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College Station, Texas

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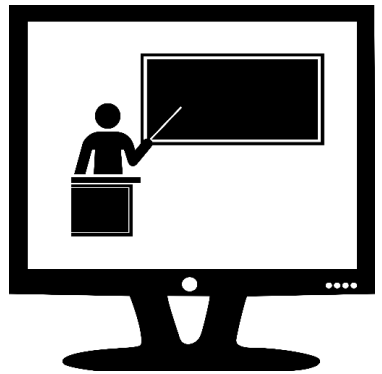
Augmenting Pavement Maintenance Decisions with Structural Evaluation

Presenter: Reuben Williams, P.E.

Presentation Overview

- Introduction
- Structural vs Functional Pavement Performance
- Pavement Evaluation Technologies
- Pavement Functional Evaluation
- Pavement Structural Evaluation
  - Traditional vs Non-destructive testing
  - Project Level vs Network Level
  - Pavement Rehabilitation Design Methodologies
- Pavement Management System & M&R Decisions
- Use of pavement structural performance in PMS
- Conclusions



Introduction

- Most Pavement Management Systems are based on pavement surface condition only.
- Pavement surface condition only provide a portion of the overall pavement condition and needs to be complemented with structural evaluation.
- Project level pavement rehabilitation design is needed to ensure most cost-effective strategy is selected.
- Non-destructive testing and analysis techniques are most widely used for project level pavement rehabilitation design.
- Life Cycle Cost Analysis (LCCA) is needed to ensure proper set of M&R activities are applied to the life cycle of a pavement structure

Pavement Performance

Structural:

the ability of the pavement to withstand the combine action of traffic and environment without developing appreciable distress.

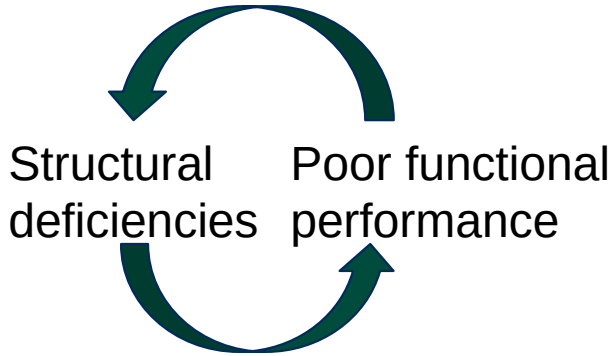
Functional:

the ability of the pavement to provide a smooth, safe ride for the comfort and convenience of the traveling public.

Pavement Performance

Functional performance and structural performance are related

- Ride quality is impacted by:
  - Cracking
  - Potholes
  - Shoving…



- Rough road would generate high dynamic loads which could lead to structural distresses

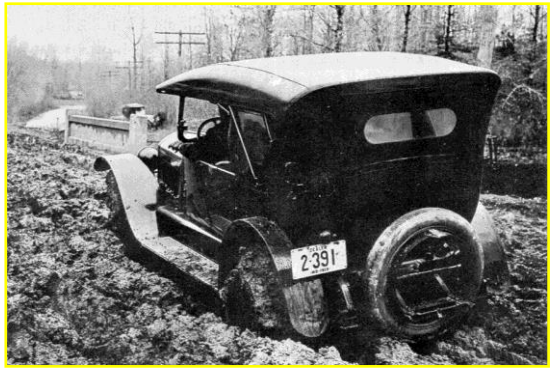
Rough Pavement

Smooth Pavement

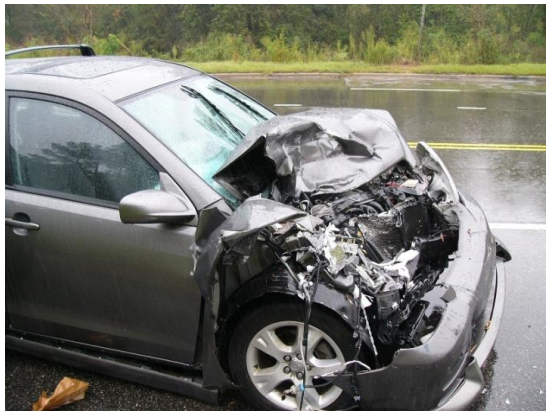
Functional Performance

Roughness leads to increases in:

- Vehicle operating costs
- User delay
- Accidents
- User dissatisfaction



Friction loss leads to increases in wet weather accidents



Structural Performance

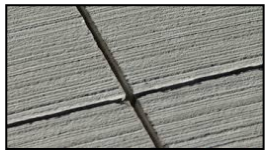
Governed by pavement layer thicknesses and types, pavement layer moduli, subgrade/support carrying capacity, seasonal variation and traffic.

- Distresses:
  - Fatigue cracking
  - Rutting
  - Potholes
  - Under design
  - Patch deterioration
  - Construction deficiencies
  - Loss of support
  - …

Pavement Performance Affected By

Materials



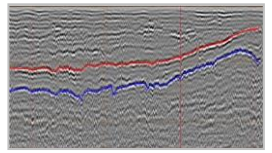
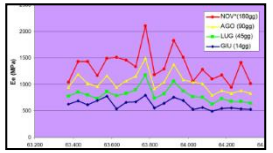



Processes




Construction



Loading




Environment




M&R Treatment Selection

Potential Solutions

- Corrective Maintenance
  - Crack seal
  - Patching
- Preventative Maintenance
  - Fog/Slurry/Chip Seals
  - Microsurfacing
- Rehabilitation
  - Mill and overlay
  - In-place recycling
  - Full Depth Reclamation
- Reconstruction

Material Testing and Modeling

- Quality of materials
  - Toughness, soundness, angularity, roughness, etc.
- Deterioration and Cumulative Damage models

Pavement Evaluation Technologies

Pavement
Functional Performance Evaluation

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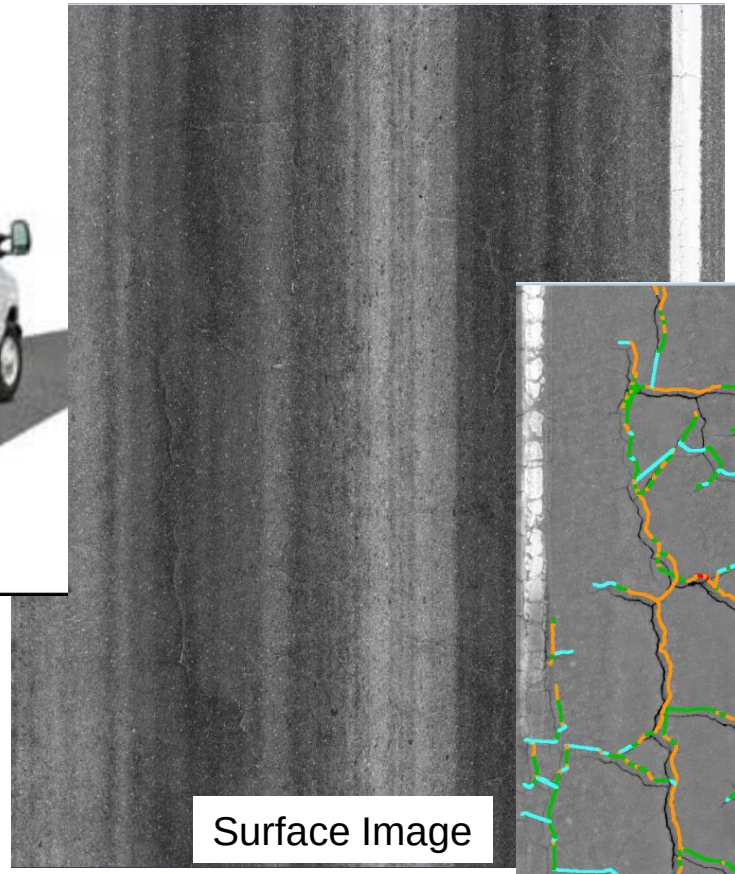
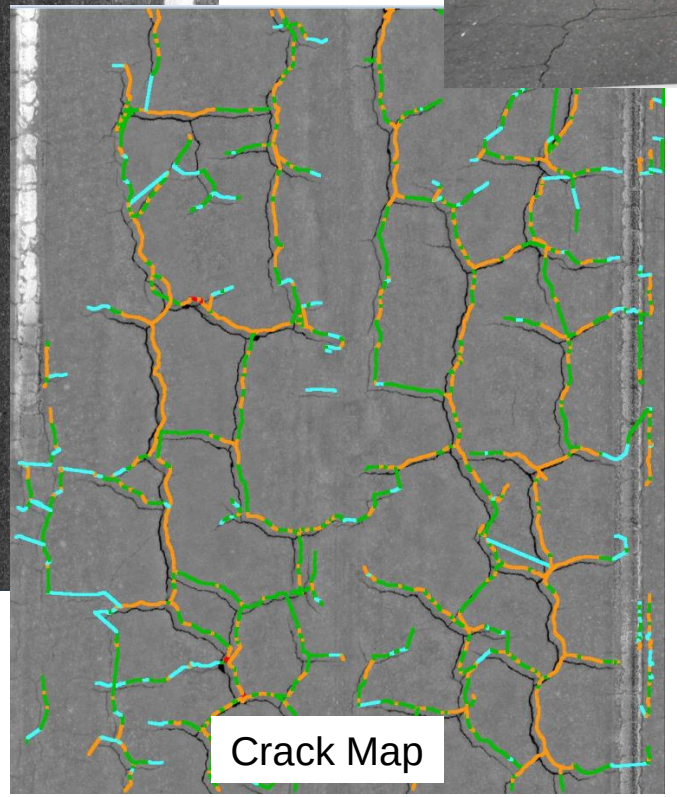
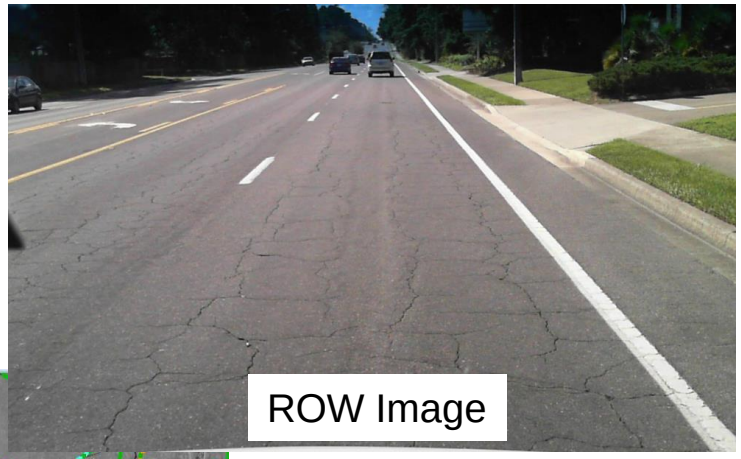
Pavement Surface Distress

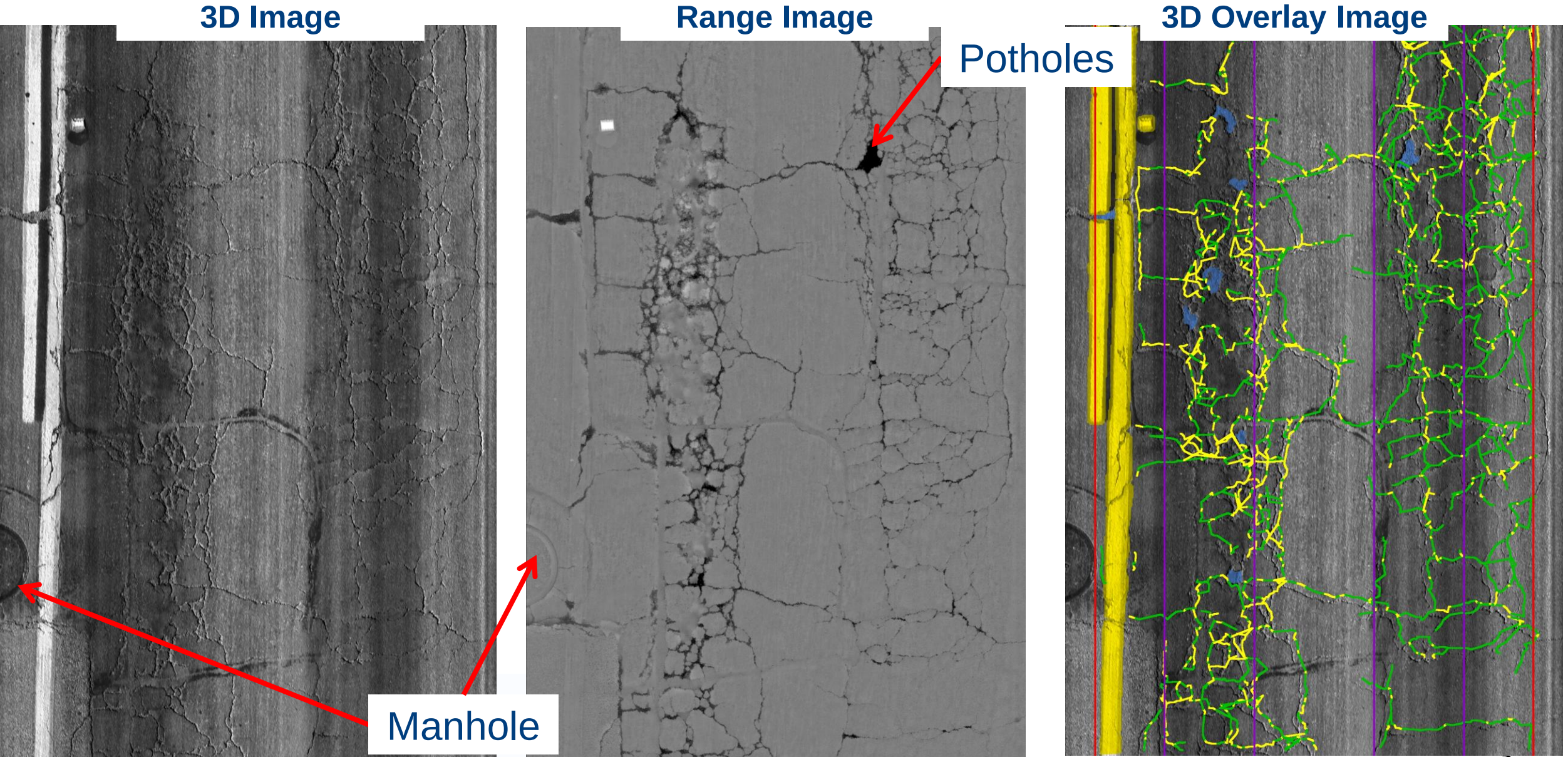






- Automated crack measurement
- IRI & Localized Roughness
- Slab Faulting
- Wheel Path Rutting
- Pavement X-slope, Grade, Curvature
- Right of Way (ROW) images
- Linear & Geo-referenced distress & Images

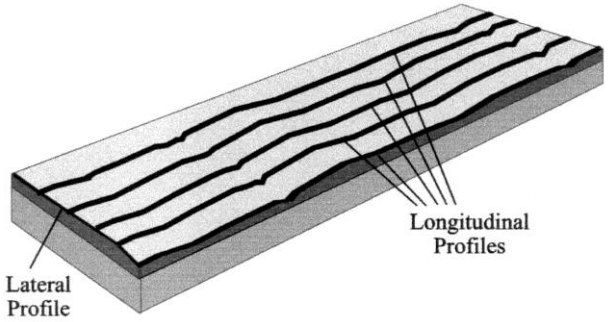
Example LCMS Pavement Images



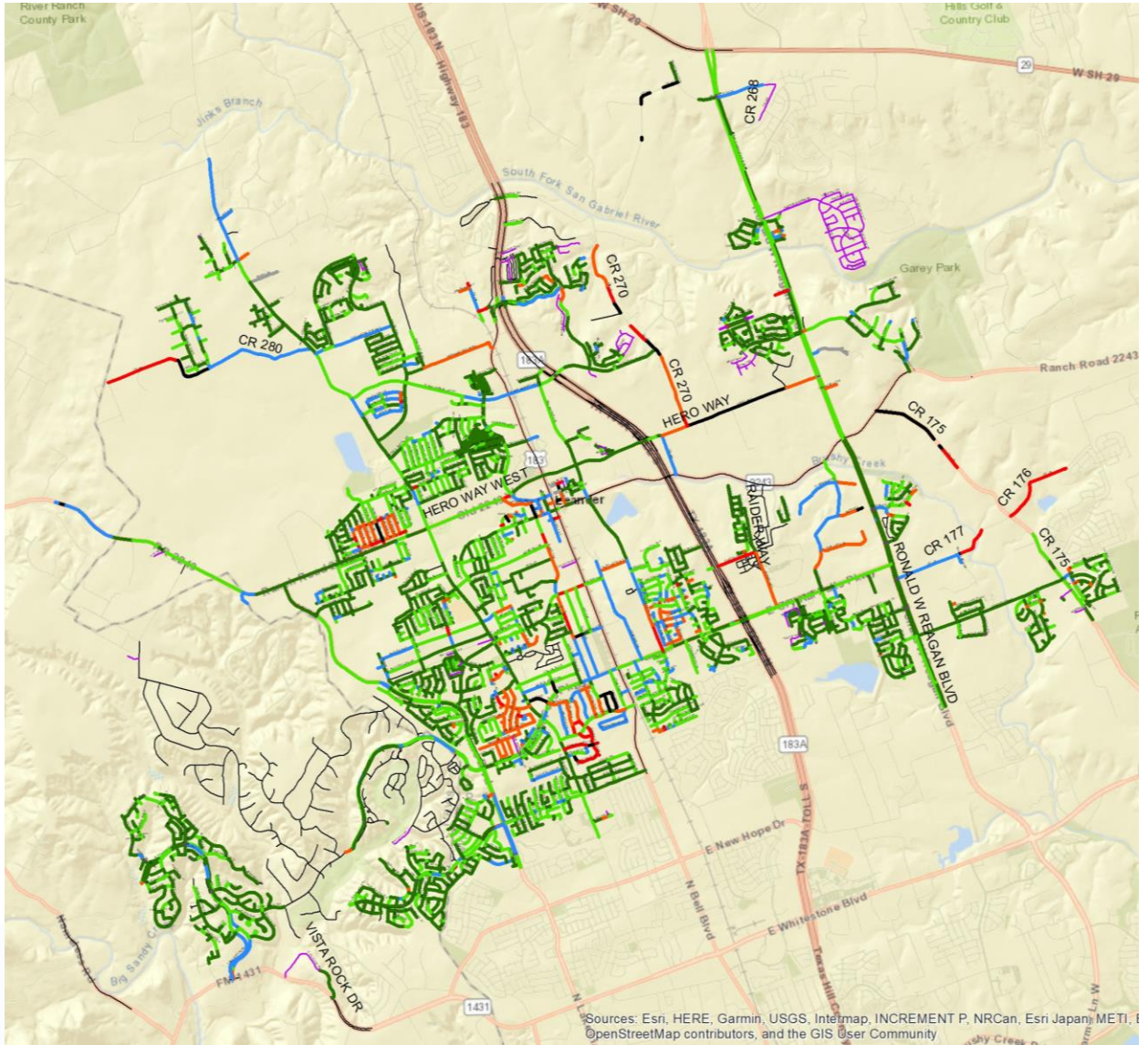
Pavement Surface Roughness

Inertial Lase Profiler

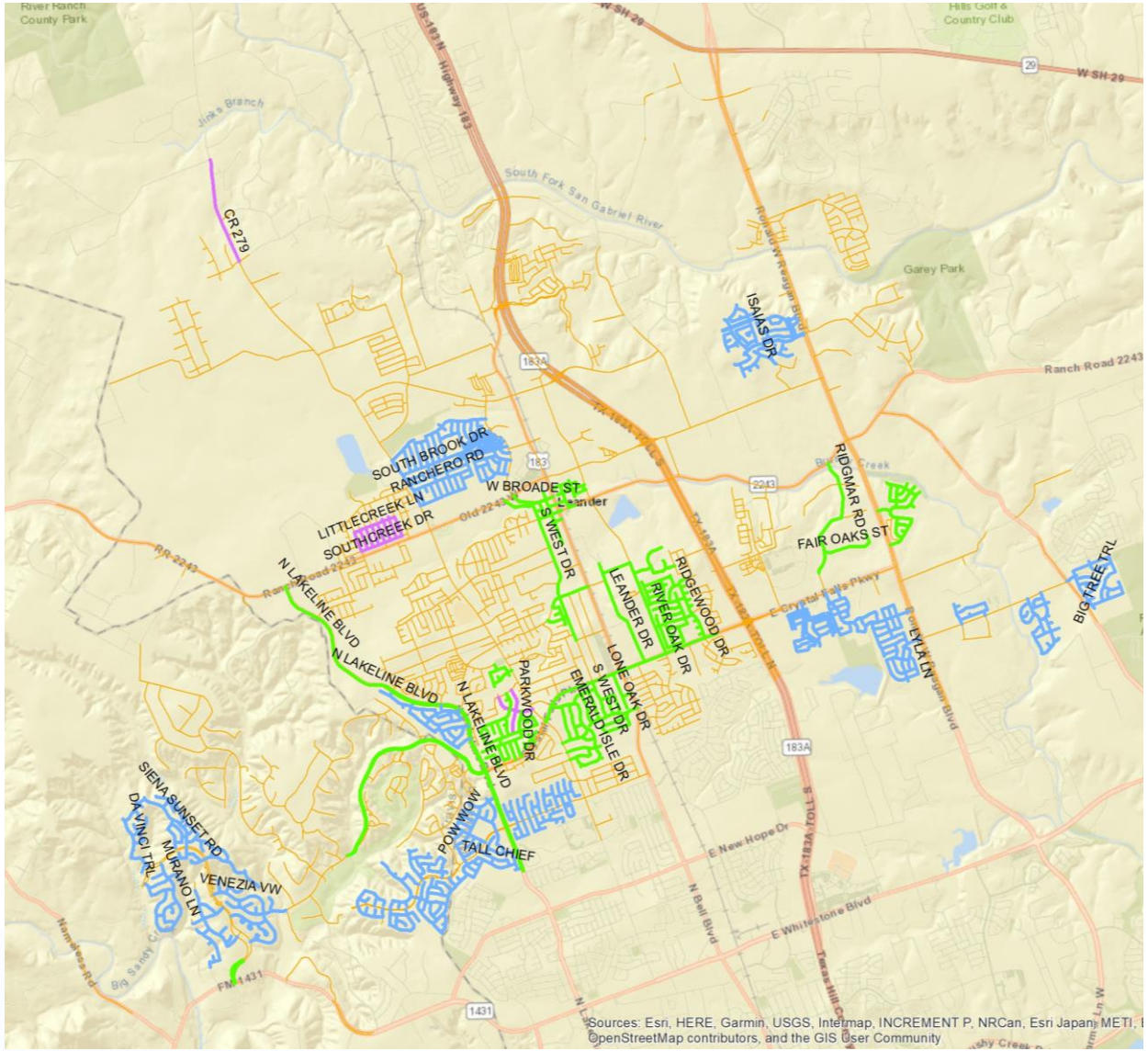
- Longitudinal profile,
- International Roughness Index (IRI),
- Localized Roughness (Bumps & Dips)
- Construction QC/QA
  - TxDOT Tex 1001s Certified
  - Meets ASTM E950 Class 1



Condition Score Map



Work Plan Map



Pavement Friction Measurements

Locked Wheel Skid Testing

Continuous Slip Friction Testing

Pavement Structural Evaluation & Rehabilitation Design

Traditional Geotechnical Investigation

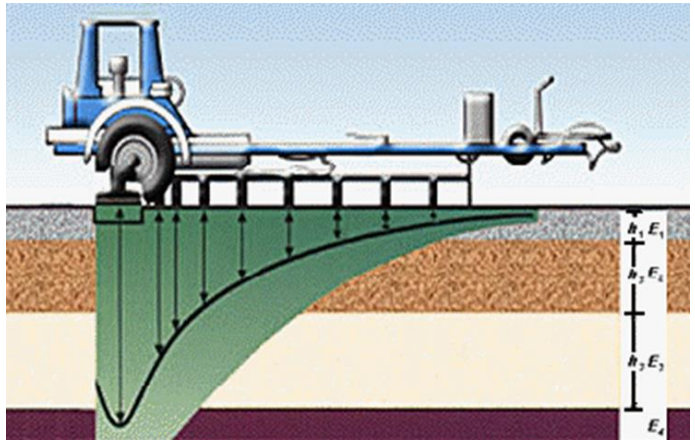
- Coring and boring
- Soil Classification (sieve analysis, Atterberg limits)
- Dynamic Cone Penetrometer
- In-place Moisture
- CBR
- R-Value
- Maximum Density
- Plate load test

Falling Weight Deflectometer (FWD)

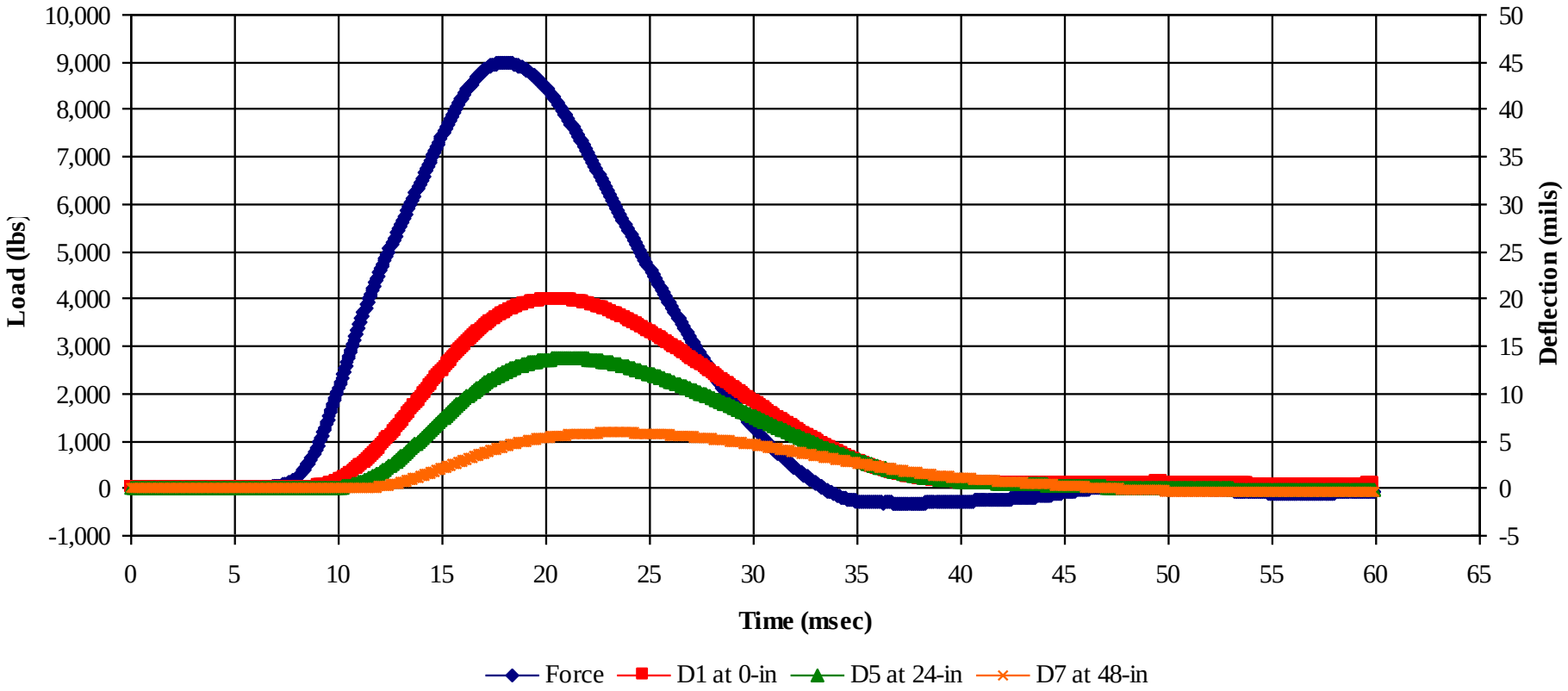
FWD generates a transient, impulse-type load of

- 20 - 30 msec duration
- Approximates the effect of a 30-50 mph moving wheel load.
- Any desired (peak) load level between

  FWD: 1,500 – 27,000 lb.
  HWD: 6,500 – 72,000 lb.



FWD Load/Deflection Pulse (w/ selected sensors)



Why use Deflection Data - FWD?

Determine in-situ elastic layer moduli of pavement layers

Determine structural capacity of pavement structures

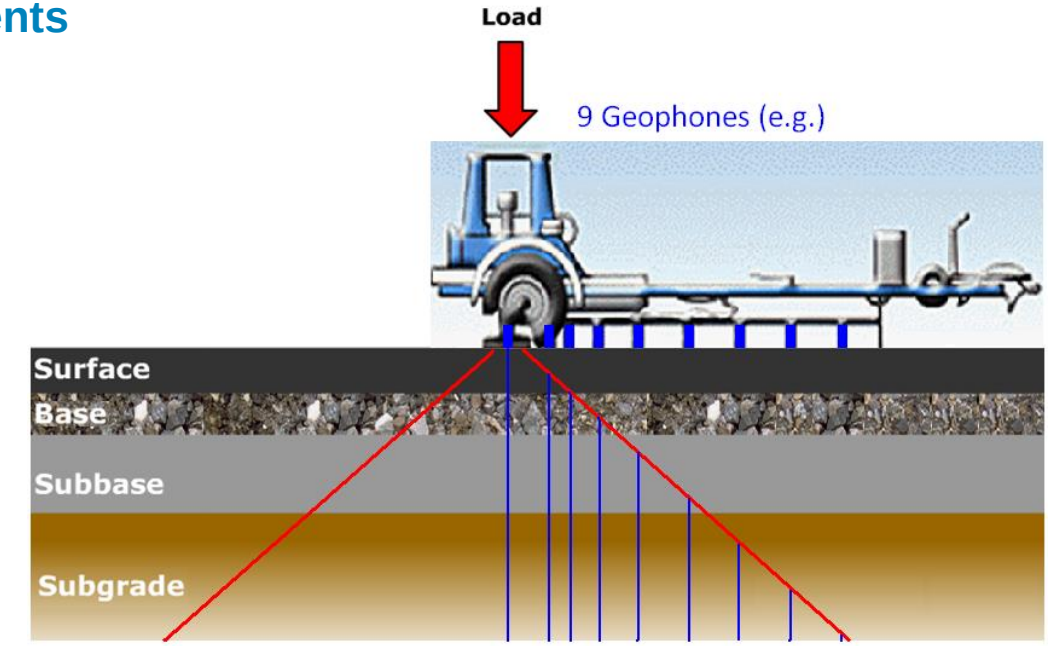
Determine load transfer efficiency on jointed concrete pavements

Determine seasonal traffic load restrictions

Estimate remaining life of pavement structure

Develop overlay, rehabilitation, and reconstruction strategies

Pavement Management



Why use Deflection Data - FWD?

- Project Prioritization
- Develop pavement coring plans
- Aid in forensic investigations
- Locate voids beneath concrete pavements
- Determine stress sensitivity of pavement structures
- Pavement Condition Number (PCN) for Airports
- Quality Control and Quality Assurance

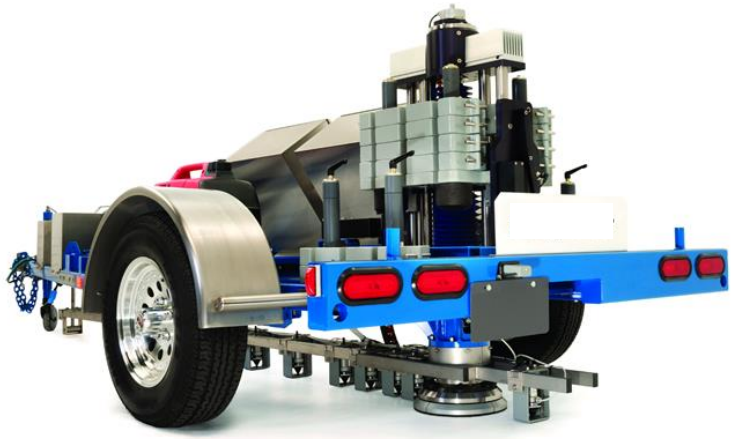
Structural Testing Project Level vs Network Level

Project Level

- Most commonly used
- MR&R decisions related to specific pavement sections
- Select & support best treatment option for a specific area
- Design of AC overlay thickness, rehabilitation, full depth reclamation, reconstruction

Network Level

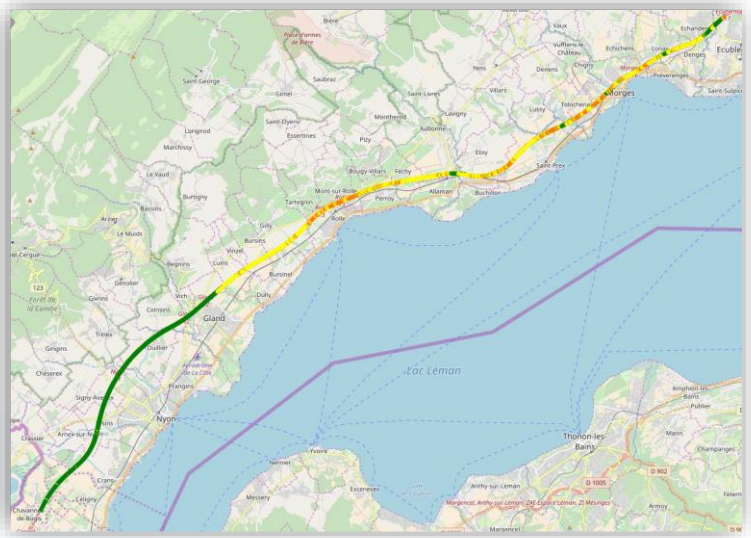
- Select, prioritize & rank project areas based upon available funding & priorities
- Used as part of Pavement Management Systems
- Identify areas for Project Level Evaluation



Pavement Structural Evaluation

Network Level Evaluation:

- Much higher test interval (typically 0.1 – 0.25 miles)
- Used to identify pavement sections in need for rehabilitation
- Used to determine PMS structural condition indices
  - Load and Temperature normalized Center Deflections
  - Structural Condition Index (SCI), Base Layer Index (BLI), Area, SN
  - Composed PCI
- Used for void detection and LTE problems on rigid pavements



Pavement Structural Evaluation

Project Level Evaluation:

- Selection of specific set of rehabilitation and/or reconstruction alternatives
- Determine pavement structural adequacy
- Determine pavement remaining life
- Use of design period, Equivalent Single Axle Loads (ESAL) and environmental conditions

What is Needed for Pavement Rehab Design?

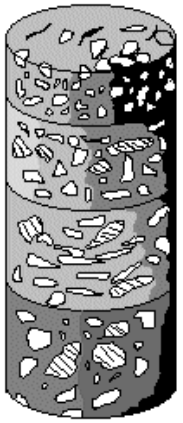
Load/Deflection data from FWD testing

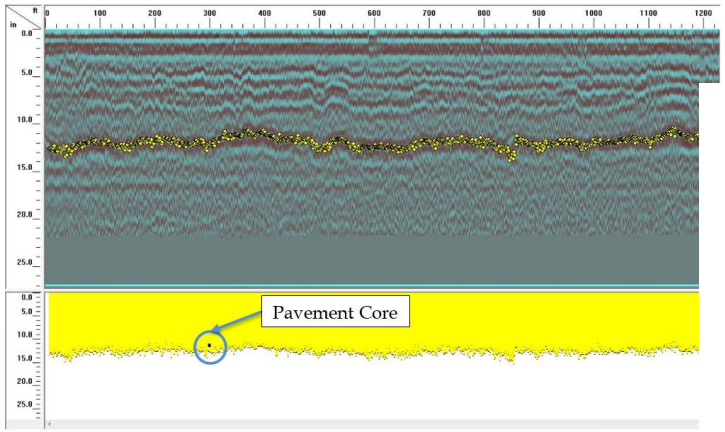
Traffic Information (Traffic Index/ESAL/Aircraft Mix)

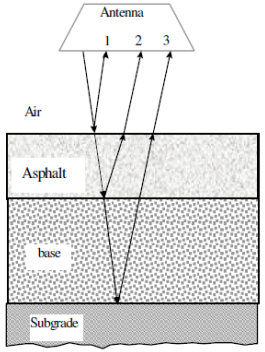
Surface Condition (ROW Images)

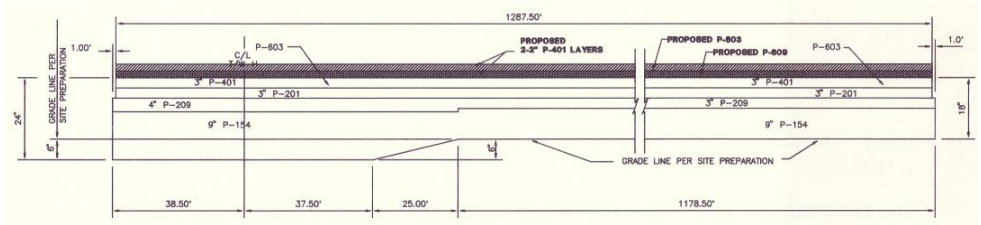
Pavement Structural Thicknesses

- Coring / Boring (2-3 cores per mile)
- Geotechnical Investigation
- Ground Penetrating Radar (GPR)









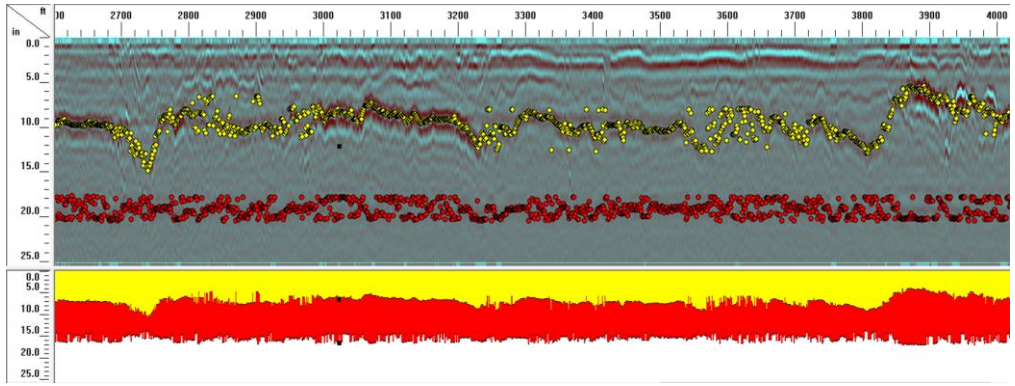
Ground Penetrating Radar (GPR)

Uses radar waves to determine pavement layer dielectric constant

Continuously determine pavement layer thicknesses

Requires known pavement layer thickness and types for GPR calibration

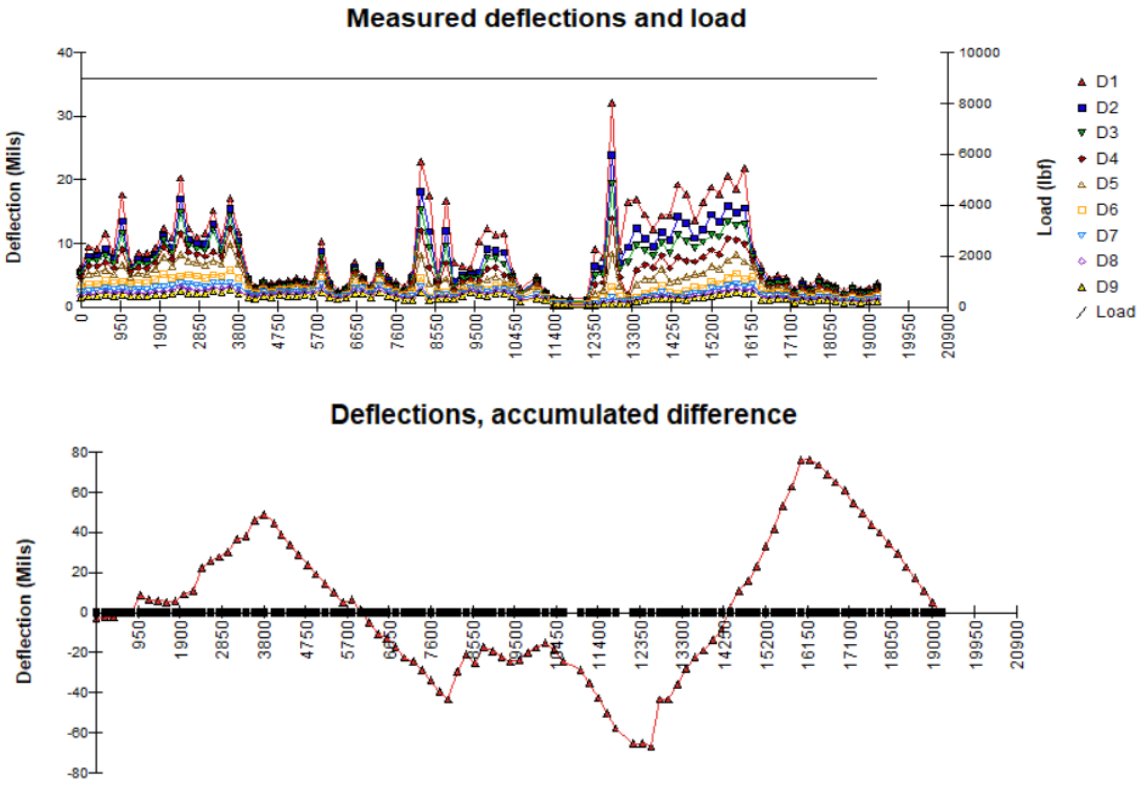
- Coring / Boring
- As-built plans
- Construction history



Optimizing Pavement Coring Locations

Use FWD measured Deflections & GPR:

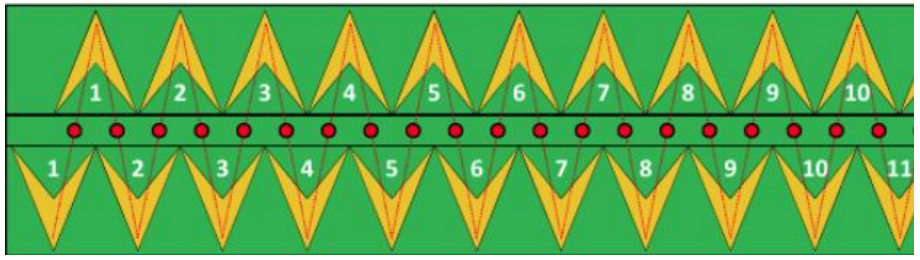
- Change is the slope of the accumulated difference deflection
- Right of way surface conditions
- GPR data (needs calibration)



Pavement cores reduced from ~10-18 to 5!!!!

3D Ground Penetrating Radar (GPR)

Full coverage of all lanes using 2 overlapping passes

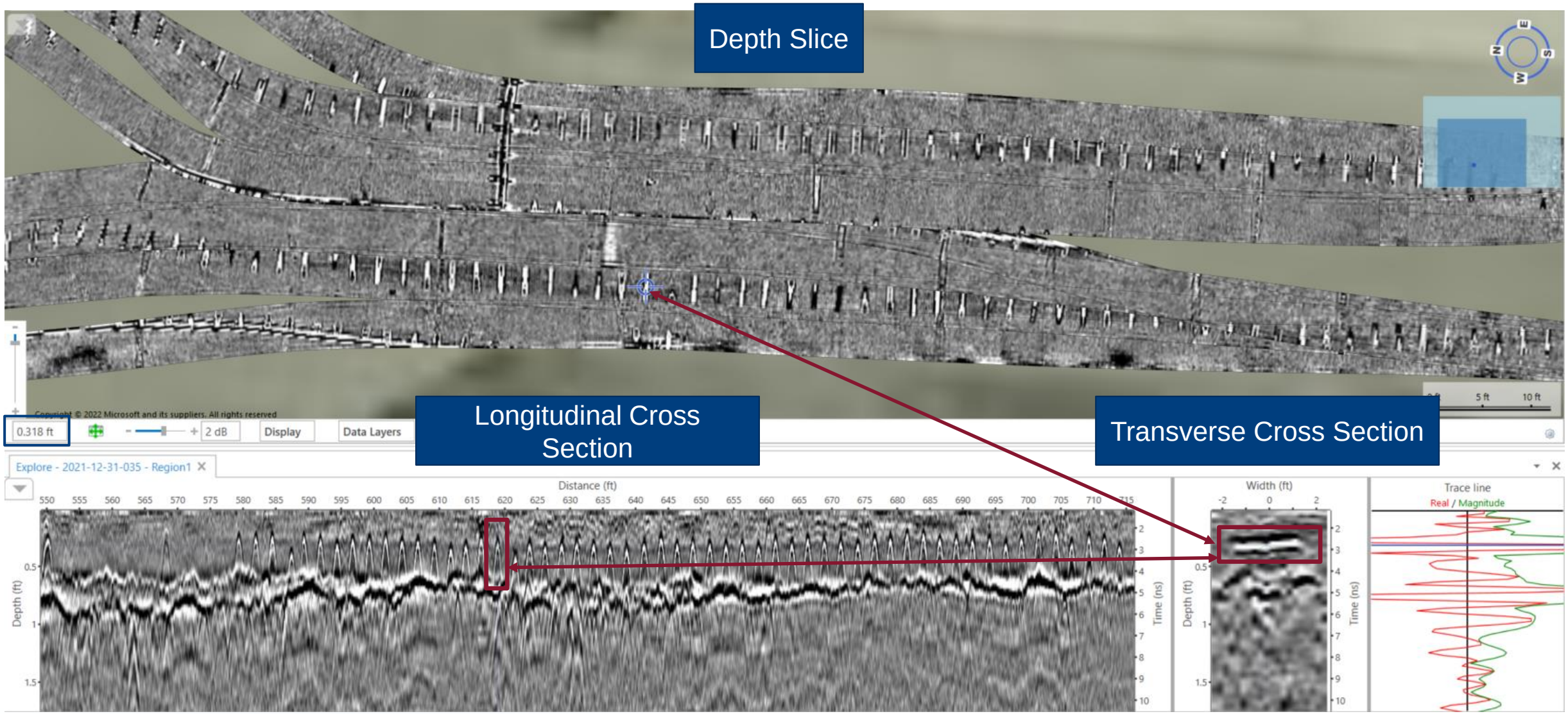


5 ft wide, 3 in. scan spacing

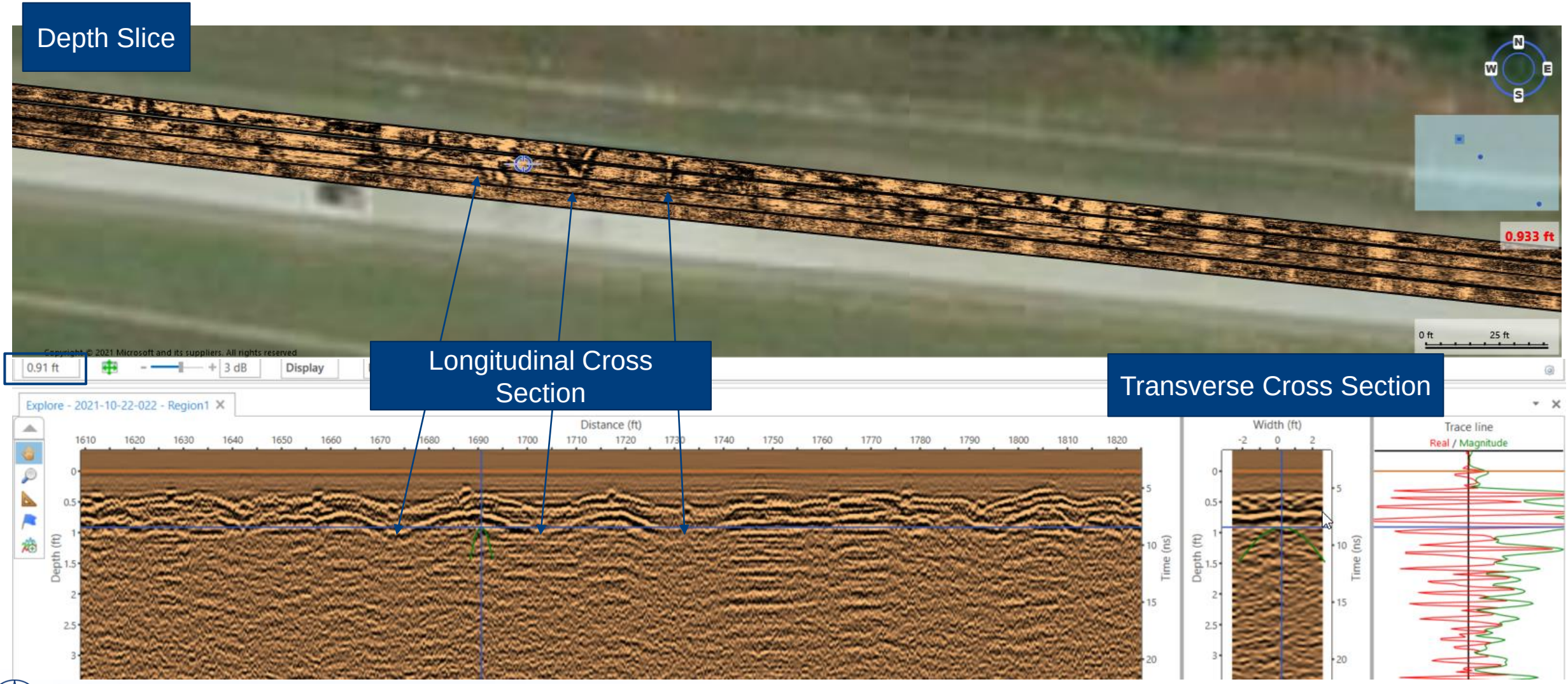
4 Antennas (300 MHz to 3GHz)

Close Contact for Deeper Scans

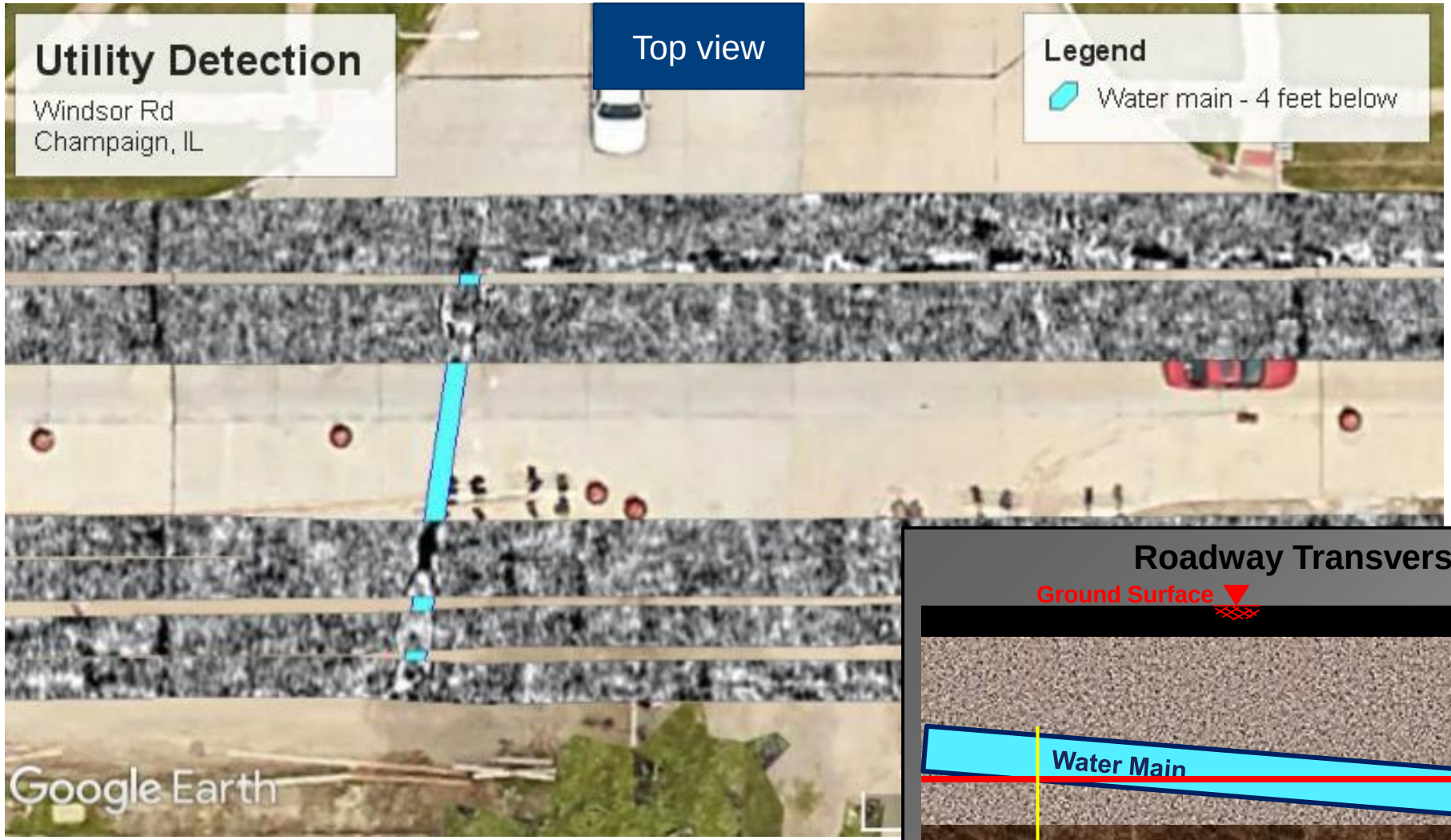
Tie-bars along transverse and longitudinal joints

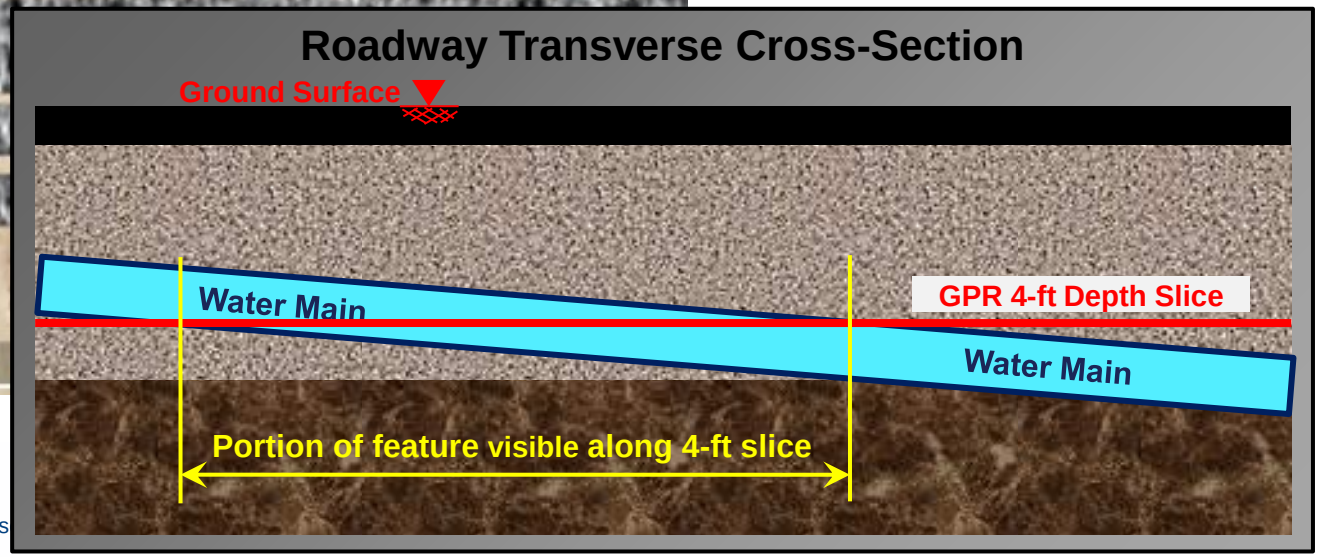


Voids under the PCC slabs
Interstate-20 Augusta, GA



Utilities



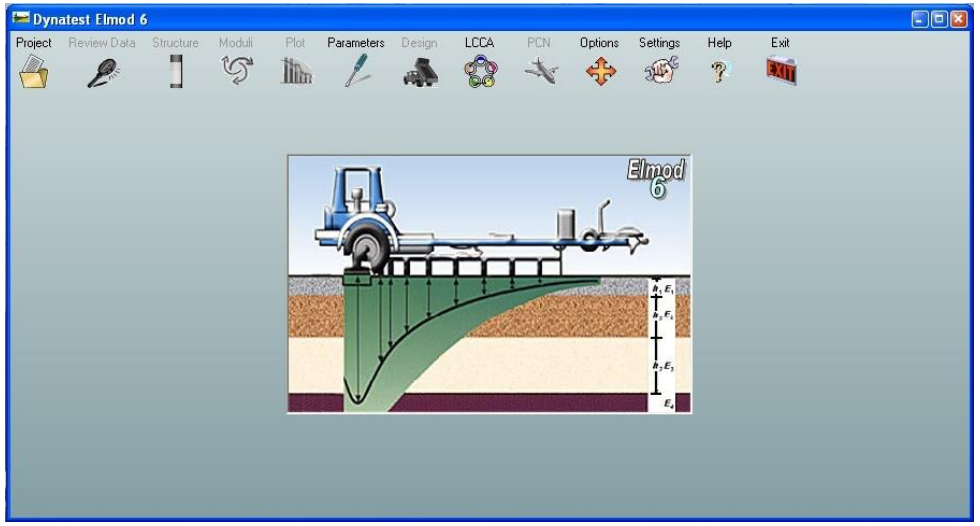


Pavement Layer Moduli Backcalculation

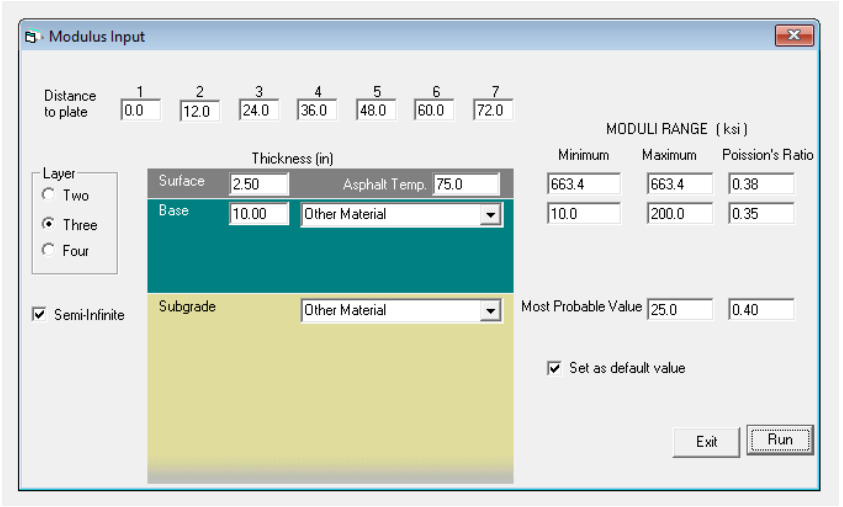
Backcalculation is the process of converting measured pavement deflections into layer moduli

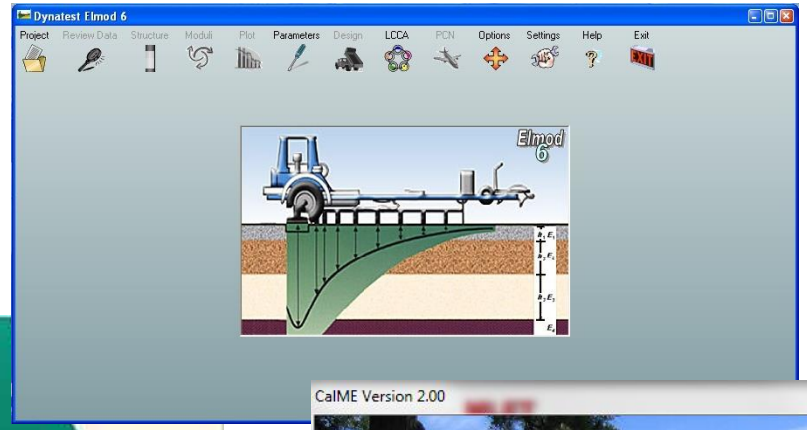
Backcalculation is done in an iterative process for each FWD tested location

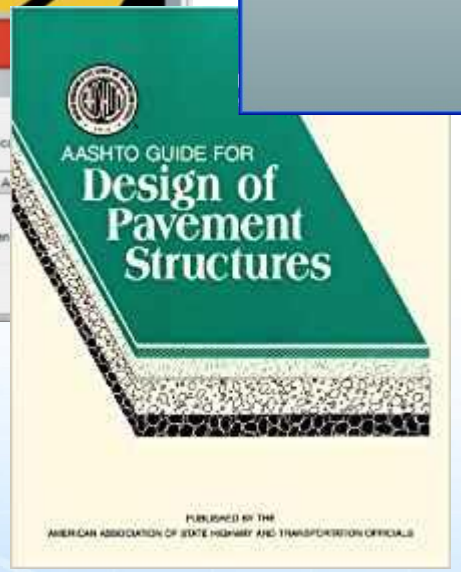
ELMOD 6.0

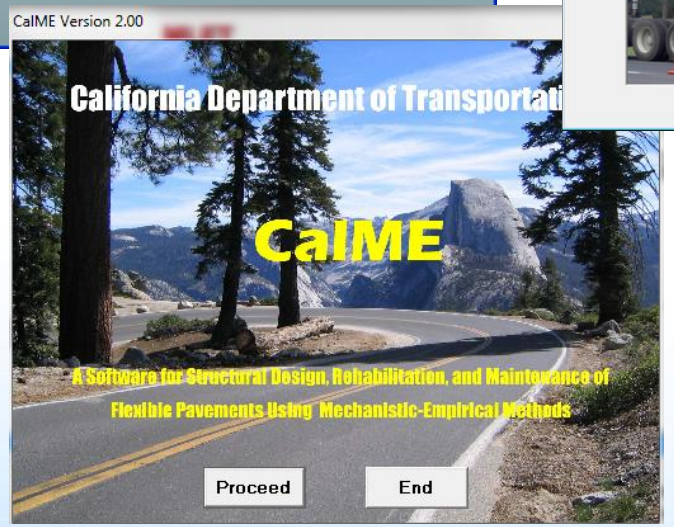


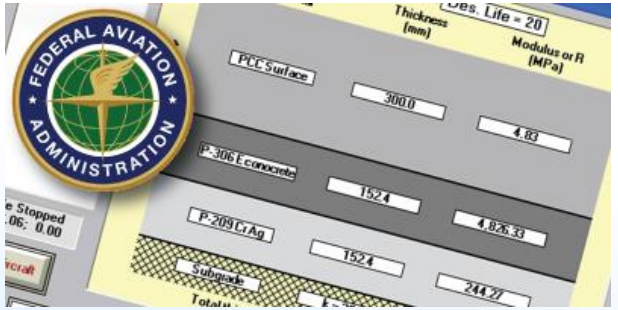
Modulus 6.0











Pavement
Rehabilitation Design Methodologies

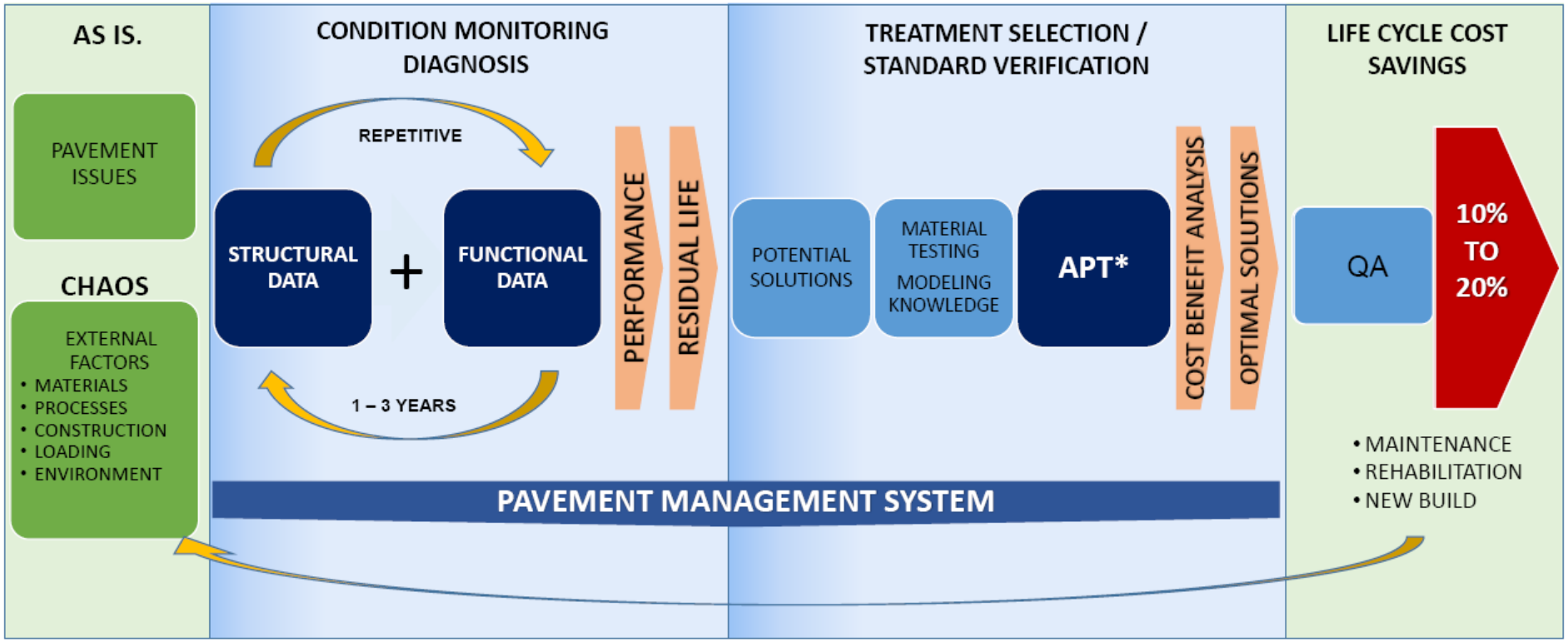
Pavement Management System

Provide analytical tool to optimize the available funding or justify additional funding to improve the roadway network conditions.

Allocate and prioritize the most cost-effective maintenance & rehabilitation alternatives at the right time to the right pavement utilizing:

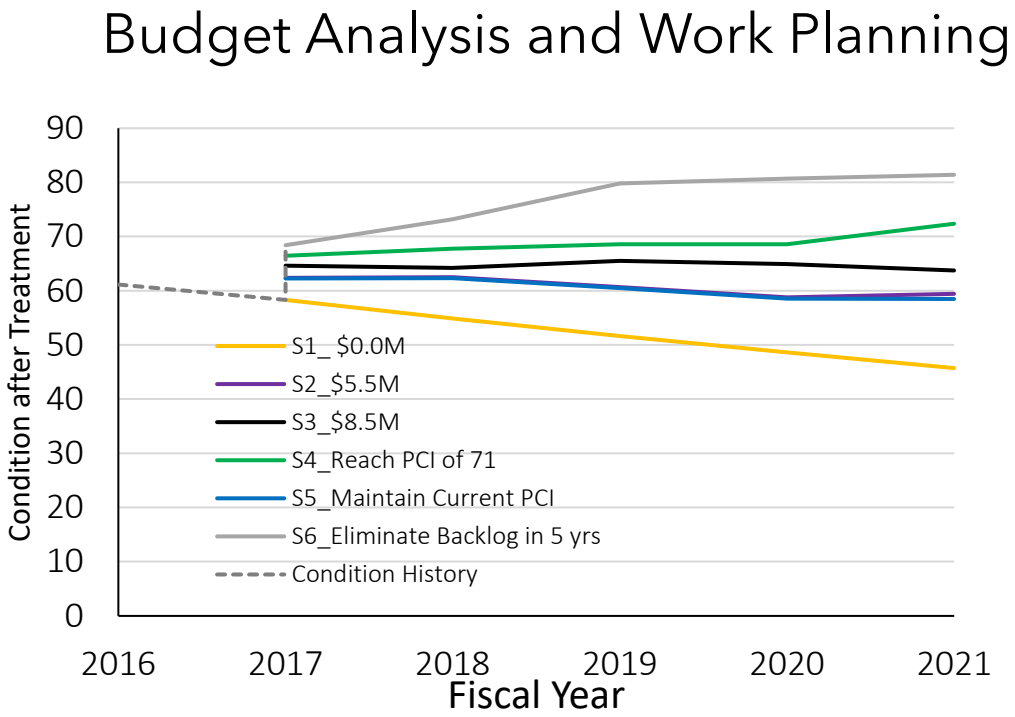
- Performance Indices (Functional and Structural)
- Benefit/Cost Analysis
- GIS
- Local Construction Practices
- Technical Specifications

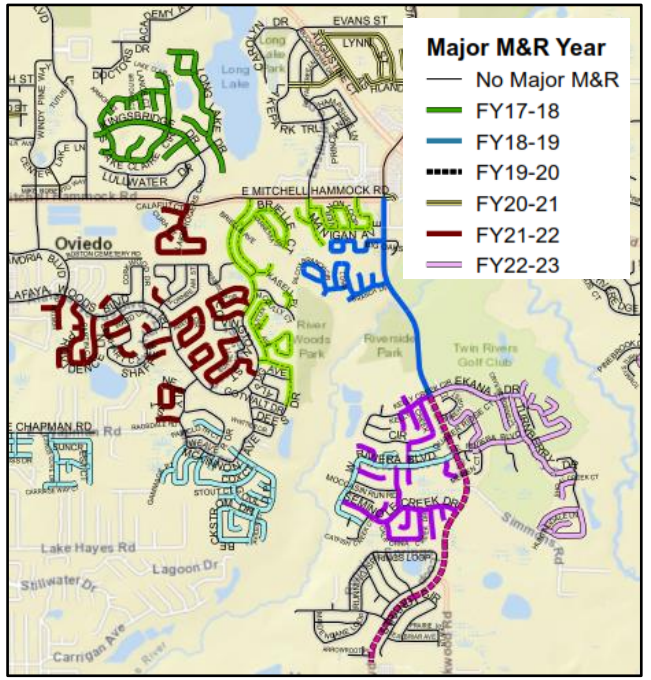
Pavement Management System Cycle



* APT = Accelerated Pavement Testing

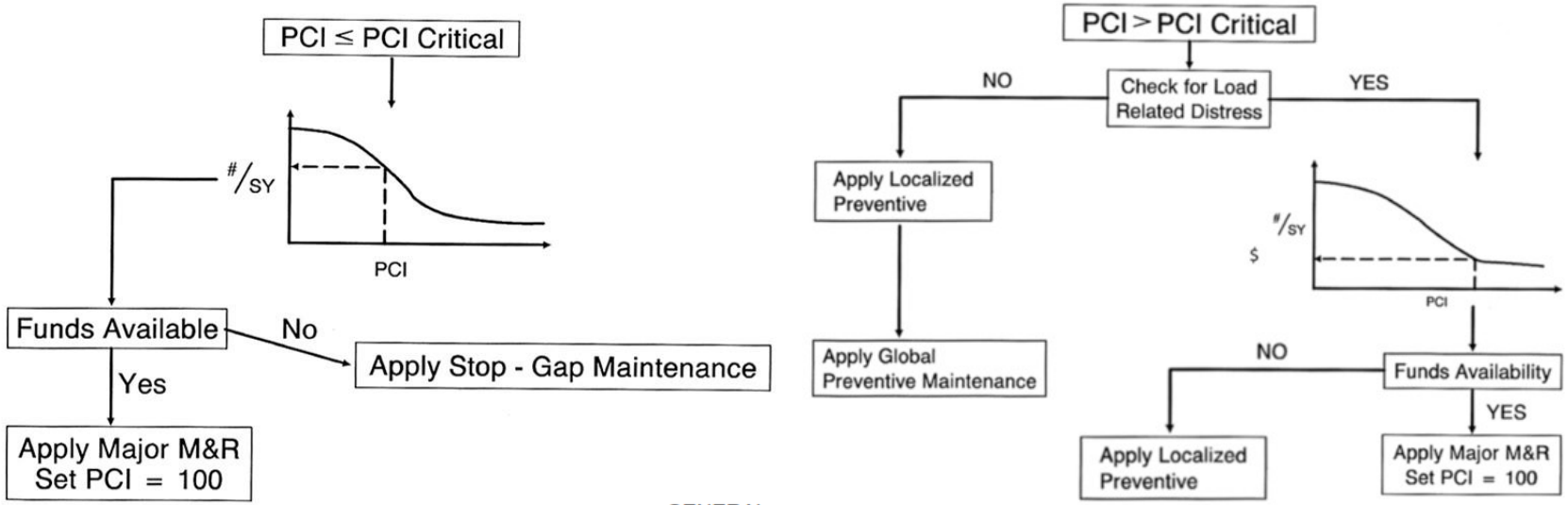
Pavement Management Program



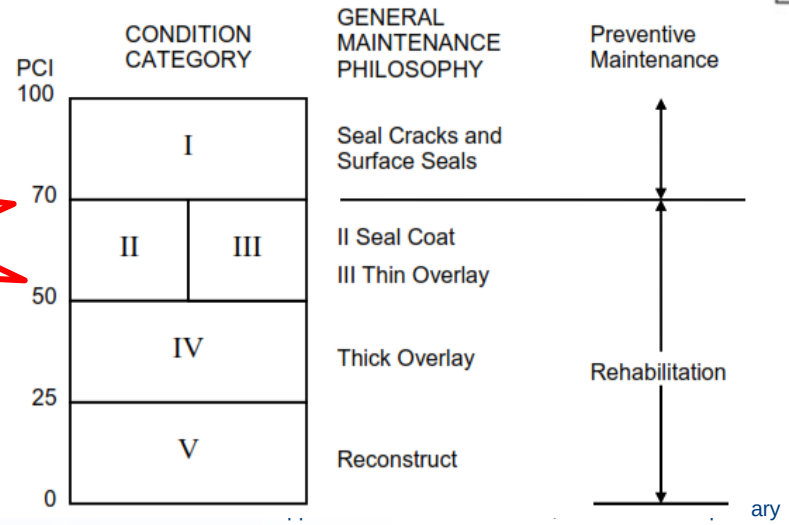


Pavement Management Program

Development of M&R Costs, Strategies, Policies & Decision trees



No Structural Index

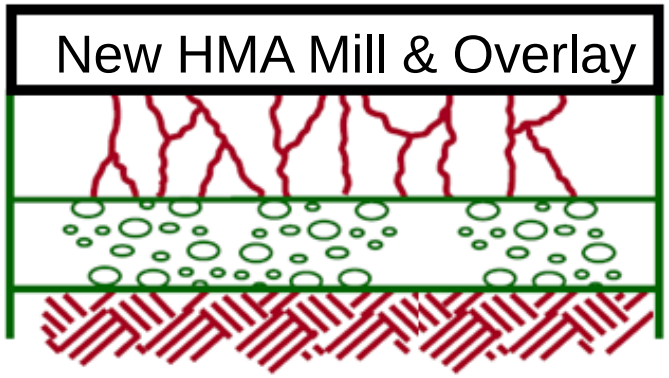


PCI based M&R Decisions

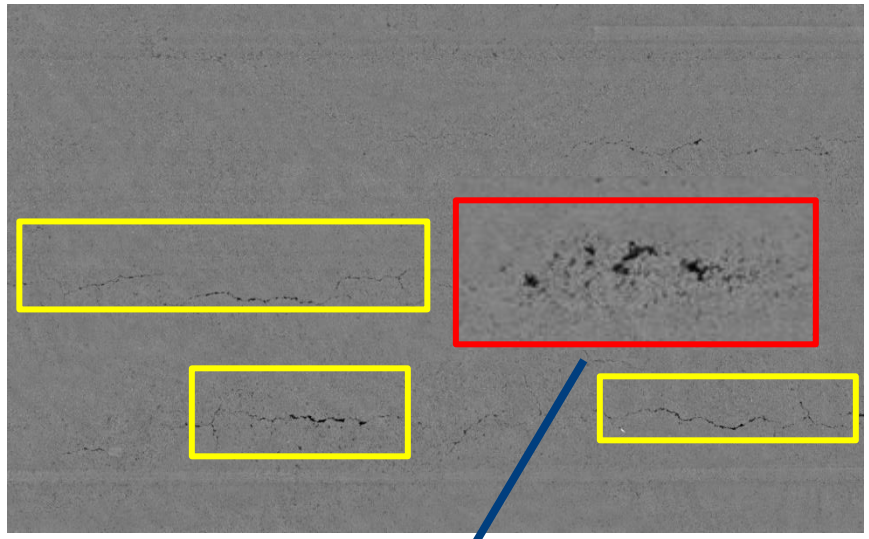
PCI Based PMS Limitation

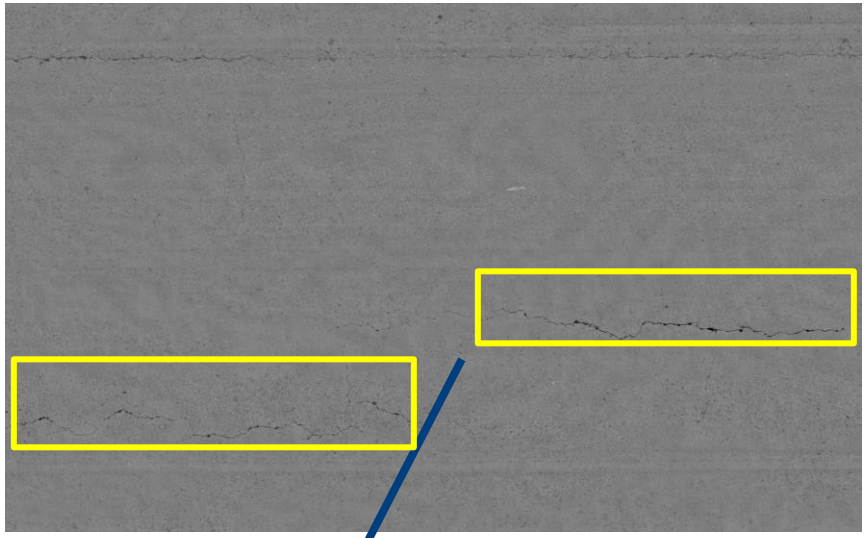
PCI<50

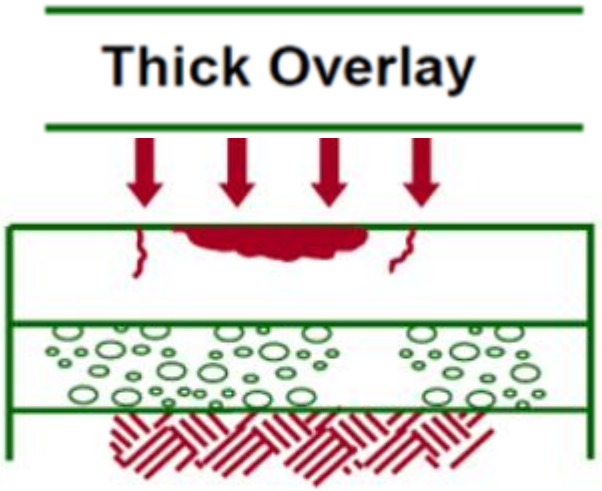
No Structural Performance Data

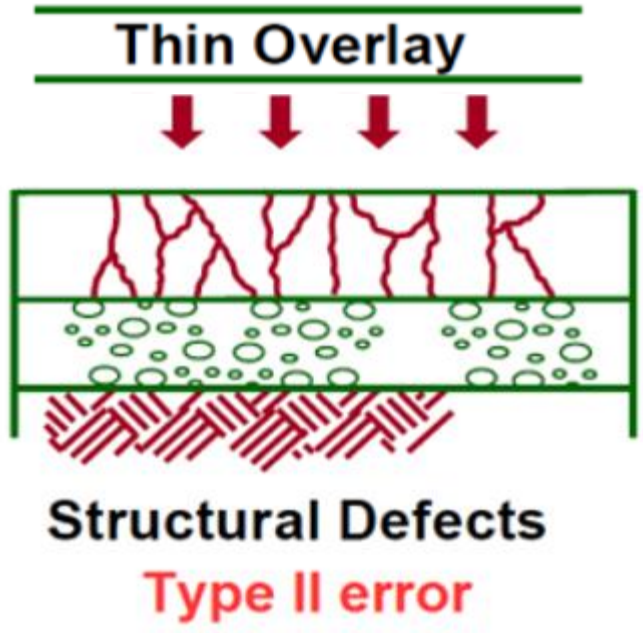


PCI=100



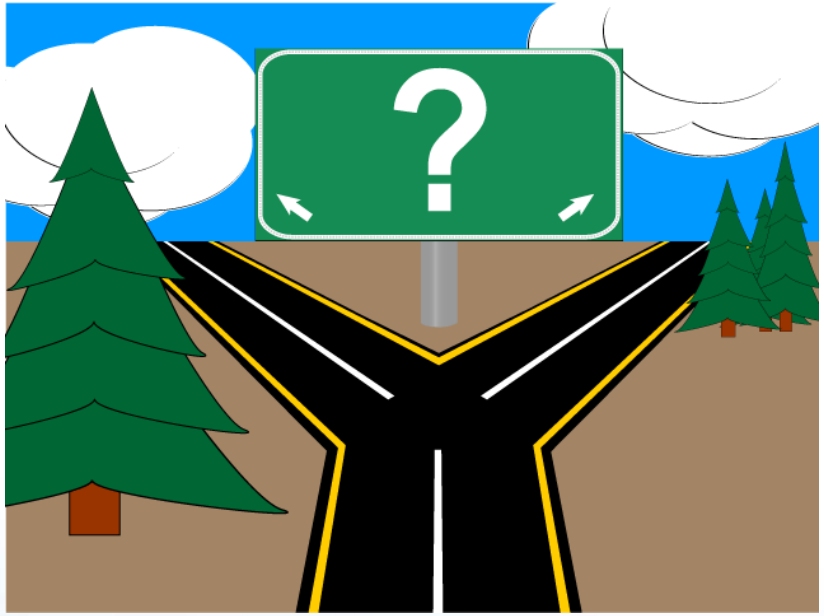






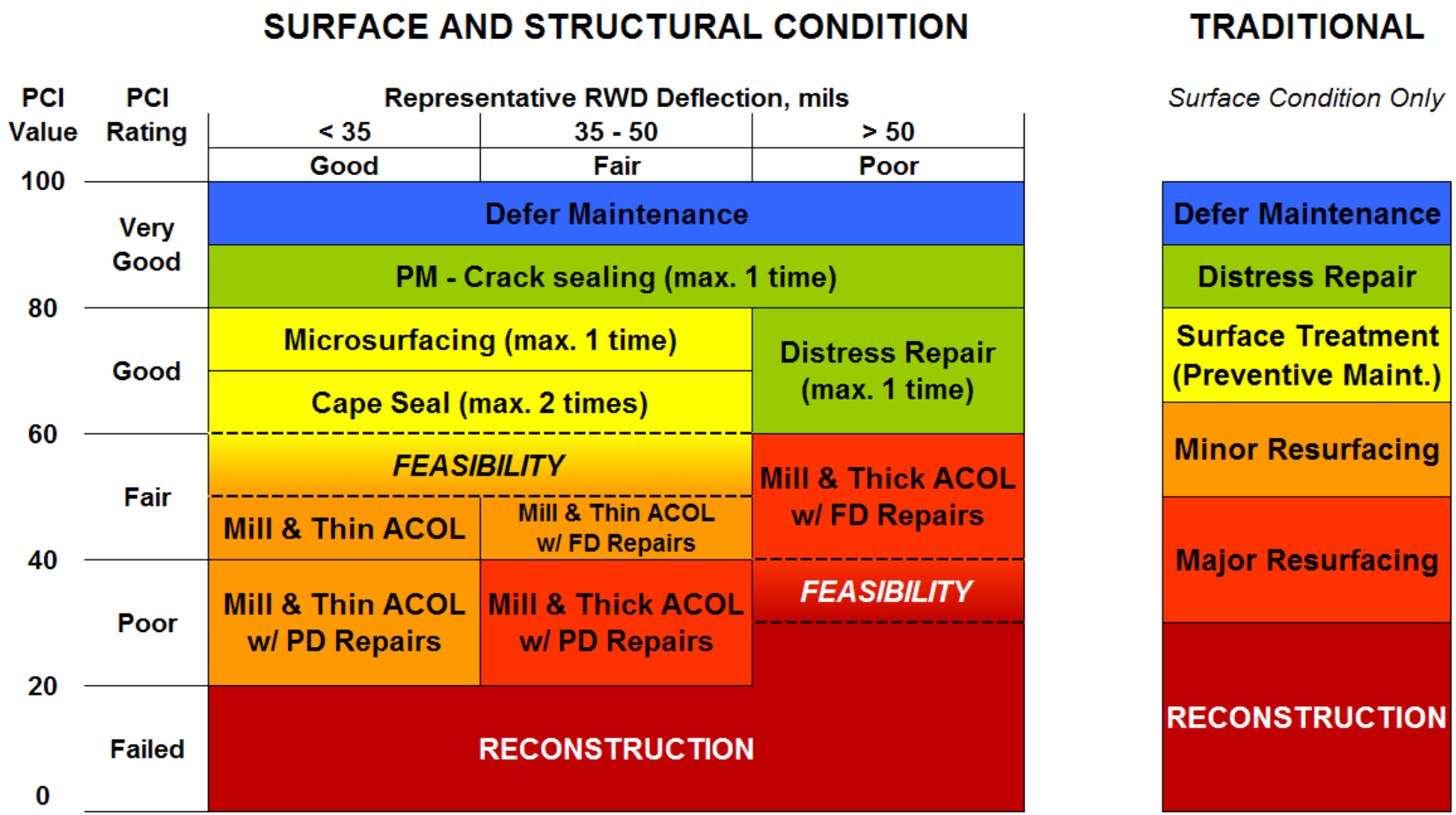
Primary Products of Pavement Structural Evaluation

- ✓ Enhance decision making process in PMS
- ✓ Provides tool to better select right treatment to fix root cause of pavement failure
- ✓ Better forecast future conditions
- ✓ Prioritized listings
- ✓ Pavement rehabilitation design and LCCA to select most cost-effective solution



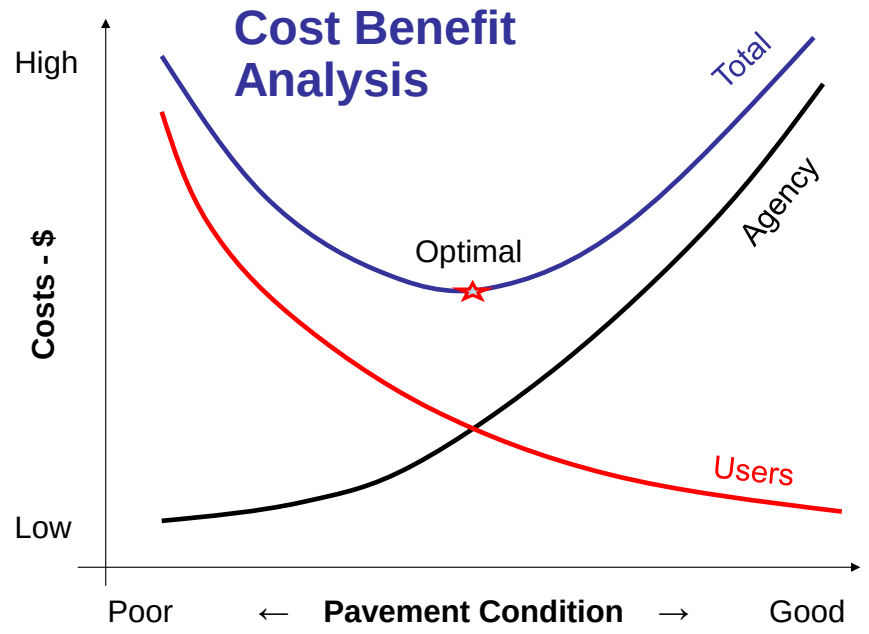
Use of Pavement Structural Performance in PMS

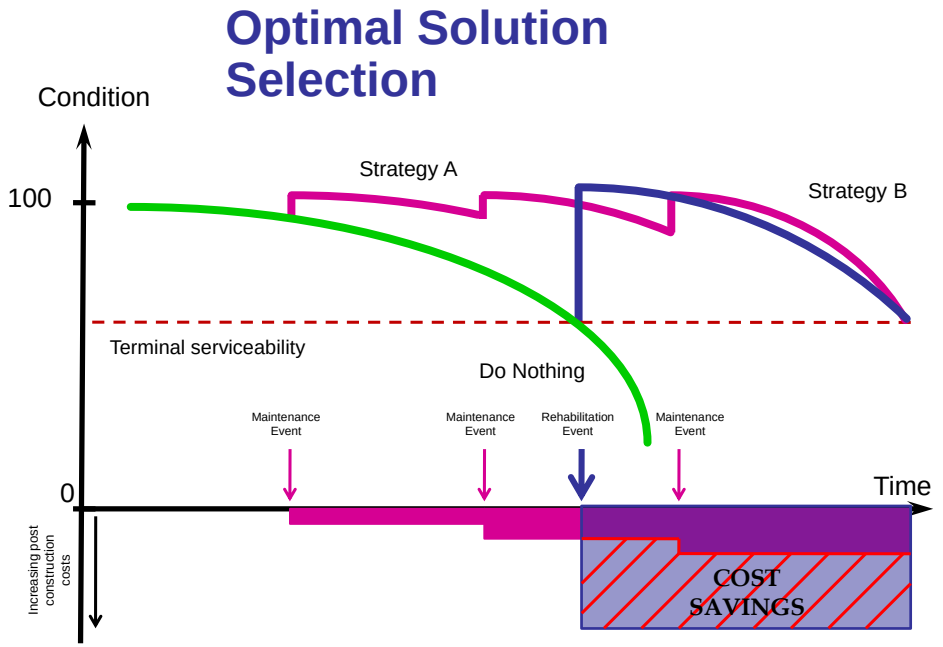
Combining Functional and Structural Condition



Cost Benefit Analysis and Optimal Solution Selection

Considering construction, maintenance, rehabilitation, AND user costs





Pavement Structural Performance to Select Most Cost-Effective Set of Alternatives

Life Cycle Cost Analysis:

- Most Comprehensive
- Requires:
  - Traffic
  - Pavement layer thicknesses and types
  - FWD derived layer moduli
  - Pavement remaining life
  - PCI

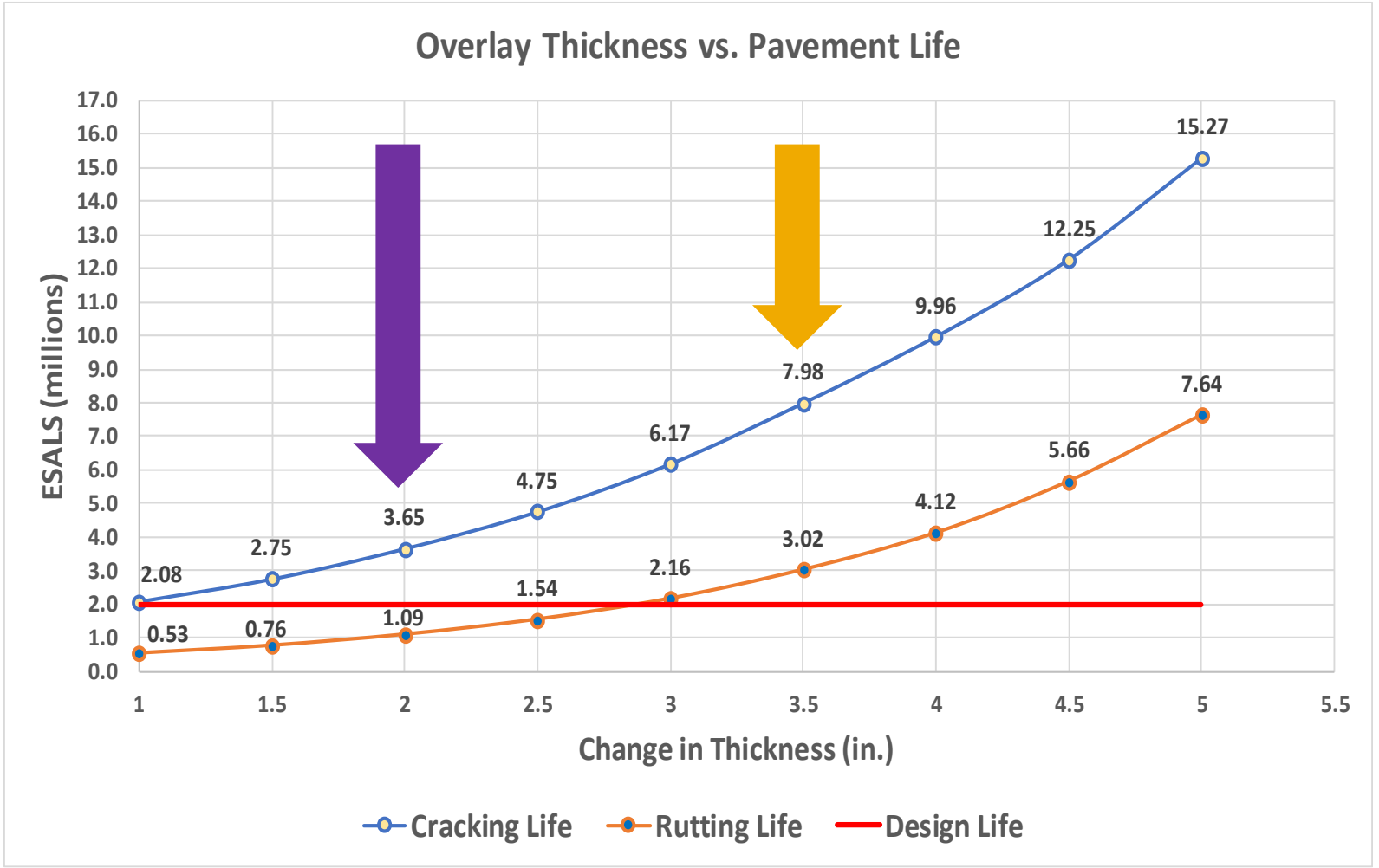
Agency	Total	Year	Action	Year	Action	Year	Action
72499	127315	2019	AC thin course	2025	AC thin course	2031	Seal coat
77574	122356	2018	AC thin course	2024	AC thin course	2030	Seal coat
167955	203107	2017	Seal coat	2023	AC ov 4	2030	Seal coat
198068	254696	2016	Recycling	2026	AC thin course		
203970	263859	2020	AC inlay	2028	Seal coat		

Cost of Overlays

Cost of too little?

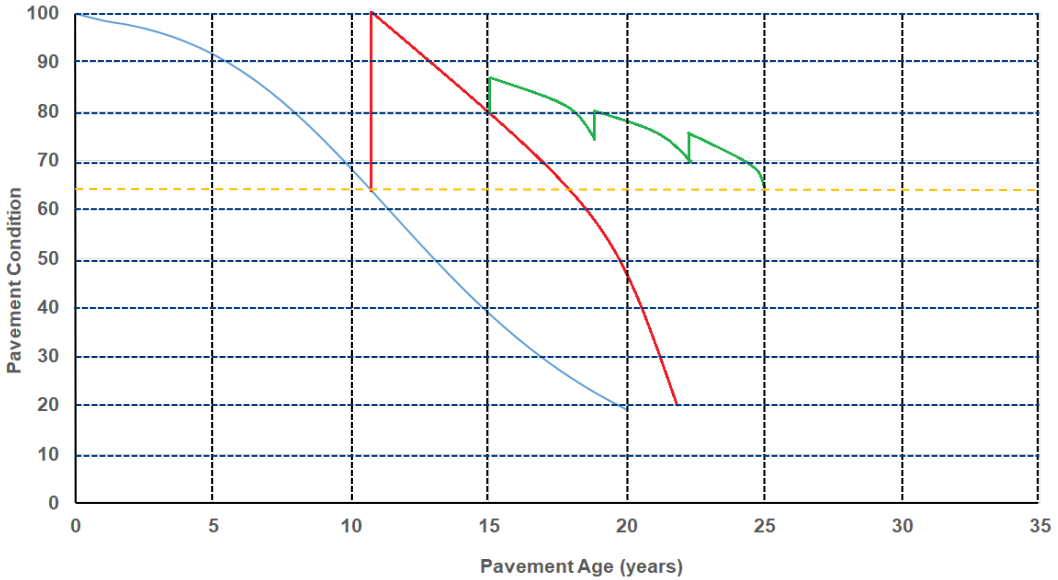
Cost of too much?

Overlay Thickness	$ Per Lane Mile
½ in.	$13,589
1 in.	$27,179
1 ½ in.	$40,768

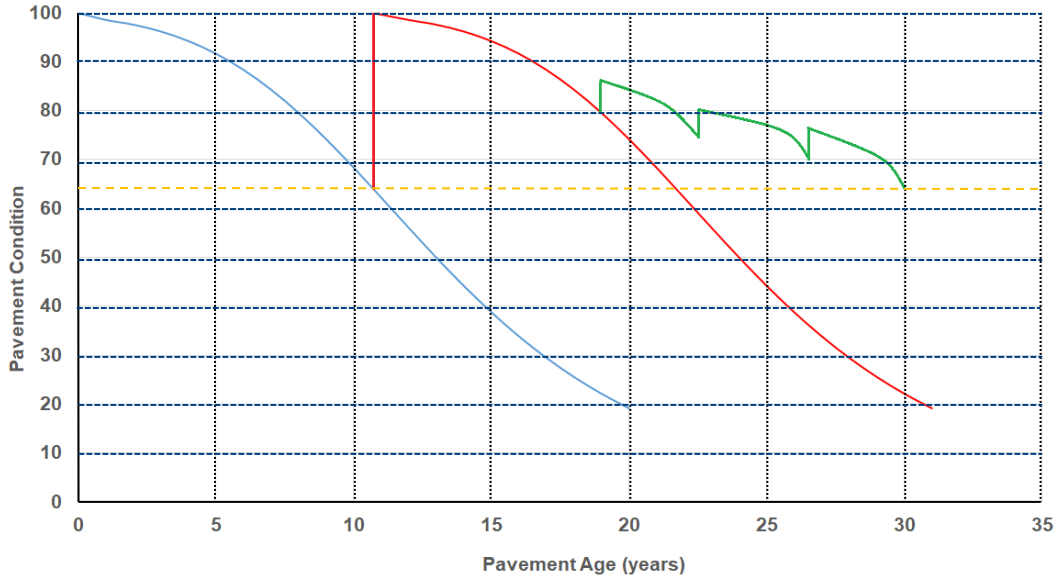


http://www.txdot.gov/business/letting-bids/average-low-bid-unit-prices.html

LCCA Example

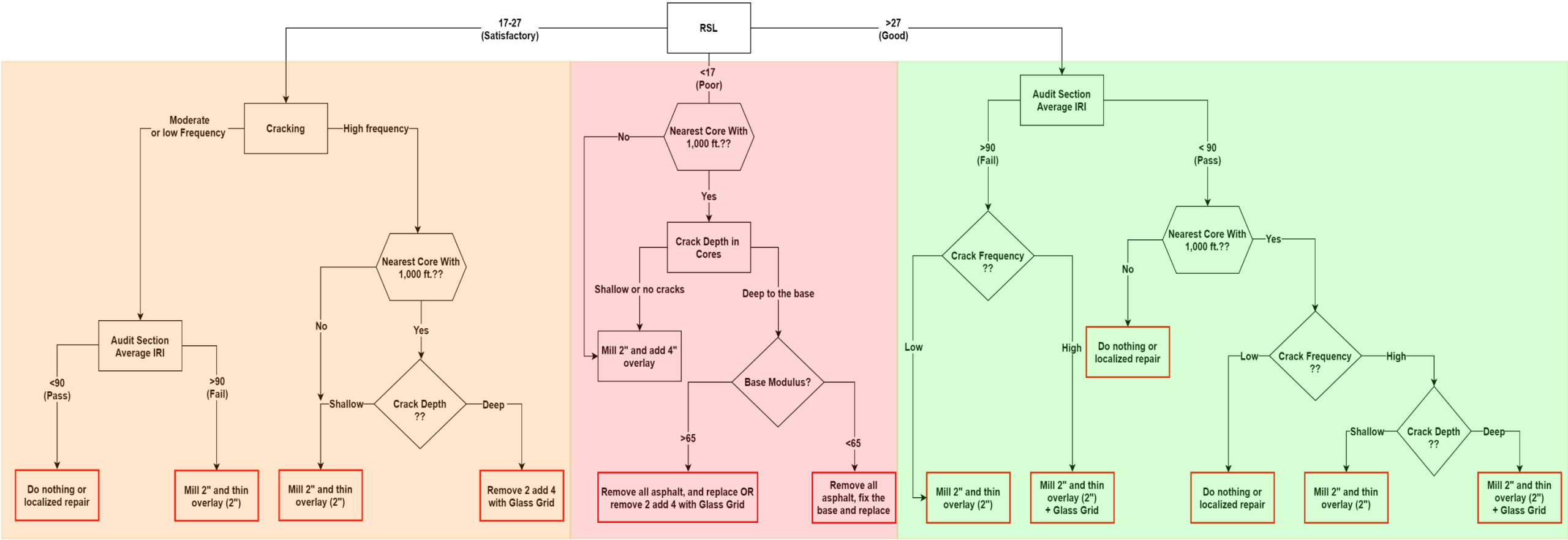


2” Mill & HMA Overlay @ Year 11 = $100,000/mile
Surface Treatment #1 @ Year 15 = $30,000/mile
Surface Treatment #2 @ Year 19 = $30,000/mile
Surface Treatment #3 @ Year 23 = $30,000/mile
Total Investment = $190,000/mile
Pavement Life PCI > 65 is 25 years

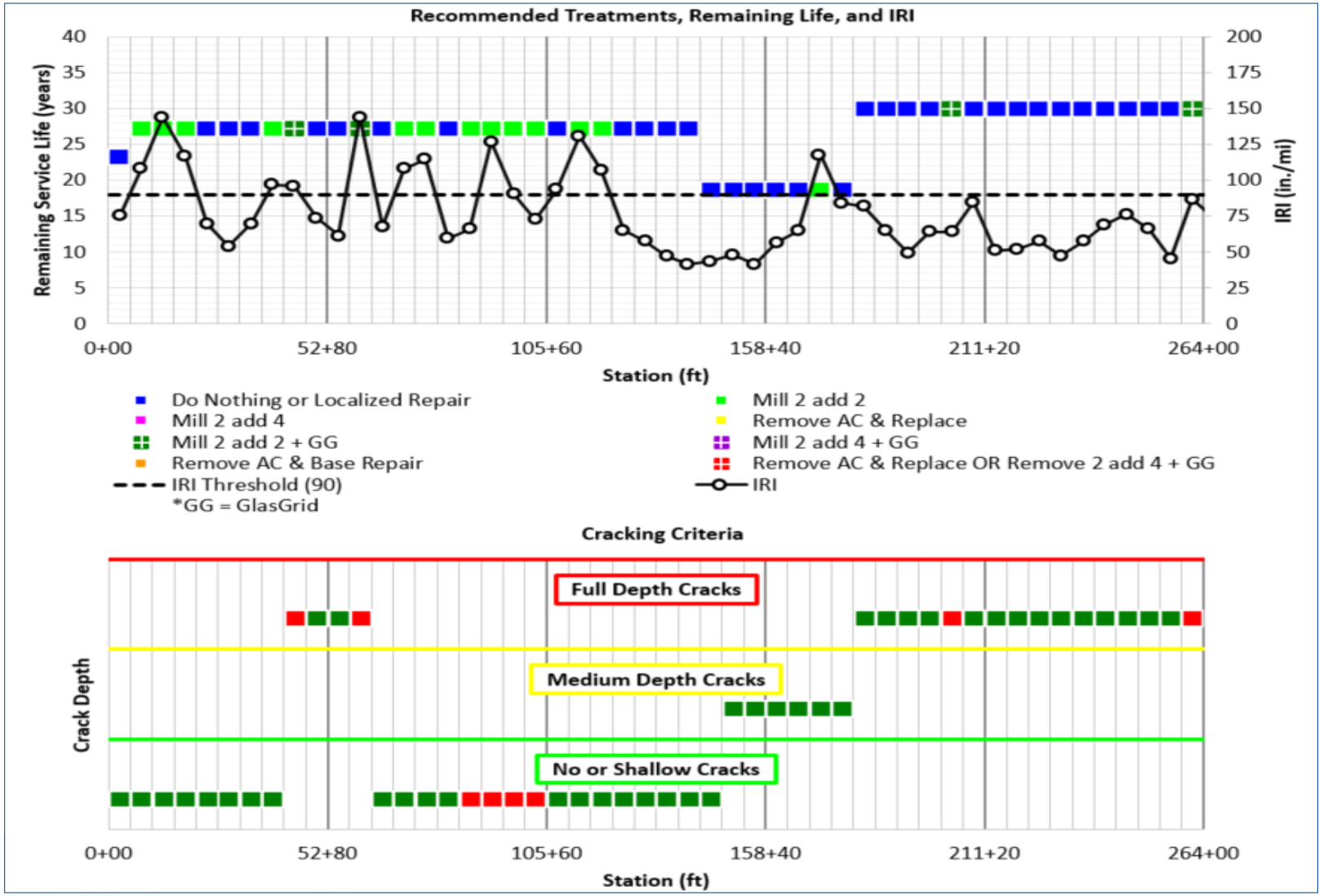


2” Mill & 3” HMA Overlay @ Year 11 = $130,000/mile
Surface Treatment #1 @ Year 19 = $30,000/mile
Surface Treatment #2 @ Year 23 = $30,000/mile
Surface Treatment #3 @ Year 27 = $30,000/mile
Total Investment = $220,000/mile
Pavement Life PCI > 65 is 30 years

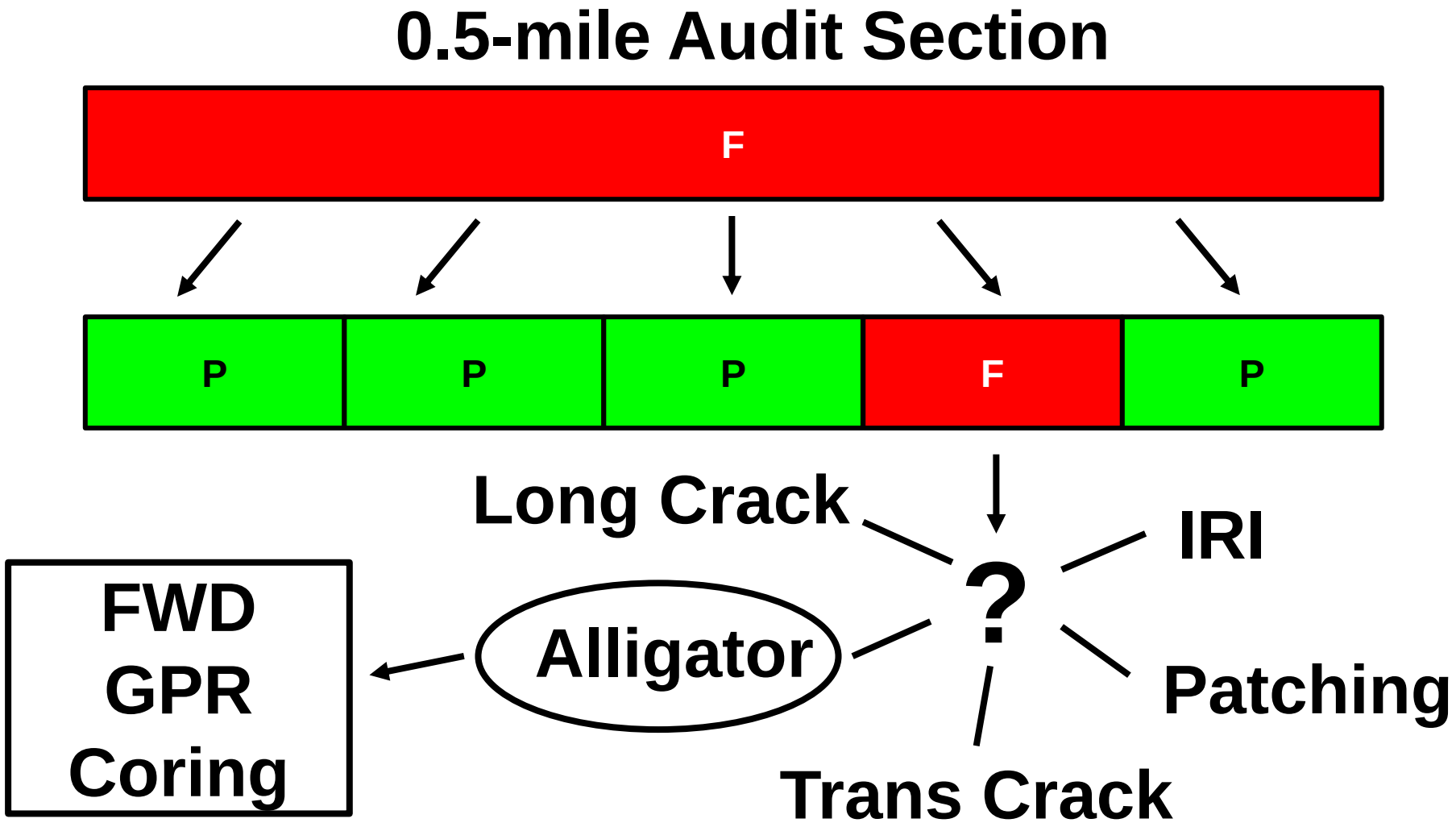
M&R Decision Tree based on Pavement Functional and Structural Performance



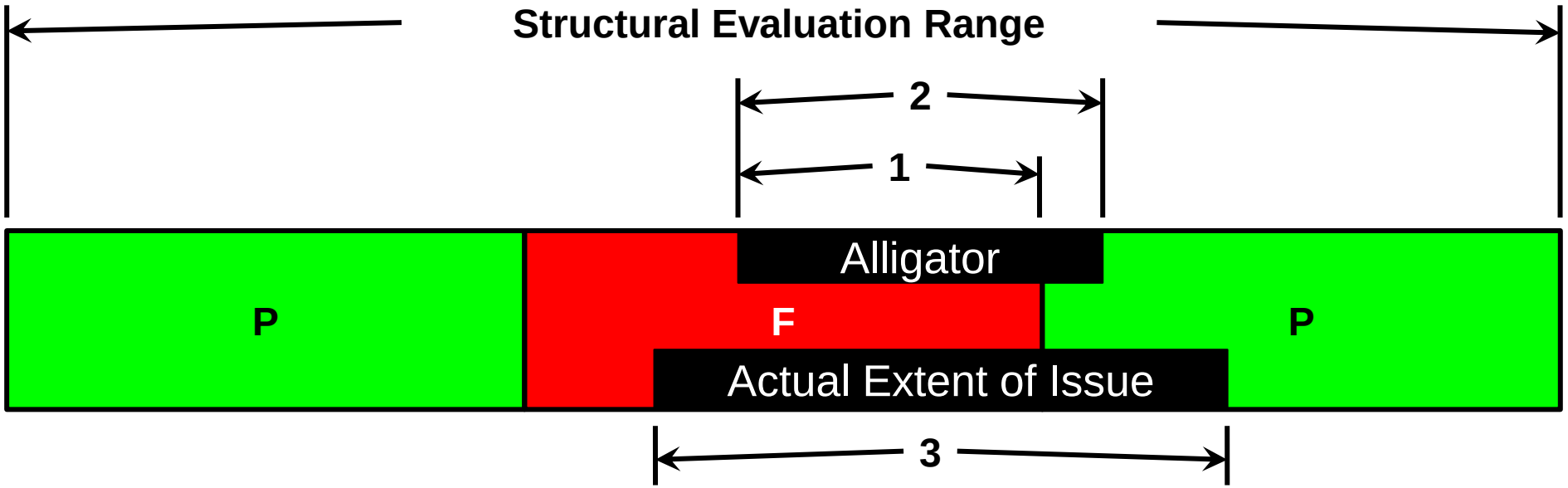
M&R Recommendations based on Pavement Remaining Life and Surface Condition



Drilling Down with Project Level Information – Why?



Extent of the Issue – Identifying Proper Repair Limits



1 – Only addresses visible extent of distress within failed 0.1-mile section
2 – Addresses all visible distress into adjacent 0.1-mile section
3 – Structural evaluation to determine actual extent of structural damage

Session Recap

- PCI based PMS lacks structural performance characteristics
- Comprehensive PMS program must account for pavement structural capacity
- M&R decisions and budget allocation need to consider both pavement functional and structural performance
- FWD and GPR are non-destructive pavement evaluation tools that can be used for both project and network level
- A structural condition index/parameter can be incorporated into the PMS program
- Network level pavement structural evaluation is useful to enhance PMS decision making process and isolate areas that require project level evaluation
- Project level pavement structural evaluation is needed to determine most cost-effective M&R alternative based on LCCA and comprehensive pavement condition assessment

Thank You!

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