

Maintenance and Operations Resilience: Improving System Management and Performance During Adverse and Extreme Weather



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Webinar**

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Arizona Asset Universe

Arizona

140,000 maintenance lane miles

7,800 bridges

1 International border

Arizona Department of Transportation

30,000 maintenance lane miles connecting those 140,000

4,700 bridges

10 maintenance and construction districts

1,500 facility buildings

Spread over 114,000 square miles

Our assets operate from sea level to 8,000 feet

Temperatures below 0°F to over 120°F

Arizona Department of Transportation

- **Weather related process identification**
- **Risk-based approach development**
- **Assessing resilience and strategy identification**
- **Maintenance and operations extreme weather projects underway**
- **Performance measures, continuous improvement and incident specific knowledge development**

Extreme Weather Process Identification

- **ADOT's 2013 CAFR reflects \$19.3b in book value/capital assets.**
- **Replacement costs of those assets would be multiple times that in today's dollars.**
- **Current drought event in the Southwestern United States is ranked as one of the top five (5) strongest historically.**

Williams, Park A. et al. 2012 Los Alamos Labs

- **Current national drought has contributed to over \$30b in damages and affected over 80% of the Nation's 3,143 counties.**

Smith, Adam B. and Richard W. Katz. 2013 NOAA

- **ADOT assets are vulnerable to increased surface temperatures, sudden increased precipitation, wildfire induced flooding, severe erosion, drought-related dust storms and slope failures.**

Impacts



Impacts



Impacts



Extreme Weather Process Identification

2012

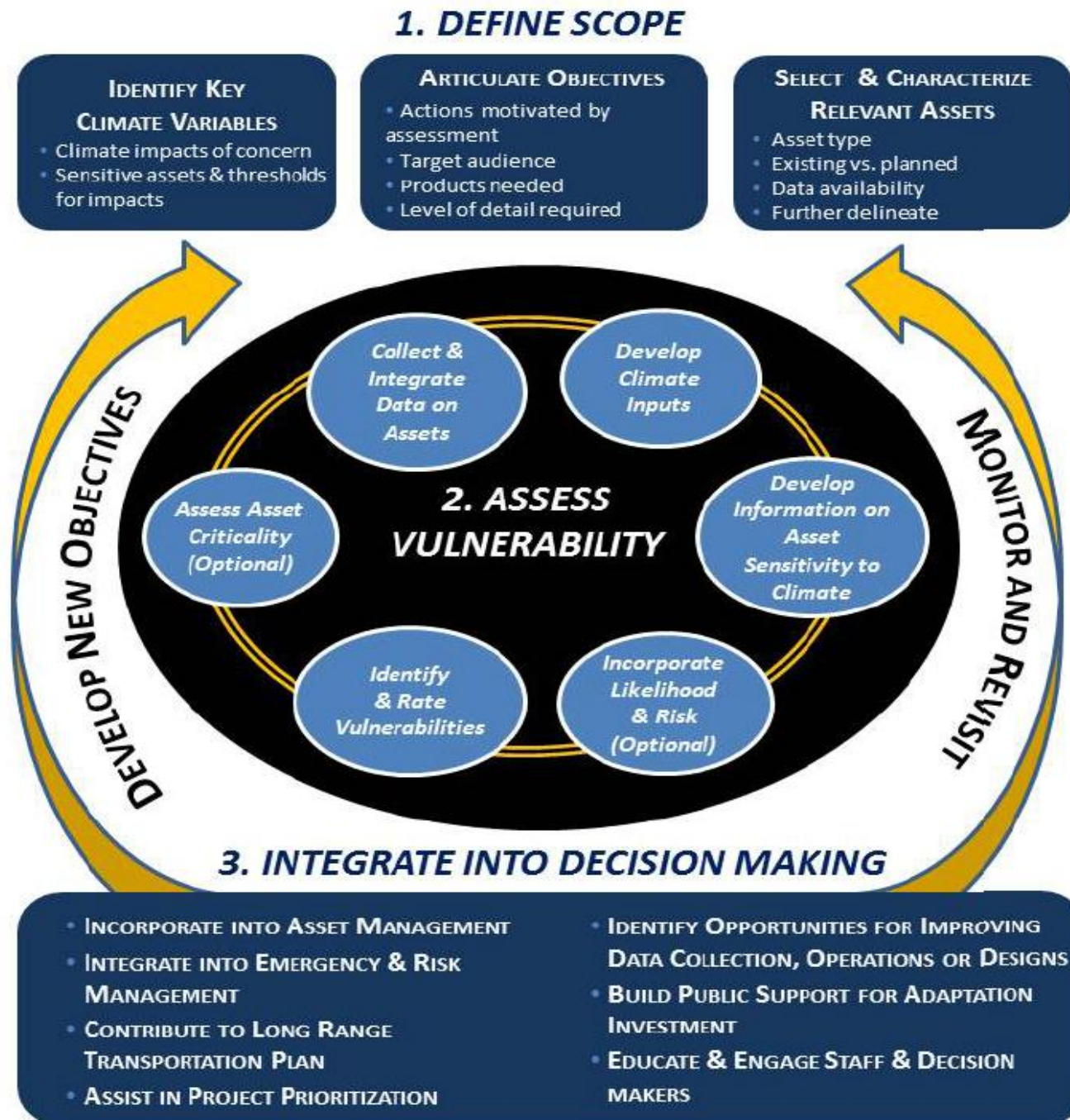
Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona FHWA-AZ-13-696

Integrating Extreme Weather Risk into Transportation Asset Management AASHTO - Mike Myers et al

Climate Change & Extreme Weather Vulnerability Assessment Framework FHWA

One of our goals was to move beyond a preliminary assessment and find ways to bring the lessons learned to the forefront.

Framework



Risk-based Approach

2013

ADOT moved to tap into the national dialogue on adaptation, peer exchanges, technical expertise and potential funding.

Risk-Based Adaptation Frameworks . . . A Synthesis of Practice

TRB Transportation Research Circular E-C181

National Symposium: Impacts of Extreme Weather Events on Transportation – Washington D.C.

Jennifer Toth - ADOT's State Engineer State Engineer & Deputy Director for Transportation measurably increases motorist safety initiatives <http://www.pullasidestayalive.org/>

Extreme Weather Risk-based Approach

2014

\$250,000 FHWA/ADOT pilot effort to assess the vulnerability of critical infrastructure to extreme weather for the major Arizona highway corridor (I-19, I-10, and I-17 Nogales to Flagstaff)

Objectives

- **Integrate infrastructure data, stakeholder input, reasonable defensible long-term climate models**
- **Contribute to the national adaptation process and enhance the FHWA Vulnerability Assessment Framework**
- **Develop risk models for multiple ecoregions/ecosystems**
- **Develop joint agency adaptation strategies**

Extreme Weather Stressors

2014 FHWA Extreme Weather Vulnerability Assessment

Further complicated by elevations, eco-regions and how structures would respond to current and future events. The objective of the FHWA assessment was to identify and characterize key extreme weather vulnerability hotspots.

- Heat extremes
- Change in frequency of freeze-thaw cycles
- Change in the amount of snow/winter precipitation
- Wildfire
- Flooding
- Landslides/rockfall/slope failure

Extreme Weather Potential Effects

2014 FHWA Extreme Weather Vulnerability Assessment Stressor considerations on infrastructure/future design criteria

- **Shortened pavement life (heat, freeze-thaw, snow plowing)**
- **Culverts - design capacity, maintenance frequency**
- **Bridges - design capacity, maintenance frequency**
- **Roadside erosion**
- **Road closures from flooding/fire/rockfall/dust/low water crossings**
- **Shifting periods for paving operations**
- **Winter storm maintenance costs**
- **Storm drain design**
- **Other**

Vulnerability Assessment Data Sets

- **Transportation Infrastructure Assets (ADOT)**
 - Feature Inventory System
 - Bridge Rating System
 - Highway Performance Monitoring System
 - Culvert capacity data
 - Roadside vegetation, stabilization, habitat
- **Climate data and models**
 - Land cover
 - Hydrological modeling
 - Coupled Model Intercomparison Project Phase 5 (CMIP5)
 - Dust storm models
- **Criticality**
 - Economic importance
 - Transportation alternatives

Processing CMIP5 Climate Data

- **Original Approach:** Use FHWA CMIP Processing tool. BUT, processing downscaled CMIP5 daily climate projections at high spatial resolution over large study area would be extremely labor intensive.
- **Modified approach:** Developed custom script to batch process and map CMIP downloads
- Tool aggregates data into transportation-relevant statistics (including those from original CMIP Processing Tool)
- Additionally fits generalized extreme value (GEV) distributions for extreme rainfall events (1% and 2% chance)

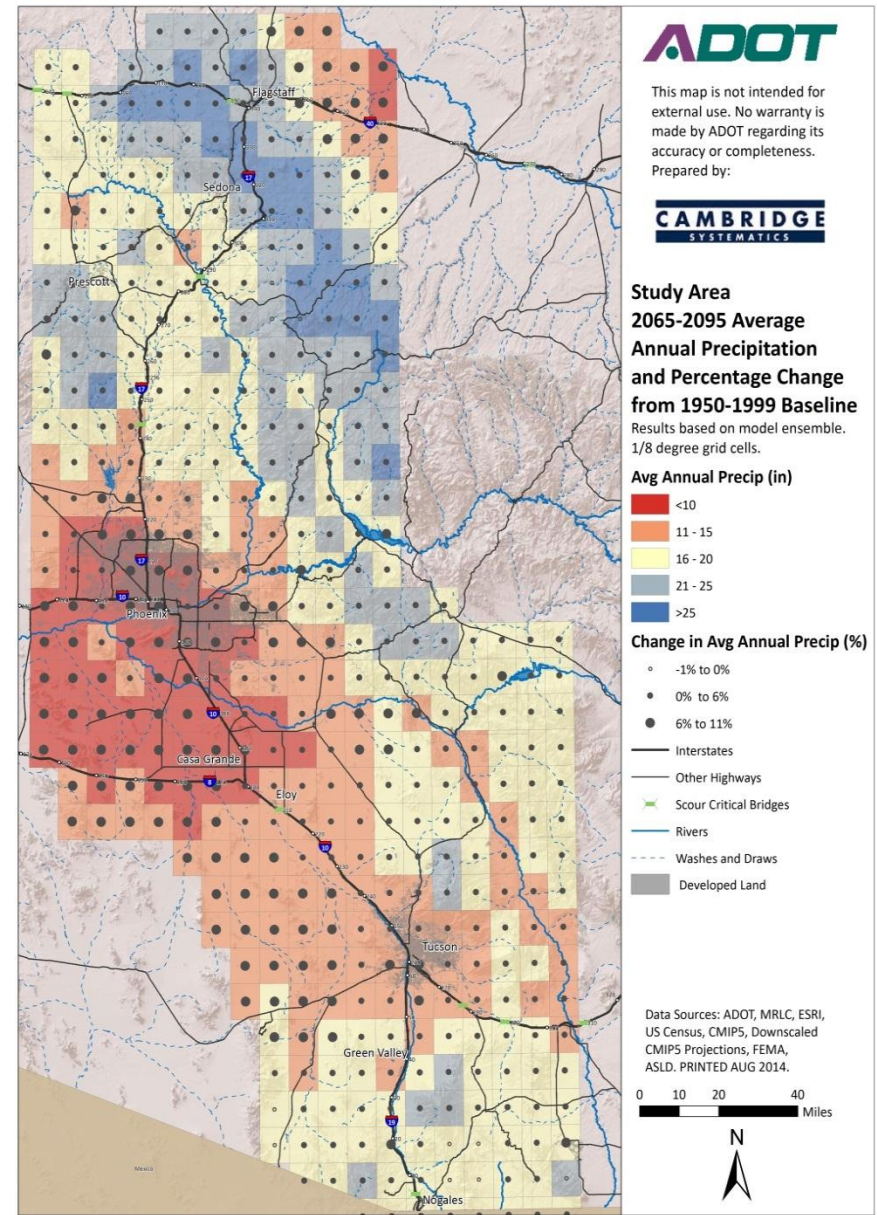


Image credit: Cambridge Systematics

Lessons Learned

- **More confidence in climate temperature projections than in the precipitation projections – need to focus on extrapolating historical precipitation data for now**
- **Precipitation seasonality modeling difficult – ADWR**
- **CMIP processing experience had a host of lessons learned**
- **Determining appropriate Representative Concentration Pathways – ADOT primarily concerned with extreme impacts**
- **Natural climate variability representation – what metrics to use – currently looking at climatology, atmospheric variability, surface temps, historic precipitation data**
- **Address bias implications for the precipitation data but also Pacific sea surface temps. (i.e. ENSO)**

Lessons Learned

- **Gather something more than just 24-hr maximum precipitation event numbers – scale up to address erosion, sediment, scour, run-off, flooding, man-made structures**
- **Internal guidelines development to allow implementation into construction contracts regarding this material - specifically the higher risk drainage structures and system pinch points**
- **ADOT effort addresses unique component of ecoregions and biotic communities impacts as our corridor study covers about sea level to 6000'**
- **Currently looking at 3 ecoregions and 8 biotic communities – 5 of which intersect our corridor study**
- **Watershed – Complementary USGS/ADOT partnering project under development**

Developing a Risk-based Approach

The challenge – Continue considering the balance between predictable asset deterioration curves, the sudden and unpredictable nature of extreme weather events and long term climate trends and new models for life cycle cost analysis.

- **Develop asset subsets that reflect an accurate picture**
- **Identify and evaluate relevant asset/maintenance datasets**
- **Assess availability and accuracy of spatial information on assets**
- **Collect data that is necessary to scope and objectives**
- **Engage local experts on data gaps**
- **Develop clear data management strategy**

Developing a Risk-based Approach

ADOT chose drainage/hydraulics to develop an initial set of risk-based approaches to address three areas of need:

- **Extreme weather maintenance and operations resilience benefits**
- **Transportation asset management requirements (MAP-21 TAMP)**
- **Contribute to the Agency's Five (5) Strategic Focus Areas through advanced risk-based analysis and life cycle cost models:**
 - **Safety**
 - **Financial Resources**
 - **Innovation**
 - **Infrastructure Health**
 - **Workforce Development**

Developing a Risk-based Approach

ADOT identified the erratic and abrupt nature of flood, hydraulic-related failure and extreme weather impacts on maintenance and operations as an excellent entry point to cope with new external threats and develop a strategic and systematic process for continuous improvement.

Specifically, identifying a repeatable process that addresses these sudden and unpredictable events would allow a ADOT to further their preservation and replacement life cycle projection activities, incorporate cost effective and defensible strategies and supplement their Moving Ahead for Progress in the 21st Century (MAP-21) risk-based TAMP rulemaking requirements.

Assessing Resilience & Strategy Identification

How do we shift from a deterministic preset design frequency basis and statistical risk of failure – i.e. extreme events not considered - To a probabilistic analysis approach that inputs additional vulnerabilities and considerations not previously considered

What is ADOT after – Identification of a reasonable universe of additional vulnerabilities and risk considerations not previously considered or required in maintenance and operations

ADOT's yearly budget for snowplowing and winter storm maintenance is between \$4 million and \$8 million, depending on the severity. This figure includes labor costs, equipment expenses, fuel and deicer chemicals

Assessing Resilience & Strategy Identification

OK Great – Helpful – But what constitutes a reasonable universe

Implement a new probabilistic end-to-end engineering-based asset adaption process and ensure that it incorporates:

- **Current design requirements**
- **Extreme event data / modeling where appropriate**
- **Stakeholders**
- **Constructability flexibility**
- **Life cycle cost considerations (operations and maintenance)**
- **Prioritization characteristics for TAMP/Performance Measures**
- **Environmental review connectivity (NEPA)**
- **And lends confidence and validity to funding constraint**

Incident Examples

Standard design overrun by extreme event - August 19, 2014
Initial Assessment - The culverts along the E-W running frontage road could not handle the Skunk Creek flows hence frontage road then acted like a dam. The water did an end-around and then had nowhere to go but south on I-17. The local road going east-west probable culprit. Likely had a lower design year for Skunk Creek than the interstate standard for I-17. Culverts are sized based on a design frequency for the class of roadway - highest is 50 years. This flood event was much more than a 50-year event (50 years means once every 50 years which equates to a 2% chance/any given year).

Incident Examples



Incident Examples

**Standard design overrun by vexing ground water source
Crazy Creek Bridge on I-40 (someone in the frontier days must have known something already to name it that)**

**2000 event was severe - scoured under and exposed the piers
floor was constructed returning it to original height**

**2004 surface and sub-surface water moved under and around
repairs included an enhanced slope with concrete baffles to
slow the velocity of surface wash flows. Event will have the
flows going west to east, toward Colorado River. Other times
low flow events will have the wash meander west/south/east.**

Incident Examples



Incident Examples



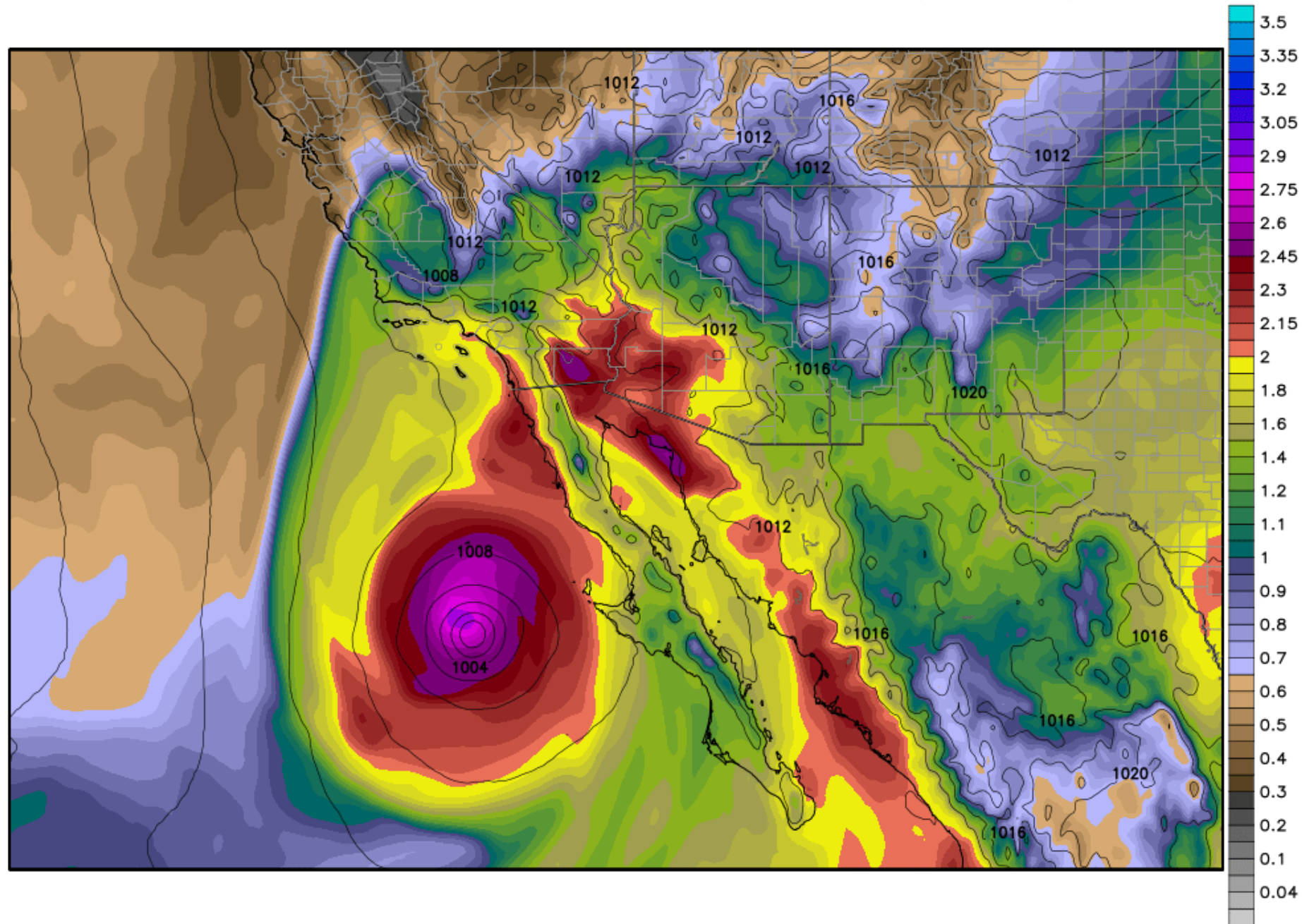
Incident Examples

Second major event – September 8, 2014

**Rainfall two to four inches widespread across Phoenix
Post-Tropical Cyclone Norbert, formerly a hurricane, is located
off the Baja California coast on Monday morning, channeling
warm, moist air northward into the Southwest desert, fueling
the record-setting precipitation.**

**Surpassed the rainiest calendar day on record at Phoenix Sky
Harbor International, which has received over three inches of
rain since the early morning hours. The previous record of
2.91 inches was set in 1933.**

ECMWF Column Water [inch] & MSLP [hPa] INIT: 00Z08SEP2014 fx: [006] hr --> Mon 06Z08SEP2014
Min/Max 998.4 :|: 1023.1 hPa



Incident Examples



Incident Examples

Third major event – September 27, 2014

Phoenix has received 5.09 inches of rainfall. Second-wettest September on record. The highest documented recorded was set in 1939 with 5.41 inches.

These series of storms has seriously impacted already tight maintenance budgets and have specific real time LOS risks:

- **Vehicle performance (e.g., traction)**
- **Driver capabilities/behavior**
- **Road treatment strategy**
- **Traffic signal timing**
- **Speed limit control**
- **Evacuation decision support**
- **Institutional coordination**

Strategies

**New risk-based approach – now adds the probabilistic elements
Need to look at each critical point throughout the entire system**

**Bridge/waterway example for an end-to-end engineering-based
asset adaption process -**

**Watershed area, current design, roadway alignment, physical and
environmental constraints, roadway approach, drainage
considerations, deck drainage, hydraulics report**

AND

**Layer in the unique probabilistic elements that could allow the
simultaneous assessment of the hazards and the needed
performance of the given infrastructure being considered**

ADOT Specific Projects – Five

ADOT/USGS Partnering Project - Develop customized GIS/ data analytics where USGS footprint/mission intersect with ADOT's infrastructure footprint/mission. Especially as they relate to incidents of stormwater, flooding, forest fires - flows, debris, sediment, roadside. 2014 / 2015

Finalize upgrade of ADOT's Feature Inventory System and drainage related assets and create asset data subsets to monitor critical hydraulic-related issues 2013 / 2014

ADOT Specific Projects

ADOT issued its Highway Drainage Design Manual - Hydrology in 1993. At that time it represented a significant advancement in the practice of hydrology for highway drainage design in Arizona. The 1993 Manual was the result of an extensive research and validation effort. The methods and procedures within the manual represented the state of the practice at that time.

The latest edition of the Manual updates, refine, and improves the methods for estimating storm water runoff, cognizant of the diverse nature of hydrologic conditions in Arizona.

Reevaluation of 2D hydraulic modeling usage is also underway

ADOT Specific Projects

The 2014 FHWA extreme weather pilot project focuses on a transportation corridor connecting Nogales, Tucson, Phoenix and Flagstaff, Arizona.

Particular value was identified with this area since it encompassed both the high-growth Sun Corridor and the more rural relatively low-growth areas. Final project will provide long-term weather models that integrate the predicted effects of climate impacts on Arizona transportation assets and corridor hot spots most likely to be identified as higher risk - design, construction or maintenance .

ADOT Specific Projects

Link Events to the ADOT Transportation Asset Management Plan

- Use existing data
- Cost and/or difficulty of additional data collection
- Be clear on what is measurable
- Develop a single process identifying performance measures and targets
- Contribute to life-cycle costs reduction for managing assets
- Identify new analytical approaches for operations and maintenance
- Measurably contribute to asset category financial forecasting
- Improve capital investment prioritization discussions

ADOT Strategic Focus Areas

Connecting these risk-based approaches and continuous process improvements to agency performance.

Financial Resources

- **Maximize existing agency financial resources**
- **Pursue sustainable funding solutions**

Innovation

- **Evaluate all functions, facilities and processes to determine new approaches and efficiencies**
- **Challenge and incentivize to identify savings and efficiencies**

Infrastructure Health

- **Develop comprehensive data management program**
- **Develop comprehensive performance mechanisms to evaluate overall transportation system health**

M&O Event/Project Goals

- Establish presence quickly
- Breakdown damage into workable pieces
- Do not underestimate use of ITS/communications capabilities
- Ensure debris removal/disposal contract and procurement processes are up to date
- Ensure local public agency debris/work zones overlaps identified
- ADOT management, ADOT Environmental Planning Group, Arizona Department of Environmental Quality clear on debris/waste piles
- ADOT lucky to have a 50+ year veteran overseeing HazMat section
- Know key contacts for traffic and signal control measures

Continuous Improvement - Next Steps

Sequencing and Cascading effects – Oak Ridge NL and DoE

Implementation pathway toward systematized collection

NCHRP Report 753

A Pre-Event Recovery Planning Guide for Transportation

NCHRP Report 750

Climate Change, Extreme Weather Events, and the Highway System

Continuous Improvement - Next Steps

Completion of FHWA Extreme Weather Pilot Project 2014

FHWA INVEST Round (1) 2014

Further connectivity projects – ADOT's FIS and TAMP 2015

FHWA INVEST Round (2) 2015

ADOT/USGS Partnering Project- Develop customized GIS/ data analytics where USGS footprint/mission intersect with ADOT's infrastructure footprint/mission 2014 / 2015

Continuous Improvement - Next Steps

ADOT - AASHTO TERI Database Proposal 884 Integrating Climate Change and Extreme Weather into Transportation Asset Management Plans. Now NCHRP 25-25 Funded

Advanced Economic & Engineering Considerations

VOLPE Risk Based Framework

Subset Analytics – develop true picture design mechanisms that account for age, demand level, maintenance continuums, storm impacts

Knowledge Sharing

Capture lessons learned - have centralized repository

Leverage nationwide content that is circumstance specific

U.S. Global Change Research Program <http://ncanet.usgcrp.gov/>

Climate Data Initiative <https://www.data.gov/climate/>

**Transportation Research Board – Climate Change
<http://www.trb.org/main/SpecialtyPageClimateChange.aspx>**

**FHWA Planning, Environment, Realty
<http://www.fhwa.dot.gov/hep/>**

Questions?

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