

Virtual Surface for Runway, Multi-Lane Highways, Bridge Decks at 1mm Resolution

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Outline

- PaveVision3D Ultra (3D Ultra) system
- Airport runway evaluation
- Multi-lane highway evaluation
- Virtual bridge deck



Common Problems

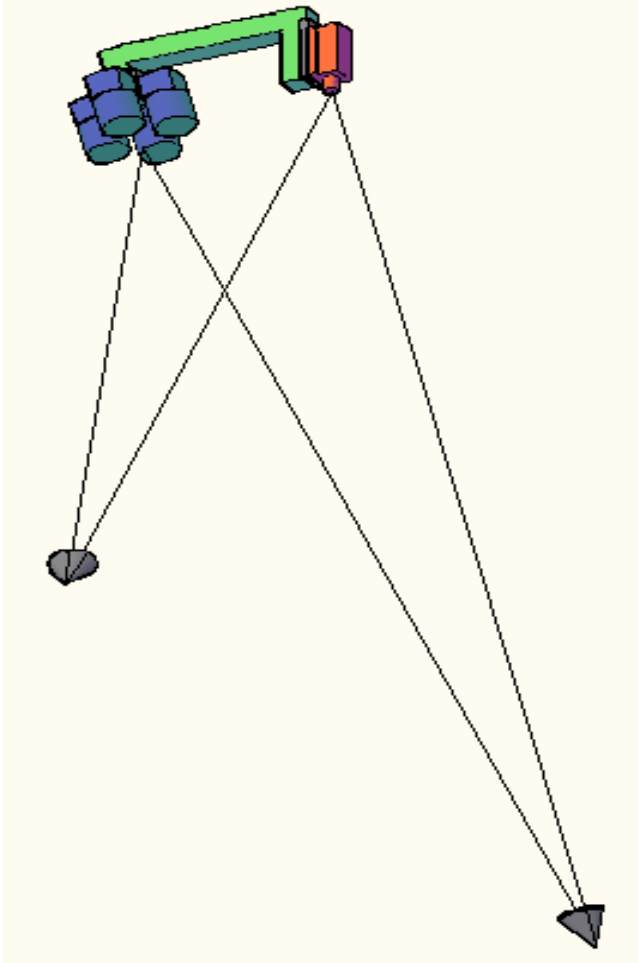
- ❑ Accurate and timely pavement surface characteristics: critical for performance evaluation and safety
- ❑ Poor quality of field condition data
 - ❖ Particularly cracking
- ❑ Operating 3D Profile Line Rate
 - ❖ 4000 -8000/sec: 4mm to 6mm (1/4") resolution at 60MPH
 - ❖ Good enough for some purposes; not sufficient

PaveVision3D Ultra

- Use multiple sensors
- Increase 3D profile line rate to 30,000/second
- Complete coverage of pavement lane
 - ❖ 1mm resolution in 3D at collection speed up to 60MPH
- High-precision IMU
 - ❖ Grades, curves, cross slope



PaveVision3D Ultra - Existing



PaveVision3D Ultra - New



PaveVision3D Ultra - New

- Green lasers: previous red lasers
 - More uniform illumination
 - Substantially better sensitivity for 3D cameras
 - Consistently higher quality data, regardless of ambient light condition changes and pavement color variations

 - 3D Ultra: simultaneously acquire both 3D "Range" and "Intensity" data
 - Totally synchronized with pixel-to-pixel accuracy
 - Complement each other for cracking detection and rutting measurement
-

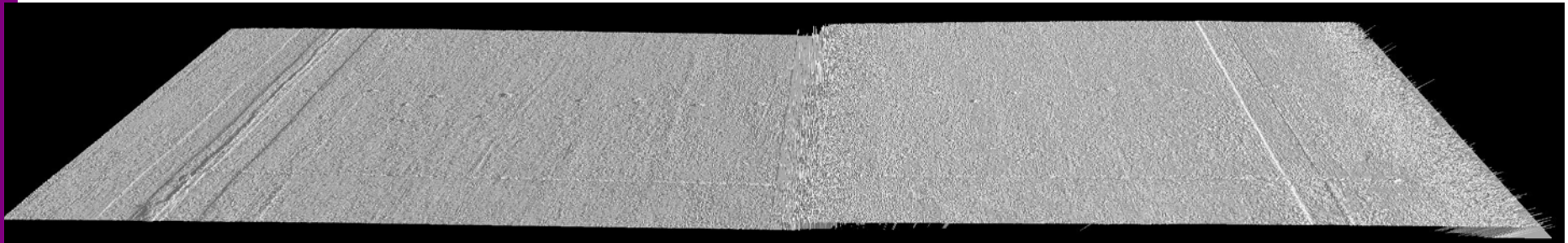
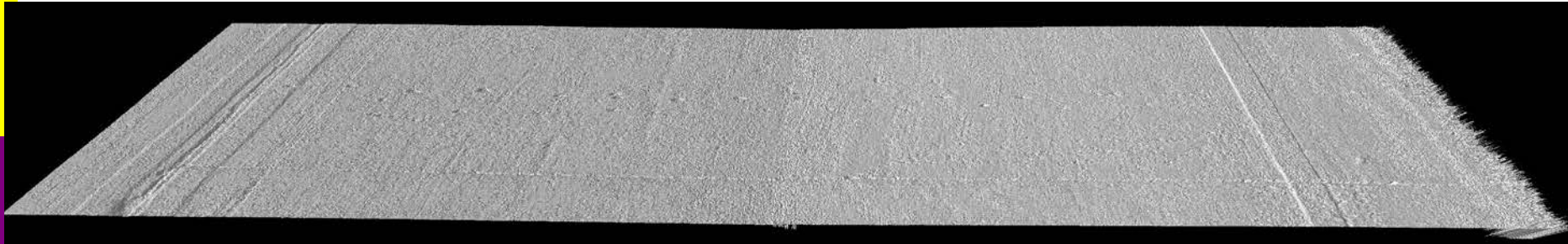
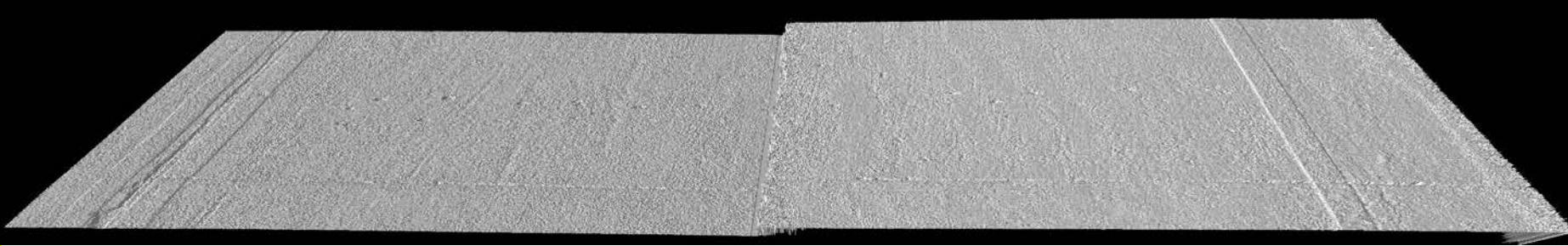
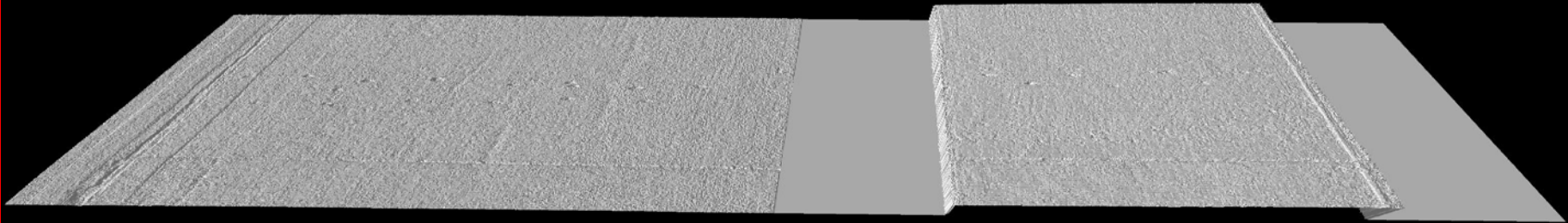


Green Laser Testing

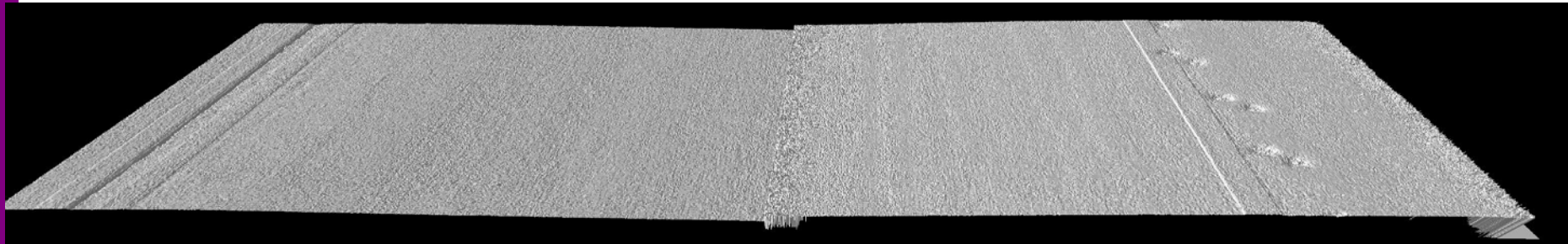
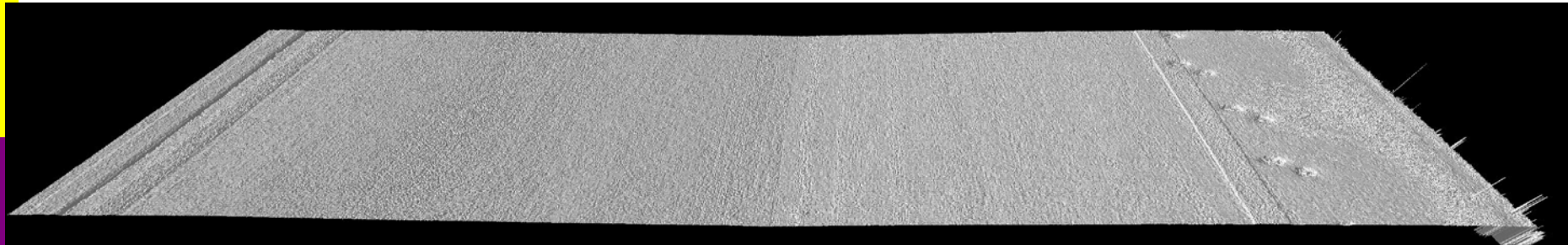
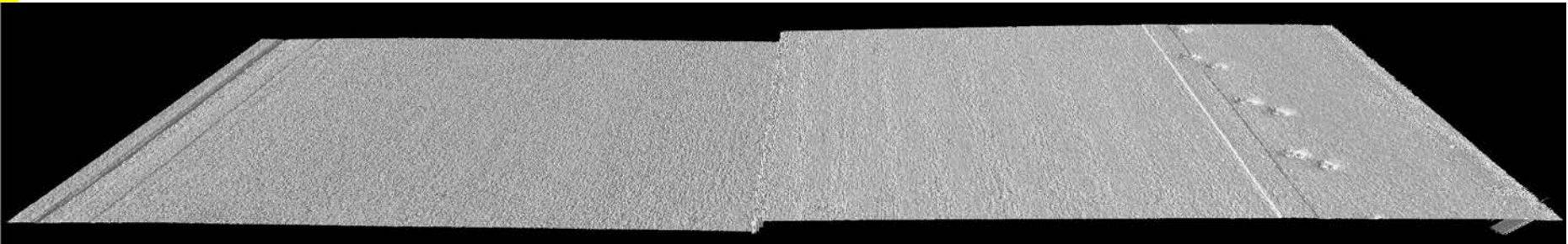
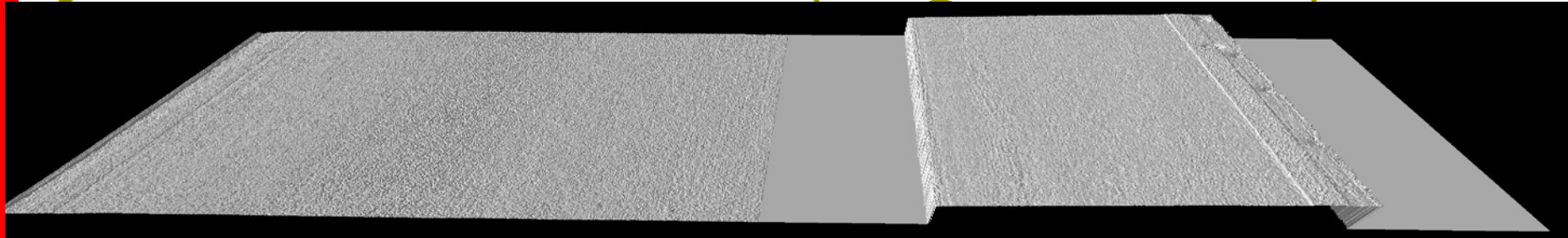
- Left: red laser; Right: green laser
- Field Testing
 - Brand New Asphalt (Husband Rd)
 - Brand New PCC (Jardot St)
 - Typical Surface at High Speed (US51)
- Various exposure time setting



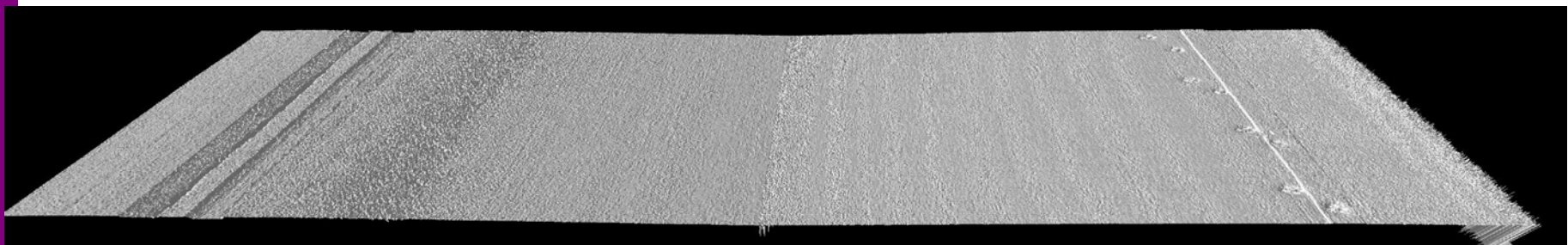
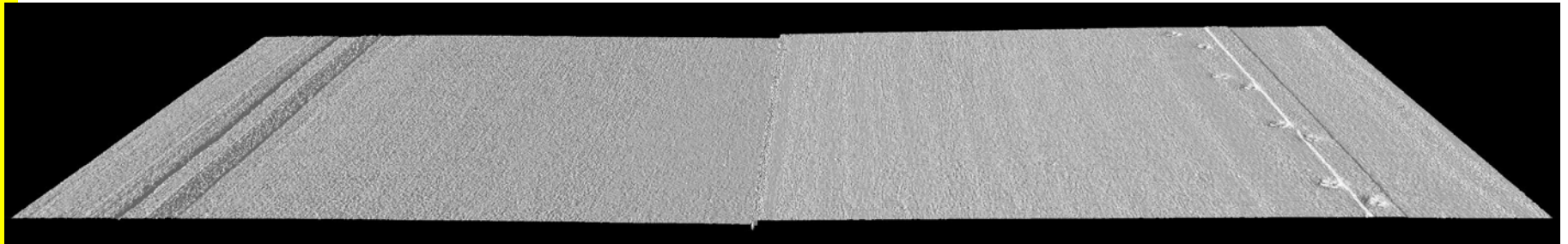
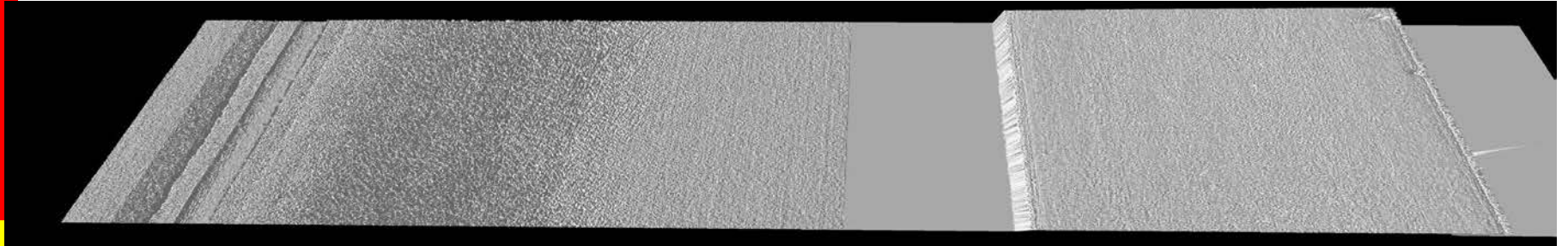
Jardot – New PCC (Exposure #1)



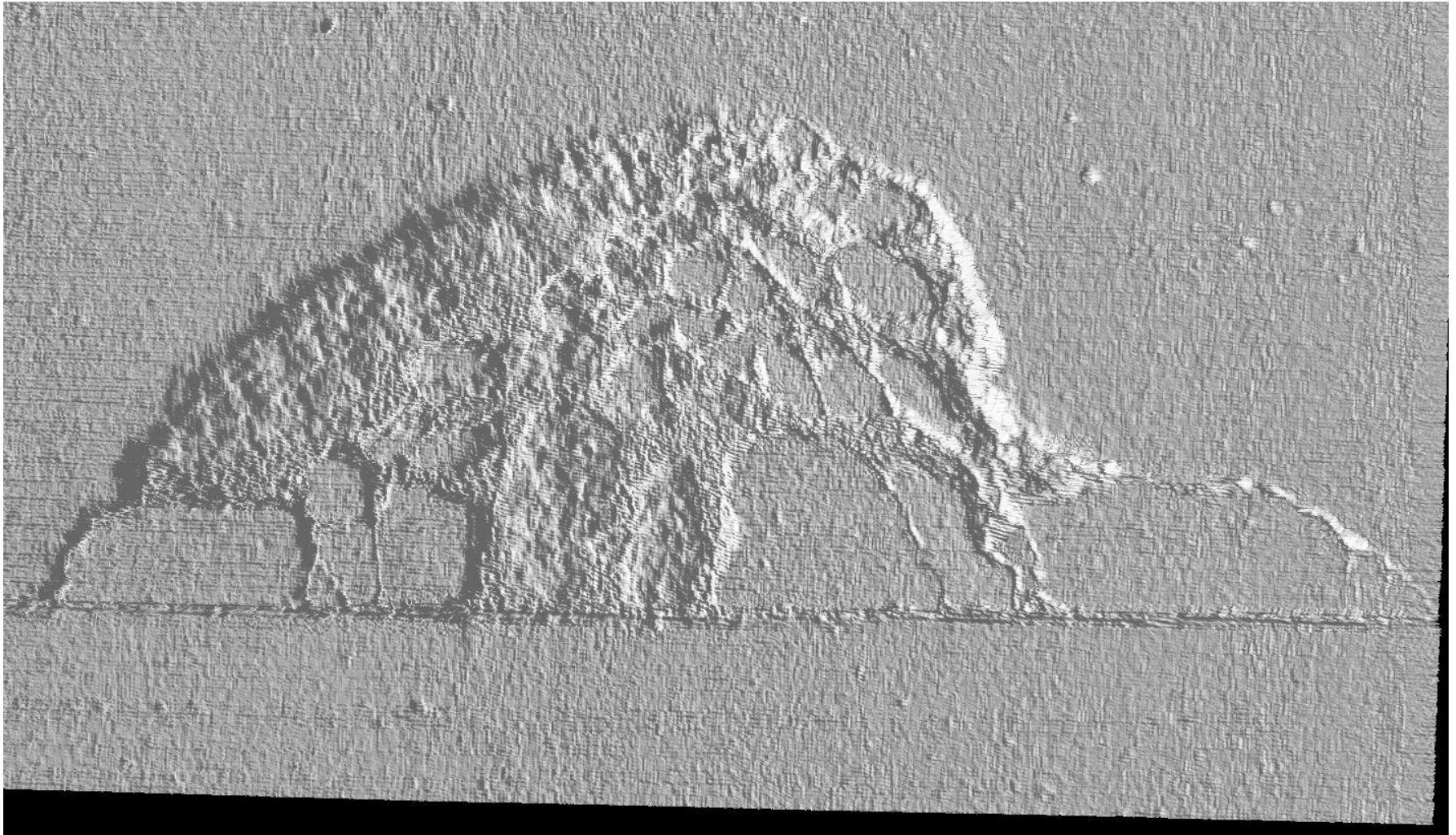
Jardot – New PCC (Exposure #2)



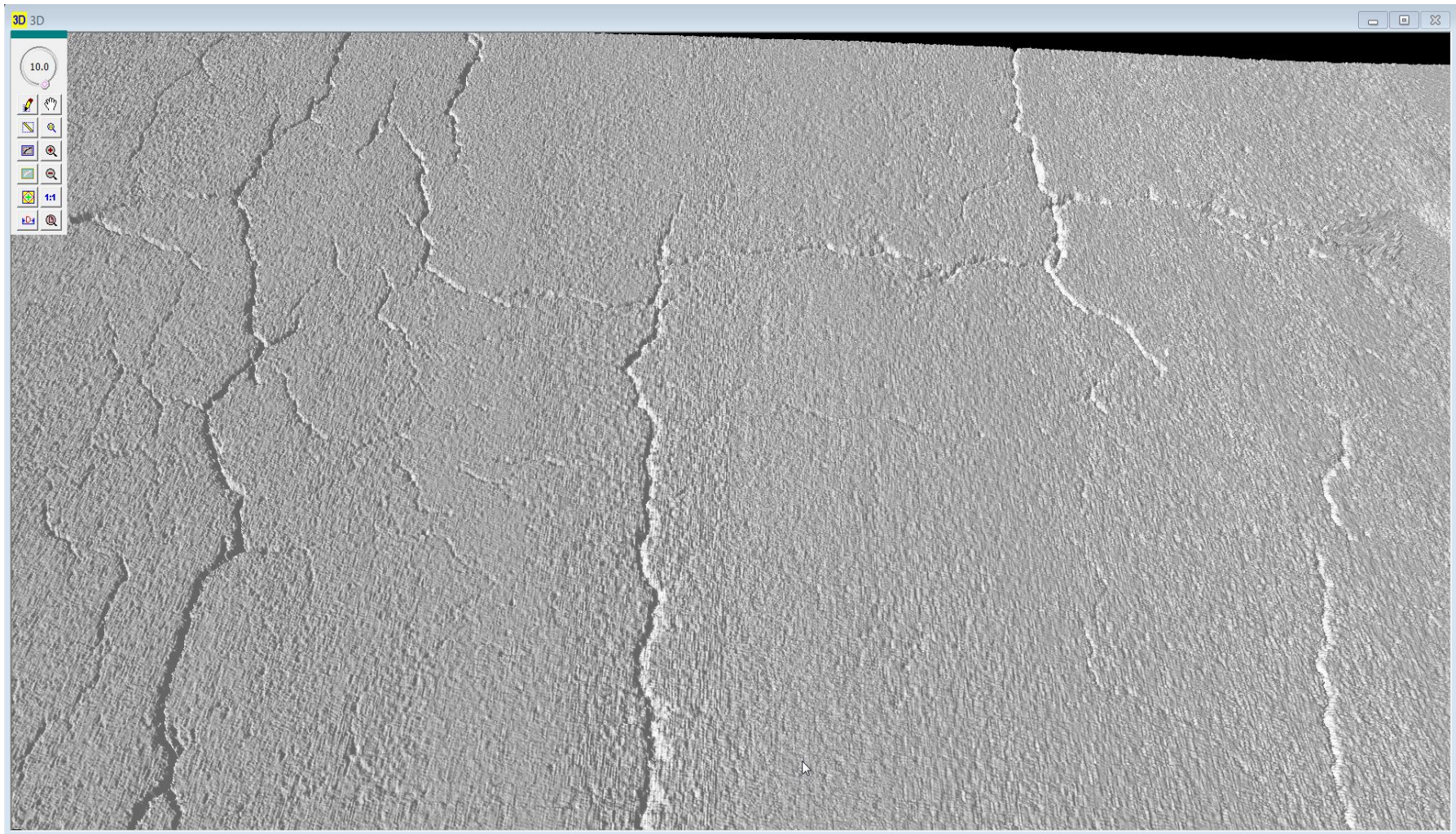
Jardot – New PCC (Exposure #3)



New 3D Data - Example



New 3D Data - Example



New 3D Data - Example

The screenshot displays a software interface for 3D data analysis, divided into several panels:

- Pavement Image:** A vertical strip on the left showing a grayscale image of a road surface. A red horizontal line highlights a specific section. The vertical axis is labeled with stationing values: 001.4720, 001.4715, 001.4710, 001.4705, 001.4700, 001.4695, 001.4690, and 001.4685.
- 3D 3D:** A large central panel showing a 3D surface scan of the road, rendered in a light gray color. A vertical scale on the left indicates a height of 10.0.
- ROW Images:** A small panel at the bottom left showing a color photograph of a road with a white pickup truck and a red truck in the distance.
- Information:** A panel at the bottom right containing a table of data points.

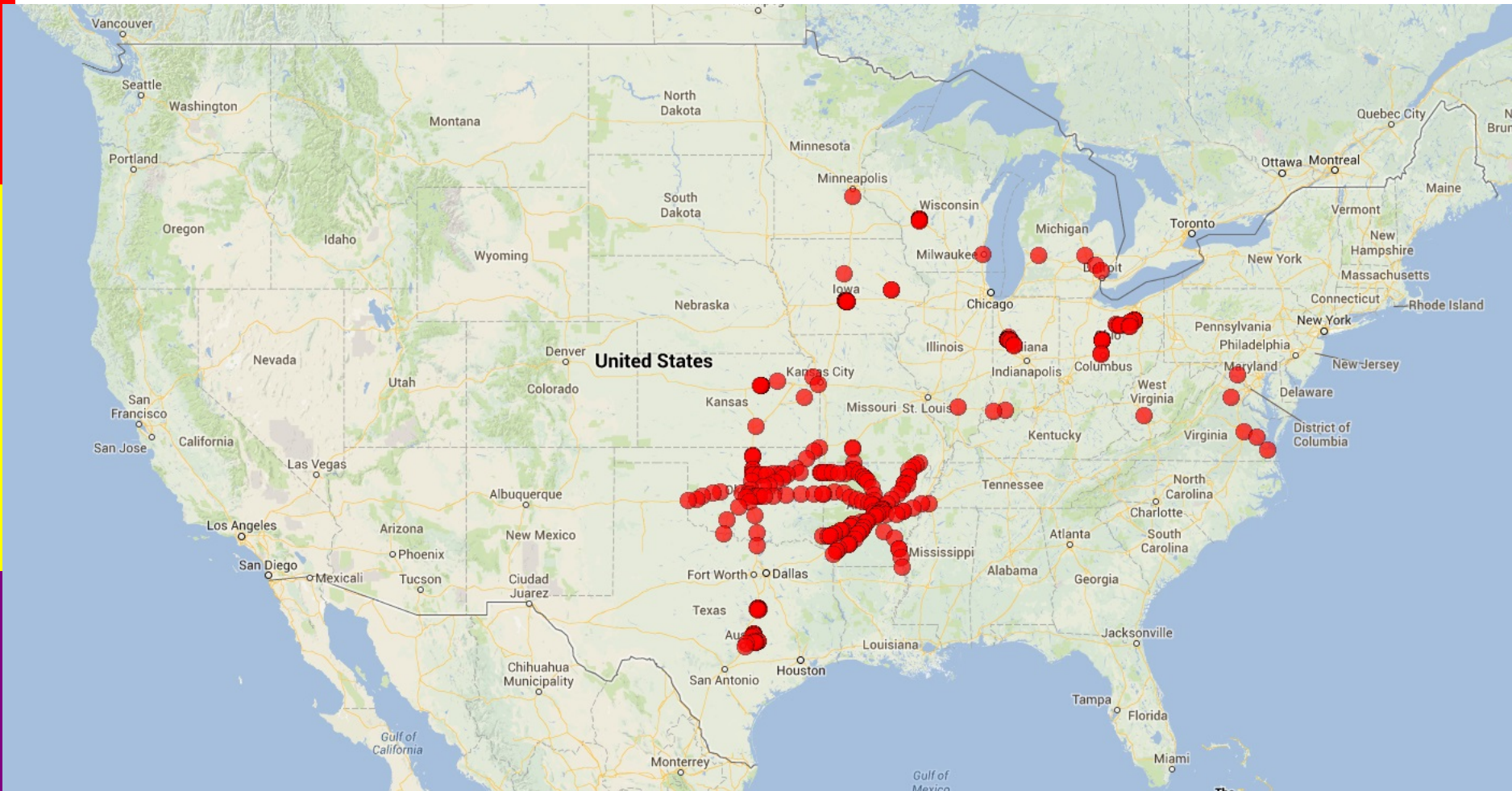
Value	Memo	Folder	Memo
0	Rutting	C:\Users\TranInfralab\Desktop\65-NB-southS...	Database
0	Roughn.	C:\Users\TranInfralab\Desktop\65-NB-southS...	4KImage
40.442562	Latitude	C:\Users\TranInfralab\Desktop\65-NB-southS...	RowImage
-86.840347	Longitud		
1851.61 ft	Altitude		
58.0 mph	Speed		
Imperial	Unit		
18.100 ft	RSPOfs		
WISDist	Coordine		

3D Ultra Applications

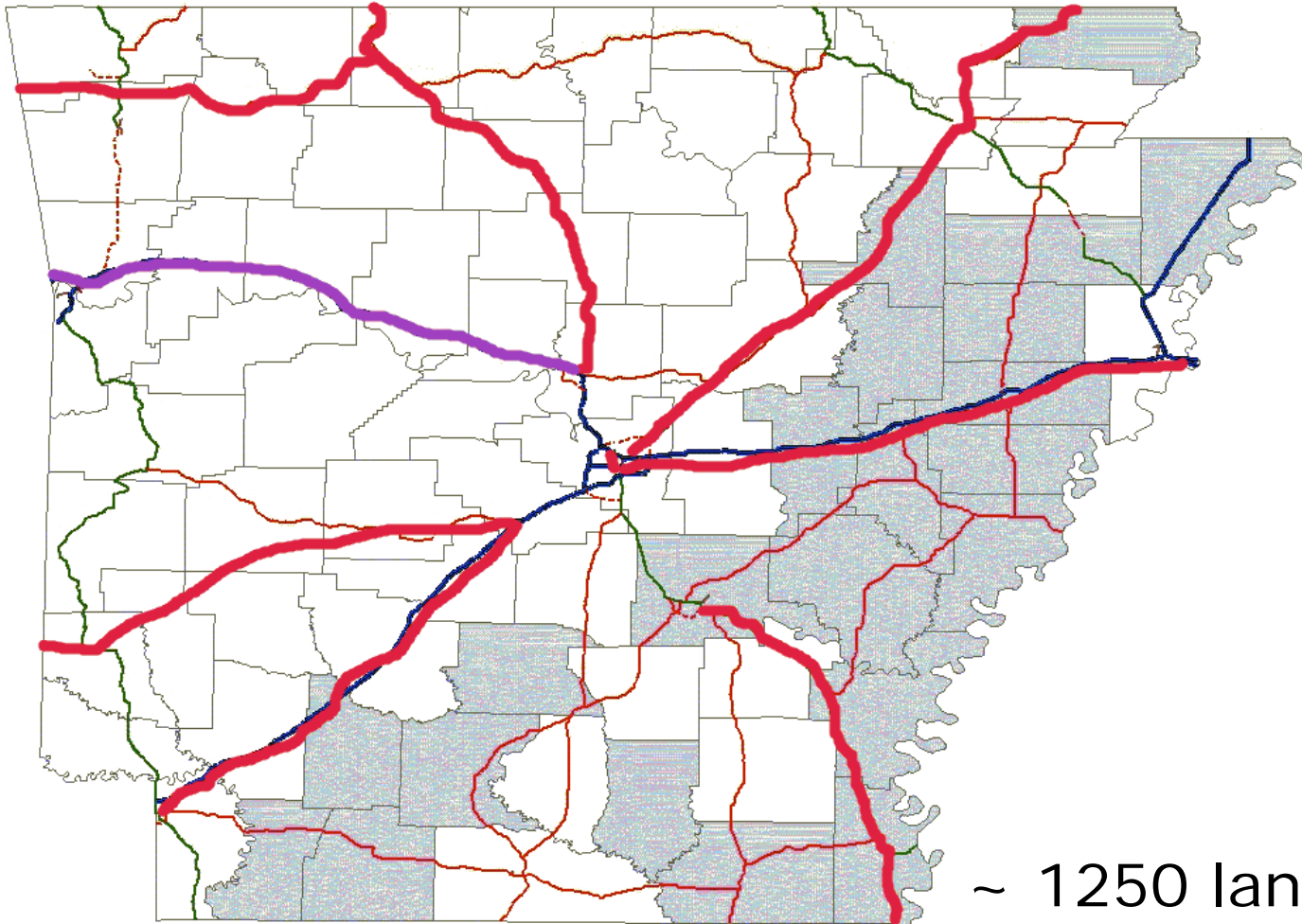
- Virtual surface for visualization
 - Multi-lane highway
 - Airport runway
 - Bridge deck
- Cracking: 1mm cracks at 60mph
- Safety analysis: macro-texture (MPD), hydroplaning, grooving
- Transverse profiling for rutting
- Longitudinal profiling for roughness & faulting



Multi-Lane Highway Evaluation

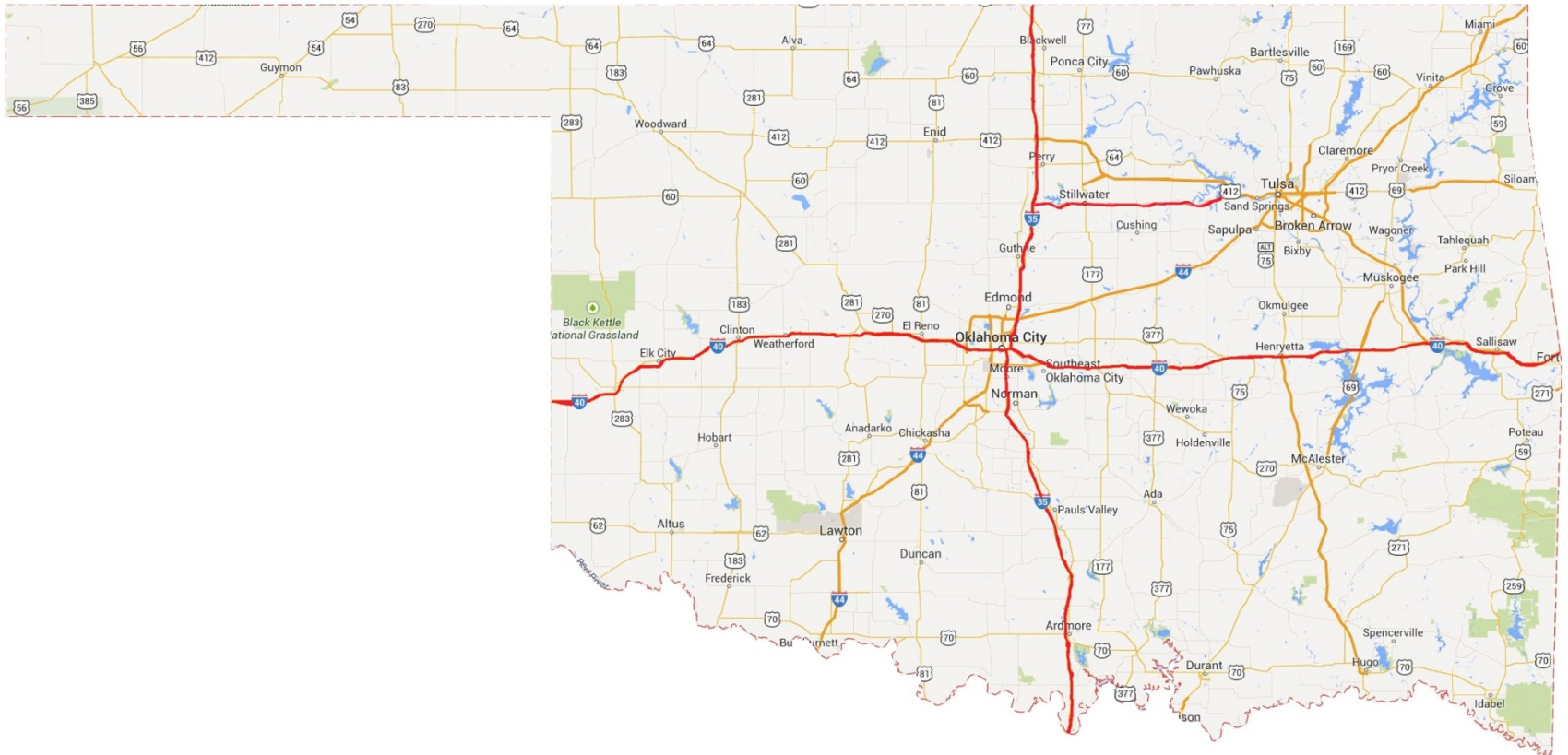


AHTD NHS Survey



~ 1250 lane miles

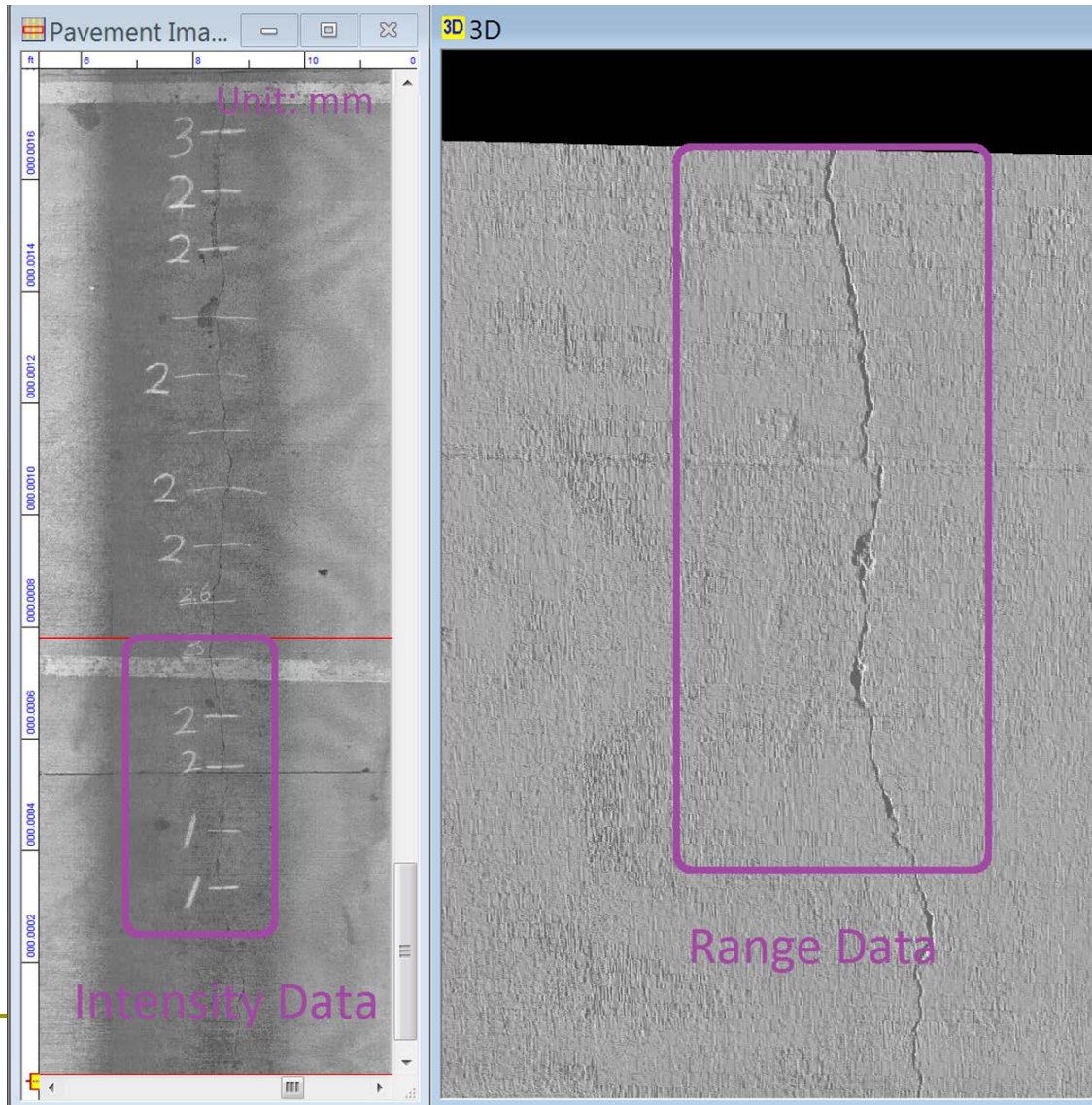
ODOT Interstate Survey



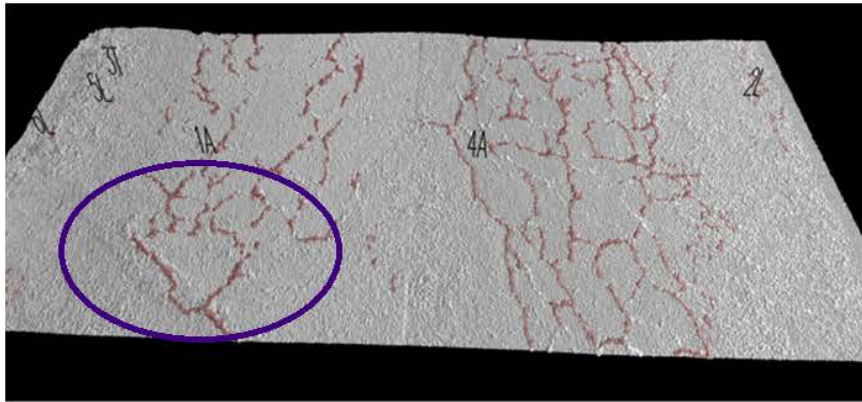
~ 1628 lane miles



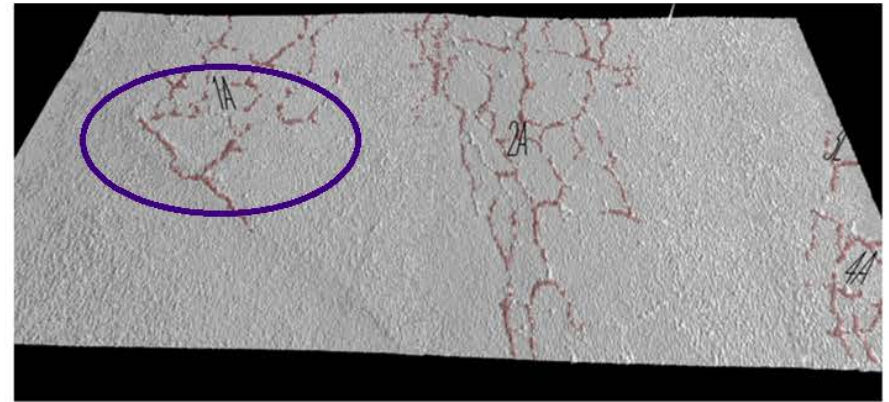
Crack Data Validation



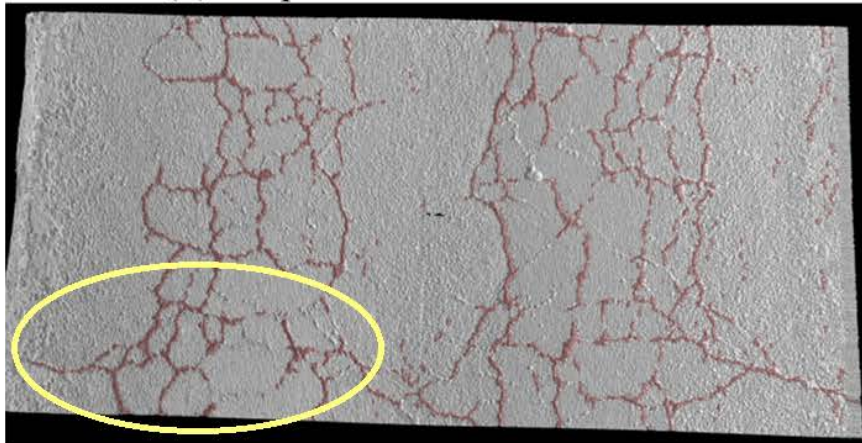
Crack Data Validation



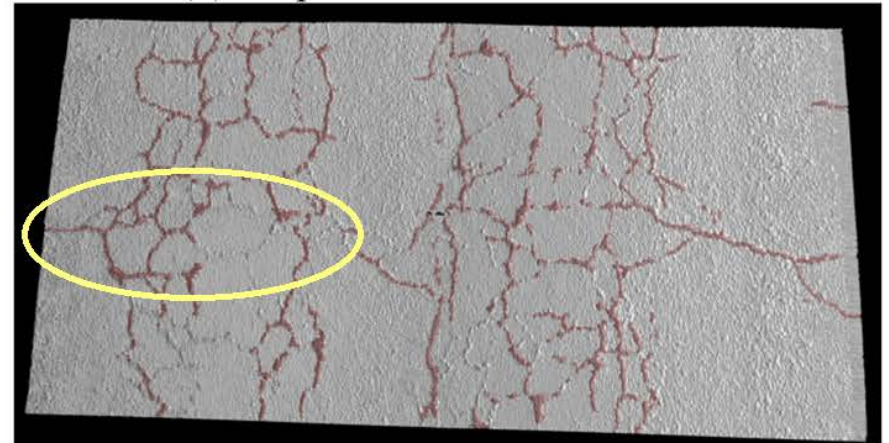
(a) Elephant Road #1 40km/h



(a) Elephant Road #1 80km/h



(b) Elephant Road #2 40km/h

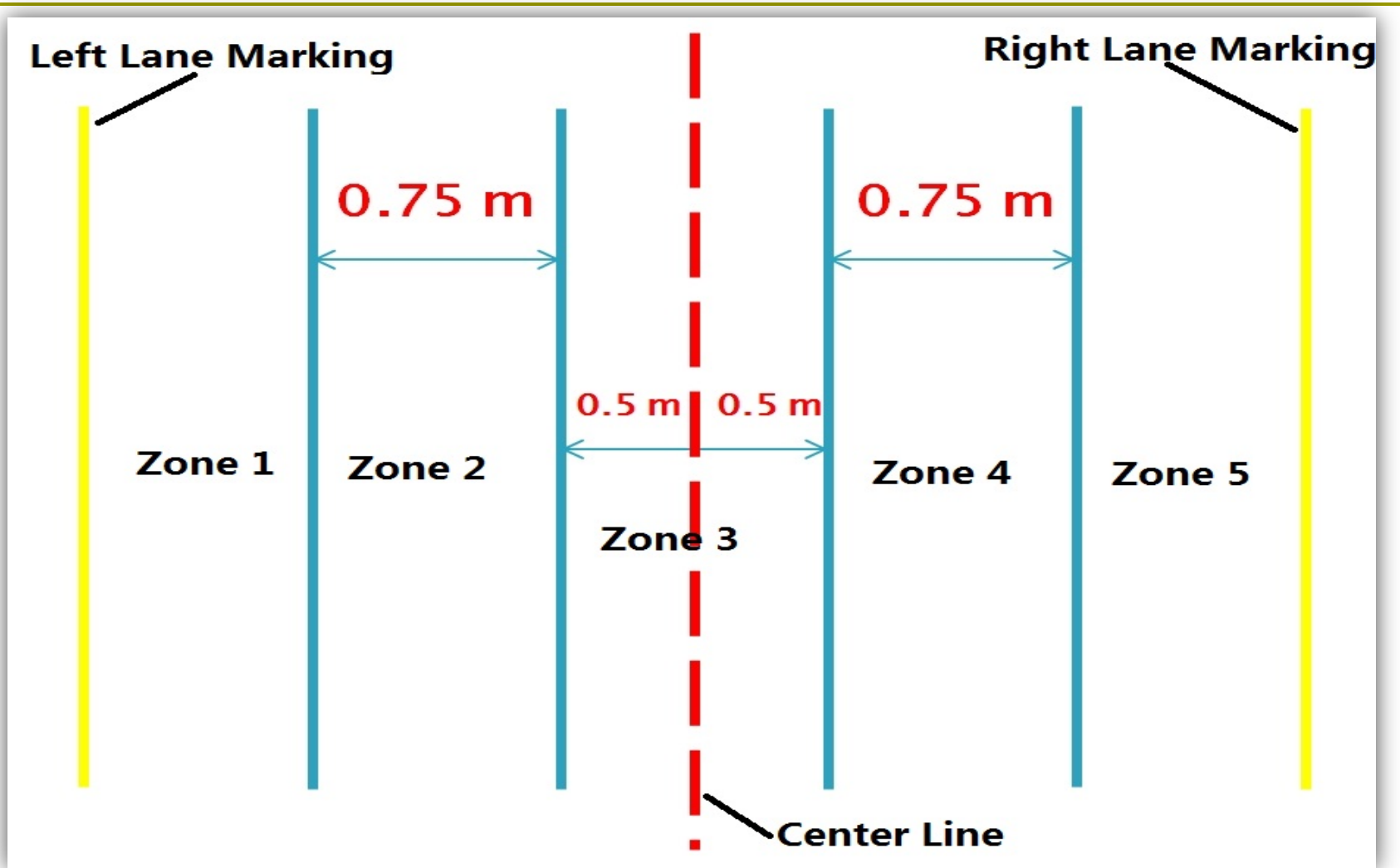


(b) Elephant Road #2 80km/h

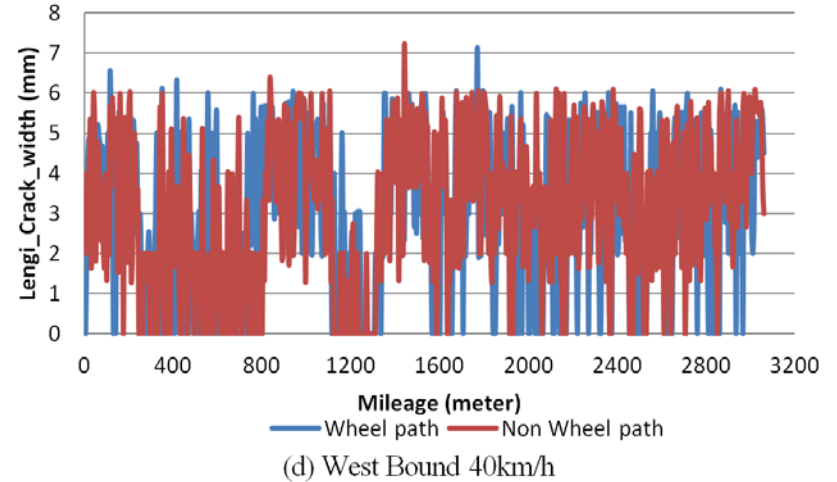
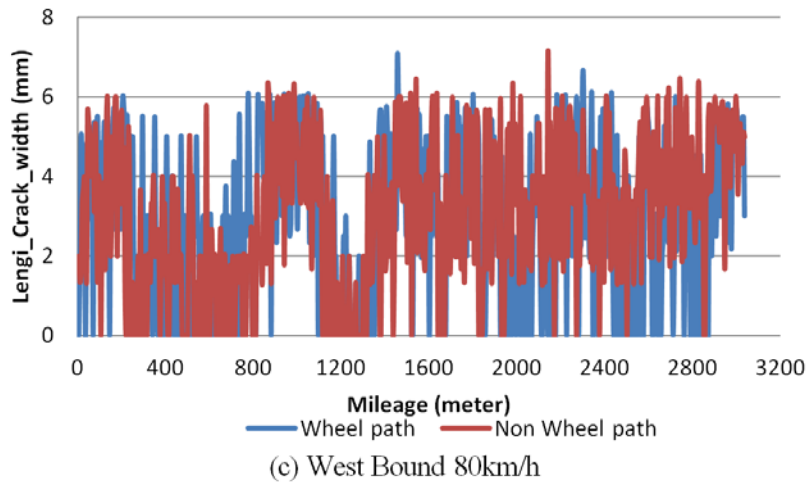
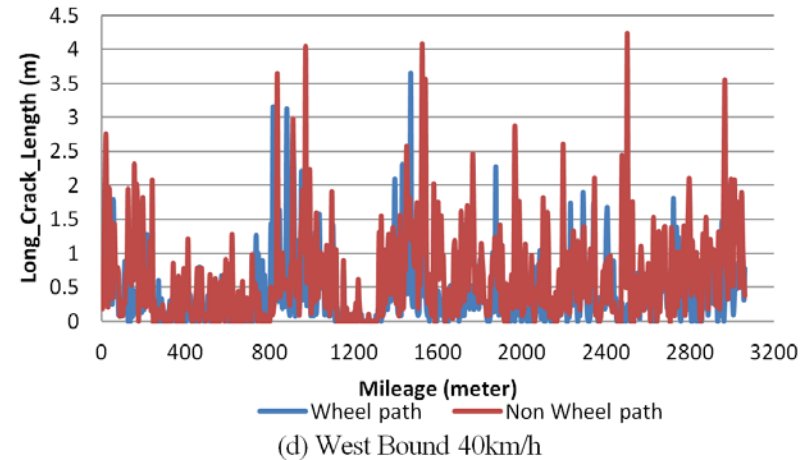
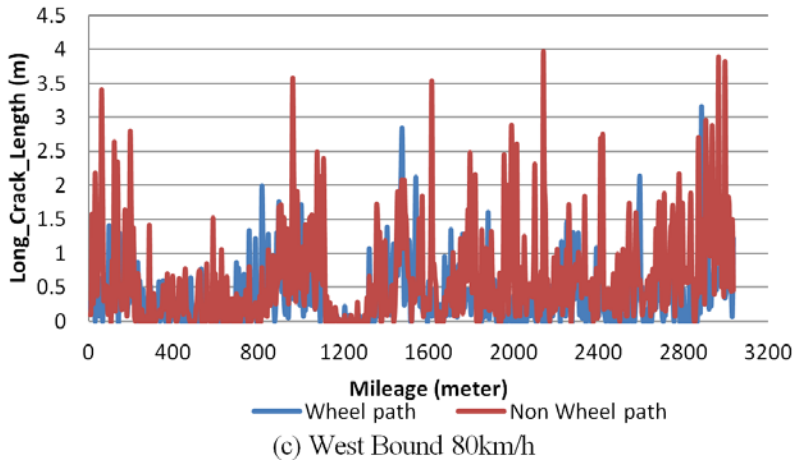
AASHTO PP67-10 Protocol

- Two cracking properties
 - Cracking length & width
- Three cracking types (by orientation)
 - Transverse, longitudinal & pattern cracking
- Five zones
 - Defined by WP & NWP

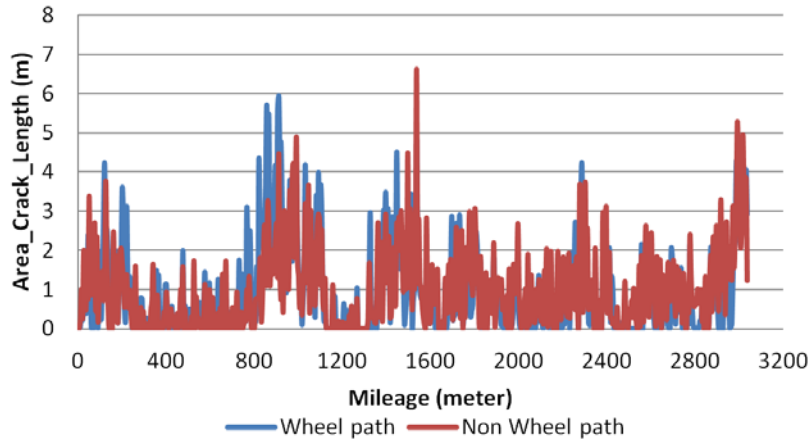
Wheelpath (WP) Definition



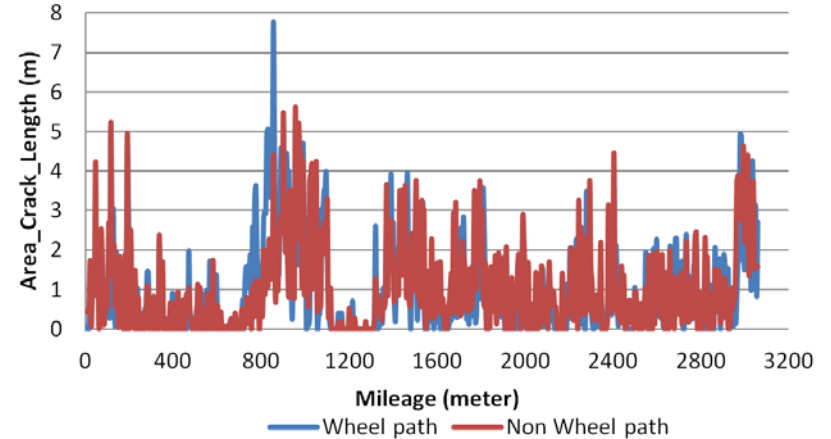
Longitudinal Cracking



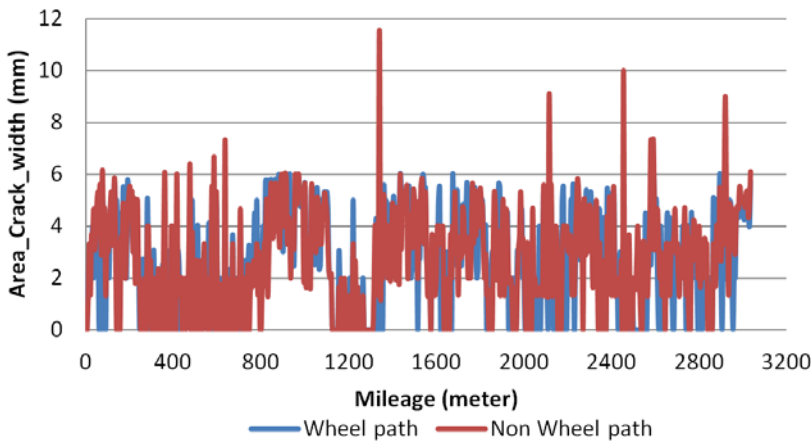
Area Cracking



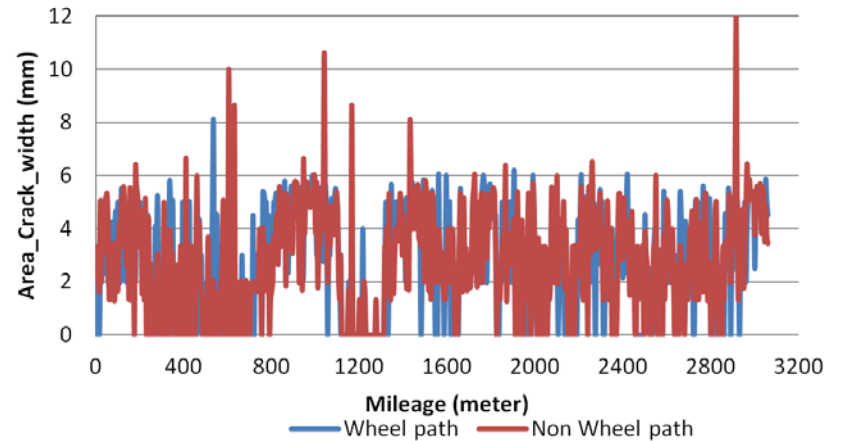
(c) West Bound 80km/h



(d) West Bound 40km/h



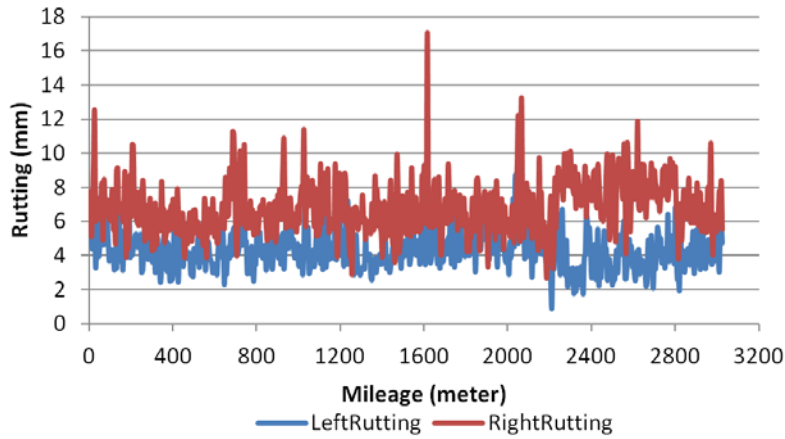
(c) West Bound 80km/h



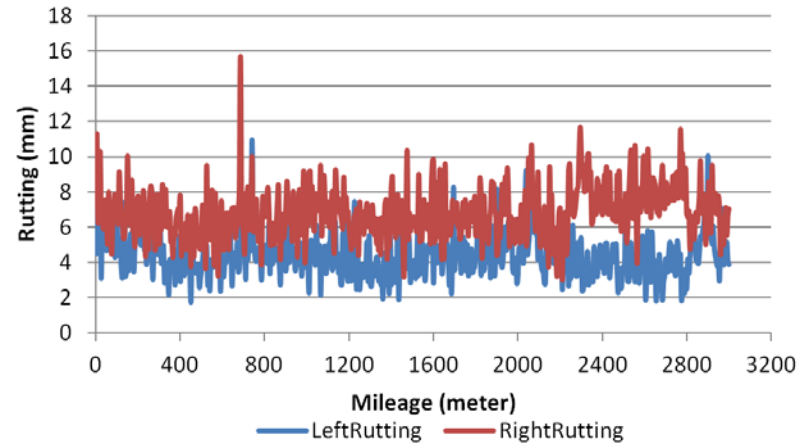
(d) West Bound 40km/h



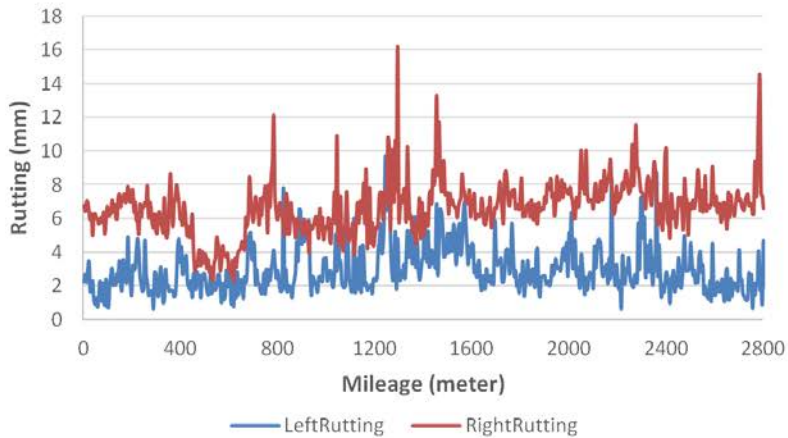
Rutting



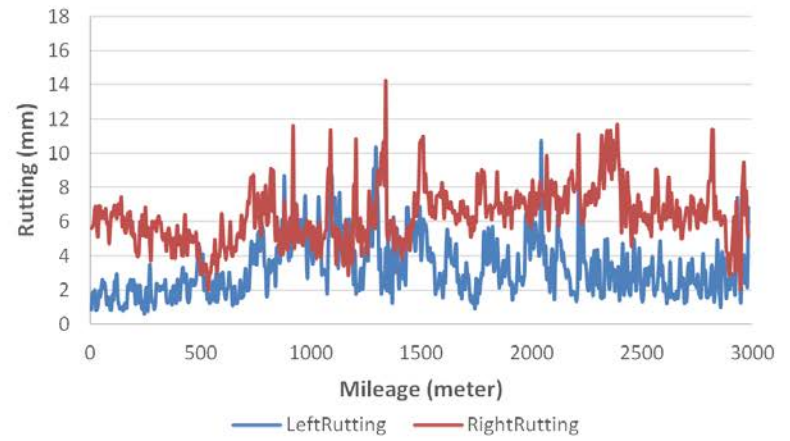
(a) East Bound 80km/h



(b) East Bound 40km/h

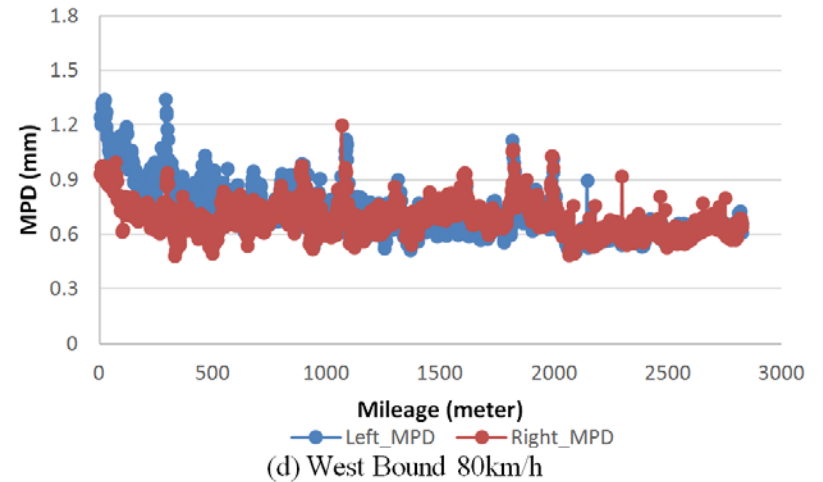
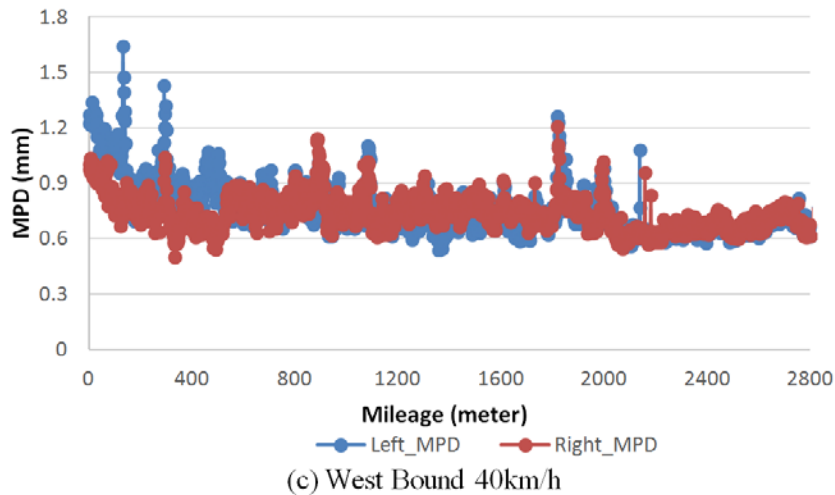
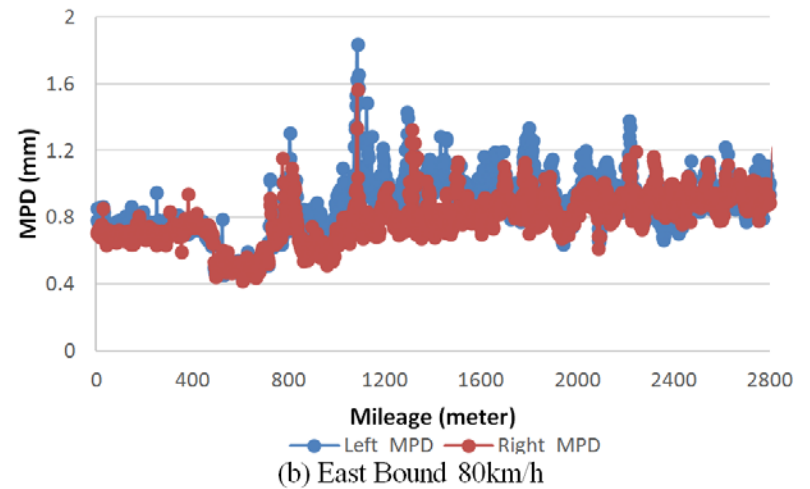
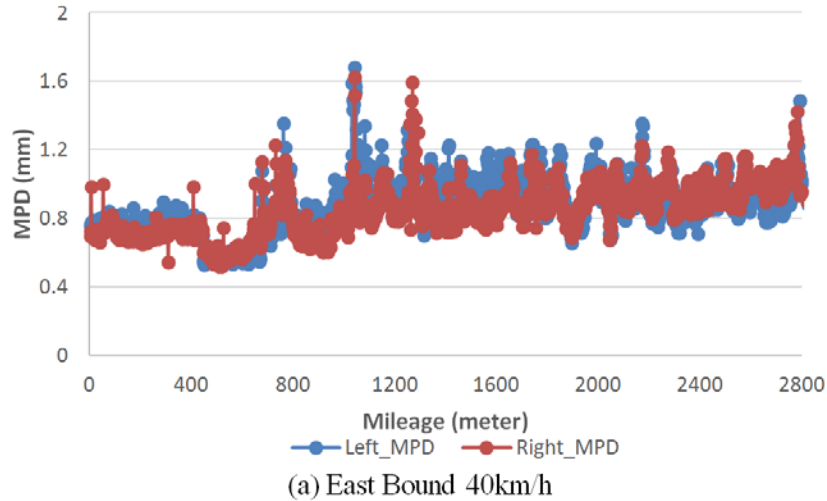


(a) East Bound 40km/h



(b) East Bound 80km/h

Macro-Texture



Hydroplaning Evaluation

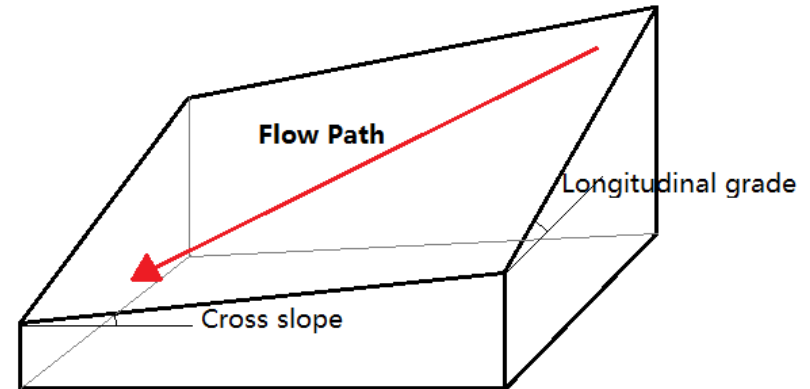
- Inertial Measurement Unit (IMU) Data
 - ❖ Positioning, cross slope and vertical slope
- PaveVision3D texture data
- Hydroplaning speed model
 - ❖ Water film depth: pavement texture, pavement type, cross slope, vertical grade, rain intensity
 - ❖ Hydroplaning speed: FHWA PAVDRN model

PAVDRN Model

$$WFD = \left[\frac{nL_f I}{36.1S_f^{0.5}} \right]^{0.6} - MTD$$

$$S_f = (S_l^2 + S_c^2)^{\frac{1}{2}}$$

$$L_f = W \frac{S_f}{S_c}$$



$$HPS = 26.04WFD^{-0.259} \quad (WFD \text{ (in)} < 0.095)$$

$$HPS = 3.09 A \quad (WFD \text{ (in)} \geq 0.095)$$

WFD: Water Film Depth (in)

MTD: Mean Texture Depth (in)

HPS: Hydroplaning (Hydroplaning) Speed (mph)

L_f: Flow path length (in)

S_f: Flow path slope (mm/mm)

S_l: Longitudinal grade

S_c: Cross slope

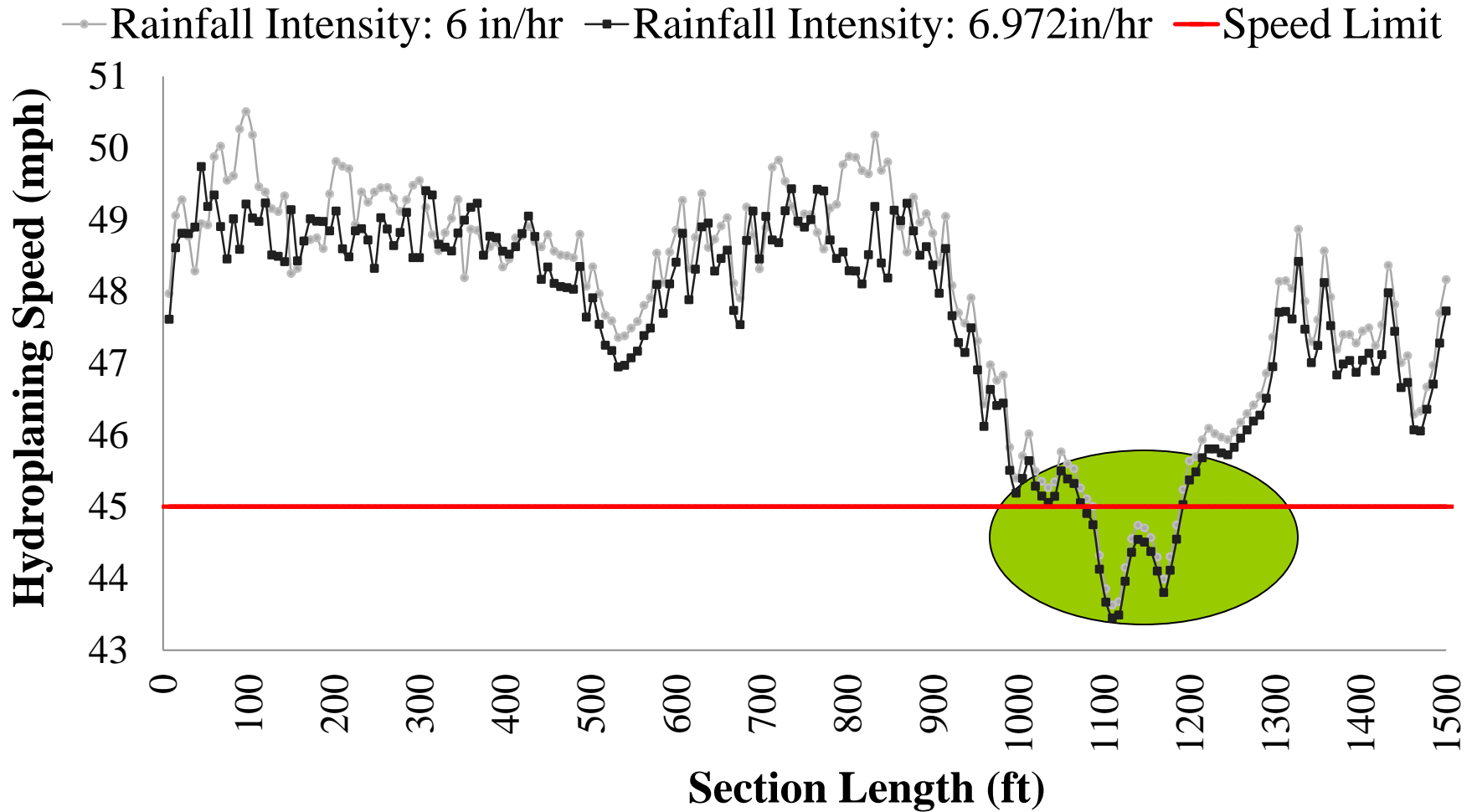
I: (*i* - *f*) = Excess rainfall rate (in/hr)

i: Rainfall intensity (in/hr)

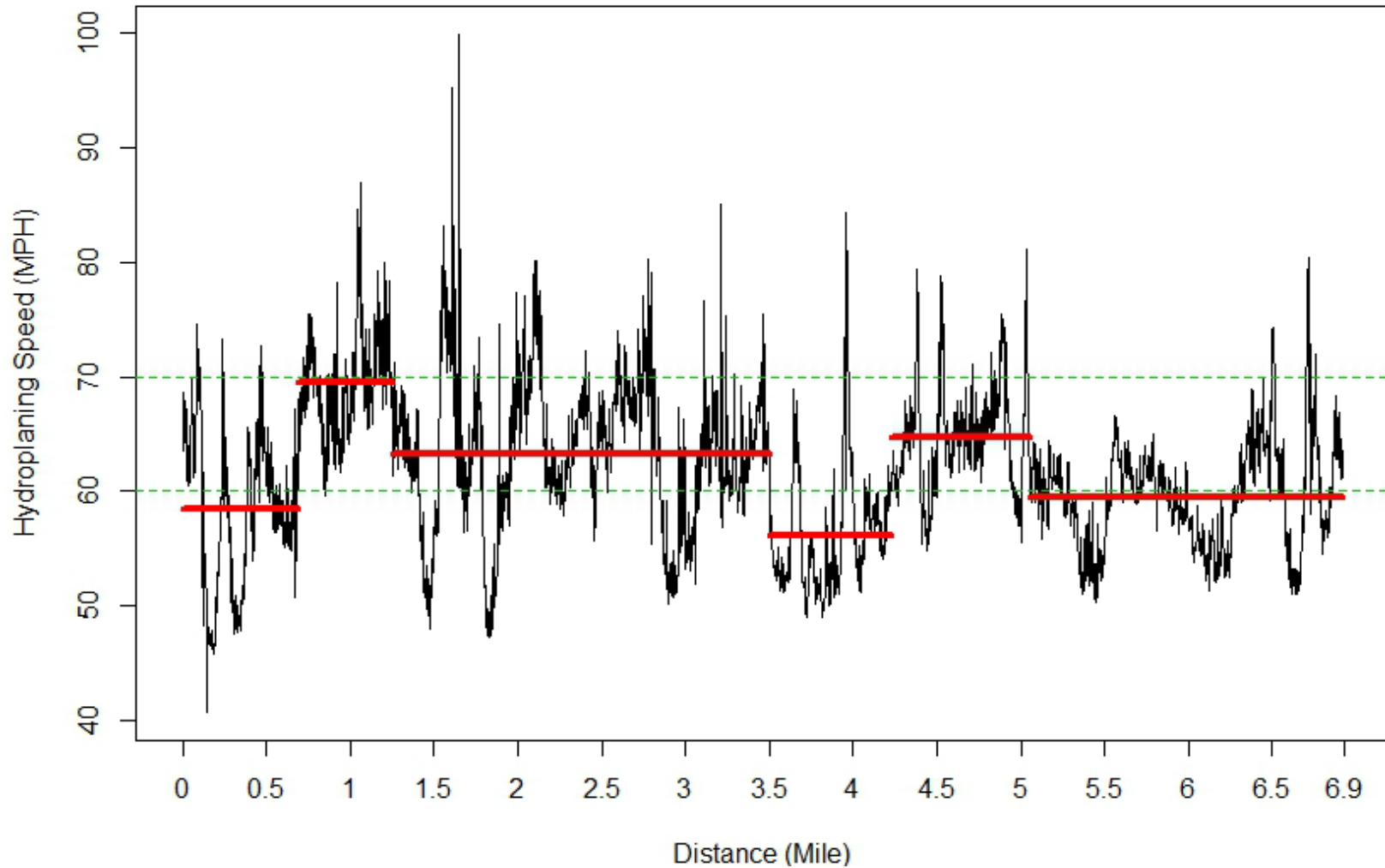
f: Infiltration rate or permeability of pavement (in/hr)

n: Manning's roughness coefficient

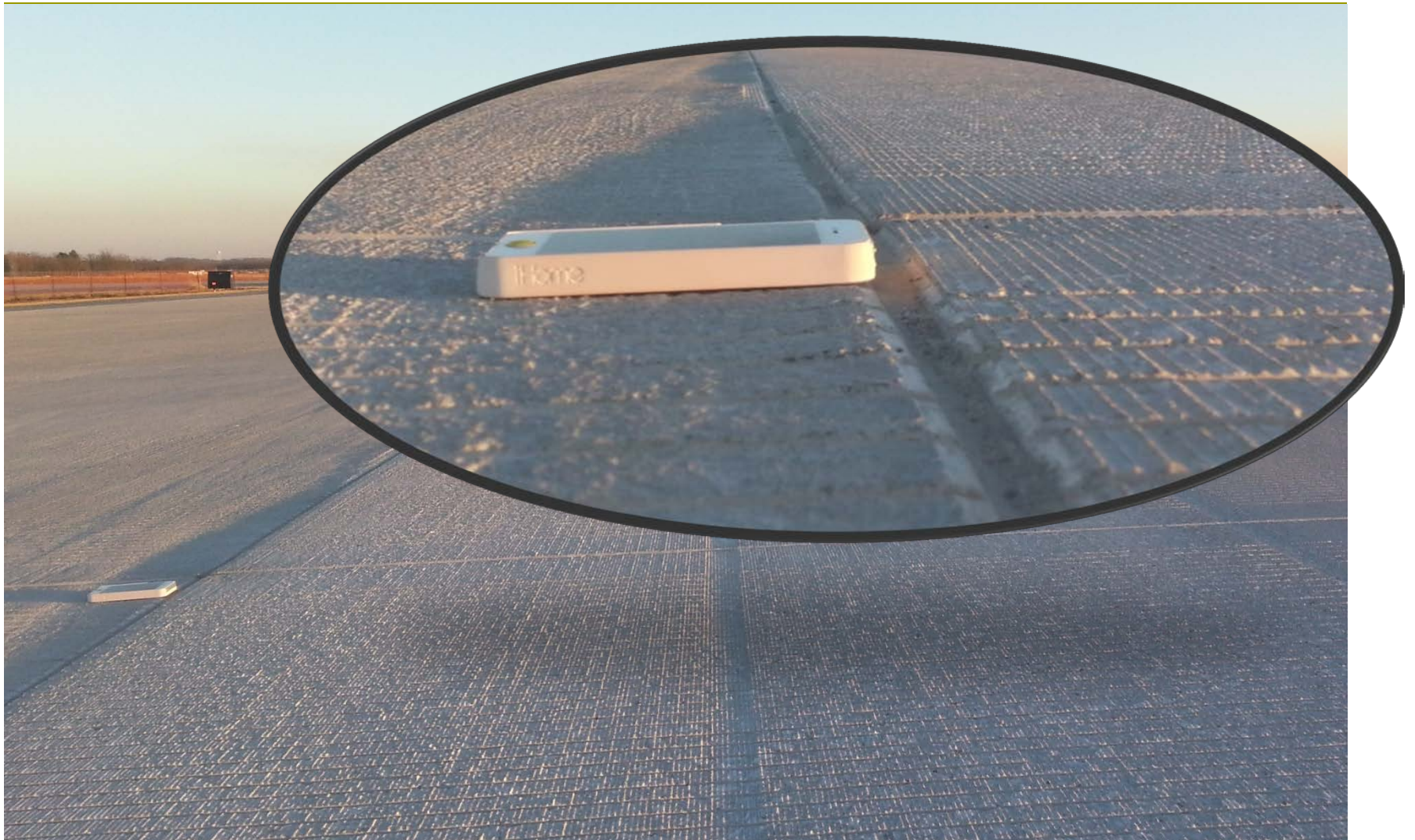
Hydroplaning Evaluation



Hydroplaning Segmentation



Full Size Runway Evaluation

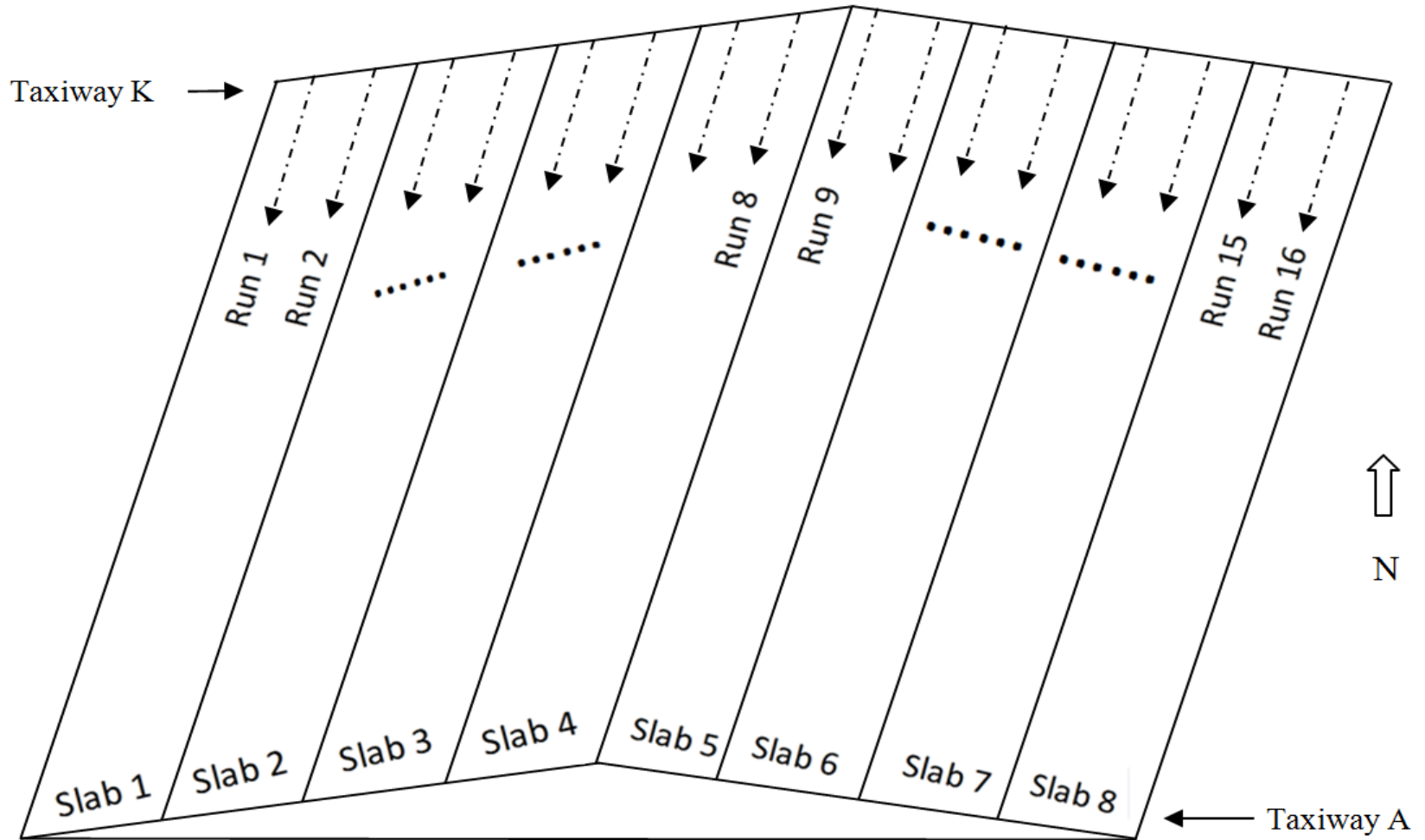


Evaluation Objectives

- ❑ PaveVision3D Ultra imaging of runway and taxiways at 1mm resolution
- ❑ PCI analysis
- ❑ Longitudinal profiling
 - Boeing Bump Index (BBI)
- ❑ Runway groove identification, measurement, evaluation
- ❑ Transverse profiling



Runway Data Collection

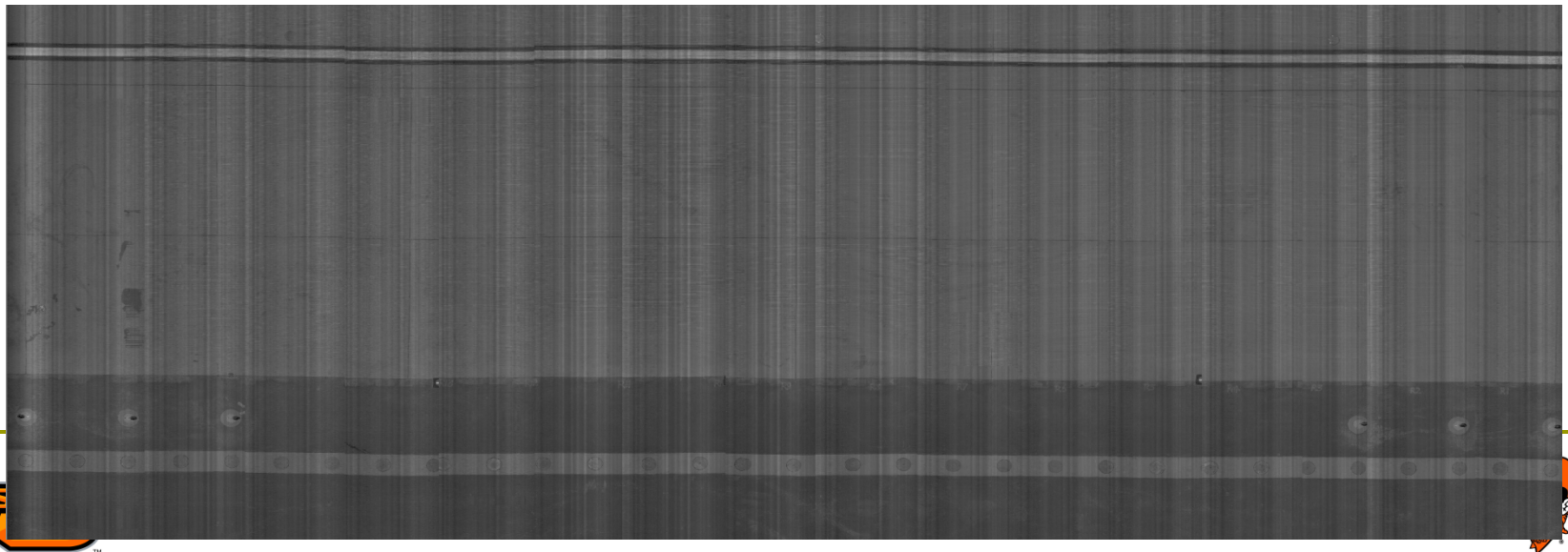
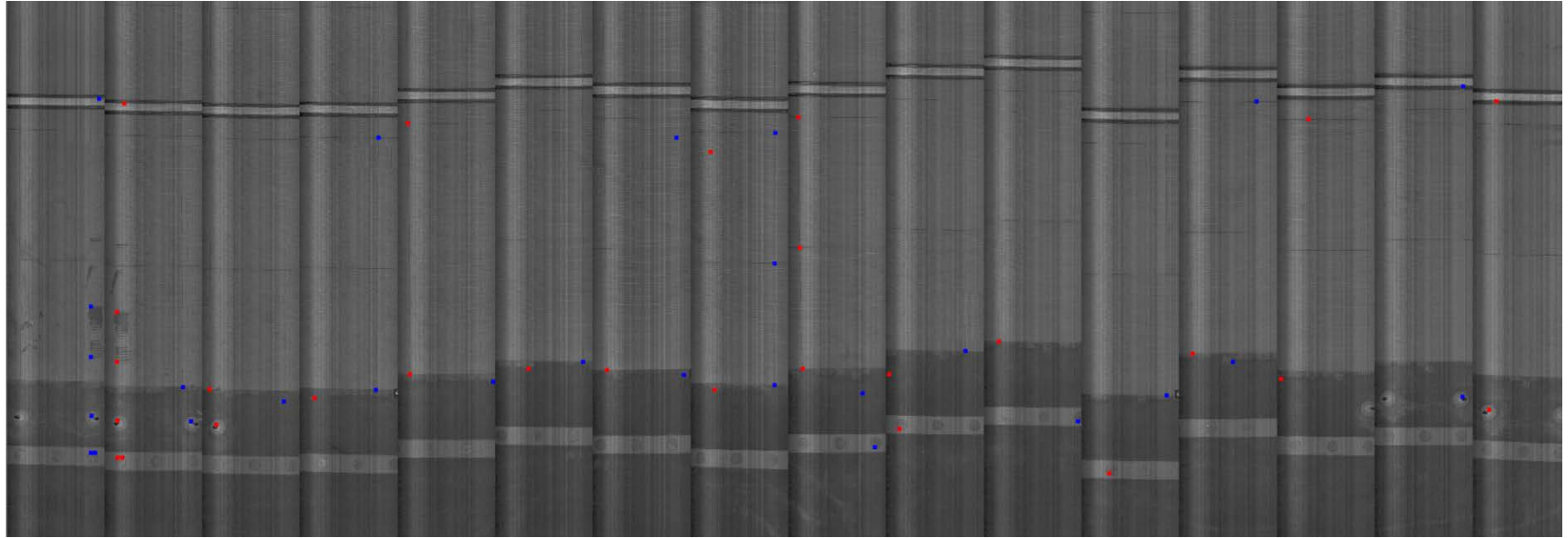


Airport PCI Analysis

- ❑ PCI – Pavement Condition Index
- ❑ Quantitative Measure of Pavement Condition
- ❑ FAA AC 150/5380-6A (ASTM D5340-03)
- ❑ Pavement distress
 - Type
 - Quantity
 - Severity



MHIS-Airport2D: Stitching



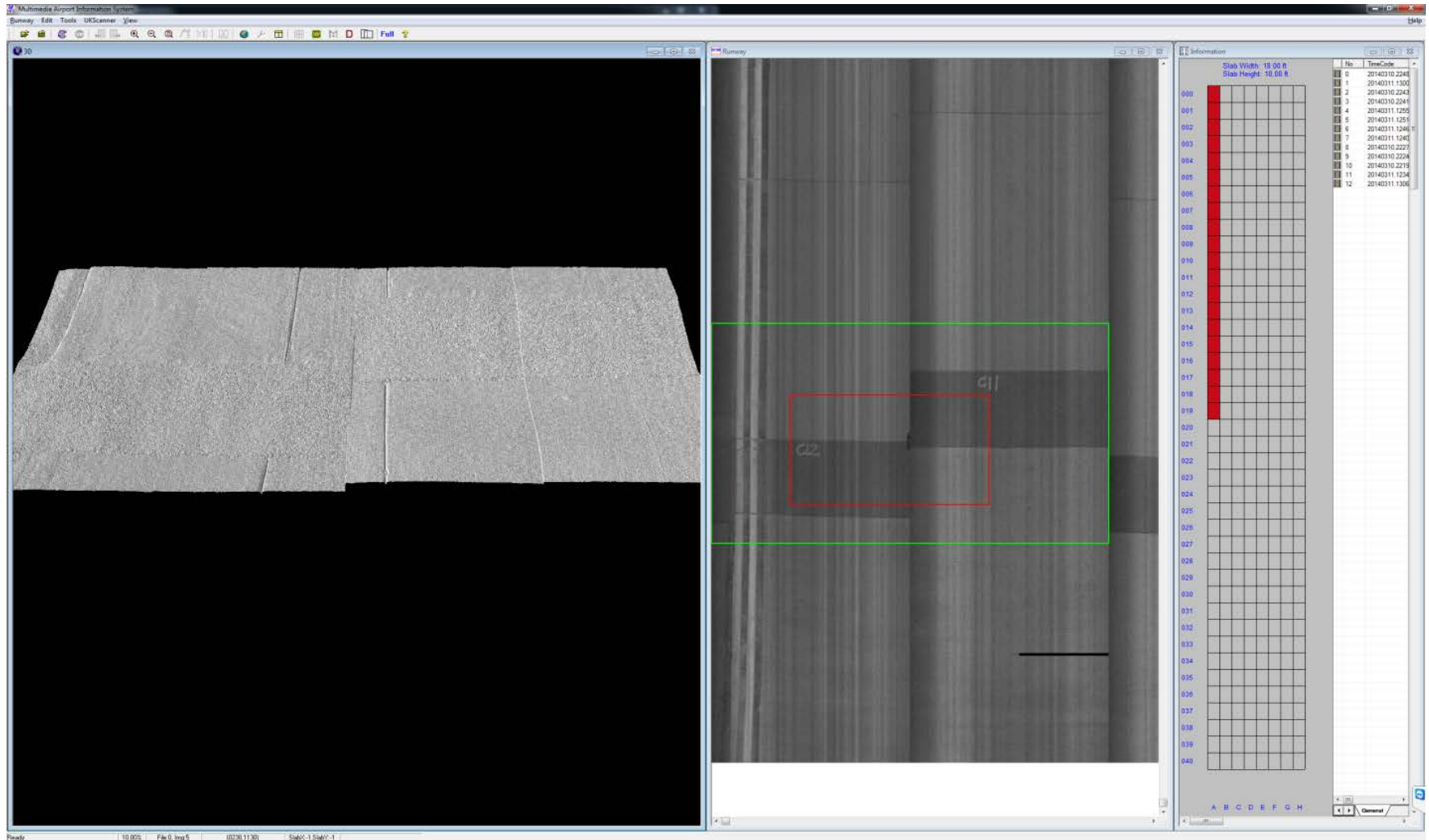
MHIS-Airport2D: PCI Analysis

The screenshot displays the MHIS-Airport2D software interface. On the left, a window titled "Runway" shows a grayscale image of a runway with a green dashed grid overlay. On the right, an "Information" panel displays a data table with columns for "No", "TimeCode", and "Road". A red box highlights a 4x4 grid of cells in the information panel, corresponding to rows 000-003 and columns A-D. The data table contains 26 rows of data, each with a unique TimeCode and a "Road" value.

No	TimeCode	Road
0	20090327.034206.203	AT
1	20090327.034039.640	AT
2	20090327.033859.390	AT
3	20090327.033704.234	AT
4	20090327.033525.812	AT
5	20090327.033334.843	AT
6	20090327.033207.343	AT
7	20090327.033035.468	AT
8	20090327.032901.093	AT
9	20090327.032734.359	AT
10	20090327.032602.781	AT
11	20090327.032429.937	AT
12	20090327.032304.140	AT
13	20090327.032138.859	AT
14	20090327.032013.890	AT
15	20090327.031826.671	AT
16	20090327.031703.625	AT
17	20090327.031533.843	AT
18	20090327.031417.296	AT
19	20090327.031251.828	AT
20	20090327.031130.187	AT
21	20090327.030957.515	AT
22	20090327.030822.484	AT
23	20090327.030703.125	AT
24	20090327.030523.609	AT
25	20090327.030404.687	AT



MHIS-Airport3D Interface



PCI Results

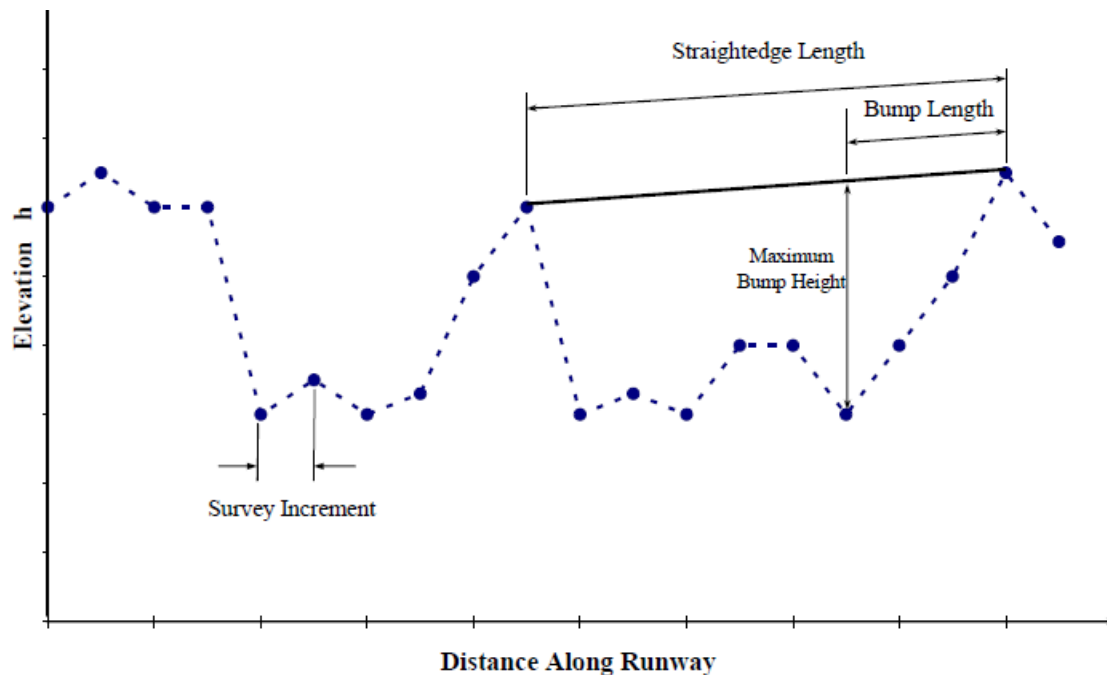
Location		PCI
Runway Overall		91
Runway Segment	Taxiway K-C	92
	Taxiway C-E	89.3
	Taxiway E-F	92.8
	Taxiway F-A	90.7

- PCI: excellent condition
- Many surface issues: not in PCI procedure
 - Surface irregularity
 - Groove problems
 - Surface grinding
 - Construction problems



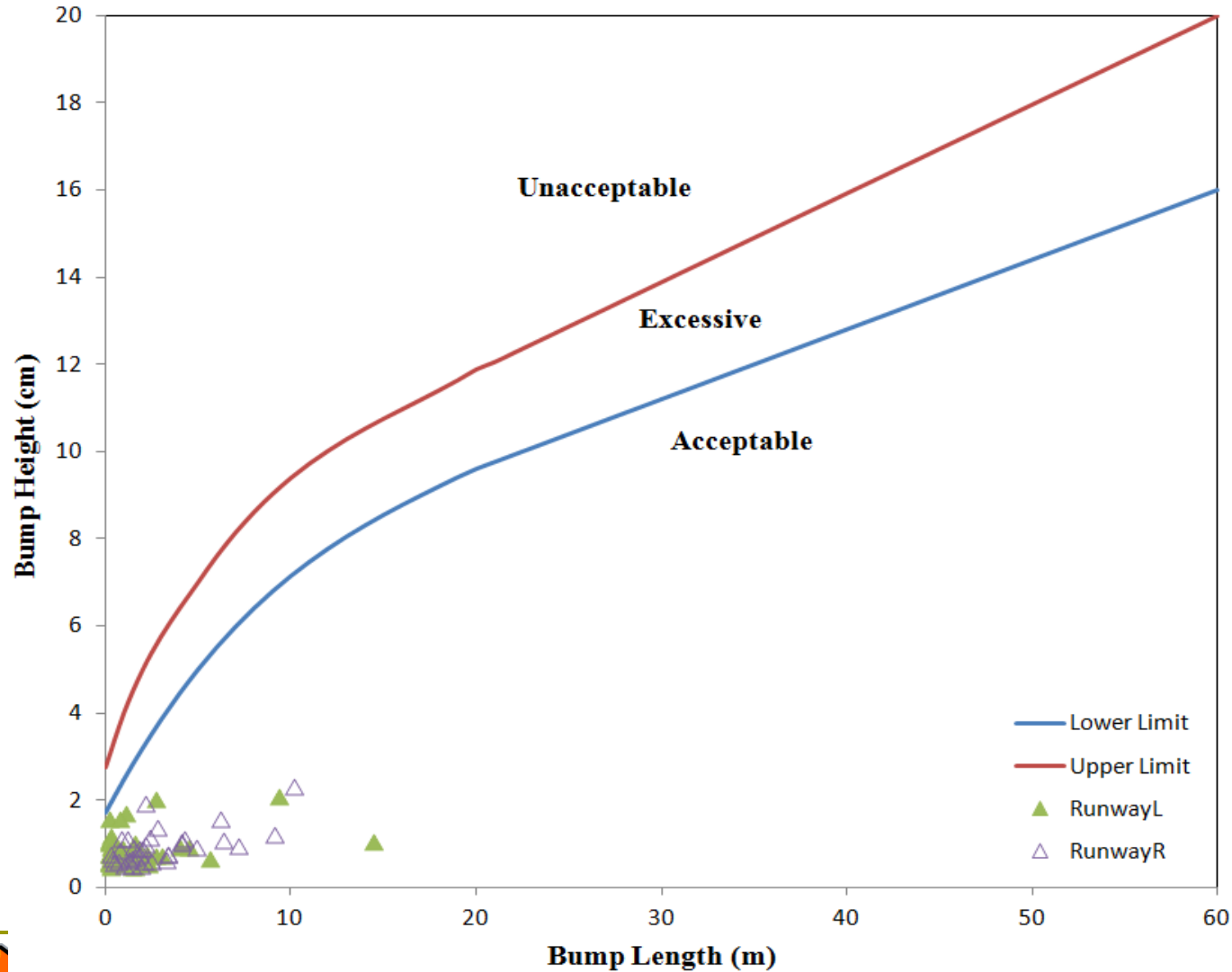
Runway Longitudinal Profiling

- Boeing Bump Methodology
 - FAA AC 150/5380-9

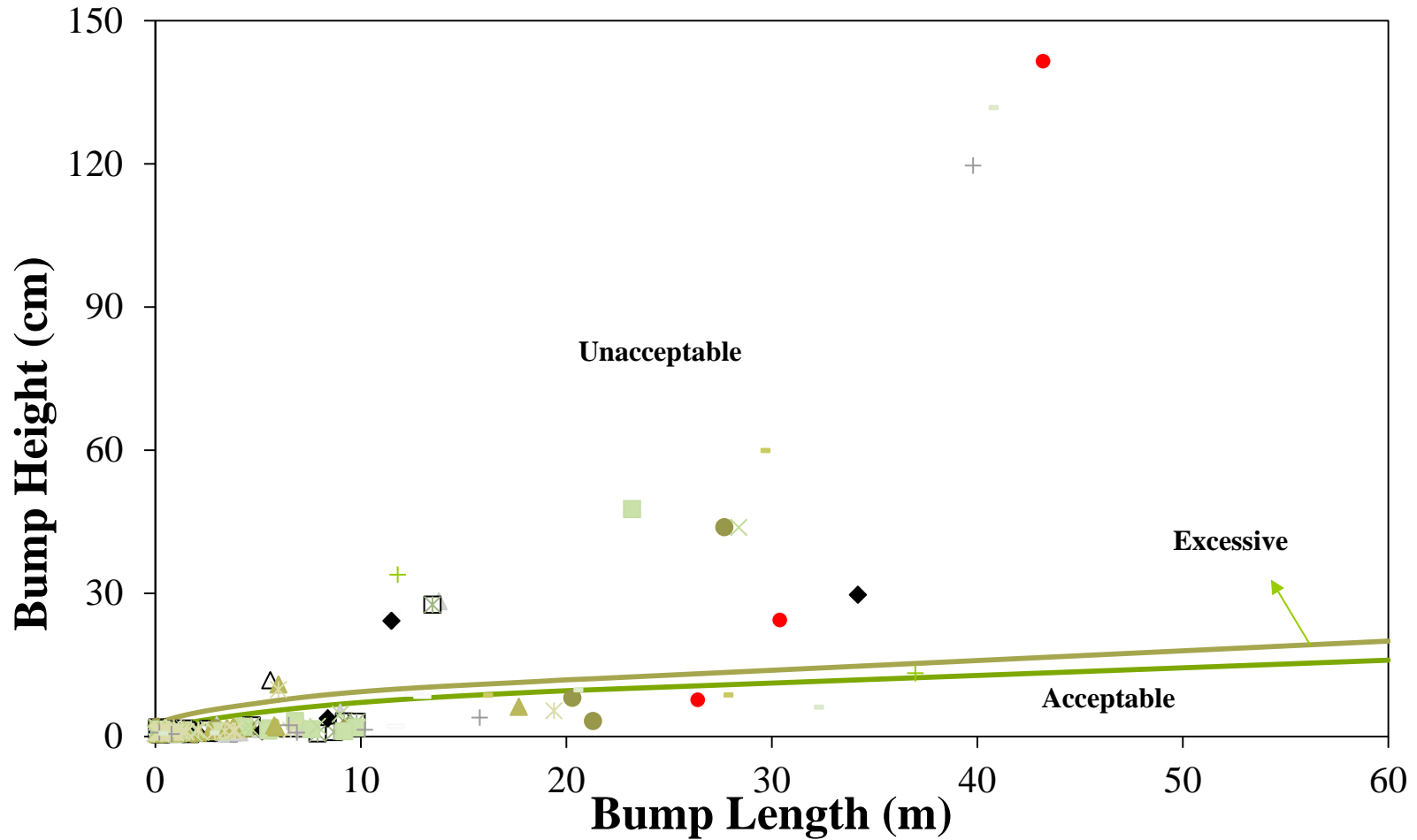


BBI = (measured bump height) / (limit of acceptable bump height)

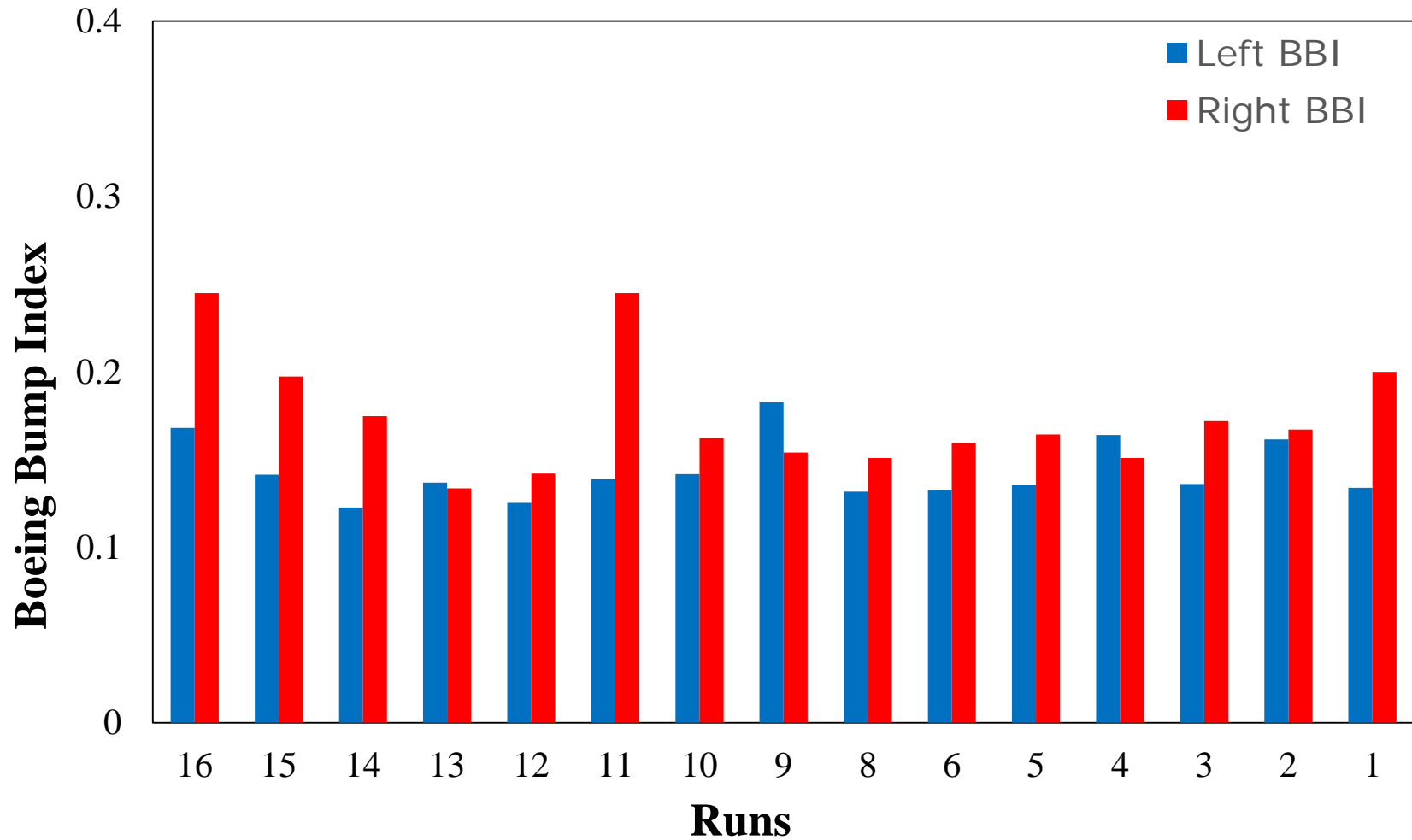
Runway Boeing Bumps



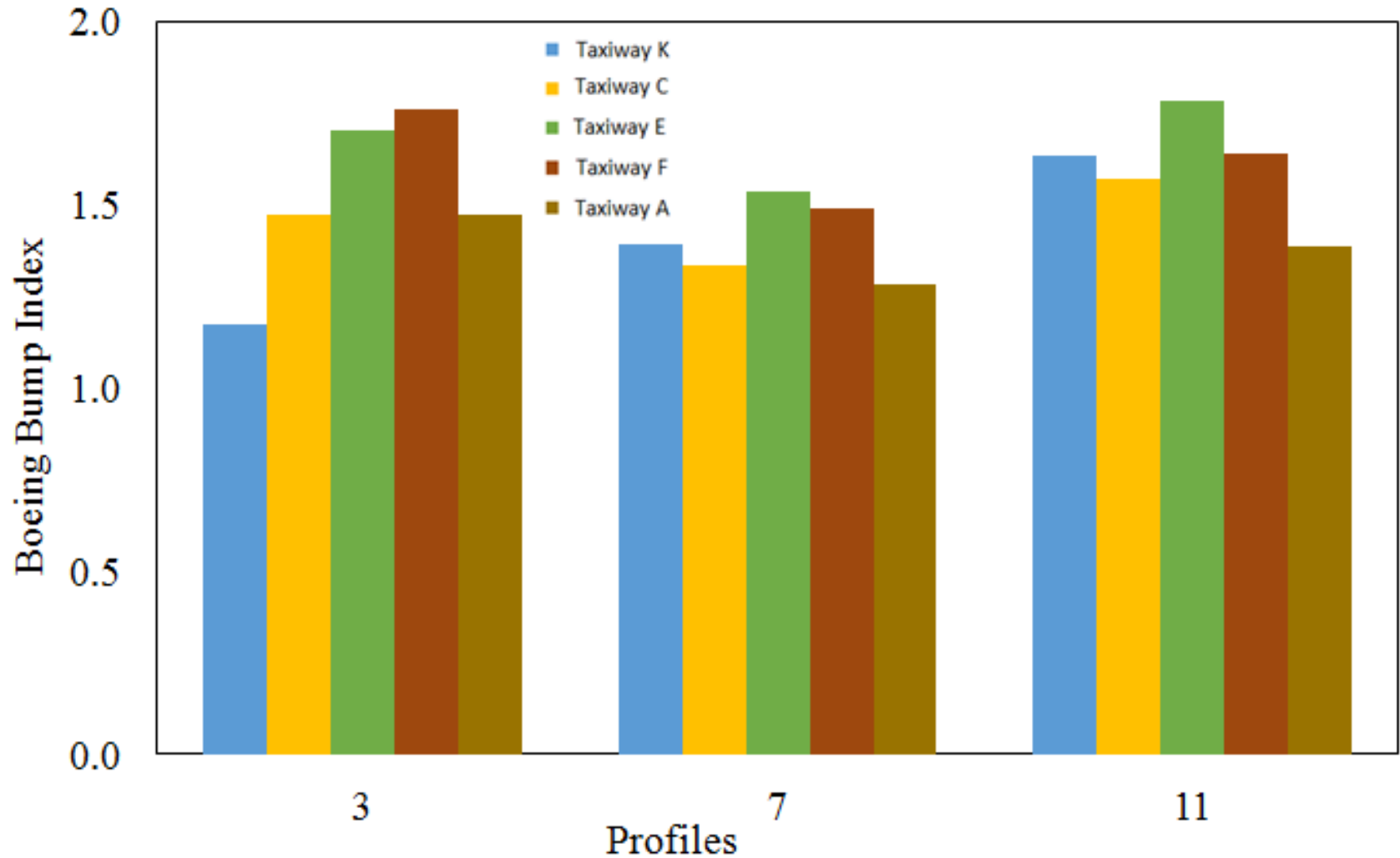
Taxiway Boeing Bumps



Runway BBI

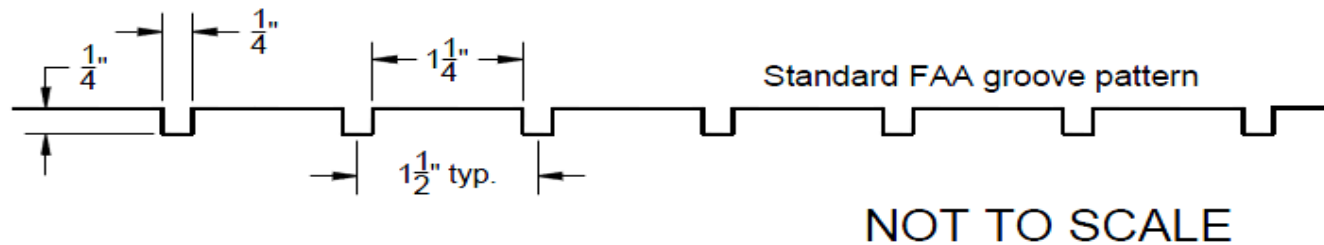


Taxiway BBI



Runway Groove Evaluation

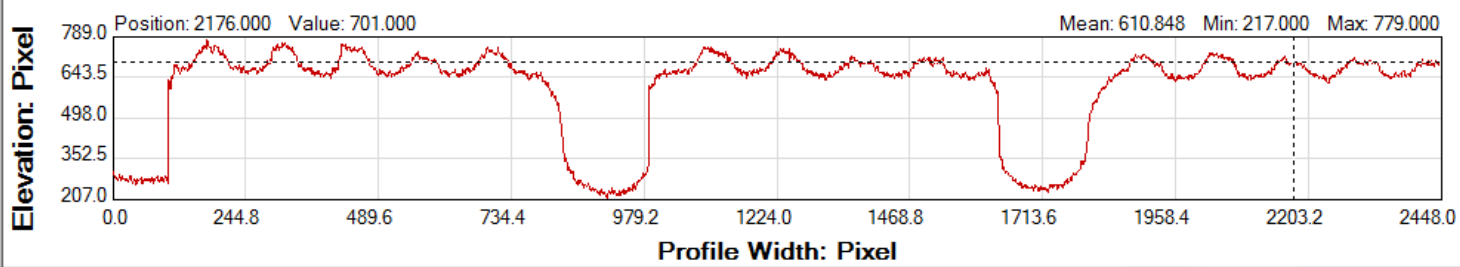
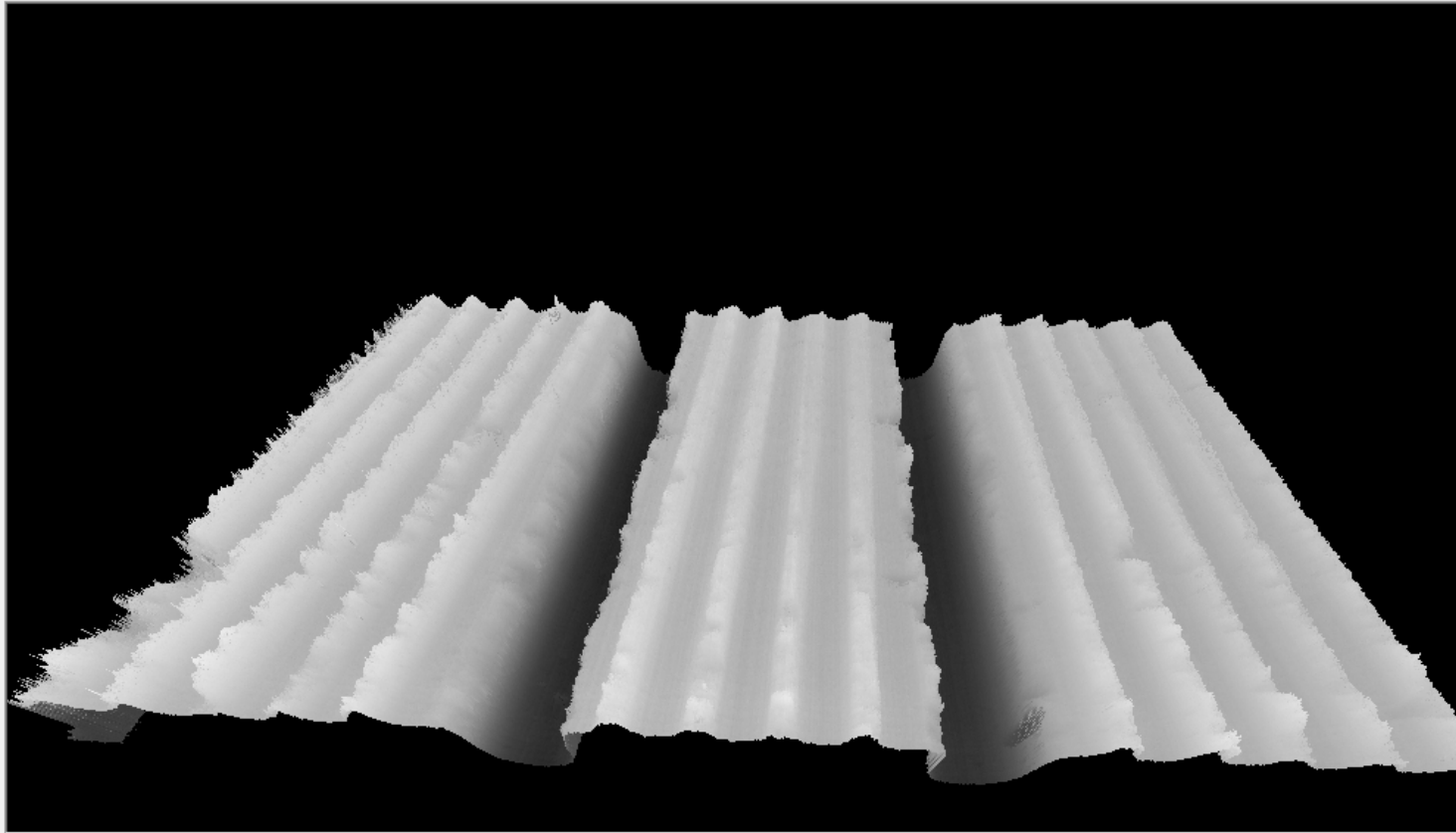
- Standard Rectangle Groove (AC 150/5320-12C)



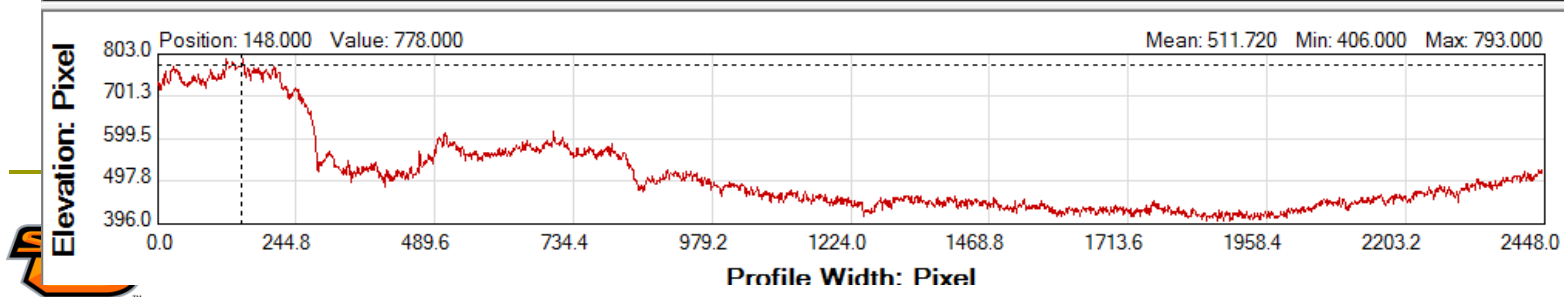
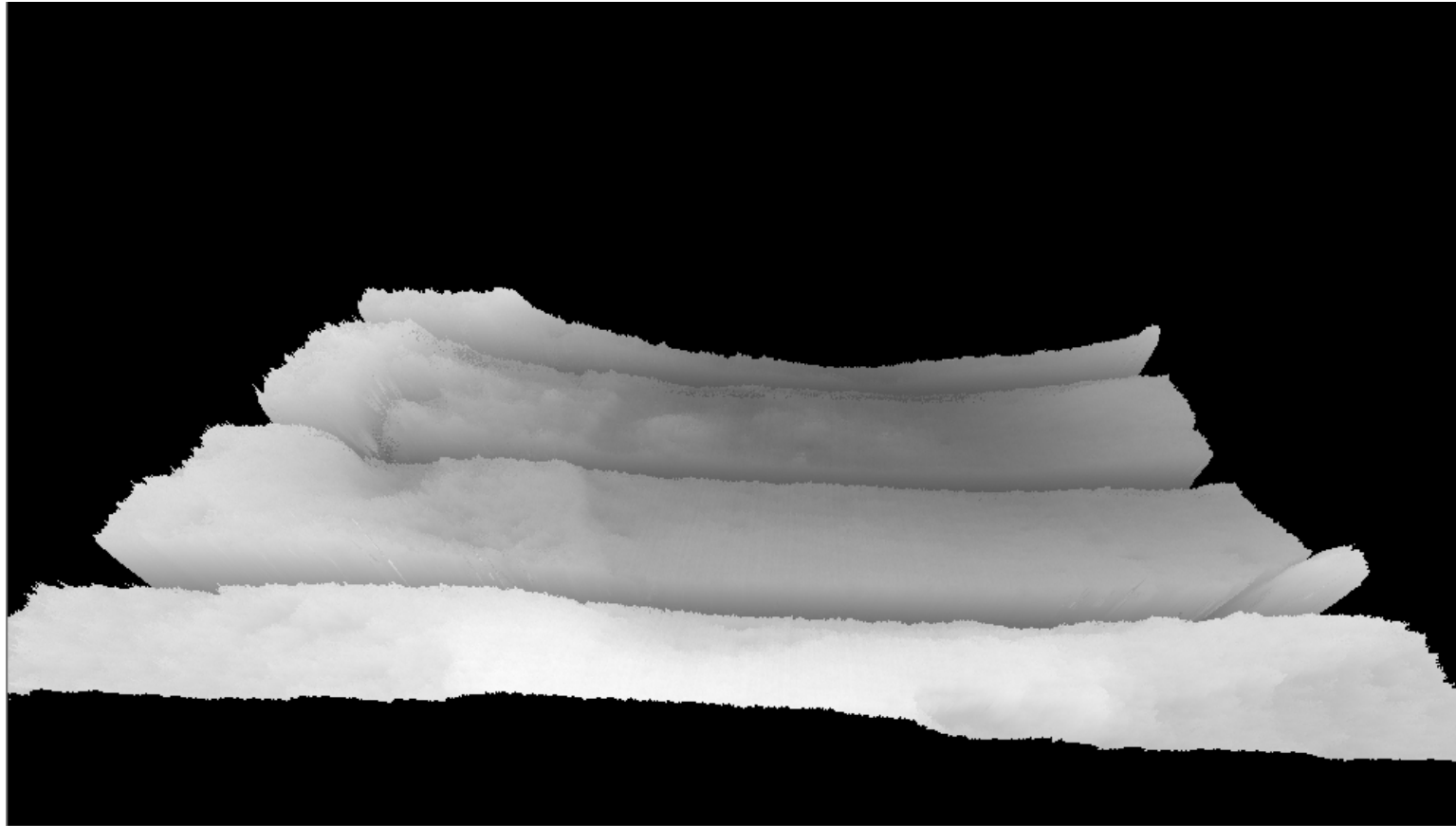
- Groove Tolerance

Groove type	Recommended configuration (Unit: in)		Tolerance (Unit: in)		Acceptable range			
			Lower limit	Upper limit	Unit: inch		Unit: mm	
Rectangular	Depth	1/4	-1/16	1/16	0.19	0.31	4.76	7.94
	Width	1/4	0	1/16	0.25	0.31	6.35	7.94
	Spacing	1 1/2	-1/8	0	1.38	1.5	34.9	38.1

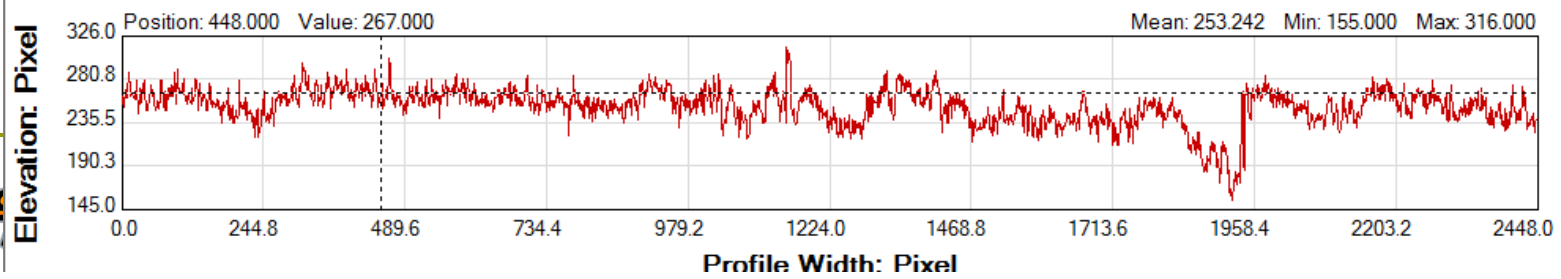
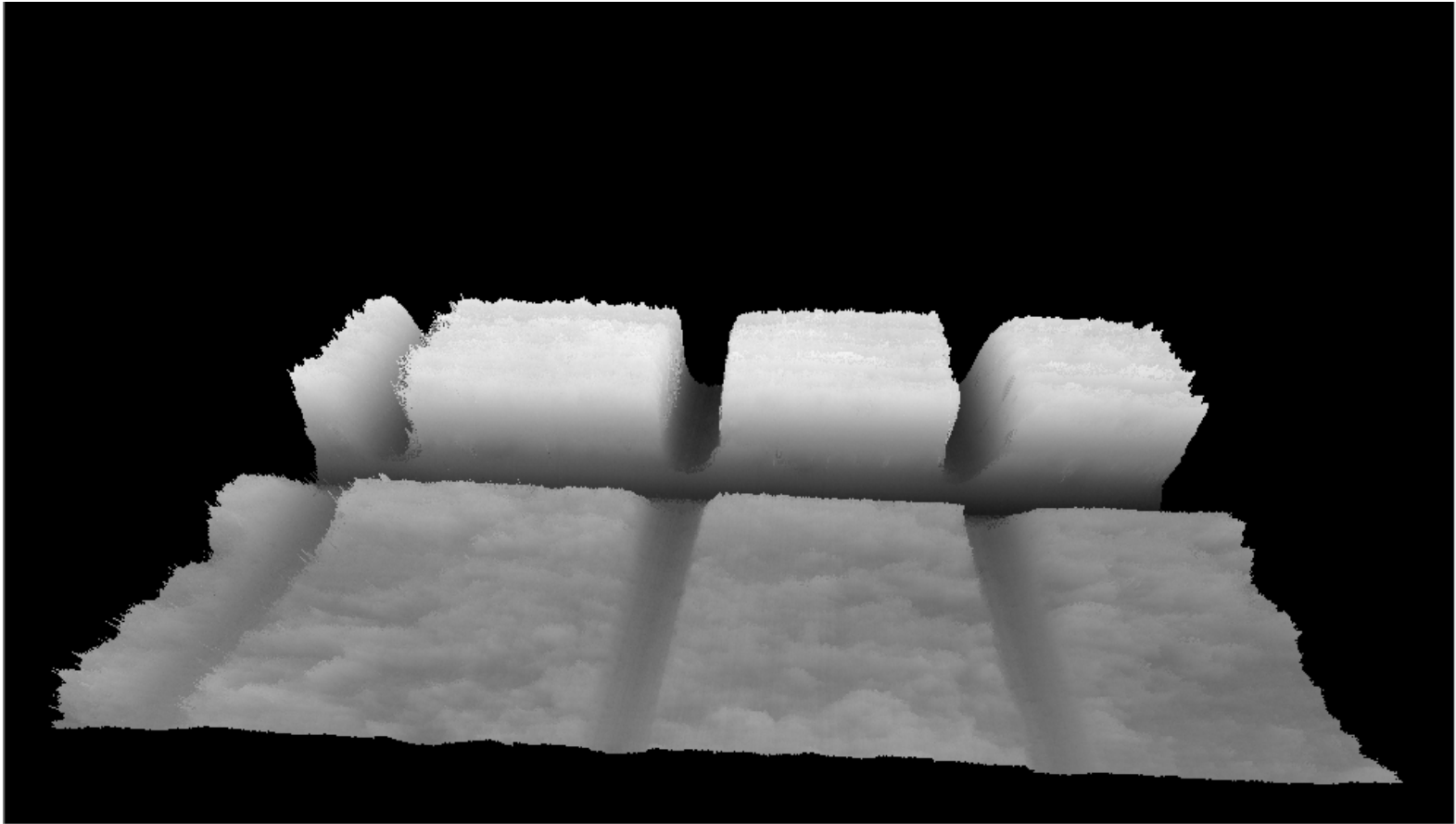
Grinded Surface



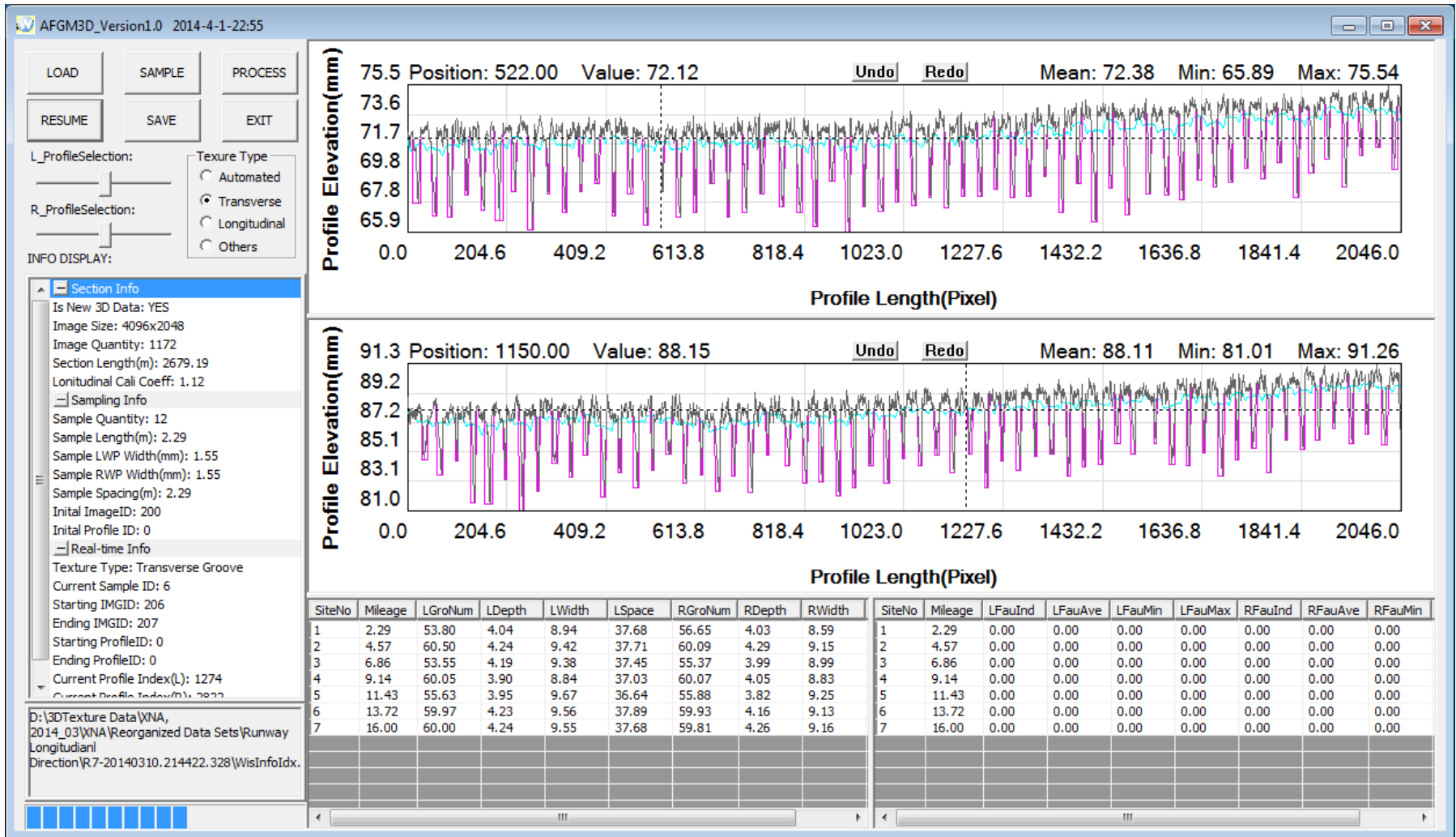
Grinded Surface



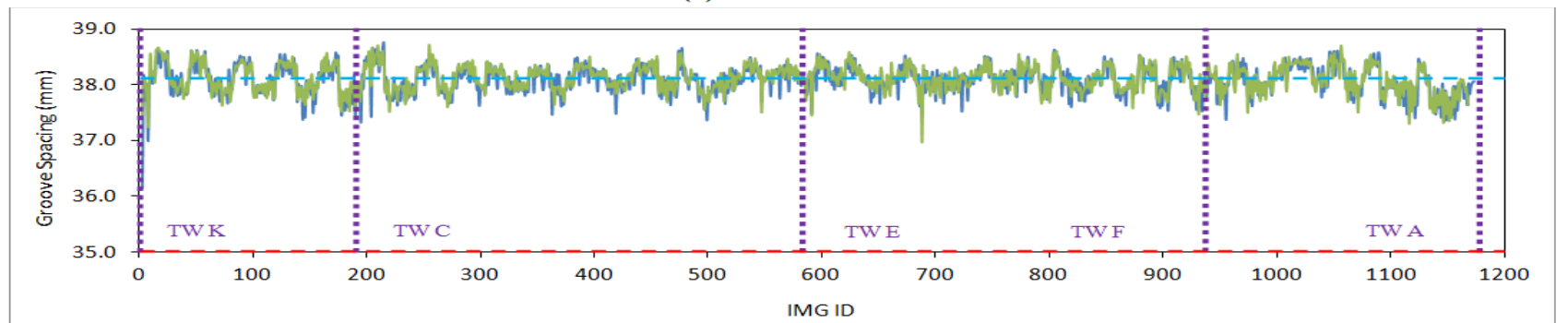
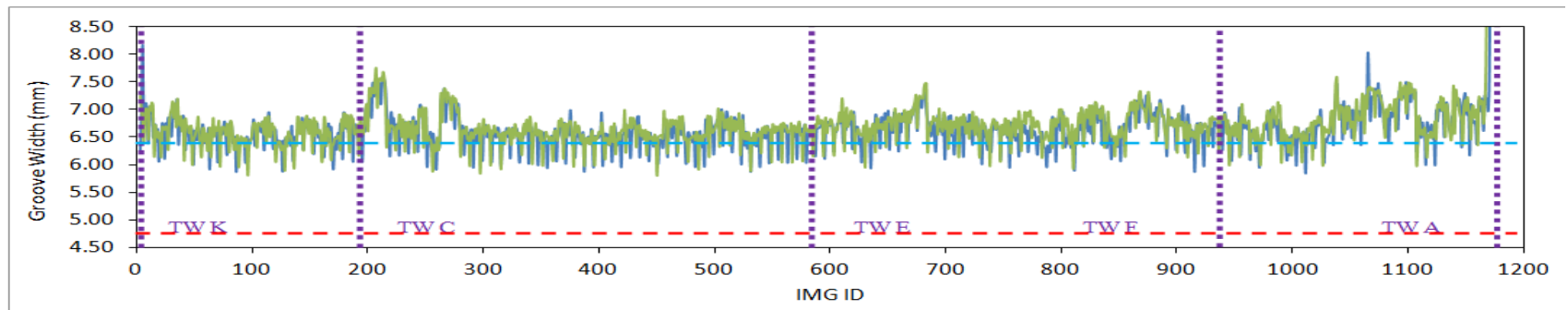
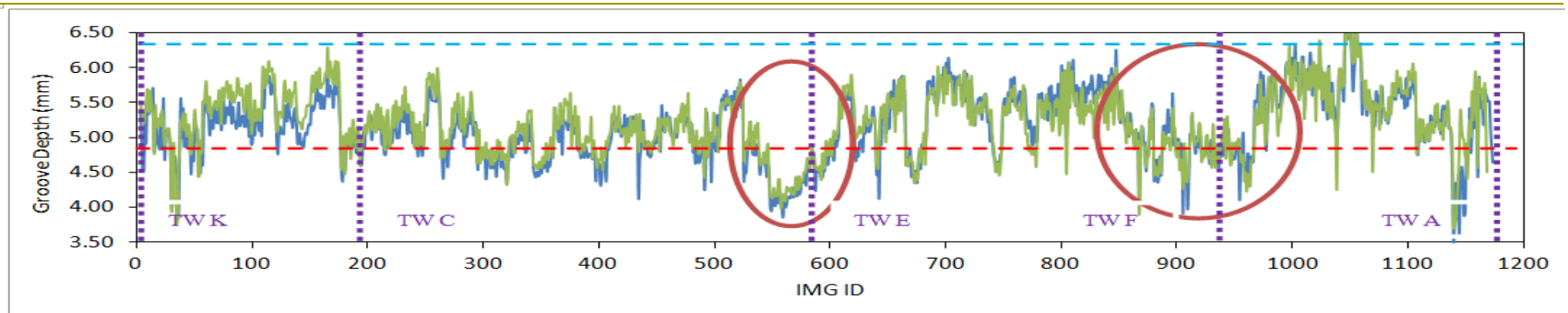
Uneven Surface



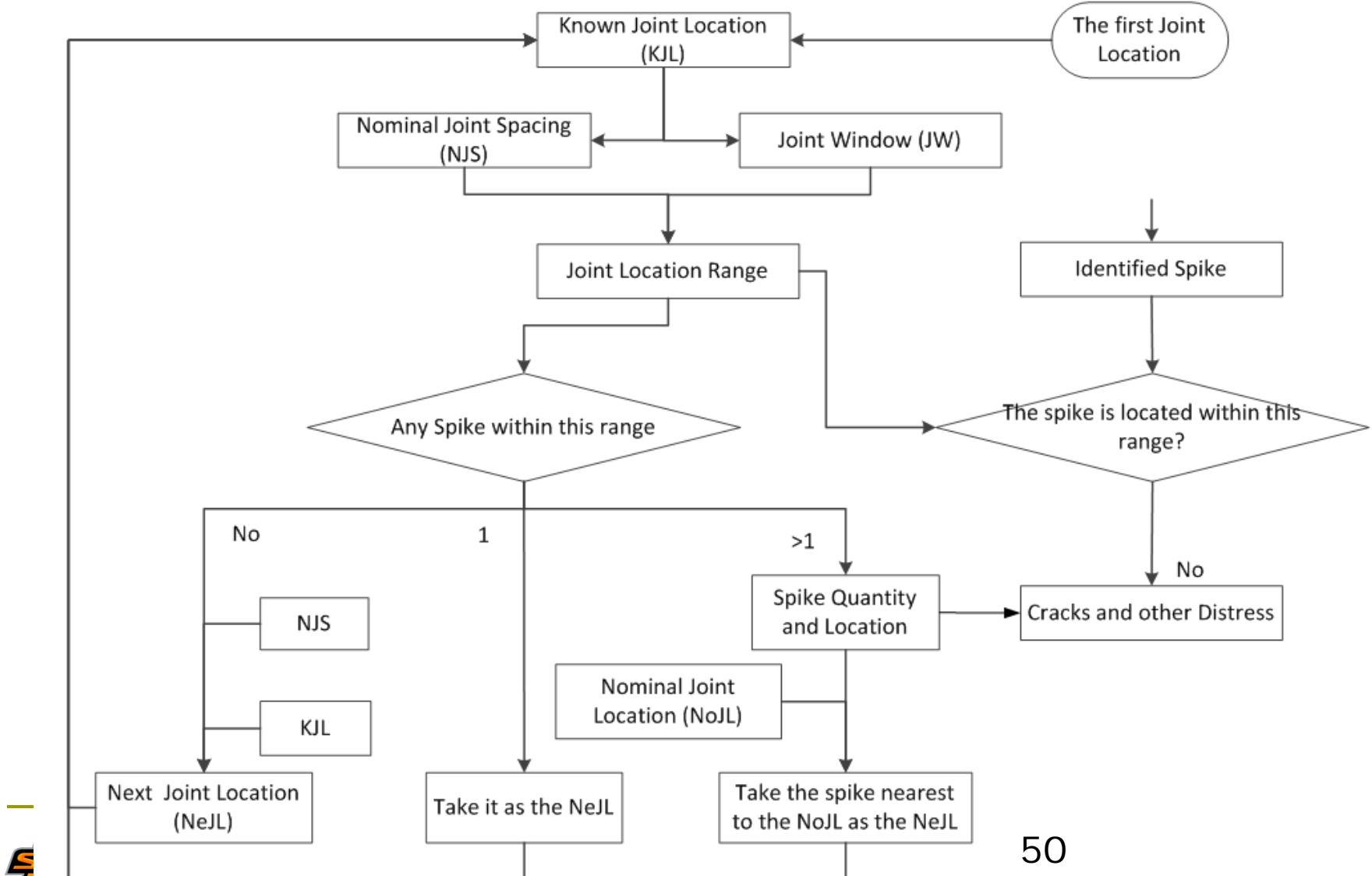
ProGroove3D Interface



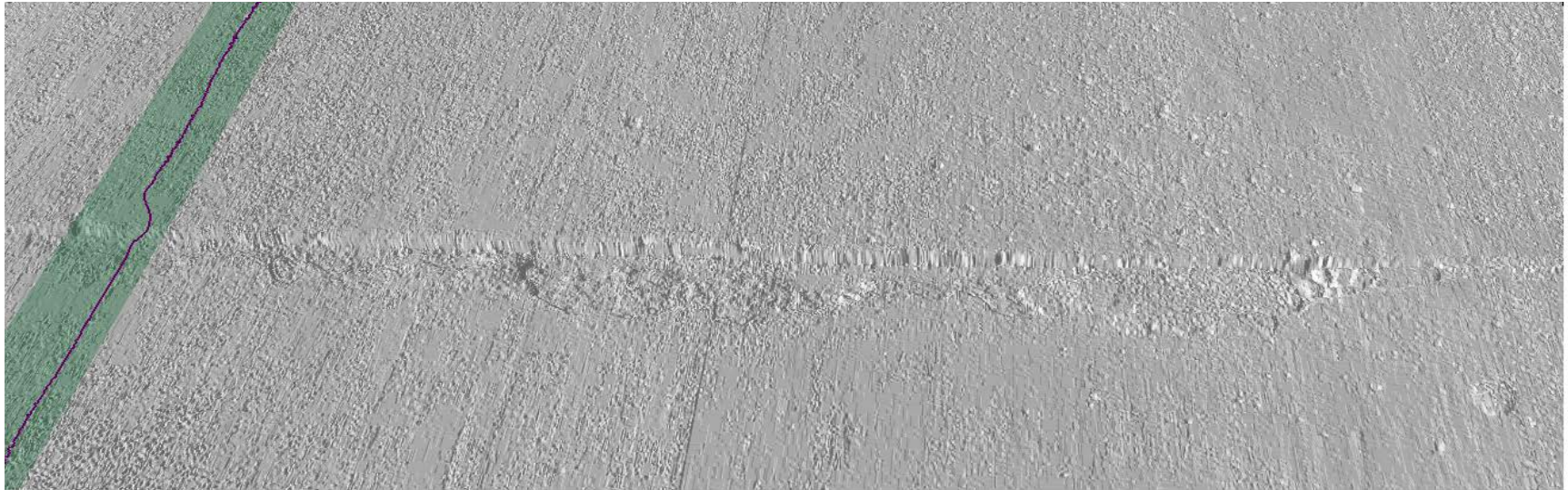
Groove Evaluation (Keel Runs 7&8)



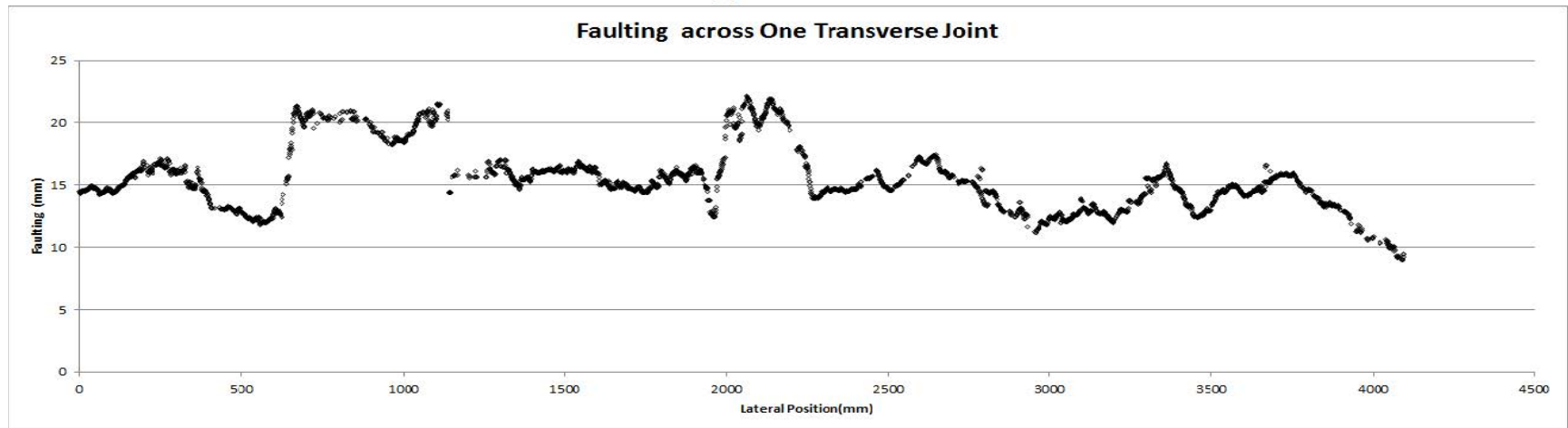
Automated Faulting Measurement



Example Faulting Results

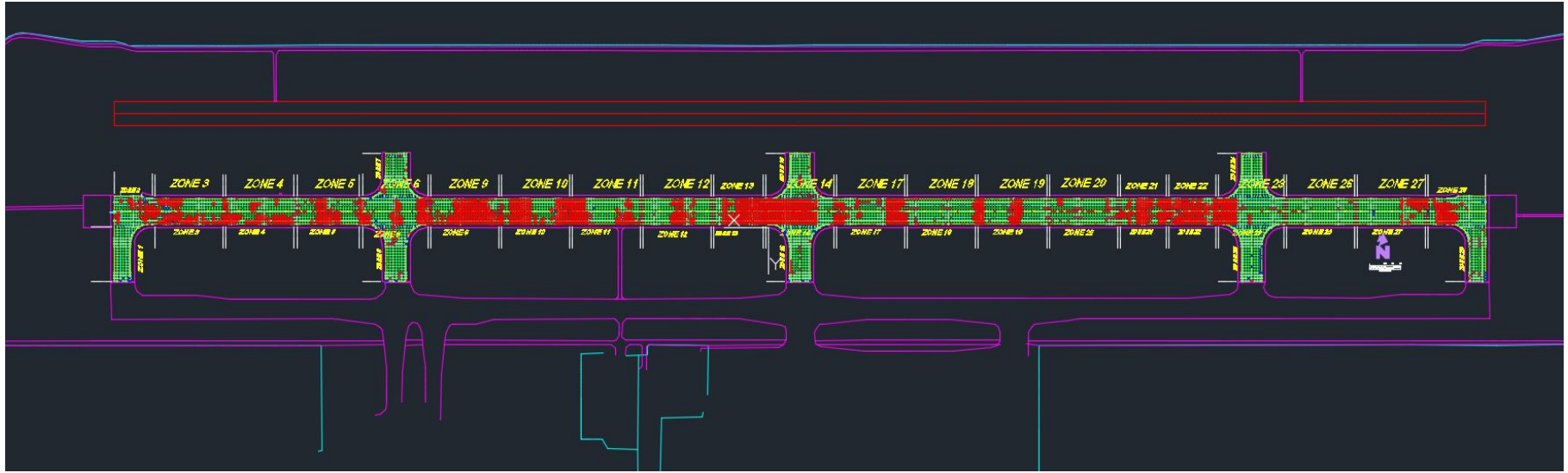


(a)



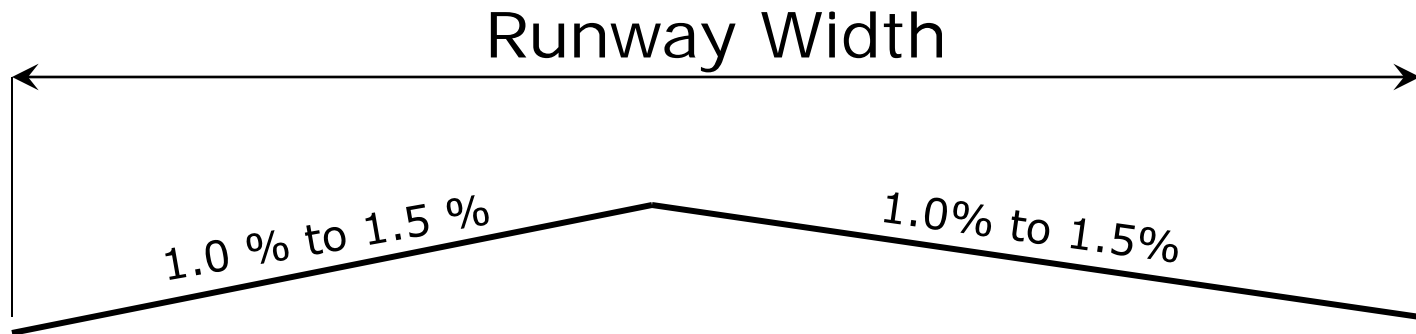
(b)

Groove/Joint Evaluation

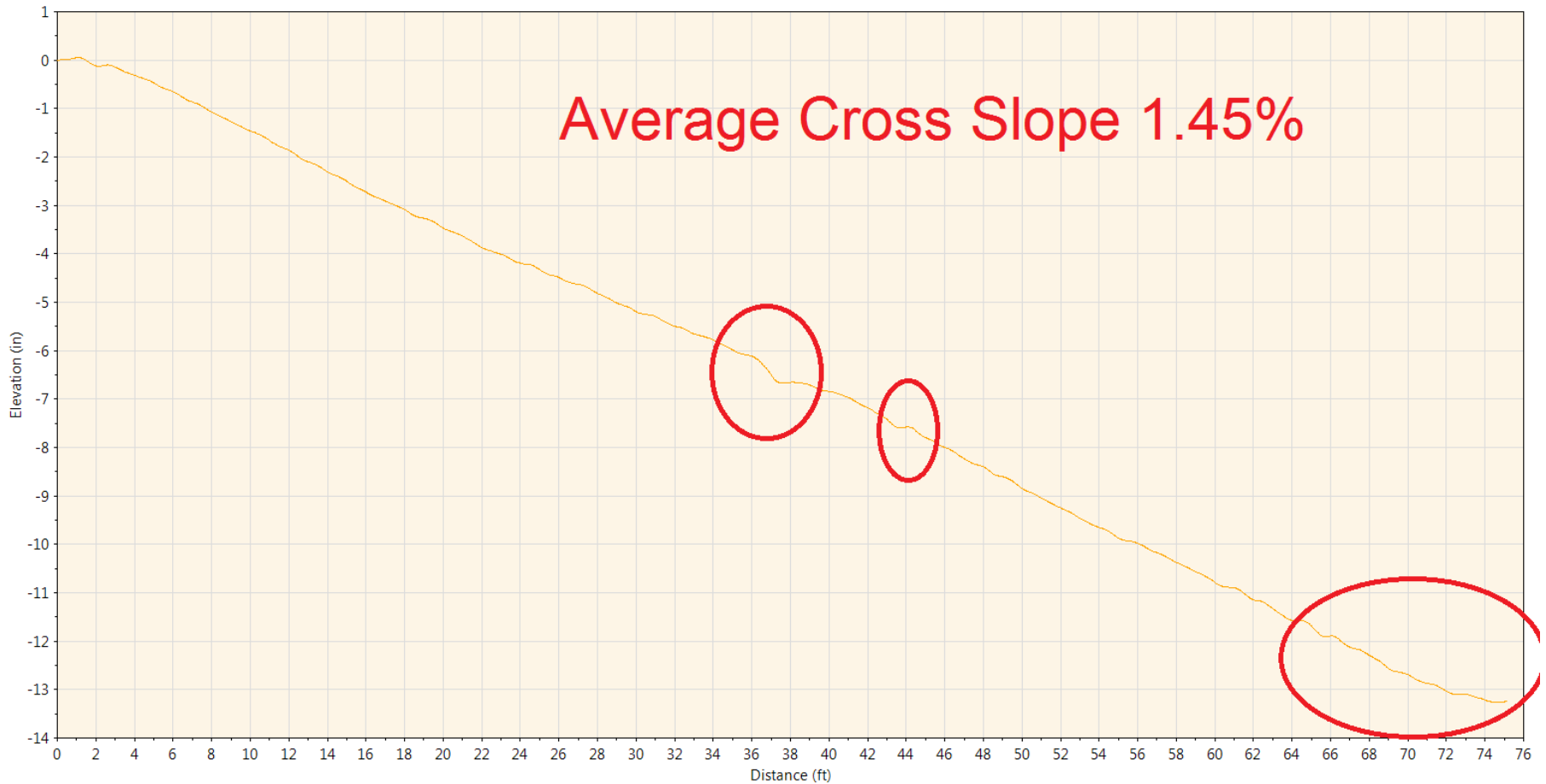


Transverse Profiling & Cross Slope

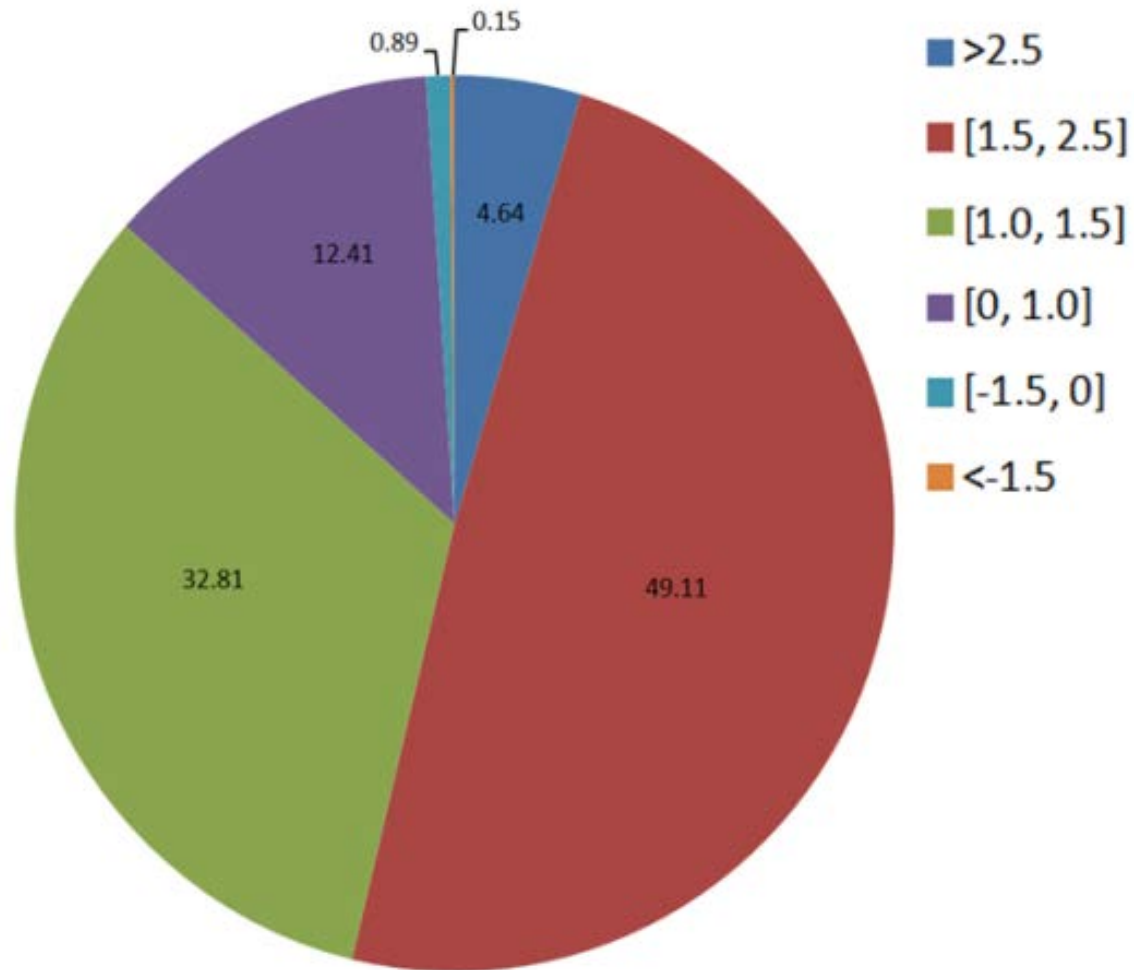
- Cross Slope Calculation
 - AASHTO method
 - TxDOT method
 - Linear regression method
- Transverse Grade – Category C & D Airports (FAA Guidance)



Example Cross Slope (West-Half)



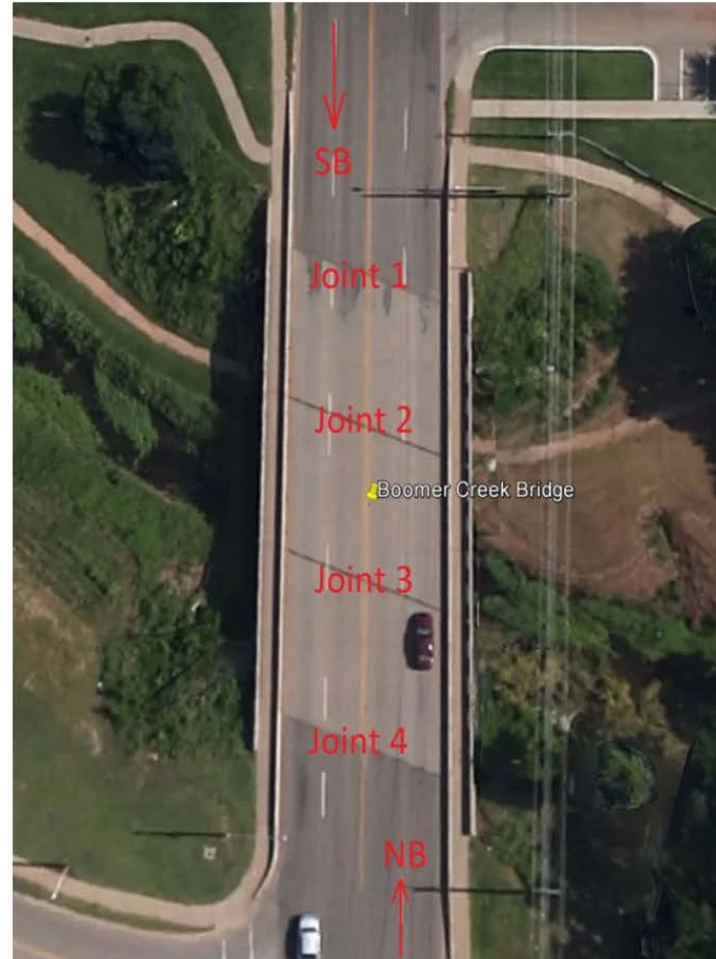
Cross Slope Evaluation



Bridge Deck Evaluation



(a) Bridge Location



(b) Bridge Deck

Bridge Deck (Joint #1 & #2)



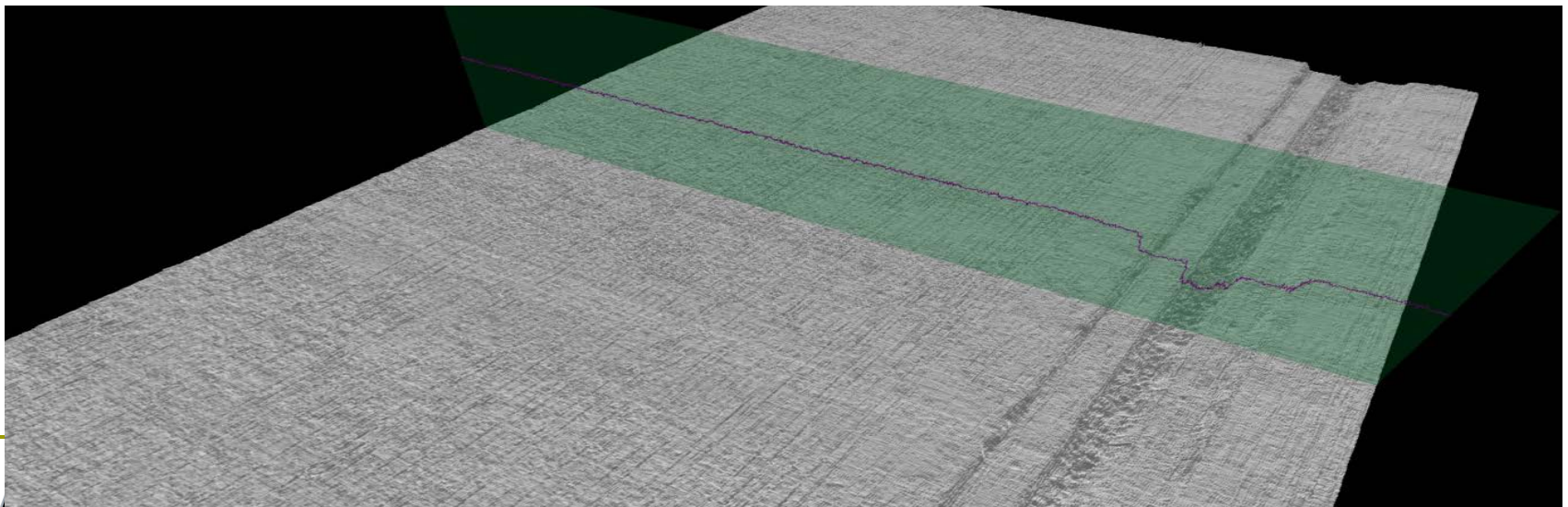
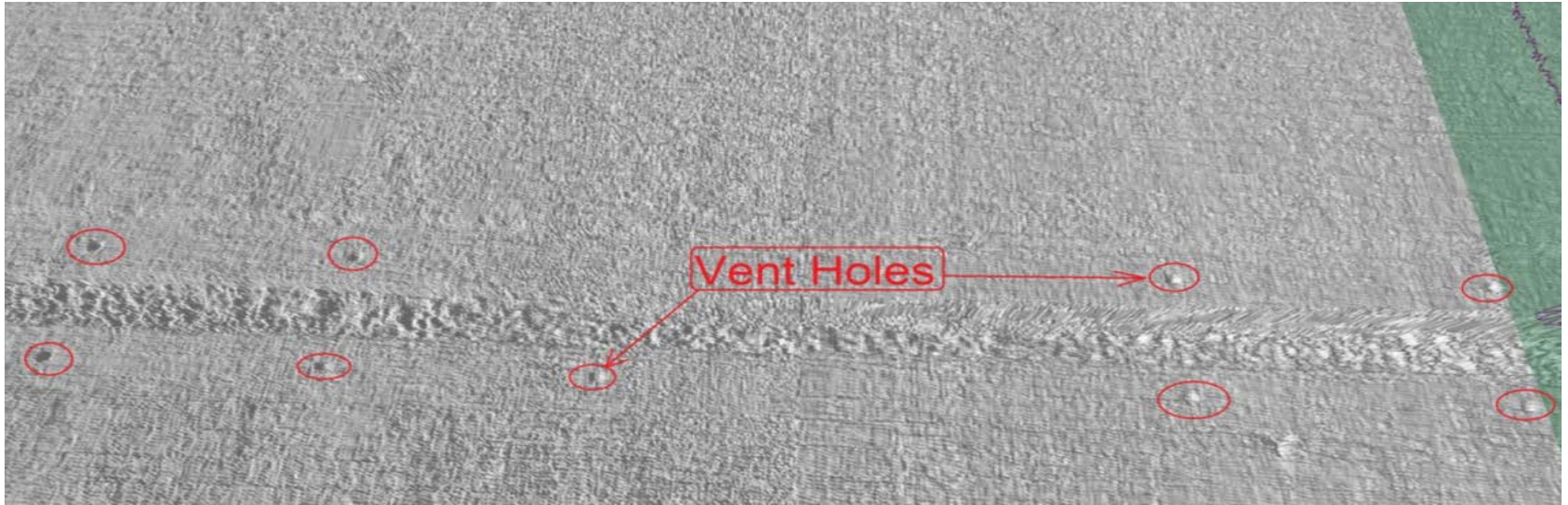
Virtual Bridge Deck (Joint #1)



Virtual Bridge Deck (Joint #2)



Virtual Bridge Deck



Conclusions

- PaveVision3D Ultra system
 - 1mm surface data at 60mph
 - Stitch images from multiple passes to establish virtual surface

- Various applications
 - Multi-lane highway
 - Airport runway
 - Bridge deck