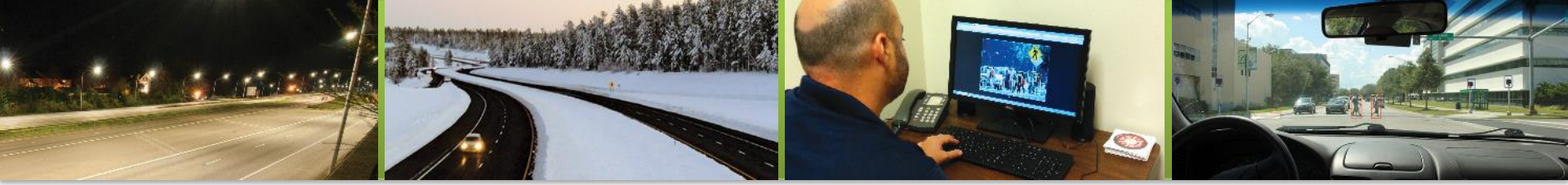

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Advanced Methods to Identify Asphalt Pavement Delamination (R06D)
Ground Penetrating Radar (GPR)
Texas Department of Transportation

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Peer Exchange
August 1-3, 2018

Texas Department of Transportation
Texas A&M Transportation Institute
U.S. Department of Transportation
Federal Highway Administration
American Association of State Highway and Transportation Officials
AASHTO

Outline

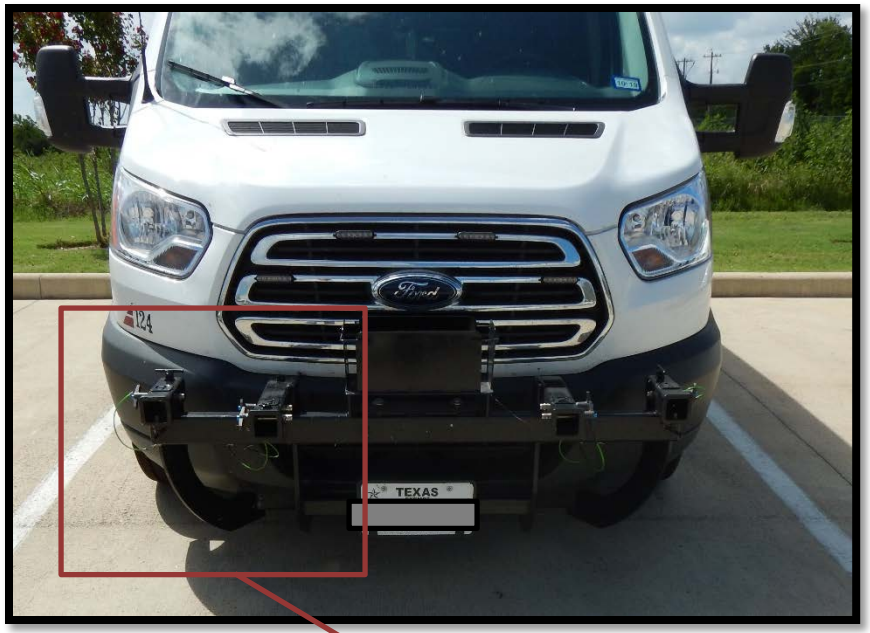
- 3D Radar mounting Information
- 3D Radar compared to Texas GPR system
  - Software & Analysis
    - PaveCheck
    - Examiner
    - Roadscanners – Road Doctor
- Field Test Sites
- Other sections Tested (Concrete Pavement)
- General 3D Radar Antenna Evaluation
- Conclusions and Recommendations

Antenna Mounting Details

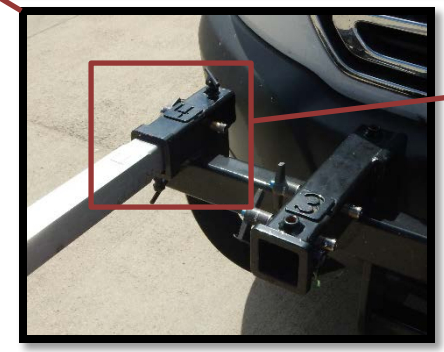
- Front of Vehicle
  - Consider this to be safer for operation
- 4 foot From Vehicle
  - Far enough away to minimize interference
- 18 inches from pavement to bottom of antenna
  - Ground clearance for safe operation

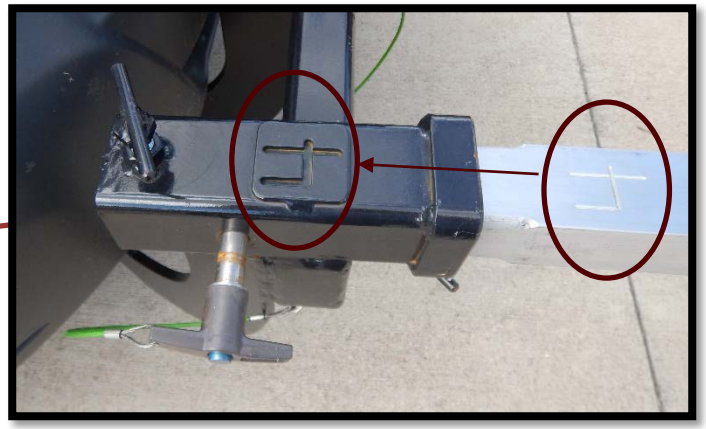
TTI's Mounting System

Mounting System - Bumper

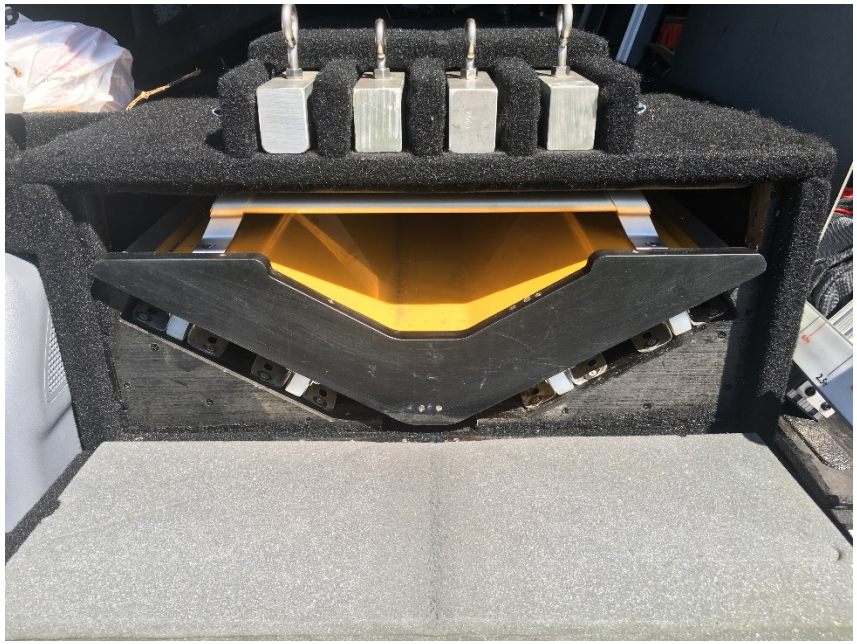


Aluminum Support Bars
Use 4 connection locations on antenna



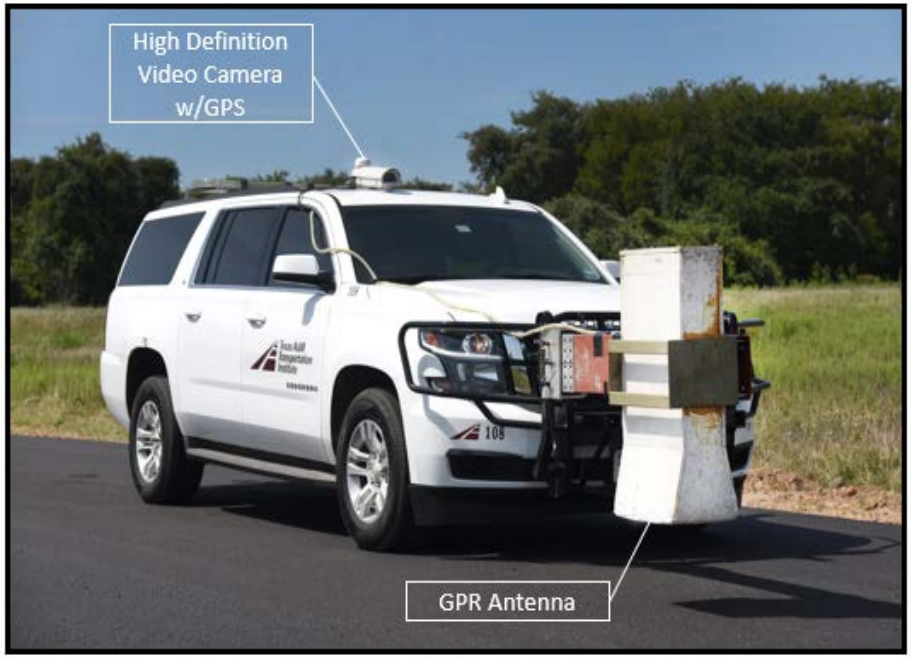


Storage during Transport



GPR – Comparison to Texas System

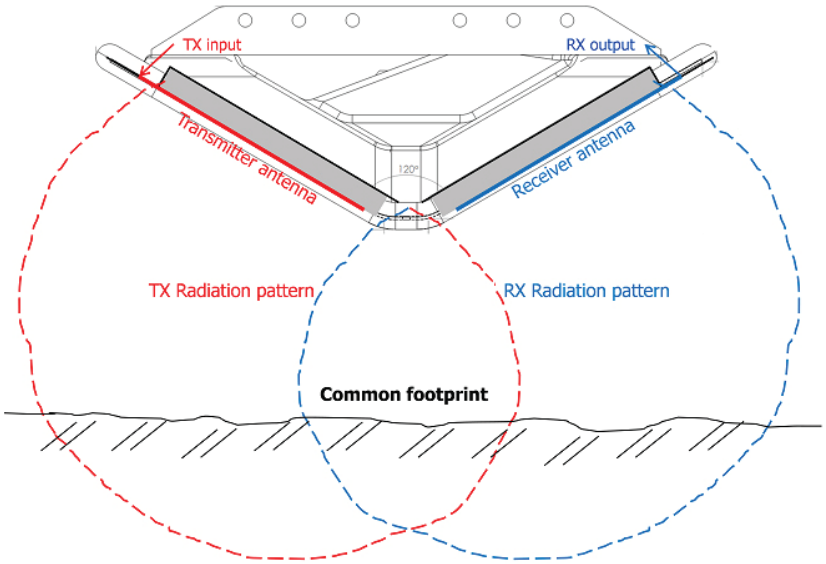
TTI 1GHz System



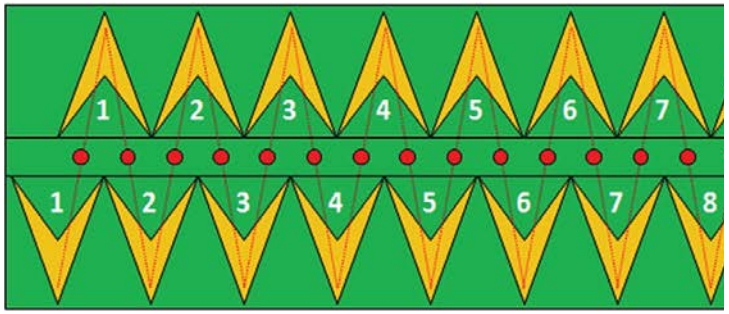
3D Radar System

GPR – 3D Radar

3D-Radar Antenna Specifications	
Technical Specifications	DX1821 Antenna
Width	5.9 ft
Frequency Range	200-3000 MHz
Number Of Channels	21
Channel Spacing	3 in
Effective Scan	5.2 ft
Direct Wave Suppression	> 50 dB
Polarization	Linear (in-line direction)
Size	5.9'x1.9'x0.7'
Weight	61.7 lbs



Antenna Configuration



Example Scan Pattern

Collection Settings 3D Radar

3D-Radar Collection Settings					
Pavement Surface	**[2]Trigger Spacing**		**Time Window**	**Dwell Time**	**Max Speed**
	(in)	**(cm)**	**(ns)**	**(us)**	**(mph)**
Concrete & BRG	3.0	7.6	50	0.6	43.5
[1]concrete/flexible	6.0	15.5	50	0.6	89
Flexible	12.0	30.5	50	0.6	175

1. Use for concrete pavement when need to test at >45mph; use for flexible pavement when closer spacing is needed;
2. Trigger Spacing can be increased to 36” in order to save data storage and still provide adequate network level data. If spacing is adjusted, use multiples of 3".

Note: Collection settings are preliminary and final recommendations are still under review.

GPR Comparison - Collection

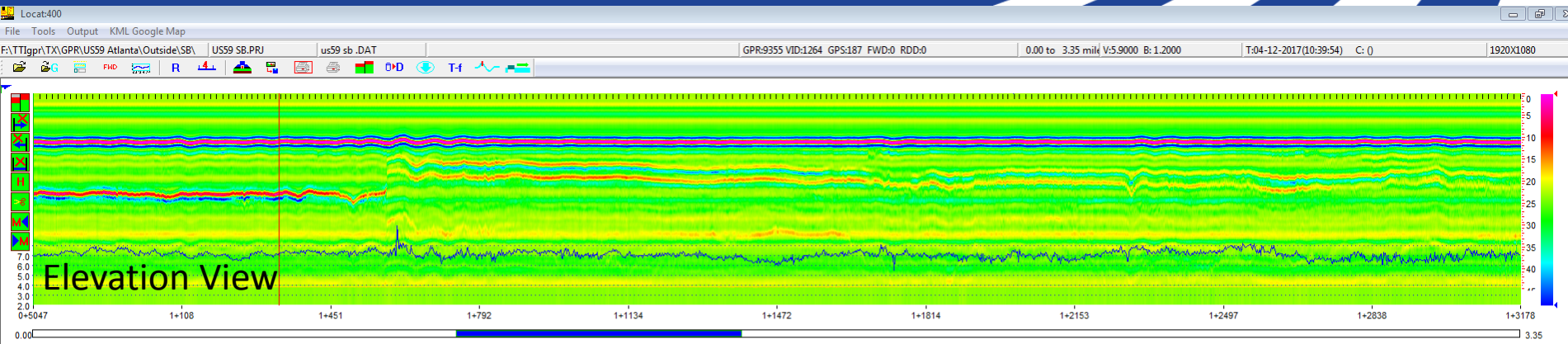
TTI 1GHz System

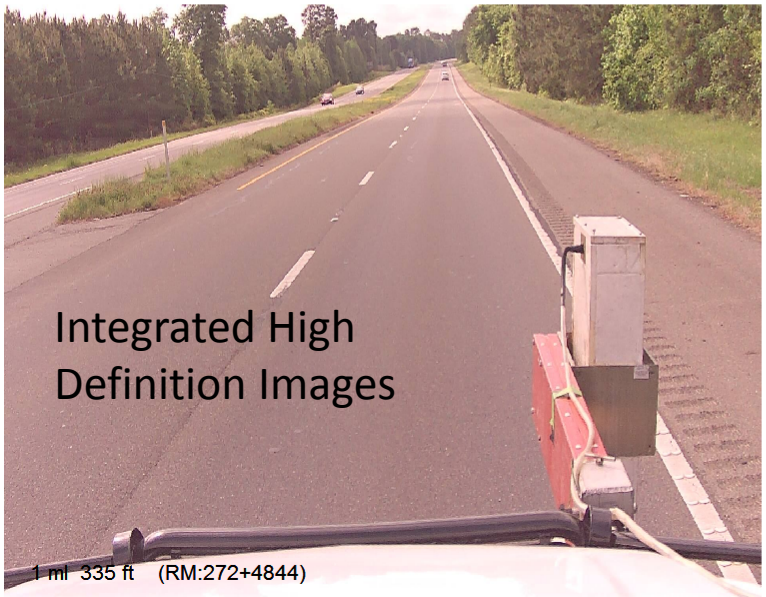
- Flexible Pavement
  - Collect at Highway Speed
  - Collection interval 24”+
  - Significant Data Storage Required
    - US 59, 3.35 miles 1 run required ~19,000 KB of storage

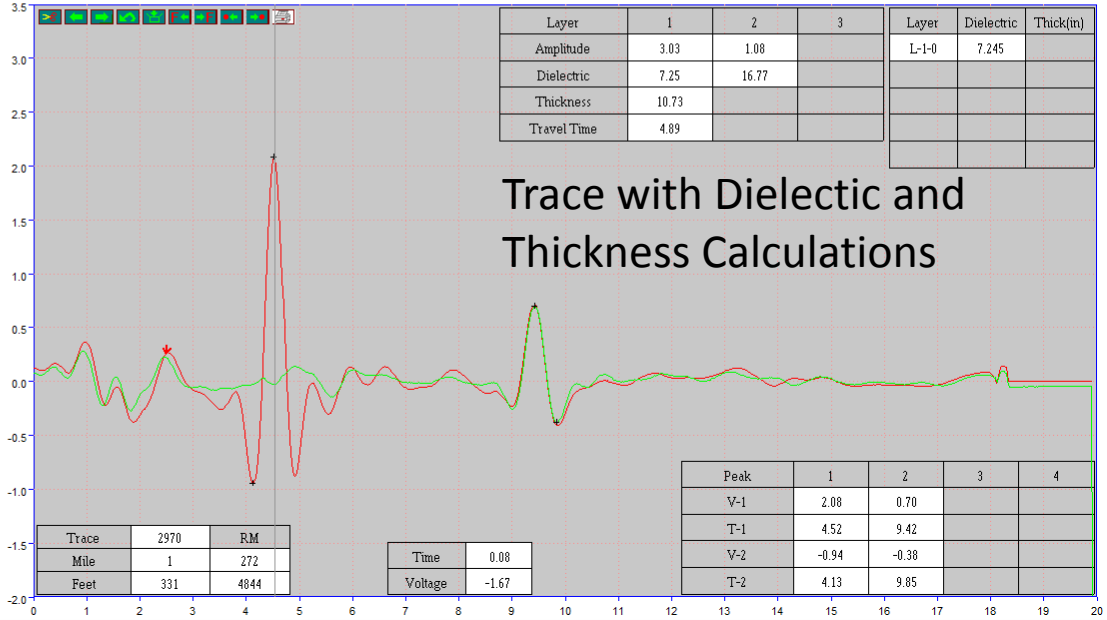
3D Radar System

- Flexible Pavement
  - Collect at Highway Speed
  - Collection interval 12”+
  - Significant Data Storage Required
    - US 59, 3.35 miles 1 run required 1,578,000 KB of storage

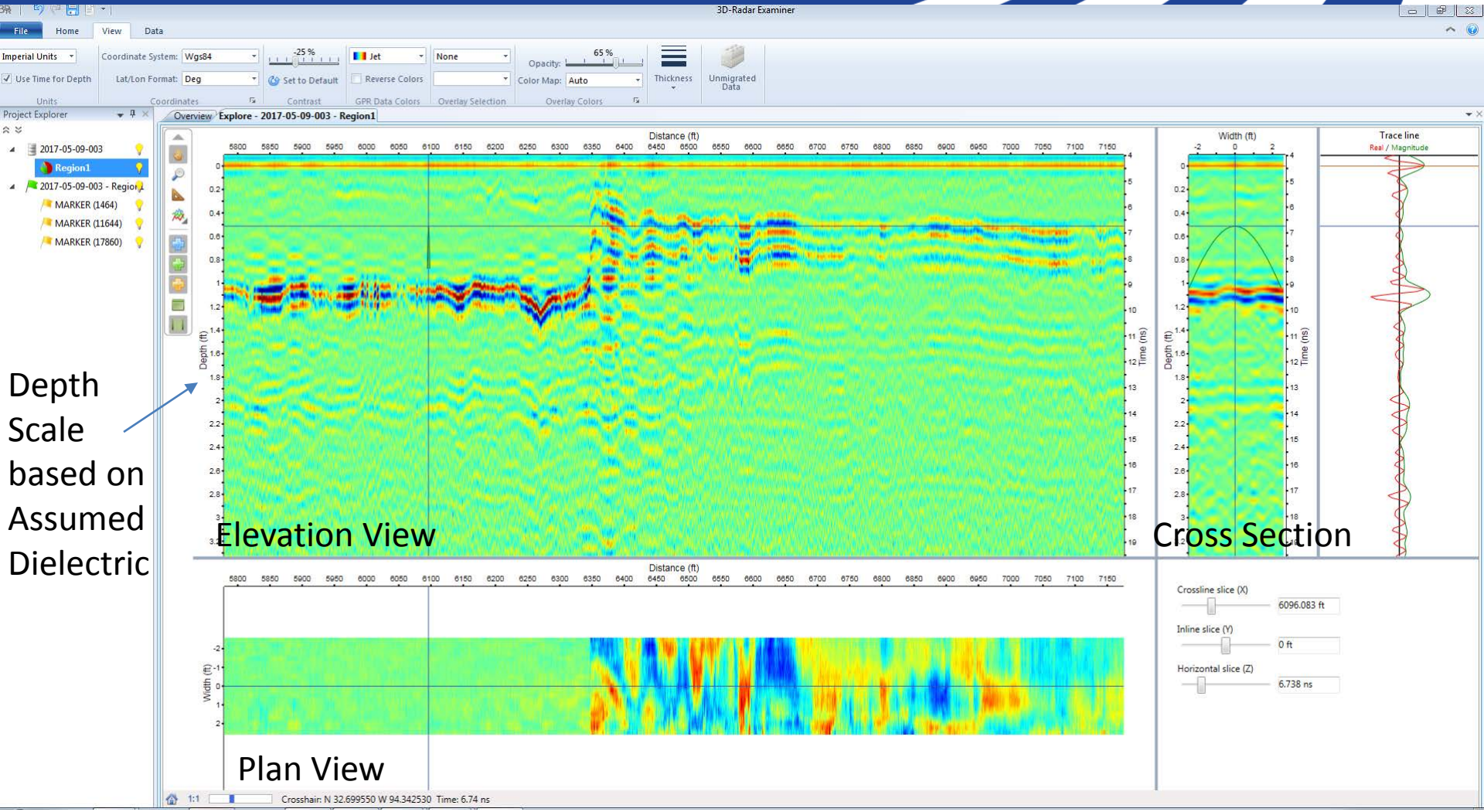
TTI – PaveCheck Software







3D Radar Examiner Software



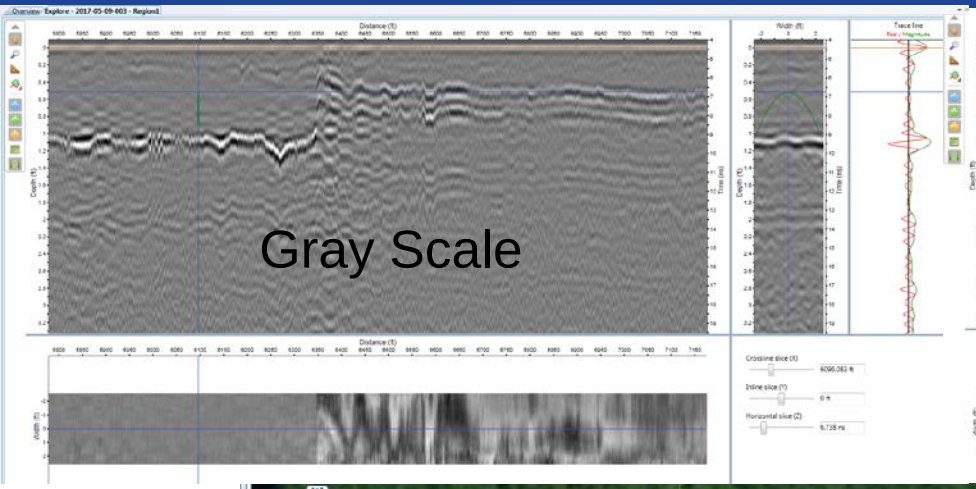
Depth Scale based on Assumed Dielectric

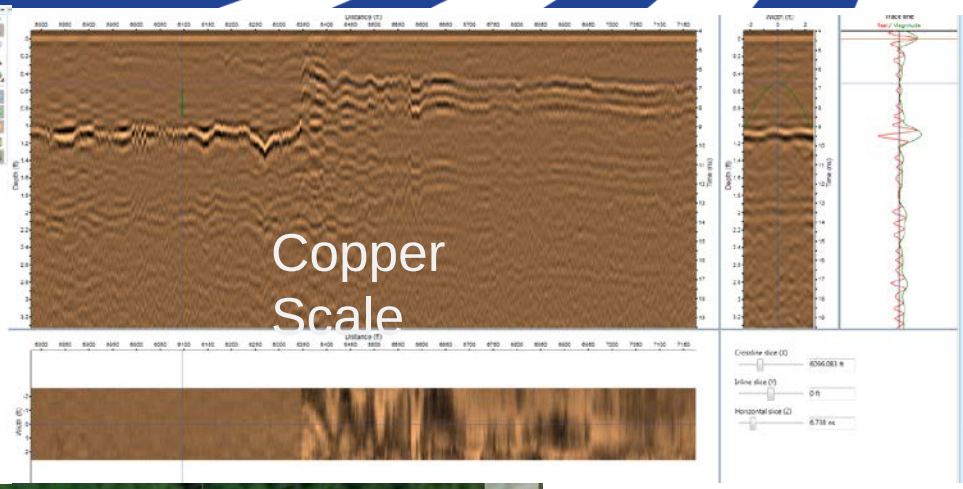
Elevation View

Cross Section

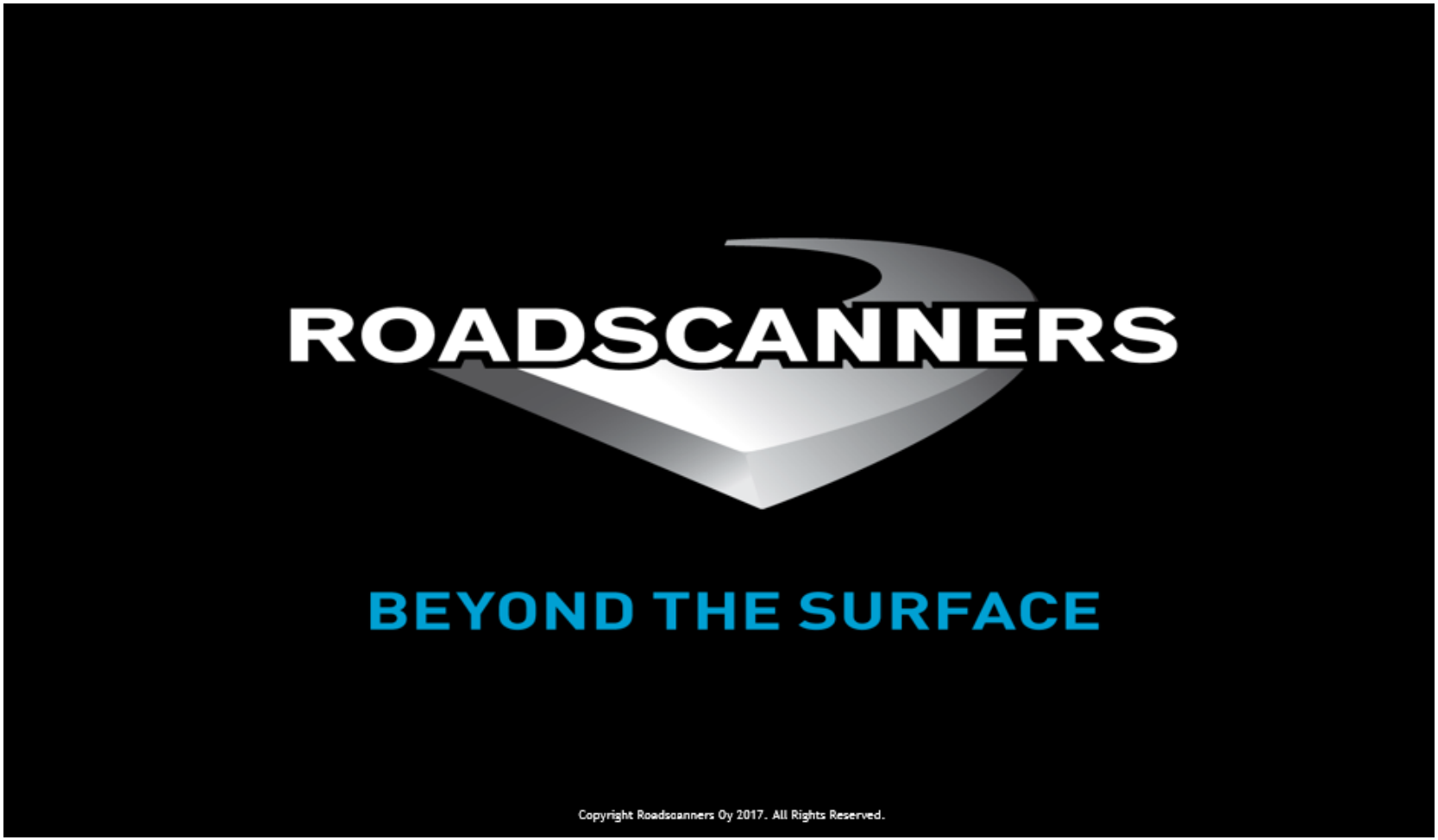
Plan View

3D Radar Examiner Software

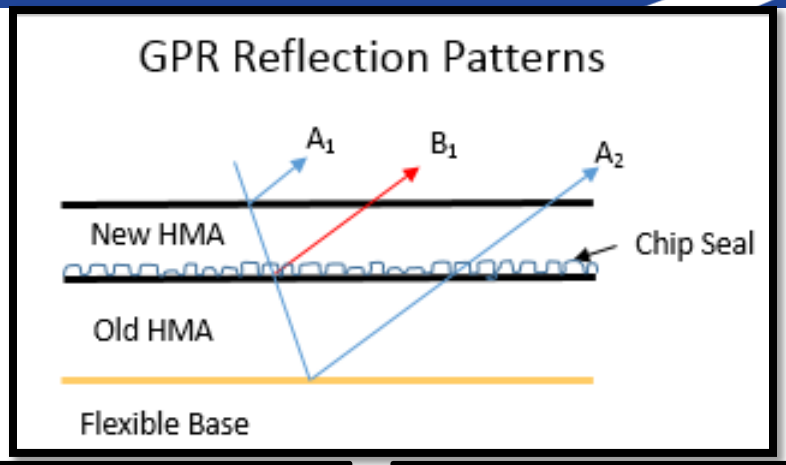




ROADSCANNERS Software

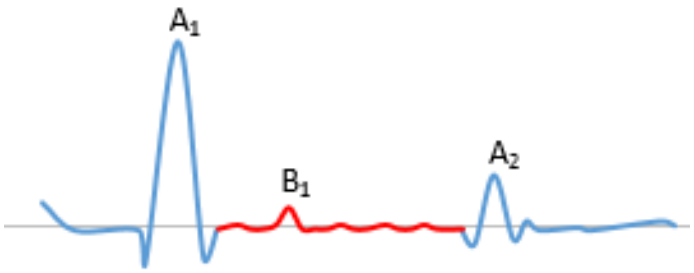


Trace Patterns



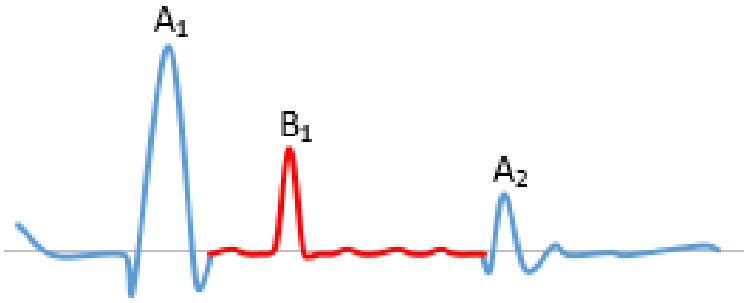
Case-1: Normal

B_1 Positive, very small reflection
Little dielectric contrast between new and old HMA

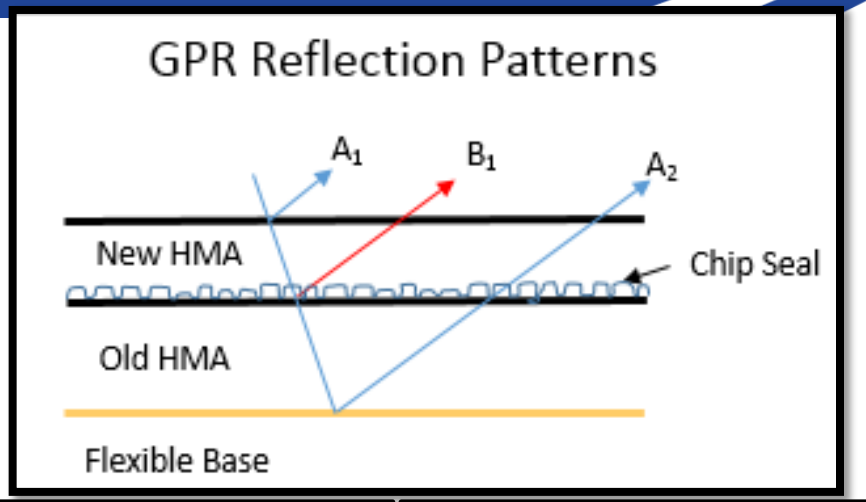


Case-2: Trapped Moisture

B_1 Large Positive reflection
A_2 reflection is smaller than B_1



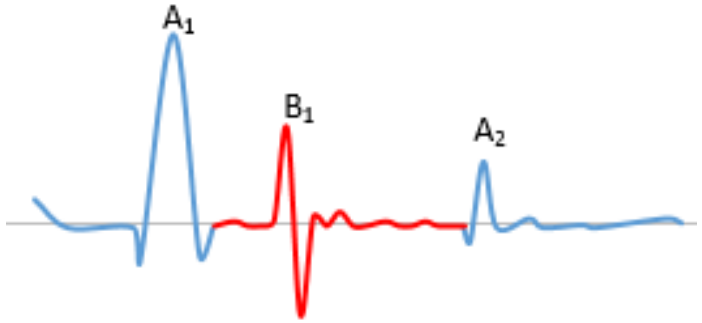
Trace Patterns



Case-3:

Thin Layer of Moisture on Top of Seal

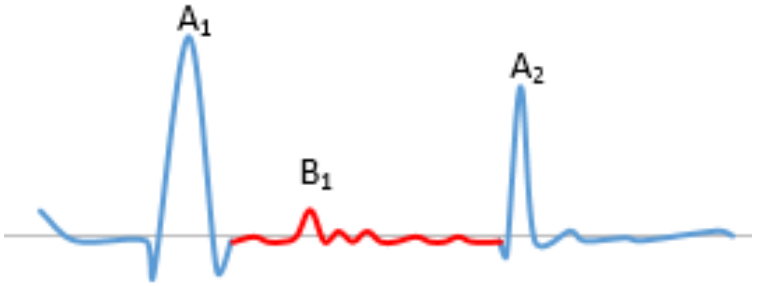
B_1 Overlapping Positive and Negative reflections



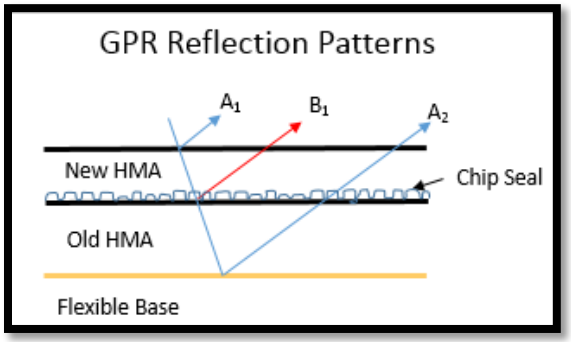
Case-4:

Moisture Trapped in Base Layer

A_2 Reflection increases significantly

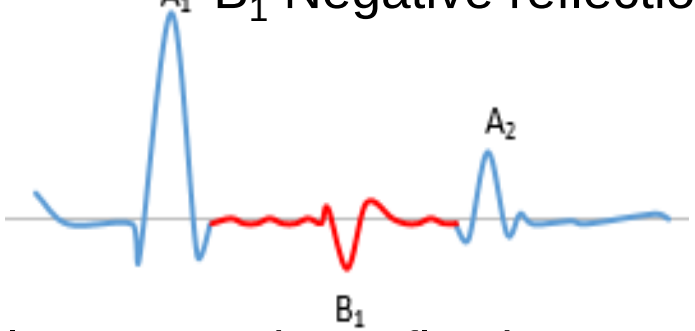


Trace Patterns



Case-5: Lower HMA Severely Deteriorated-Stripping

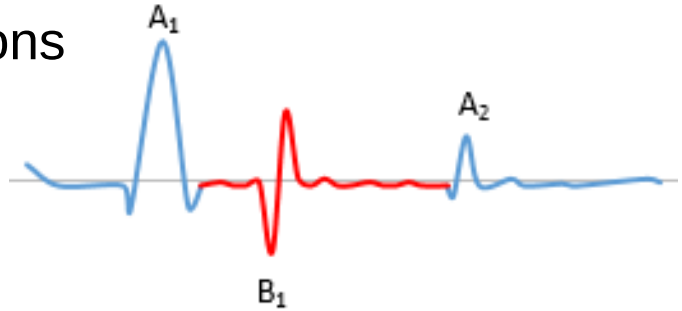
A_1 B_1 Negative reflections



Note: large negative reflections may be high void area, stripping or debonding

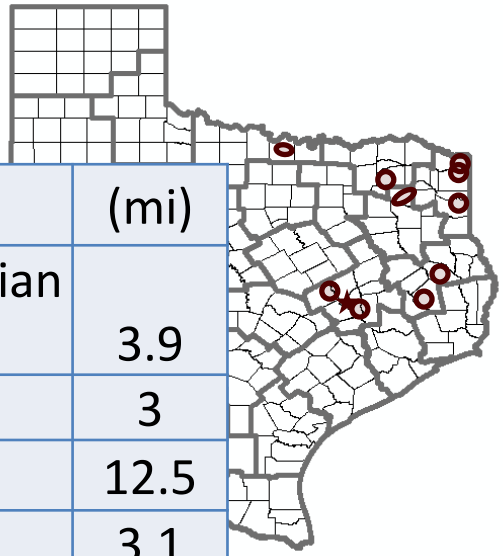
Case-6: Stripped Layer to Good HMA

B_1 Overlapping Negative and Positive reflections



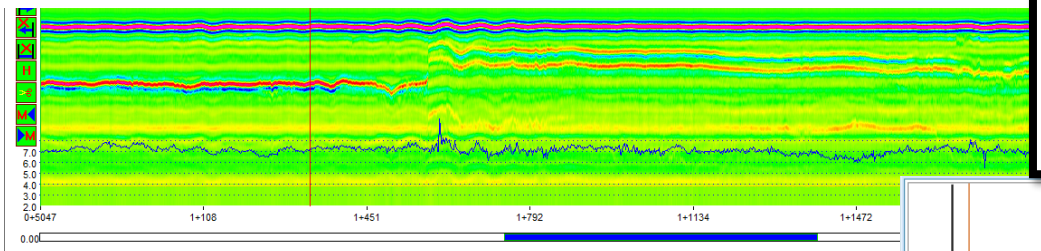
Note: Pattern may also appear when a Light weight aggregate Chip Seal is between good layers. No moisture present.

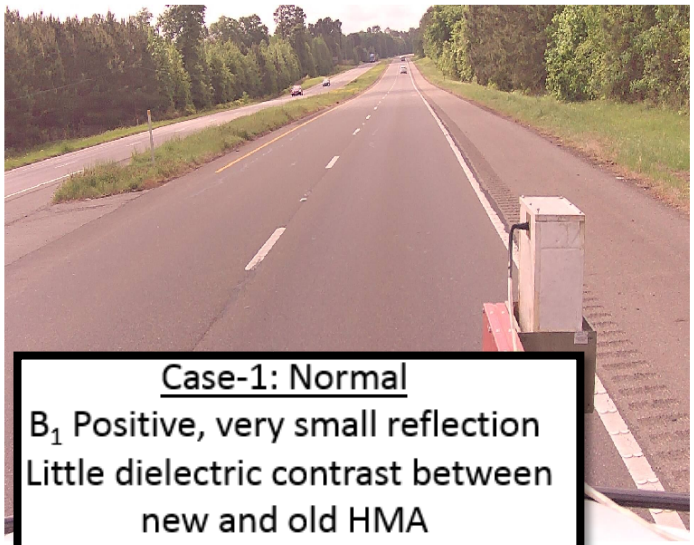
GPR Test Locations - Texas

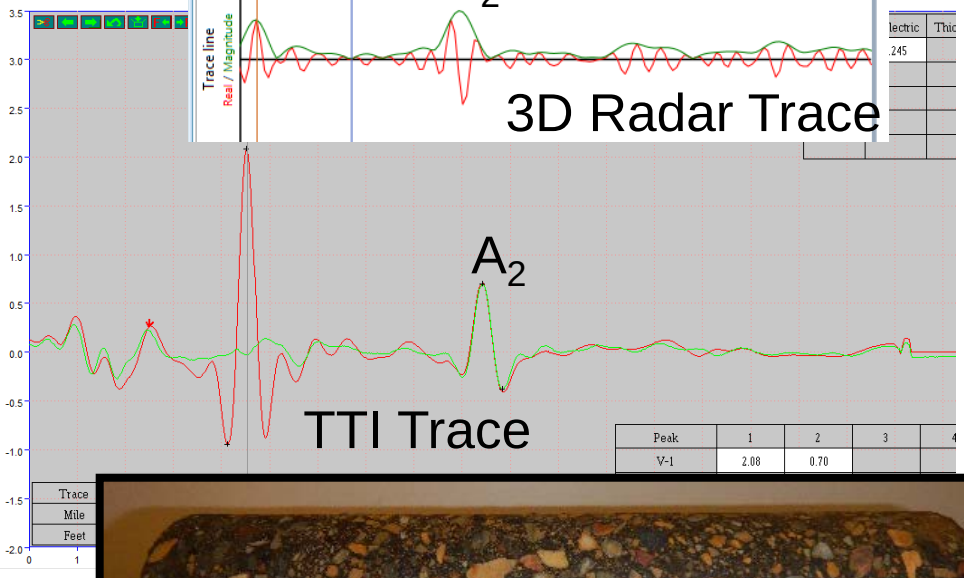


HWY	District	Limits	(mi)
US 59	Lufkin	Milton Creek to end grass median S of Leggett	3.9
US 69	Lufkin	Start FM 841 E for 3 mi	3
SH 19	Paris	Delta Co. to Sulphur Springs	12.5
US 59	Atlanta	Marion Co. line to FM 1997	3.1
IH 30	Atlanta	State Line to TRM 218	6
IH 30	Atlanta	TRM 153 to TRM 181	30
US 82	Wichita Falls	Nocona to St. Jo	12
US 79	Bryan	FM 2095 to Brazos River	4.5
FM 2347	Bryan	FM 2154 to FM 2818	1

Comparison – US 59 ATLANTA District

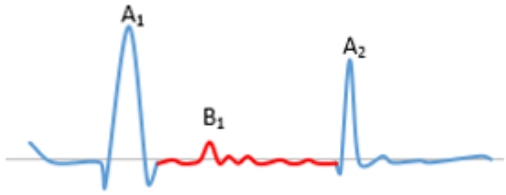






Case-4: Moisture Trapped in Base Layer

A_2 Reflection increases significantly



A_2

3D Radar Trace

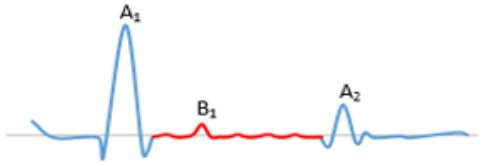
A_2

TTI Trace

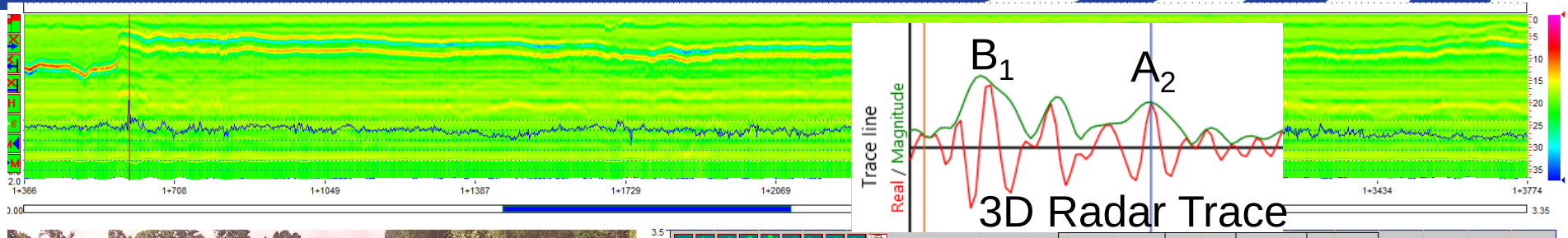
Case-1: Normal

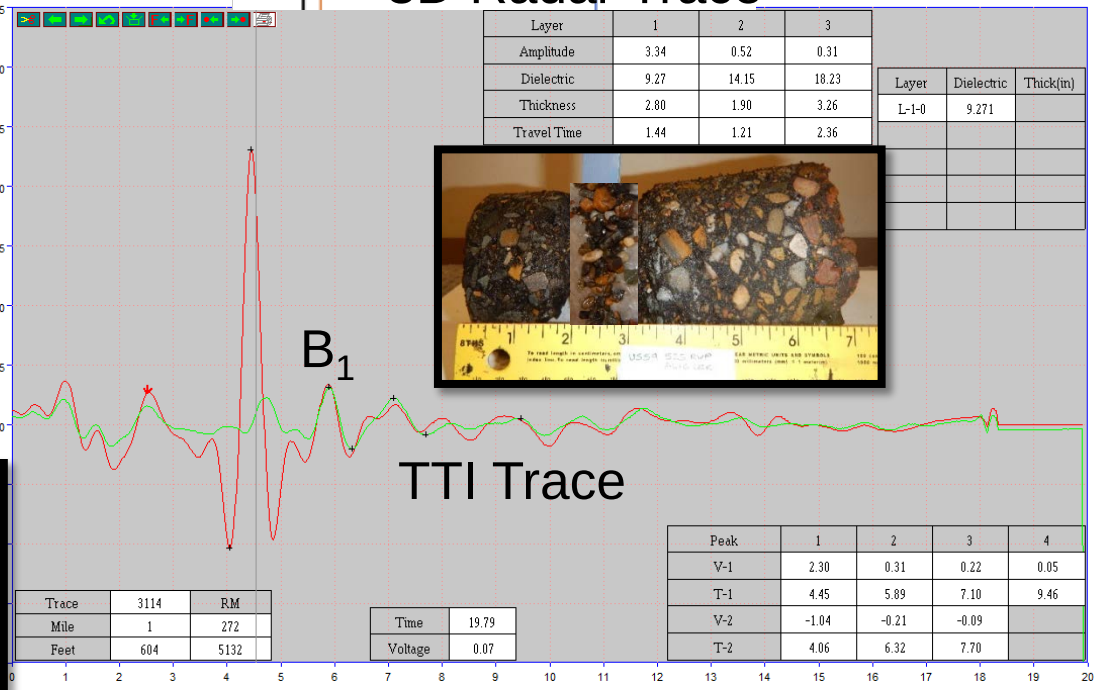
B_1 Positive, very small reflection

Little dielectric contrast between new and old HMA



Comparison – US 59 Atlanta District





Layer	1	2	3
Amplitude	3.34	0.52	0.31
Dielectric	9.27	14.15	18.23
Thickness	2.80	1.90	3.26
Travel Time	1.44	1.21	2.36

Layer	Dielectric	Thick(in)
L-1-0	9.271	

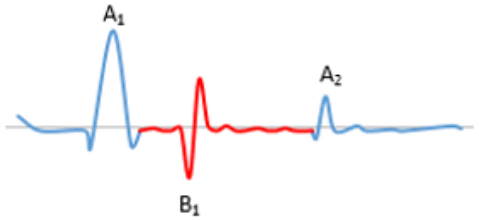
Trace	3114	RM
Mile	1	272
Feet	604	5132

Time	19.79
Voltage	0.07

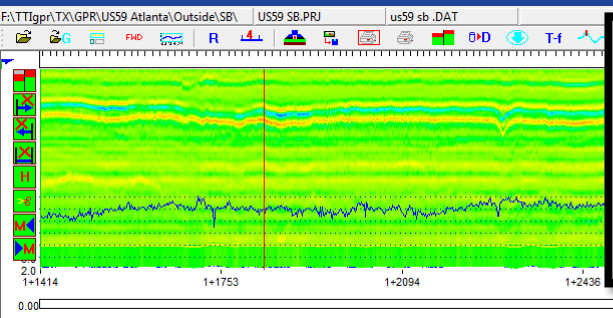
Peak	1	2	3	4
V-1	2.30	0.31	0.22	0.05
T-1	4.45	5.89	7.10	9.46
V-2	-1.04	-0.21	-0.09	
T-2	4.06	6.32	7.70	

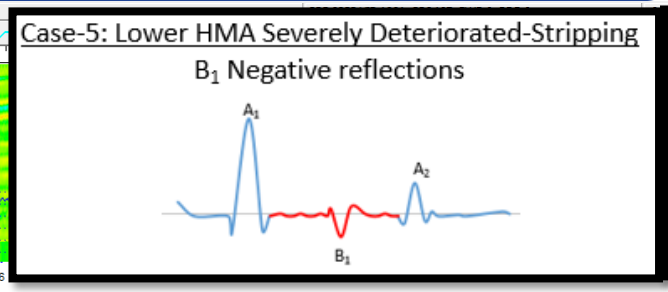
Case-6: Stripped Layer to Good HMA

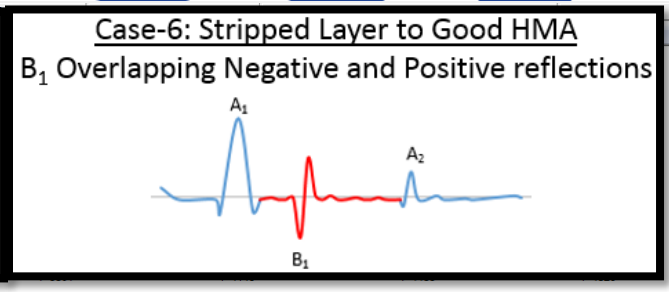
B_1 Overlapping Negative and Positive reflections

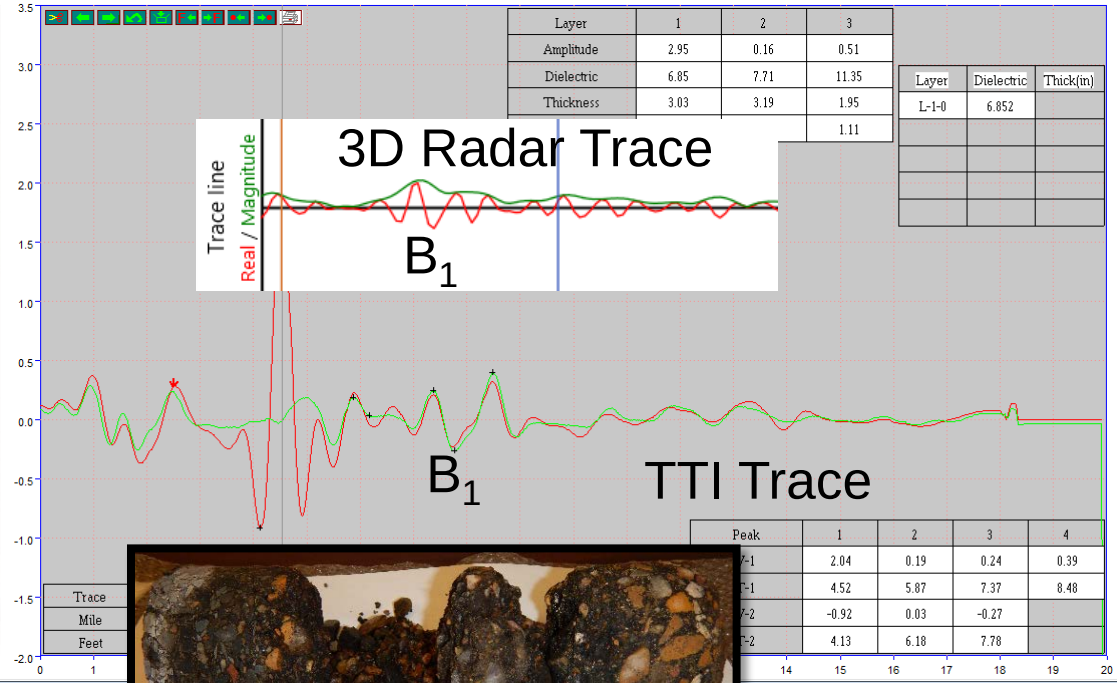


Comparison US 59 Atlanta District

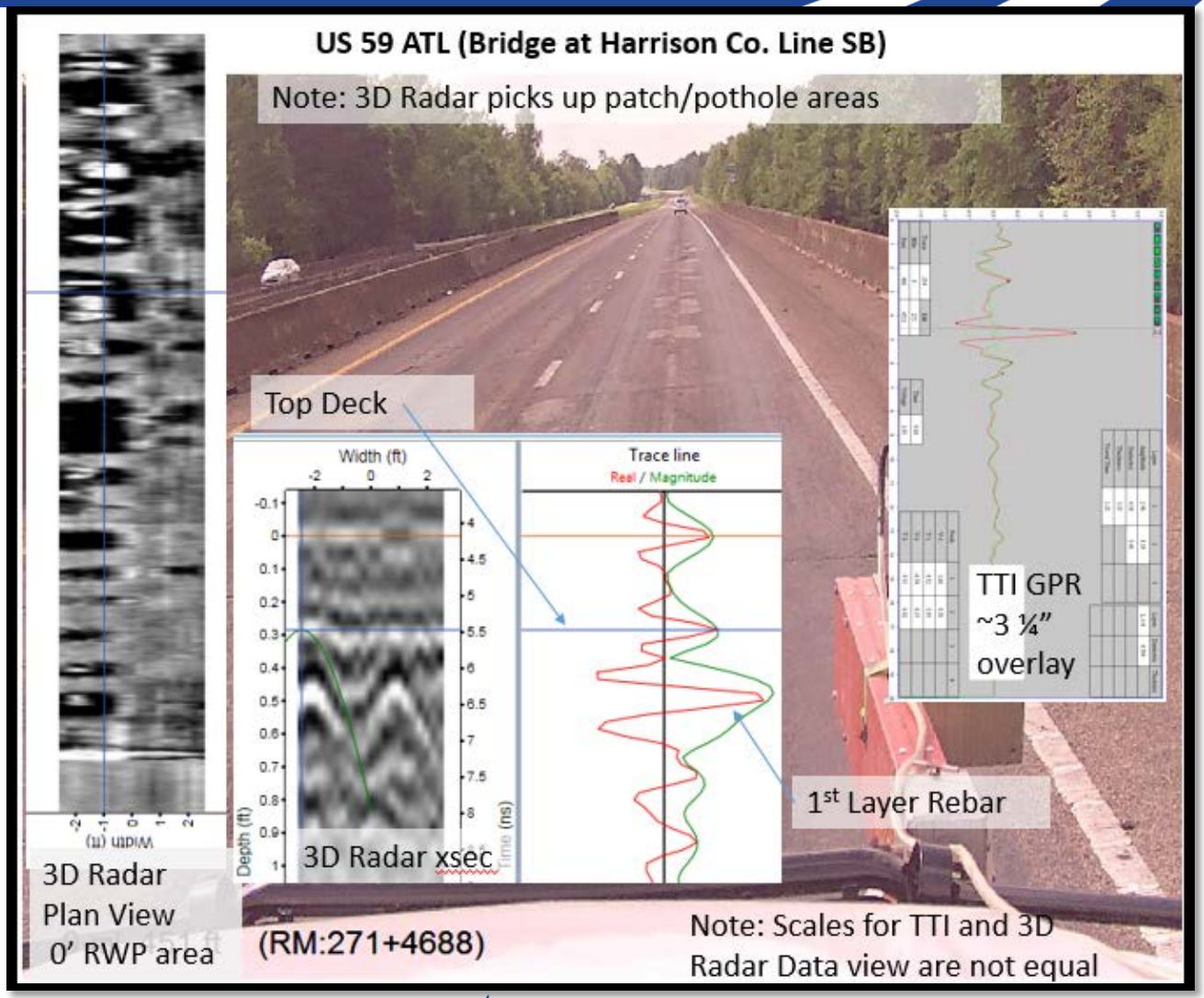




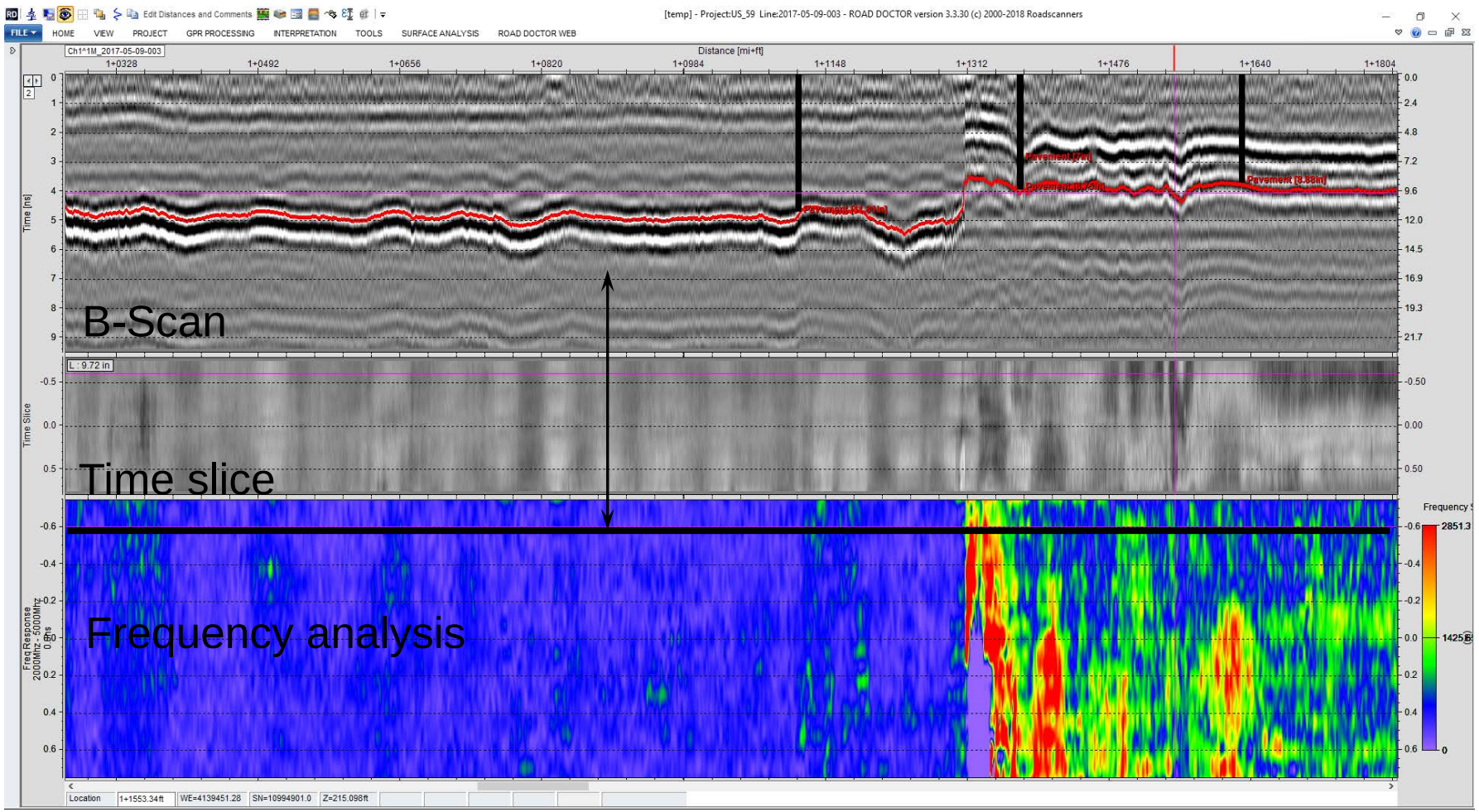




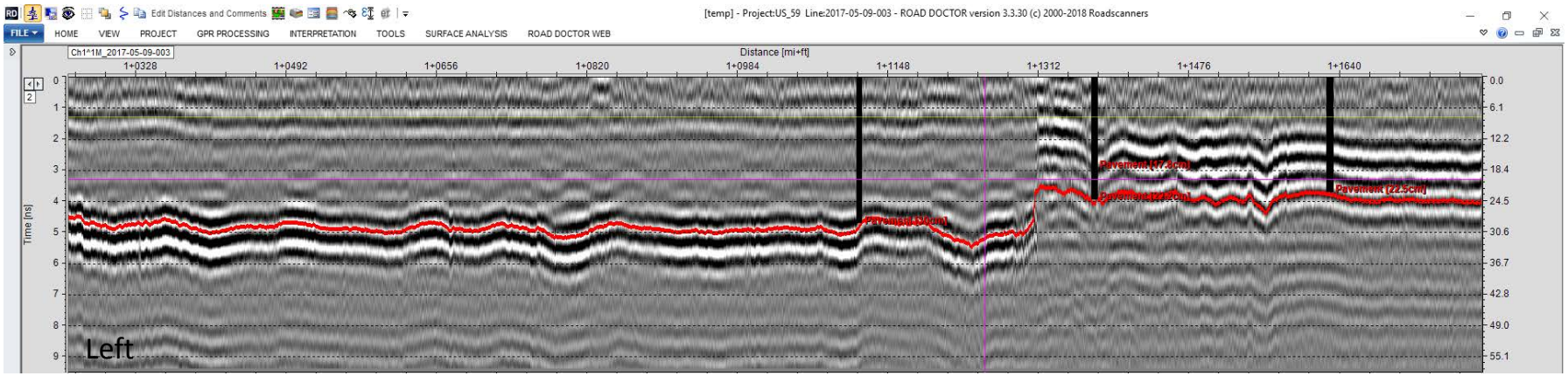
Comparison – US 59 Atlanta District

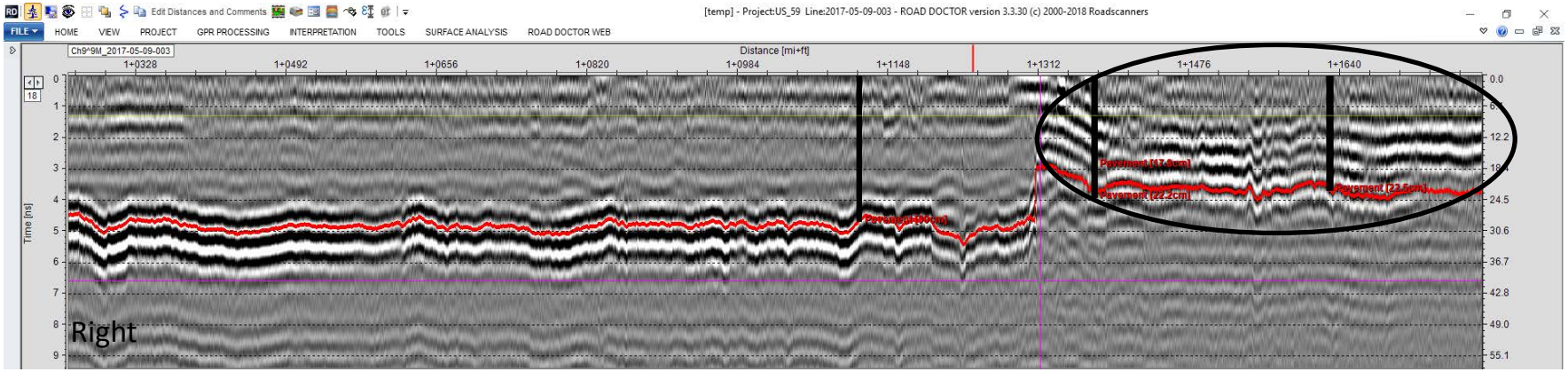


US 59 – Road Doctor
Left side 1mi+255ft to 1mi+ft1795

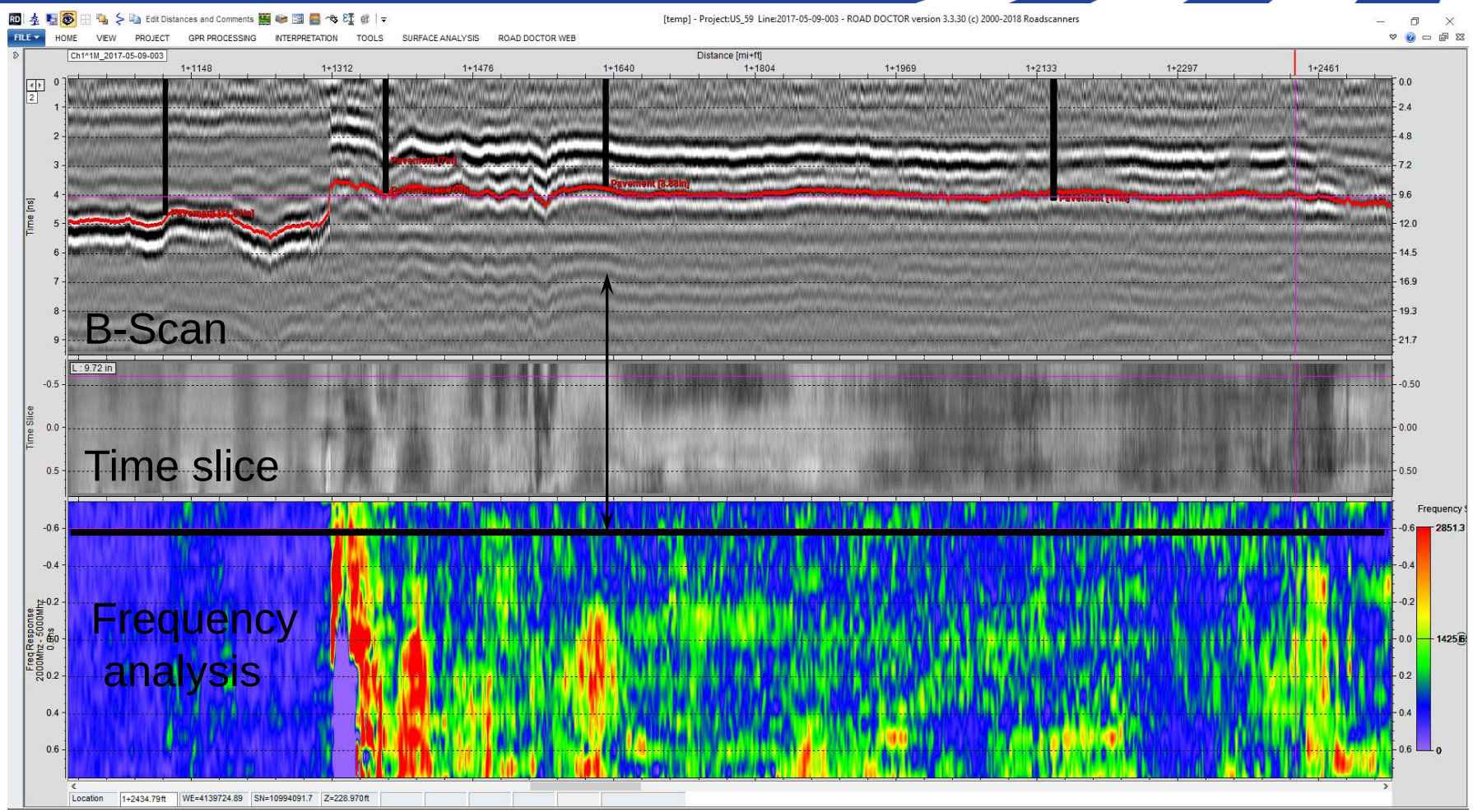


US 59 – Road Doctor
B-Scan 1mi+255ft to 1mi+ft1795

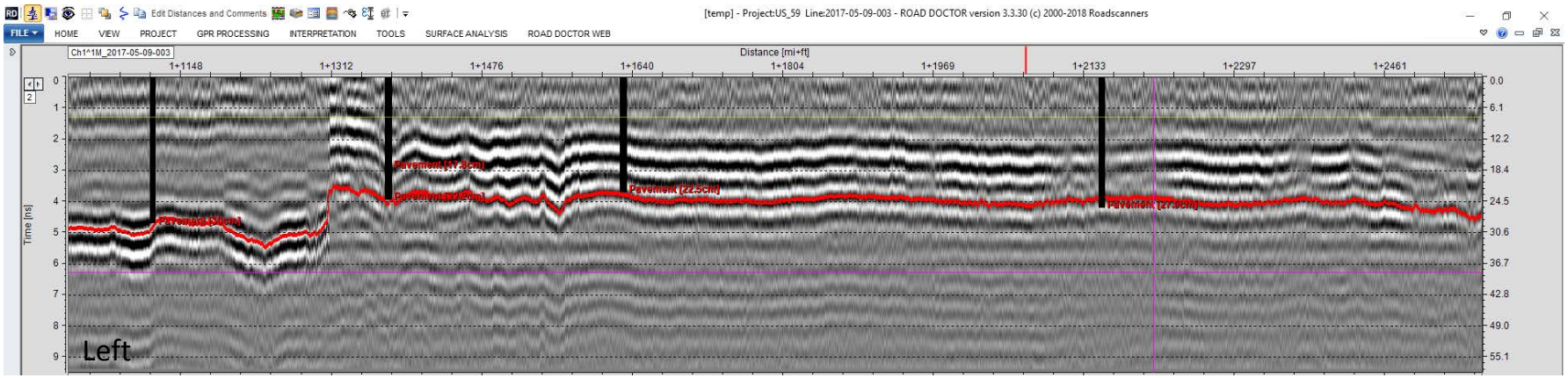


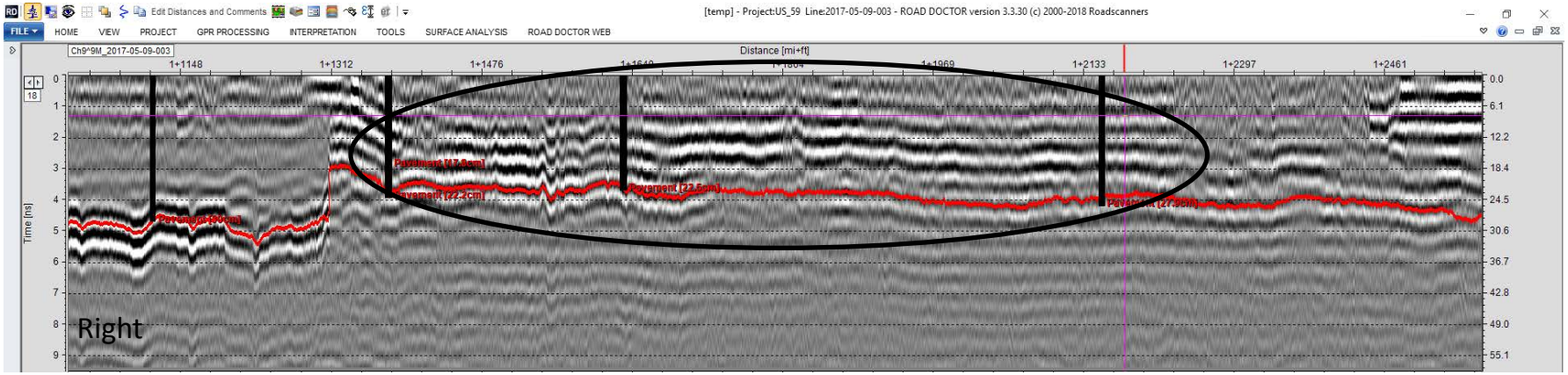


US 59 – Road Doctor
Left side 1mi+1030ft to 1mi+2565ft

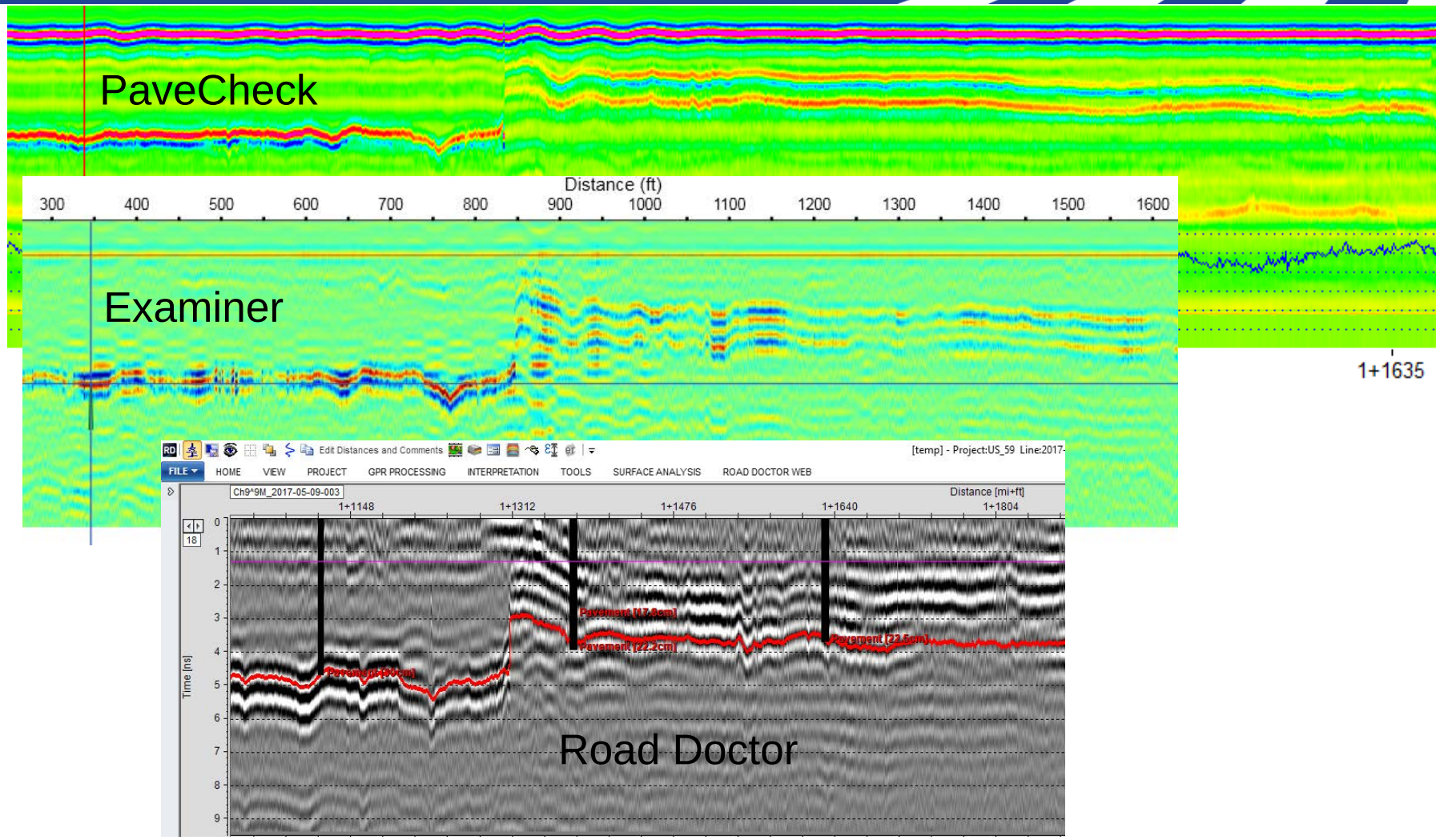


US 59 – Road Doctor
B-Scan 1mi+1030ft to 1mi+2565ft





All Software Elevation Views



US 59 – ROADSCANNERS
Frequency Analysis Map

ROADSCANNERS

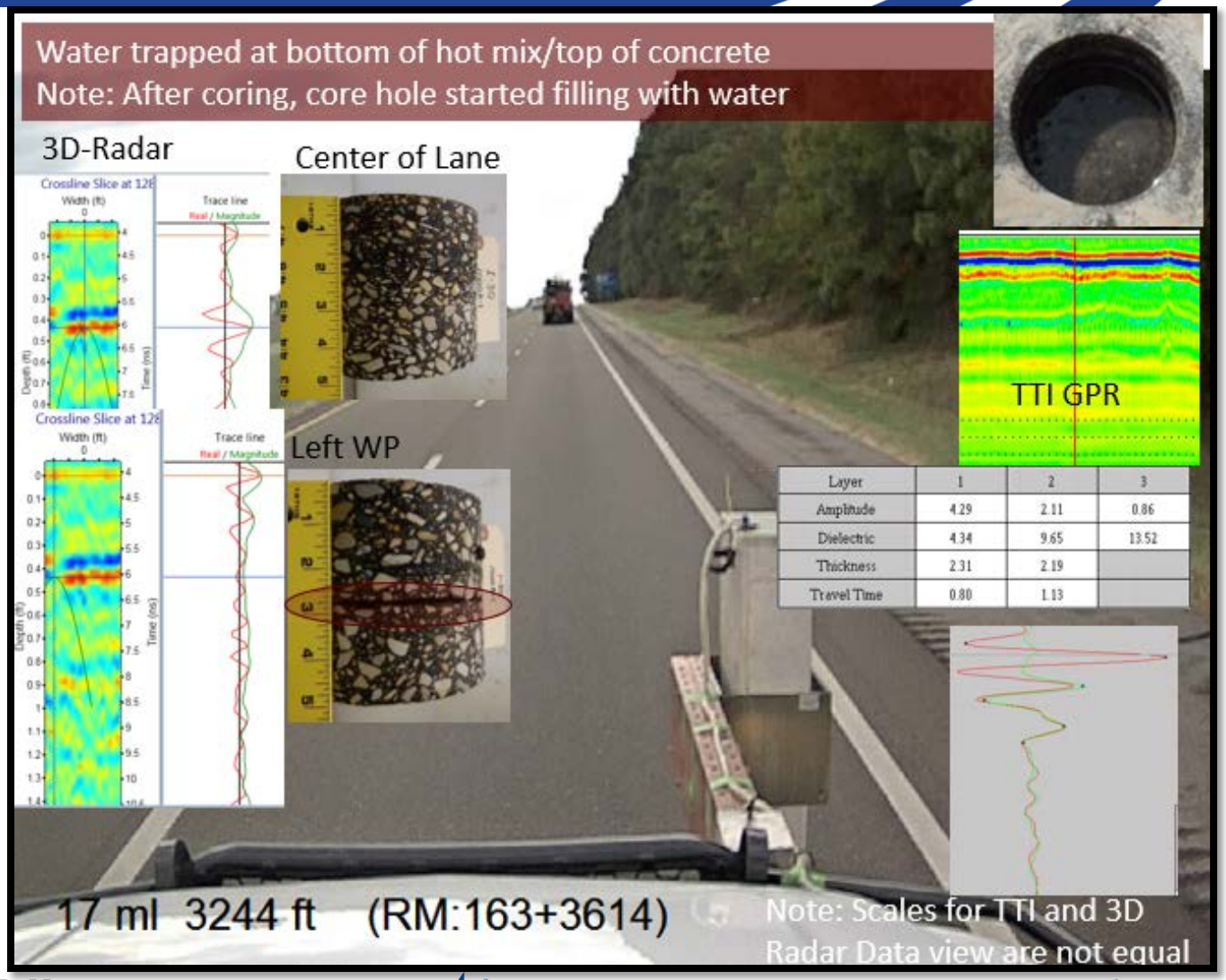
Data Survey Recommendations

- 10 scans/meter for 50 to 80ns range
- Distance between the antenna and the vehicle
- Use markers if possible on core locations
- Take the road marking line as reference and drive parallel to it
- Depending on the width of the lane and the antenna, several parallel measurements can be considered to follow the changes in transverse direction

Data Processing

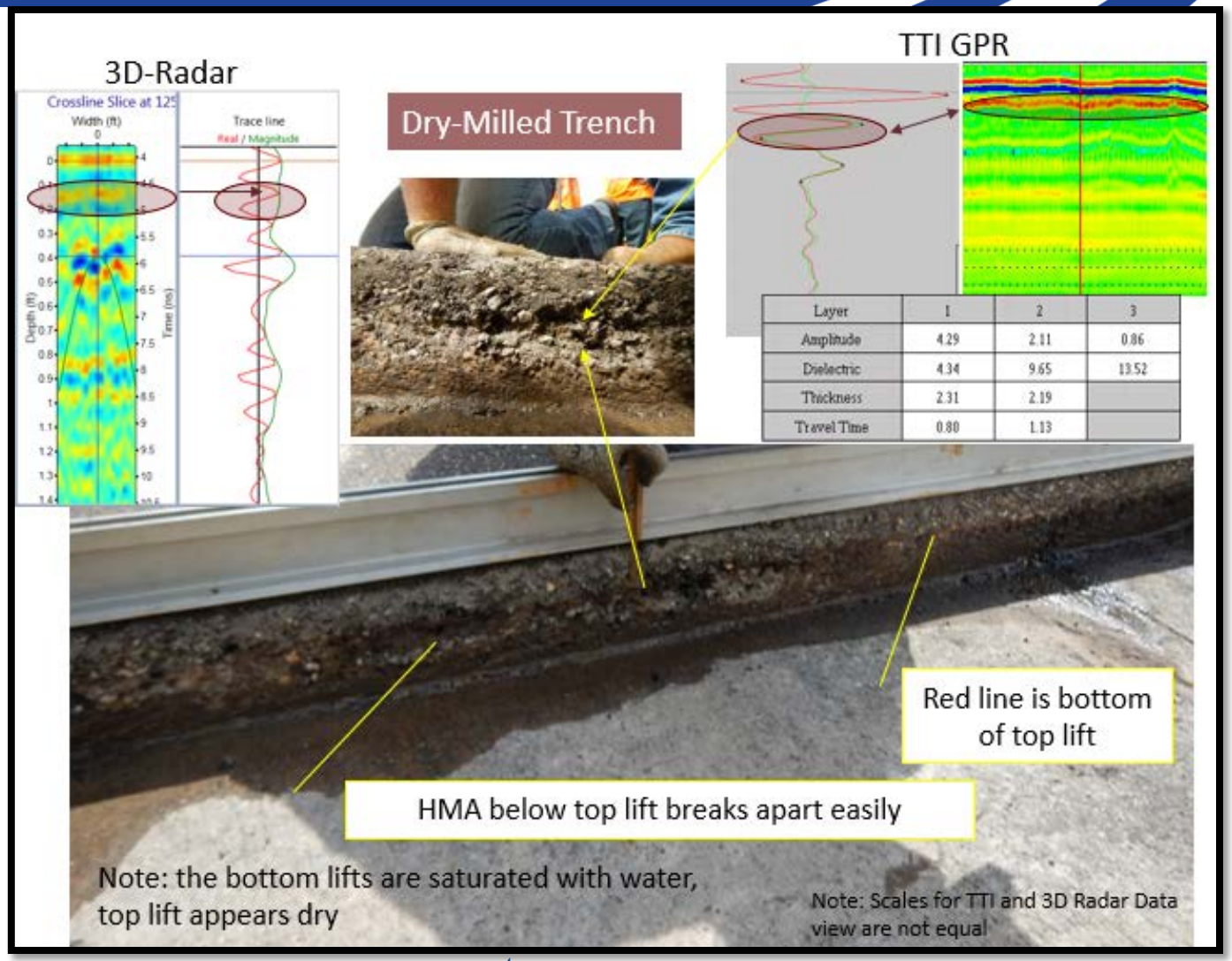
- Kaiser windowing filter
- High pass and low pass filter
- Antenna bouncing removal
- Background removal

Comparison - I30 Atlanta District



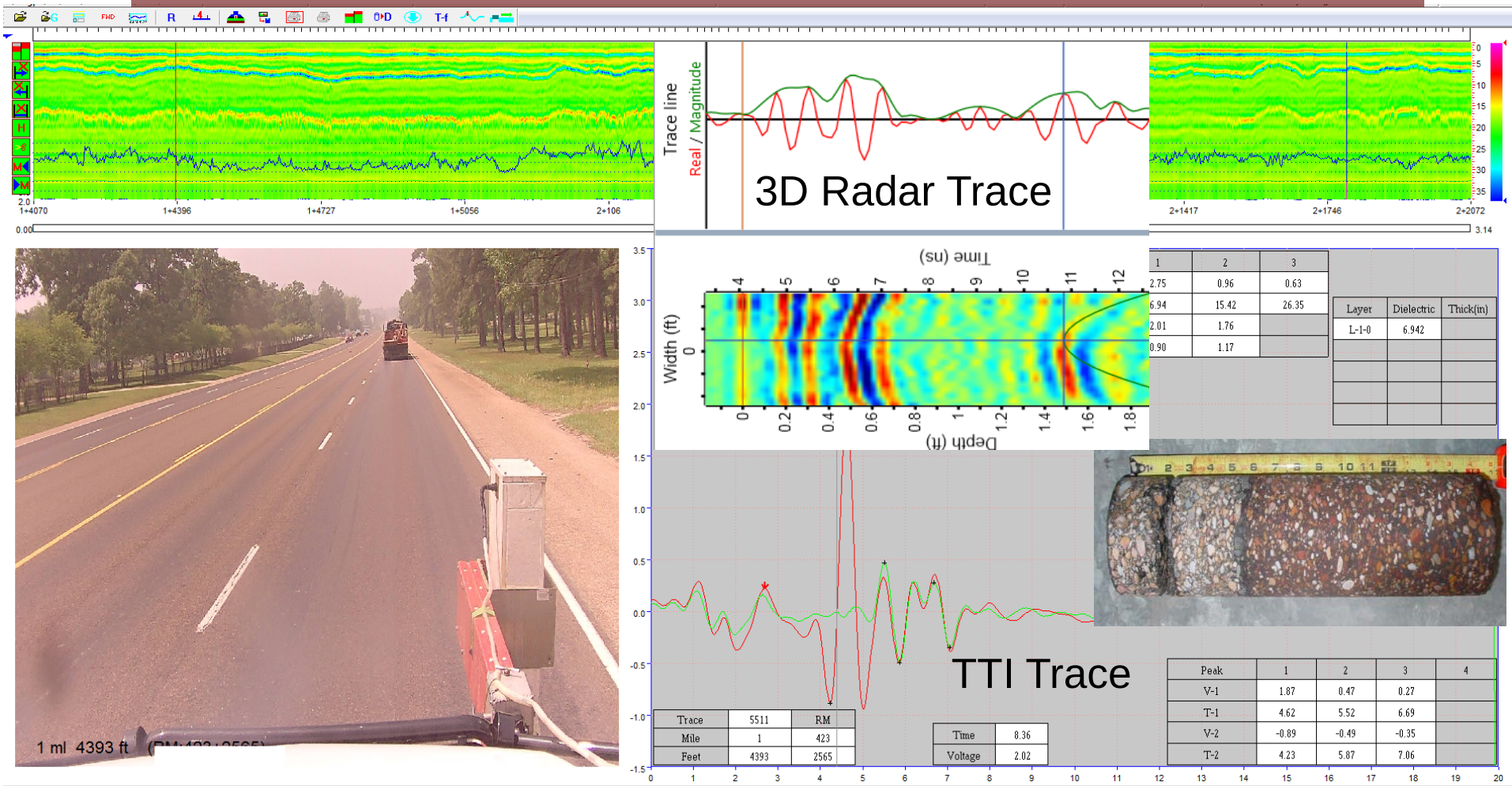
Comparison - I30 Atlanta District

Comparison - I30 Atlanta District

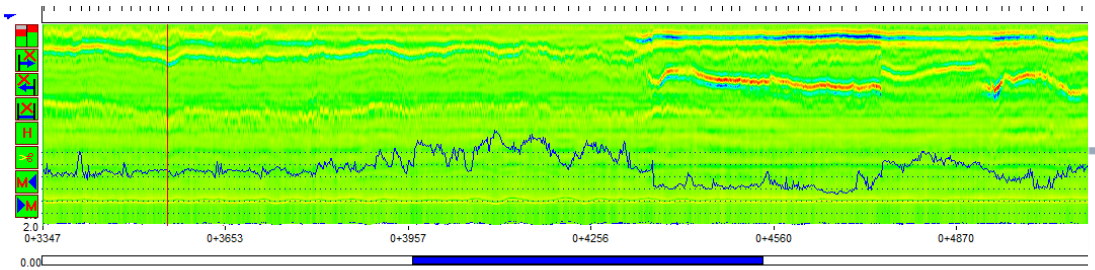


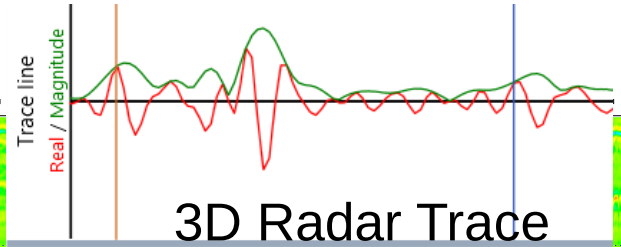
Comparison – US 69 Lufkin District

Note: Light Weight Aggregate causes a pattern similar to stripping.

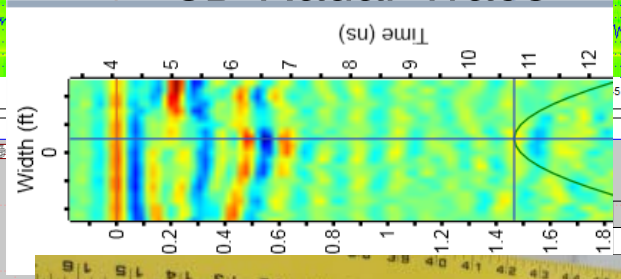


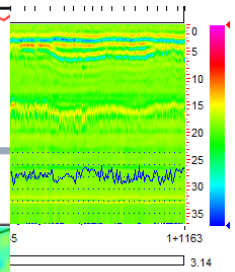
Comparison – US 69 Lufkin District





3D Radar Trace



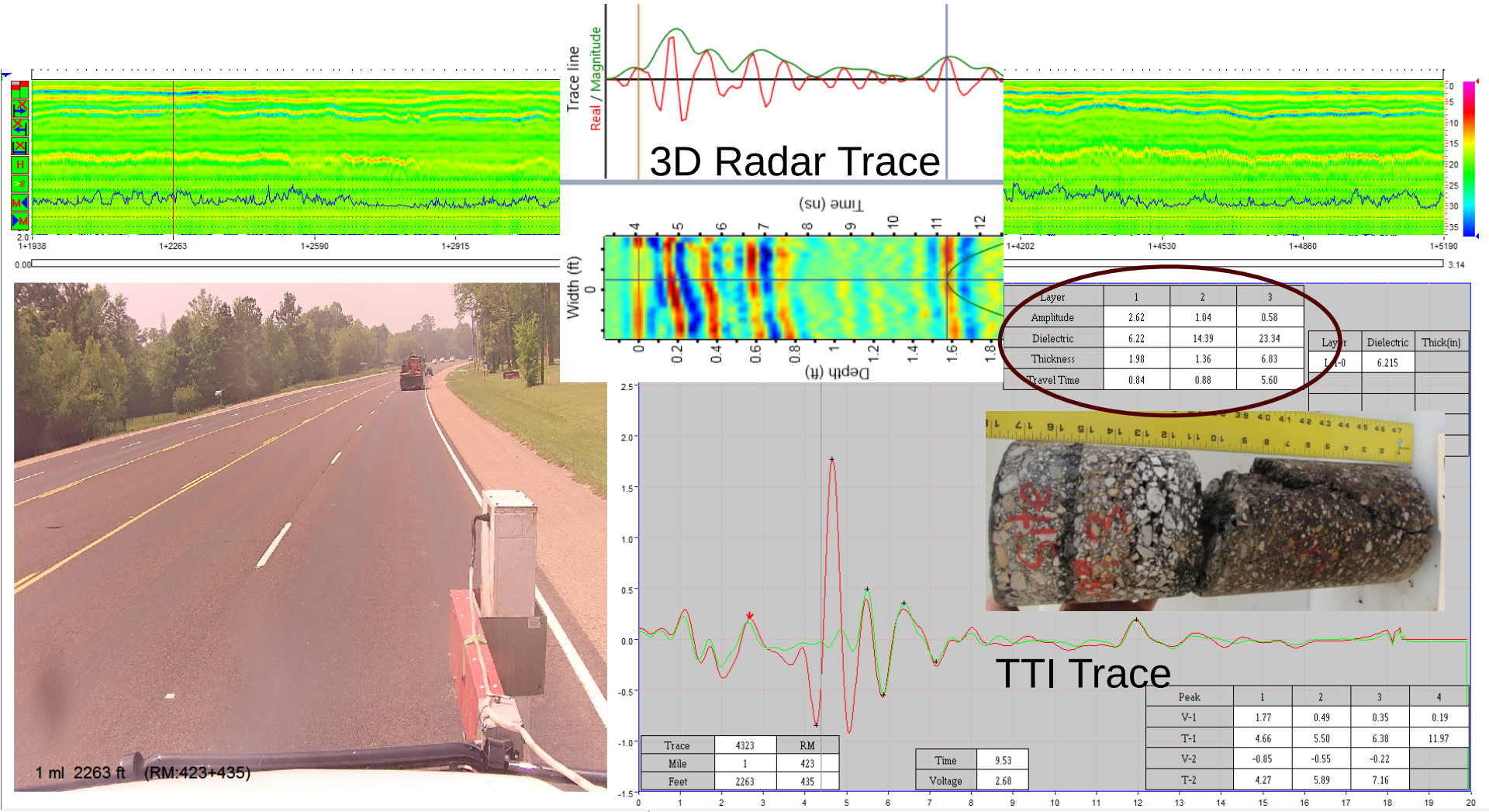


Layer	Dielectric	Thick(in)
L-1-0	6.489	

TTI Trace

Peak	1	2	3	4
V-1	1.80	0.13	0.31	
T-1	4.58	6.03	7.25	
V-2	-0.87	-0.28	-0.29	
T-2	4.19	6.40	7.62	

Comparison – US 69 Lufkin District



Layer	1	2	3
Amplitude	2.62	1.04	0.58
Dielectric	6.22	14.39	23.34
Thickness	1.98	1.36	6.83
Travel Time	0.84	0.88	5.60

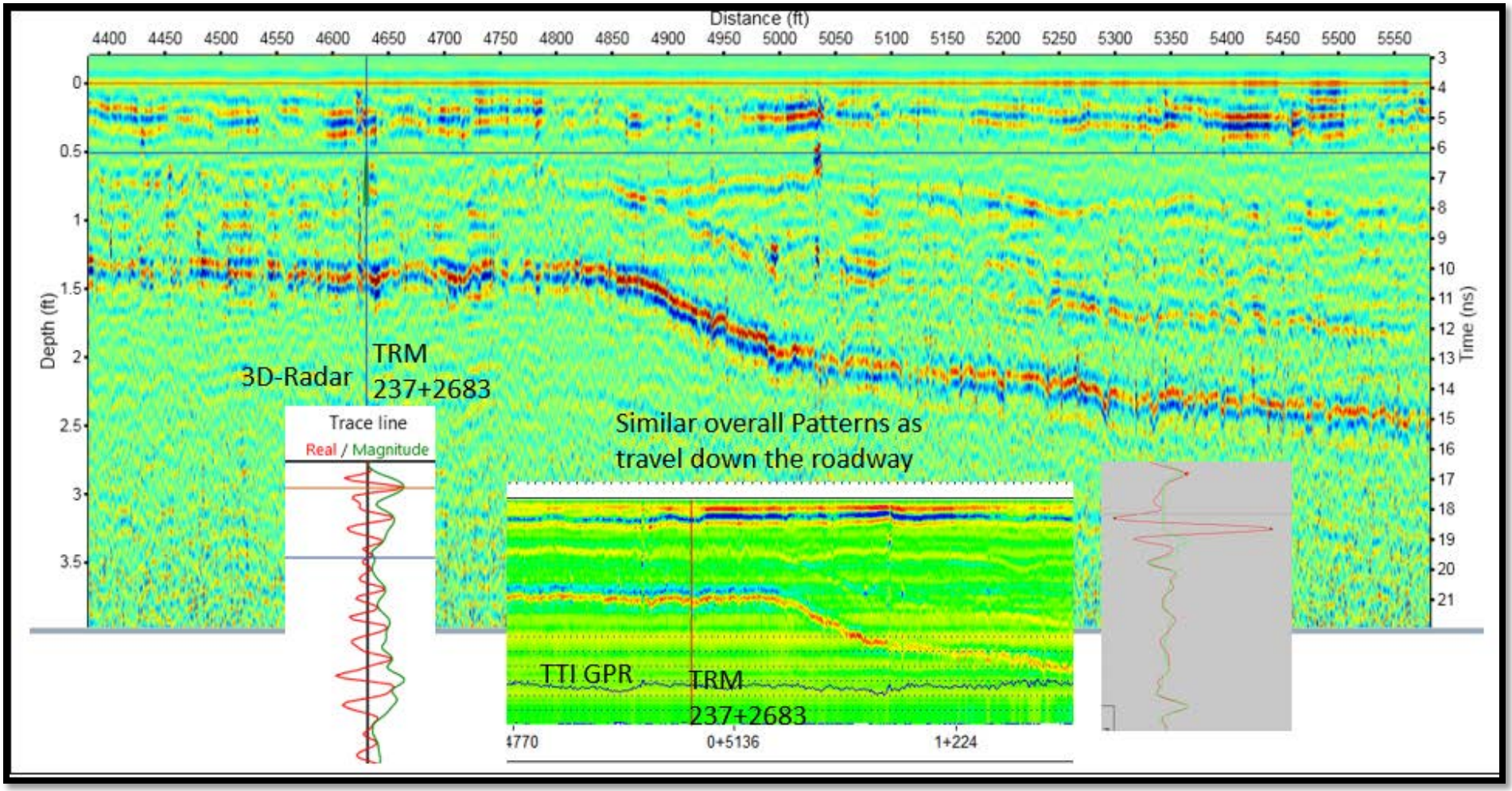
Layer	Dielectric	Thick(in)
1	6.215	

Trace	4323	RM
Mile	1	423
Feet	2263	435

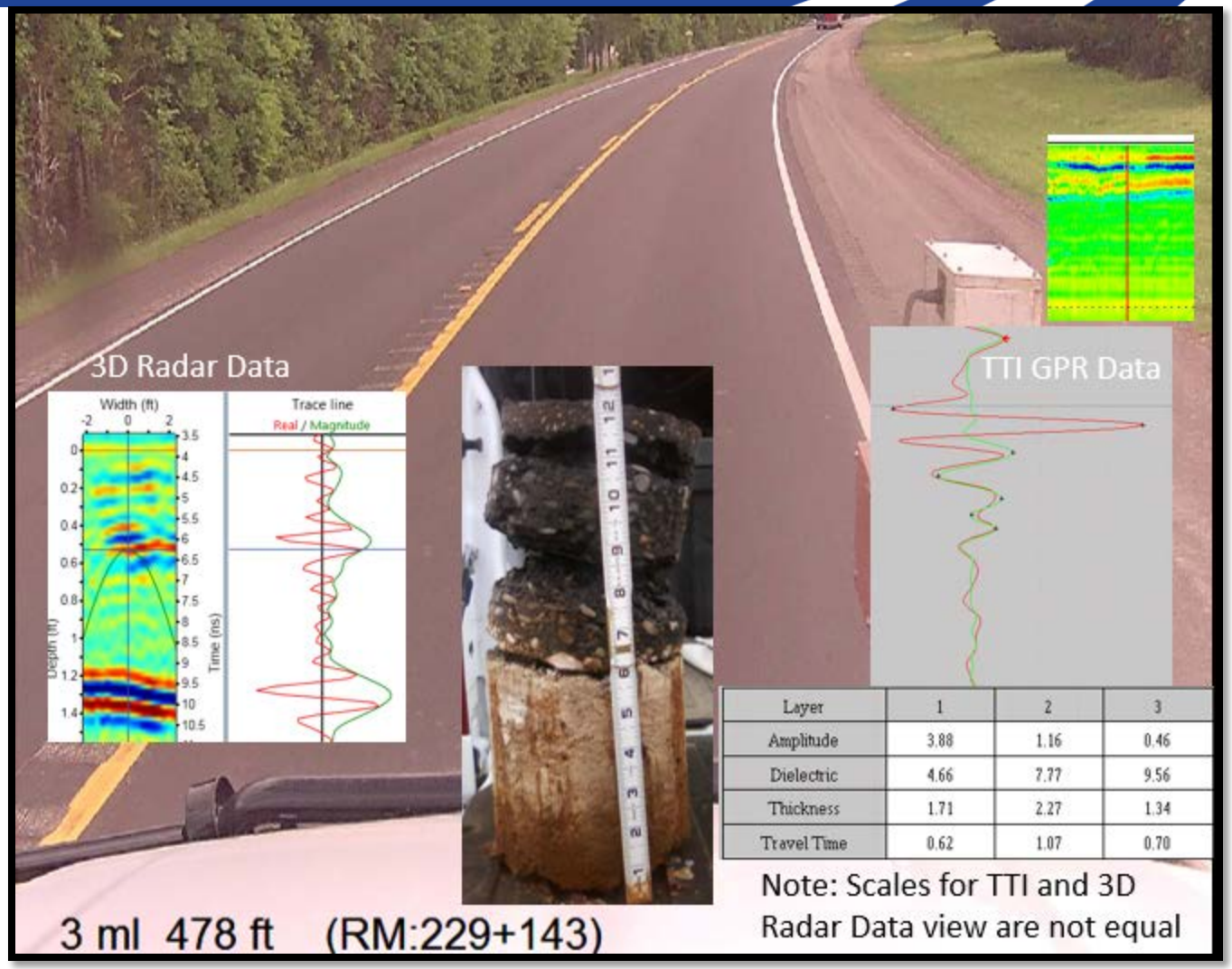
Time	9.53
Voltage	2.68

Peak	1	2	3	4
V-1	1.77	0.49	0.35	0.19
T-1	4.66	5.50	6.38	11.97
V-2	-0.85	-0.55	-0.22	
T-2	4.27	5.89	7.16	

Comparison – SH 19 Paris District

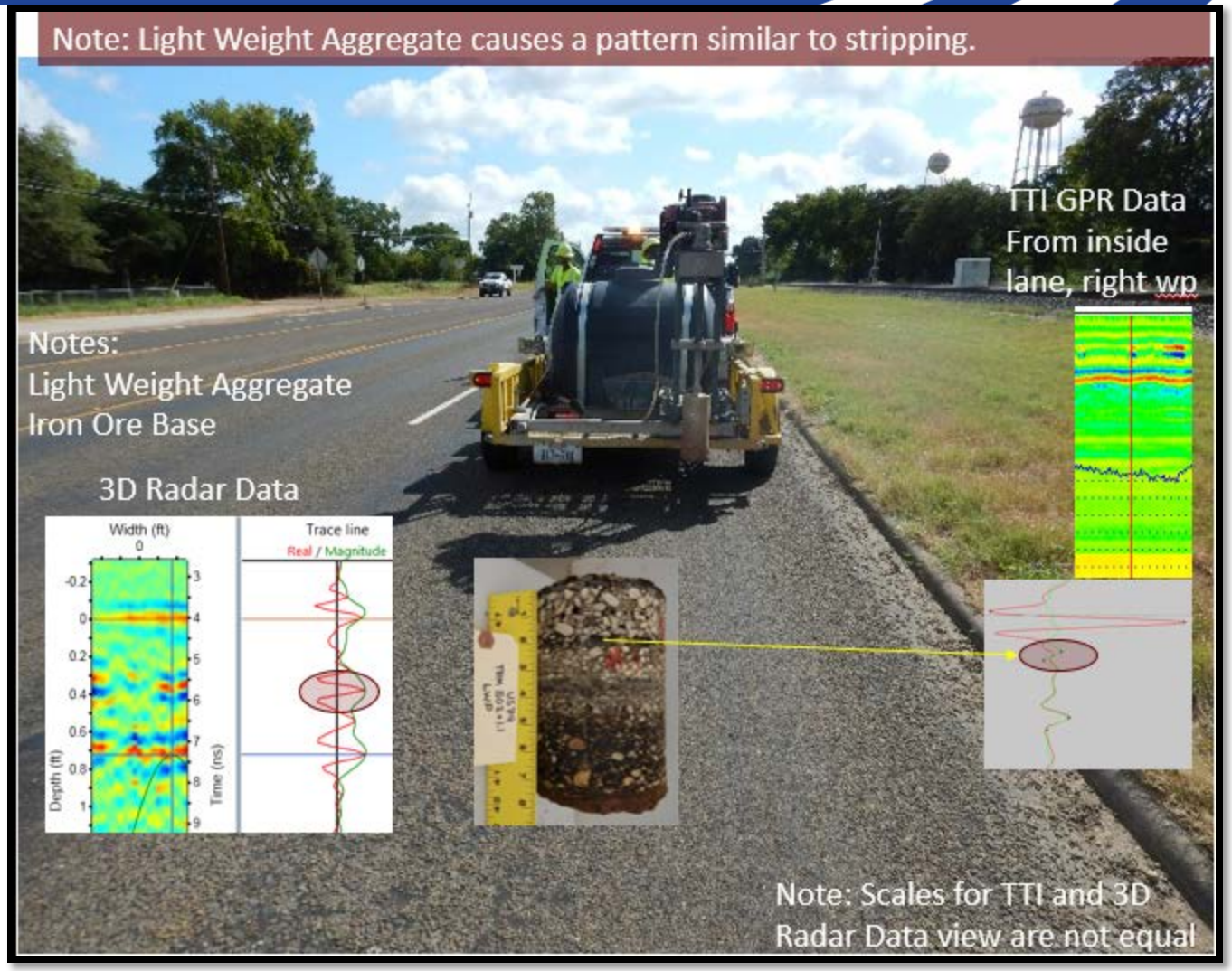


Comparison – SH 19 Paris District

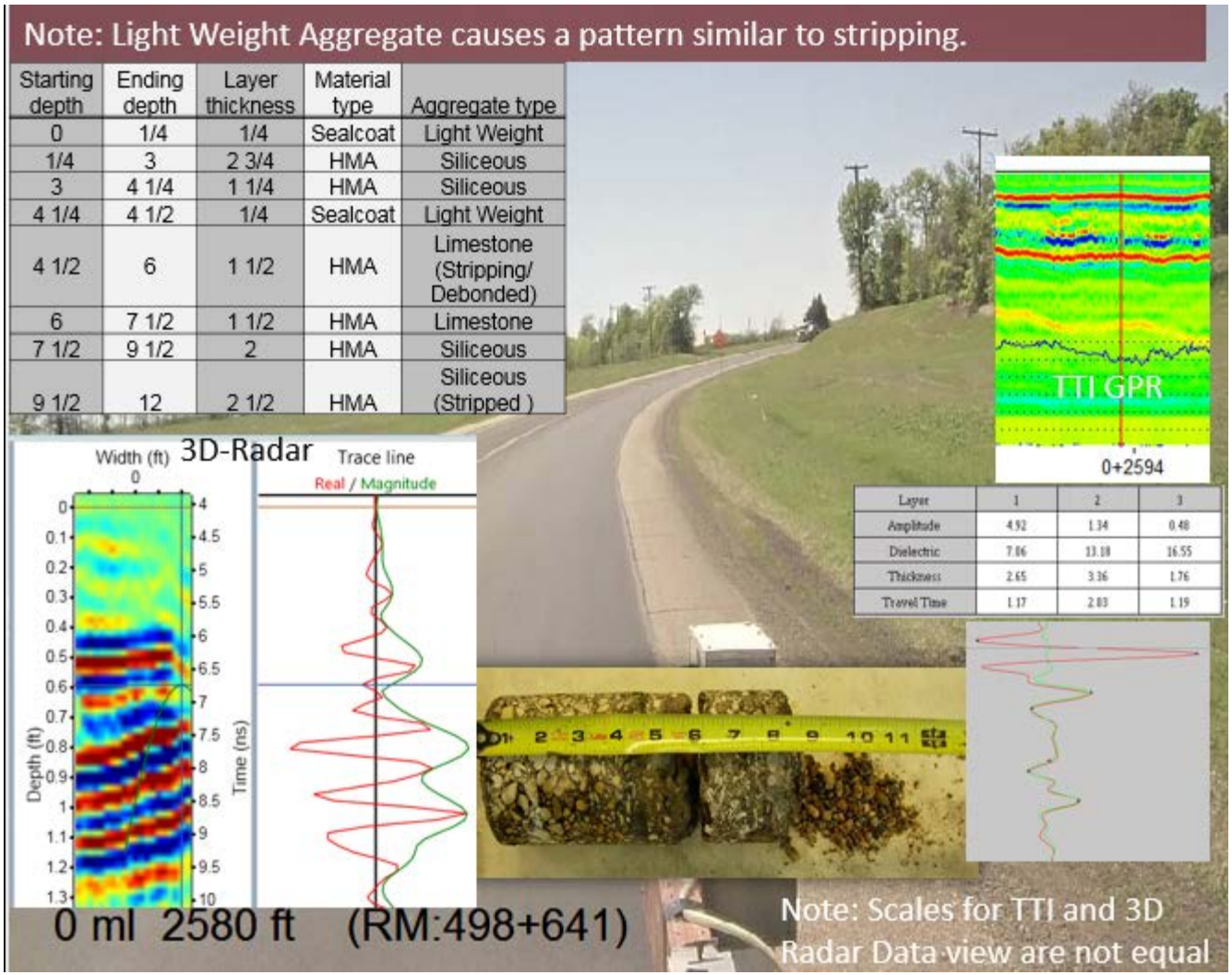


Layer	1	2	3
Amplitude	3.88	1.16	0.46
Dielectric	4.66	7.77	9.56
Thickness	1.71	2.27	1.34
Travel Time	0.62	1.07	0.70

Comparison – US 79 Bryan District

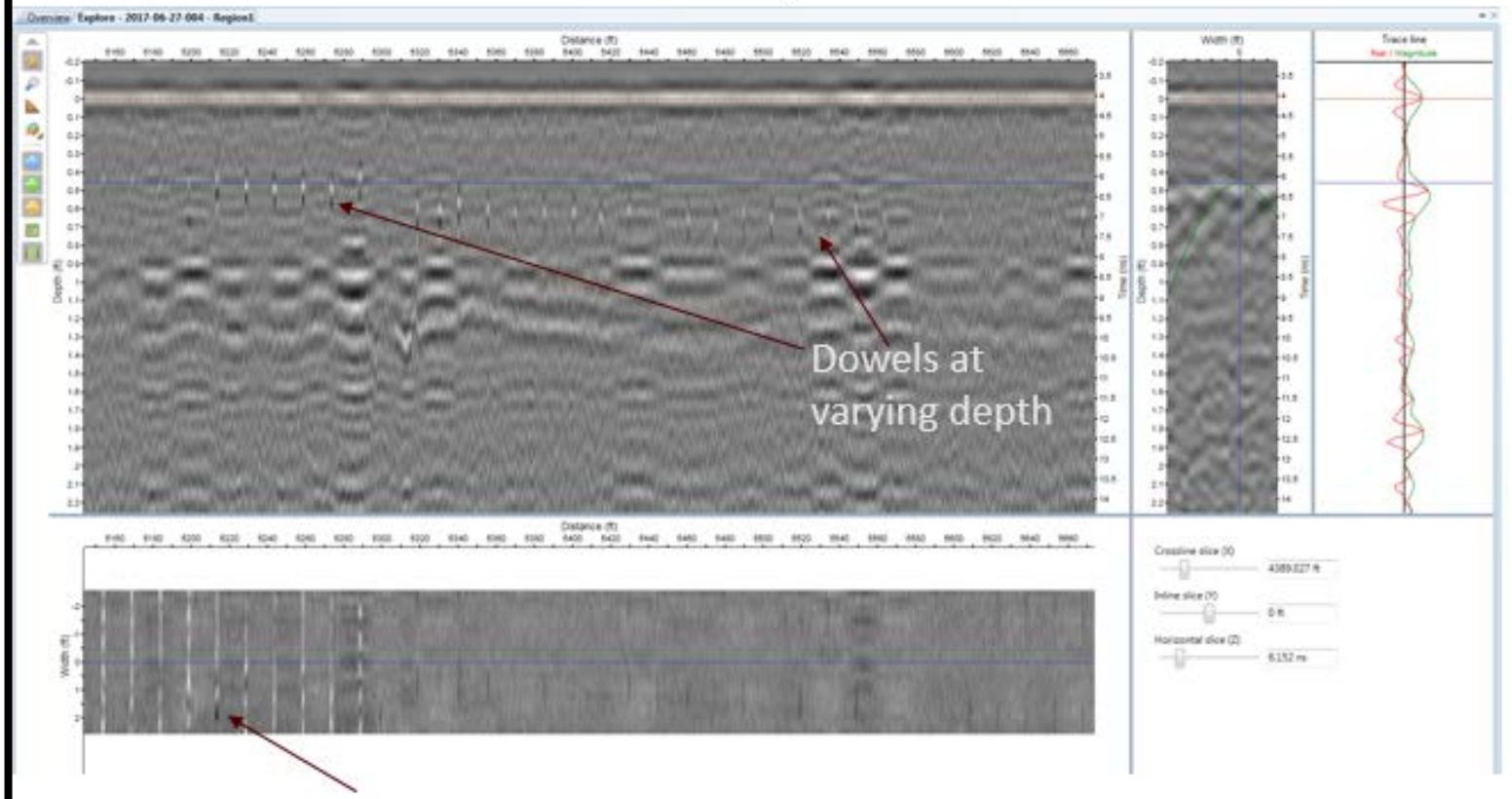


Comparison – US 79 Bryan District



Concrete Pavement
US 59 Atlanta District

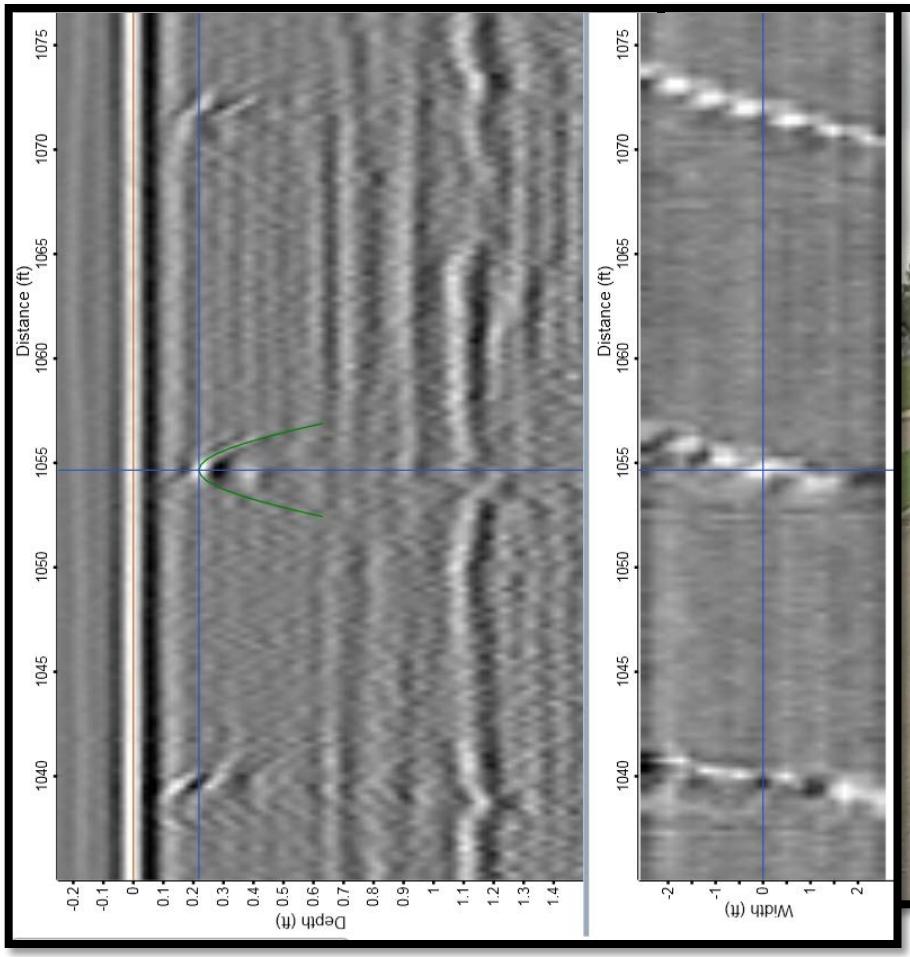
Dowels appear to be straight, transversely, however depth within pavement vary both transverse and as travel down roadway.



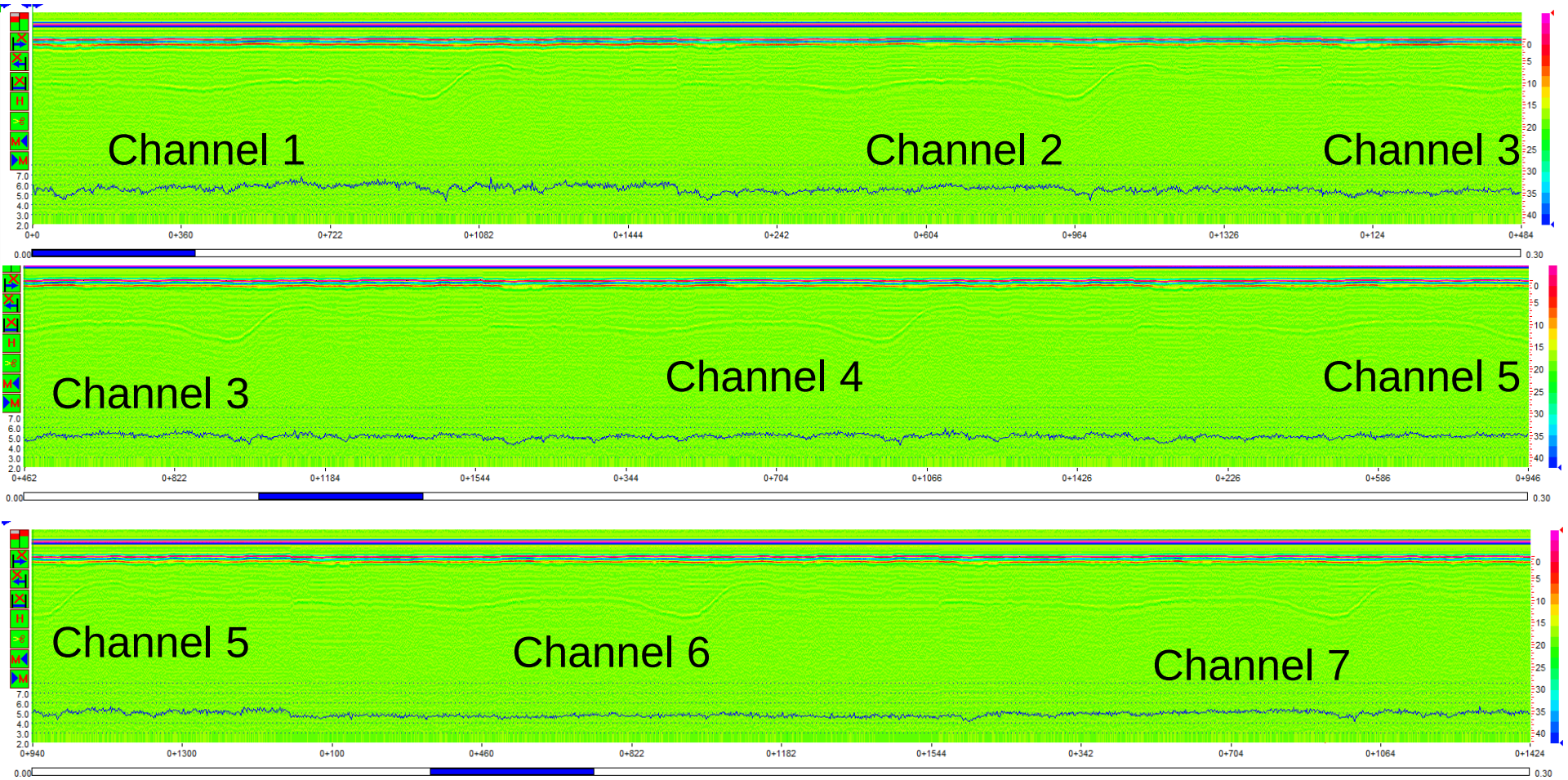
Note: as dowel pattern disappears, this indicates varying depth transversely. Also, pattern disappears as travel down roadway due to depth change.

Concrete Pavement
FM 2347 Bryan District

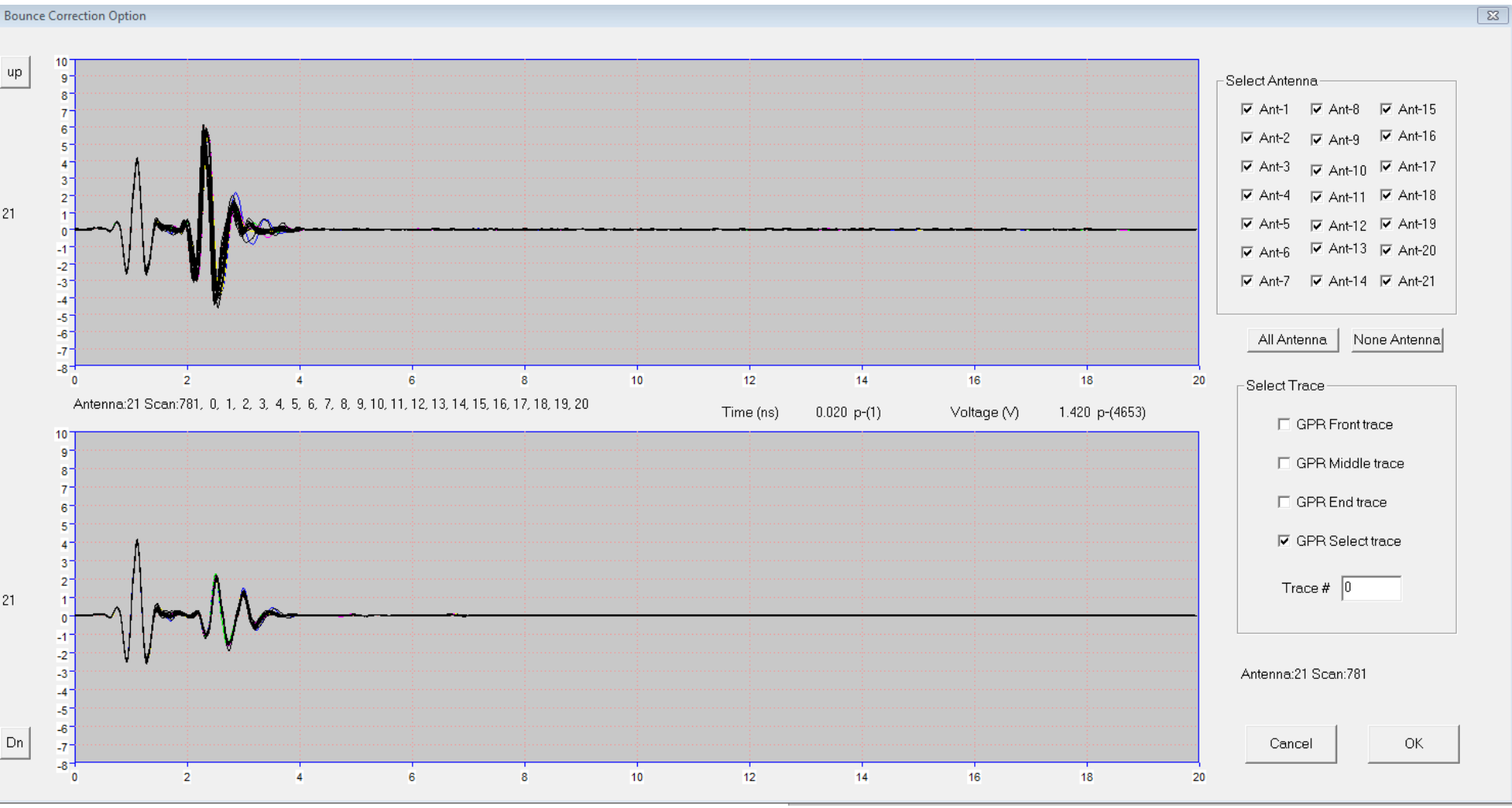
3D Radar indicates skewed dowel baskets, sawed joints are not skewed.



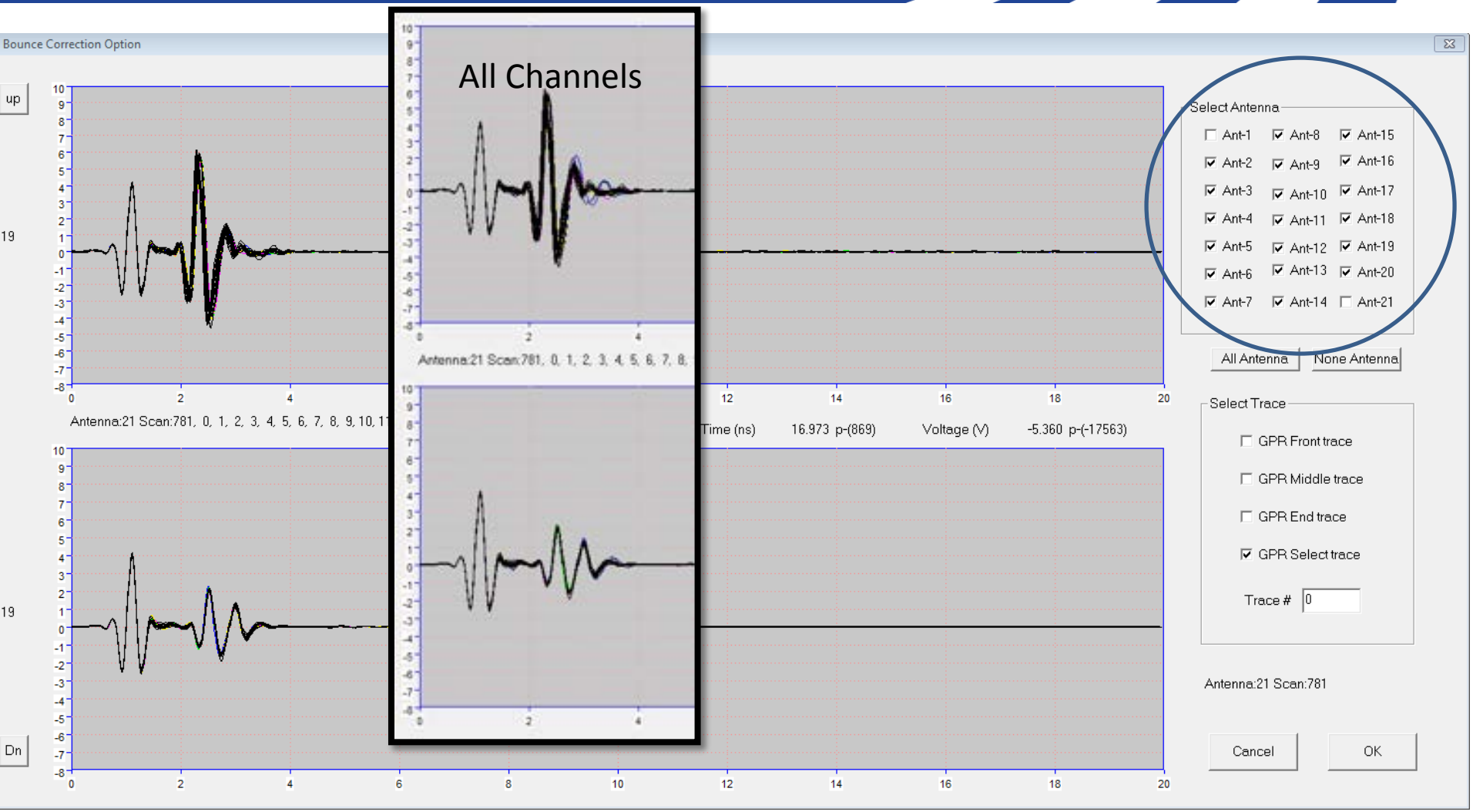
Antenna – Modified PaveView Software



Antenna

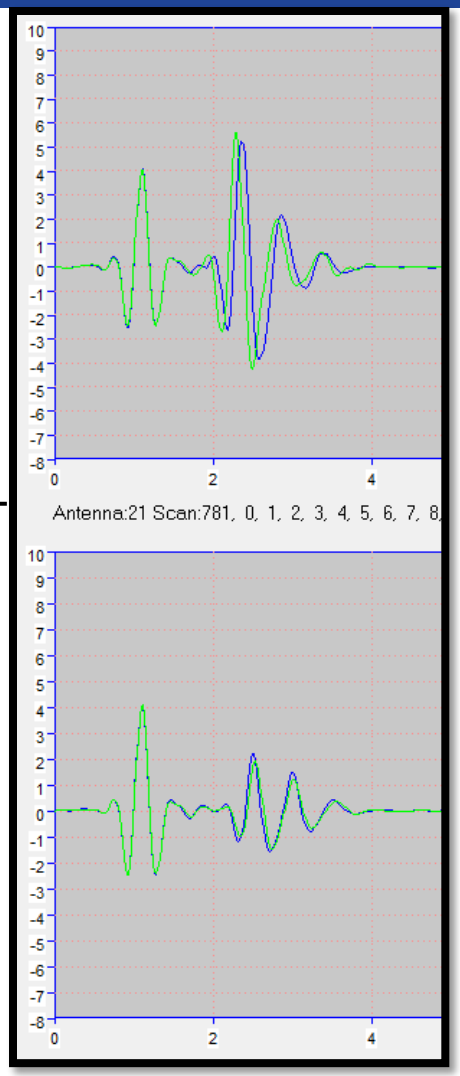

Bounce Correction Option
up
21
21
Dn
Antenna:21 Scan:781, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20
Time (ns) 0.020 p-(1)
Voltage (V) 1.420 p-(4653)
Select Antenna
Ant-1 Ant-8 Ant-15
Ant-2 Ant-9 Ant-16
Ant-3 Ant-10 Ant-17
Ant-4 Ant-11 Ant-18
Ant-5 Ant-12 Ant-19
Ant-6 Ant-13 Ant-20
Ant-7 Ant-14 Ant-21
All Antenna
None Antenna
Select Trace
GPR Front trace
GPR Middle trace
GPR End trace
GPR Select trace
Trace # 0
Antenna:21 Scan:781
Cancel
OK

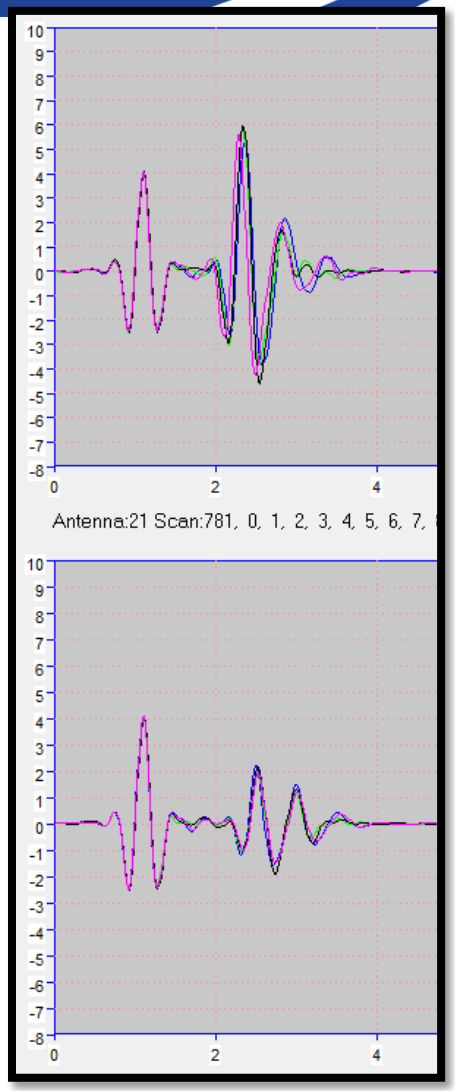
Antenna


Bounce Correction Option
All Channels
Antenna:21 Scan:781, 0, 1, 2, 3, 4, 5, 6, 7, 8,
Antenna:21 Scan:781, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Time (ns)
16.973 p-(869)
Voltage (V)
-5.360 p-(-17563)
Select Antenna
Ant-1 Ant-8 Ant-15
Ant-2 Ant-9 Ant-16
Ant-3 Ant-10 Ant-17
Ant-4 Ant-11 Ant-18
Ant-5 Ant-12 Ant-19
Ant-6 Ant-13 Ant-20
Ant-7 Ant-14 Ant-21
All Antenna
None Antenna
Select Trace
GPR Front trace
GPR Middle trace
GPR End trace
GPR Select trace
Trace #
0
Antenna:21 Scan:781
Cancel
OK
up
Dn

Antenna

Channels 1 & 21



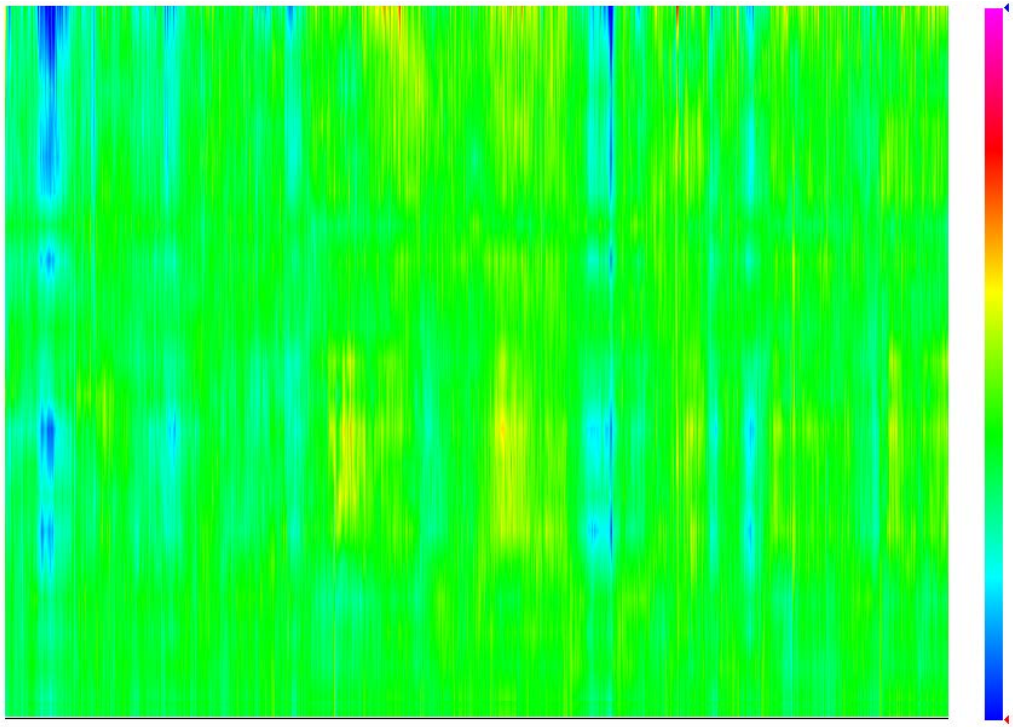


Channels
1, 10, 11 & 21

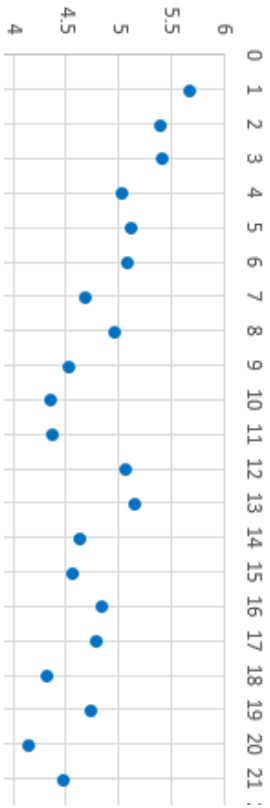
Dielectric Plot

Channel 1 at Top

Channel 21 at Bottom



Graph of Average Dielectric per channel



Conclusions: Concrete Pavement

Some potential uses to help with the forensic evaluation of concrete pavement are:

Analyze orientation of Dowel Baskets

- Skewed
- Level
- Depth

Conclusions - Flexible Pavement

- In general the patterns follow the patterns we expect based on past experience.
  - The false patterns encountered, help justify the need to take verification cores.
- It is very difficult to distinguish between severity of deterioration/delamination.
  - While the patterns are similar, severe stripping tends to have much larger amplitude.

Recommendations

- Data collection
  - Improve data storage efficiency during collection
  - Increase data points per trace
- Examiner Software
  - Integrate video/images
  - Calculate dielectric
  - Calculate layer thickness based on calculated dielectrics
  - Use peak to fix elevation for surface instead of time
- Continue to evaluate the 3D Radar System