Assessment of Flood-Induced Damage in Hot Mix Asphalt (HMA) Pavements

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Acknowledgements

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  - FHWA DTFH61-12-R-00055
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- DOTs
  - Arizona
  - Maine
  - Nevada
  - Oklahoma

Outline

- Problem statement
- Objectives
- Approach
- Scope of work
- Results
- Conclusions and Recommendations
- Future work

Problem Statement

There is a lack of information on how to determine the *optimum* or most reasonable time to reopen a roadway to traffic after flooding

Need for Research

- Decision to reopen a roadway is currently based on visual inspection and experience
- NDT to evaluate structural capacity
- Guidance on how to determine the optimum time to reopen a roadway based on pavement structural capacity

Objectives

Provide guidance on decision-making, risk assessment, evaluation of options, and classification as emergency or permanent repairs

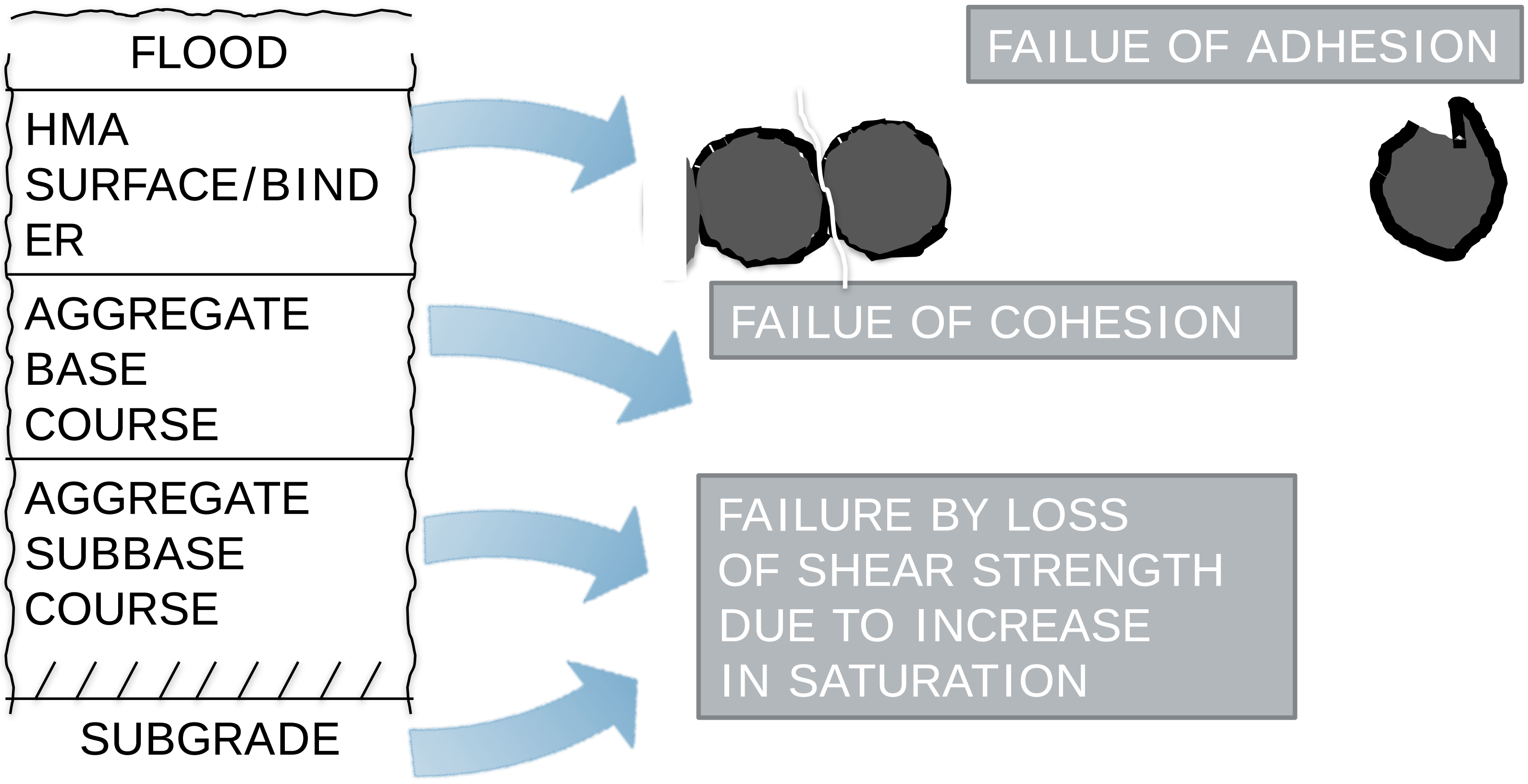
Objectives

- Develop guidelines on how to assess flooded pavements for short term impacts – primary focus
- Determine the best timing to allow emergency, heavy repair equipment, or other vehicles on the roads to balance access and damage to the roadway
- Develop framework for future assessment of long term impacts of flooding on pavements

Research Approach

Develop guidelines in the form of decision trees using Bayesian Statistical Decision theory

Impacts of flooding



Research Approach

Flooding Event

How much change in moisture content of pavement layers over time?

How are the material properties affected?

How is the pavement performance affected?

Is it validated with field data?

Open or close the road?

Scope of work

Develop guidelines through experiments, analyses of data, a review of existing data and information, and building a framework

Scope of work

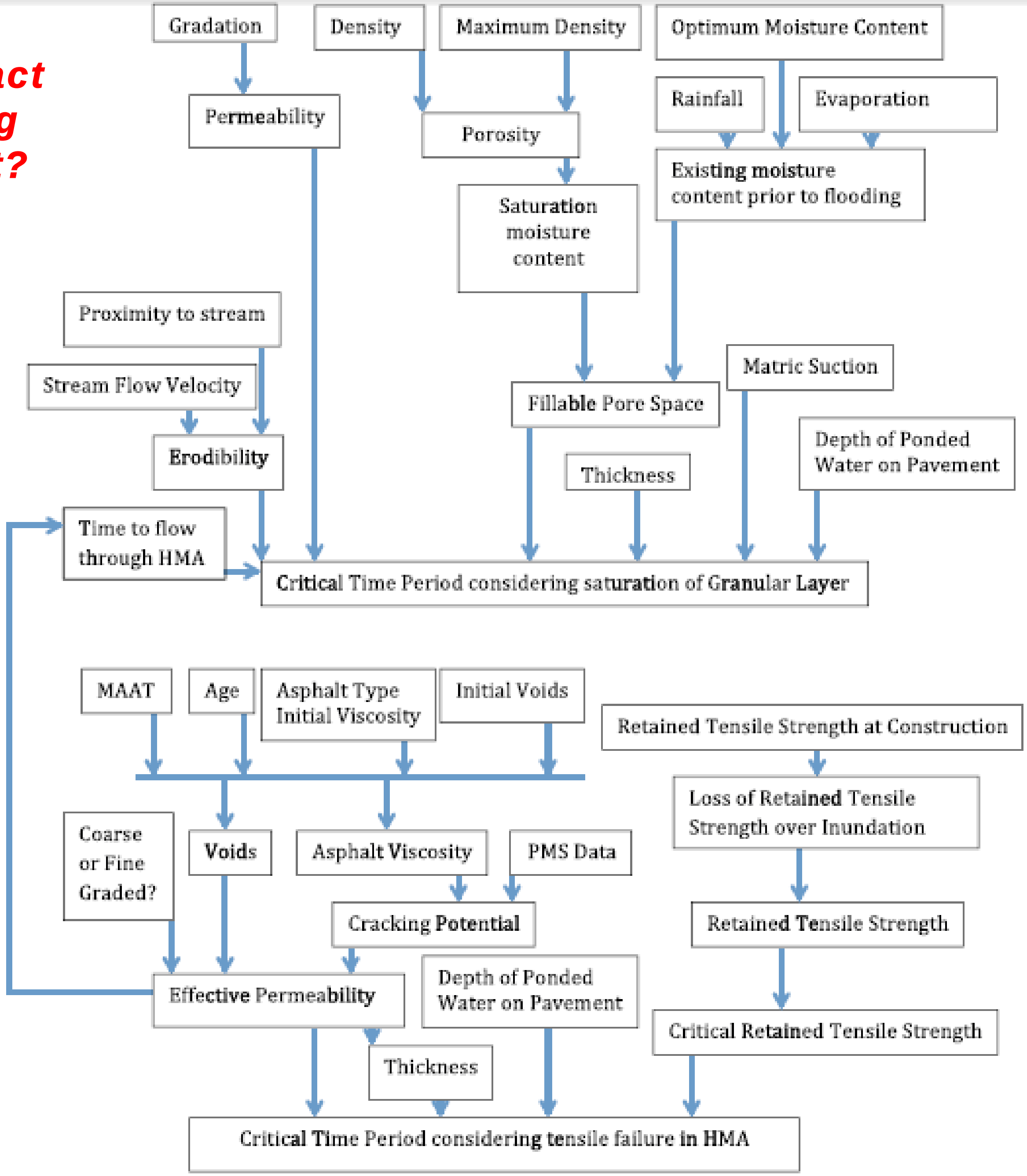
- Task 1: Variation in Moisture of Pavement Layers
- Task 2: Material Characterization
- Task 3: Pavement Performance Evaluation
- Task 4. Validation Testing
- Task 5: Decision Tree

Results

Is the impact of flooding significant?

System Dynamics Map

MAJOR PARAMETERS



CONNECTIONS

Determination of Critical Time of Flooding for Damage of Hot Mix Asphalt Pavements with Granular Base Course Layers

Courtesy: US Army Corps of Engineers

Overview

View and Change Parameters

Simulate

Unfurl Model

System Dynamics model available at: http://goo.gl/1esRKC

Show a plot of effect of voids/thickness

Screenshot from SD Simulation

What are the options to repair infrastructure when flooding and other natural events occur?

- Hydraulic analysis
- Raising the grade of the roadway
- Raising the height for a bridge replacement

Hydraulic Analysis

- To determine the most practical and economical grade raise elevation
  - To provide for a subgrade and a base layer that are free of ***saturation due to rising water in the basin*** at its current and future levels.
  - Based on predicted precipitation, evaporation and total storage in the basin

Other Tools and Methods Used by State DOTs

- Iowa DOT uses a combination of NDT testing and uses Google Maps for mapping pre-event conditions of roadways.
  - Rebuilding shoulder materials, shifting from granular shoulders to flexible or rigid pavement shoulders, in areas with a history of flooding
  - Construction of a sacrificial berm in limited locations

- Pennsylvania DOT maintains a road condition reporting system that tracks when a road is closed and re-opened (by segment) for flooding.

Other Tools and Methods Used by State DOTs

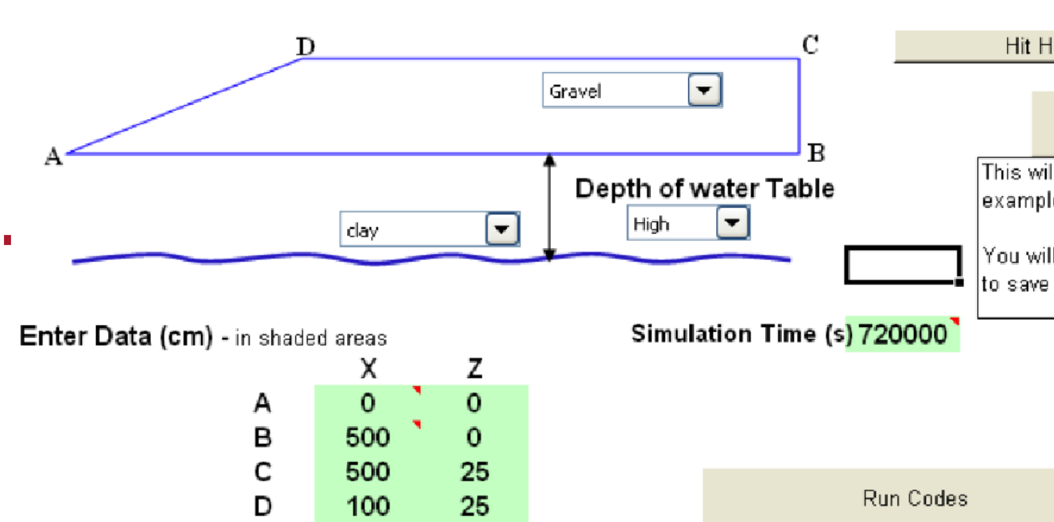
- North Dakota DOT collects pavement distress data with an automated collection vehicle prior to establishing the routing detours after a flooding event or during seasons of high water tables.

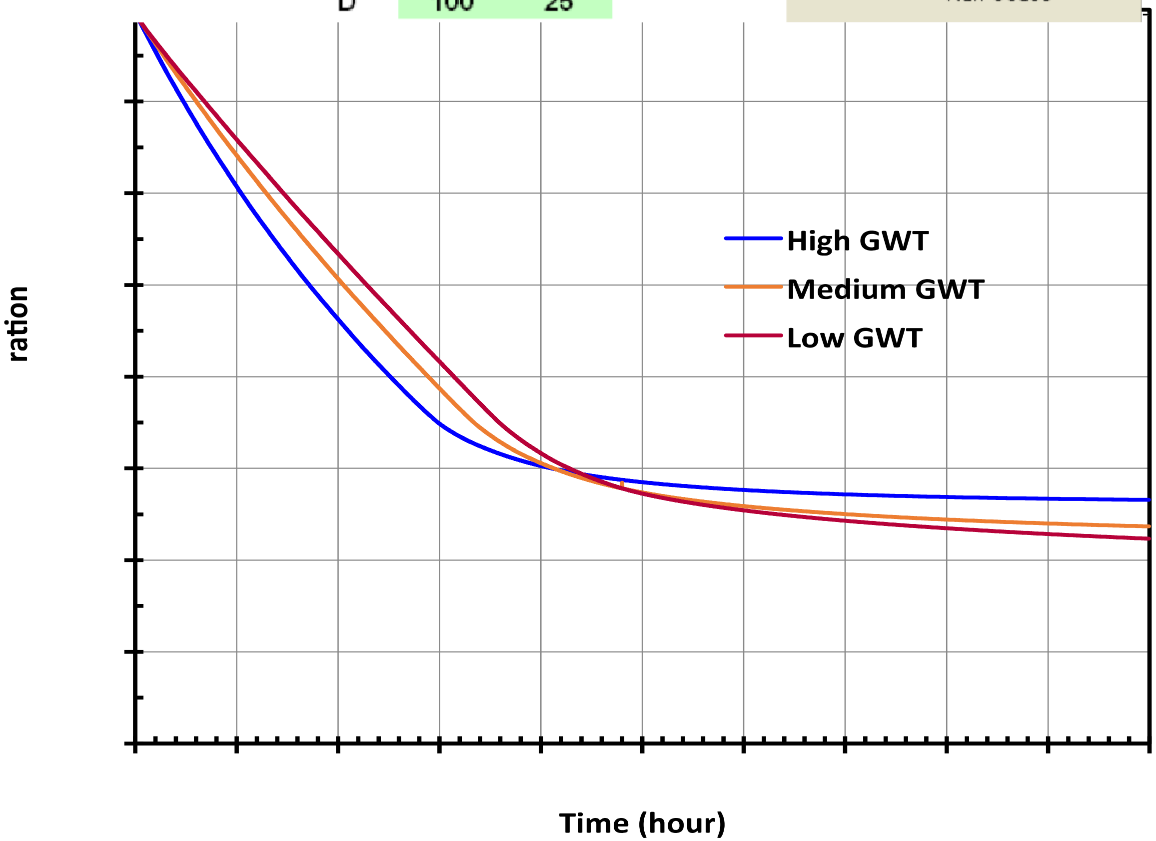
- Remaining Structural Service Life (RSSL) :
- Determination for RSSL analyses based on the length of time that a roadway will be inundated.
  - If a pavement will be inundated for an extended time (> 1 year) such as in closed basins, the roadway is either re-aligned outside of the closed basin or raised to get the pavement above the water line.
  - However, RSSL analyses would be applied if the pavement is saturated, but not inundated.

Other Tools and Methods Used by State DOTs

Prior to establishing detour routes, MassDOT conducts a quick inspection of the pavements (augmented by photologs), so that necessary resurfacing or repairs are done to the roads

- Missouri DOT uses a combination of non-destructive structural testing, comparisons with their DOT standards and pavement management database, and an analysis considering future heavy traffic load volumes.
  - Level of analysis for the determination of replacement-in-kind or restoration-in-kind designs is more extensive for the primary routes; <u>however, it is very minimal for the secondary route system in its state</u>



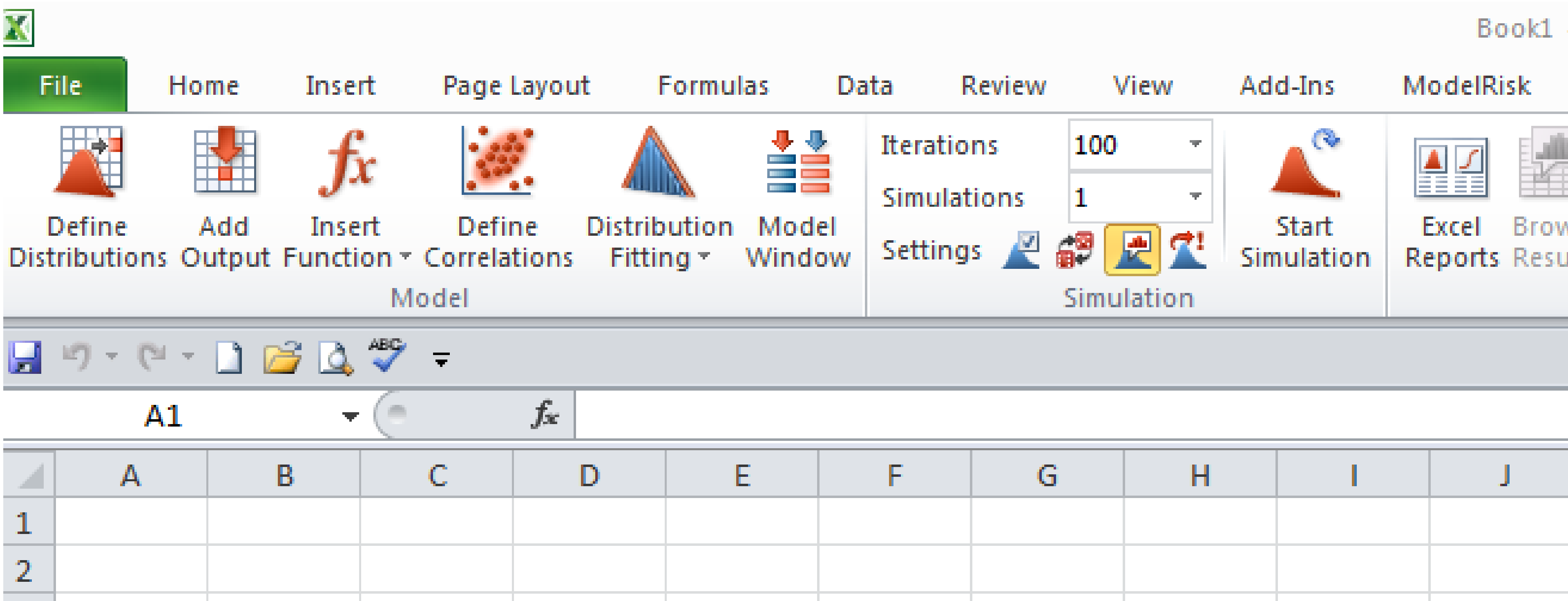


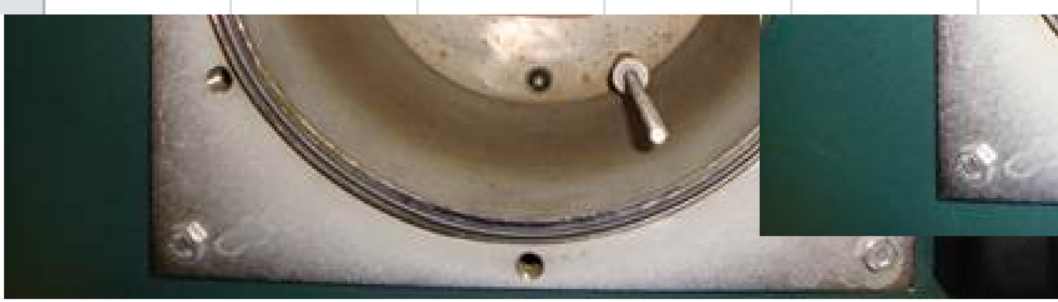
Results of hydraulic analysis

Impact on Hot Mix Asphalt (HMA)

- A framework
  - A rational and a practical method to test HMA mixes under realistic conditions
  - Utilization of the results to assess the damage
  - Use of a mechanistic-empirical (M-E) procedure
    - A relatively easy and less time consuming procedure of a simulation method + testing procedure
    - A probabilistic method for analysis of performance
    - A determination of the “risk” of loss of pavement life

Tools and Techniques





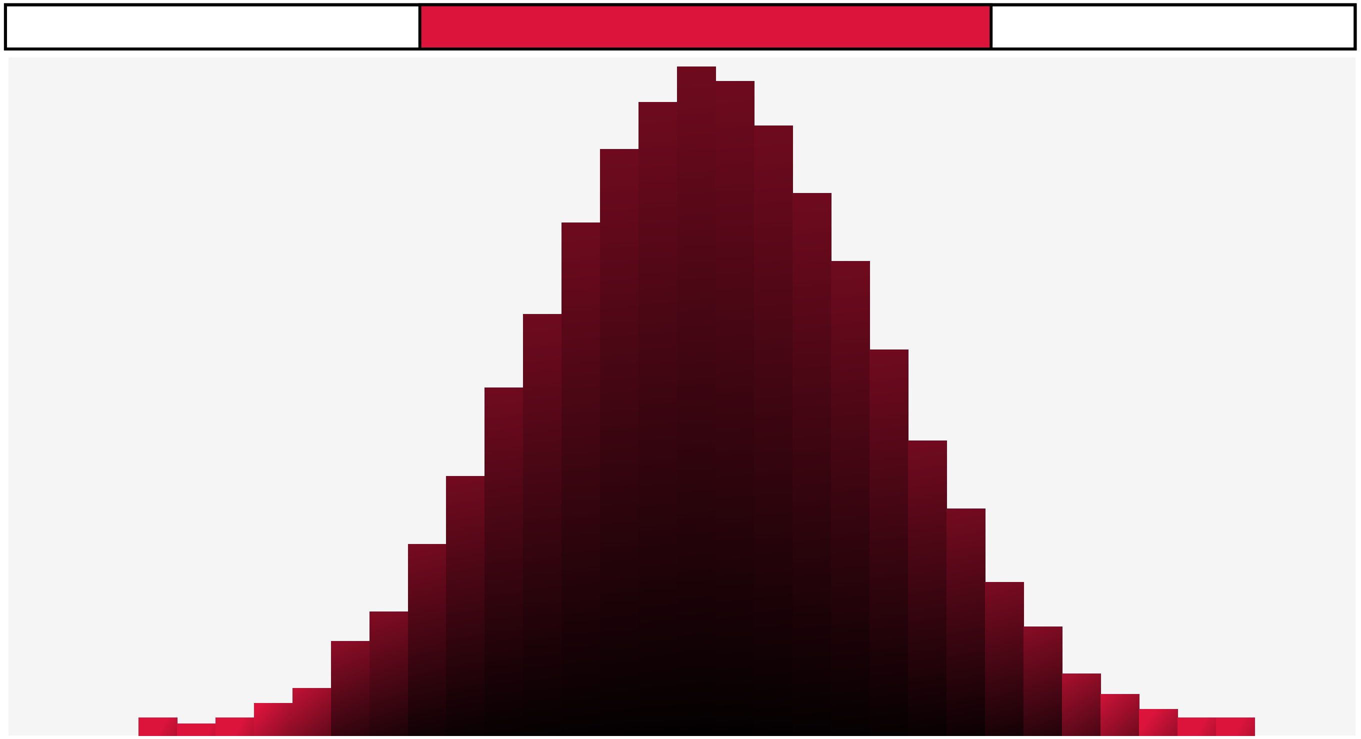
Developed Framework

- Test HMA samples with the Ultrasonic Pulse Velocity device and determine modulus before and after conditioning
- Su
- Di

Step by Step process that guides the user through a series of logical and sequential steps

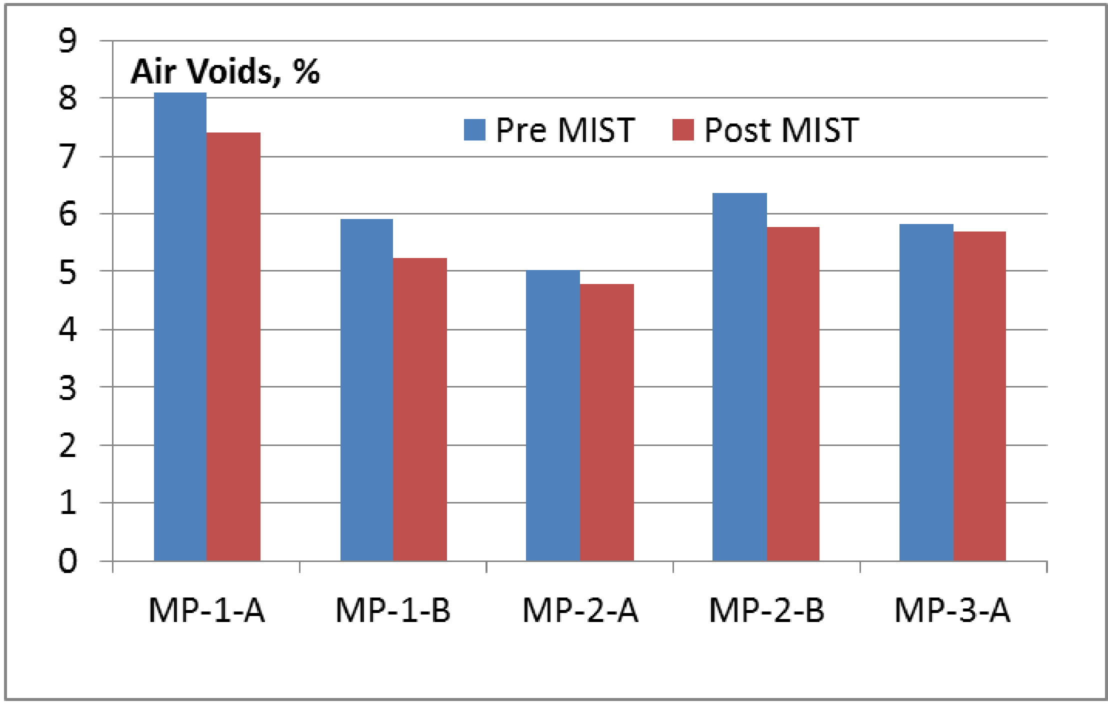
  – e) Calculate the mean and standard deviation of (Pre MIST E_d – Post MIST E_d);
  – f) Using the data from steps d and e, run a Monte Carlo simulation to determine the 90% confidence limit for loss of pavement life
  – g) For variability in thickness, utilize thickness data in step b) and step f)

Example



MIST and CoreDry to determine time to saturation and drying

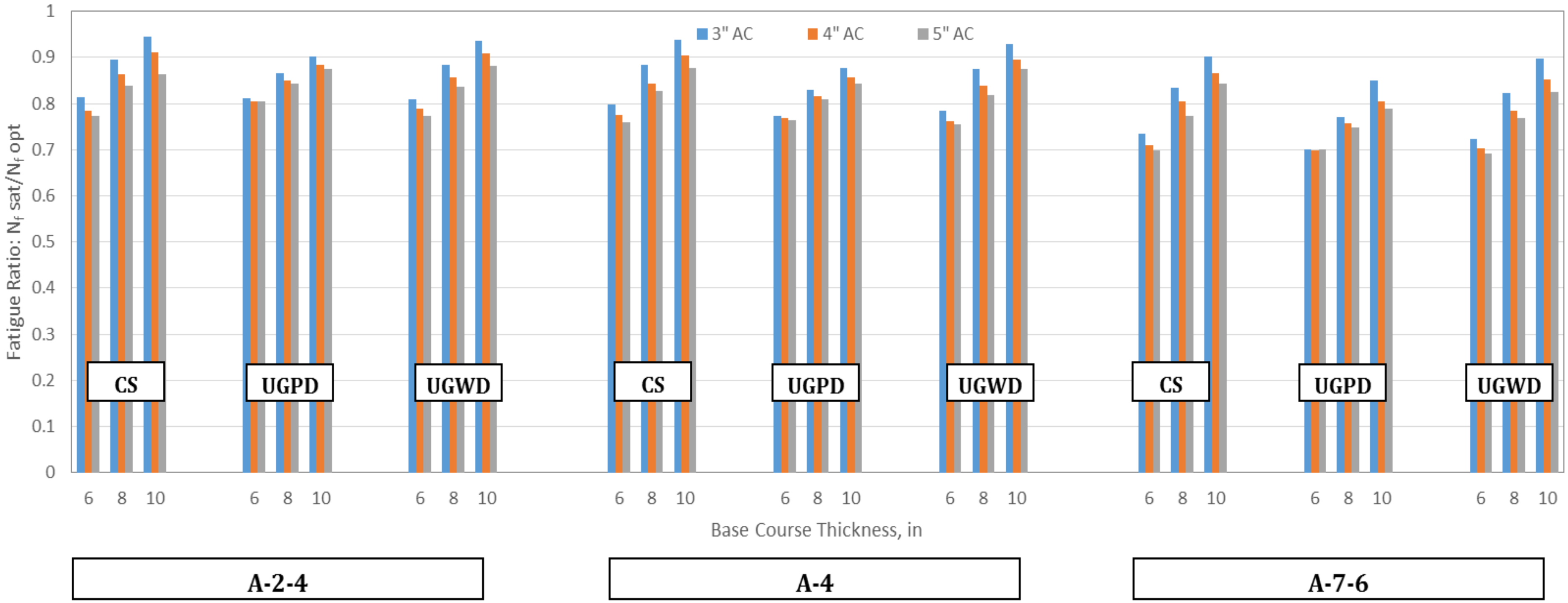
- Saturation after MIST, 100%
- Check for change in voids, porosity
- Neither +ve nor –ve change in air voids/porosity is desirable



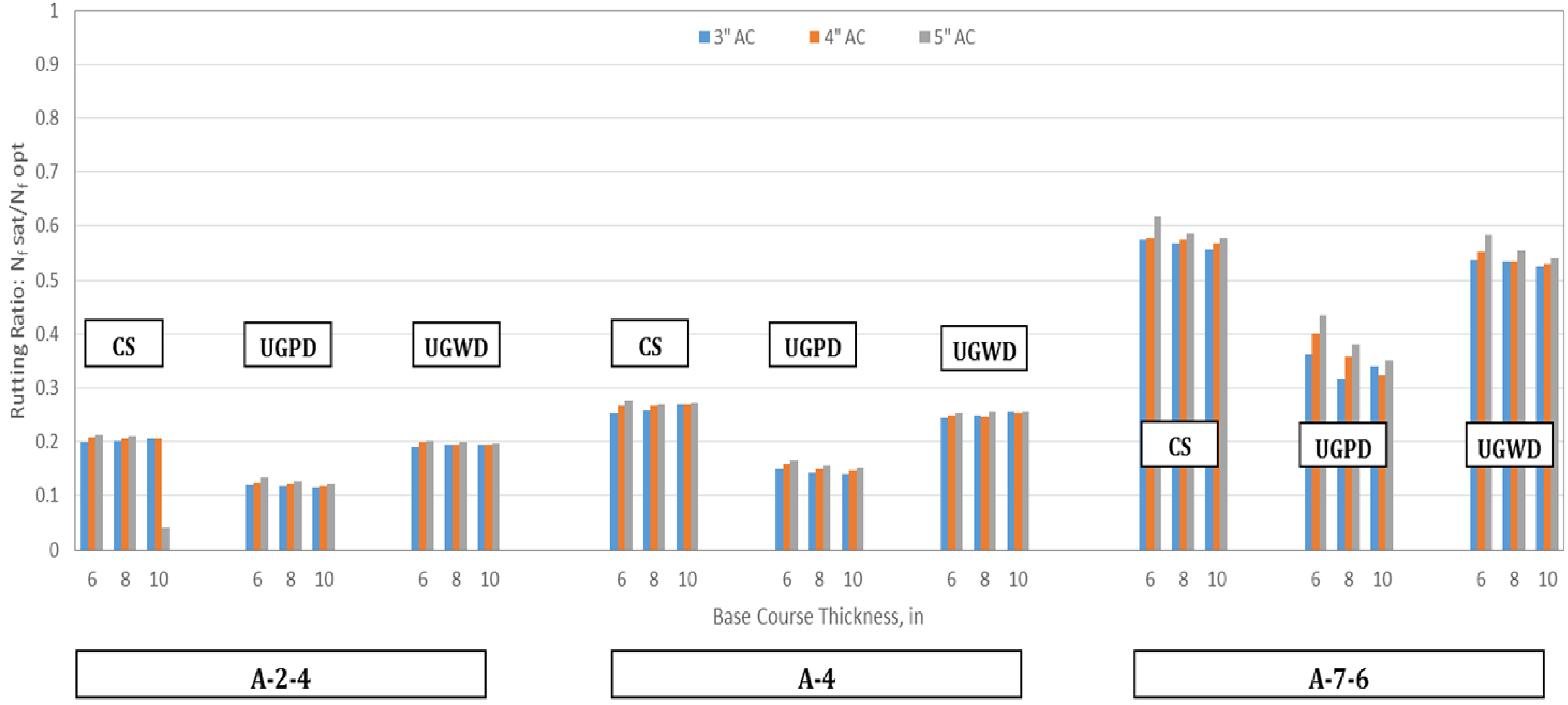
Impact of saturated condition

HMA **3, 4, 5 in**
Base **6, 8, 10 in** **Crushed stone, well drained and poorly drained uncrushed gravel**
Subgrade **A-2-4, A-4, A-7-6**

Impact of saturated conditions



Impact of saturated condition



Federal Highway Administration (FHWA) Emergency Relief (ER) Program

U.S. Department of Transportation
Federal Highway Administration

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Emergency Relief Program

Description: Congress authorized in Title 23, United States Code, Section 125, a special program from the Highway Trust Fund for the repair or reconstruction of Federal-aid highways and roads on Federal lands which have suffered serious damage as a result of (1) natural disasters or (2) catastrophic failures from an external cause. This program, commonly referred to as the emergency relief or ER program, supplements the commitment of resources by States, their political subdivisions, or other Federal agencies to help pay for unusually heavy expenses resulting from extraordinary conditions.

The applicability of the ER program to a natural disaster is based on the extent and intensity of the disaster. Damage to highways must be severe, occur over a wide area, and result in unusually high expenses to the highway agency. Applicability of ER to a catastrophic failure due to an external cause is based on the criteria that the failure was not the result of an inherent flaw in the facility but was sudden, caused a disastrous impact on transportation services, and resulted in unusually high expenses to the highway agency.

Funds Available: $100 million is authorized annually for the ER Program under 23 U.S.C. 125. Congress has periodically provided additional funds for the ER program through supplemental appropriations. MAP-21 eliminated the $100 million per State event cap. The total ER obligations for U.S. Territories (American Samoa, Commonwealth of Northern Mariana Islands, Guam, and Virgin Islands) is limited to $20 million in any fiscal year.

How are decisions made?

Federal Highway Administration (FHWA) Emergency Relief (ER) Program

Eligibility:

Federal Share: Approved ER funds are available at the pro-rata share that would normally apply to the Federal-aid facility damaged. For Interstate highways, the Federal share is 90 percent. For all other highways, the Federal share is 80 percent. The Federal share for permanent ER repairs may amount to 90 percent if the combined eligible ER expenses incurred by the State in a Federal fiscal year exceeds the annual apportionment of the State under 23 U.S.C. section 104 for the fiscal year in which the disasters or failures occurred.

Timeline:

Emergency repair work to restore essential travel, minimize the extent of damage, or protect the remaining facilities, accomplished in the first 180 days after the disaster occurs, may be reimbursed at 100 percent Federal share. The 180 day time period for 100 percent eligibility of emergency repairs may be extended if a State cannot access a site to evaluate damages and the cost of repair.

How to Apply: It is the responsibility of individual States to request ER funds for assistance in the cost of necessary repair of Federal-aid highways damaged by natural disasters or catastrophic failures. A notice of intent to request ER funds filed by the State Department of Transportation with the FHWA Division Office located in the State will initiate the ER application process. States are required to submit an application for ER funding to FHWA within two calendar years of the date of the disaster. The application must include a comprehensive list of all eligible project sites and repair costs.

Key Information related to ER Program & infrastructure system resiliency

http://www.fhwa.dot.gov/map21/qandas/qaer.cfm

Example: Flooding event in Arizona

Detailed Damage Inspection Report For FHWA ER Program

DETAILED DAMAGE INSPECTION REPORT
(Title 23, Federal-aid Highways)

Report Number	
Sheet 1	of 1
FHWA Disaster Number	**AZ10-1**
Inspection Date	**1-22-2010 to 1-24-2010**
Federal-aid Route Number	**ER-LLA-0(204)B**
State: **AZ**	County: **LA PAZ CO.**

Location (Name of Road and Milepost:

Salome Road MP 1 to MP 16

Description of Damage:

1. Pavement loss on low water crossings at shoulders. 2. Shoulder erosion causing pavement edge/vertical drop offs. All repairs listed below occurred before July 21, 2010.

Cost Estimate

	Description of Work to Date (Equipment, Labor, and Materials)	Unit	Unit Price	Quantity	Cost Completed	Cost Remaining
Emergency Repairs	Loader	HR	$ 60.00	8	$480.00	0%
	Motor Grader	HR	$ 80.00	18	$1,440.00	0%
	Dump Truck (s)	HR	$ 75.00	5	$375.00	0%
	Pickup (s)	HR	$ 25.00	42	$1,050.00	0%
	Labor	HR	$ 21.50	100	$2,150.00	0%
	Material -				$0.00	
	ABC	Tons	$ 8.50	12	$102.00	0%
	Material -				$0.00	
	Pit Run	Tons	$ 5.00	24	$120.00	0%
	Method			Subtotal	$5,717.00	
	X Local Forces	__ State Forces	_ Contract	PE/CE		
				Emergency Repair Total		$5,717.00

Example: Flooding event in Arizona

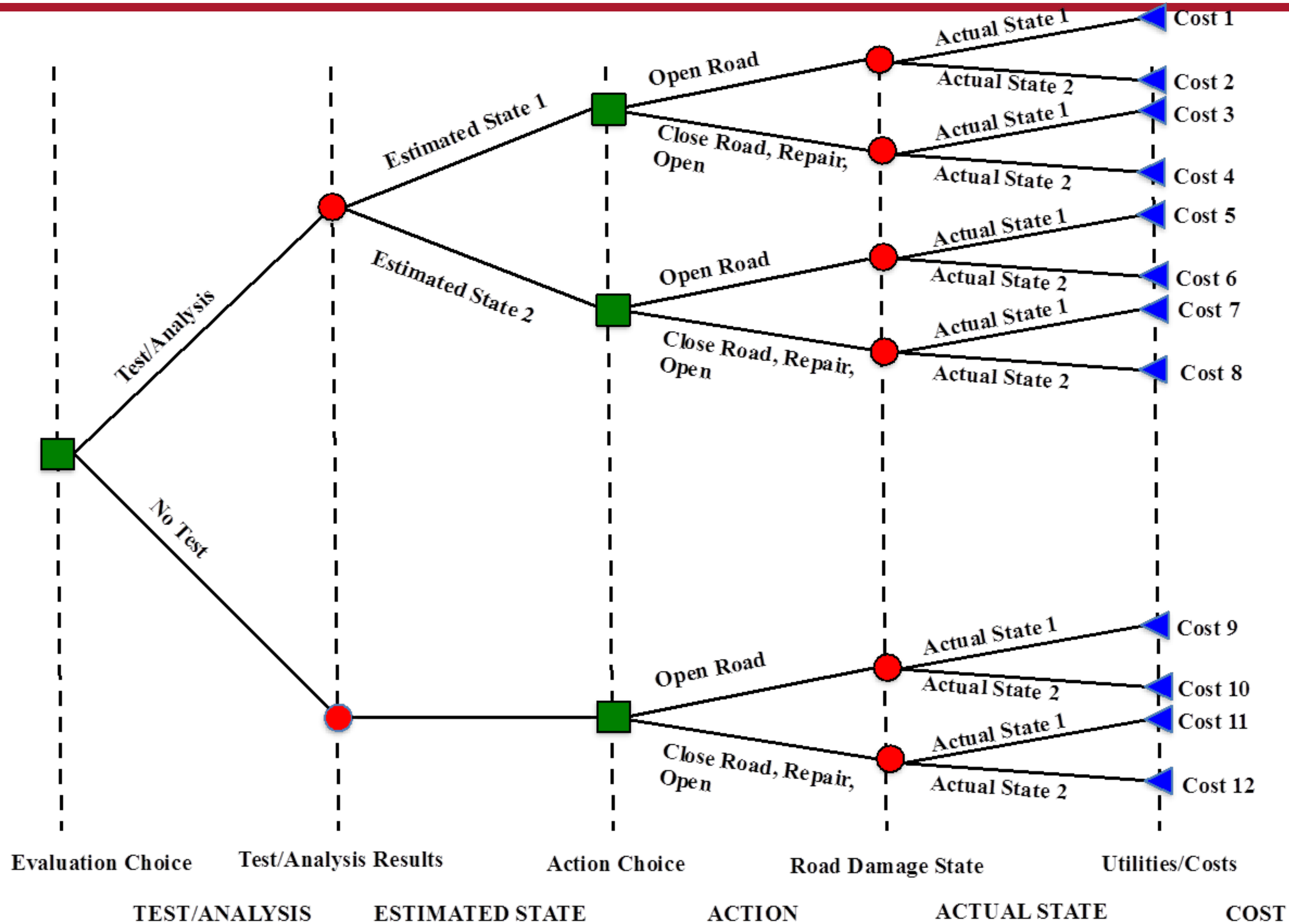
Permanent Restoration	Pit Run	Ton	$ 5.00	4,799	$ 25,816.07	0%
	Asphalt	Ton	$ 80.00		$ -	100%
	Hauling	Load	$ 75.00	196	$ 14,700.00	10%
	Labor	HR	$21.50	1484.5	$ 31,916.75	10%
	Equipment	Hrs		1,131	$ 49,933.26	10%
	Low water crossing with asphalt will have to go out to bid due to cost, this will be completed at a later date.					
	Method			Subtotal		$ 122,366.08
				PE/CE		
	X Local Forces	__ State Forces	X Contract	Right-of-way		
				Perm. Repair Total		$122,366.08
Environmental Assessment Recommendation						
	___ Categorical Exclusion	___ EA/EIS			Estimated Total	$128,083.08

Decision Tree

Flood Waters on Pavement surface	Closed to all traffic	Closed to all traffic	Restricted traffic (emergency vehicles only)
Flood Waters at Shoulder Rounding	Closed to all traffic	Restricted traffic (emergency vehicles only)	Open to traffic
"Normal" Ditch Flows	Closed to all traffic	Passenger vehicles with restricted trucks if pavement in 'good' condition	Open to traffic
	Allowable Loads less than AADTT	Allowable Loads near AADTT	Allowable loads greater than AADTT

Applied Research Associates, Inc., 2013

Decision Tree



Decision Tree

- Should we open or close the road?
- Should we conduct NDT?
- Decisions generally made in terms of:
  - Direct dollar losses
  - Downtime
  - Deaths/injuries

Poster presentation on decision tree

5:00 p.m.–7:00 p.m., *Great Hall* and West Court

Poster Session and Reception

Decision-Making Tool for Assessment of Flooded Pavements

Ricardo Medina, Paul Kirshen, and Jo Daniel, University of New Hampshire

Conclusions and Recommendations

System Approach

- Systems approach can be utilized to map the different factors that govern the impact of flooding on pavements, and their relationships
- A system dynamics model has been developed to simulate the interactions between the significant parameters
- Model confirms the significant impact of air voids, asphalt mix stiffness/aging and thickness of HMA layer

Impact of flooding on HMA

- The Moisture Induced Stress Tester (MIST) and the Ultrasonic Pulse Velocity (UPV) method can be used effectively as moisture conditioning and evaluating loss of performance related properties as a result of flooding
- A risk based quantification of loss of pavement life of hot mix asphalt (HMA) pavements due flooding has been developed

Decision Tree

- Payoff is affected significantly by losses associated with opening the road to traffic when the pavement is not sound
- Additional testing is warranted under certain conditions to reduce the uncertainty that may be present in the visual survey/inspection results
- Need to determine utility functions and testing accuracy

Pavement Evaluation

- Significant effect on
  - Fatigue performance
  - Rutting performance
- Significant parameters
  - Type of base course material
  - Thickness of HMA
  - Type of subgrade material

Future work

Pavement Performance Evaluation

- Evaluations of impact of saturation
- Identification of critical/non-critical cases
- Identification of cases where accurate data on saturation level is needed
- Bearing capacity analysis for one-time short-term flooding events

Validation Testing

- LTPP sections:
- Field sections:
  - Arizona: Fall 2014 event
  - Nevada: Fall 2014 event
  - Working with Oklahoma on Spring 2015 events

Decision Tree

- Reliability values for test results
- Probability values for damage states
- Utility function
- Application tool development
- Application testing with agencies
- Guidelines development

Thank You!