, a "3-2-1" countdown pattern of clear reflective pavement markers assist you in exiting the road during heavy fog.

Please do your part as well to avoid becoming an accident statistic. Reduce your speed and allow extra distance between vehicles in front of you when driving in Central California fog. It's also a good idea to phone the Caltrans Highway Information Network at 1-800-427-ROAD (7623) for statewide highway information. That way if travel conditions appear severe, you can consider postponing or rescheduling your trip until the fog clears.

CHP Pace Car Program

When visibility is reduced to less than 500 feet, the California Highway Patrol implements its "Pace Car Program." CHP vehicles escort traffic through dense fog when needed. Officers utilize their flashing lights to lead vehicles at a safe pace through areas of heavy fog. Keeping traffic speeds at a reduced and consistent pace during these conditions helps to minimize accidents and maximize safe travel on our state roads.

visit our website at www.FogUniversity.com

Appendix G

Summary of Results from the Driver Survey and Focus Groups

This appendix contains detailed summary information on the results of the driver survey and focus groups described in Chapter 2 of this report.

Tables G-1 through G-5 provide information on preferred media channels for obtaining weather and transportation information, as well media channels through which respondents have been exposed to ADOT's "Pull Aside, Stay Alive" campaign. This information is broken down by gender (Table G-1), age group (Table G-2), length of Arizona residency (Table G-3), target county (Table G-4), and ADOT subscriber status (Table G-5).

Tables G-6 through G-9 provide information on respondents' opinions of ADOT's dust-related PSAs, with responses broken down by gender, age, target county, and ADOT subscriber status. These tables provide information on which of the two videos was preferred by respondents (Table G-6), was more impactful (Table G-7), and was most likely to change respondents' actions when driving in dusty conditions (Table G-8). Table G-9 provides supporting data for the information presented in Tables G-6 through G-8.

Table G-1. Summary of Survey Findings by Gender

Gender	Weather Info	Media Used (25% or more)	Media Preferred (25% or more)	ADOT Tools Used	How Heard: PSA (25% or more)
Female n=1,198	• Often seeks info before trip: 31% • Influences travel plans: 52% (n=1,064) • Highly aware dust storms: 81% • Knows what to do: 53% • Follow tips: 74%	• n=1,064 • **NWS: 69%** • **ADOT: 53%** • **AZ511 system: 27%** • Websites: 61% • DMS: 60% • Radio: 56% • TV: 53% • Wireless alerts: 47% • Mobile apps: 45% • Social media: 32% • PSAs (radio/TV): 30%	• n=1,064 • Wireless alerts: 56% • Radio: 49% • Mobile apps: 42% • E-mail alerts: 37% • TV: 35% • Websites: 32% • PSAs: 29% • Social media: 27%	• n=669 • Website: 64% • Advisory/e-mail: 35% • AZ 5-1-1 phone: 28% • Traffic cameras: 14% • Advisory/cell-text: 11% • Campaign: 10% • ADOT Twitter acct: 6% • ADOT FB page: 6% • ADOT Blog: 1%	• n=804 • TV PSAs: 51% • News media: 38% • ADOT website: 30% • Radio PSAs: 29% • DMS: 25%
Male n=1,353	• Often seeks info before trip: 31% • Influences travel plans: 43% (n=1,201) • Highly aware dust storms: 85% • Knows what to do: 71% • Follow tips: 68%	• n=1,201 • **NWS: 70%** • **ADOT: 49%** • **AZ511 system: 31%** • Websites: 67% • DMS: 57% • Radio: 55% • TV: 53% • Mobile apps: 44% • Wireless alerts: 39% • PSAs (radio/TV): 27%	• n=1,201 • Radio: 49% • Wireless alerts: 47% • Mobile apps: 43% • Websites: 40% • E-mail alerts: 36% • TV: 34%	• n=726 • Website: 66% • AZ 5-1-1 phone: 35% • Advisory/e-mail: 34% • Traffic cameras: 21% • Advisory/cell-text: 11% • Campaign: 8% • ADOT Twitter acct: 7% • ADOT FB page: 4% • ADOT Blog: 2%	• n=974 • TV PSAs: 54% • ADOT website: 37% • News media: 36% • Radio PSAs: 34% • DMS: 26%

Statistically higher percentage of woman than men use: ADOT (53 and 49 percent, respectively), Wireless alerts sent to mobile devices (47 and 39 percent, respectively), social media (32 and 17 percent, respectively), and PSAs (30 and 27 percent, respectively).

Statistically higher percentage of women than men prefer to obtain or receive information via: Wireless alerts sent to mobile devices (56 and 47 percent, respectively), social media (27 and 12 percent, respectively), and PSAs (29 and 23 percent, respectively).

Statistically higher percentage of men than women: Use the Arizona 511 system (31 and 27 percent, respectively) and prefer to obtain or receive information via websites (40 and 32 percent, respectively).

Table G-2. Summary of Survey Findings by Age Group

Age Group	Weather Info	Sources/Media Used (25% or more)	Media Preferred (25% or more)	ADOT Tools Used	How Heard: PSA (25% or more)
16–34 **n=271**	• Often seeks info before trip: 19% • Influences travel plans: 30% (n=221) • Highly aware dust storms: 76% • Knows what to do: 51% • Follow tips: 59%	• n=221 • **NWS: 76%** • **ADOT: 49%** • **AZ511 system: 24%** • Websites: 65% • DMS: 59% • Mobile apps: 56% • Social media: 51% • Wireless alerts: 50% • Radio: 49%; TV: 40%	• n=221 • Wireless alerts: 57% • Mobile apps: 50% • Social media: 45% • Websites: 36% • Radio: 36% • TV: 25% • E-mail alerts: 24%	• n=123 • Website: 71% • Advisory/e-mail: 26% • AZ 5-1-1 phone: 25% • ADOT Twitter acct: 21% • ADOT FB page: 16% • Traffic cameras: 15% • Campaign: 12% • Advisory/cell-text: 7% • ADOT Blog: 4% • Haboob Haiku: 2%	• n=170 • ADOT website: 40% • TV PSAs: 34% • Social media: 32% • DMS: 31% • News media: 30% • Websites or blogs: 26% • Radio PSAs: 24%
35–64 **n=1,779**	• Often seeks info before trip: 30% • Influences travel plans: 47% (n=1,600) • Highly aware dust storms: 85% • Knows what to do: 64% • Follow tips: 70%	• n=1,600 • **NWS: 68%** • **ADOT: 51%** • **AZ511 system: 31%** • Websites: 66% • DMS: 59% • Radio: 56%; TV: 52% • Mobile apps: 47% • Wireless alerts: 45% • PSAs (radio/TV): 27% • Social media: 24%	• n=1,600 • Wireless alerts: 54% • Radio: 49% • Mobile apps: 45% • Websites: 37% • E-mail alerts: 37% • TV: 32% • PSAs: 24%	• n=994 • Website: 66% • AZ 5-1-1 phone: 33% • Advisory/e-mail: 33% • Traffic cameras: 19% • Advisory/cell-text: 11% • Campaign: 9% • ADOT Twitter acct: 6% • ADOT FB page: 5% • ADOT Blog: 1%	• n=1,248 • News media: 35% • ADOT website: 34% • TV PSAs: 34% • Radio PSAs: 33% • DMS: 26%
65+ **n=501**	• Often seeks info before trip: 41% • Influences travel plans: 59% (n=444) • Highly aware dust storms: 80% • Knows what to do: 64% • Follow tips: 80%	• n=444 • **NWS: 72%** • **ADOT: 53%** • **AZ511 system: 25%** • TV: 64% • Websites: 57% • Radio: 56% • DMS: 55% • PSAs (radio/TV): 37% • Wireless alerts:34% • Mobile apps: 31%	• N=444 • Radio: 53% • TV: 49% • E-mail alerts: 42% • Wireless alerts:39% • PSAs: 35% • Websites: 32% • Mobile apps: 30%	• n=278 • Website: 58% • Advisory/e-mail: 42% • AZ 5-1-1 phone: 29% • Traffic cameras: 15% • Advisory/cell-text: 9% • Campaign: 9% • ADOT Twitter acct: 3% • ADOT FB page: 3% • ADOT Blog: 1%	• n=360 • TV PSAs: 63% • News media: 46% • ADOT website: 32% • Radio PSAs: 31%

Table G-3. Summary of Survey Findings by Length of Arizona Residency

Arizona Residency	Weather Info	Sources/Media Used (25% or more)	Media Preferred (25% or more)	ADOT Tools Used	How Heard: PSA (25% or more)
1–4 yrs. n=182	• Often seeks info before trip: 37% • Influences travel plans: 56% (n=156) • Highly aware dust storms: 62% • Knows what to do: 47% • Follow tips: 79%	• n=156 • **NWS: 66%** • **ADOT: 47%** • Websites: 60% • DMS: 51% • TV: 51% • Mobile apps: 51% • Wireless alerts: 47% • Radio: 44% • Social media: 39% • PSAs & e-mail alerts: 25%	• n=156 • Wireless alerts: 57% • Mobile apps: 48% • E-mail alerts: 40% • TV: 39% • Websites: 32% • Social media: 26% • Radio: 26%	• n=79 • Website: 58% • Advisory/e-mail: 41% • Traffic cameras: 14% • ADOT FB page: 11% • AZ 5-1-1 phone: 10% • Advisory/cell-text: 10% • Campaign: 10% • ADOT Twitter acct: 8% • ADOT Blog: 1%	• n=118 • TV PSAs: 50% • News media: 43% • ADOT website: 30% • DMS: 25% • Radio PSAs: 23%
5–9 yrs. n=264	• Often seeks info before trip: 29% • Influences travel plans: 52% (n=233) • Highly aware dust storms: 78% • Knows what to do: 51% • Follow tips: 71%	• n=233 • **NWS: 70%** • **ADOT: 55%** • Websites: 65% • DMS: 58% • Mobile apps: 54% • TV: 53%; Radio: 50% • Wireless alerts:47% • PSAs (radio/TV): 31% • Social media: 29% • E-mail alerts: 26%	• n=233 • Wireless alerts:55% • Mobile apps: 47% • Radio: 45% • Websites: 37% • E-mail alerts: 37% • TV: 35% • Social media: 27% • PSAs: 25%	• n=134 • Website: 67% • Advisory/e-mail: 46% • AZ 5-1-1 phone: 13% • Advisory/cell-text: 10% • ADOT Twitter acct: 10% • Traffic cameras: 9% • ADOT FB page: 7% • Campaign: 6% • ADOT Blog: 2%	• n=185 • News media: 44% • ADOT website: 31% • TV PSAs: 49% • Radio PSAs: 29%
10+ Yrs. n=2056	• Often seeks info before trip: 31% • Influences travel plans: 47% (n=1,837) • Highly aware dust storms: 86% • Knows what to do: 66% • Follow tips: 70%	• n=1,837 • **NWS: 70%** • **ADOT: 51%** • **AZ511 system: 32%** • Websites: 64% • DMS: 60% • Radio: 57%; TV: 53% • Wireless alerts:43% • Mobile apps: 43% • PSAs (radio/TV): 29%	• n=1,837 • Radio: 51% • Wireless alerts:51% • Mobile apps: 41% • E-mail alerts: 36% • Websites: 36% • TV: 34% • PSAs: 26%	• n=1,160 • Website: 65% • Advisory/e-mail: 33% • AZ 5-1-1 phone: 36% • Traffic cameras: 19% • Advisory/cell-text: 10% • Campaign: 9% • ADOT Twitter acct: 6% • ADOT FB page: 5% • ADOT Blog: 1% • Haboob Haiku: 1%	• n=1,460 • TV PSAs: 53% • News media: 36% • ADOT website: 35% • Radio PSAs: 33% • DMS: 26%

Table G-4. Summary of Survey Findings by Target County

Target County	Weather Info	Sources/Media Used (25% or more)	Media Preferred (25% or more)	ADOT Tools Used	How Heard: PSA (25% or more)
Maricopa n=1,525	• Often seeks info before trip: 29% • Influences travel plans: 46% (n=1,353) • Highly aware dust storms: 85% • Knows what to do: 64% • Follow tips: 70%	• n=1,353 • **NWS: 68%** • **ADOT: 55%** • **AZ511 system: 31%** • Websites: 63% • DMS: 60% • Radio: 57%; TV: 56% • Wireless alerts: 47% • Mobile apps: 46% • PSAs: 29% • Social media: 24%	• n=1,353 • Wireless alerts: 54% • Radio: 49% • Mobile apps: 43% • E-mail alerts: 37% • TV: 35% • Websites: 34% • PSAs: 24%	• n=875 • Website: 63% • Advisory/e-mail: 38% • AZ 5-1-1 phone: 30% • Traffic cameras: 19% • Advisory/cell-text: 12% • Campaign: 9% • ADOT Twitter acct: 8% • ADOT FB page: 5% • ADOT Blog: 1% • Haboob Haiku: 1%	• n=1,060 • TV PSAs: 52% • News media: 39% • ADOT website: 37% • Radio PSAs: 31% • DMS: 28%
Pima n=385	• Often seeks info before trip: 33% • Influences travel plans: 47% (n=340) • Highly aware dust storms: 83% • Knows what to do: 61% • Follow tips: 73%	• n=340 • **NWS: 71%** • **ADOT: 44%** • Websites: 62% • DMS: 59% • Radio: 58%; TV: 50% • Mobile apps: 41% • Wireless alerts: 34% • PSAs (radio/TV): 28% • Social media: 22%	• n=340 • Radio: 51% • Wireless alerts:44% • Mobile apps: 42% • Websites: 37% • TV: 36% • E-mail alerts: 34% • PSAs: 31%	• n=182 • Website: 68% • AZ 5-1-1 phone: 31% • Advisory/e-mail: 26% • Traffic cameras: 14% • Campaign: 12% • Advisory/cell-text: 7% • ADOT Twitter acct: 6% • ADOT FB page: 6% • ADOT Blog: 1%	• n=295 • TV PSAs: 54% • Radio PSAs: 37% • News media: 34% • ADOT website: 24%
Pinal n=195	• Often seeks info before trip: 34% • Influences travel plans: 62% (n-172) • Highly aware dust storms: 83% • Knows what to do: 61% • Follow tips: 73%	• n=172 • **NWS: 69%** • **ADOT: 48%** • **AZ511 system: 24%** • Websites: 59% • TV: 55% • Wireless alerts: 54% • DMS: 53% • Radio: 52% • Mobile apps: 44% • PSAs (radio/TV): 31% • Social media (23%) • E-mail alerts (22%)	• n=172 • Wireless alerts:63% • Radio: 49% • Mobile apps: 44% • TV: 36% • E-mail alerts: 34% • PSAs: 27% • Websites: 26%	• n=96 • Website: 59% • Advisory/e-mail: 33% • AZ 5-1-1 phone: 24% • Traffic cameras: 10% • Advisory/cell-text: 10% • ADOT FB page: 6% • ADOT Twitter acct: 4% • Campaign: 2% • ADOT Blog: 1% • Haboob Haiku: 1%	• n=295 • TV PSAs: 54% • Radio PSAs: 37% • News media: 34% • ADOT website: 24% • DMS: 24%

Table G-5. Summary of Survey Findings by ADOT Non-Subscribers

	Weather Info	Sources/Media Used (25% or more)	Media Preferred (25% or more)	ADOT Tools Used	How Heard PSA (25% or more)
Non Subscribers n=1,092	• Often seeks info before trip: 31% • Influences travel plans: 50% (n=975) • Highly aware dust storms: 82% • Knows what to do: 62% • Follow tips: 72%	• n=975 • **NWS: 72%** • **ADOT: 43%** • **AZ511 system: 25%** • Websites: 65% • DMS: 58% • Radio: 54% • TV: 50% • Mobile apps: 46% • Wireless alerts: 43% • Social media: 31% • PSAs: 26%	• n=975 • Wireless alerts: 53% • Radio: 45% • Mobile apps: 44% • Websites: 34% • TV: 32% • E-mail alerts: 29% • PSAs: 25% • Social media: 25%	• n=520 • Website: 70% • AZ 5-1-1 phone: 33% • Traffic cameras: 20% • Advisory/e-mail: 19% • Advisory/cell-text: 10% • Campaign: 9% • ADOT Twitter acct: 8% • ADOT FB page: 7% • ADOT Blog: 1% • Haboob Haiku: 1%	• n=725 • TV PSAs: 51% • News media: 35% • Radio PSAs: 32% • ADOT website: 25% • DMS: 26%

A statistically significant higher percentage of non-subscribers than ADOT subscribers reported:

- Using social media (31 and 18 percent, respectively)
- Having heard about the “Pull Aside, Stay Alive” campaign through social media (25 and 14 percent, respectively)
- Preferring to obtain or receive information via social media (25 and 14 percent, respectively)

Among those reporting use of ADOT communication tools, a statistically significant higher percentage of non-subscribers than ADOT subscribers reported:

- Using the ADOT website (70 and 62 percent, respectively)
- Using the ADOT Facebook page (7 and 4 percent, respectively)

Table G-6. Survey Results Indicating Which Video Respondents Preferred

	Liked Dust on the Horizon N = 805	Liked 9-1-1 Call N = 813
Gender	• 50% (406) female • 50% (399) male	• 49% (397) female • 51% (416) male
Age	• 7% (56) were ages 16 to 34. Represented 41% of those ages 16-34 (N = 137) • 72% (579) were age 35 to 64 Represented 49% of those ages 35-64 (N = 1,175) • 21% (170) were ages 65 and older Represented 56% of those ages 65 and older (N = 306) • Mean age: 54	• 10% (81) were ages 16 to 34 Represented 59% of those ages 16-34 (N = 137) • 73% (596) were age 35 to 64 Represented 51% of those ages 35-64 (N = 1,175) • 17% (136) were ages 65 and older Represented 44% of those ages 65 and older (N = 306) • Mean age: 52
Target County	Of the 789 *Arizona* respondents who preferred *Dust on the Horizon*: • 58% (460) lived in Maricopa County Represented 48% of those living in Maricopa (N = 954) • 16% (123) lived in Pima County Represented 48% of those living in Pima (N = 255) • 9% (69) lived in Pinal County Represented 54% of those living in Pinal (N = 127)	Of the 801 *Arizona* respondents who preferred *9-1-1 Call*: • 62% (494) lived in Maricopa County Represented 52% of those living in Maricopa (N = 954) • 17% (132) lived in Pima County Represented 52% of those living in Pima (N = 255) • 7% (58) lived in Pinal County Represented 46% of those living in Pinal County (N = 127)
ADOT status	ADOT subscribers (N = 936) • 50% (466) of ADOT subscribers liked Dust on the Horizon Non-subscribers (N = 682) • 50% (339) of non-subscribers liked Dust on the Horizon	ADOT subscribers (N = 936) • 50% (470) of ADOT subscribers liked 9-1-1 Call Non-subscribers (N = 682) • 50% (343) of non-subscribers liked 9-1-1 Call

Overall, among the 1,618 respondents who completed the survey and watched the videos:

- 50% (805) preferred Dust on the Horizon
- 50% (813) preferred 9-1-1 Call

Table G-7. Survey Results Indicating Which Video Respondents Thought Had the Most Impact

	9-1-1 Call Has the Most Impact N = 1,186	Dust on the Horizon Has the Most Impact N = 432
Gender	• 50% (592) female • 50% (594) male	• 49% (211) female • 51% (221) male
Age	• 10% (118) were ages 16 to 34. Represented 86% of those ages 16- 34 (N = 137) • 72% (857) were age 35 to 64 Represented 73% of those ages 35-64 (N = 1,175) • 18% (211) were ages 65 and older Represented 69% of those ages 65 and older (N = 306) • Mean age: 52	• 4% (19) were ages 16 to 34 Represented 14% of those ages 16-34 (N = 137) • 74% (318) were age 35 to 64 Represented 27% of those ages 35-64 (N = 1,175) • 22% (95) were ages 65 and older Represented 31% of those ages 65 and older (N = 306) • Mean age: 542
Target County	Of the 1,168 *Arizona* respondents who thought *9-1-1 Call* had the most impact: • 62% (722) lived in Maricopa County Represented 76% of those living in Maricopa (N = 954) • 15% (178) lived in Pima County Represented 70% of those living in Pima (N = 255) • 8% (89) lived in Pinal County Represented 70% of those living in Pinal (N = 127)	Of the 422 *Arizona* respondents who thought *Dust on the Horizon* had the most impact: • 55% (232) lived in Maricopa County Represented 24% of those living in Maricopa (N = 954) • 18% (77) lived in Pima County Represented 30% of those living in Pima (N = 255) • 9% (38) lived in Pinal County Represented 30% of those living in Pinal County (N = 127)
ADOT Status	ADOT subscribers (N = 936) • 73% (503) thought 9-1-1 Call has the most impact Non-subscribers (N = 682) • 74% (503) thought 9-1-1 Call has the most impact	ADOT subscribers (N = 936) • 47% (433) thought Dust on the Horizon has the most impact Non-subscribers (N = 682) • 26% (179) of non-subscribers thought Dust on the Horizon has the most impact
By Best Liked Video	Among the 813 respondents who *liked 9-1-1 Call* the best • 98% (796) thought 9-1-1 Call has the most impact Among the 805 respondents who *liked Dust on the Horizon* the best • 48% (390) thought 9-1-1 Call has the most impact	Among the 813 respondents who *liked 9-1-1 Call* the best • 2% (17) thought Dust on the Horizon has the most impact Among the 805 respondents who *liked Dust on the Horizon* the best • 52% (415) thought Dust on the Horizon has the most impact

Overall, among the 1,618 respondents who completed the survey and watched the videos:

- 73% (1,186) thought 9-1-1 Call had the most impact
- 27% (432) thought Dust on the Horizon had the most impact

Table G-8. Survey Results Indicating Which Video Is Most Likely to Change Driver Behavior When Driving in Dust Storm Conditions (Continued)

	9-1-1 Call Likely to Change Behavior N = 945	Dust on the Horizon Likely to Change Behavior N = 673
Gender	• 49% (466) female • 51% (479) male	• 50% (337) female • 50% (336) male
Age	• 11% (101) were ages 16 to 34. Represented 74% of those ages 16-34 (N =137) • 74% (700) were age 35 to 64 Represented 60% of those ages 35-64 (N =1,175) • 15% (144) were ages 65 and older Represented 47% of those ages 65 and older (N =306) • Mean age: 51	• 5% (36) were ages 16 to 34 Represented 26% of those ages 16-34 (N = 137) • 71% (475) were age 35 to 64 Represented 40% of those ages 35-64 (N = 1,175) • 24% (162) were ages 65 and older Represented 53% of those ages 65 and older (N =306) • Mean age: 55
Target County	Of the 931 *Arizona* respondents who thought *9-1-1 Call was likely to change their behavior*: • 63% (585) lived in Maricopa County Represented 61% of those living in Maricopa (N =954) • 15% (136) lived in Pima County Represented 53% of those living in Pima (N =255) • 8% (72) lived in Pinal County Represented 57% of those living in Pinal (N =127)	Of the 659*Arizona* respondents who thought *Dust on the Horizon was likely to change their behavior*: • 56% (369) lived in Maricopa County Represented 39% of those living in Maricopa (N =954) • 18% (119) lived in Pima County Represented 47% of those living in Pima (N =255) • 8% (55) lived in Pinal County Represented 43% of those living in Pinal County (N =127)
ADOT Status	ADOT subscribers (N = 936) • 58% (542) thought 9-1-1 would change their driving behavior Non-subscribers (N = 682) • 59% (403) thought 9-1-1 would change their driving behavior	ADOT subscribers (N = 936) • 42% (394) thought Dust on the Horizon would change their behavior Non-subscribers (N = 682) • 41% (279) of non-subscribers thought Dust on the Horizon would change their driving behavior

	9-1-1 Call Likely to Change Behavior N = 945	Dust on the Horizon Likely to Change Behavior N = 673
By Best Liked Video	Among the 813 respondents who *liked 9-1-1 Call* the best • 91% (740) thought 9-1-1 Call was more likely to change their driving behavior Among the 805 respondents who *liked Dust on the Horizon* the best • 25% (205) thought 9-1-1 Call was more likely to change their driving behavior	Among the 813 respondents who *liked 9-1-1 Call* the best • 9% (73) thought Dust on the Horizon was more likely to change their driving behavior Among the 805 respondents who *liked Dust on the Horizon* the best • 75% (600) thought Dust on the Horizon was more likely to change their driving behavior
By Most Impactful Video	Among the 1,186 respondents who thought *9-1-1 Call had the most impact* • 75% (896) thought 9-1-1 Call was more likely to change their driving behavior Among the 432 respondents who thought *Dust on the Horizon had the most impact* • 11% (49) thought 9-1-1 Call was more likely to change their driving behavior	Among the 1,186 respondents who thought *9-1-1 Call had the most impact* • 25% (290) thought Dust on the Horizon was more likely to change their driving behavior Among the 432 respondents who thought *Dust on the Horizon had the most impact* • 89% (373) thought Dust on the Horizon was more likely to change their driving behavior

Overall, among the 1,618 respondents who completed the survey and watched the videos:

- 58% (945) thought 9-1-1 Call was most likely to change their driving behavior
- 42% (673) thought Dust on the Horizon was most likely to change their driving behavior

Table G-9. Summary of Respondents' Demographics (Continued)

Female (N = 803)	Like Best Number/Percent of Total		Most Impact Number/Percent of Total		Change My Behavior Number/Percent of Total	
Dust	406	**51%**	211	26%	337	42%
9-1-1 Call	397	49%	592	**74**%	466	**58**%

Male (N = 815)						
Dust	399	**49%**	221	27%	336	41%
9-1-1 Call	416	**51%**	594	**73**%	479	**59**%

Age 16-34 (N = 137)						
Dust	56	41%	19	14%	36	26%
9-1-1 Call	81	**59%**	118	**86%**	101	**74**%

Age 35-64 (N = 1,175)						
Dust	579	**49%**	318	27%	475	40%
9-1-1 Call	596	**51%**	857	**73**%	700	**60%**

Age 65+ (N = 306)						
Dust	170	**56%**	95	31%	162	**53%**
9-1-1 Call	136	44%	211	**69%**	144	47%

Maricopa Cty. (N = 954)	Like Best Number/Percent of Total		Most Impact Number/Percent of Total		Change My Behavior Number/Percent of Total	
Dust	460	**48%**	232	24%	369	39%
9-1-1 Call	494	**52%**	722	**76**%	585	**61**%

Pima Cty. (N = 255)						
Dust	123	**48%**	77	30%	119	47%
9-1-1 Call	132	**52%**	178	**70**%	136	**53**%

Pinal Cty. (N = 127)						
Dust	69	**54**%	38	30%	55	43%
9-1-1 Call	58	46%	89	**70**%	72	**57**%