Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona

Final Report 696
March 2013

Arizona Department of Transportation
Research Center

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Prepared by:
Wendy Tao and Caroline Leary
Cambridge Systematics, Inc.
555 12th Street, Suite 1600
Oakland, CA 94607

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007

in cooperation with
U.S. Department of Transportation
Federal Highway Administration

This report was funded in part through grants from the Federal Highway Administration, U.S. Department of Transportation. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data, and for the use or adaptation of previously published material, presented herein. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation or the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names that may appear herein are cited only because they are considered essential to the objectives of the report. The U.S. government and the State of Arizona do not endorse products or manufacturers.

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-AZ-13-696		

4. Title and Subtitle	5. Report Date
Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona	March 2013
	6. Performing Organization Code
7. Author	8. Performing Organization Report No.
Wendy Tao and Caroline Leary	
9. Performing Organization Name and Address	10. Work Unit No.
Cambridge Systematics, Inc. 555 12th Street, Suite 1600 Oakland, CA 94607	11. Contract or Grant No. SPR-PL1 (177) 696
12. Sponsoring Agency Name and Address	13. Type of Report & Period Covered
Arizona Department of Transportation 206 S. 17th Avenue Phoenix, Arizona 85007	Final (02/2012-03/2013)
	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This research study presents recommendations for the Arizona Department of Transportation (ADOT) to continue working toward being more resilient, flexible, and responsive to the effects of global climate change. The main objectives were to identify key individuals within ADOT with decision-making authority relevant in incorporating climate change adaptation in planning, design, and operations; review literature and best practices for climate change adaptation as relevant to the desert Southwest; develop a research agenda for ADOT to further understand the impacts of climate change on the agency (including a knowledge-mapping exercise using an online survey questionnaire, structured interviews, and focus groups); and identify key areas for further research.

By initiating this study, there is already an internal interest and momentum at ADOT for climate adaptation planning. Without institutional support, however, it will be difficult to continue forward with the research agenda in a more extensive study. To move beyond a preliminary assessment, ADOT will have to find ways to bring its lessons learned to the forefront and into the national spotlight. This study reveals that ADOT already experiences extreme heat and dust storms, and thus it will be the first to develop tools and techniques that can be applied to other states and regions that will experience climate impacts that Arizona will face first. The study provides some recommendations for ADOT to tap into the national dialogue on climate adaptation so it will not miss opportunities for peer exchange and potential funding and technical assistance.

17. Key Words	18. Distribution Statement	23. Registrant's Seal
Climate change, climate adaptation, online surveys, decision-making, forecasting, Arizona, transportation system	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161	

19. Security Classification	20. Security Classification	21. No. of Pages	22. Price
Unclassified	Unclassified	110	

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ACRONYMS

AASHTO .....American Association of State Highway and Transportation Officials

ADEQ .....Arizona Department of Environmental Quality

ADOT .....Arizona Department of Transportation

ASD.....Administrative Services Division

ASU.....Arizona State University

AZGFD .....Arizona Game and Fish Department

BMP .....Best Management Practices

CO_2e.....carbon dioxide equivalent

CCAG .....Climate Change Advisory Group

CLIMAS .....Climate Assessment for the Southwest

COG .....Council of Governments

DCDC .....Decision Center for a Desert City

DOT .....Department of transportation; ADOT's counterpart in another state

ECD.....Enforcement and Compliance Division

EPA.....U.S. Environmental Protection Agency

FEMA .....Federal Emergency Management Agency

FHWA.....Federal Highway Administration

FIS.....Feature Inventory System

FMLA .....Federal Land Management Agency

GHG.....Greenhouse gas

GIS .....Geographic Information System

HAASM .....The Highway Agency Adaptation Strategy Model

ICLEI .....Local Governments for Sustainability

IPCC.....Intergovernmental Panel on Climate Change

ITD.....Intermodal Transportation Division

LED.....Light-emitting diode

LRTP.....Long-Range Transportation Plan

MAG .....Maricopa Association of Governments

MAP-21.....Moving Ahead for Progress in the 21st Century

MPD.....Multimodal Planning Division

MPO.....Metropolitan Planning Organization

MSLT.....Maintenance Service Leadership Team

MTC.....Metropolitan Transportation Commission

NCAR .....National Center for Atmospheric Research

NEPA .....National Environmental Policy Act

NGO.....Non-Governmental Organization

NJTPA.....North Jersey Transportation Planning Authority

NRC .....National Research Council

NOAA.....National Oceanic and Atmospheric Administration

NPCC.....New York City Panel on Climate Change

OES.....Office of Environmental Services

PAG.....Pima Association of Governments

PECOS .....PErformance COntrolled System

RTP .....Regional Transportation Plan

RWIC .....Regional Weather Information Center

SQL.....Structured Query Language

STIP .....State Transportation Improvement Plan

TAC.....Technical Advisory Committee

TIP.....Transportation Improvement Programs

TOC.....Traffic Operations Center

TRB.....Transportation Research Board

TSG.....Transportation Services Group

UCAR .....University Corporation for Atmospheric Research

USGCRP.....U.S. Global Change Research Program

USFW .....U.S. Fish and Wildlife Service

WCI.....Western Climate Initiative

ACKNOWLEDGMENTS

The authors are especially grateful for the contributions of the highly engaged and well-informed Technical Advisory Committee assembled for this research report, including Beverly Chenausky, Ed Stillings, Kristen Keener Busby, Meesa Otani, Michael Traubert, Orrin Shaw, Rebecca Swiecki, Thor Anderson, Tom Kombe, and Victoria Carella. Of particular note are the comments and leadership provided by Charles Beck in ADOT Environmental Planning, whose initial ideas for the work expanded into a thoughtful preliminary study of climate adaptation.

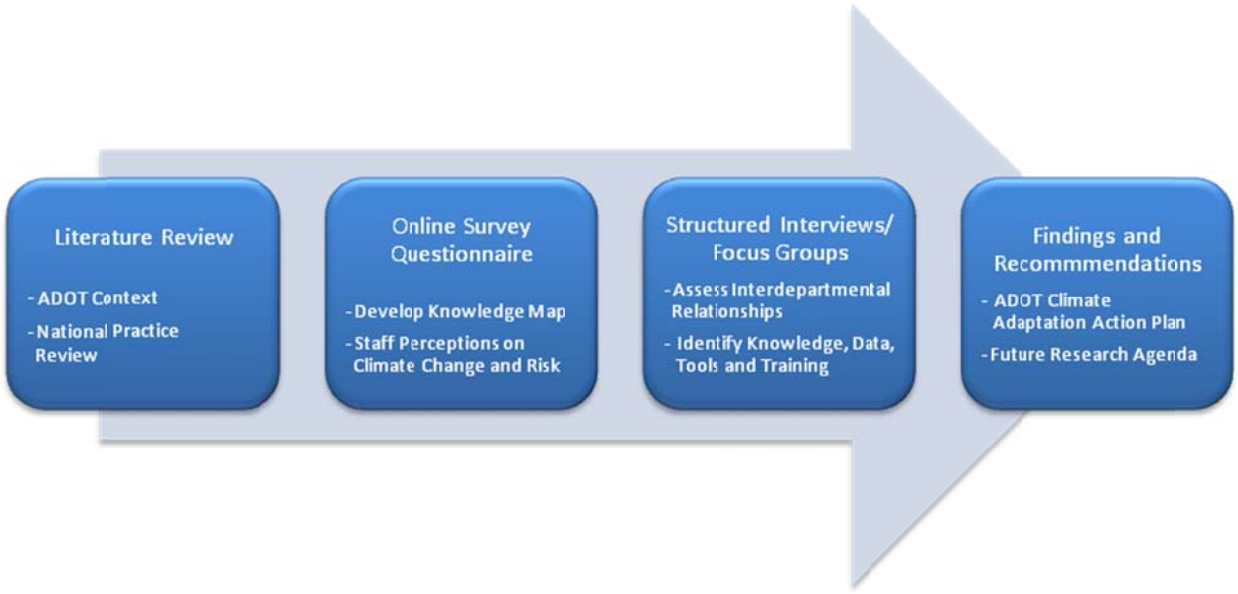
EXECUTIVE SUMMARY

The reality of a changing climate means that transportation and planning agencies need to understand the potential effects of changes in temperature, storm activity, and precipitation patterns on the transportation infrastructure and services they manage. These changes can result in increased heat waves, droughts, storm activity, early snowmelt, and wildfires, among other impacts that could pose new challenges for the Arizona Department of Transportation (ADOT).

STUDY PURPOSE AND RESEARCH APPROACH

The goal of this study was to establish a path for the ADOT to continue working toward being more resilient, flexible, and responsive to the effects of global climate change.

The research approach for this study began with a literature review, then used an online survey questionnaire as well as structured interviews and focus groups, and finally summarized findings. The ADOT effort involved four main work tasks, as illustrated in Figure 1, culminating in a set of findings and recommendations for further research or action.



Source: Cambridge Systematics, Inc., 2012.

Figure 1. ADOT Climate Adaptation Study Research Plan

IMPACTS TO ADOT

Arizona belongs to the Southwest region of the United States, an area stretching from the southern Rocky Mountains to the Pacific Coast. Due to the wide variety of landscapes including mountains, plateaus, deserts, and plains, the Southwest is a complex region highly affected by the changing climate.

The effects of climate change in the Southwest appear to be underway with the prospect of increased droughts and higher summer temperatures. Based on a U.S. Global Change Research Program synthesis, which reviewed a list of key climate-related impacts for the country, several

key climate-related impacts are projected to affect the Southwest region, including heat waves, early snowmelt, drought, urban heat island effects, degraded air quality, wildfires, and effects on ecosystems and wildlife habitats.

Arizona has an extensive and expansive transportation infrastructure system, including more than 6,000 miles of roads and highways, nearly a dozen commercial airports, and several major passenger and freight rail lines.

Climate variability and extreme events, such as storms and precipitation of increased intensity, will require changing operational responses from transportation providers. While U.S. transportation providers already address the impacts of weather on transportation system operations in a diverse range of climatic conditions, existing planning does not take into account long term changes in climate. Operational changes may include adjusting maintenance (both in the timing and type of maintenance), improved monitoring of conditions (both climatic and infrastructure conditions), incorporating climate scenario modeling into infrastructure planning, modifying procedures for emergency management, and altering construction schedules. In general, operational changes will apply to procedural planning at varying degrees of adjustment. For example, greater use of technology, such as climate scenario modeling, can enable infrastructure providers to monitor climate changes and receive advance warning of potential failures due to changing conditions (such as water levels and currents, wave action, winds, and temperatures) exceeding what the infrastructure was designed to withstand.

While transportation planning efforts do take weather conditions into account in the design of infrastructure, there is less examination of whether current design standards are sufficient to accommodate climate change. For example, the increased summer temperatures and the increased number of very hot days may result in additional highway asphalt rutting. Arizona already uses heat-resistant paving materials, although effects of climate change may magnify or accelerate the need for maintenance. If climate projections indicate that the current number of days exceeding a certain temperature will occur more frequently, the design standards for pavement would need to be updated to consider these changing conditions. Examples of design strategies include development and application of new, heat-resistant paving materials; greater use of heat-tolerant street and highway landscaping; proper design/construction of milling out ruts; and overlay with more rut-resistant asphalt.

STUDY FINDINGS

Major summary findings from the online survey are summarized below:

- **Climate change is affecting ADOT operations.** The majority of people (56 percent of respondents) believe that climate change is affecting ADOT operations, and 50 percent of respondents believe that ADOT should have a role in planning for climate change.
- **ADOT employees address a variety of time horizons in their jobs.** When asked how far into the future respondents look to make their decisions, 36 percent of responses were “short term” (less than one year), 35 percent were “mid term” (one to five years), 23 percent were long term (more than five years), and 6 percent were “Other”.
- **Most of the identified climate impacts are seen as relevant to employees’ job functions.** Respondents could choose from a list of potential climate change impacts,

including heat effects, such as highway asphalt rutting, early snowmelt that could increase the risk of floods, and many others; and indicate whether each of nine impacts was relevant to performing their current job. The climate impacts that received the most "relevant" responses were:
    - Intense Precipitation (79 percent of responses were Relevant),
    - Heat (69 percent of responses were Relevant), and
    - Wildfires (66 percent of responses were Relevant).
- **Respondents had a lot to say about specific climate effects and tools, data, and guidance needs.** Highlights from the climate change effects question include a concern about how particular effects, such as how heat affects humans (road workers, etc.); maintenance-related concerns such as potholes, wildfire, and precipitation effects; and indirect effects, such as financial effects.

In addition to these findings, ADOT staff suggested key areas for future research, listed in Table 1 below, under the categories of updating information, interdisciplinary coordination, and data needs and future planning.

Table 1. Areas for Future Research in Climate Adaptation for ADOT

Topic	Areas for Future Research
Updating Information and Existing Guidelines and Specifications	• Update the National Oceanic and Atmospheric Administration's (NOAA) floodplain map. • Create a guidebook linking climatological events, risk analysis, and economic impact. Suggest a risk-based approach that moves beyond standard formulas. • Create protocols for specific climate events because the current approach is ad hoc response. • Work with the U.S. Army Corps of Engineers to evaluate the design of certain facilities. • Consider ecosystem development guidelines and include the maintenance department's input to figure out the long-term impacts. Include topics such as wildlife connectivity to provide a holistic view.
Interdisciplinary and Interagency Coordination	• Involve partners that are more forward on climate change issues, such as the Maricopa Association and Governments (MAG) and the Pima Association of Governments (PAG), the Arizona State University (ASU) Sustainability Program and Arizona Department of Environmental Quality. • Enable structural engineers and people that focus on drainage to interact. Connectivity, roadside management and landscaping also are key elements that could be improved by better coordination. • Connect with the Federal Emergency Management Agency (FEMA) and bring them into ADOT's work, especially on route planning and emergency response. This could provide access to funding as well. • Start an interdisciplinary forum with regular follow-through that includes the budget office in the discussion.
Data Needs and Future Planning	• Collect information on future climate projections on specific regions to see what happens with temperature and seasonality and precipitation at a very local district level – when do certain impacts take place and what is the magnitude? • Develop scenarios for adaptation. • With new Moving Ahead for Progress in the 21st Century (MAP-21) legislation, there will be performance measures related to the long-range transportation plan (LRTP). Developing performance measures with climate impacts (mitigation or adaptation) to raise awareness and provide linkage to other work within ADOT.

The study identified overarching institutional constraints and impediments to implementing climate adaptation planning that ADOT would have to overcome to further climate adaptation within the agency. By initiating this preliminary study of climate adaptation for the statewide

transportation system in Arizona, there already is an internal interest and momentum at ADOT for climate adaptation planning. Without institutional support, however, it will be difficult to continue forward with the research agenda in a more extensive study.

RECOMMENDATIONS AND NEXT STEPS

The next step for ADOT in considering climate adaptation is to develop a framework, process, and set of goals and objectives for how to consider these issues within the current organizational framework. There also is a role for coordination beyond the internal ADOT agency. For instance, linkages made with Arizona Department of Environmental Quality (ADEQ) and local universities, such as Arizona State University (ASU) and the University of Arizona, as well as regional metropolitan planning organizations (MPOs) and councils of governments (COGs), will be important in moving the dialogue further.

To move beyond a preliminary assessment of climate adaptation, ADOT will have to find ways to bring its lessons learned to the forefront and into the national spotlight. This study reveals that ADOT already experiences extreme heat and dust storms, and thus it will be the first to develop tools and techniques that can be applied to other states and regions that will experience climate impacts that Arizona will face first. The study provides recommendations for ADOT to tap into the national dialogue on climate adaptation, so it will not miss opportunities for peer exchange and potential funding and technical assistance. An upcoming set of Federal Highway Administration (FHWA)-sponsored pilot projects can build on this preliminary study for furthering research and implementation on climate adaptation.

CHAPTER 1. INTRODUCTION

The reality of a changing climate means that transportation and planning agencies need to understand the potential effects of changes in temperature, storm activity, and precipitation patterns on the transportation infrastructure and services they manage. These changes can result in increased heat waves, droughts, storm activity, early snowmelt, and wildfires, among other impacts that could pose new challenges for the Arizona Department of Transportation (ADOT).

PURPOSE

The goal of this study was to establish a path for the ADOT to continue working toward being more resilient, flexible, and responsive to the effects of global climate change. The main objectives of this study included the following:

- Identify key individuals within ADOT with decision making authority relevant in incorporating climate change adaptation in planning, design, and operations;
- Review relevant literature and best practices for climate change adaptation as relevant to the desert southwest;
- Develop a research agenda for ADOT to further understand the impacts of climate change on the agency; and
- Identify key areas for further research on climate change adaptation for ADOT's statewide transportation system beyond the scope of this study.

REPORT OUTLINE

This research report is comprised of the following five main chapters:

- **Chapter 1** covers the purpose of the study, the outline of the report, and the main principal findings.
- **Chapter 2, Literature Review** identifies potential climate change impacts (in the southwest United States, in particular) applicable to the Arizona transportation infrastructure. The results include a matrix and description of potential climate impacts, and how they may affect transportation operations and infrastructure design, as well as planning and project development processes.
- **Chapter 3, Materials, Methods, and Data** presents research to conduct a "knowledge mapping" exercise to help determine the planning, project development, and asset management process flow at ADOT. This exercise is designed to target decision making points that could incorporate information about current weather-related disruptions and/or future climate stressors.
- **Chapter 4, Discussion of Results** summarizes findings from the online survey questionnaire and focus groups conducted to execute the research described in the methodology.
- Finally, **Chapter 5, Research Recommendations** identifies a suite of recommendations related to climate adaptation that ADOT could incorporate into its decision making processes.

The research approach for this study began with the literature review, then used an online survey questionnaire as well as structured interviews and focus groups to refine the knowledge map, and

finally summarized the findings. As discussed in the research approach, the ADOT effort involves four main work tasks, as illustrated in Figure 2, culminating in a set of findings and recommendations for further research or action.

Source: Cambridge Systematics, Inc., 2012.

Figure 2. ADOT Climate Adaptation Study Research Plan

PRINCIPAL FINDINGS

By initiating this preliminary study of climate adaptation for the statewide transportation system in Arizona, there is already an internal interest and momentum at ADOT for climate adaptation planning. Without institutional support, however, it will be difficult to continue forward with the research agenda in a more extensive study.

Starting with the inventory of ADOT's existing projects and research on climate change and environmental sustainability, followed by the online survey and focus group interviews with ADOT staff, the study has identified some overarching institutional constraints and impediments to implementing climate adaptation planning beyond the preliminary assessment. These include the following:

- ADOT does not have an overall set of clear, concise goals for its planning activities related to climate change, risk assessment, or adaptation. This is a nascent field that requires new thinking, new approaches, and interdisciplinary departmental support. This preliminary assessment helps identify gaps and introduces some areas for further research; but without management support, it will be difficult to implement elements of a climate adaptation plan. The proposed development of a department-wide climate adaptation plan framework would remedy this impediment.
- The recent reorganization of ADOT management may have clarified who within the senior management could have responsibility for such an effort; however, it has not been apparent in the analysis of the ADOT organizational structure from the perspective of the

staff or the researchers of this assignment. There are a number of champions at the staff level for this work, but identifying a group of committed individuals at the management level would be critical in moving this agenda forward.

- Because climate adaptation itself is interdisciplinary, it requires the technical and social support of a variety of actors within ADOT and external to the agency. The focus groups identified numerous activities currently involved with climate adaptation, but there is opportunity to expand the breadth of the interest that overlaps with other activity in the agency related to environmental and sustainability issues. This could be remedied with a separate ADOT research project inventorying environmental-related activity in the agency, a so-called "environmental audit."
- State DOTs are suffering from diminishing funding for operations, preservation, and capital expansion because of three adverse trends:
    - Federal and state gas tax rates have been flat or declining since 1996, compared to the costs of construction and operations, which have been rising much faster than inflation;
    - Federal reauthorization for transportation has been stalled, and the proposed Moving Ahead for Progress in the 21st Century (MAP-21) legislation will likely maintain or cut current levels; and
    - Average asset age of ADOT's transportation infrastructure is reaching its threshold for major maintenance and reconstruction.

These trends are likely to exacerbate the present funding scarcity in the coming years with no obvious immediate relief, and thus it is important to seek funding opportunities when they are available. This project suggests working with the numerous efforts that are already initiated in ADOT, which are related to risk assessment, asset management, evaluation, and response and other adaptation responses to extreme weather events. These efforts are well underway and can be leveraged by identifying possible funding partners.

To move beyond a preliminary assessment of climate adaptation, ADOT will have to find ways to bring its lessons learned to the forefront and into the national spotlight. Because ADOT already experiences extreme heat and dust storms, it will be the first to develop tools and techniques that can be applied to other states and regions that will experience climate impacts that Arizona will face first. If ADOT does not tap into the national dialogue on climate adaptation, it will miss opportunities for peer exchange and potential funding and technical assistance. An upcoming set of Federal Highway Administration (FHWA)-sponsored pilot projects can leverage existing staff interest and be an ideal venue to showcase ideas already in development within ADOT.

CHAPTER 2. LITERATURE REVIEW

This review of literature identifies potential climate change impacts (in the Southwest United States, in particular) that would be applicable to the Arizona transportation infrastructure. The review:

- Identifies recently published reports and ongoing projects as well as sources of data that are relevant for Arizona's geography.
- Includes a matrix and description of potential climate impacts and how they may affect transportation operations and infrastructure design, in addition to planning and project development processes.

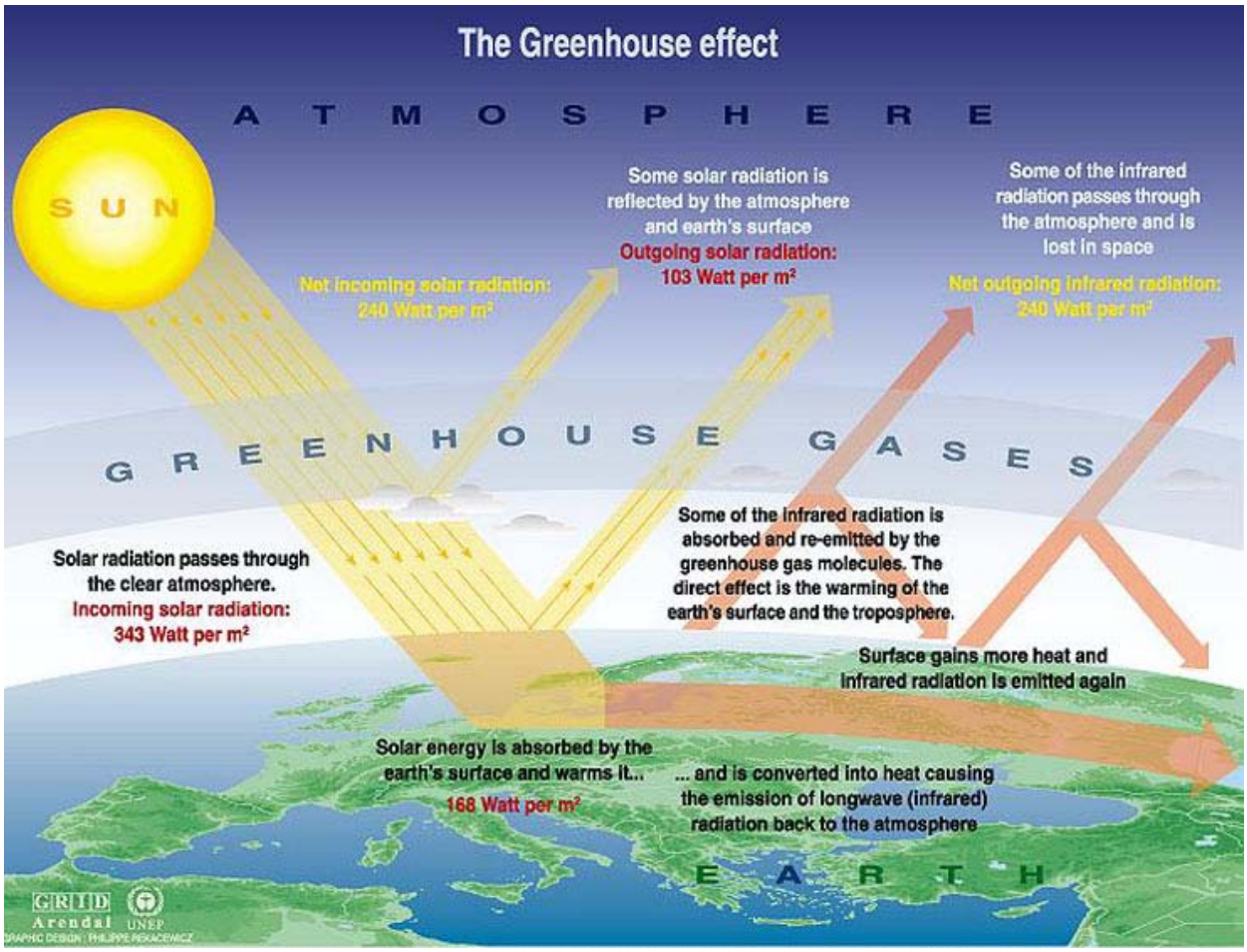
This literature review provides an introduction and background for the project, discusses climate impacts relevant in the Southwest and Arizona, outlines what the latest research suggests could be the climate effects on transportation infrastructure, lists resources and climate change adaptation actions in the transportation sector occurring at the national scale and in Arizona, lists references used in this review, and finally lists other works consulted during this research in the References. Appendix A also provides background on broader literature around climate adaptation, including recent frameworks conducted elsewhere in the United States and internationally.

A BRIEF OVERVIEW OF CLIMATE CHANGE

The "greenhouse effect" is the warming of the earth's surface and lower atmosphere due to the presence of greenhouse gases (GHG), such as carbon dioxide, methane, and water vapor. These GHG let the sun's energy through to the ground, but impede the passage of energy from the earth back into space (Le Treut, 2007).

Most of the energy emitted from the sun, in the form of solar radiation, travels down through the earth's atmosphere and is absorbed by the earth's surface; a small proportion is reflected straight back into space by clouds and by the earth's surface. The absorption of solar radiation causes the earth's surface and lower atmosphere to warm up (see Figure 3).

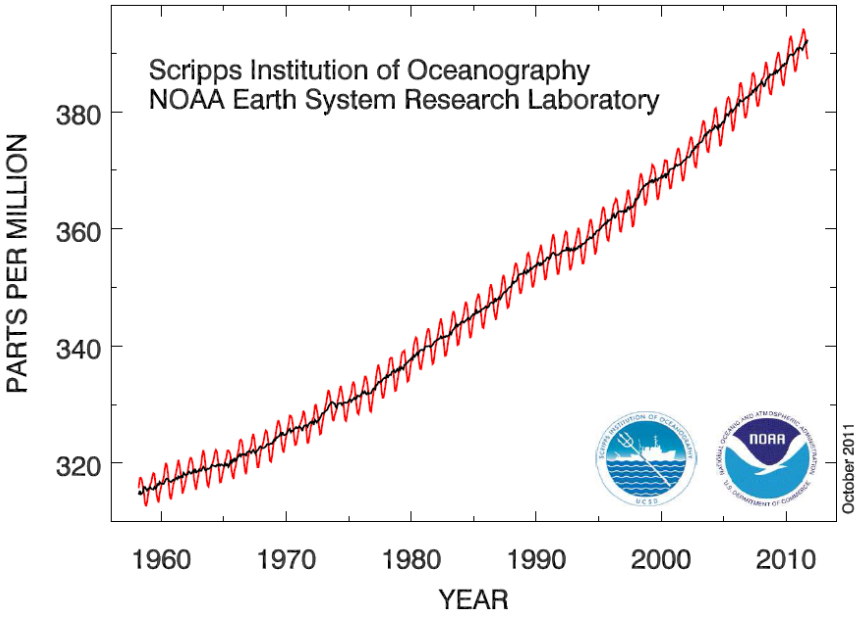
The warmed earth emits infrared radiation, which is absorbed readily by GHG in the atmosphere, such as water vapor, carbon dioxide, and methane. Absorption of infrared radiation causes the atmosphere to warm and emit its own infrared radiation. The earth's surface and lower atmosphere warm until they reach a temperature where the heat radiation emitted back into space, plus the directly reflected solar radiation, balance the absorbed energy coming in from the sun. As a result, the surface temperature of the earth is around 59 degrees Fahrenheit (°F) on average; or approximately 90°F warmer than it would be if there was no atmosphere. This is called the natural greenhouse effect.



Source: International Panel on Climate Change, 2007.

Figure 3. The GHG Effect

If the concentration of GHG is increased, then there will be more absorption of infrared radiation. The earth's surface and the lower atmosphere will warm further until a balance of incoming and outgoing radiation is reached again. This extra warming is called the enhanced greenhouse effect. Figure 4 shows the observed increase in global carbon dioxide concentrations over the past 50 years. Its concentration has been building up in the earth's atmosphere since the beginning of the industrial era in the mid-1700s, primarily due to the burning of fossil fuels (coal, oil, and natural gas) and the clearing of forests. Human activities also have increased the emissions of other GHG, such as methane, nitrous oxide, and halocarbons (Forster et al., 2007).

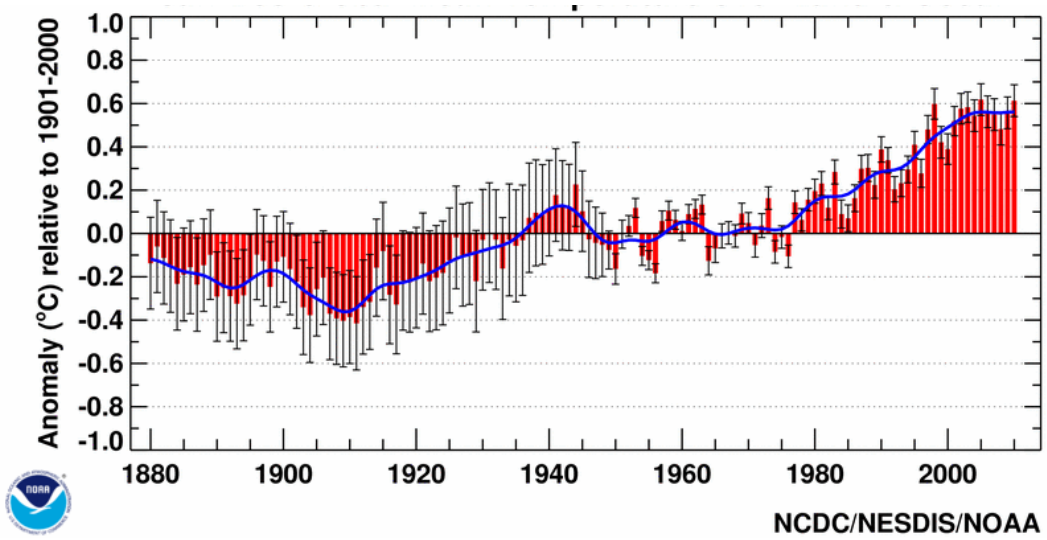


Source: National Oceanic and Atmospheric Administration (NOAA), 2011.

Figure 4. Atmospheric Carbon Dioxide at Mauna Loa Observatory

Figure 5 shows that the observed global mean temperature over land and ocean also has increased over the same time period. The year 2010 tied with 2005 as the warmest year since recordkeeping began in 1880. The annual global combined land and ocean surface temperature was 1.12°F above the 20th century average. The 2010 combined land and ocean surface temperature in the Northern Hemisphere also was the warmest on record, while the combined land and ocean surface temperature in the Southern Hemisphere was the sixth warmest such period on record. Warming trends over the 20th century are documented for nearly all locations that have sufficient data, except the North Atlantic Ocean near Greenland and Iceland, and the southeastern United States.

The magnitude of the enhanced greenhouse effect is influenced by various complex interactions in the earth-ocean-atmosphere system. Many processes and feedback loops must be accounted for in order to realistically project climate changes resulting from particular GHG emission scenarios. These complications are the source of much of the debate that has occurred about the likely magnitude and timing of climate changes due to the enhanced GHG effect. Nevertheless, the scientific community has near-consensus that these global trends tend toward more frequent or severe effects in the future.



Source: NOAA, 2011.

Figure 5. Observed Global Mean Temperature over Land and Ocean

PROJECTED CONSEQUENCES OF CLIMATE CHANGE TO THE SOUTHWEST

Arizona belongs to the Southwest region of the United States, an area stretching from the southern Rocky Mountains to the Pacific Coast. Due to the large variety of landscapes including mountains, plateaus, deserts, and plains, the Southwest is a complex region highly affected by the changing climate.

The effects of climate change in the Southwest already appear to be underway, with the prospect of increased droughts and higher summer temperatures (U.S. Global Change Research Program [USGCRP], 2009). Based on a U.S. Global Change Research Program synthesis, which reviewed a list of key climate-related impacts for the country, several key climate-related impacts are projected to affect the Southwest region including heat waves, early snowmelt, drought, urban heat island effects, degraded air quality, wildfires, and effects on ecosystems and wildlife habitats (USGCRP, 2008; Robles and Enquist, 2010).

Heat Waves

Extreme temperature is usually considered in terms of severity and frequency as well as duration. Because average temperatures are rising, and extreme temperatures are rising even more, the frequency of heat waves and hotter high temperature extremes are growing (Pew, 2011). Longer-lasting heat waves will demand more air conditioning and can overburden electric utilities, increasing the risks of brownouts and blackouts. Brownouts occur when a power company intentionally reduces the voltage for a certain percentage of customers, generally in an emergency situation, causing the lights to dim. A blackout is a power outage or failure in an electricity network (Blume, 2007).

Droughts

Diminished water resources are expected in semiarid regions, because as the overall atmosphere warms, it is able to hold more water, increasing the length of time between rain events and the amount of rainfall in an individual event (Pew, 2011). Water supplies are already scarce in the Southwest, and projected reductions in spring rain and snowfall could reduce the ability to fill reservoirs to meet summed demand (USGCRP, 2009). As of 2009, much of the Southwest remained in a drought that began in 1999, and is only being exacerbated by record warming; the risk for "megadroughts" or decades-long droughts is increasing in probability (UCGCRP, 2009).

Urban Heat Island Effects

Heat islands are areas, typically cities or industrial sites, that have consistently higher temperatures than their surrounding areas, leading to greater retention of heat from buildings, concrete, and asphalt. Major cities in Arizona, including Phoenix, are already urban heat islands; and the magnitude of projected temperature increases only magnifies the many stresses to health, electricity, and water supply in an area that already experiences high summer temperatures (UCGCRP, 2009). Heat islands tend to be significantly warmer than their surrounding rural areas; and although the global land warming trend is unlikely to be influenced by increasing urbanization (IPCC, 2007), the effects of warming can influence the overall temperature of an existing heat island. Thus, these heat island effects will not have global impacts, but will be felt locally.

Early Snowmelt

Mainly because the average temperature is expected to increase, it is estimated that the late winter-spring mountain snowpack will continue to decline in the Southwest, and its snow will melt earlier in the season (CLIMAS, 2012a).

Flash Flooding

Flash flooding is the rapid flooding of low-lying areas often caused by heavy rain in a compressed time scale; flash floods result when precipitation falls on saturated or dry soil with poor absorption ability. Thus, the combination of extreme precipitation combined with increased drought has the potential to create these events. However, the current climate models have a low confidence in projecting changes in flooding events; whether climate change increases the number of flash flooding events is still uncertain (IPCC, 2012).

Degraded Air Quality

Rising temperatures can result in declining air quality in already degraded areas, or create new areas of low air quality, if ozone-producing emissions are maintained (USGCRP, 2009).

Wildfires

It is likely that fires will increase in the Southwest. Record wildfires are driven by rising temperatures and related reductions in spring snowpack and soil moisture (USGCRP, 2009). The 2002 Rodeo-Chedisky fire was the largest Arizona fire in recorded history. That incident created a level of severe burning unprecedented in ponderosa pine forests (Pew, 2007). The combination of fire exclusion and exotic species has made dry woody systems more sensitive to drought conditions, and increased the likelihood of greater fire intensity and spread in the future (Pew, 2007). Climate-fire dynamics also will alter iconic landscapes like the Sonoran Desert, as succulents are replaced by red brome and buffle grass (UCGCRP, 2009).

Wildlife Habitats

Climate change will likely exacerbate the current rate of habitat loss in Arizona. At a minimum, it will lead to the changes in composition and structure of ecosystems, loss or fragmentation of habitat, and the alteration of hydrology. Researchers have agreed that warming is already occurring across many habitats and watersheds in the Southwest, and species and ecological effects associated with this warming are already apparent (Robles and Enquist, 2011). In a study commissioned by the Southwest Climate Change Initiative, researchers found that 90 percent of habitats in the Southwest have warmed significantly in the past 55 years, and very likely contributed to ecological changes in 40 percent of southwestern habitats. This resulted in changes in the timing of species events, widespread insect infestations and forest tree mortality. Habitats having the highest temperature change and the most species of conservation concern include subalpine forests, piñon-juniper woodlands, sage shrublands, and Colorado Plateau canyonlands and grasslands. These habitats include at least 119 plant and animal species affected by climate change (Robles and Enquist, 2011).

CLIMATE CHANGE IMPACTS ON TRANSPORTATION INFRASTRUCTURE

Arizona has an extensive and expansive transportation infrastructure system, including more than 6,000 miles of roads and highways, nearly a dozen commercial airports, and several major passenger and freight rail lines. This infrastructure could be vulnerable to such impacts as those outlined in Arizona's Executive Order 2005-02, including prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, and reduced snowpack.

The reality of a changing climate means that transportation and planning agencies must understand the potential effects of climate change.

The significant uncertainties inherent in projecting long-term changes to climate, coupled with the long service life of most ADOT infrastructure and assets, present a complex challenge for the agency's decision makers. Approaching these choices using a climate vulnerability and risk framework will enable ADOT to consider multiple dimensions of risk when directing investments, ensuring the long-term resiliency of infrastructure and assets, as well as the crucial operations they support.

In 2008, the Transportation Research Board (TRB) published Special Report 290, *Potential Impacts of Climate Change on U.S. Transportation* (National Research Council [NRC], 2008). In this report, adaptation to climate change within the transportation sector falls into three categories of actions: 1) operational changes, 2) design changes, and 3) other actions.

Climate variability and extreme events, such as storms and precipitation of increased intensity, will require changing operational responses from transportation providers. While U.S. transportation providers already address the impacts of weather on transportation system operations in a diverse range of climatic conditions, existing planning does not take into account long-term changes in climate. Operational changes may include adjusting maintenance (both in the timing and type of maintenance), improved monitoring of conditions (both climatic and infrastructure conditions), incorporating climate scenario modeling into infrastructure planning, modifying procedures for emergency management, and altering construction schedules. In general, operational changes will apply to procedural planning at varying degrees of adjustment. For example, greater use of technology, such as climate scenario modeling, can enable infrastructure providers to monitor climate changes and receive advance warning of potential failures due to changing conditions (such as water levels and currents, wave action, winds, and temperatures), exceeding what the infrastructure was designed to withstand.

While transportation planning efforts do take weather conditions into account in the design of infrastructure, there is less examination of whether current design standards are sufficient to accommodate climate change. For example, the increased summer temperatures and the increased number of very hot days may result in additional highway asphalt rutting. Arizona already uses heat-resistant paving materials, although effects of climate change may magnify or accelerate the need for maintenance. If climate projects indicate that the current number of days exceeding a certain temperature will occur more frequently, the design standards for pavement would need to be updated to consider these changing conditions. Examples of design strategies include development and application of new, heat-resistant paving materials; greater use of heat-tolerant street and highway landscaping; proper design/construction of milling out ruts; and overlay with more rut-resistant asphalt.

In addition to operational and design changes, other types of adaptation options are available for transportation infrastructure. Transportation planning and land use controls, especially concerning new construction and development, can integrate projected climate changes into the planning process. For example, development can be restricted or prohibited in zones most at risk from storm surges, flooding, and wildfire events. In addition, culverts could be revisited or expanded to deal with increased extreme precipitation events. From the policy side, long-range planning and promoting cross-agency collaboration are two examples of other potential adaptation actions for transportation planning.

SUMMARY OF CLIMATE IMPACTS RELEVANT FOR ARIZONA'S TRANSPORTATION INFRASTRUCTURE

The Federal Highway Administration (FHWA) produced a summary of studies investigating adaptation options for transportation infrastructure, organized by climate impact. Table 2 adapts this summary of studies with a focus on climate impacts relevant for Arizona's geography.

Table 2. Projected Climate Impacts on Arizona's Infrastructure

Climate Impact	Potential Infrastructure Impact	Operational Responses	Design Strategies	Other
Increased summer temperatures, increases in very hot days and heat waves	Highway asphalt rutting, possible movement of liquid asphalt (NRC, 2008).	More maintenance (CCSP, 2008)	Development of new, heat-resistant paving materials	
			Greater use of heat-tolerant street and highway landscaping (NRC, 2008)	
			Proper design/construction, milling out ruts	
			Overlay with more rut-resistant asphalt (CCSP, 2008)	
	Thermal expansion of bridges (NRC, 2008).	Increased ongoing maintenance (CCSP, 2008)	Ensure that bridge joints can accommodate anticipated thermal expansion	
			Designing for higher maximum temperatures in replacement or new construction (NRC, 2008)	
	Limitation on construction periods during summer (NRC, 2008).	Shifting construction schedules to cooler parts of day (NRC, 2008)		
Increased precipitation	Flooding of roads (frequency and magnitude are estimated to increase).	Ensure bridge openings/ culverts sufficient to deal with flooding	Protection of critical evacuation routes	Seek alternative routes
		Improve drainage	Upgrading of road drainage systems	Improve flood protection
		Improved asphalt/concrete mixtures	Increases in culvert capacity	Risk assessment for new roads
		Perform adequate maintenance	Increases in pumping capacity for tunnels	Emergency contingency planning (CCSP, 2008)
		Minimize repair backlogs (CCSP, 2008)	Increases in the standard for drainage capacity for new transportation infrastructure and major rehabilitation projects (NRC, 2008)	Greater use of sensors for monitoring water flows
		Increases in real-time monitoring of flood levels		Restriction of development in floodplains (NRC, 2008)

Table 2. Projected Climate Impacts on Arizona's Infrastructure (Continued)

Climate Impact	Potential Infrastructure Impact	Operational Responses	Design Strategies	Other
		Integration of emergency evacuation procedures into operations (NRC, 2008)		
Increases in intense precipitation events	Increases in weather-related delays and traffic disruptions (NRC, 2008).			
	Increases in flooding of roadways; increases in road washout, landslides, and mudslides that damage roadways, increased bridge scour in the short term, compromised integrity of roads and bridges due to increased soil moisture (Department for Transport, 2004; NRC, 2008; CCSP, 2008).	Expansion of monitoring systems of bridge scour, land slopes, and drainage systems (NRC, 2008)	Upgrading of road drainage systems (NRC, 2008)	
			Increases in the standard for drainage capacity for new structures (CCSP, 2009)	
			Pavement grooving and sloping	
			Greater use of sensors for monitoring water flows (CCSP, 2008)	
Changes in seasonal precipitation and river flow patterns	Potential benefit if frozen precipitation shifts to rainfall (NRC, 2008).			
	Increased risk of floods, landslides, and damage to roads (areas where precipitation changes from snow to rain in winter and spring thaws) (NRC, 2008).		Conduct risk assessments for all new roads (Department for Transport, 2004)	
			Encourage cooperation among drainage authorities (CSIRO, 2007)	
			Improved essential services planning (NRC, 2008)	
	Increased variation in wet/dry spells and decrease in available moisture may cause degradation of road foundations (CSIRO, 2007).			
Decline of late-season snowpack (CLIMAS, 2012b)	Indirect impacts expected; general implications include reduced streamflow and water supplies. This could result in increased wildfires (Guido, 2008).	Integration of emergency evacuation procedures into operations (NRC, 2008)		
Increases in drought conditions	Increased risk of mudslides in areas deforested by wildfires (NRC, 2008).	Vegetation management (NRC, 2008)		

Source: Adapted from the FHWA document *Literature Review: Climate Change Vulnerability Assessment, Risk Assessment, and Adaptation Approaches*, 2009.

POTENTIAL ADOT DEPARTMENTAL RESPONSIBILITY FOR CONDUCTING A STUDY OF CLIMATE ADAPTATION FOR ARIZONA

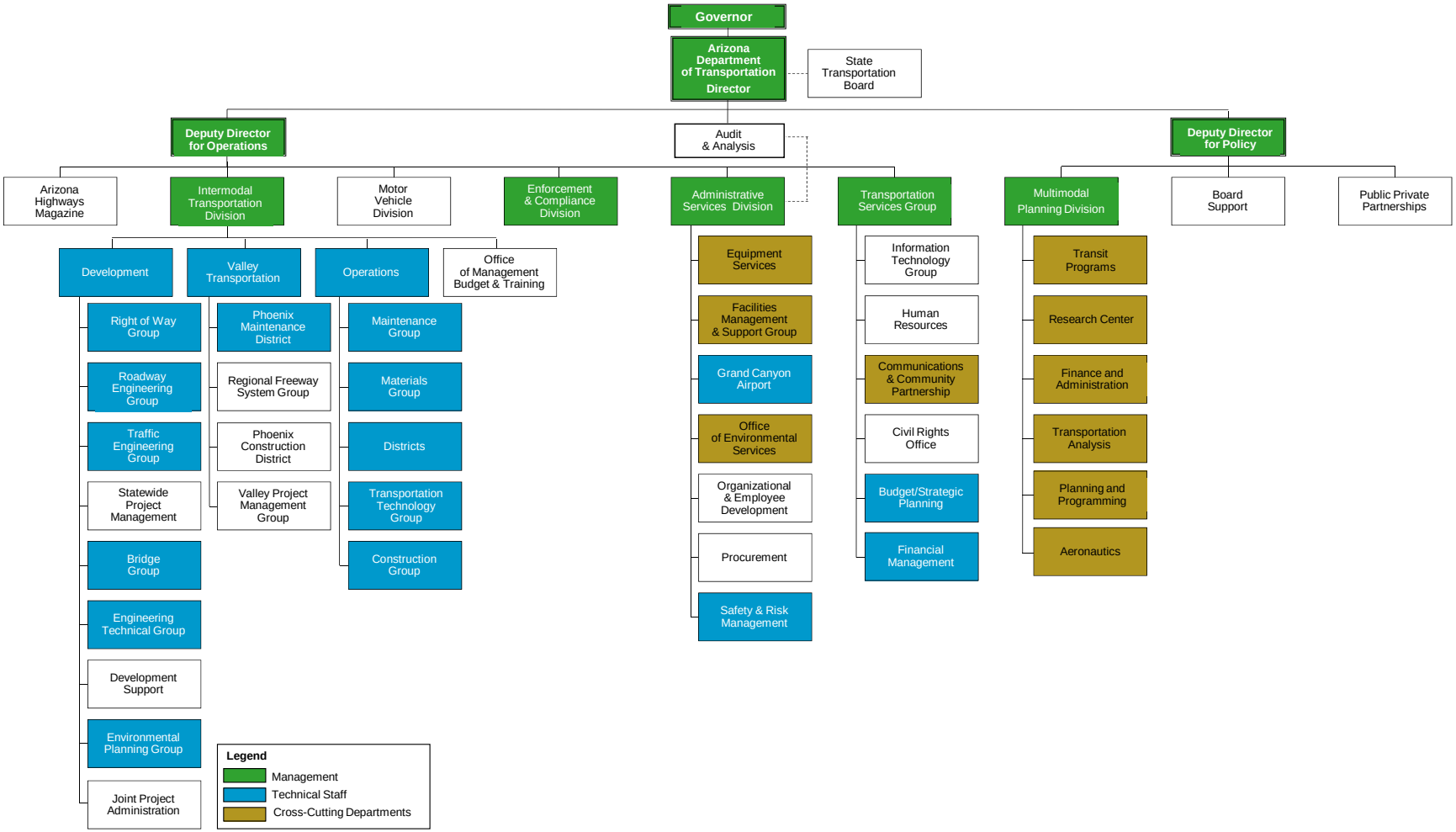
Because climate change adaptation is an interdisciplinary responsibility, many individuals and departments within ADOT would be identified for carrying out plans, risk assessments, and adaptation actions.

This section provides a preliminary list of stakeholders within ADOT, who might be involved in performing planning assessment, changing operational or design practices, or providing monitoring and feedback in responses to climate impacts. This list may be modified based on input from ADOT and from the findings of further research on this subject.

Figure 6 suggests ADOT internal departments that would likely be involved if undertaking a preliminary study of climate adaptation for the statewide transportation system in Arizona. The shaded boxes in three colors indicate internal departments that would be involved in addressing climate adaptation, which fall into three main categories/roles of responsibility:

1. **Management staff.** Shaded in *Green,* individuals in these departments support the overall effort for inclusion of climate adaptation within the departments' business practices, providing opportunities for cross-departmental work and planning for a potential change in practice or new opportunity to integrate climate adaptation in the department.
2. **Technical staff.** Shaded in *Blue,* individuals in these departments may have direct planning, operations, or design responsibilities that would consider climate adaptation in their practices. These departments would have a direct role in responding to climate impacts listed in Table 3.
3. **Cross-cutting departments.** Shaded in *Gold,* individuals in these departments would likely work across disciplines providing data or input to management and technical staff. For example, when addressing the issue of roadway flooding, the Systems and Regional Planning Department, housed in the Multimodal Planning Division, would work with the Bridge, Environmental Planning, and Roadway Engineering Groups, housed in the Intermodal Transportation Division, in order to figure out how any changes to bridges and culverts in particular locations might affect evacuation route planning. Also, the Data Management and Analysis Department would provide maps and survey data for a variety of climate impacts for various departments within ADOT.

Table 3 assigns preliminary ADOT departmental responsibility for responses to the potential Arizona-specific climate impacts summarized in Table 2. The ADOT departments listed in Table 3 are color-coded to correspond with the three main categories or roles of responsibility listed above and included in Figure 6.



Source: Arizona Department of Transportation, recreated by Cambridge Systematics, Inc., 2012. Note: This chart/table was developed in August 2012. Changes in position titles and relationships will be needed with subsequent management and organizational changes

Figure 6. ADOT Organizational Chart (with Shaded Colors Suggesting Involvement in a Preliminary Climate Adaptation Study).

Table 3. Matrix of Climate Impacts, Responses, and Potential ADOT Departmental Responsibility

Potential Infrastructure Impact	Responses (Operational, Design-Related, or Other)	ADOT Technical Staff Responsibility	ADOT Cross-Cutting Department Responsibility	ADOT Management Responsibility
Increased costs to all ADOT operations	• Long-range planning strategies to fund adaptation strategies • Changes in guidelines, codes, and manuals	TSG – Budget/Strategic Planning TSG – Financial Management ITD – Development ITD – Operations ITD – Districts	MPD – Planning and Programming MPD – Finance and Administration	Governor, ADOT Director, Deputy Director for Operations, Deputy Director for Policy, Intermodal Transportation Division (ITD), Enforcement & Compliance Division (ECD), Administrative Services Division (ASD), Transportation Services Group (TSG), Multimodal Planning Division (MPD)
Highway asphalt rutting, possible movement of liquid asphalt (NRC, 2008)	• Perform more maintenance (CCSP, 2008)	ITD – Maintenance Group	MPD – Planning and Programming, Transportation Analysis Research Center ASD – Office of Environmental Services, Facilities Management & Support Group	Deputy Director for Operations Deputy Director for Policy ITD ASD MPD
	• Develop new, heat-resistant paving materials	ITD – Materials Group		
	• Increase use of heat-tolerant street and highway landscaping (NRC, 2008)	ITD – Environmental Planning Group		
	• Implement proper design/construction, mill out ruts	ITD – Roadway Engineering Group		
	• Overlay with more rut-resistant asphalt (CCSP, 2008)	ITD – Materials Group		
Thermal expansion of bridges (NRC, 2008)	• Increase ongoing maintenance (CCSP, 2008)	ITD – Maintenance Group	MPD – Planning and Programming, Transportation Analysis; Research Center	Deputy Director for Operations Deputy Director for Policy ITD MPD
	• Ensure that bridge joints can accommodate anticipated thermal expansion	ITD – Bridge Group		
	• Design for higher maximum temperatures in replacement or new construction (NRC, 2008)	ITD – Construction Group		
Limitation on construction periods during summer (NRC, 2008)	• Shift construction schedules to cooler parts of day (NRC, 2008)	ITD – Districts ASD – Safety & Risk Management	ASD – Office of Environmental Services	ITD ASD
Flooding of roads (frequency and magnitude will increase)	• Ensure bridge openings/culverts sufficient to deal with flooding	ITD – Bridge Group, Operations, Engineering Technical Group, Environmental Planning Group	MPD – Transit Programs, Research Center, Finance & Administration, Transportation Analysis, Planning and Programming, Aeronautics TSG – Communications & Community Partnership	Deputy Director for Operations Deputy Director for Policy ITD ASD TSG MPD
	• Protect critical evacuation routes	ITD – Maintenance [Emergency Preparedness Team]		
	• Seek alternative routes	ITD – Maintenance [Emergency Preparedness Team]		

Table 3. Matrix of Climate Impacts, Responses, and Potential ADOT Departmental Responsibility (continued)

Potential Infrastructure Impact	Responses (Operational, Design-Related, or Other)	ADOT Technical Staff Responsibility	ADOT Cross-Cutting Department Responsibility	ADOT Management Responsibility
	• Improve drainage	ITD – Roadway Engineering Group		
	• Upgrade road drainage systems	ITD – Roadway Engineering Group		
	• Improve flood protection	ITD – Environmental Planning Group		
	• Improve asphalt/concrete mixtures	ITD – Engineering Technical Group, Materials Group		
	• Increase culvert capacity	ITD – Roadway Engineering Group		
	• Conduct risk assessment for new roads	ASD – Safety & Risk Management		
	• Perform adequate maintenance	ITD – Maintenance, Roadway Engineering Group, Environmental Planning Group		
	• Increase pumping capacity for tunnels	ITD – Roadway Engineering Group		
	• Conduct emergency contingency planning (CCSP, 2008)	ITD – Maintenance (Emergency Preparedness Team)		
	• Minimize repair backlogs (CCSP, 2008)	ITD – Maintenance Group		
	• Increase the standard for drainage capacity for new transportation infrastructure and major rehabilitation projects (NRC, 2008)	ITD – Roadway Engineering Group		
	• Increase use of sensors for monitoring water flows	ITD – Roadway Engineering Group, Environmental Planning Group		
	• Conduct more real-time monitoring of flood levels	ITD – Environmental Planning Group		
	• Restrict development in floodplains (NRC, 2008)	ITD – Environmental Planning Group		
	• Integrate emergency evacuation procedures into operations (NRC, 2008)	ITD – Maintenance (Emergency Preparedness Team)		
Increases in weather-related delays and traffic disruptions (NRC, 2008)	• Maintain effective traffic operations and communications systems	ITD – Operations, Transportation Technology Group, Valley Transportation, Phoenix Maintenance District, Districts ASG – Grand Canyon Airport		ITD

Table 3. Matrix of Climate Impacts, Responses, and Potential ADOT Departmental Responsibility (continued)

Potential Infrastructure Impact	Responses (Operational, Design-Related, or Other)	ADOT Technical Staff Responsibility	ADOT Cross-Cutting Department Responsibility	ADOT Management Responsibility
Increases in flooding of roadways; increases in road washout, landslides, and mudslides that damage roadways, increased bridge scour in the short term, compromised integrity of roads and bridges due to increased soil moisture (Department for Transport, 2004; NRC, 2008; CCSP, 2008)	• Expand monitoring systems of bridge scour, land slopes, and drainage systems (NRC, 2008)	ITD – Engineering Technical Group, Roadway Engineering Group	MPD – Transportation Analysis, Planning and Programming	Deputy Director for Operations ITD
	• Upgrade road drainage systems (NRC, 2008)	ITD – Roadway Engineering Group		
	• Increase the standard for drainage capacity for new structures (CCSP, 2009)	ITD – Roadway Engineering Group		
	• Implement pavement grooving and sloping	ITD – Materials Group		
	• Increase use of sensors for monitoring water flows (CCSP, 2008)	ITD – Roadway Engineering Group, Environmental Planning Group		
Increased risk of floods, landslides, and damage to roads (areas where precipitation changes from snow to rain in winter and spring thaws) (NRC, 2008)	• Conduct risk assessments for all new roads (Department for Transport, 2004)	ITD – Operations	MPD – Transportation Analysis, Planning and Programming TSG – Communications and Community Partnership	ITD ASD TSG
	• Improve essential services planning (NRC, 2008)	ITD – Maintenance [Emergency Preparedness Team]		
	• Encourage cooperation among drainage authorities (CSIRO, 2007)			
Increased variation in wet/dry spells and decrease in available moisture may cause degradation of road foundations (CSIRO, 2007)	• Perform adequate maintenance	ITD – Maintenance Group		ITD
Increased risk of mudslides in areas deforested by wildfires (NRC, 2008)	• Monitor high-risk areas	ITD – Environmental Planning	ITD – Office of Environmental Services MPD – Planning and Programming, Transportation Analysis	Deputy Director for Operations ITD TSG
	• Conduct emergency contingency planning (CCSP, 2008)	ITD – Maintenance [Emergency Preparedness Team]		

Note: This chart/table was developed in August 2012. Changes in position titles and relationships will be needed with subsequent management and organizational changes

Table 3. Matrix of Climate Impacts, Responses, and Potential ADOT Departmental Responsibility (continued)

Potential Infrastructure Impact	Responses (Operational, Design-Related, or Other)	ADOT Technical Staff Responsibility	ADOT Cross-Cutting Department Responsibility	ADOT Management Responsibility
Increased risk of unanticipated plant and wildlife migrations on transportation system, change in ecosystem habitats for protected species	• Work with natural resource agencies to develop strategies and monitor habitat loss and ecosystem change	ITD – Environmental Planning, Right-of-way Group, Roadway Engineering Group ASG – Safety and Risk Management	MPD – Planning and Programming, Research Center, Transportation Analysis ITD – Office of Environmental Services TSG – Communications and Community Partnership	Deputy Director for Operations Deputy Director for Policy ITD MPD TSG
	• Apply riparian management techniques and stream management to sustain flows and moderate effects of warming air and stream temperatures (Robles and Enquist, 2011)	ITD – Environmental Planning		
	• Monitor plant and wildlife migration on ADOT assets, review road kill and crash data, design for supportive wildlife crossing areas	ITD – Environmental Planning, Roadway Engineering Group		

Source: FHWA (2009) and Arizona Department of Transportation, recreated by Cambridge Systematics (2012), from Working Paper 1 of this study.
Note: This chart/table was developed in August 2012. Changes in position titles and relationships will be needed with subsequent management and organizational changes

ARIZONA-SPECIFIC ADAPTATION EFFORTS

Because climate change impacts differ by geographic region, research that focuses on the desert Southwest and Arizona is especially important to this project and ADOT. Relevant research centers and efforts are summarized below by organization.

Arizona State University's Global Institute of Sustainability and Decision Theater (WaterSim)

The Decision Theater, a research facility with a focus on collaborative decision making, is housed in Arizona State University's (ASU) Global Institute of Sustainability. The facility's objective is to provide a laboratory equipped with state-of-the-art tools to provide support for decision makers faced with difficult challenges. Decision Theater focuses on addressing complex issues that are often accompanied by complex and disparate data sets. The research facility highlights its "immersive" 3-D environment, which includes numerous modeling, visualization, and simulation tools. Decision Theater incorporates tools from many fields, including academia, consulting, and policy analysis. The facility's staff members come from many disciplines, including geology, biophysics, public policy, and engineering, among others (ASU, "Decision Theater," 2012).

One relevant project is called WaterSim, a model created by ASU's Decision Theater that addresses the problem of water resources management, a critical topic for the State of Arizona due to the projected increase in drought conditions and decrease in water supply. WaterSim currently contains data for Central Arizona and has four main objectives:

1. Understand how to manage water supply and demand in urban areas;
2. Assess different water management policies;
3. Understand the effect of climate change and growth scenarios on a region's water system and water management policies; and
4. Understand how to make decisions related to complex problems around which there is much uncertainty.

Currently, WaterSim may be used by researchers, water policy managers, and the general public. The tool is available in three ways: 1) in Decision Theater, 2) on the Internet, and 3) via a public domain model programming interface called WaterSim API Version 5.0 (ASU, "WaterSim," 2012).

Southwest Climate Change Network

The Southwest Climate Change Network is a web-based network created to encourage dialogue and information sharing related to climate change in the Southwest among many groups, including scientists, natural resource managers, policy-makers, community groups, the public, and the media. The network's ultimate goal is to understand climate change in the region in order to best respond and adapt to it. The network is administered by the Institute of the Environment and the Climate Assessment for the Southwest (CLIMAS) at the University of Arizona. Content includes a blog that serves as a forum through which network users may share information, ask climate change-related questions, and post feedback to other posts. Users also may ask questions or provide feedback using the website's "Contact Us" feature. Additionally, the Southwest

Climate Change Network contains a news feed from selected, credible sources; explanation of various climate change concepts and impacts; and resources such as guides and manuals aimed at helping governments, businesses, and community leaders address climate change adaptation. The web-based network also includes a searchable database of scientific articles about climate change, as well as a regularly updated "featured articles" section (Southwest Climate Change Network, 2012).

CLIMAS (Climate Assessment for the Southwest)

The CLIMAS program, established in 1988, is housed at the University of Arizona's Institute for the Environment. Its mission is to equip the region to respond to climate change impacts. The main activities include research on both the causes and consequences of climate change and variability in the Southwest region of the United States. CLIMAS takes a collaborative approach to research, and encourages information sharing between various stakeholders, such as the academic community, the private sector, the nonprofit sector, and the general public. In August 2007, the program began its third phase, which focuses on climate and water systems and learning about the risk, resilience, variability, and change within those systems, as well as supporting decision making processes and facilitating partnerships and the exchange of knowledge.

CLIMAS recently released a report entitled *Southwest Climate Assessment Summary for Decision Makers* (October 2012) with a full report, *Assessment of Climate Change in the Southwest United States: A Technical Report Prepared for the U.S. National Climate Assessment* to follow shortly thereafter. This document, developed by a consortium of research institutes, is a comprehensive report focusing on climate change impacts and adaptation strategies in Arizona and New Mexico and the connection between people, the environment, and climate change. One chapter is dedicated to transportation. This report will eventually be incorporated into the National Climate Assessment report, which is scheduled to be published in 2013.

OTHER CLIMATE CHANGE EFFORTS IN ARIZONA

Arizona has been active in climate change research and other efforts for a number of years. The following summaries highlight a few of the State's critical documents and milestones.

Governor Brewer's Executive Order (2010)

Executive Order 2010-06, also known as the "Governor's Policy on Climate Change," was signed by Arizona Governor Janice Brewer in December 2010. The order highlights the increase in GHG emissions projected for the State; and acknowledges the State's efforts to address emissions, including its graduated renewable energy requirement for electric utilities. The order states that, while Arizona will remain part of the Arizona-Sonora Regional Climate Change Initiative, The Climate Registry, and the Western Climate Initiative (WCI), Arizona will not implement the GHG cap-and-trade proposal that the WCI has moved forward. This decision relates to the concern that a cap-and-trade system would place the State at a disadvantage relative to other states, because of the costs the system would impose on its economy. Additionally, the order calls for the establishment of the Climate Change Oversight Group to monitor the WCI's

work, as well as federal legislation and executive orders. The order also calls for the State to comply with the requirements set forth by ADOT with regard to purchasing state vehicles. All vehicles must either be hybrids, use fuels that produce low levels of GHG emissions, or use alternative fuels. The ultimate goal was that, by January 2012, all state vehicles achieve the standards outlined above. In February 2010, Governor Brewer pulled Arizona out of the WCI's cap-and-trade program; and in 2012, she withdrew her State from California's Advanced Clean Car Program, making it unlikely that state vehicles would achieve the hybrid and/or alternative fuel standards.

Arizona's Climate Change Action Plan (2006)

As part of its charge per Executive Order 2005-02, the Arizona Climate Change Advisory Group (CCAG) created the State's Climate Change Action Plan in 2006. The plan's main objective was to provide recommendations for reducing the State's GHG emissions in various sectors. The policies, included in the Transportation and Land Use chapter of the plan, are especially relevant for ADOT. Fourteen policies for both the light-duty and freight sectors were presented in the plan, including some regulatory policies (such as alternative fuels standards and a 60 mph speed limit for commercial trucks), as well as many incentive-based policies (such as hybrid promotion and the promotion of multimodal transit) and technology-based policies (such as the reduction of idling through truck stop electrification and other tools). Results from implementing the policies were quantified, and a cumulative savings of 91 million metric tons carbon dioxide equivalent (CO_2e) was projected between 2007 and 2020. This chapter also projects that implementation of these policies would result in a net savings to Arizona's economy.

ADOT Participation in the American Association of State Highway and Transportation Officials (AASHTO) Regional Climate Change Workshop (2011)

In April 2011, ADOT shared its experience with climate change adaptation in an AASHTO climate change workshop. Topics included scientific information and general trends with regard to GHG emissions and transportation. The presentation highlighted Arizona's experience in creating its Climate Change Action Plan and recommended policies for state DOTs to consider such as adopting GHG-reduction targets and implementing strategies that will be most effective in reducing GHG emissions. This event provided an important opportunity for collaboration and information sharing among state DOTs.

ADOT Participation in North America 2050 (2012)

North America 2050, created in March 2012, is a partnership among numerous states in the United States, as well as Canadian provinces. The organization's goal is to facilitate the development and implementation of cost-effective policies that will help its members achieve a "low-carbon economy," foster job creation and energy independence, and protect public health and the environment. Currently, there are 20 members. Mexican states are also welcome. North America 2050 focuses on its goals through member participation in the following Working Groups: Benefits, Power Sector, Industry 2050, Sequestration, Sustainable Biomass, and Offsets. Members belong only to the Working Groups relevant to the challenges they face. Participating

states may invite experts from the private sector, academic institutions, and non-governmental organizations (NGOs) to participate in the Working Groups.

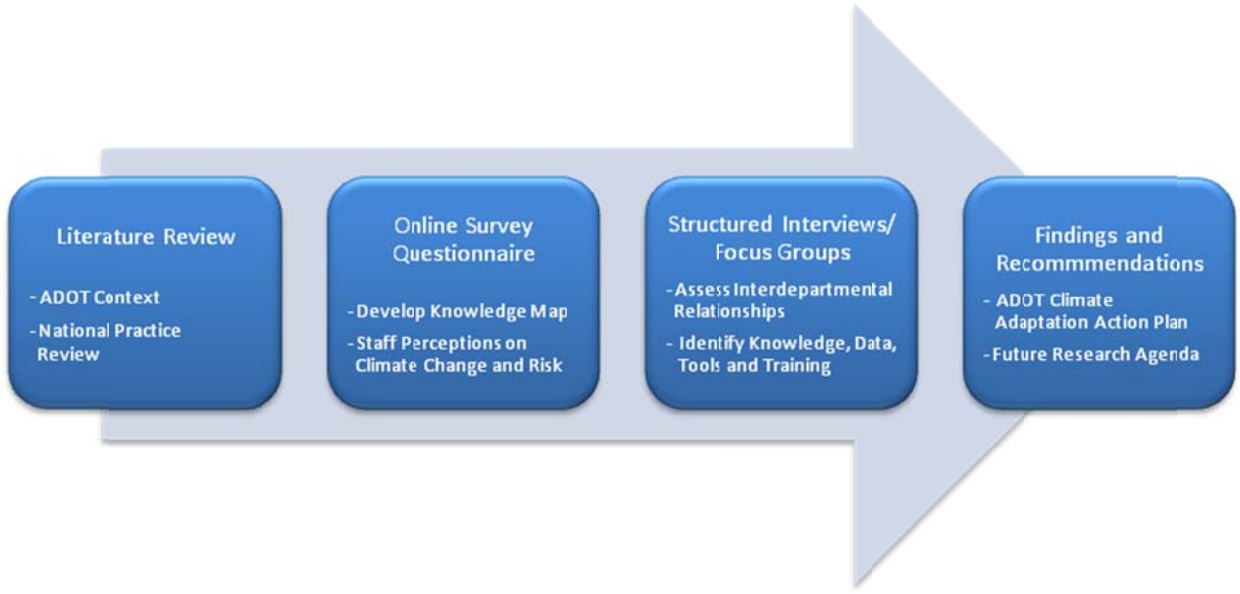
CHAPTER 3. MATERIALS, METHODS, AND DATA

As part of the overall goal to help ADOT become more resilient with respect to climate change, the first preliminary assessment step is to conduct a "knowledge mapping" exercise to help determine the planning, project development, and asset management process flow at ADOT. This exercise could begin to zero in on decision-making points that could (or currently) incorporate information about current weather-related disruptions and/or future climate stressors.

RESEARCH APPROACH

The research approach for this study began with the literature review, used an online survey questionnaire, structured interviews and focus groups to refine the knowledge map, then summarized the findings.

The ADOT climate adaptation research plan effort involved four main work tasks, as illustrated in Figure 7. These steps culminated in a set of findings and recommendations for further research or action, which are included in the Chapter 4, *Discussion of Findings*; and Chapter 5, *Research Recommendations*.



Source: Cambridge Systematics, Inc., 2012.

Figure 7. ADOT Climate Adaptation Study Research Plan

The purpose of conducting the online survey questionnaire was to achieve the following:

- Refine the "Knowledge Map" by identifying key ADOT staff with decision-making authority and the ability to incorporate climate change adaptation into planning, design, and operations in their precise job functions.
- Gauge staff perceptions about how certain climate scenarios would impact ADOT's facilities and processes.

The purpose of the focus groups was to provide more insight into the institutional context for adaptation planning at ADOT, and to achieve the following outcomes:

- Identify ADOT's relevant guidelines and specifications where climate impacts may modify design or operational thresholds.
- Map out relationships between departments specific to investment decision making and functions where collaboration is sufficient, as well as where it could be improved.
- Brainstorm existing and potential tools, data, guidance, or other resources related to extreme weather or climate change that individuals wished they had to help inform decision-making activities.

ONLINE SURVEY QUESTIONNAIRE

An eight-question survey focused on climate change adaptation was developed by the project team after receiving input from members of the Technical Advisory Committee (TAC) regarding clarity and content. The survey was sent to hundreds of ADOT staff members by the ADOT Research Center on August 16, 2012.

More than 250 people responded to the survey, which covered the following topics:

- **Introduction** provides background on this research project, as well as some basic information and web links about climate change adaptation.
- **Climate Change Adaptation Background** inquires about the respondents' exposure to the climate change issue, and whether or not it affects job responsibilities.
- **Future** inquires about the time horizon respondents address in their job functions (e.g., short term, mid term, long term).
- **Climate Change Effects** provides respondents with a detailed list of climate change effects related to transportation (e.g., asphalt rutting, increased risk of floods, wildfires); and asks them whether or not these effects are relevant to their job functions.
- **Department Information** seeks to identify existing policies within respondents' departments related to extreme weather events.
- **Tools** asks respondents what tools, data, or other guidance related to extreme weather and climate effects they would like to help with decision making processes.
- **Next Steps** inquires about respondents' interest in participating in a focus group.

The online survey instrument is included in Appendix B with results of the survey in Appendix C.

FOCUS GROUPS

After the completion of the online survey, more than 70 survey respondents replied that they would be willing to participate in an interview or focus group regarding their job function, and how their job might be affected from specific climate impacts.

Cambridge Systematics and the TAC reviewed this list and developed a short list of interviewees for this part of the research. Specifically, interviewees were identified based on their interest and insights from their survey responses. Due to the scope and timeframe of the project, the primary research and data collection includes only information from in-person interviews and focus

groups in Phoenix at the ADOT headquarters. However, staff located in regional offices and outside of headquarters also provided e-mail feedback.

The initial plan was to conduct four focus groups on the first day centered on ADOT responses to specific climate impacts, and four focus groups on the second day centered on ADOT processes for managing climate adaptation. Based on availability and interest of ADOT staff, five focus groups were conducted over a two-day period from September 24 to 25, 2012, as shown in Table 4.

Table 4. List and Themes for Climate Adaptation Focus Groups

Date	Time	Workshop
Sept 24, 2012	8:30 a.m.-10:00 a.m.	1A: Climate Impact Focus on Heat, Droughts, and Heat Island Effects
Sept 24, 2012	10:30 a.m.-12:00 p.m.	1B: Climate Impact Focus on Intense Precipitation, Snowmelt, Late-Season Snowpack, Wildfires, Air Quality, and Wildlife Habitat Loss
Sept 24, 2012	3:30 p.m.-5:00 p.m.	1D: Process Organization and Communication – Where in the Organization Can We Think about Climate Adaptation and How Do We Communicate it?
Sept 25, 2012	8:30 a.m.-10:00 a.m.	2A: Asset Inventories, Vulnerability and Risk Assessments, and Prioritization and Funding of Adaptation Projects
Sept 25, 2012	1:30 p.m.-3:00 p.m.	2C: Response Planning for Adaptation – including Planning, Design Engineering, Operations-Maintenance Strategies

Cambridge Systematics facilitated these five themed focus groups on site at the ADOT headquarters. Total attendance was 14 ADOT staff, including several members of the TAC. Appendix D shows the focus group preparation guide, the sign-in sheet with list of participants, and the interview guides for each of the five focus groups conducted.

CHAPTER 4. DISCUSSION OF FINDINGS

By initiating this preliminary study of climate adaptation for the statewide transportation system in Arizona, there is already an internal interest and momentum at ADOT for climate adaptation planning. Without institutional support, however, it will be difficult to continue forward with the research agenda in a more extensive study.

Based on the inventory of ADOT's existing projects and research on climate change and environmental sustainability, followed by the online survey and focus group interviews with ADOT staff, several issues emerged that led to recommendations in Chapter 5.

SUMMARY FINDINGS – ONLINE SURVEY QUESTIONNAIRE

The survey included eight questions. Five questions were multiple choice, and four questions allowed the opportunity for respondents to elaborate on their answers with an open-ended response portion. One question asked only for open-ended feedback, and two questions collected demographic information in text fields.

Major summary findings are summarized below:

- **Climate change is affecting ADOT operations.** The majority of people (56 percent of respondents) believe that climate change is affecting ADOT operations, and 50 percent of respondents believe that ADOT should have a role in planning for climate change.
- **ADOT employees address a variety of time horizons in their jobs.** Question 4 asked how far into the future respondents look to make their decisions; 36 percent of responses were "short term" (less than one year), 35 percent were "mid term" (one to five years), 23 percent were long term (more than five years), and 6 percent were "Other".[1]
- **Most of the identified climate impacts are seen as relevant to employees' job functions.** Question 5 displayed a list of potential climate change impacts including heat effects, such as highway asphalt rutting, early snowmelt that could increase the risk of floods, and many others. The respondents were asked to indicate whether each of these nine impacts was relevant to performing their current job. The climate impacts that received the most "relevant" responses were intense precipitation (79 percent of responses were relevant), heat (69 percent of responses were relevant), and wildfires (66 percent of responses were relevant).
- **Respondents had a lot to say about specific climate effects and tools, data, and guidance needs.** Two open-ended questions received many responses: 1) Question 5B, which asked people to elaborate on any "relevant" responses from the climate change effect matrix, or describe any other potential climate impacts that might affect your job; and 2) Question 7, "What tools, data, guidance, or other resources related to extreme weather or climate change do you wish you had to help inform your decision-making activities?" Highlights from the climate change effects question include a concern about how particular effects, such as how heat affects humans (road workers, etc.); maintenance-related concerns, such as potholes, wildfire, and precipitation effects; and indirect effects, such as financial effects.

[1] For this question, respondents were allowed to select more than one response.

SUMMARY FINDINGS – FOCUS GROUPS

Based on the five focus groups and 14 ADOT staff from a cross-section of planning, environmental, engineering, operations, administration, and communications staff, the section distills the key findings from the research. Table 5 shows the key findings from the focus groups.

Table 5. Key Findings from the Focus Groups

Topic	Key Findings
Climate Impacts: Increased Number and Duration of Heat Days	• The existing weather conditions already are considered "extreme" in parts of Arizona, so when dealing with climate change and climate adaptation, the metrics have to be different in Arizona than for other states. There is an opportunity for research conducted and implemented at ADOT to be applied as best practices. • Areas that require further research include pavement dyeing, more heat-resistant sealant for lane lines, electric loads and features in tunnels, choice of material for bridge deck joints, and determining the seasonal sensitivity for pouring rubberized asphalt.
Climate Impacts: Increased and More Intense Precipitation	• Focus group participants were particularly concerned about flash flooding and the increased requirement for more effective or higher capacity drainage systems. • Because ADOT's roadway system is so extensive, the expectation of increased or more intensive precipitation may have a large effect on operations. Currently, there is very little planning for the 1/100-year flood or the 1/300-year flood, for example.
Climate Impacts: Dust Storms (Uncertain)	• Although it is uncertain how climate change might affect the frequency of dust storms in Arizona, it is already clear that the existing weather patterns are a detriment to Arizona drivers. There is a need for public safety campaigns.
Existing Guidelines and Specifications	• ADOT adheres to the Roadway Design Guidelines (last updated May 2012), which provide standard specifications for infrastructure design, including roadway design, roadway drainage, and earthwork. • In the current design standards, there are factors built in (e.g., exceedance thresholds for stormwater, thickness of pavement, height of bridge columns, etc.). These design standards take into account a buffer for extreme weather events. However, if climate change forces us to evaluate the range of impacts and the possibilities that far exceed our current understanding of weather events, this would be a new area for ADOT. ADOT staff would have to wait to see the type of figures and assumptions built into the climate projections to see if they can believe in changing these thresholds.
Examples of Successful Interagency Efforts	• Examples of successful interagency efforts involving ADOT that could serve as models for implementation include the Best Management Practices in Stormwater Management, Building a Quality Arizona, Wildlife Crossing and Connectivity Projects, and LEED Green Design standards.
Emergency Risk and Response	• ADOT has had to respond to many "emergency projects" in recent years, especially with wildfires. If ADOT were to better integrate maintenance with design earlier in the process, this would reduce the number of emergency projects.
Communications and the Political Environment	• ADOT has had success in communicating existing weather-related impacts to drivers, but has had less experience in describing climate impacts or climate change. With the current political environment in Arizona, discussing climate change can be difficult. However, leveraging scenarios that branch out from present day weather-related impacts can be a useful approach. • It would be useful to get involvement of partners that are more forward on climate change issues, such as Maricopa Association of Governments (MAG) and Pima Association of Governments (PAG). In addition, the ASU Sustainability Program and Arizona Department of Environmental Quality also could be strong partners.
Funding and the Need for an Economic Driver	• There is always a shortage of funding within state DOTs. However, the purpose of a climate adaptation plan is to examine current planning, design, and operations practices to determine what strategies could be employed that are low-cost, high-reward strategies.

Table 5. Key Findings from the Focus Groups (Continued)

Topic	Key Findings
Current ADOT Resources for Climate Adaptation Planning	• There are numerous efforts that are already initiated in ADOT, which are related to risk assessment, asset management, evaluation and response, and other adaptation responses to extreme weather events. These efforts are well underway and can be leveraged if further work should progress from this study. These include the following: o Arizona's Disaster Recovery Framework, o The ADOT Feature Inventory System (FIS) program, o The ADOT Maintenance Service Leadership Team (MSLT), o Efforts to Separate the Budgets for Maintenance versus Emergency Response, o Correlating Extreme Weather Trends with Maintenance Budgets, and o Geographic Information System (GIS) and Spatial Mapping Capabilities.
Interactions with other Environmental Initiatives	• A variety of other environmental initiatives taking place at ADOT were noted during the interviews. Participants noted that, aside from a recent sustainability workshop convened by AASHTO in 2011, there were not many venues to begin various environmental projects within the department. Nevertheless, several key initiatives were mentioned: o Solar Highway Initiative, o Arizona's Energy Plan, o ASU programs, and o Environmental Policies, Management, and Compliance Plan.

In addition to these findings, ADOT staff suggested key areas for future research as listed in Table 6 below.

Table 6. Areas for Future Research in Climate Adaptation for ADOT

Topic	Areas for Future Research
Updating Information and Existing Guidelines and Specifications	• Update the National Oceanic and Atmospheric Administration's (NOAA) floodplain map. The floodplain maps are not great; Arizona is using the Federal Emergency Management Agency's (FEMA) maps, which are not accurate for Arizona. If the underlying data are going to change (i.e., NOAA's data was based on old data), updating the information with current data on drainage could be beneficial. • Create a guidebook linking climatological events, risk analysis, and economic impact. Suggest a risk-based approach that moves beyond standard formulas. • Create protocols for specific climate events because the current approach is ad hoc response. • Work with the U.S. Army Corps of Engineers to evaluate the design of certain facilities. We generally overdesign based on current guidelines. If features are overdesigned, the engineering and maintenance teams do not have an incentive to change it. Changing these assumptions could reduce costs. An adaptation plan should review existing design guides. • Consider ecosystem development guidelines and include the maintenance department's input to figure out the long-term impacts. Include topics such as wildlife connectivity to provide a holistic view.
Interdisciplinary and Interagency Coordination	• Make connections with MAG and other councils of governments (COG) for next steps in adaption planning. • Talk about climate impacts across disciplines. Enable structural engineers and people that focus on drainage to interact. Connectivity and roadside management and landscaping also are key elements that could be improved by better coordination. • Connect with FEMA and bring them into ADOT's work, especially on route planning and emergency response. This could provide access to funding as well. • Get involvement of partners that are more forward on climate change issues, such as MAG and PAG. The ASU Sustainability Program and Arizona Department of Environmental Quality also could be strong partners. • Start an interdisciplinary forum with regular follow-through that includes the budget office in the discussion.

Table 6. Areas for Future Research in Climate Adaptation for ADOT (Continued)

Topic	Areas for Future Research
Data Needs and Future Planning	• Collect information on future climate projections on specific regions to see what happens with temperature and seasonality and precipitation at a very local district level – when do certain impacts take place and what is the magnitude? • Develop scenarios for adaptation. • With the new MAP-21 legislation, there will be performance measures related to the long-range transportation plan (LRTP). Developing performance measures with climate impacts (mitigation or adaptation) could be a fruitful way to raise awareness and provide linkage to other work within ADOT.

DETAILED FINDINGS – ONLINE SURVEY QUESTIONNAIRE

This section discusses findings in more detail, and communicates themes gleaned from the survey responses. The specific findings described here support the summary findings.

Survey Population

The online survey was open between August 16 and September 6, 2012. The initial e-mail invitation was sent on August 16, and one reminder was sent the week of August 20. Of more than 300 ADOT employees who began to fill out the survey, 255 people provided complete responses. Job categories were assigned to the respondents to identify the diversity of job types represented in these data.

Figure 8 illustrates that employees from ADOT's Design and Engineering Departments represent the largest group of survey respondents (29 percent), while Administration and Communications staff are the second largest group (22 percent) and "Other" represent 20 percent. "Other" includes staff that did not fall in any other category, or staff who entered generic job titles that did not clearly place them in any of the other categories. Job title information was not a mandatory field on the survey, so people who did not provide this information are included in the "Not Identified" category.

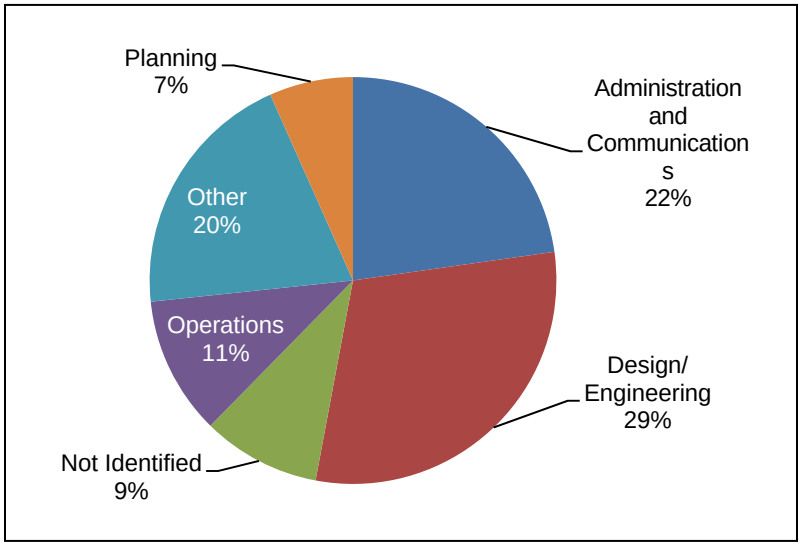
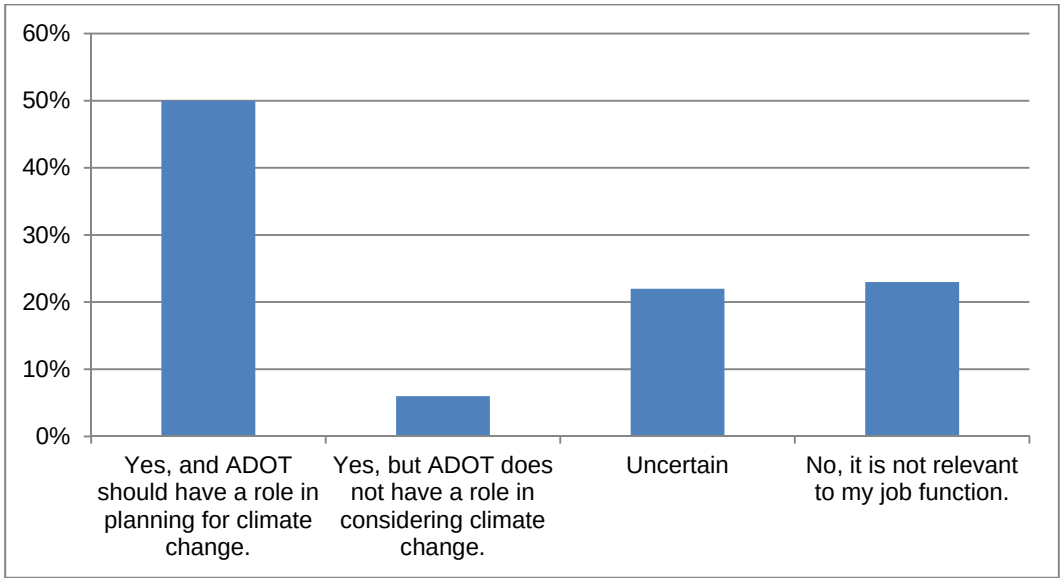


Figure 8. Respondents by Job Type

Relevance of Climate Change Impacts

Question 3 asked respondents whether or not climate change affects ADOT operations. Figure 9, which displays the Question 3 responses, shows that the majority of respondents believe that climate change is affecting ADOT operations. Additional highlights are summarized below:

- About 50 percent of respondents believe that in their current job function, climate change is affecting ADOT operations, and that ADOT should have a role in planning for climate change.
- Only 6 percent of respondents believe that ADOT does not have a role in considering climate change.
- The remaining respondents are split equally. About 22 percent are uncertain about the answer to this question, and 22 percent believe that it is not relevant to their job function.



Note: There were 253 responses to this question.

Figure 9. Question 3 Responses
(In Your Current Job Function, Do You Think that Climate Change Is Affecting ADOT Operations?)

The relevance of climate change impacts to ADOT employees also is addressed in Question 5, which provides a matrix of potential impacts to the transportation system that might result from climate impacts or events, such as heat waves, early snowmelt, more frequent and severe droughts, and many others. This list of impacts was taken from the literature review completed earlier in this project. The question asks respondents to indicate whether, and how, these impacts would affect how they perform their jobs.

Many of the climate impacts were deemed relevant by respondents. While the number of responses for each impact varied, the range of responses was small: between 193 and 206. For all impacts but one (wildlife habitat), the number of "relevant" responses was greater than the number of "not relevant" responses.

The climate impacts that received the most relevant responses were: intense precipitation (79 percent of responses were relevant), heat (69 percent of responses were relevant), and wildfires (66 percent of responses were relevant).

The results of Questions 3 and 5 support the finding that many respondents believe that climate change impacts are relevant to ADOT operations and to employees' specific job functions.

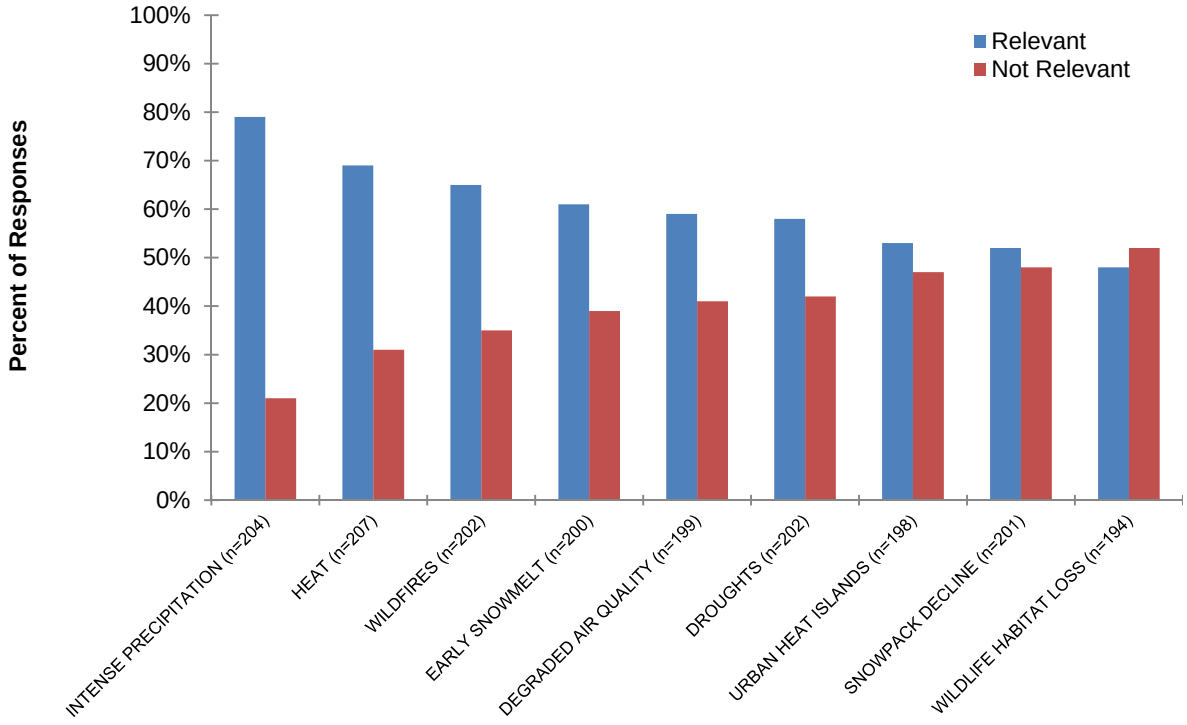


Figure 10. Relevance of Climate Change Impacts

Decision Making Time Horizon

Another topic that is important to climate change adaptation is how far into the future people look to make decisions. For an agency to adapt to projected climate changes, it must consider its own cycles. For example, what is the current pavement maintenance cycle, and how might that need to be modified given predictions of more extreme heat days? In order to find out the time horizons under which people operate, Question 4 asks respondents to identify how far into the future they look to make decisions.

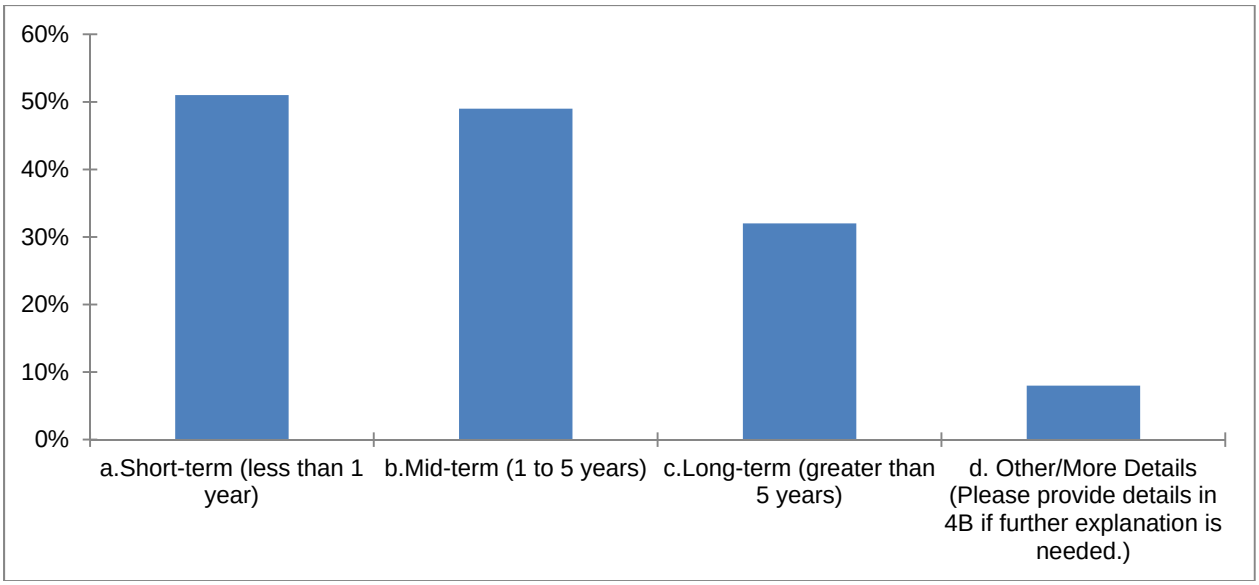


Figure 11. Question 4 Responses
(In Your Current Job Function, How Far into the Future Do You Typically Look to Make Your Decisions?)

A summary of the responses shown in Figure 11 is included below.

- The majority of responses (51 percent) were short term (less than one year), followed closely (49 percent) by mid term (one to five years). Respondents were allowed to select more than one response.
- Roughly one-third of responses were long term (greater than five years).

Question 4 included a follow-up question (4B) that asked respondents: Your job function corresponds to a larger planning or investment cycle (e.g., the capital investment plan, the State Transportation Improvement Plan (STIP), the long-range plan), please provide that information here. Feedback from the 42 open-ended responses included the following:

- Specific planning efforts, such as the Regional Transportation Plan (RTP), STIP, local Transportation Improvement Programs (TIP), Transit Capital Plan, Long-Range Plans, and the Statewide Transportation Framework (Vision for 2050).
- Communications-related efforts.
- Environmental efforts, including specific projects involving water, pavement preservation, construction, and slope management.

In summary, within ADOT there are a variety of planning and decision making cycles. The existence of numerous cycles is an important factor when considering how ADOT might adapt to climate impacts in the future.

Complete Responses

Summaries of the responses by question are included in Appendix C. Multiple choice questions are formatted as charts; for questions that requested open-ended feedback, full text responses are included.

The feedback received from these responses provided rich information about people's job functions and perspectives, and helped develop the focus groups. While it is difficult to quantify the data received through these questions, a few important themes were woven through these responses. Some of these echo the information learned from other areas of the survey:

- Respondents shared many concerns about climate impacts that are affecting ADOT employees and citizens, including extreme heat effects, high winds, dust storms (haboobs), and other specific events.
- Respondents would like access to more tools that would help address climate change effects, including climate and air quality data and communications tools.

DETAILED FINDINGS – FOCUS GROUPS

This section summarizes detailed responses from the focus group, and is categorized into main themes.

Climate Impacts: Increased Number and Duration of Heat Days

Overall, focus group participants expressed concern about the impacts of increased heat or longer durations of hot days in Arizona and the effects on ADOT operations. The existing weather conditions already are considered "extreme" with parts of Arizona hitting 126°F in the last few decades. Highlighted key points are as follows:

- When dealing with climate change and climate adaptation, the metrics have to be different for Arizona than for other states. There is an opportunity for research conducted and implemented at ADOT to be applied as best practices in other states.
- ADOT should research more effective methods for adapting to increased heat. One idea is to dye the pavement, if this could be a cost-effective option. Dyeing the pavement to a lighter color would cool the temperature of the pavement. In addition, having the pavement dyed in earth tones can be good for the environment, pedestrian health, and even for drivers to see the lines in the pavement.
- Heat deteriorates lane lines on the roadways. ADOT could invest in better sealants for lane lines so they do not deteriorate as quickly in the heat.
- Electric loads are affected by high heat. For example, the Interstate 10 Deck Park tunnel has a large electric load for lighting. This peak load for lighting, as well as other electrical features (dynamic message signs, loop detectors, etc.), may need to be reconsidered. The current methods are using high pressure sodium, but other options such as light-emitting diode (LED) are becoming available and cost effective. It would be worth researching the impacts of transitioning to these lighting modes that are less heat intensive and sensitive.
- Bridges are affected by high heat days. Currently, bridge deck joints are often made of concrete, which can deteriorate more quickly in hot weather. This deterioration could cause a high risk to traffic safety if the deterioration increases the risk of failure. The cost implications to changing this, however, could be high. The federal government currently matches bridge construction costs at around 94 percent in Arizona, but if deteriorated deck joints cause the bridge to be replaced earlier than projected, it is unclear whether the federal government could match construction costs at the same level.

- There is a "season" for putting in rubberized asphalt (spring and the fall), because this form of asphalt can only be laid during 75- to 80-degree maximum outdoor temperatures. If we expect climate change in Arizona to increase temperatures overall (even during the currently cooler season), there will be a shorter season for putting in the asphalt; this may in fact inhibit the use of this type of asphalt completely. Rubberized asphalt is looked to as a sustainable option for many cities – it reduces noise and has a relatively low environmental impact. Many communities feel the benefit of rubberized asphalt. Thus, there are tradeoffs to adapting for climate and working towards sustainability.
- Accounting for pavement alone, there will be increased costs for spot repairs and "mill and fill" projects due to faster deterioration from heat.

Climate Impacts: Increased and More Intense Precipitation

Focus group participants were concerned about flash flooding and increased requirements for more effective, higher capacity drainage systems. Key points are as follows:

- There are currently 70 pump houses operating in the State that collect and manage excess drainage from large precipitation events. Increased rainfall or more concentrated rainfall may change the requirements for pump house capacity, as well as the culvert size for different segments of the drainage system.
- Because ADOT's roadway system is so extensive, the expectation of increased or more intensive precipitation may have a large effect on operations. Currently, there is very little planning for the 1/100-year flood or the 1/300-year flood, for example.
- Intense precipitation causes harm to wildlife habitats in many places, particularly rural areas.
- During intense precipitation events (in Yuma, for example), there are problems with washes and ditches. These events loosen rock-bearing soil, which slides downslope creating ditches with vertical drop-offs of up to 5 feet. We could expect increasing events of this nature to be very costly for ADOT.
- The bridge from Interstate 87 out of the Mesa/Salt River area was rebuilt several times in one year because of flood issues. In addition, around State Route 87, there have been incidents of rockslides and landslides from increased precipitation.
- The climate studies seem to be projecting that the ecosystems in Arizona are shifting northward (i.e., ecosystems that were in southern Arizona are migrating northward). This creates numerous biological impacts and changes the areas where flooding impacts would occur. It is a nonlinear system.

Climate Impacts: Dust Storms (Uncertain), Wildfire, and Wildlife

The following comments also were made on various other climate impacts:

- Although it is uncertain how climate change might affect the frequency of dust storms in Arizona, it is already clear that the existing weather patterns are a detriment to Arizona drivers. Currently, there are approximately 12 Road Weather Information System (RWIS) stations positioned throughout the State, and especially in rural areas, to warn about impending giant dust storms. There may be the need for more such instrumentation.
- Dust storms have really increased in the last two to three years. There is a need for public safety campaigns.

- With wildfires projected to be increasing in frequency in the future, there would be many impacts to the economy, including a hit to elk hunting, a key tourist attraction in some parts of the state.
- Habitats will be harmed with changing wildlife crossing and connectivity impacts.

Existing Guidelines and Specifications

ADOT adheres to the Roadway Design Guidelines (ADOT 2012, last updated May 2012), which provide standard specifications for infrastructure design, including roadway design, roadway drainage, and earthwork. Some guidelines are formulaic, but all require professional judgment in application. Focus group participant comments include the following:

- There are standard construction specifications that deal with design for infrastructure. Then there are "special terms" that might not be a part of standards, but would be negotiated with every project. ADOT published the document 'Standard Specifications for Road and Bridge Construction.
- For environmental review, weather-related impacts may be discussed on a case-by-case basis in situations that might require nonstandard mitigation measures.
- Regarding electrical infrastructure, different components have a certain rating. There is an assumption about temperature ranges that is made in engineering design.
- ADOT has a stormwater management best management practices guide for environmental compliance.
- In the current design standards, there are factors built in (e.g., exceedance thresholds for stormwater, thickness of pavement, height of bridge columns, etc.). These design standards take into account a buffer such that it would be difficult for current weather events to exceed a certain threshold that impacts design. However, if climate change forces us to evaluate the range of impacts and the possibilities that far exceed our current understanding of weather events, this would be a new area for ADOT. ADOT staff would have to wait to see the type of figures and assumptions built into the climate projections to see if they can believe in changing these thresholds.

Examples of Successful Interagency Efforts

Developing a climate adaptation plan requires ADOT to participate with different levels and departments of government. Thus, we wanted to inquire about ADOT's previous examples of successful interagency efforts, both in idea and implementation. These could serve as models moving forward.

Best Management Practices (BMP) in Storm Water Management. This effort was the result of a consent agreement in the early 2000s. Through a process that involved the U.S. Environmental Protection Agency (EPA), ADOT developed an environmental management hierarchy for BMPs with a central coordination committee and district coordinators. The air quality and "low-volume waste" initiatives emerged from this, as well as the policy on municipal sewers.

Building a Quality Arizona. This long-range, cross-disciplinary plan involved COGs and metropolitan planning organizations (MPO) from around the State, along with ADOT, the

Arizona State Legislature, the Governor's Office, and the business community, to talk about state infrastructure needs.

Wildlife Crossing and Connectivity Projects. There are a variety of these projects, including elk crossing projects on State Route 260 and I-40, as well as a bighorn sheep overpass project on U.S. Route 93. These are examples of interdisciplinary studies done in collaboration with Arizona Game and Fish Department, the Bureau of Land Management, and others. These have been successful interagency projects.

There is an effort to supply wild rams with overpasses and to use cameras for observations. Through the environmental process, ADOT was able to coordinate with the Arizona Game and Fish Department (AZGFD), Sky Island Alliance, and offer options for better provision of wildlife connections.

Some of these studies have been ad hoc. Thus, the ADOT Office of Environmental Services (OES) has been working on policies to standardize the efforts. The problem is that these studies, while interdisciplinary and often successful, can be very time and labor intensive.

LEED Green Design. This was an example of a success because it first identified the State's movers and shakers with business and economic development. Instead of couching this effort under climate change, it could be under a broader, more appealing terminology, such as "smart transportation planning" or "smart transportation initiatives."

Emergency Risk and Response

The following comments were made on ADOT's ability to respond to emergency risk and extreme or catastrophic events:

- ADOT tends to be reactive in terms of fire recovery. Districts have been drained of money based on recovery and fires, instead of filling potholes or resurfacing. One role of the budgeting office could be to determine how to split the funds, so there is a pot of money focused for response efforts versus maintenance funds.
- ADOT has had to respond to many "emergency projects" in recent years, especially with wildfires. If ADOT were to better integrate maintenance with design earlier in the process, this would reduce the number of emergency projects. Things to keep in mind upfront are how will we deal with extra runoff and will we need to do removal? Thinking through an entire process using risk analysis and assessment techniques could mean cost avoidance later on down the line.
- Safety and economic issues were mentioned as well. For example, I-40 is commonly shut down in cases of bad snowstorms; ; more frequent snowstorms could be a problem. I-40 is a major route and, if traffic has to be rerouted, alternate routes are hundreds of miles away. Closing the road affects not only passenger vehicles, but also freight vehicles, which could have negative economic impacts.
- For natural disaster events, there are spikes in funding requirements. If the spike gets high enough, federal funding comes in, in the form of project cost reimbursements.

Communications and the Political Environment

ADOT has had success in communicating existing weather-related impacts to drivers, but has had less experience in describing climate impacts or climate change. With the current political environment in Arizona, discussing climate change can be difficult. However, leveraging scenarios that branch out from current day weather-related impacts can be a useful approach. Focus group participants noted the following:

- The communications department has been leading a driver awareness campaign over the course of 2012. The haboob (giant dust storms) effort, in particular, received much media attention ("haboob haiku" advertisements). Snow is the next campaign. The communications team has learned that focusing on the climate impact itself (without getting into the term "climate change") has been effective.
- ADOT places focus on drivers. I-40 is one example of a roadway in which driver awareness is critical, as it is often closed for dust and snow. High winds also are an impact about which people should be aware. Arizona is still relatively young in terms of managing politics; it is still a "who do you know" environment. You have to back everything up with fact.
- Weather information could be used for public service campaigns. For example, "Pull Aside, Stay Alive" for dust storms. Currently, the high winds and dust storms are announced on the message boards. The traffic operations center (TOC) manages the prescribed messages.
- ADOT does do work in educating drivers in certain conditions. Some press releases do include tips about hydration, smart practices, and climate conditions.
- It might be useful to have a campaign on climate change more specifically, and to look at best practices around the country on how climate change is communicated in campaigns.
- The hope for this project is to create dialogue and possibly circumvent the politics.
- It would be useful to get involvement of partners that are more forward on climate change issues, such as the Maricopa Association of Governments (MAG) and the Pima Association of Governments (PAG). In addition, the ASU Sustainability Program and Arizona Department of Environmental Quality (ADEQ) could also be strong partners.

Funding and the Need for an Economic Driver

There is always a shortage of funding within state DOTs. However, the purpose of a climate adaptation plan is to examine current planning, design, and operations practices to determine what strategies could be employed that are low-cost, high-reward strategies. Focus group participants discussed the following on the topic of funding:

- Regarding funding, there is a lot more money available for infrastructure costs than for maintenance; there is very little maintenance funding.
- Climate change is affecting the desert southwest, but it is important to design a program that will be accepted by ADOT personnel. It is important to overcome "economic inertia" and explore what can be done, even if it costs more money. There is an underlying political will question on whether a relevant program if designed it will be accepted. Climate change, more generally, is not currently well accepted.
- Most entities are more responsive to cost-saving initiatives than to environmental or other types of initiatives. If people are interested in making any changes, they would have to

convince the council members and elected officials that it was an issue of importance. The elected officials are the most important, and winning their support is a big task for ADOT and others involved.
- Finding opportunities to share resources between agencies also is very important and can save money (equipment, materials costs).
- ADOT's focus has been highway construction, based in part on federal funding use guidelines or restrictions. The funding gap between new investment/construction and maintenance it is rather large. A better balance needs to be reached between new construction and provisions for maintenance.
- Cost-benefit is always an issue of importance, and most initiatives have to be backed up by a cost-benefit framework.

Current ADOT Resources for Climate Adaptation Planning

Numerous efforts related to risk assessment, asset management, evaluation, response; and other adaptation responses to extreme weather events are already in progress at ADOT. These efforts are well underway and can be leveraged if further work should progress from this study. Focus group participants noted the following efforts:

- **Arizona's Disaster Recovery Framework**
    - At the time of the interviews, the Arizona Disaster Recovery Framework was just being rolled out. This effort set up a framework for dealing with emergency events and effort involved federal, state, and local partners to bring in tools so ADOT is ready for road closures, etc. The partnerships are already in place. This is a new effort, but could be leveraged for climate adaptation issues.
- **FIS (Feature Inventory System) Program**
    - FIS is a comprehensive roadway asset management system for the state, including features such as culverts among others. If this effort is completed, it could be used for many things.
- **MSLT (Maintenance Servant Leadership Team)**
    - MSLT is an organized team of mid-level engineering managers and superintendents. It is a great resource or channel for voicing concerns or opening dialogue on issues of asset management, maintenance, and design. The goal is to connect the predesign, design, and maintenance employees.
    - MSLT coordinates the different highway technicians. They disperse the directives through "orgs" to cover the areas. They would be the users of the FIS.
    - They also work with district engineers to identify risk areas andreview outdated information. Districts have offices that identify issues in their area (decentralized), and then request funding from headquarters to fix those issues.
    - There is a weekly staff meeting with district engineers in the MSLT. The once-a-week meeting may be a trigger point for discussing climate adaptation, although typically there are more pressing issues on hand.
- **Budgeting for Routine Maintenance versus Emergency Response**
    - ADOT currently combines the funds for routine maintenance with those for emergency response. By separating the funds, the department would not risk depleting all the funding for maintenance during one or two major disasters or major events. Currently, maintenance districts tend to be opaque about the data

and how they apply the money for use (for instance, their budget requests may be as short as two pages, with no backup). Figuring out what is spent is a challenge in and of itself.
    - Routine maintenance is still deferred by the districts; and although maintenance crews had intended to do these tasks, the work often is sidelined due to emergency response needs. Emergency response funding is usually more attractive for legislators.
    - Once costs are isolated, there is still a lot of guesswork. Each maintenance district manages its own funding. ADOT has a decentralized system, and there is little resource sharing at the district level.
    - PErformance COntrolled System (PeCoS) is the maintenance database management system. There are many issues. Right now, it collects a lot of information, but one typically needs Structured Query Language (SQL) data coding to extract the data. It keeps track of use (data and equipment), but does not really help with needs.
    - For instance, the database records the cubic yards of mix used, but does not say whether it is used to fill 20 small potholes or one large pothole. It is hard to get feedback on the activities (for instance, Globe might need a certain type of snowplow for its hilly terrain whereas Holbrook needs plows for a flatter terrain).
    - It is particularly important to collect data from field managers, and to aim for usability of the project.
- **Correlating Extreme Weather Trends with Maintenance Budgets**
    - The budget office is trying to correlate extreme weather trends with the future needs of the maintenance organizations. Each maintenance organization has a different need based on its own geography and roadway characteristics.
    - One effort of interest will be to categorize vehicle accidents according to whether they are "typical" accidents or weather-related incidents. There are costs associated with weather events; upon initial assessment of data (from at least six years prior), the peaks are much greater than the troughs. The budget office is working with the risk management office to deal with the risks of natural disasters. There can be "reserves" built in, depending on the funding system, if the district or department is so lucky to have additional resources that are not depleted by the end of the year.
- **GIS and Spatial Mapping Capabilities**
    - The budget office is working with the GIS department to develop district profiles and a spatial mapping environment for analysis. This will enable the visualization of equipment and road needs with existing weather trends, such as snowfall information.
    - Currently, this data is focused on past trends, although there may be interest in considering future climate projections. The technical side of spatial mapping is straightforward, but there may be barriers at the leadership level when integrating climate change into the model. For example, ADOT would have to agree on a statewide projection or future climate scenario (and an ADOT-approved projection is unlikely to happen without state guidance).
    - Currently, ADOT's budget analysis can only change the confidence level for future climate projections (from an actuarial point of view). For instance, the risk

might be higher for certain precipitation events – and the factor would change in the model. It could be useful to incorporate this in the model.

Interactions with Other Environmental Initiatives

A variety of other environmental initiatives are taking place at ADOT that were noted during the interviews. Participants noted that, aside from a recent sustainability workshop convened by AASHTO in 2011, there were not many venues to begin various environmental projects within the department. Nevertheless, several key initiatives were mentioned:

- **Solar Highway Initiative**
  - In 2011, an ADOT staff engineer proposed a pilot solar highways initiative program for the department. At that time, they engaged the Governor's Office of Energy Policy and the ADOT Office of Public-Private Partnership (P3) Initiatives. This proposed pilot project, which is currently inactive, included a cost-effective way to provide lighting for tunnels on the highway. As alternative energy costs fall, this is something that may need to be revisited.
- **Arizona's Energy Plan**
  - The state's Energy Plan currently is more than 20 years old. However, there is interest in developing an energy-transportation nexus, which could have implications for climate change mitigation.
- **ASU Programs**
  - Decision Center for a Desert City (DCDC) describes itself as a "boundary organization" that bridges the gap between academic research and policy-making. Their goal is to look at relationships among climate change, water supplies, and urbanization in Phoenix. They designed WaterSim, a system dynamics model that looks at different scenarios for growth, water supply, and water demand; and can predict the impact of droughts on state watersheds, regional growth, etc.[2]
  - Decision Theater is the center with high technology aimed at supporting decision making. It is staffed by experts in the sciences and policy, and is part of the Global Institute of Sustainability at ASU.
- **Environmental Policies, Management, and Compliance Plan**
  - The ADOT Office of Environmental Services (OES) will be releasing an environmental policies plan (current draft form has 19 policies, which include smart transportation and recycling) that could be incorporated into long-range planning. The policies plan is scheduled to be released at the end of 2012.
- **Importance of Individual Efforts**
  - With environment initiatives, it only takes a few individuals to build momentum. For instance, the AASHTO workshop in 2011 showed how top management became engaged in sustainability issues. For this workshop, ADOT executive leadership asked many senior staff to attend.
  - It will be important to work with people in key positions to understand what climate adaptation might mean in their respective organizations. The decision for future research projects will be based on joint committees across the department.

[2] http://dt.asu.edu/category/projects/environment-projects.

- OES is particularly responsive to environmental issues and climate change impacts on ADOT's system.

Areas for Future Research for Climate Adaptation Planning

The following ideas emerged as areas for further research in futures stages of work on climate adaptation within ADOT. Focus group participants brainstormed a variety of research and applications to this initial preliminary assessment:

- Update the National Oceanic and Atmospheric Administration's (NOAA's) floodplain map. Having more data would improve and help engineers when designing roads. Follow up with drainage engineers. They use rainfall intensities in their model for design. If these are going to change (i.e., NOAA's map was based on old data), updating the information with current data on drainage could be beneficial. The floodplain maps are not great; ADOT is using Federal Emergency Management Administration (FEMA) maps, which are not accurate for Arizona. The size and exact boundaries of the floodplain, plus the associated risks, are uncertain. Some ASU researchers are trying to update these maps.
- Make the linkage between climatological events and economic impact by developing a guidebook for climate adaptation at ADOT. For ADOT's purpose, guidelines do not have to set thresholds. Although a guideline should have structure, do not force the use of standard formulas, but apply a more risk-based approach.
- Create protocols for dealing with specific climate events. Right now, ADOT's response is ad hoc. In particular, it would be worthwhile to create protocols for dust events.
- Make connections with MAG and other COGs if the path of adaptation planning is selected.
- Talk about climate impacts more across disciplines. Enable structural engineers and people who focus on drainage to have better perspectives (and longer time horizons in the design process), and talk about these impacts. Connectivity and roadside management and landscaping also are key elements that could be improved by better coordination.
- Erosion and roadside vegetation problems need to be addressed. Develop a policy to address this issue as it will likely worsen.
- Connect with FEMA and bring them into ADOT's work, especially on route planning and emergency response. This could help with greater access to funding as well.
- Develop scenarios for adaptation.
- There could be a role for agencywide or project-specific performance measures. The FHWA is looking to streamline the process at some time. The FHWA just gives guidance, but still has to be interpreted by the State.
- The number one issue is the availability and reliability of the data. Those who are working to give us the most up-to-date data have to put in more time into generating something we can grasp – such as rainfall, temperature, etc. Currently, the data is not very useful. It is not at the level where we can put it to use. Once you start thinking about the data, then you can start thinking about alternatives — one roadway would be a poor choice in abandoning a particular alignment if all routes are equal.
- Perhaps climate adaptation needs to go into the National Environmental Policy Act (NEPA) process — are there ways to bring climate adaptation into environmental review?

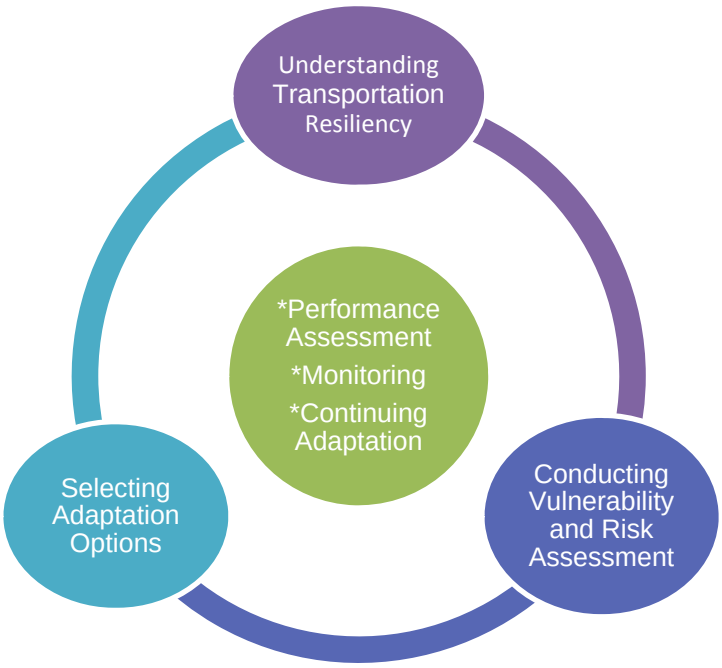
- It would be useful to have an interdisciplinary forum, but it would require follow-through, and it would be important to have a budget analyst involved with the discussion. For instance, construction and maintenance could both like to increase culvert side, but a budget analyst would have to make the tradeoff in cost. No one is currently doing the analysis for routine roadway maintenance versus deterioration costs, and whether to fund new construction. One major challenge is the "silo effect" between construction and maintenance. Construction and planning are funded because they lead to ribbon-cuttings, whereas maintenance is often left with little budget to keep up the project. There currently is a lack of communication to deal with these problems.
- Collect information on future climate projections on specific regions to see what happens with temperature and seasonality and precipitation at a very local district level — when do certain impacts take place, and what is the magnitude?
- With new MAP-21 legislation, there are huge efforts on performance measures related to the LRTP. Developing performance measures with climate impacts (mitigation or adaptation) could be a fruitful way to raise awareness and provide linkage to other work within ADOT.
- Currently, there is no such thing as an ecosystem development guideline. However, these would help tell us how we can adapt. It would be great to have maintenance department's input and figure out the long-term impacts. Include topics such as wildlife connectivity to provide a holistic view.
- Work with the U.S. Army Corps of Engineers to evaluate the design of certain facilities. Currently, decisions on designs are made according to a manual, but this may be formulated using outdated assumptions, etc. and sometimes result in the overdesign of certain facilities. If features are overdesigned, the engineering and maintenance teams do not have an incentive to change it. Changing these assumptions could reduce costs. An adaptation plan should review existing design guides.

CHAPTER 5. RESEARCH RECOMMENDATIONS

This chapter takes the findings from the online survey and interviews, and identifies a set of recommendations for the inclusion of climate adaptation into ADOT decision making. We are recommending that ADOT continue to conduct further research on climate adaptation, as well as identify appropriate existing management teams, to determine whether it can integrate climate adaptation into various planning and programming activities for climate adaptation planning.

DEVELOP AN OVERALL FRAMEWORK FOR CLIMATE ADAPTATION FOR ADOT

Effective climate adaptation requires an ongoing, iterative process of understanding transportation infrastructure resiliency, conducting a vulnerability and risk assessment, and then selecting adaptation actions. This is a cycle that then feeds into performance assessment, monitoring, and continuing adaptation, as shown in Figure 12.



Source: Cambridge Systematics, Inc., 2012.

Figure 12. A Conceptual View of Risk Assessment and Adaptation for Transportation Decision Making

This process requires a range of technical skills, quality data sources, and institutional collaboration to bring together the scientific, engineering, and planning resources necessary to make good decisions. Climate impacts assessment and adaptation planning is not a stand-alone process, however. In order for climate impacts assessment and adaptation strategies to be pursued effectively, they must be integrated into the ongoing transportation decision making process.

When designing new infrastructure, there will be a need to switch from designing with standards developed for historic climate trends to designing for future (and uncertain) climate projections — transportation infrastructure is sufficiently long lived that it will not be prudent to base plans on historic averages. Other possible changes to the design phase include the need for a broader systems approach and risk management procedures to incorporate climate change into decision making and defining appropriate design characteristics. This long-range perspective needs to be balanced with monitoring for near-term changes that may require more immediate design adjustments.

In addition to the direct effects on transportation infrastructure and services, climate change will catalyze changes in the environmental, demographic, and economic conditions within which transportation agencies conduct their work. In the long run, these broader changes may have very significant secondary impacts on the transportation sector that will need to be examined as part of the planning process. For example, changes in population centers induced by shifts in weather conditions will affect travel demand. As regions of agricultural production shift, freight flows may likewise change.

The next step for ADOT in considering climate adaptation is to develop a framework, process, and set of goals and objectives for consideration of these issues within the current organizational framework. There also is a role for coordination beyond the internal ADOT agency. For instance, the linkages made with Arizona Department of Environmental Quality and local universities, such as ASU and University of Arizona, as well as regional MPOs and COGs, will be important in moving the dialogue further.

ESTABLISH AN ENGAGED PROJECT TEAM

To build success and create champions for climate adaptation efforts within ADOT, it would be important to assemble an internal team to guide the day-to-day progress and focus on the challenges of additional research, targeted implementation, or continuous coordination and engagement throughout the agency. The TAC members from the research effort could be retained to continue the efforts initiated from this project.

Other possible champions to engage for further research study could include the following ADOT staff with responsibilities that will be well aligned to implement any recommendations from this study and future climate adaptation planning efforts:

- State Engineer
- State Maintenance Engineer
- Director, Office of Environmental Services
- Emergency Response Supervisor
- Media Relations Officer
- Director, Budget, Strategic Planning and Research
- Champion and Sponsor of Preliminary Study of Climate Adaptation Study

The lead champion or champions for the climate adaptation efforts should include a dedicated staff of internal experts, who will be involved in implementing projects or initiatives developed through the research or planning.

CONDUCT AN ENVIRONMENTAL AUDIT OF ADOT BUSINESS PRACTICES AND ACTIVITIES ALIGNED WITH CLIMATE ADAPTATION PLANNING

Finding ways to adapt to a changing climate is an interdisciplinary effort; it requires the technical and social support of a variety of actors within ADOT and external to the agency. Several efforts have showcased activity that pertains to a larger umbrella of sustainability.

Many staff members are unaware of employees in other departments or districts who are working on similar issues. This set of focus groups began to uncover some of these efforts, including the Arizona Disaster Recovery Framework for dealing with emergency events; FIS, where assets are collected and logged through a common database and could be mapped using GIS; and the efforts the budget office is studying to correlate weather events with the maintenance budget, as well as other projects, such as the solar highway initiative and the environmental policies initiative. Creating a forum for sharing these ideas, whether through a workshop, an online forum, or even an electronic social network, could build momentum and encouragement to pursue projects that may be stuck in organizational "silos."

SEEK NEW OPPORTUNITIES FOR FUNDING

One of the major findings of this research was the strong interest to connect climate adaptation to economic value. There always is a shortage of funding within state DOTs. In the longer-term horizon, the purpose of a climate adaptation plan is to examine current planning, design, and operations practices to determine what strategies could be employed that are low cost and high reward. In the short run, there is a need to look for funding through various channels to continue internal efforts for climate adaptation planning.

For instance, the Office of Federal Lands Highway and the FHWA associate administrators for the offices of Infrastructure and of Planning, Environment, and Real Estate recently clarified that federal aid and Office of Federal Lands Highway funding may be used for climate change adaptation work. The memorandum notes that creating a more resilient transportation system is a priority for the FHWA, and provides some examples of eligible uses of federal aid and Federal Lands Highway funds to consider the potential impacts of climate change and extreme weather events, and apply adaptation strategies.

As this area evolves, federal funding through various channels may emerge. ADOT will have to be aware of the possibilities that will arise through planning, research, and disaster relief (FEMA) resources.

PURSUE AN FHWA CLIMATE ADAPTATION PILOT

ADOT should respond to the request for solicitations the FHWA has released in November 2012 for a new round of project funding for climate adaptation pilot projects. In 2010, the FHWA funded five DOTs and MPOs to pilot a conceptual model to use in conducting vulnerability and risk assessments of infrastructure to the project impacts of global climate change. Projects from the following agencies were selected and completed by November 2011:

- Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area
- New Jersey DOT and North Jersey Transportation Planning Authority (NJTPA)
- Virginia DOT
- Washington State DOT
- Oahu MPO

This pilot program was jointly sponsored by the FHWA Office of Environment, Planning, and Real Estate and the Office of Infrastructure. In the previous round of funding, five awards were made, totaling approximately $1 million in federal funding. By federal statute, a 50-percent, nonfederal match was required for these funds to be awarded to the pilot areas. In-kind contributions, such as staffing, could be counted toward the match requirement.

Information Regarding the 2013-2014 FHWA Adaptation Pilots

FHWA is soliciting proposals from state departments of transportation (DOTs), metropolitan planning organizations (MPOs), federal land management agencies (FLMAs), and tribes to partner with in piloting approaches to conduct climate change and extreme weather vulnerability assessments of transportation infrastructure and to analyze options for adapting and improving resiliency. This pilot program is being jointly sponsored by two FHWA offices — the Office of Environment, Planning, and Real Estate and the Office of Infrastructure.

Second Round of the FHWA Adaptation Pilots

A second round of pilot funding has been released November 15, 2012. The grant opportunity is open to MPOs, state DOTs, Federal Land Management Agencies (FMLAs), and Tribes. Eight to 15 awards are expected, ranging from $75,000 to $300,000. A 100-percent, nonfederal match will be required, and in-kind funding is acceptable.

For this round of funding, it is anticipated that eight to 15 new pilots will be funded; and priority will be given to noncoastal agencies that have been moving ahead with preliminary climate adaptation assessments. ADOT is a prime candidate for this pilot project. It is intended that lessons learned from this research study contribute to a proposal effort led by ADOT. A link to the solicitation by FHWA was available at the following site: http://www.fhwa.dot.gov/environment/climate_change/adaptation. The document linked to the *Memorandum for Solicitation for Pilot Projects: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options Analyses.*

FINAL REMARKS

This preliminary study of climate adaptation at ADOT revealed several key climate impacts most relevant for ADOT personnel, specifically intense precipitation, heat, and wildfires. A survey conducted for this study and a set of focus group discussions revealed that climate change is affecting ADOT operations at a multitude of levels. To determine more precisely how these effects can be better managed by ADOT, three areas of research are warranted. First, ADOT staff needs to better understand how existing guidelines and specification do or do not take climate

impacts into account and update information to better match projected needs. Second, ADOT staff should play a more active role in interdisciplinary and interagency coordination activities on understanding their role in adapting for a changing climate. Third, ADOT staff should put an emphasis on finding better and more accurate data to assess the impacts of climate change; this is important for future planning within the department. Overall, this preliminary study provided a more complete understanding of the current state of climate adaptation activities within the department and the gaps that need to be filled in moving forward with this topic.

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APPENDIX A. LITERATURE REVIEW

RELEVANT CLIMATE CHANGE DATA AND RESOURCES

Several main international and national data resources provide background for climate change science, research, and methodology.

The International Panel on Climate Change (IPCC)

IPCC Fourth Assessment Report: Working Group I Report is the most comprehensive document to date for understanding the human connection to global climate change. The report, titled *The Physical Science Basis* (2007), is a working group contribution to the IPCC Fourth Assessment Report describing progress in understanding the human and natural drivers of climate change, observed climate change, climate processes and attribution, and estimates of projected future climate change.

U.S. Global Change Research Program (USGCRP)

Sponsored by 13 departments and agencies, this program coordinates federal research on changes in the global environmental and its impacts to society. The program advances science in the areas of climate change and global change research to observe and understand short- and long-term changes in climate, the ozone layer, and land cover. The goal is to estimate future changes and vulnerabilities and risks associated with those changes, as well as to provide scientific information for policy making. This program has documented numerous national assessments commissioned by the program, and have played prominent roles in international assessment such as those for the IPCC.

National Oceanic and Atmospheric Administration (NOAA)

NOAA's climate portal provides climate information and services related to understanding climate. It provides educational materials, up-to-date news and research, mapping resources, and links to underlying data and analyses related to the climate.

National Center for Atmospheric Research (NCAR)

NCAR is a federally funded research and development center devoted to service, research, and education in the atmospheric and related sciences. NCAR's mission is to understand the behavior of the atmosphere and related physical, biological, and social systems; to support, enhance, and extend the capabilities of the university community and the broader scientific community — nationally and internationally; and to foster transfer of knowledge and technology for the betterment of life on Earth. The National Science Foundation is NCAR's primary sponsor, with significant additional support provided by other U.S. government agencies, other national governments, and the private sector.

University Corporation for Atmospheric Research (UCAR)

UCAR is a nonprofit consortium of North American member universities that provides services and promotes partnerships to a collaborative community of researchers and educations dedicated to understanding the atmosphere. The mission is to support and extend the capacities of the university community to better understand the complex processes that make up the earth's system, from the ocean floor to the sun's core.

State-of-the-Practice Adaptation Frameworks for Transportation Planning. To date, various frameworks have been introduced to facilitate efforts by state, regional, and local governments and agencies to accomplish two major tasks:

1. Consider potential climate change-induced vulnerabilities and risks to the transportation system; and
2. Identify potential adaptation strategies at a relatively conceptual (planning, policy, or sketch) level.

These frameworks all address, to varying degrees, three core elements:

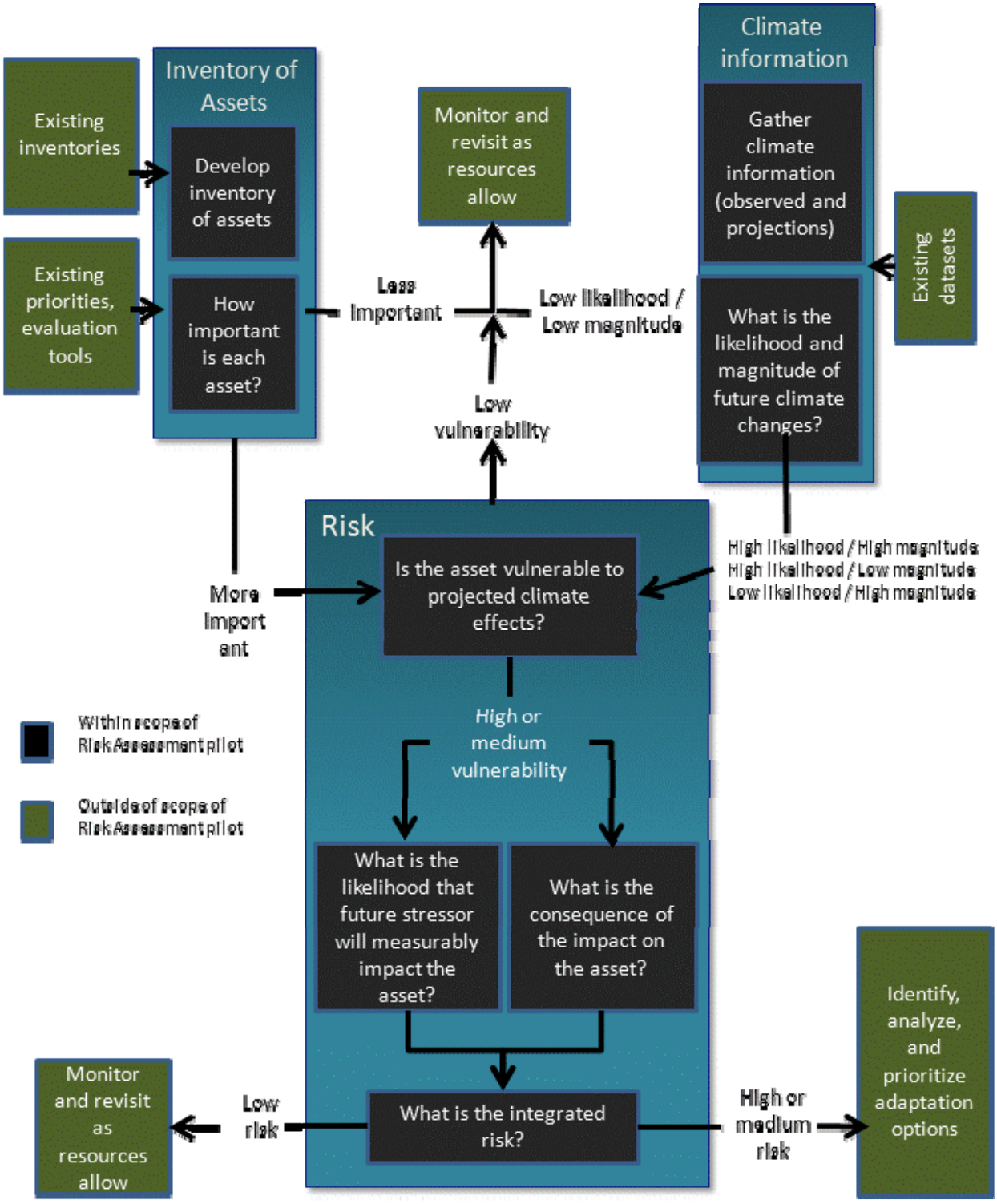
1. Building an inventory of critical assets;
2. Gathering information on future climate scenarios; and
3. Assessing the potential vulnerability and risk of assets.

However, they diverge from one another in their treatment of adaptation strategies, integration into planning processes, monitoring, and subsequent reassessment; some frameworks are designed as continuous processes.

FHWA Conceptual Risk Assessment Model. Prominent examples of recent and ongoing work include the FHWA Conceptual Risk Assessment Model or framework, which was developed to help transportation agencies identify infrastructure at risk for exposure to climate change stressors and determine which threats carry the most significant consequences. The FHWA model is shown in Figure 13.

The FHWA framework emphasizes a specific sequencing of the core assessment elements: inventory, climate data, vulnerability, and risk to obtain an undefined measure of "integrated risk" for projects, programs, and operations. This framework does not, at this point, incorporate explicit feedback cycles (monitoring and reassessment) or an adaptation module. These elements are under consideration, however, as the FHWA reviews input from the five pilot projects it selected to test and provide feedback about the framework. Projects from the following agencies were selected and implemented in 2011:

- MTC in the San Francisco Bay Area,
- New Jersey DOT and NJTPA,
- Virginia DOT,
- Washington State DOT, and
- Oahu MPO.



Source: Adapted from FHWA, 2011.

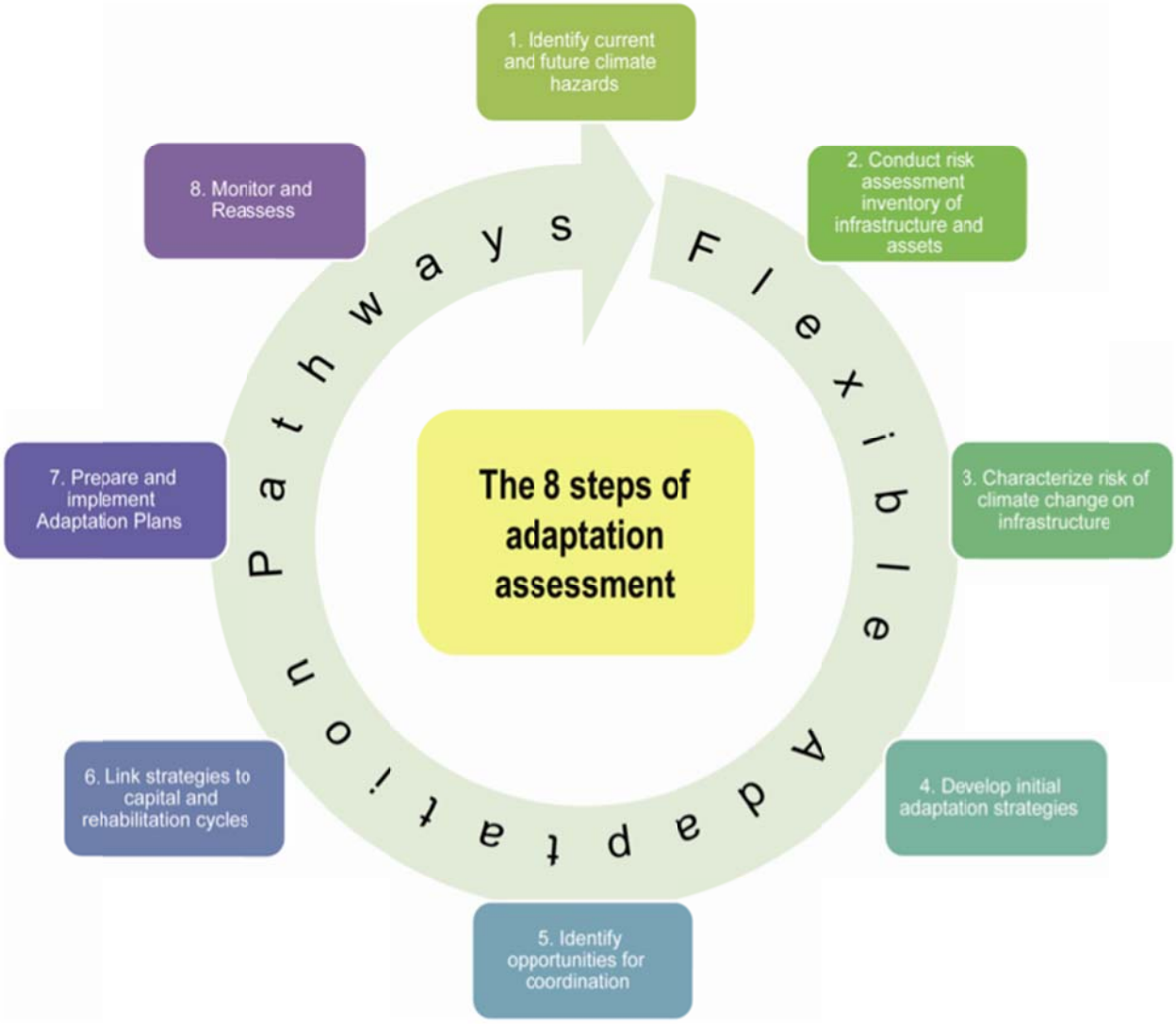
Figure 13. FHWA Pilot Climate Change Conceptual Risk Assessment Model

While complete reports are not yet available for all pilot projects, some preliminary findings have been released. Table 5 summarizes recommendations made by a few of the participating agencies about the FHWA framework.

New York Panel on Climate Change. Another leading framework for infrastructure adaptation was developed by the New York Panel on Climate Change (NPCC).[3] Although created specifically for New York City as part of the Climate Change Adaptation in New York City report (2010), it is designed to be used in a variety of contexts, with region-specific adjustments related to climate risk information, critical infrastructure, and acceptable climate protection levels. It provides a feedback loop comprised of eight steps designed to be incorporated into three processes: risk management, maintenance and operations, and capital planning.[4] The steps are illustrated in Figure 14 (NPCC, 2010).

[3] Refer to the NPCC Adaptation Assessment Guidebook: http://www.nyas.org/publications/Media/VideoDetail.aspx?cid=ba3dada7-4ed2-4cc4-96f3-0680e7c7be04

[4] The FHWA Model overlaps with Steps 1, 2, and 3 of the NPCC framework.



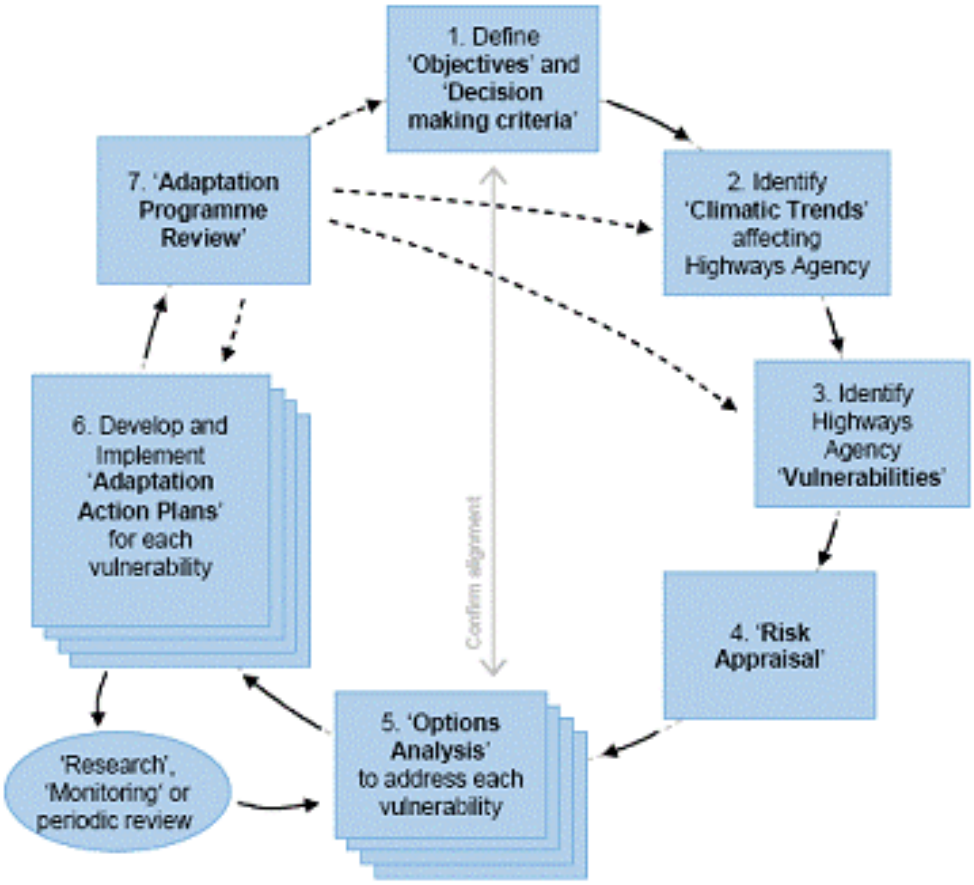
Source: NPCC Climate Change Adaptation: Building a Risk Management Response (2010).

Figure 14. New York City Process for Adaptation Planning

ICLEI Adaptation Framework. Local Governments for Sustainability (ICLEI) embraces a similar feedback loop, which includes front-loaded asset inventory and climate stressor data collection steps, introduces the idea of establishing targets or thresholds for acceptable risk, and then heavily emphasizes the development and implementation of adaptation plans. This framework is accompanied by proprietary modules and tools developed to assist with the process.

U.K. Highway Agency Adaptation Strategy Model. In the international context, perhaps the most fully developed adaptation framework is that described in the U.K. Highway Agency's Climate Change Adaptation Strategy, Volume 1. The Highway Agency Adaptation Strategy Model (HAASM) is a seven-step process for developing a climate change program. It provides a method for prioritizing risk and identifies staff members responsible for different climate change

adaptation program development efforts. Importantly, this framework introduces the concept of "defining objectives and decision making criteria" prior to launching into the core asset inventory/climate data/vulnerability and risk steps. Similar to previous "loop" frameworks, the U.K. Model follows the development and implementation of climate adaptation strategies with a program review and assessment, as shown in Figure 15.



Source: Climate Change Adaptation Strategy and Framework, Revision B, November 2009.

Figure 15. U.K. Highways Agency Adaptation Strategy Model

APPENDIX B. SURVEY INSTRUMENT

Pre-Survey Text

The Arizona Department of Transportation (ADOT) Research Center has begun a research effort related to climate change adaptation and needs your help with the following survey. The survey includes 8 questions and can be completed in 10 minutes or less. The two main objectives are summarized below:

1. Gauge staff perceptions about how certain climate scenarios would impact ADOT's facilities and processes and
2. Identify individuals interested in participating in focused, in-depth interviews to take place in the subsequent phase of the project.

ADOT is interested in learning more about climate change effects and their relevance to agency operations. To effectively answer that question, the research team must gain a clear understanding of current ADOT operations.

The information you provide will be used to inform the research team about the processes that occur within ADOT as well as the relationships between various activities and departments. It will also describe the staff's familiarity and experience with the topic of climate change adaptation.

Finally, the results of this survey will be summarized and included in a final research report, providing an important first step in defining ADOT's consideration of climate change effects in its current and future operations. For additional background on the survey, please click the "Adaptation background" link below.

Adaptation background

You may also contact Tom Kombe at ekombe@ azdot.gov for further questions.

Introduction

1. Please enter your name and job title.

Name

Job Title

Climate Change Adaptation Background

2. What exposure do you currently have on climate change issues? (Check all that may apply.)

- ☐ Local and national media (nightly news, newspapers, radio, etc.)
- ☐ Conversations with friends and family
- ☐ Conversations with colleagues
- ☐ Workshops, seminars, or conferences
- ☐ Other

2B. If you selected "Other" as a response to Question 2, please elaborate here.

3. In your current job function, do you think that climate change is affecting ADOT operations?

- ○ Yes, and ADOT should have a role in planning for climate change.
- ○ Yes, but ADOT does not have a role in considering climate change.
- ○ Uncertain

○ No, it is not relevant to my job function.

Future

4. In your current job function, how far into the future do you typically look to make your decisions? (Check all that may apply.)

- ☐ a. Short-term (less than 1 year)
- ☐ b. Mid-term (1 to 5 years)
- ☐ c. Long-term (greater than 5 years)
- ☐ d. Other/More Details (Please provide details in 4B if further explanation is needed.)

4B. If your job function corresponds to a larger planning or investment cycle (e.g., the capital investment plan, the STIP, the long-range plan), please provide that information here.

Climate Change Effects

5. There is a near consensus in the scientific community that the global climate is changing – although these effects remain uncertain. In Arizona, this may mean an increase in heat waves, early snowmelt, more frequent and severe droughts, magnified urban heat island effects, degraded air quality, an increase in wildfires, and a change in wildlife habitats, for example. The following are key potential impacts that may results from these conditions. Please help us understand whether, and how, these impacts would affect the way in which you perform your job, if relevant.

	Relevant	Not Relevant
A. HEAT - Highway asphalt rutting, possible movement of liquid asphalt; thermal expansion of bridges; or limitation on construction periods during summer	○	○
B. DROUGHTS - Increased risk of mudslides in areas deforested by wildfires	○	○
C. URBAN HEAT ISLANDS - Local effects	○	○
D. EARLY SNOWMELT - Increased risk of floods, landslides, and damage to roads; increased variation in wet/dry spells and decrease in available moisture may cause degradation of road foundations	○	○
E. DECLINE OF LATE-SEASON SNOWPACK - Indirect impacts expected; general implications include reduced streamflow and water supplies. This could result in increased wildfires.	○	○
F. INTENSE PRECIPITATION - Increases in weather-related delays and traffic disruptions; increases in flooding of roadways; Increases in road washout, landslides, and mudslides that damage roadways, increased bridge scour in the short term, compromised integrity of roads and bridges due to increased soil moisture	○	○
G. DEGRADED AIR QUALITY - Reduced air quality; risk of non-conformity	○	○
H. WILDFIRES - Effects on transportation system and operations	○	○

I. WILDLIFE HABITAT LOSS - Effects on transportation system	○	○

5B. Please elaborate on any "relevant" responses from Question 5 or describe any other potential climate impacts that might affect your job.

Department Information

6. Does your department have any existing policies or practices that relate to responses or risk mitigation from extreme weather events or weather-related disruption? (e.g., pavement design manual, flood risk management manual)

- ○ Yes
- ○ No

6B. Please elaborate on your response to question 6 here.

Tools

7. What tools, data, guidance, or other resources related to extreme weather or climate change do you wish you had to help inform your decision-making activities?

Next Steps

8. If you are willing to participate in an interview or focus group regarding your job function and how it might be affected from to the climate impacts described in this survey, please provide you phone number or email below. Interviews will last approximately 30 minutes and likely take place in September.

Phone Number	
Email	

APPENDIX C. SURVEY RESPONSES BY QUESTION

The following section includes a brief summary of survey responses by question. Multiple choice questions are summarized in charts and the full text answers to open-ended questions are included. All data came from the survey, as collected through the Qualtrics survey website.

Question 1: Name and Job Title

The first question asked people to include their name and job title. A wide range of ADOT staff from a variety of departments responded to the survey. The total number of respondents was 235. Table 7 lists the respondents' job titles.

Table 7. Question 1 Responses

Job Title
Partnering Facilitator
Economist
Accountant
GIS Analyst/Transportation Planner
Community Relations Officer
Program Manager
Senior Engineer
Contract Database Administrator
Intern
Manger, Aeronautics
Revenue Administrator
Transportation engineering specialist
Office Manager
Transportation Engineering Specialist
Constituent Services Officer
Management – Finance
Environmental Compliance Evaluator
Public Information Officer
Traffic Operator
Research Project Manager
Title Examiner
Geotechnical Engineer
Administrative Assistant
Management – Revenue Accounting
Accountant
Management Analyst
Transportation Construction Technician
Receptionist
Team Leader
Land Manager
Maintenance Engineer
Transportation Construction Technician
Media Relations Officer
Transportation Engineering Permits Technician
Highway. Operation Technician
Technical Editor
Transportation Engineer
Engineer-Manager
Management – Communications
R/W Agent
Development Engineer

Job Title
Construction Tech
Senior Project Manager/Architect
Traffic Records Manager
R/W Titles Manager
Traffic Signal and Lighting Technician
Construction inspection
Transportation Engineer Specialist
Transportation Construction Technician
Traffic Signal and Lightning Technician
Transportation Engineer Specialist
Transportation Engineer Specialist
Const Tech
Fleet Analyst
Transportation Engineering Associate
Highway Operations Supervisor
Intern
Transportation Engineer Specialist.
Transportation Engineering Specialist
Supervisor
Geotechnical Planning Engineer
Fiscal Services Specialist
Engineer-in-Training
Transportation Construction Technician
Senior Community Relations Officer
Transportation Engineer
Engineering Specialist
Biologist
Engineering Specialist
Fuel Tax Licensing & Refunds Supervisor
Transportation Engineering Specialist
Administrative Assist
Transportation Construction Technician
Transportation Engineer Specialist
State Bridge Engineer
Program Project Specialist
Regional Transportation Planner
Transportation Eng. Specialist
Fiscal Service Specialist
Management – Water/Wastewater Ops
Environmental Coordinator
Senior Resident Engineer

Job Title
Transportation Engineer
Public Information Officer
Maintenance Technician
Airport Grants Manager
Administrative Services Officer
Transportation Engineering Specialist/Project Manager
Electrical Operations Engineer
Transportation Engineer Specialist
Airport Engineer
Manager – Transit
Statewide Striping

Job Title
Management 3 Traffic Signal/Lighting Operations
Construction Tech
Supervisor
Senior Transportation Planner
GIS and Statistical Analyst
Tax Analyst
Transportation Engineer
Planner

Question 2A: What exposure do you currently have on climate change issues? (Check all that may apply.)

Figure 16 summarizes the responses to this question. The number of respondents was 253, while 595. Respondents were allowed to select more than one response.

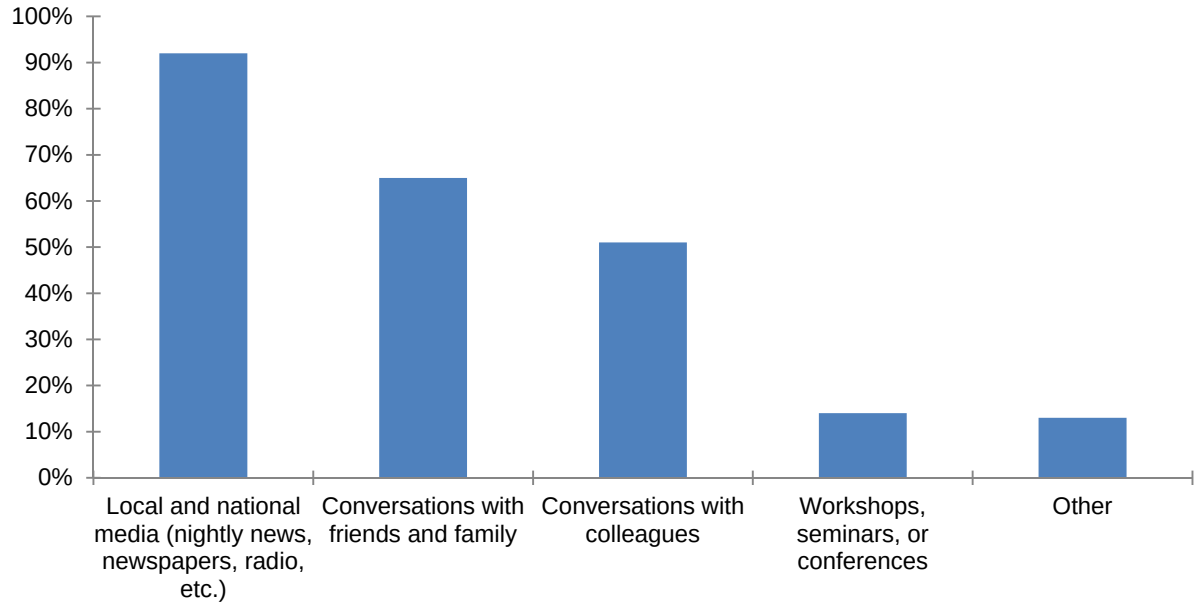


Figure 16. Question 2 Responses

Question 2B: Open-Ended Response

Question 2 had a follow-up question. Those that selected "Other" were given the opportunity to elaborate. This question received 30 responses, which are included in Table 8 below.

Table 8. Question 2B Responses

Responses
Environmental Planning Courses at ASU
Social Media/Facebook/Twitter.
We see it here in Seligman every day. we watch the weather so our crews can be prepared for anything, and warn them when the weather suddenly changes with more wind, electricity in lightning bolts, and snow. Our crews are out there in it.
Internet
Several college level courses discusses climate change issues, as I has a degree from a college of agriculture.
Read up on the subject in Time, Newsweek etc. magazines
Professional publications
Belief system outlets, books, pamphlets, etc.
Alternatives views about the validity of climate change and the causes for it.
College course in sustainable communities
Face to Face conversations with scientists and meteorologists.
Am the owner of Sun Miner LLC, a solar energy technology consultancy. This is a secondary job with respect to my position at ADOT.
Trade Journals
Graduate level work on climate research and analysis
Mother Nature is the one who controls the Earth's climate changes. Also, in question three you should have a "No" all by itself as climate change is relevant to anyone's job function.
My own observation of Arizona climate through 65 years of living in Arizona.
Periodicals, Web sites, Environmental Organization
Discussions within my doctoral coursework
Internet research
For example, Arizona and advocacy reports: http://www.azclimatechange.gov/download/O40F9347.pdf or http://www.bikeleague.org/resources/reports/pdfs/climate_change_bicycling.pdf
Lecture on impacts of climate change on Phoenix – can't remember who sponsored it. Evening event, one in a series of lectures, not all about climate.
I studied climate change in college.
To believe in this farce is insane. No tangible evidence exists noting that "climate change" has anything to do with humans. It is, if anything, a natural phenomena about which we have no control over. All evidence to support same has been debunked and the issue should be dropped with no further funds expended on it.
TV. Computer, Radio, Newspaper
Scientific literature
Scientific magazines and journals such as Conservation, National Geographic, etc.
Field observations, exposure to the elements in the region where I work and live. (Northeastern Arizona)
Frequent traveling throughout different parts of the state.
Internet
Observation, The world has been changing since conception and will to the end...Man is not responsible, corporations would like you to believe that we are to aid in profits..The Sun is in charge of Mother nature. Oh and air today is 100% better the in the 60s and 70s with twice the people...

Question 3: In your current job function, do you think that climate change is affecting ADOT operations?

Figure 17 summarizes the Question 3 responses. There are 253 responses to this question.

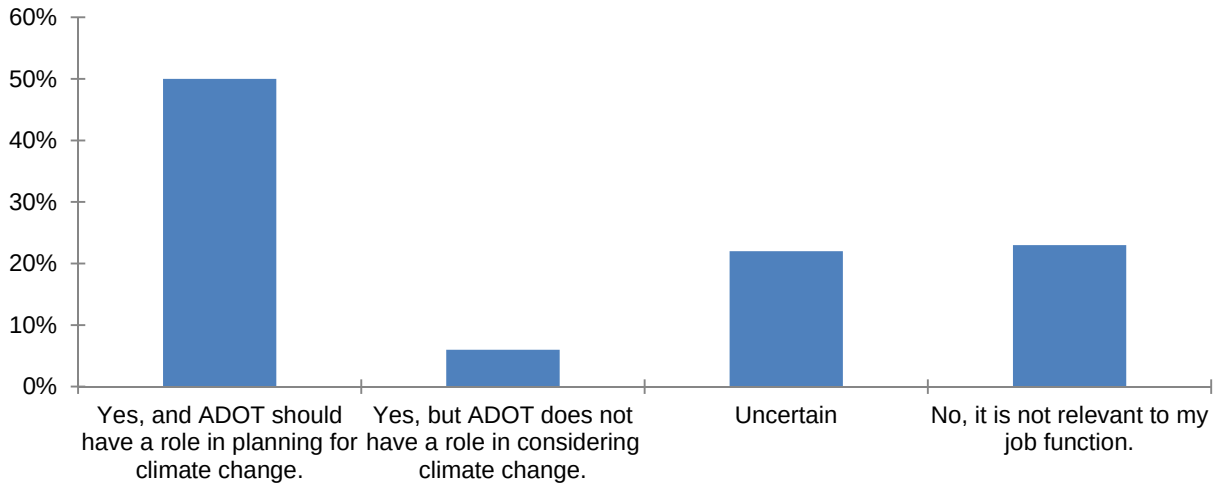


Figure 17. Question 3 Responses

Question 4: In your current job function, how far into the future do you typically look to make your decisions? (Check all that may apply.)

Figure 18 summarizes the responses to Question 4. The number of respondents was 247, while the number of actual responses was 346, as people were allowed to select more than one response.

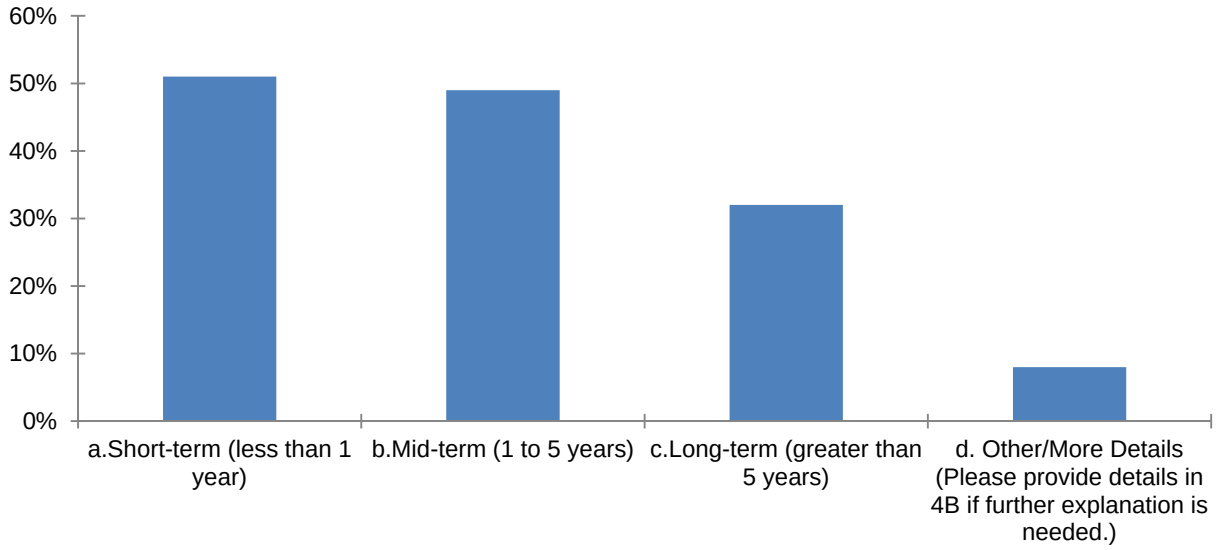


Figure 18. Question 4 Responses

Question 4B: If your job function corresponds to a larger planning or investment cycle (e.g., the capital investment plan, the STIP, the long-range plan), please provide that information here.

After respondents indicated how far into the future they look to make decisions, they were offered the opportunity to include an open-ended response if their job corresponds to a larger planning or investment cycle. Table 9 includes the 43 responses to Question 4B.

Table 9. Question 4B Responses

Responses
RTP, 20 year budget plan
Local TIPs, STIPs and the Long – Range Plan.
Climate can affect aircraft performance, runway lengths and other related facilities. Our master plans for airports typically go out 20 years.
My job is dependent on the Climate Changes- We are a reactive department to report the changes and Climate changes can severely impact what we do.
Everyone should always be planning in a 7 year cycle, which what the weather usually runs. We need to be prepared in any eventuality, and having the right equipment is key to intermodal success.
I work in the transit grant programs and provide capital information for the STIP. Transit capital investments require forecasting when replacement equipment should be purchased and how to plan for all agencies that require replacement equipment.
The ADOT Public Information Office, which is part of Communication and Community Partnerships, does work with information from the agency's Five-Year Program and long range planning process (as examples) in providing answers to questions from media and other customers.
In long-range planning we anticipate needs 20+ years into the future.
Not sure how to respond to this as my job relates to properties containing wells and water rights which can begin and end in a day or in some cases perpetually.
As development engineer, I work with the district engineer to plan for highway needs in the long-term (5-year transportation plan and beyond). Increased temperatures lead to more rapid highway deterioration and increased maintenance. Increased rainfall intensities lead to greater erosion and damage to the highway infrastructure. Future projects will need to look at innovative temperature-resistant treatments in increase pavement longevity. Future projects will need to incorporate drainage features that can handle increased runoff and improve the durability of highway features (e.g., shoulders) to the increased erosive effects of greater intensity rainfall
More efficient traffic control systems to avoid slow moving traffic.
decisions regarding facility construction or upgrades and how temperatures will affect what type of HVAC eq.- Effects of extreme cold snaps on water system freeze up.- how dropping groundwater levels affect water wells.- how excessive rain events can affect drainage or accumulation of rainwater at ADOT sites and possible contaminants getting off site.
I am responsible for managing the Slope Management Program (770xx), and developing budgets for geotech field work, geotech design, pavement design, laboratory testing and on-call consultants.
I have seen projects above a 20 year plan.
I work with COGs and MPOs to help them develop their LRTP and TIP
Part of my job is to be involved in the development of individual projects, mainly from the field construction point of view.
Planning for drinking water wells. Climate (long-term drought) effects groundwater levels. When the groundwater levels are lower this has a cause and effect on the ability to obtain sustainable water supplies throughout the western states including Arizona. Resulting in drilling deeper wells and increasing the cost to install wells and a higher operating cost to pump water from greater depths.
Airport development Master Plans forecast out 20 years. Grants we issue have various sponsor compliance requirements extending out 20 years.
I work on both pavement preservation projects, which will be constructed in 1-3 years, and also on mid-size projects like adding climbing lanes, which could be constructed in 1-10 years from now, depending when construction funding is identified in the STIP.
Have proposed to the agency a Solar Highways Program addressing long term goals.
My job function takes me into the development of the processes and procedures involved in the STIP and 5-year plan.
The initial cost and long-term life-cycle costs play a major factor in the decisions I make in regards roadway improvements.

Table 9. Question 4B Responses (Continued)

Responses
In the field of Construction we deal with the day to day- I am personally in an office so it has little to do with me at this time but we do have people on the freeway projects in the heat and it is always in the forefront of our minds to make sure that they are prepared for all types of weather situations. We also have to plan schedules biased on weather which is week to week.
Planning for wildlife features or infrastructure is usually long term in nature.
I look generations into the future on climate change. Obviously these survey is not truly relevant to climate change issues.
As a manager for this org I have to manage a budget plan for work activity. During winter and summer season.
Fleet Equipment Acquisition – having an economic life of 10-15 years
We have a wide variety of projects we do environmental planning for – some are long range – 30 years, and most are short range – build it this year with project improvements life expectancy of 5 to 25 years.
I assist in contract generation and negotiation that MAY be related at times.
Planning for automated accounting systems that support these functions
None
I am the District representative for projects in Development. This includes small short term projects to projects that are large and are planned for years in the future.
The Office of Environmental Services is trying to get more and more engaged in decisions early on at this agency. We have been involved in BQAZ, and What Moves You Arizona. We help focus capital investments for environmental issues within the agency including vehicle wash racks, salt storage sheds, and above ground storage tanks. To date we have not been involved in programming of funding for the 5 year program. We are trying to get involved in some of these decisions, however, a culture change and shift in how ADOT does things needs to happen. We are happy to engage in these discussions.
ADOT Statewide Bicycle and Pedestrian Plan – see http://www.azbikeped.org/statewide-bicycle-pedestrian.html and http://www.azbikeped.org/studyupdate/index.asp
As a planner, we typically look far into the future – sometimes 40 – 50 years. The bqAZ Statewide Transportation Framework is Arizona vision for a thriving, sustainable transportation network and looks to 2050.
Regional Transportation Plan (RTP)
Priority based planning.
I comment on plans for projects during the reviews to ensure my concerns are addressed.
We review the five year Airport Capital Improvement Program.
Because my job often requires that I work in the field, I plan on daily and weekly weather forecasts. Depending on the project status, or progress, it is necessary to sometimes consider where the project will be 3 or 6 months ahead and plan construction accordingly.
yes we have job functions corresponds to a large planning but investments cycle to the long range plan is contingent on budget the state of Arizona is in right now.
Five-year program and MAG Regional Freeway Plan
hour by hour day by day

Question 5: Relevance of Climate Impacts

Question 5 displayed a list of potential climate change impacts, including heat effects such as highway asphalt rutting, and early snowmelt which could increase the risk of floods, and many others. The respondents were asked to indicate whether each of these nine impacts was relevant to performing their current job; and if so, how the impacts were relevant. The number of responses for each question is indicated in Figure 19, which provides an overall summary of responses.

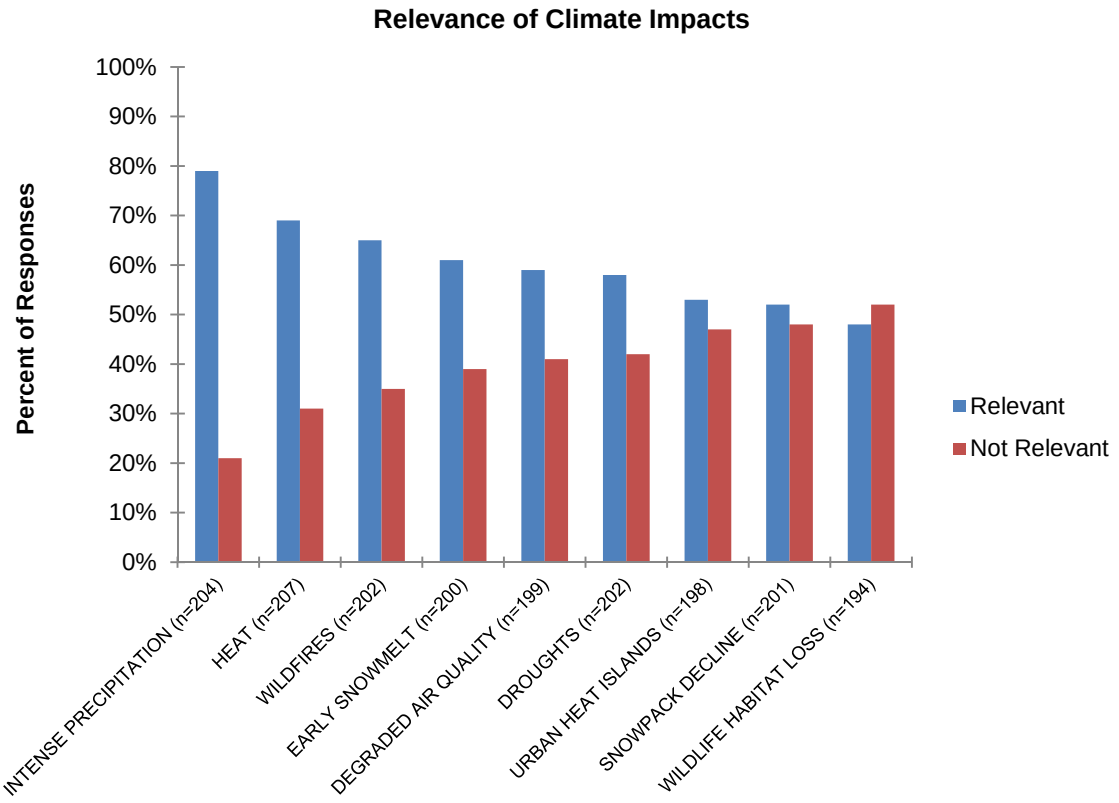


Figure 19. Question 5 Responses

Question 5B: Open-Ended Feedback on "Relevant" Responses

Question 5B requested that respondents elaborate on any "relevant" responses from Question 5, or describe any other potential climate impacts that might affect their jobs. There were 116 responses to this question, included as entered into the survey in Table 10 below.

Table 10. Question 5B Responses

Responses
Degraded air quality is a risk to my health when I need to be outside.
certain federal revenues for conducting air quality performance
The answers that i selected "relevant" are because we are dealing with most of them now and they are causing damage to the roads.
In GIS we gather most or all of this data and it can all be made relevant to what products we produce for our maps.
Construction crew time in exposed heat may cause projects to run longer.
Lack of air conformity may change the way we program projects and the level of funding received through the TIPs and STIP. Lack of conformity may also lead to a larger push for bike / ped non roadway improvements.
Working in construction, any road closures due to weather effects our schedule and costs. Excess water in this part of AZ makes the subgrade, which is mainly clay, very hard to build on. Wildfires can destroy the road, structures, guardrail etc...
All climate changes will have an effect on how ADOT conducts business – climate changes and elements will affect how roads will be constructed and equally changes in the materials used in construction.
As a student of civil engineering, I can say with 100% certainty that all the issues listed above are definitely relevant to the purpose and responsibility of ADOT and must be addressed appropriately in a timely manner.
The affectations described for roads, in many cases, have the same affect on runways and taxiways. Wildfires cause visual degradation thus impacting safe flight.

Table 10. Question 5B Responses (Continued)

Responses
As an accounting administrator, these factors impact in indirect ways. Keeping the buildings at a comfortable temperature and maintaining safe/healthy air quality in the work environment in downtown Phoenix are important to the well-being and productivity of staff. In addition, we need to be concerned about the ability of staff to safely commute. Those who take buses are exposed to the weather conditions and could have adverse reactions to the heat or the air.
Issues during construction such as quality of product received from the contractor, maintaining traffic during construction projects, and the contractor having to do rework due to weather damage.
Anything that affects highway transportation could affect our jobs.
Excessive humid weather
All relevant situations would affect the public which in turn effects the way I do my job.
I am affected personally from these conditions, but from a work standpoint, I am only affected because of the related financial changes that may occur (more overtime to clear roads or take care of issues, for example).
Limiting work based on the time of the day during the summer months. Increased environmental regulations due to climate change.
My job function is to communicate to interested parties (e.g., the community, stakeholders, internal audiences) what ADOT is doing to make Arizona's transportation system personally relevant. The transportation challenges that Arizonans may face due to climate change are my concern because I want to let them know that ADOT is aware and is doing something about it. I may not be the boots on the ground, replacing asphalt or fighting brush fires, but I will be telling that story in such a way (I hope) that would gain us support. That support would, ideally, turn into the dollars the agency would use to respond appropriately to the challenges that climate change will create.
We are responsible for updates AZ511 so if there is a chance that any of those features will impact traffic or require any roadways we will need to react to it. Wildlife habitat loss could affect us but most of the time no it will not.
I did not originally select "Relevant" for any climate effect, but the survey made me enter text here. Then, it still returned me to this page. So, I have entered one "Relevant" response, but it is not correct-just an artifice to get me beyond Page 5.
5B. A. B. C. D. E. F. G. H. I. I do research on the property being considered for acquisition. I don't really have any input into how it is used or what happens to the land once we get it. I have not marked relevant on anything I don't know what they want.
Our involvement occurs any time soil or rock conditions are impacted by climate change.
if you watch the regular previous weather cycles, usually 7 years with a 50 or 100 year cycle change you can usually plan better for any occurrence. If you just go 'oh, it's raining' and move on, that doesn't solve anything. down here we have to deal with the rapid wash out in arroyos, and plan our buildings around flood plains, respect and build our roads around nature's normal floodplains, not ignore it to have it washed out later. That's just stupid to ignore floodplains, rock falls, etc. You have to use common sense in the planning, plotting, and building of roads so that they will be solid, safe and effective for many years.
May impact State Airport operations
I didn't select relevant for any climate effects. I marked G only because the survey would not let me continue. My unit records the revenues for ADOT which includes revenues that pay for the highways. These would indirectly effect me and would not change the way I perform my job.
G: I have allergies, and I might not be able to work on days that are very bad air quality.
A through E could potentially have an impact on the rural transit agencies that utilize FTA grant funds. The majority of these agencies run a portion or all of their service on AZ highways. So any of the factors listed above could have an impact on their bus routes. Additionally, some of the rural transit agencies have been used for evacuation purposes due to wildfires and flooding in their community or nearby communities.
During pavement placing ambient temperatures must be below 100 degrees F to gain allowable strength. So concrete is usually placed from 8:00 p.m. to 8:00 am. Concrete temperature tolerances can be flexed but at a certain point too much heat can stop structures from making PSI strength. During sample testing, ambient temperatures and concrete temperatures are taken and this last summer at any time during the night, temps have been hovering around 95 degrees F. With global temperatures on the rise placing concrete at anytime day or night could possibly be affected.
As the population in AZ continues to increase, the need for more water increases as well. This not only affects those living here, but it also affects the ability to put out fires when they occur across the state. As it pertains to my job, the climate outside directly affects the climate in the building I work in. Consequently, the temperature in our building can range from as cold as a freezer to warm in other parts. When it is over 100 degrees outside and you work in a building that the temperature is 68 degrees, it cannot be good for the body to go from one extreme to another. We had guns to measure the temperature in our cubicles and it was 68 degrees on a daily basis. This must also be considered when discussing climate control. Employees should not have to work under such extreme conditions. I was diagnosed with walking pneumonia and am not certain that the conditions I just described contributed to it.

Table 10. Question 5B Responses (Continued)

Responses
these issues may affect our asphalt design and specifications. Projects will be generated by some of these things...repair of pavements, drainage repairs and structures due to deforestation from forest fires (we have seen these projects in the last few years), bridge scour retrofit projects are ongoing – heavier flows may affect the design of scour retrofits.
My main job function is to coordinate the management of the vegetation in rural right-of-ways. Invasive weed treatment, recovery zone clearing, pavement & bridge preservation through herbicide application, and environmental stewardship. All work to ensure a healthy, native ecosystem that is able to withstand wildfires, droughts, discourage unwarranted animal crossing, keep drainages clear, and maintain road surface stability. Changes in weather impact all aspects of my work on a regular basis, drastic changes have a cascade effect that can de devastating. For example, we had a terrible drought last year followed by a hard winter. Many of the plants we normally herbicide treated either didn't seed or never came out of dormancy from the drought, or then died from the frost. That resulted in weeks of scheduled spraying activities being canceled and material not being used. Instead, we turned our attention to vegetation that had been killed by the frost. Later that year we faced the worse fire season southern AZ had seen in years. All resulting from extreme weather that year.
I develop and execute public safety campaigns; so any climate change issues that put the health and safety of the motoring public at risk could require a public safety campaign. For example, our team developed and executed a dust storm awareness and safety campaign to educate the public about driving safely (or opting not to drive) if they find themselves stuck in a dust storm on the highway. So certainly if issues such as flooding, landslides, mudslides, etc. become serious/frequent enough to impact drivers, then I would become involved in the public education effort.
Many of these change present a potential for increase flooding and runoff from watersheds that host the roadways. Heat is not such a factor in the SE Arizona. The change in climate could have a dramatic effect on long term land uses and reduce the traffic volumes if employment decline yields a population reduction.
My job is to test liquid asphalt. Currently the highest performance grade we test is at PG76-16; since global warming might cause rutting, we might need to have some grade bumping in the near future. It would mean new specifications need to be set, and definitely more testing to be done.
As a member of the agency's "media team," I would need to be aware and prepared to answer questions about any of the subjects that are listed in Question 5. It would involve communication with subject matter experts on those topics.
The quality of the roadway would be greatly impacted due to significant climate change and the continued population growth around the State would also affect how ADOT deals with roadway issues.
I manage the Contracts & Specifications section for advertisement of projects for highway construction. A – Temperature changes will affect the type of asphalt pavement used, the time window for applying asphalt, etc. G – Air quality issues may impose new restrictions or conditions on methods and timing of construction work to minimize any additional impacts to air quality due to construction work. The other factors would all seem to impact ADOT directly or indirectly, and while not so much in my area would definitely impact design of those projects and maintenance after construction.
Increased need for communication with the public as a result of intense rail/snow.
The factors listed above are inconsistently presented. Some state a potential impact on the transportation system, and others do not. Yet, each of the factors could present an impact. This inconsistency can affect the way survey takers respond, and can lead to skewed data. ANYTHING that affects the transportation system can affect planning because it could alter the lifespan of a facility, create need where it did not previously exist, etc.
This job is involved with the drilling and abandonment of wells for highway development and for use in irrigating lands associated with leases, and water rights associated with Land owned and Maintained by ADOT and or Tenants, with environmental impacts associated with these rights. I am indirectly involved as the go between on these projects and am responsible for keeping a watch. Drought, run off of flood water or even moving asphalt could impact the lands associated with the lands, wells (irrigation, potable). Maybe I am just indirectly affected. The job would have more monitoring, restrictions might need to be in place? Not sure?

Table 10. Question 5B Responses (Continued)

Responses
HEAT – As development engineer, I need to consider and recommend potential treatments for highways as we develop project to improve the highway system. Changes may involve asphalt and oil treatments, and the type of asphaltic concrete used in construction. URBAN HEAT ISLANDS – As development engineer in the hottest part of the state (Yuma), effects on the Interstate system due to increased temperatures will be observed first in the Yuma District (even before observed in Phoenix). Yuma can serve as the "canary in the mine" for the testing of new products and observation of the warning signs of heat stress to highways. INTENSE PRECIPITATION – Unlike other areas of the state, Yuma District has the lowest concentration of plants adjacent to highways. Thus, increased precipitation results in higher flows and more erosion of the components of highway systems (e.g., shoulders). DEGRADED AIR QUALITY – Yuma County is a non-attainment areas for PM10. Drier climate can result in increased air-borne pollutants (i.e., dust) that causes non-attainment. As a result, environmental regulations affecting construction projects increase which in turns alters construction practices and increases costs. WILDLIFE HABITAT LOSS – Drier climate increases the need for wildlife migrations as wildlife (e.g., wild horses, wild burros, and bighorn sheep) move to seek grass and other food and water. This movement increases vehicle/wildlife conflicts and the mitigation measures needed to provide wildlife passages (e.g., wildlife bridges). Mitigation measures drive up the cost of highway projects. The Arizona Game and Fish Department has already contacted Yuma District to discuss potential mitigation measures for future projects.
The design and maintenance of building roofs, HVAC and Electrical systems. Affect the decisions to maintain or replace equipment and review of long term or short term saving. The intensity of the sun affects nearly every component of a structure.
Climate change affects all the above which affects ADOT.
Lets guess, One air is cleaner now that in the 60s, with 10times the population. Climate has been changing since the start of time. People cannot adapt to changes today, looking for reasons and blame. Heat and toad rutting materials are better and you do not see near the amount of rutting as 30 years ago, Remember 17 to Flagstaff as a prime example. Life and products need maintenance Wildlife there are more Deer, Elk, Bears, Mountain Lions, Bob Cats, Duck now than when Pilgrims landed, Drought and additional hunting pressure has decreased Quail, But Dove population are increasing. Look to history for Weather...not in years but in 1000 of years. Water could be a problem. so they have been saying for the 50- years I have been in Arizona.
B-droughts affect water levels and water quality from wells. A and C-increased strain on building HVAC systems. more snow/wind affects building roof design. E- affects water levels and water quality from wells. F-affects ability to drain building sites and increases possible contaminants leaving ADOT property. G-outside workers possible increased breathing problems.
High winds knock down traffic control and dust storms cause visibility issues, which cause safety issues on constructions sites. Also wind bursts can knock down and have knocked down bridge false work before the walls or bottom deck have been poured. Also SRP letting out dam water all at once down the Salt River, like in 1993, hit the Mill Road Bridge false work and knocked it down before the bottom deck and walls had been poured. This was like a flash flood that came down the river channel. Besides these 'climate impacts' endangering people's lives, they cause thousands of dollars of damage and cause a lot of re-work.
D) No snow and /or early snow melt will affect how often our plow trucks and other equipment is used. We may suddenly have too many of one type and not enough of another. h) As the NIMS resource typing person for Equipment Services this will effect what equipment we need to help out FEMA
Intense precipitation could obscure video detection at intersections.
Added emergency callouts to respond to rockslides, etc.
As a geotechnical engineer, excess precipitation is our main nemesis. Add in a wildfire and we are in for trouble. Thermal expansion and contraction are problems as well. Some structures are damaged due to expansion, and erosion issues arise when contraction occurs.
Whether I end up a designer or resident engineer, I will have to help remedy some/all of these issues.
These could impact projects that affect the driving public or stakeholders and that would require community relations informing the public.
Wild fires may damage bridges and interfere with highway transportation (smoke-visibility, heat, smoke-particulates, soil degradation-erosion or flash flooding, land slides, loss of life and property, wildlife dislocation, etc.). Road kills of dislocated animals may increase but generally not a significant problem unless certain species are to be protected. Snow melt will be a problem mainly in counties experiencing annual snow fall, limited to northern tier counties in Arizona. However, heat may reduce snow accumulation in first place. Intense precipitation could increase due to availability of particulates in the air (smoke, dust) as droplet nucleus. Dust storms may increase due to drought periods and reduced surface vegetation to hold moisture.
Seasonality of migrating birds coming in early can change our avoidance timing. We often deal with birds protected under the Migratory Bird Treaty Act. Loss of habitat can also increase chances of wildlife becoming listed on the Endangered Species List and thus require a higher level of consultation if we are doing work in their habitat.

Table 10. Question 5B Responses (Continued)

Responses
All of these could result in additional projects, including emergency reconstruction projects, which would have to be bid (on a priority basis) through Contracts & Specs Section
High heat makes it rough to work outside.
Heat affects when we can place certain types of asphalt. Heat also affects what time of day we can pave. If it is too hot or cold no asphalt can be placed. Rain delays construction progress. More rain means construction is delayed and the project runs longer.
no comments
Most of our projects take place in the higher country and the winter affects on the construction season has changed over the years
Everything I see as "relevant" to performance of my job, is related to my commute to work. These things could affect how I get to work.
Drought conditions elevate the fire risk and the need to obtain water supplies. Fire has caused damage to the electrical power supply that delivers power to the remote water pumping well for the Sunset Point Rest Area. The wastewater disposal system located at the Mazatzal Rest Area experienced damaged by a wild fire. The fire burnt the disposal infrastructure causing the rest area to be closed until the necessary repair were made to restore the disposal system. During wild fire events, partly treated wastewater from the Sunset Point Rest Area has been used as a water source for bucket drops in fire areas. This practice of utilizing partly treated wastewater at as a water source is environmentally unsound. This practice was done without ADOT permission on more than one occasion. Where there is a sufficient water supply, storage and fire pumping capacity local fire responders have used water form an ADOT reservoir to fill water tanker trucks. During the most resent fire event near the Mazatzal Rest Area the fire responders requested ADOT provide water to fill tank trucks. Since the rest area is currently closed there no electrical power to operate the fire pump.
Changes in the environment may cause direct and indirect impacts to ADOT roadways, structures or features specifically related to flooding, landslides, washouts etc. Our agency's emergency or urgent response likely require environmental compliance measures concurrently, or after the fact. the presence, absence or relative abundance of wildlife populations would be impacted either positively or negatively by climate change, and our compliance responses or requirements may change accordingly.
Since I put together the scope of a pavement preservation or climbing lane project, if climate change makes the pavement rut or underperform, we would need to suggest a better asphalt mix used, or do pavement preservation projects more often. If there are more mudslides or heavier rainfall/drainage, that would result in better/more drainage and better ways to protect the road from getting flooded (higher elevation, deeper banks/ditches, or use of barriers.
Heat – increases portion of year when certain maintenance work cannot be done. Air Quality – operate many stationary fossil engines that are regulated for emissions. Intense Precipitation – operate a system of pump stations that may be inadequate.
I am involved with traffic-related designs for construction projects. Any effect(s) on our pavement markings or on the need for more frequent projects due to adverse of effects of pavement durability could affect my job (designs), but I don't know that any of the current "impacts" are significant in this regard (maybe yes and maybe no).
A – Heat effects on asphalt also damage airfield pavements and access roads to airports. Shrinkage due to heat and exposure cause premature severe cracking in many airfield pavements. This is an increase maintenance expense for ADOT's pavement management program. Extreme heat may soften pavements to the point of airport closure – ie, Lake Havasu closes the airport at 120 degrees Fahrenheit because the asphalt is too soft for landing – aircraft loading would cause permanent damage to the pavement. B – Droughts – Extremely arid conditions reduce viability of erosion control vegetation, therefore potentially creating additional wildfire hazards, additional erosion control projects that involve other protection besides vegetation F – Intense Precipitation – Erosion damage repair and erosion control projects, retention system changes and expansions are needed at airports where intense precipitation has caused threats to the airfield safety. H – Wildfires – Wildfires impact airports by either burning the facility itself, or by use of the facility by heavy aircraft to fight the fire. Both these activities damage pavements, fire itself may also damage lighting, radio antennas, weather equipment, electrical vaults, and navigational aids. We at times need to fund projects to assist in repairs. An increase in wildfires may result in an increase of emergency projects of this type. I – Wildlife Habitat Loss – Loss of wildlife habitat due to wildfires, development, or drought, sometimes brings wildlife to live at or near airports. Airports often maintain their own drainage retention, vegetation for erosion control, and fencing. Some animals find the enclosed area with access to water and grass attractive. Especially where the traffic stays on the runway and the people stay in the buildings and airplanes. Unfortunately, wildlife can be a hazard at airports and removal of wildlife attractants, studies of wildlife at airports, and higher fencing to keep wildlife out of the airport are all additional grant projects for ADOT. For example, we have funded projects to repair damage done by gophers tunneling under pavements, projects for special studies to keep elk, antelope, and cows off of airfields, and many fencing projects to make the fence higher or stronger because 3' tall barbed wire was not sufficient.

Table 10. Question 5B Responses (Continued)

Responses
Transit helps to mitigate the effects of these impacts to the community. As emergency events increase, there is an increased demand on transit to help support the communities. They help evacuate communities and provide shelter when an emergency strikes on the road. The drivers are trained to deal with emergencies. Anything that impacts the roadways also impact the transit programs. Transit agencies frequently adjust and find safe alternatives in coordination with emergency management to events. We train our drivers to deal with emergencies and we train our managers to coordinate with safety and security personnel. In addition, increased transit use equates to decreased air pollutions and decreased congestion helping to mitigate these problems while moving people efficiently.
Examining culverts and all other drainage features of the roadway is a large focus of my job. A change in water flow one way or another will change the way I assess these assets.
As my job requires that I verify ADOT's compliance with environmental regulations and commitments, any element which increases the potential for and severity of environmental impact will impact how I proceed with my basic job duties.
The relevant factors listed in Question number 5 not only impact the end product quality in construction, but also the health risks involved with Roadway construction. Long-term exposure to heat and bad air cause fatigue, nausea, and heat stroke.
Most of the relevant answers will impact the quality of stormwater that is running off of our roadways and rights-of-way.
The warmer the climate the more wildlife will search for cooler climate. Slides and such will impact my travel by closing roads I must work on. I core roadways and dig test pits alongside existing roads. If the heat continues to rise not only will the surface temps affect my work, it will adversely affect me.
We are in Construction – what we do is roads, bridges, asphalt paving, repairing and maintaining safe drivable roads and traffic situations- IE all relevant to our work.
Long and short range planning for wildlife mitigation and infrastructure improvements has a definite potential to be impacted by climate change. This also applies to vegetation management. Both development and maintenance of native vegetation along our roadsides will be modified by climate change in significant ways. The introduction of invasive species is also an issue that will likely be modified by climate change.
"F" Beside what's listed above, we deal with many more potholes, for one example.
Climate effects everyone's job no matter what position a person holds in the work force. Driving to and from work is affected. Driving to lunch, doctor appointments, babysitter, etc. I am really not sure where you are going with this climate change issue.
as described..
I believe that things may be getting warmer for the intermediate term, but that a cooling trend is on the way. We need to plan for both but be flexible in our investments: don't sell all the snow plows, we will need them again.
Working in the pavement design area relevant responses will effect work load and design requirements. Other potential impacts would include placement dates for certain asphalt products(ACFC's,chip seals).
From dry summer heat pavement asphalt, we are getting lots of rubber tire tread coming off and littering roadways.
When we do environmental planning we look a a huge variety of issues and try to mitigate the effects of our projects. We need to understand the total environment we operate in and how this applies to the size of culverts, the length of the snowplowing and de-icing season, the impacts to wildlife and their habitat, the amount of debris likely to flow into our stormwater channels and detention basins, and the construction windows that may be modified by changing patterns of cold or hot seasons.
While these do not have a DIRECT effect on my position or the work I perform, any time the environment changes significantly, it affects performance and effectiveness of staff. Simply deciding to drive to work or take transit; costs related to driving; temperature within the building; need to remain indoors during smoke-filled days – these all affect performance and increase health risks which affect efficiency.
so good!
A survey based on the hypothesis, "There is a near consensus in the scientific community that the global climate is changing" will provide insights about people's perception about climate changes, but the results of an unproven hypothesis should only be used for social studies, not engineering decisions. I'm disappointed that the ADOT TRB is dabbling in social perceptions. If you are running out of things to do, why not update the approved product list that has been neglected for years. I am not ignoring climate changing data. I believe that the change is cyclical and not an out of control phenomena. Paul R. David
Any sort of project delays that result from weather issues not only prolong the construction process (and thus the inconvenience to the traveling public) but may also result in having to back up and repair something that has already been constructed. Depending on the type of event that caused the delay, there could be a significant financial burden then placed on the project or the contractor to complete repairs.
Desertification of reservation lands and resulting increase in incidence of dust storms along I-40 and other ADOT highways.

Table 10. Question 5B Responses (Continued)

Responses
All of the above, due to working in Central Materials Lab.
More rain means after hour work, cleaning roads so traffic can flow, fixing washouts, and erosion on sides of road.
Dust storms in Arizona affect my job.
Does not affect my job.
Since I work in highway construction, any of the above statements that affect the integrity of the road make it relevant to my job. Additionally, I usually volunteer to plow snow and assist maintenance with storm events. Thus changes are relevant to me for this reason also.
Washouts and flash floods do have an effect on the roadways in our area.
Changes in precipitation patterns and flooding can impact foundation design considerations. Loss of habitat could restrict our site investigation activities.
In my calculations of the costs and lifecycle of road features, certain aspects of climate change will impact the outcome.
Public transportation has received some major cuts lately due to the economy. Not having enough buses and public transportation opportunities would increase people's likelihood to drive by themselves and further degrade air quality. With the increased development, there will be more wildlife habitat loss as well as an increase in wildfires due to less natural erosion control measures such as forests and bushes. You left out dust storms which also effect the ecosystem.
Climate changes impact the projects we have scheduled across the state; which would cause an impact to the closing out of such projects for our department.
All of these issues are going to impact ADOT with an increased need for funding. Maintenance costs will increase. Things like wildfire and flooding will create greater erosion problems. This will result in more damage to infrastructure, increased maintenance to clean pipes, increased flooding due to clogged pipes. Wildlife will have to shift habitats due to damaged ecosystems, this will result in the potential need to put game fencing in areas not previously fenced that way. ADOT will need to design drainage systems (pipes, culverts etc.) to larger sizes to accommodate increased flows etc. etc. Maintenance will have more damage to respond to. ADOT will have to focus on being proactive when State's of Emergency are declared by the Governor or President. ADOT is getting better at taking advantage of funding created under these States of Emergency. Things like buffering erosion problems early after a fire by getting seeding established as part of the recovery effort is important. There are tons of iterations on how these things will impact ADOT. We simply need to be as proactive as possible rather than reactive.
I work at the GCNP Airport, a remote, forested area prone to lightning strikes and wildfires especially during drought. Additionally, there are many large and widely mobile wildlife species, ie elk, deer, coyote, mountain lion that would be driven into roadways and residential areas due to habitat reduction and fire. My current commute is short but I need to travel to Phoenix for meetings occasionally. The drive is near/through Flagstaff, a mountainous area that has suffered wildfire and subsequent erosion, flashfloods, and landslides onto roadways. And finally, over the two hundred highway miles to Phoenix there are many areas that are vulnerable to erosion, washout, and landslides.
"Relevant" responses apply to all "traffic," whether that's motor vehicle, pedestrian, or bicycle, while using a highway for purposes of travel
All "relevant" factors would require positive efforts to mitigate the negative effects indicated (i.e., greater effort on dust control, increased difficulty finding water sources, etc.)
Mitigation measures in environmental clearances may have to be revised to ensure compliance with NEPA in the face of climate change. To the extent that FHWA funds landscape as part of a project, they expect that landscape to have a good chance of survival. When no irrigation is provided such landscape with the expectation that "water harvesting" will provide sufficient water, then ADOT needs to know if the design and water calculations reflect our arid environment impacted by climate change. Right now we need better research to support this on transportation related projects and until we can get it to work better, we need to continue to include irrigation systems in FHWA funded projects.

Question 6: Existing Policies or Practices

Question 6 asked, "Does your department have any existing policies or practices that relate to responses or risk mitigation from extreme weather events or weather-related disruption (e.g., pavement design manual, flood risk management manual)?" The results are included in Figure 20.

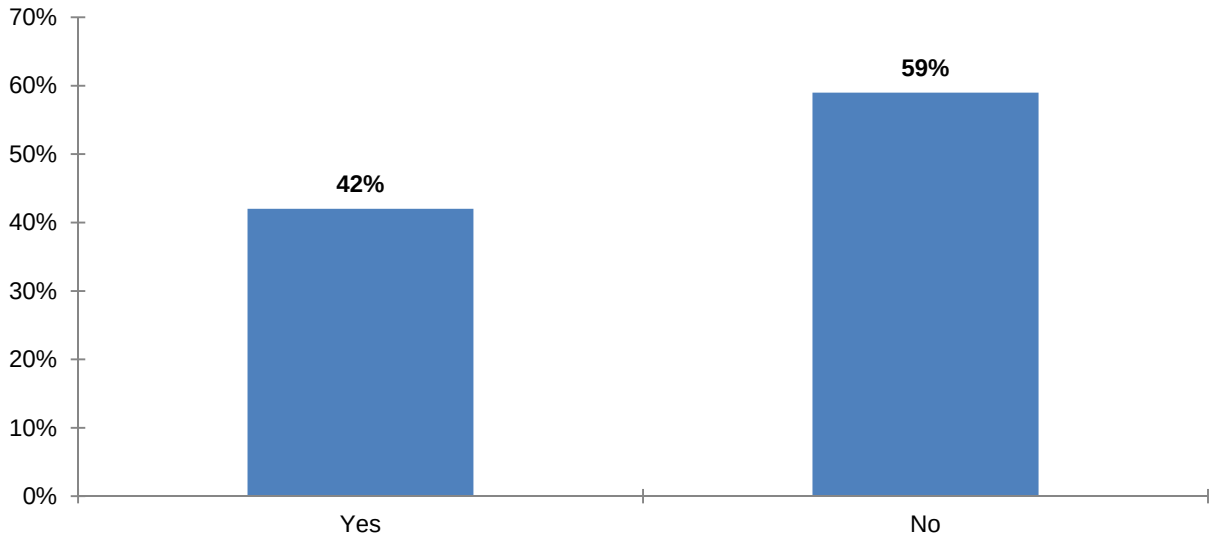


Figure 20. Question 6 Responses

Question 6B: Open-Ended Feedback

Respondents were given the opportunity to elaborate on any details related to Question 6. There were 94 responses to this question, included as entered into the survey in Table 11 below.

Table 11. Question 6B Responses

Responses
Unsure
I believe the department has ways of handling emergencies related to road closures and how to get the road open. This would be more on the maintenance side instead of construction.
I work in Right-of-way at the moment, which only deals with legality and not engineering technicality. But in the Roadway department, documents such as the pavement design manual definitely exist and most probably contain sections pertaining to weather related events.
If they have any, I am not aware of them.
In construction management we make sure the contractor provides us with a product, as called for in contract plans, derived from those policies.
Standard Specifications address “acts of god”
Training for flood mitigation
Continuation Of Operations Plan (COOP)
It goes over procedures on how to handle each event.
Again, I only do research on property, I have no input as to the use after acquisition.
There is no written policy but we expect to called upon once roadways are impacted by soil/rock conditions.
yes it probably does, but I am just a small cog in the larger gearworks of life.
Storm Water Pollution Plan in accordance with ADEQ mandates
I am not aware of any ADOT internal policies regarding a weather disruption for rural transit agencies. However, FTA has guidance in place regarding risk management if the transit agency is called to assist with evacuations during an emergency. Most of the rural transit providers have a policy or procedure in effect if they are called to assist during an emergency.
I am unaware of any policies regarding a response or a risk mitigation due to extreme weather. If it rains, we don’t build? I don’’t know
If so, I am not aware of them.
not that i know of...that doesn’t mean that they don’t exist.
We have the Winter Storm Manual; we respond in situations in winter when the bridge decks have the potential to freeze. Under such conditions, our department will apply Magnesium chloride to the deck in an anti-icing effort. We have general guidance from the herbicide labels of when weather is too extreme to apply (ex. when wind is greater than 10 mph)

Table 11. Question 6B Responses (Continued)

Responses
I don't know if we do; none have been brought to my attention but I don't necessarily know if that means they don't exist.
I am not aware of any references to long-term climate change in any design manuals. All hydrologic design parameters are related to historic events. There is no factor that I am aware of that would adjust design parameters in anticipation of more extreme events due to climate change.
I am not sure about this one.
The ADOT media team, as part of the Communication and Community Partnerships Division, has been heavily involved in the development of media campaigns on extreme weather events. This includes public awareness campaigns on winter weather driving and dust storms.
Not sure.
I am not aware of any such policies or practices, but can't really say there are none.
I don't know. That should be one of the choices.
I would imagine more, however dust mitigation, securing wells?
Selection of the design storm event for the drainage features of highways. Highway operations personnel (i.e., maintenance orgs) are on increased alerts and more frequent responses to damage from higher intensity storms.
We are a construction organization and subsequently resort to various construction guidance manuals.
Response to emergency repairs and safety of clients and personnel.
I am not aware of any policy or practices regarding your questions in our group.
Fed regulates,,,,
UPS systems at most signal.
best management practices for site drainage. using the most efficient HVAC systems and practices to save energy
ADOT Risk Management Office SWPPP – ADOT Erosion and Pollution Control Manual ADOT AZPDES Awareness Training Manual NHI – Soil Slope and Embankment Design Workbook
We issue snow equipment reports daily that let not only all of ADOT but also up to the Governors level know what percentage of snow removal equipment is ready to deploy.
I am unsure.
i don't know if we do, i assume not.
We respond to everything that affects public travel, it's what we do.
I don't believe we have any written policies, but in practice we pay attention to the weather, leave our work mobile phones on at all times (at least I do) and contact relevant district personnel (or vice versa) if things really go south. If it is an emergency, we will mobilize staff to the site immediately. Kind of like being on-call 24/7.
I'm not sure, but I think so.
It is a function of our division to provide information to the public about weather related impacts to highways, freeways, projects etc.
This is a qualified "yes" since I have not studied those manuals due to the nature of my work. Whatever known facts are at the time of releasing those publications, periodic modifications, due to availability of factual information, may be necessary.
I don't deal with the above items, but I am sure we have some.
I am not sure if there is any policies.
ADOT can allow a winter shut down if the contractor cannot do their controlling item(s) of work. This has to be requested by the contractor per our Standard Specifications.
Not applicable.
Our districts practices include post storm review of BMPs structures in our maintenance yards, along with the first priority (the roadway). This represents part of my job responsibilities.
I believe that we have some of these, but I have not used them in my position.
Project scheduling is effected by weather, so delays may need to be allowed. There have also been incidences of storm damage (for example to a runway) that necessitated the issuance of an emergency grant funds.
roadway design manual and pavement design manual are used in Roadway Predesign
I have a group that operates 70 pump stations in the Phoenix Maintenance District. This system is used to prevent flooding of our roadways when runoff reaches a certain value.
Yes, I think so, but I'm not aware of any specifics (other than SWPPP or Best Management Practices for stormwater runoff).
We train our transit agencies on emergency evacuations and coordination with safety and security personnel. The new law requires a safety and security plan be put into place by transit agencies. We also have policies in place about emergency evacuations. The communities can use the buses to support evacuations.
Storm water pollution prevention mitigation.
Building Maintenance regularly deals with extreme weather it is a normal part of the job

Table 11. Question 6B Responses (Continued)

Responses
Our current response platform is primarily based upon stormwater events. However, we are also moving towards inclusion in U.S. Forest Service BAER (Burned Area Emergency Response) Environmental Team activities, wildfires will assume a much bigger emphasis.
Nearly all construction projects are required to have a Stormwater Pollution Prevention Plan to identify and mitigate stormwater run-off in case of a weather occurrence.
not sure
I'm guessing they do have something in place. We do all have to take a federally mandated class from FEMA and it is my understanding that the upper level management has to take more.
No, but OES is involved with developing policies and practices for some of these issues – such as with air quality and dust control mitigation for recently increased dust storms due to drought and non-vegetated adjacent lands.
I'm sure we do, but in my length of time here (1 year) I'm not personally aware of where these stored, computer, hardcopy, etc.
only as emergency response procedures
in right-of-way we only see weather related issues as lrger drainage easements, etc.
Pavement Design Manual
Emergency Response to continue operations
Environmental planning and clearances can be concurrent with the design and implementation of emergency repairs for bridges, culverts, pavement damaged by storms or wildfires, or rockslides or mudslides.
Some of these items are covered in the standard emergency plan.
Implementation of dust storm warning system. Design sign support structures for higher wind speed.
Not that I'm aware of.
When we have weather related events, we respond to them as needed, flooding, or wrecks on the roads.
Unknown
I am not sure of a definite policy but I do get warning about weather related disruptions...(via e-mail or on my cell phone and that's not necessarily from my department)
I deal with Facilities and building related maintenance issues.
Snow plan
Pavement, roadway, drainage design manuals
I handle the construction Approved Products List, (APL), which is a neutral entity. Products MSDS' are reviewed by our Health & Safety section before being placed on the APL. Contractors may or may not use products on the APL and it is at their own risk.
I believe that these unexpected disruptions are covered under the State's and/or federal guidelines we are to follow.
Not that I'm aware of. This may be something to discuss with the maintenance and design folks. Talk to the Emergency Management Folks as well (Courtney Perrier-Bear). I have not seen an effective focus within maintenance on level of service in every program area. The completion of the Features Inventory System will likely evolve into more of an asset management system. ADOT needs to look at things holistically, by getting numerous key players involved from different disciplines and program areas. The concept of a team at ADOT focused on extreme weather events would be good.
The Airport has an emergency plan and practices for lightning strike, fire, runway animal removal, and runway flood management.
Not within construction. Maintenance/operations may have policies.
We review and process clearances and are not on the front line of dealing with these risks.
I'm uncertain of what guidance is available on the subject.
Emergency Planning and Management, Emergency Action Planning, Safety Policies – Hot work, Respiratory Protection, etc., Stormwater, Design, Facilities Improvement, and the Office of Environmental Services has a host of new policies underdevelopment – many would have applicability.
Online manuals and current policies relating to mitigation on risk.
Flagstaff District has been directed to work closely with our adjacent land stakeholders in response to emergencies. For instance, after the Schultz Fire it was our maintenance staff who coordinated with Coconino County and USFS to remove debris from our U.S. 89. Our district worked with FHWA for emergency funds to improve all of our shoulder drainages to relieve flooding.
On call maintenance and things of that nature.
It's not been an issue.
My department deals with all issue that effect the hwy systems.
More long term effects of these events
I'm sure there are existing policies and practices; I'm just not aware or fully familiar with them.
I do not know.

Table 11. Question 6B Responses (Continued)

Responses
Emergency response but not sure about other documents.
I do not have the time right now to look up the specific policies and procedures, but for those working on the highways, exposed to the elements, safety is a priority.
Not a present, environmental risk management policies are under development.

Question 7: Tools, Data, and Guidance

Question 7 asked, "What tools, data, guidance or other resources related to extreme weather or climate change do you wish you had to help inform your decision making activities? There were 133 open-ended responses, which are included in Table 12 below.

Table 12. Question 7 Responses

Responses
Unsure
None at the moment
More data collection
I wish we had a daily activity announcement that let people know how long they should be exposed to the heat during summer days that exceed 100 degrees.
Carbon emissions quantification related to proposed projects.
none.
Climate comparison from year to year
I'm not sure how to answer this honestly... Sounds a little broad. Sorry
Uncertain
I need to know more about the facts relating to air quality in downtown Phoenix. What is the air quality in our building (1801 W. Jefferson)? What health problems are associated with prolonged exposure to "bad" air? What can we do to protect our staff?
I am really not in the decision making process as an Office Manager. That would apply more to inspectors.
Temperature, precipitation, intensity of rainfall
RWIS cameras located throughout the state.
None I am aware of at this time.
To tell ADOT's narrative effectively, I will need to know what the various departments can do and what they are doing to adapt to climate change.
If there was some way our department could be a part of a weather alert system prior to a storm hitting that would help a ton. Currently we react to the storm when we instead could be planning for it.
Question 7 has no main verb. It seems to ask if I wish I had climate-change tools to help me decide things. I need no such tools, and I am not even sure I have climate change, based on just a few years of observations.
Don't need any
More precise and localized precipitation information.
snowshoes and a raincoat- the ability to have emergency facilities for people who end up stranded on the freeways during snowstorms, food, water, shelter type of assistance we could help with.
My position does not require I make managerial decisions
n/a
None that I can think of.
I believe that ADOT Rural Transit Managers should have a way of being notified if there is a significant risk in one of their areas due to fires or flooding. If a rural transit provider is asked to evacuate citizens from a threat, this information should be captured and reported in the ADOT Rural Transit Manager. FTA has funding available for reimbursement purposes when a transit agency utilizes their vehicles for something other than bus service. FTA can also provide insurance coverage that may not be available under the transit provider's normal coverage. If an e-mail notice was sent to the ADOT Rural Transit Manager that something was occurring in one of their areas, the ADOT Rural Transit Manager would know to follow up with the appropriate transit agency. We often learn of the occurrence after the fact.
Better access to the web in the field so when one of those haboobs are coming are way out on the job we know to get in our trucks and off the grade so we don't end up with to much sand in our pants, and probably lungs for that matter, not that jumping in a truck could really help with that.

Table 12. Question 7 Responses (Continued)

Responses
I would like to know that the building I work in would be monitored so that it would be comfortable on a regular basis regardless of the climate outside. This seems like a normal request.
The question has been raised how much we, as vegetation managers, are impacting an area hydraulically when we remove a stand of trees next to the roadside. In areas of already high water runoff from storms, knowing how much of a water sink we are removing per acre would help us assess the impact of the area.
I am not sure if there are any; however, my observation is that ADOT as a whole can do more to reduce its own "carbon footprint" and reduce the impacts we're having on the environment which, in turn, contribute to climate change.
Crystal Ball
Change the cooling system in our building. Currently we use a chiller on the first floor, and AC on the second floor. Sometimes the chiller does not work when it is hot and/or humid outside.
Improved 5-1-1 system for providing information about weather-related events to the agency's customers.
Planned ahead on activities and support the solar power for clean air and less chemicals from powerplants industry and minimize any excessive used on motors and any engine that create air pollutions.
Work from Home (July and August)
I would like to have clearer idea on ADOT's plans for addressing climate change.
Not sure
Long-range weather forecasts and updates on (or participation in studies to develop) pavement additives and designs to increase heat resistance.
It would be nice to have access to weather information in order to plan work activities.
No response
Not sure at this time.
None, because Climate Change or formerly Global Warming does not exist.
Does not affect my job at this time.
None I can adapt...
I don't have any idea
I think the only reason we are seeing "climate Change" is all the asphalt all the roads being built everywhere.
Do construction and signal activation during the summer time in the cool areas of the state and vice versa during the winter.
Media,
Reliable predictors on future climate for future equipment purchases.
Unsure
better forecasts and more up to date
we do testing on soils and asphalt production. we don't make policy or decisions. we follow policy and procedure.
Equipment (trucks, loaders, etc.) that were dependable & specified by us to meet our needs instead of the poorly designed cheap junk we now have. Data? As you already stated weather prediction is sketchy @ best & wouldn't supply us the equipment we need to respond to incidents.
A crystal ball.
Not sure
I do not have any direct interface with activities or software related to climate change. Earlier years, I was inspecting bridges subjected to fire or flood damage. However, I reported the damages and recommended repairs. Never asked to produce a document dealing with these problems since these were outside scope of work in my working unit. However, I know this kind of activity requires a team work of many areas such as climate predictive models, knowledge of statewide soil cover condition, knowledge of hydrologic basins, knowledge of geological formations and finally practical design methods to deal with problems. In general, computer software and skillful use of it is needed to augment a skillful presentation of facts and solutions. I have had a brief exposure to producing statewide water plan for Arizona during 1986-1989 in ADWR (Water Resources).
How change in weather will affect wildlife movement and connectivity throughout the state.
Effects of trip reduction / telecommuting efforts on air quality.
Managers who can make important decisions when called upon.
None
Occasional discussion, workshop, publications, Internet excess, policies and best practices.
a list of implementation efforts from other communities
We spend a lot of time checking the forecast, might be a day or 3 weeks to see if we can do a particular type of work like paving or pour a bridge deck.
Monthly temperature change records as opposed to ten years back.
None
A GIS person to facilitate mapping of projects, issues, misc. in my district would be helpful.

Table 12. Question 7 Responses (Continued)

Responses
not applicable
10-year, 20-year, and 30-year planning tools to see what extreme weather/climate change and results from that weather that could affect the design of the roadway. Since we do pavement preservation projects every 10-15 years, if we could somewhat accurately forecast/predict extreme weather/climate change just like we get traffic count forecasts, that would help build a better roadway that will last longer and require less to maintain and operate.
Better weather prediction models. Conversion of fossil engines to electric motors.
None (at this time... to the best of my knowledge).
Not really sure as it relates to transit. I do wish we focused on researching roadway infrastructure practices that would help mitigate the urban heat island effect. It's really noticeable in the Valley. However, that's not my area of expertise or practice. I do wish we had an economic calculator that shows the impact of transit on mitigating congestion. We do almost all of our modeling on a 24 hour scale, not peak hour. Transit is not useful at the 24 hour level, instead it's best impact is at the peak hour timeframe. It would be nice to have an something that shows the benefits in a way that translates well to the public. As it relates to climate change, the greatest times of emissions correlate to peak hours as well. So showing the how transit mitigates the effect of peak hour traffic, while marginal, would be a nice tool.
A regularly scheduled newsletter.
n/a
Guidance from administration on what to consider, i.e., do we design to mitigate the heat island effect, what should our goal be, are we willing to accept increased cost to accomplish change?
Future climate models of Arizona
How extreme weather and climate change are going to affect current biotic communities, mainly vegetation along our roadways and how to best maintain our natural plant species during these changes.
Improved access to GIS tools and involvement in department wide planning activities.
do not know at this time
A central web page, etc., that explains where and when these conditions will impact my work load.
What to do in the event of a weather emergency is always a nice tool. Daily weather reports and the expected forcast for the week on our web would be nice to see.
Additional research with models to predict vegetation or biotic community changes and invasive species mapping would assist in roadside vegetation management and wildlife management near our ADOT highways. Any research showing trends in climate change specific to Arizona or the SW.
N/A
I would like to have a heart to heart with Mother Nature to get the inside scoop on what she is going to do in the short term, next 5 yrs, and in the long term, next 40 years.
Not sure
More accurate long term (6 month) forecasts for winter. This would allow us to better prepare for winter storms.
unsure
Global data updates
A longer term look at weather change historically. Greenland had been inhabited and farmed 300 years ago and is now farmable again. We need to dispense with the hysteria and look long term to realize that swings in climate is inevitable and normal.
uncertain
We are located in a rural area we need faster news update on weather. Maybe through e-mail.
Environmental data – both plant and animal
n/a
good question – I had not thought about it. We are a reactive program in ADOT EPG, not a proactive one.
Sometimes agreement scopes contain work that may be affected by environmental concerns. There should be an information location that provides generalized recommendations regarding each of those focus areas you mentioned to make sure those concerns are included in proposal or agreement scopes (e.g., wildlife issues; pavement issues, etc.)
not sure
I wish I had a meteorological database from 5000 B.C to 1880 A.D. to assist in determining whether global climate change is cyclical in nature or an unprecedented linear event.
A crystal ball.:o) There are times when projects that are awarded in the fall can start and complete due to a mild winter while other times project have to go directly into "winter shutdown" due to early snows. The opposite can be the case in the spring. Sometimes a project can start in March while other years nothing can happen until May due to the snow.
none

Table 12. Question 7 Responses (Continued)

Responses
Currently none.
As stated in Q 6,, early warning via cell phone and or e-mails may help.
Education and information about climate change.
Not applicable
Anemometers

Question 8: Interest in Focus Group

Question 8 stated, "If you are willing to participate in an interview or focus group regarding your job function and how it might be affected from to the climate impacts described in this survey, please provide you phone number or e-mail below. Interviews will last approximately 30 minutes and likely take place in September."

About 71 responses were received for this question.

APPENDIX D. INTERVIEW AND FOCUS GROUP MATERIALS

The ADOT Research Center has begun a research effort related to the adaptation of the transportation system to the effects of climate change. The project, led by Cambridge Systematics, includes a TAC representing ADOT staff from multiple disciplines.

A survey was sent out to all staff on August 16, 2012, with 255 returned completed responses. We have selected a subset of respondents as potential participants in a series of focus groups to provide more insight into the institutional context for adaptation planning at ADOT. This will help us better understand the perspectives of key ADOT staff, and help us identify recommendations for an ADOT climate adaptation action plan and research agenda. The focus groups are planned for September 24 and September 25, 2012.

The purpose of conducting the focus group interviews is to achieve the following outcomes:

- Identify ADOT's relevant guidelines and specifications where climate impacts may modify design or operational thresholds;
- Continue to refine the "Knowledge Map" by understanding how key individuals within ADOT with decision making authority might incorporate climate change adaptation into planning, design, and operations in their precise job functions;
- Map out relationships between departments specific to investment decision making and functions where collaboration is sufficient, as well as where it could be improved; and
- Brainstorm existing and potential tools, data, guidance, or other resources related to extreme weather or climate change that individuals wished they had to help inform decision making activities.

We have invited those who indicated interest on the initial survey to participate in these focus groups based on their areas of interest and survey responses.

Finally, the results of this survey will be summarized and included in a final research report, providing an important first step in defining ADOT's consideration of climate change effects in its current and future operations.

The focus groups will be held in the Engineering Building: 205 South 17th Avenue, Phoenix, AZ 85007 in the Right-of-Way Large Conference Room, Third Floor Room# 301, Engineering Building.

FOCUS GROUP SCHEDULE (SEPTEMBER 24 TO 25, 2012)

We are planning four focus groups on the first day which will center on ADOT responses to specific climate impacts, and four focus groups on the second day which will center on ADOT processes for managing climate adaptation. Ideally, each focus group will have from three to eight participants in order to provoke a lively discussion.

On Day 1, the objective will be on how ADOT staff currently responds to current extreme weather events and what might be done for potential climate impacts. Many of you have responded with your expertise on how you currently approach extreme weather events today.

The last session is a broad discussion of ADOT's management structure and figuring how climate adaptation might be best incorporated into the current organizational chart. Table 13 shows the outline of the planned focus group and theme. The time proposed may be modified based on participant availability.

Table 13. Focus Groups on Monday, September 24, 2012

Time	Workshop
8:30 a.m-10:00 a.m.	1A: Climate Impact Focus on Heat, Droughts and Heat Island Effects
10:30 a.m-12:00 p.m.	1B: Climate Impact Focus on Intense Precipitation, Snowmelt, Late-Season Snowpack
1:30 p.m.-3:00p.m.	1C: Climate Impact Focus on Wildfires, Air Quality and Wildlife Habitat Loss
3:30p.m.-5:00p.m.	1D: Process Organization and Communication – Where in the Organization Can We Think about Climate Adaptation and How Do we Communicate it?

On Day 2, the objective will be to examine the key elements of climate adaptation planning, which include the following areas:

- Compilation of asset inventories and identifying critical infrastructure;
- Assessments on vulnerability and risk, including thresholds for weather-related damage and deterioration;
- A layered plan of adaptation responses, including planning, design/engineering, and operations/maintenance strategies; and
- Prioritization and funding of adaptation projects, as well as measurement, monitoring, and program reassessment.

Due to significant interest in a few topic areas, we set aside time for an additional "Process Organization" session, as well as two "Response Planning" focus groups on Day 2. We will determine whether or not we will hold all sessions listed below later this week.

Table 14. Focus Groups on Tuesday, September 25, 2012

Time	Workshop
8:30 a.m.-10:00 a.m.	2A: Asset Inventories, Vulnerability and Risk Assessments, and Prioritization and Funding of Adaptation Projects
10:30 a.m.-12:00 p.m.	2B: Process Organization and Communication – Where in the Organization Can We Think about Climate Adaptation and How Do we Communicate it?
1:30 p.m.-3:00 p.m.	2C: Response Planning for Adaptation – including Planning, Design-Engineering, Operations-Maintenance Strategies
3:30 p.m.-5:00 p.m.	2D: Response Planning for Adaptation – including Planning, Design-Engineering, Operations-Maintenance Strategies

We welcome your participation in any of the sessions, as well as suggestions for key ADOT staff members with whom we should speak; either as participants in the focus groups or via individual interviews.

FOCUS GROUP SIGN-IN SHEET

Title	Group
Electrical Operations Engineer	1A
NEPA Planner	1A
Development Engineer	1B
Central Region Environmental Compliance Evaluator	1B
Assistant Communication Director	1B
Environmental Planning Group Manager	1B
Biology Team Lead	1B
Budget Analyst	2A
Senior Transportation Planner	2C
Creative Services Project Manager	2C
Community Relations Officer	2D
Environmental Planner	Several
Project Manager, ADOT Research	Several
Arizona State Land Department Representation	Several

INTERVIEW GUIDE

1A: Climate Impact Focus on Heat, Droughts, and Heat Island Effects

The purpose of this research effort is to help ADOT become more resilient, flexible, and responsive to climate change effects. To date, we have completed the first two steps of our research process. Step 1 was a review of the current literature relating to climate change effects on the transportation system, tailored to Arizona's climate region. Our second step, in which many of you participated, included the administration of an online survey questionnaire. We sent this questionnaire to ADOT staff and received 300 survey responses. The questionnaire responses provided us with valuable baseline information about ADOT staff's knowledge about climate change and their perspectives on climate change impacts in relation to their job roles. These interviews are the third step in our process, and we hope to gain more in-depth knowledge about ADOT as an organization and the relationships between departments. Additionally, we would like to learn more about your roles at ADOT and your perspectives on climate change and how this research effort might be helpful to you.

We would like to cover three main topics in this interview.

- Identify ADOT's relevant guidelines and specifications where climate impacts may modify design or operational thresholds;
- Understand the process of climate adaptation as per best practices today, and how your function at ADOT can fit;
- Brainstorm existing and potential tools, data, guidance, or other resources related to extreme weather or climate change that individuals wished they had to help inform decision making activities.

General Overview Questions – Warm Up (10 minutes)

1. In the on-line survey questionnaire which you filled out, we asked respondents about their perspectives on climate change. Do you think that climate change is affecting the desert southwest? If so, how?
2. How important is it for ADOT to prepare for future impacts of climate change?

Relevant Guidelines and Standards Related to Heat Impacts (20 minutes)

Let's walk through the heat impacts that we developed from the climate impacts matrix.

1. What are the impacts that you see in Arizona. Discuss any specification or guidelines that currently deal with extreme weather (heat, drought, etc). Can you foresee the changing of any design or operational thresholds based on changing temperature?

Process of Climate Adaptation at ADOT (20 minutes)

2. Could you provide an example of how ADOT has implemented an agency-wide effort (e.g., internal strategic plan, etc.)? What steps were involved?
3. What might persuade you or encourage you to plan for climate adaptation within your current work processes? Are there any existing barriers that would dissuade you from planning for climate adaptation?

Potential Tools, Resources and Areas for Further Research (10 minutes)

1. Are there any recent agency-wide events or information the project team should be aware of that could affect an internal ADOT effort to discuss and begin to incorporate the topic of climate change into the agency's work?
2. What forums are available within ADOT for voicing concern about topics, such as climate change or for suggesting changes to departmental procedures?
3. This is a preliminary study that outlines future research needs and areas of exploration. What are the areas within your area of expertise where you think there should be more research, knowledge dissemination, or awareness within ADOT?

Finally, if participants think of additional information that would be helpful to this process, they will be given an opportunity to e-mail Cambridge Systematics for a designated period of time following the focus groups, most likely one to two weeks.

1B: Climate Impact Focus on Intense Precipitation, Snowmelt, Late-Season Snowpack, (and possibly Wildfires, Air Quality and Wildlife Habitat Loss)

The purpose of this research effort is to help ADOT become more resilient, flexible, and responsive to climate change effects. To date, we have completed the first two steps of our research process. Step 1 was a review of the current literature relating to climate change effects on the transportation system, tailored to Arizona's climate region. Our second step, in which many of you participated, included the administration of an on-line survey questionnaire. We sent this questionnaire to ADOT staff and received 300 survey responses. The questionnaire

responses provided us with valuable baseline information about ADOT staff's knowledge about climate change and their perspectives on climate change impacts in relation to their job roles. These interviews are the third step in our process, and we hope to gain more in-depth knowledge about ADOT as an organization and the relationships between departments. Additionally, we would like to learn more about your roles at ADOT and your perspectives on climate change and how this research effort might be helpful to you.

We would like to cover three main topics in this interview:

- Identify ADOT's relevant guidelines and specifications where climate impacts may modify design or operational thresholds;
- Understand the process of climate adaptation as per best practices today, and how your function at ADOT can fit;
- Brainstorm existing and potential tools, data, guidance, or other resources related to extreme weather or climate change that individuals wished they had to help inform decision making activities.

General Overview Questions – Warm Up (10 minutes)

1. In the on-line survey questionnaire which you filled out, we asked respondents about their perspectives on climate change. Do you think that climate change is affecting the desert Southwest? If so, how?
2. How important is it for ADOT to prepare for future impacts of climate change?

Relevant Guidelines and Standards Related to Precipitation and Other Climate Impacts (20 minutes)

Let's walk through the climate impacts that we developed from the climate impacts matrix.

1. What are the impacts that you see in Arizona. Discuss any specification or guidelines that currently deal with extreme weather (precipitation, snowpack, etc). Can you foresee the changing of any design or operational thresholds based on changing precipitation?

Process of Climate Adaptation at ADOT (20 minutes)

2. Could you provide an example of how ADOT has implemented an agency-wide effort (e.g., internal strategic plan, etc.)? What steps were involved?
3. What might persuade you or encourage you to plan for climate adaptation within your current work processes? Are there any existing barriers that would dissuade you from planning for climate adaptation?

Potential Tools, Resources and Areas for Further Research (10 minutes)

4. Are there any recent agency-wide events or information the project team should be aware of that could affect an internal ADOT effort to discuss and begin to incorporate the topic of climate change into the agency's work?
5. What forums are available within ADOT for voicing concern about topics, such as climate change or for suggesting changes to departmental procedures?

6. This is a preliminary study that outlines future research needs and areas of exploration. What are the areas within your area of expertise where you think there should be more research, knowledge dissemination, or awareness within ADOT?

Finally, if participants think of additional information that would be helpful to this process, they will be given an opportunity to e-mail Cambridge Systematics for a designated period of time following the focus groups, most likely one to two weeks.

1D: Process Organization and Communication: Where in the Organization Can We Think about Climate Adaptation and How do we Communicate it?

The purpose of this research effort is to help ADOT become more resilient, flexible, and responsive to climate change effects. To date, we have completed the first two steps of our research process. Step 1 was a review of the current literature relating to climate change effects on the transportation system, tailored to Arizona's climate region. Our second step, in which many of you participated, included the administration of an on-line survey questionnaire. We sent this questionnaire to ADOT staff and received 300 survey responses. The questionnaire responses provided us with valuable baseline information about ADOT staff's knowledge about climate change and their perspectives on climate change impacts in relation to their job roles. These interviews are the third step in our process, and we hope to gain more in-depth knowledge about ADOT as an organization and the relationships between departments. Additionally, we would like to learn more about your roles at ADOT and your perspectives on climate change and how this research effort might be helpful to you.

We would like to cover three main topics in this interview:

- Identify ADOT's organizational chart and communicating climate adaptation internally and externally;
- Understand the process of climate adaptation as per best practices today, and how your function at ADOT can fit;
- Brainstorm existing and potential tools, data, guidance, or other resources related to extreme weather or climate change that individuals wished they had to help inform decision making activities.

General Overview Questions – Warm Up (10 minutes)

1. In the on-line survey questionnaire which you filled out, we asked respondents about their perspectives on climate change. Do you think that climate change is affecting the desert Southwest? If so, how?
2. How important is it for ADOT to prepare for future impacts of climate change?

Communicating Climate Adaptation Within and Outside of ADOT (20 minutes)

Let's walk through the organizational chart and responsibilities assigned within ADOT.

3. How receptive is ADOT staff with issues of risk management and extreme weather vulnerability. Can this be extended to think about climate impacts? How?

4. Which departments typically manage different aspects of planning, engineering, design, and decision making? Can you give an example of an interdisciplinary action or policy that was successful? How did it achieve success?
5. What type of leadership is useful in thinking through risk management within ADOT?

Process of Climate Adaptation at ADOT (20 minutes)

1. Could you provide an example of how ADOT has implemented an agency-wide effort (e.g., internal strategic plan, etc.)? What steps were involved?
2. What might persuade you or encourage you to plan for climate adaptation within your current work processes? Are there any existing barriers that would dissuade you from planning for climate adaptation?

Potential Tools, Resources and Areas for Further Research (10 minutes)

3. Are there any recent agency-wide events or information the project team should be aware of that could affect an internal ADOT effort to discuss and begin to incorporate the topic of climate change into the agency's work?
4. What forums are available within ADOT for voicing concern about topics, such as climate change or for suggesting changes to departmental procedures?
5. This is a preliminary study that outlines future research needs and areas of exploration. What are the areas within your area of expertise where you think there should be more research, knowledge dissemination, or awareness within ADOT?

Finally, if participants think of additional information that would be helpful to this process, they will be given an opportunity to e-mail Cambridge Systematics for a designated period of time following the focus groups, most likely one to two weeks.

2A: ASSET INVENTORIES, VULNERABILITY AND RISK ASSESSMENT, AND PRIORITIZATION AND FUNDING OF ADAPTATION PROJECTS

The purpose of this research effort is to help ADOT become more resilient, flexible, and responsive to climate change effects. To date, we have completed the first two steps of our research process. Step 1 was a review of the current literature relating to climate change effects on the transportation system, tailored to Arizona's climate region. Our second step, in which many of you participated, included the administration of an on-line survey questionnaire. We sent this questionnaire to ADOT staff and received 300 survey responses. The questionnaire responses provided us with valuable baseline information about ADOT staff's knowledge about climate change and their perspectives on climate change impacts in relation to their job roles. These interviews are the third step in our process, and we hope to gain more in-depth knowledge about ADOT as an organization and the relationships between departments. Additionally, we would like to learn more about your roles at ADOT and your perspectives on climate change and how this research effort might be helpful to you.

We would like to cover three main topics in this interview:

- Explore ADOT's experience with asset inventories, vulnerability assessments, and risk assessments;
- Identify and prioritize specific adaptation projects that could be developed based on key critical assets, and determine whether there might be federal or state sources of funding;
- Brainstorm existing and potential tools, data, guidance, or other resources related to extreme weather or climate change that individuals wished they had to help inform decision making activities.

General Overview Questions – Warm Up (10 minutes)

1. In the on-line survey questionnaire which you filled out, we asked respondents about their perspectives on climate change. Do you think that climate change is affecting the desert Southwest? If so, how?
2. How important is it for ADOT to prepare for future impacts of climate change?

Asset Inventories, Vulnerability and Risk Assessments (20 minutes)

1. The first step in assessing climate vulnerability on the State's transportation assets is first compiling asset inventories and identifying critical infrastructure. Explore the interviewee's role in this aspect of climate adaptation.
2. Developing a climate adaptation action plans requires performing vulnerability and risk assessments, which include thresholds for weather-related damage and deterioration.

Explore the interviewee's role in this aspect of climate adaptation.

Adaptation Projects, and The Identification of Prioritization and Funding (20 min)

1. There are a layered plan of adaptation responses, which include planning, design/engineering and operations/maintenance strategies. Explore the interviewee's role in this aspect of climate adaptation.
2. The agency will have to prioritize and allocate funding for adaptation projects, as well as continue to measure, monitoring, and reassess the program.

Explore the interviewee's role in this aspect of climate adaptation.

Potential Tools, Resources and Areas for Further Research (10 minutes)

3. Are there any recent agency-wide events or information the project team should be aware of that could affect an internal ADOT effort to discuss and begin to incorporate the topic of climate change into the agency's work?
4. What forums are available within ADOT for voicing concern about topics, such as climate change or for suggesting changes to departmental procedures?
5. This is a preliminary study that outlines future research needs and areas of exploration. What are the areas within your area of expertise where you think there should be more research, knowledge dissemination, or awareness within ADOT?

Finally, if participants think of additional information that would be helpful to this process, they will be given an opportunity to e-mail Cambridge Systematics for a designated period of time following the focus groups, most likely one to two weeks.

2C: COMMUNICATIONS AND RESPONSE PLANNING FOR ADAPTATION STRATEGIES

The purpose of this research effort is to help ADOT become more resilient, flexible, and responsive to climate change effects. To date, we have completed the first two steps of our research process. Step 1 was a review of the current literature relating to climate change effects on the transportation system, tailored to Arizona's climate region. Our second step, in which many of you participated, included the administration of an on-line survey questionnaire. We sent this questionnaire to ADOT staff and received 300 survey responses. The questionnaire responses provided us with valuable baseline information about ADOT staff's knowledge about climate change and their perspectives on climate change impacts in relation to their job roles. These interviews are the third step in our process, and we hope to gain more in-depth knowledge about ADOT as an organization and the relationships between departments. Additionally, we would like to learn more about your roles at ADOT and your perspectives on climate change and how this research effort might be helpful to you.

We would like to cover three main topics in this interview:

- Identify ADOT's organizational chart and communicating climate adaptation internally and externally;
- Explore the layered plan of adaptation responses, which include planning, design/engineering and operations/maintenance strategies.
- Brainstorm existing and potential tools, data, guidance, or other resources related to extreme weather or climate change that individuals wished they had to help inform decision making activities.

General Overview Questions – Warm Up (10 minutes)

1. In the on-line survey questionnaire which you filled out, we asked respondents about their perspectives on climate change. Do you think that climate change is affecting the desert Southwest? If so, how?
2. How important is it for ADOT to prepare for future impacts of climate change?

Communicating Climate Adaptation Within and Outside of ADOT (20 minutes)

Let's walk through the organizational chart and responsibilities assigned within ADOT.

1. How receptive is ADOT staff with issues of risk management and extreme weather vulnerability. Can this be extended to think about climate impacts? How?
2. Which departments typically manage different aspects of planning, engineering, design, and decision making? Can you give an example of an interdisciplinary action or policy that was successful? How did it achieve success?
3. What type of leadership is useful in thinking through risk management within ADOT?

Potential Tools, Resources and Areas for Further Research (10 min)

4. Are there any recent agency-wide events or information the project team should be aware of that could affect an internal ADOT effort to discuss and begin to incorporate the topic of climate change into the agency's work?
5. What forums are available within ADOT for voicing concern about topics, such as climate change or for suggesting changes to departmental procedures?
6. This is a preliminary study that outlines future research needs and areas of exploration. What are the areas within your area of expertise where you think there should be more research, knowledge dissemination, or awareness within ADOT?

Finally, if participants think of additional information that would be helpful to this process, they will be given an opportunity to e-mail Cambridge Systematics for a designated period of time following the focus groups, most likely one to two weeks.