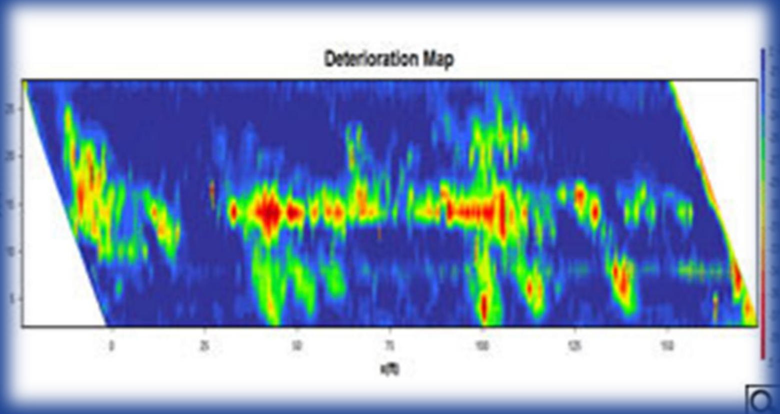
Nondestructive Testing
for
Concrete Bridge Decks (RO6A)

KENTUCKY



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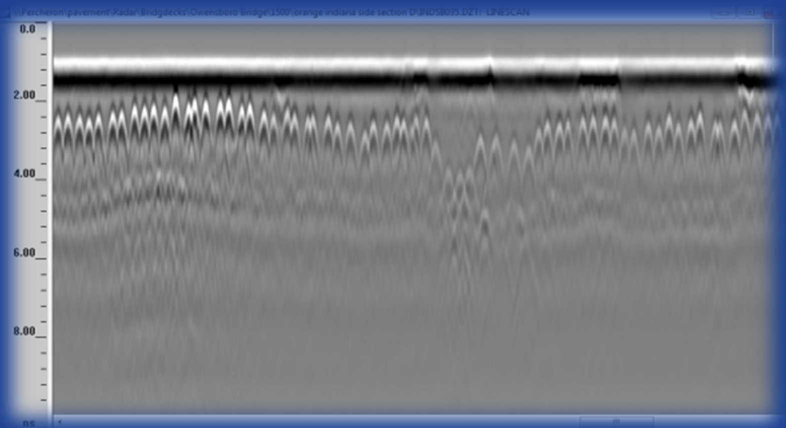


AASHTO

University of Kentucky

KENTUCKY TRANSPORTATION CABINET

SHRP2 SOLUTIONS

TOOLS FOR THE ROAD AHEAD

Outline

- Project Scope
- Discussion of Technology
  - What is Ground Penetrating Radar
    - Understanding the equipment
  - Bridge deck deterioration case studies
    - Glover Cary
    - 12th. Street Bridge
    - I-64 Bridge
- Infrared
  - Deployment
  - Typical uses
  - Challenges
- Impact Echo (awaiting field demonstration)

Scope

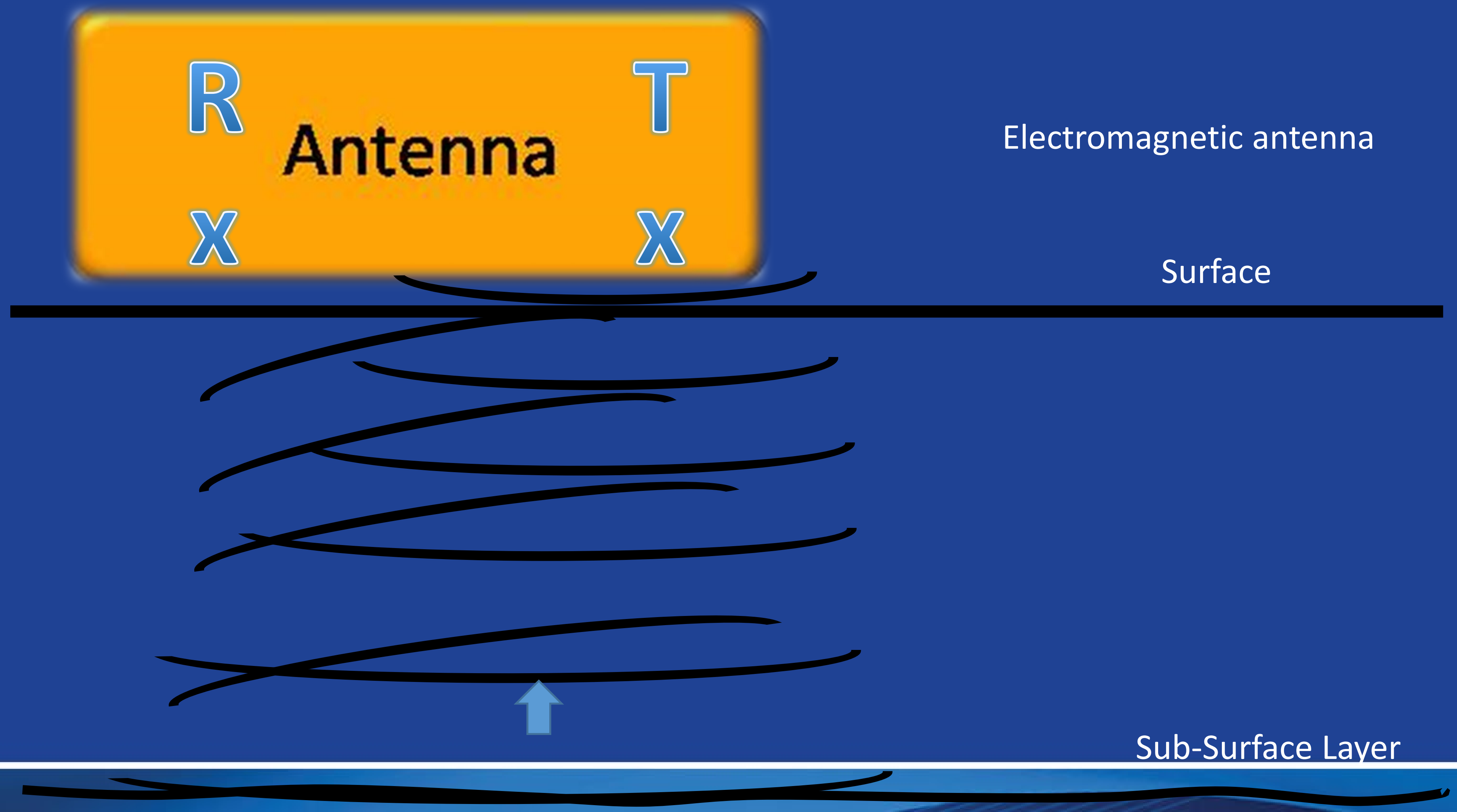
- This project will investigate the use of GPR, Infrared, and Impact Echo to determine concrete bridge deck deterioration.

Objective

- The objective will be to evaluate if one or more of these technologies can be more accurate, more thorough, more cost efficient, and safer than the current standard of practice of either chain dragging and/or visual assessment to determine concrete bridge deck deterioration

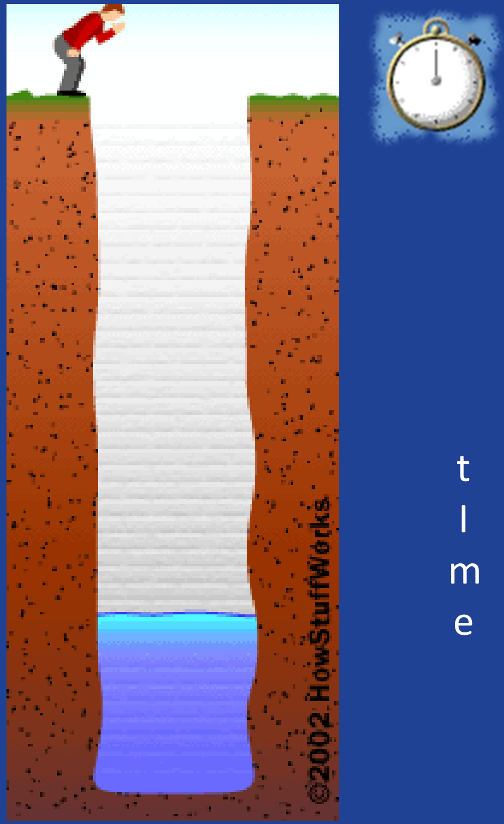
What is Ground Penetrating Radar

How GPR Works



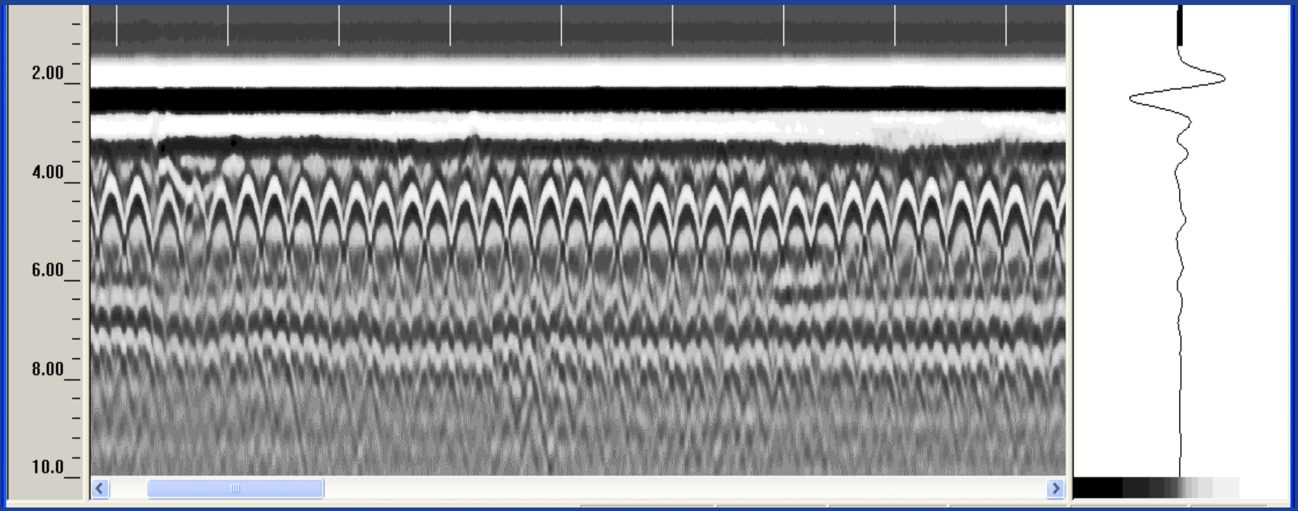
How does GPR work?

We record the two way travel time and the amplitude of the reflection

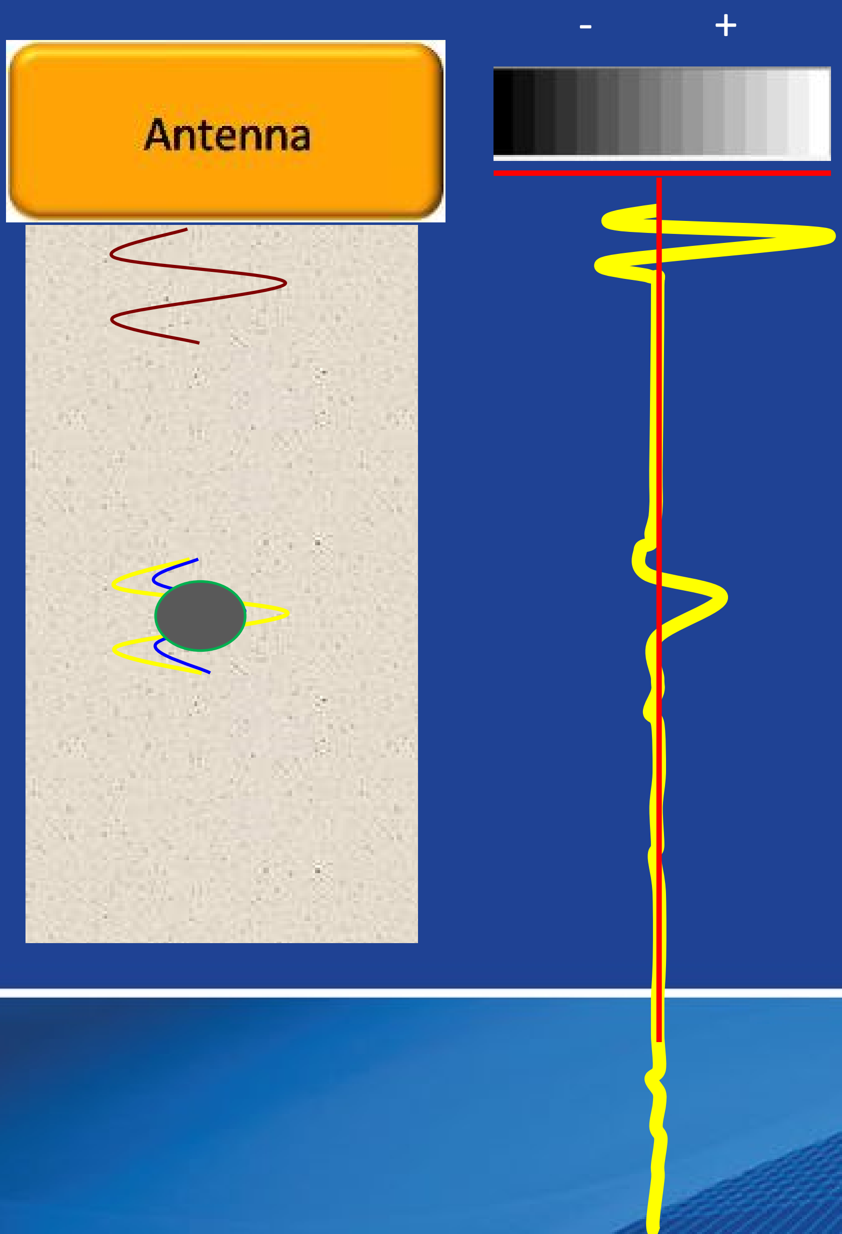


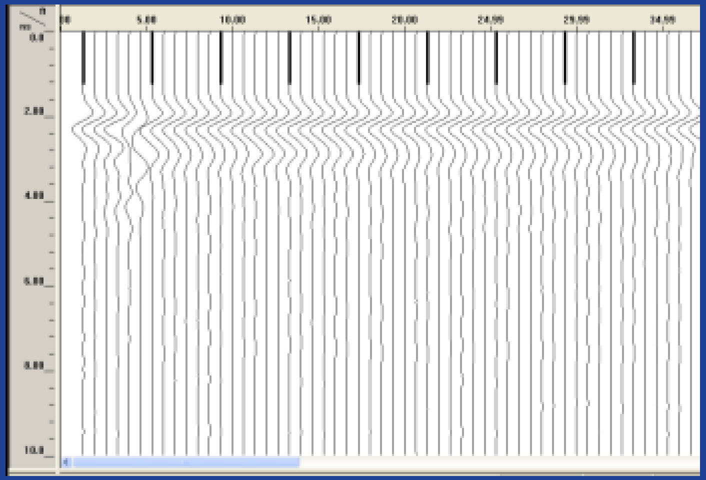
distance

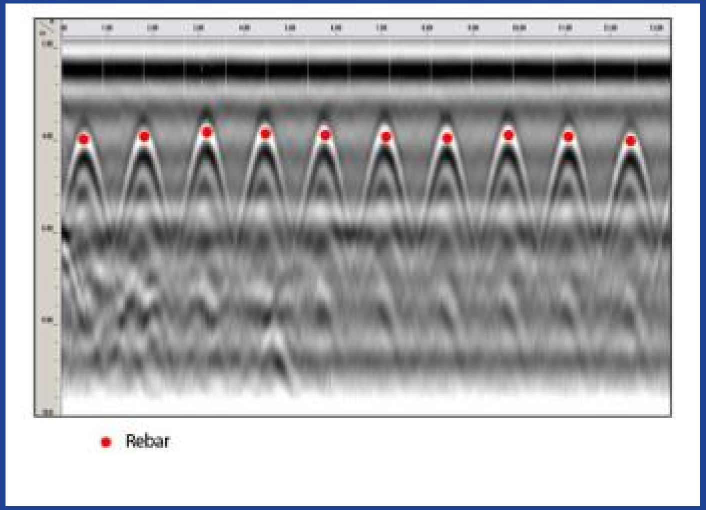
t
I
m
e



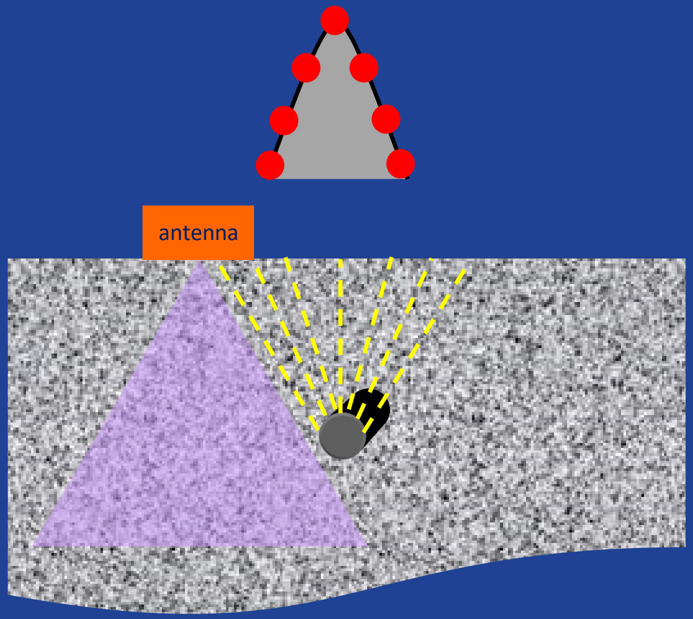
Producing multiple scans to image reinforcement







The Hyperbola shape

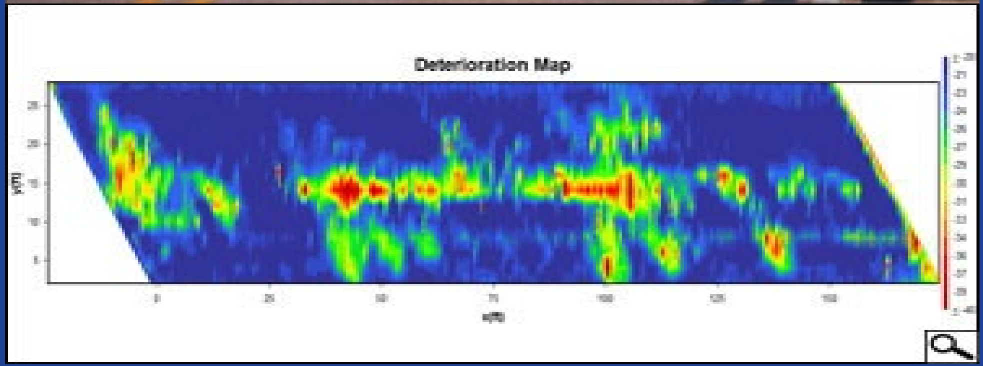


The increasing then decreasing two way travel time of the reflections from the object produces the hyperbola shape

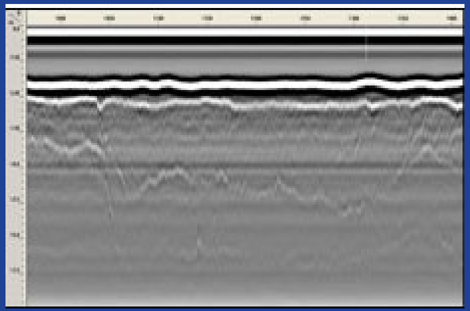
Bridge deck deterioration: The Process

Chain Dragging—Visual Survey

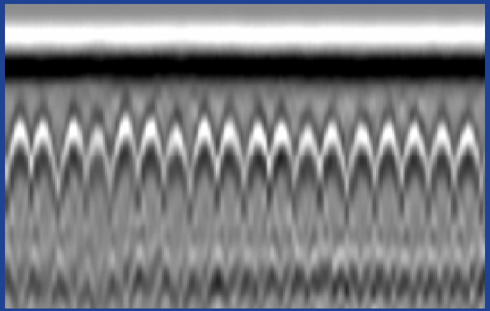
Ground Penetrating Radar



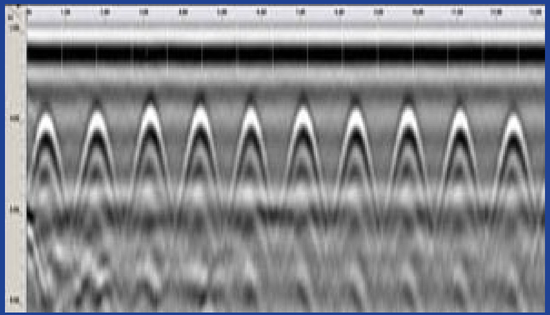
First: How to collect the data (things we tried, things we learned)



40 m.p.h. 1 scan per 3 ft.
No traffic control
Accuracy +/- 10 %



10 m.p.h. 10 scan per 1 ft.
Moving traffic control
Accuracy +/- 7.5%



4 m.p.h. 24 scan per 1 ft.
Lane closure
Accuracy +/- 5%

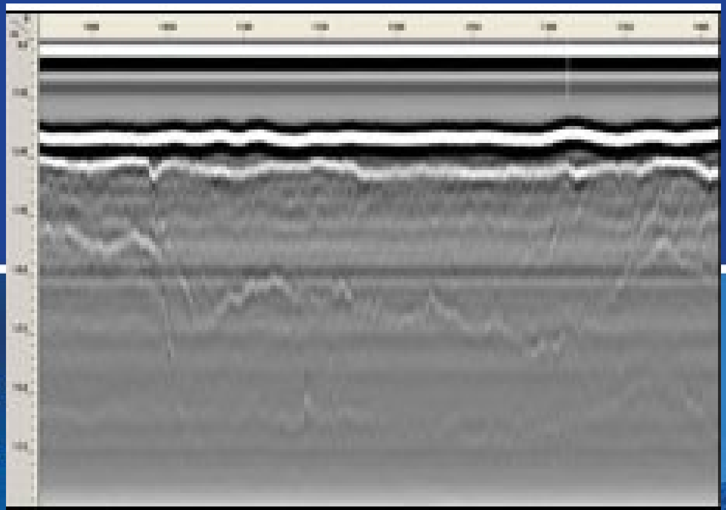
Problems encountered with interference for air-launched

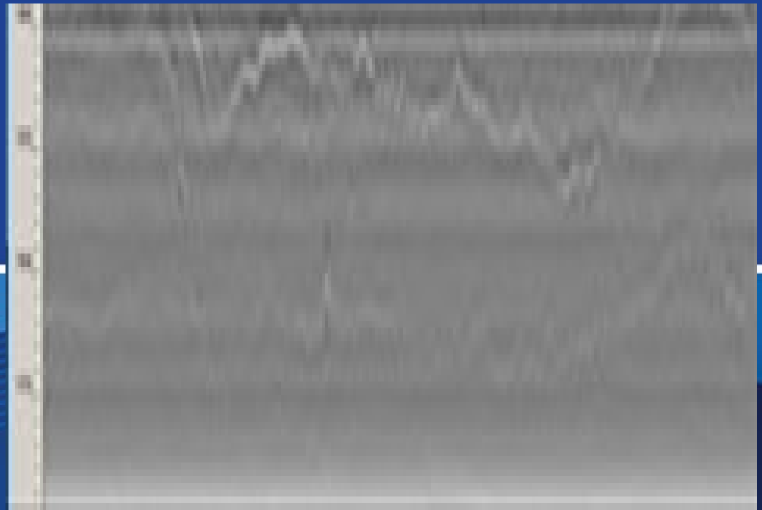
GPR transmits and receives in a specific frequency range.

Culprits (or sources of interference)

Cell Phones

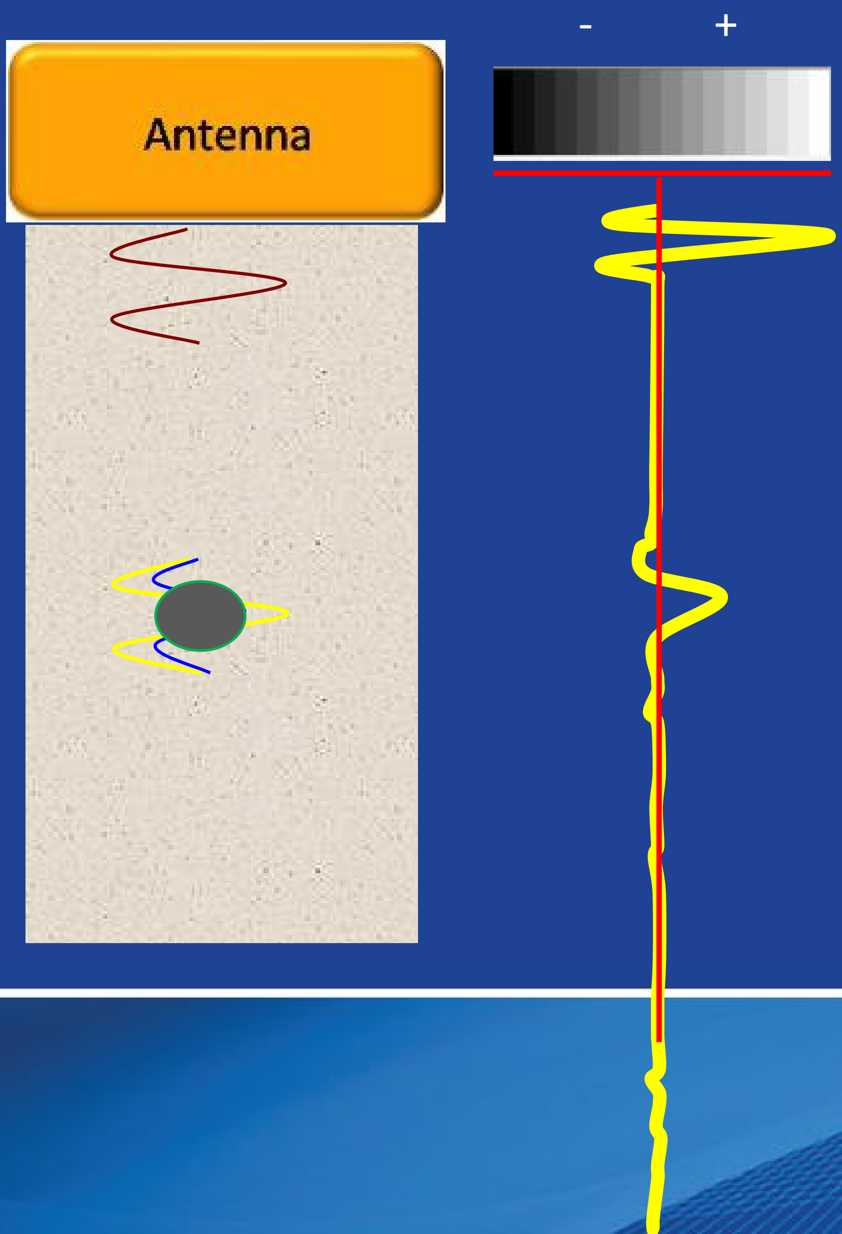
2 Way Radios

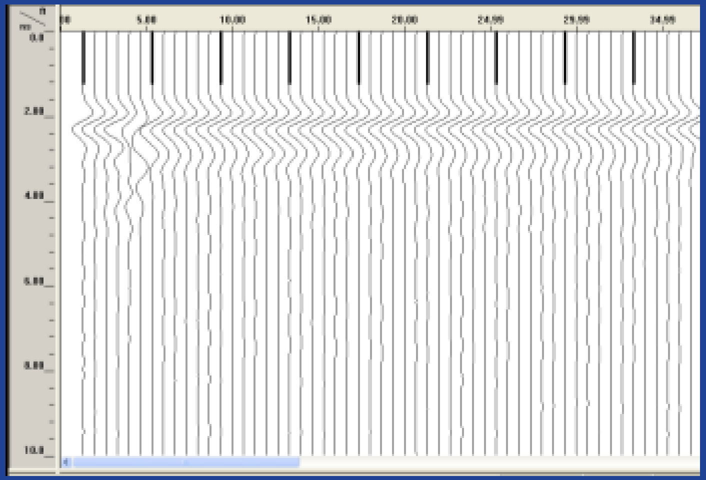


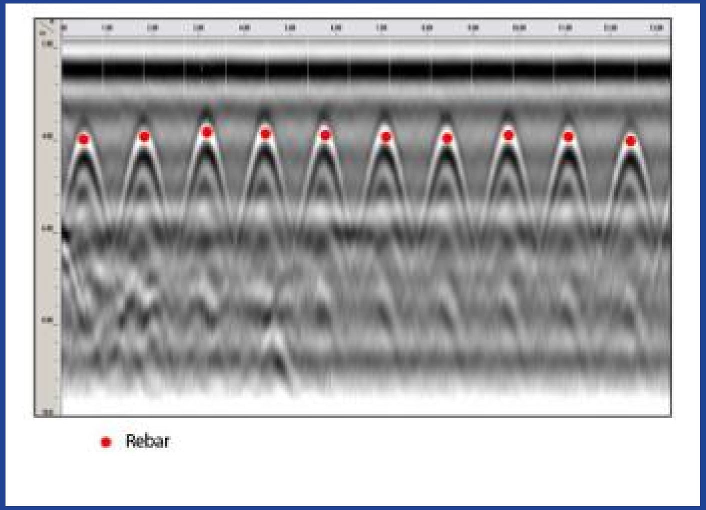


EXCELLENCE IN MOTION

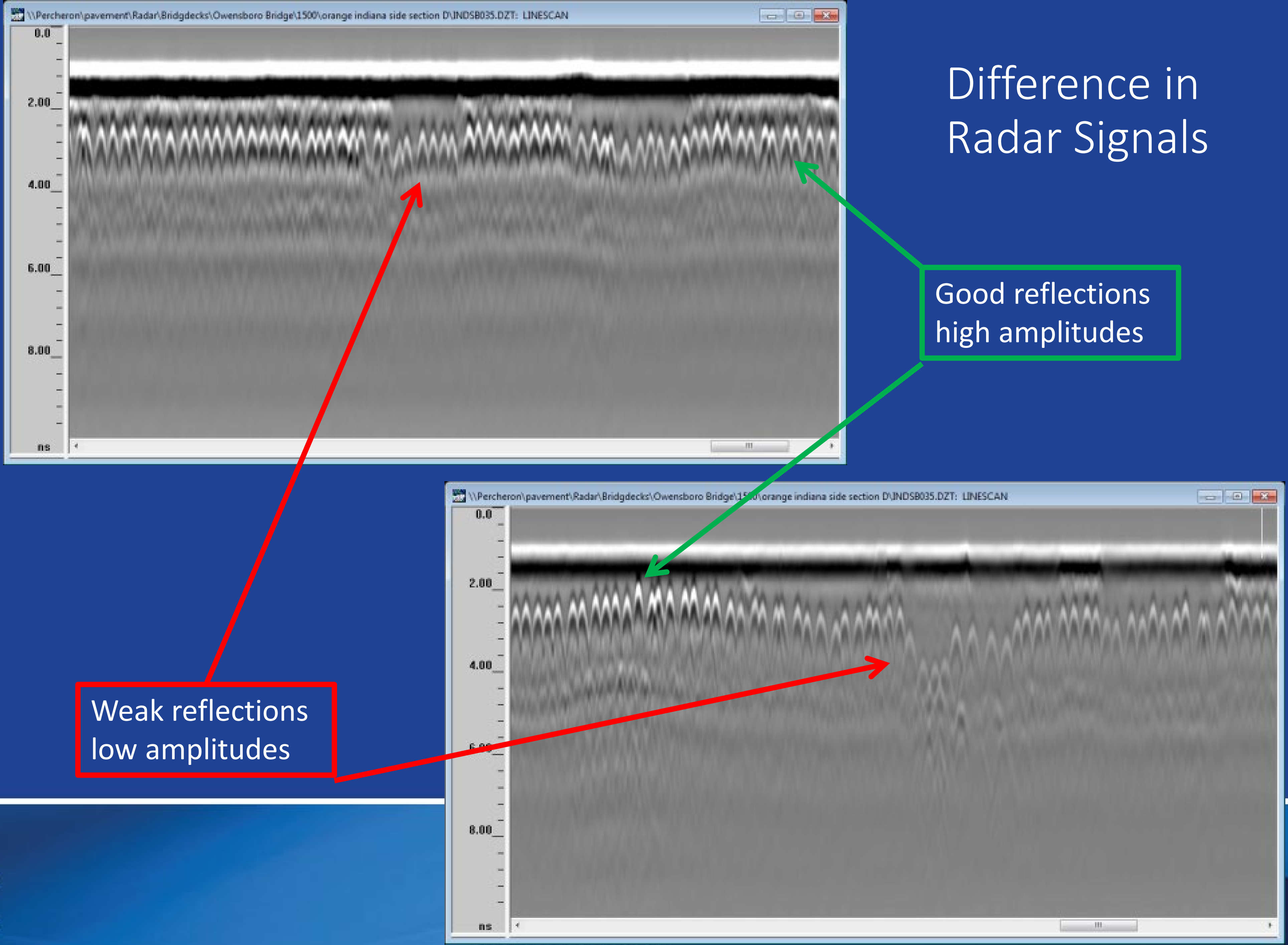
Second: How are we going to use data--amplitudes



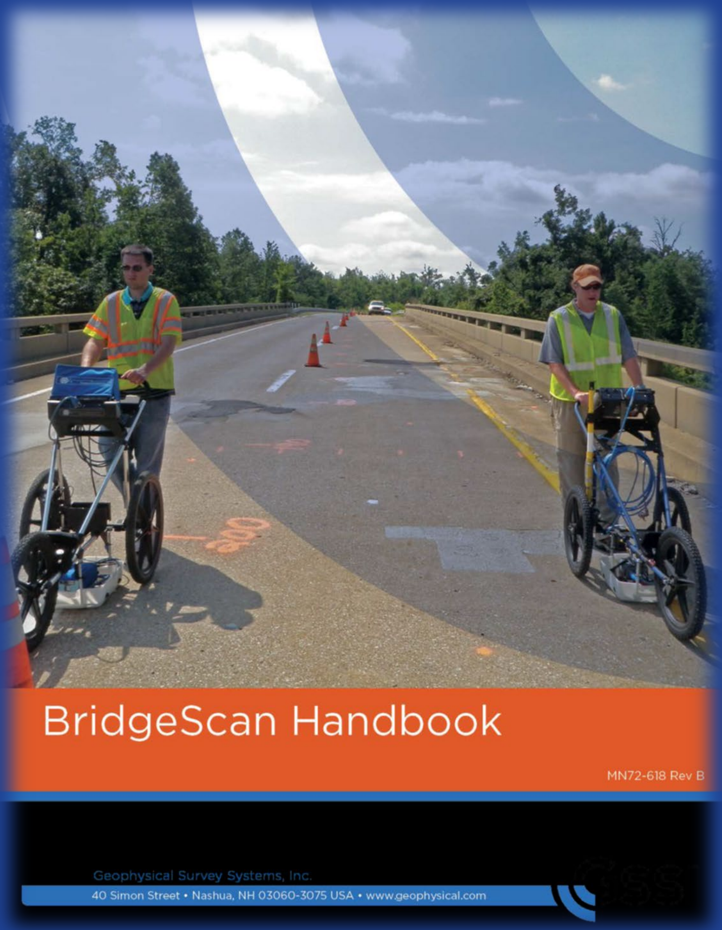


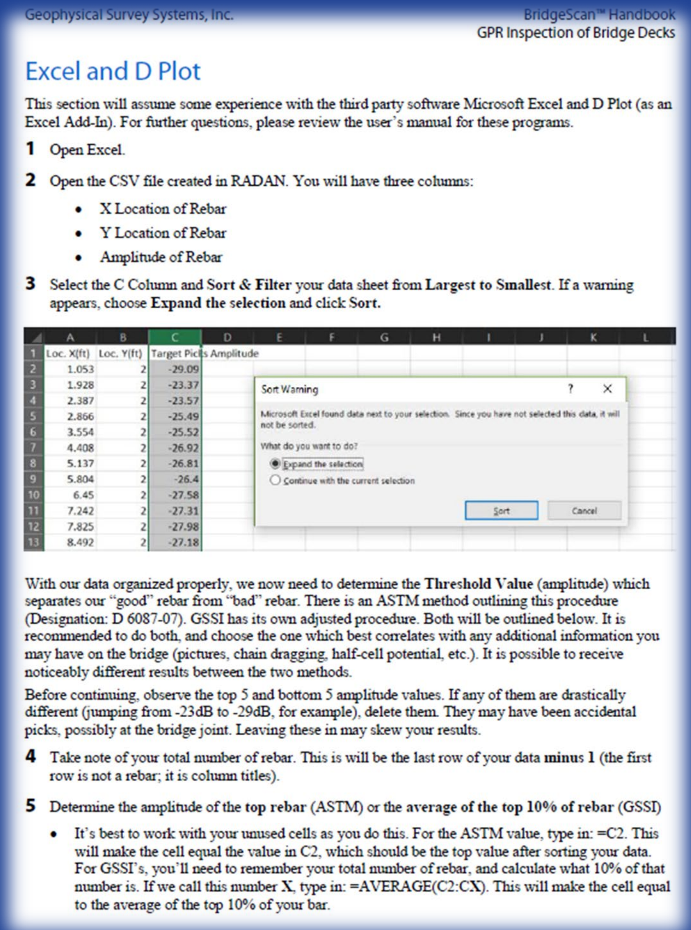


Difference in Radar Signals



Third: How are we going to process the data





Geophysical Survey Systems, Inc. — BridgeScan™ Handbook, GPR Inspection of Bridge Decks

Excel and D Plot

This section will assume some experience with the third party software Microsoft Excel and D Plot (as an Excel Add-In). For further questions, please review the user's manual for these programs.

1 Open Excel.

2 Open the CSV file created in RADAN. You will have three columns:

- X Location of Rebar
- Y Location of Rebar
- Amplitude of Rebar

3 Select the C Column and **Sort & Filter** your data sheet from **Largest to Smallest**. If a warning appears, choose **Expand the selection** and click **Sort.**

	A	B	C
1	Loc. X(ft)	Loc. Y(ft)	Target Picks Amplitude
2	1.053	2	-29.09
3	1.928	2	-23.37
4	2.387	2	-23.57
5	2.866	2	-25.49
6	3.554	2	-25.52
7	4.408	2	-26.92
8	5.137	2	-26.81
9	5.804	2	-26.4
10	6.45	2	-27.58
11	7.242	2	-27.31
12	7.825	2	-27.98
13	8.492	2	-27.18

Sort Warning
Microsoft Excel found data next to your selection. Since you have not selected this data, it will not be sorted.
What do you want to do?
- Expand the selection
- Continue with the current selection

Sort | Cancel

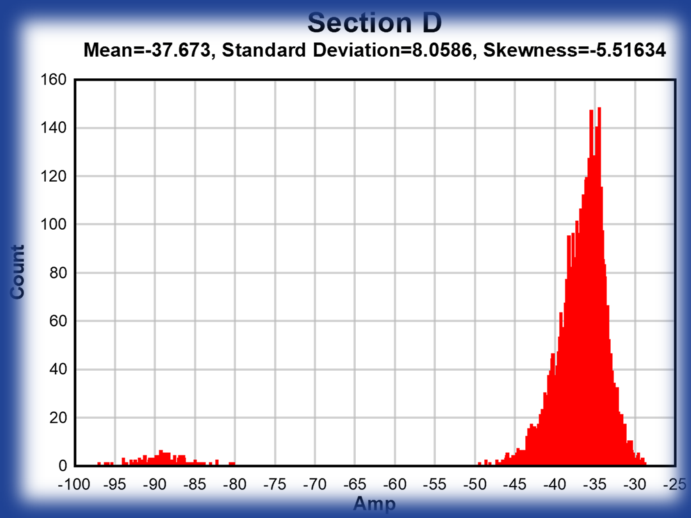
With our data organized properly, we now need to determine the **Threshold Value** (amplitude) which separates our "good" rebar from "bad" rebar. There is an ASTM method outlining this procedure (Designation: D 6087-07). GSSI has its own adjusted procedure. Both will be outlined below. It is recommended to do both, and choose the one which best correlates with any additional information you may have on the bridge (pictures, chain dragging, half-cell potential, etc.). It is possible to receive noticeably different results between the two methods.

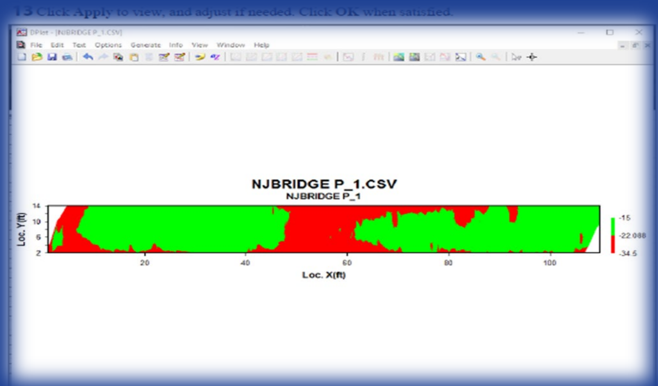
Before continuing, observe the top 5 and bottom 5 amplitude values. If any of them are drastically different (jumping from -23dB to -29dB, for example), delete them. They may have been accidental picks, possibly at the bridge joint. Leaving these in may skew your results.

4 Take note of your total number of rebar. This is will be the last row of your data **minus 1** (the first row is not a rebar; it is column titles).

5 Determine the amplitude of the top rebar (ASTM) or the average of the top 10% of rebar (GSSI)

- It's best to work with your unused cells as you do this. For the ASTM value, type in: =C2. This will make the cell equal the value in C2, which should be the top value after sorting your data. For GSSI's, you'll need to remember your total number of rebar, and calculate what 10% of that number is. If we call this number X, type in: =AVERAGE(C2:CX). This will make the cell equal to the average of the top 10% of your bar.





1. Get the handbook

2. Identify the high/low amplitude thresholds Using ASTM D6087-07

3. Plot the data D-Plot

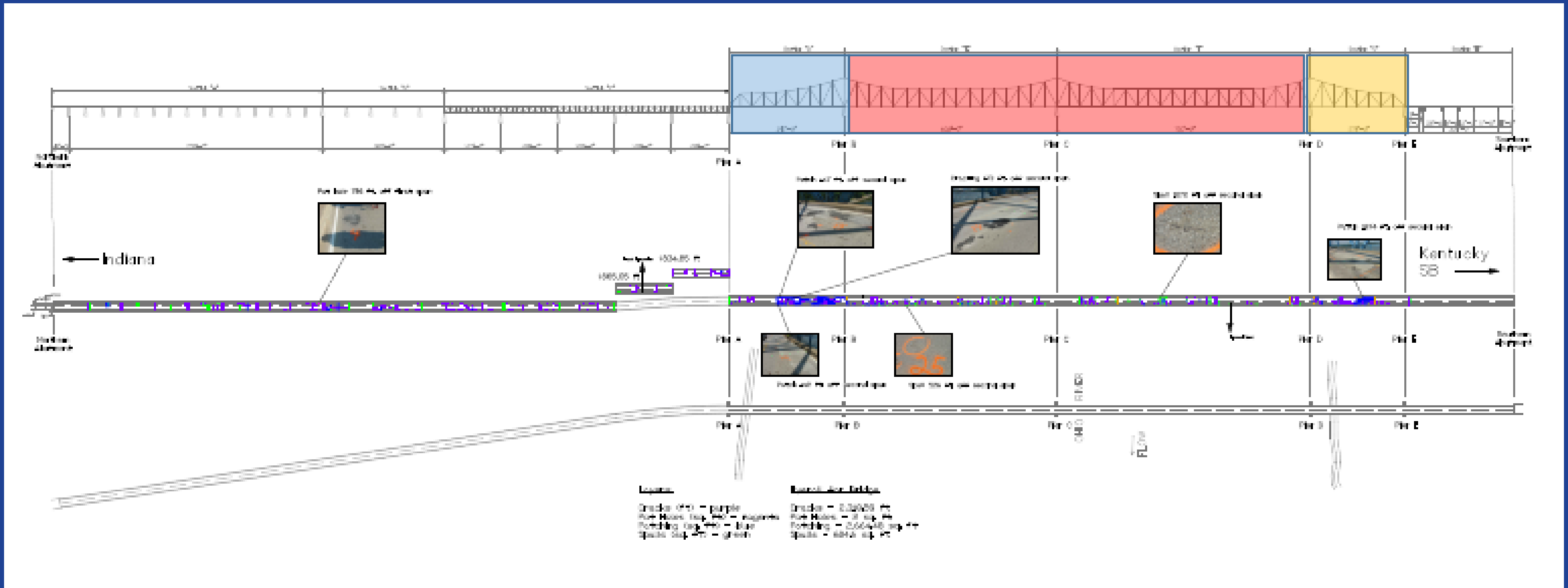
Case Study: One

- Glover Cary Bridge
  - Owensboro, KY
  - Built 1937
  - Crosses the Ohio River

Why are we concerned?

Sections

D E F G



Ground Penetrating Radar Survey

Survey lines 2’ o.c.

6 lines per lane

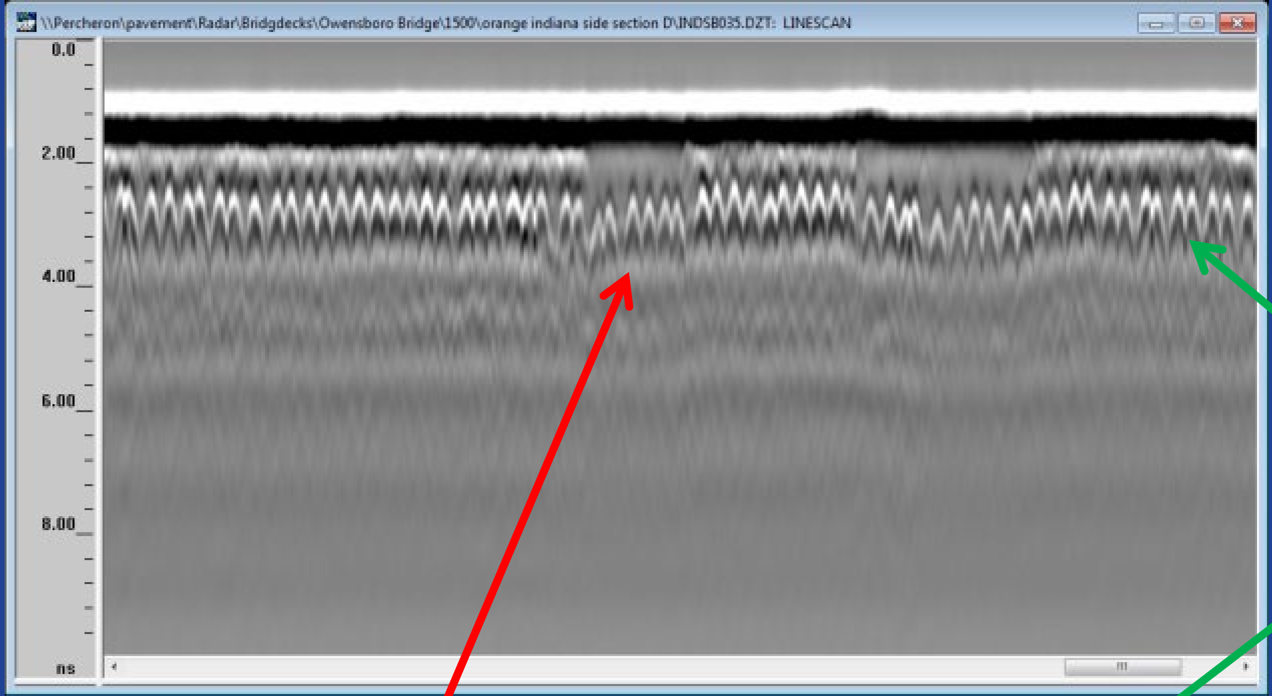
24 scans per foot

4007 ft. per line

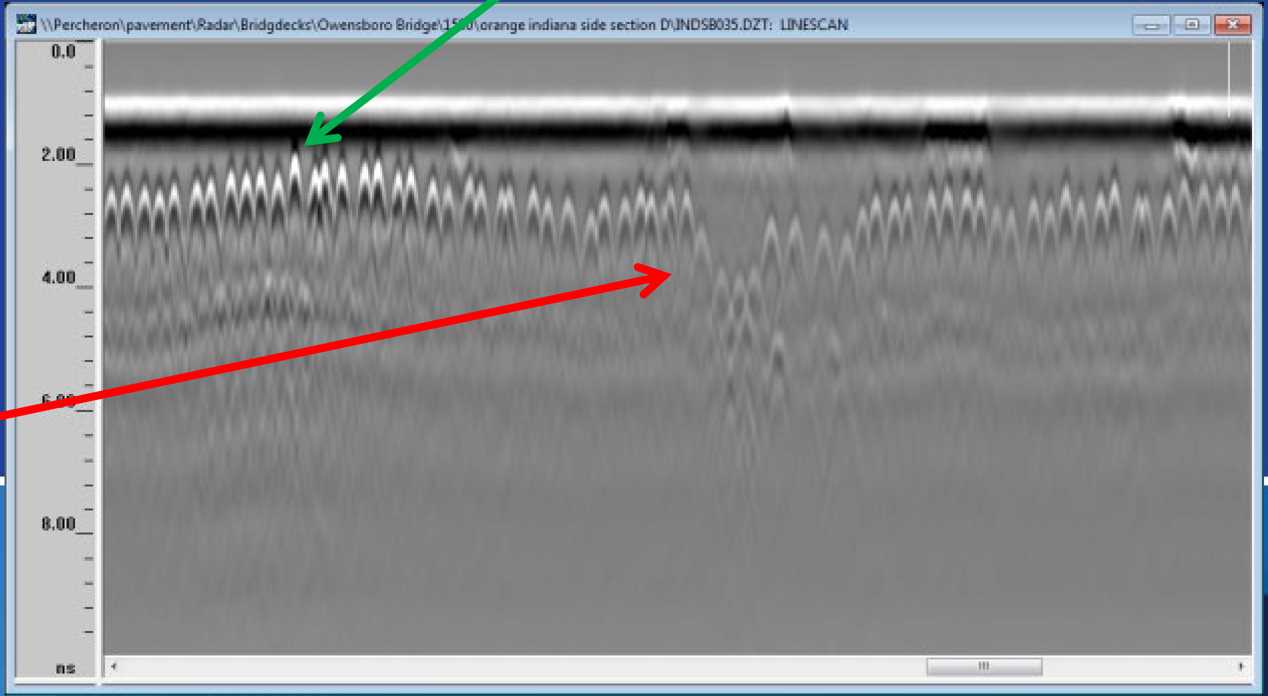
96,168 data points

Collection time 2 days

Difference in Radar Signals

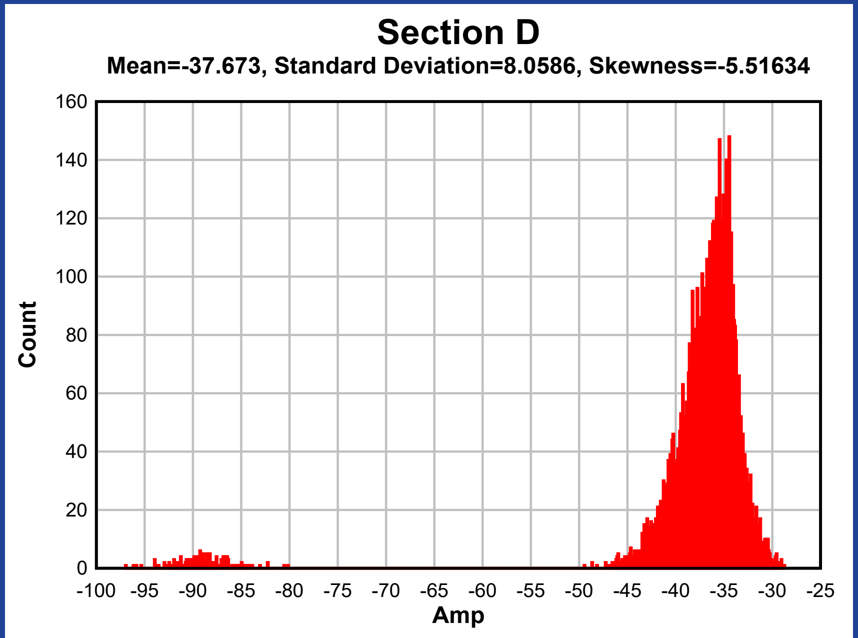


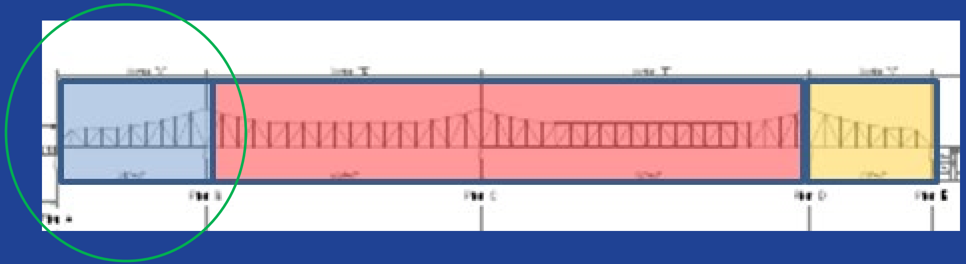
Good reflections high amplitudes

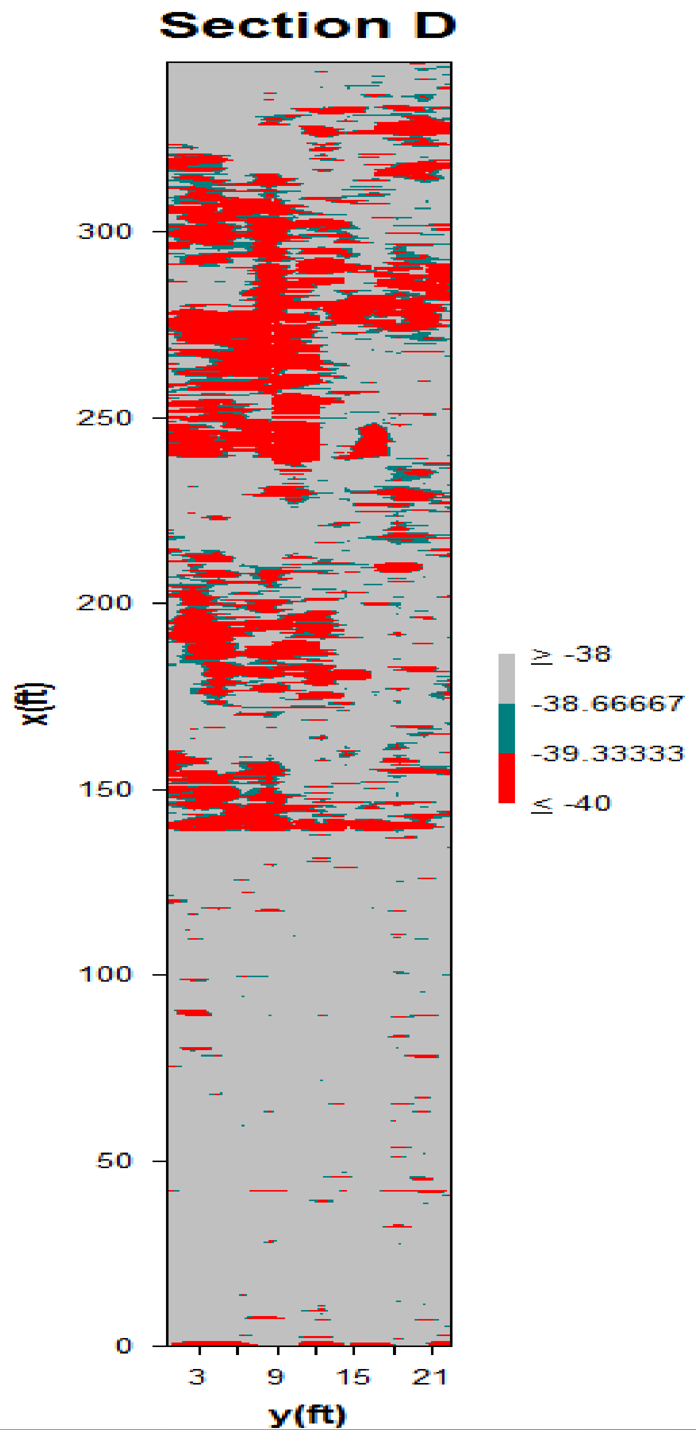


Weak reflections low amplitudes

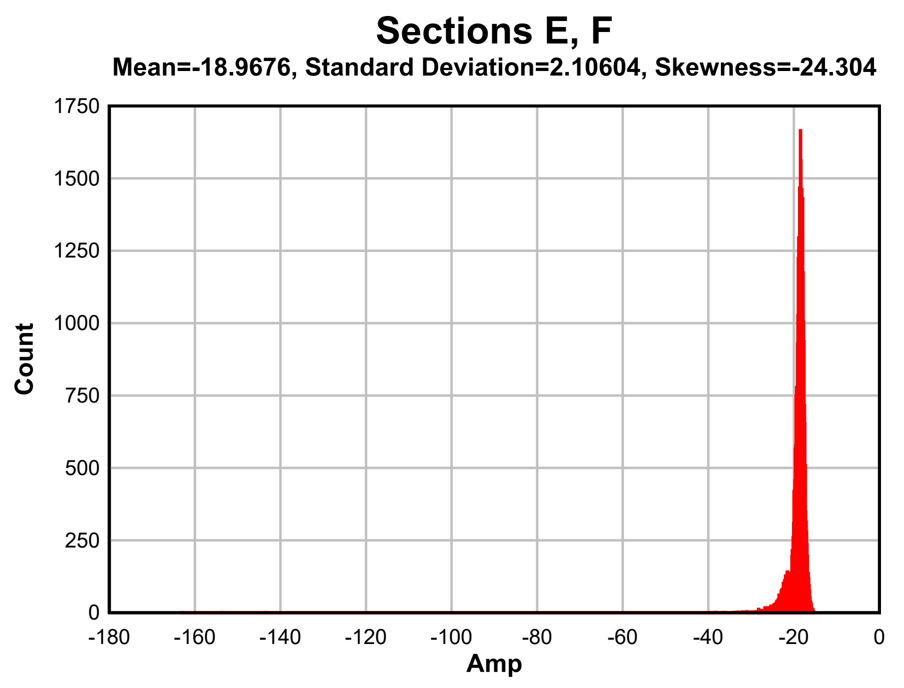
Section D: 25% +/- 5% deteriorated

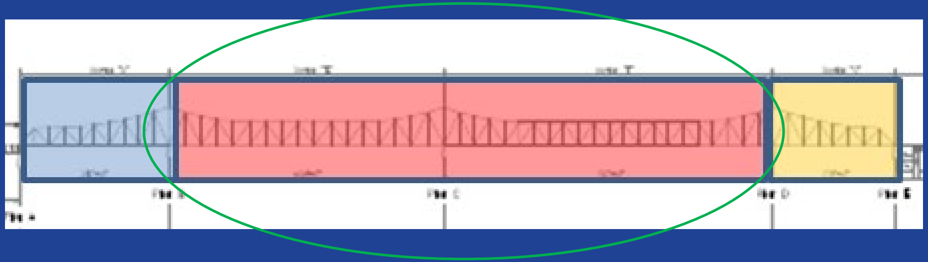


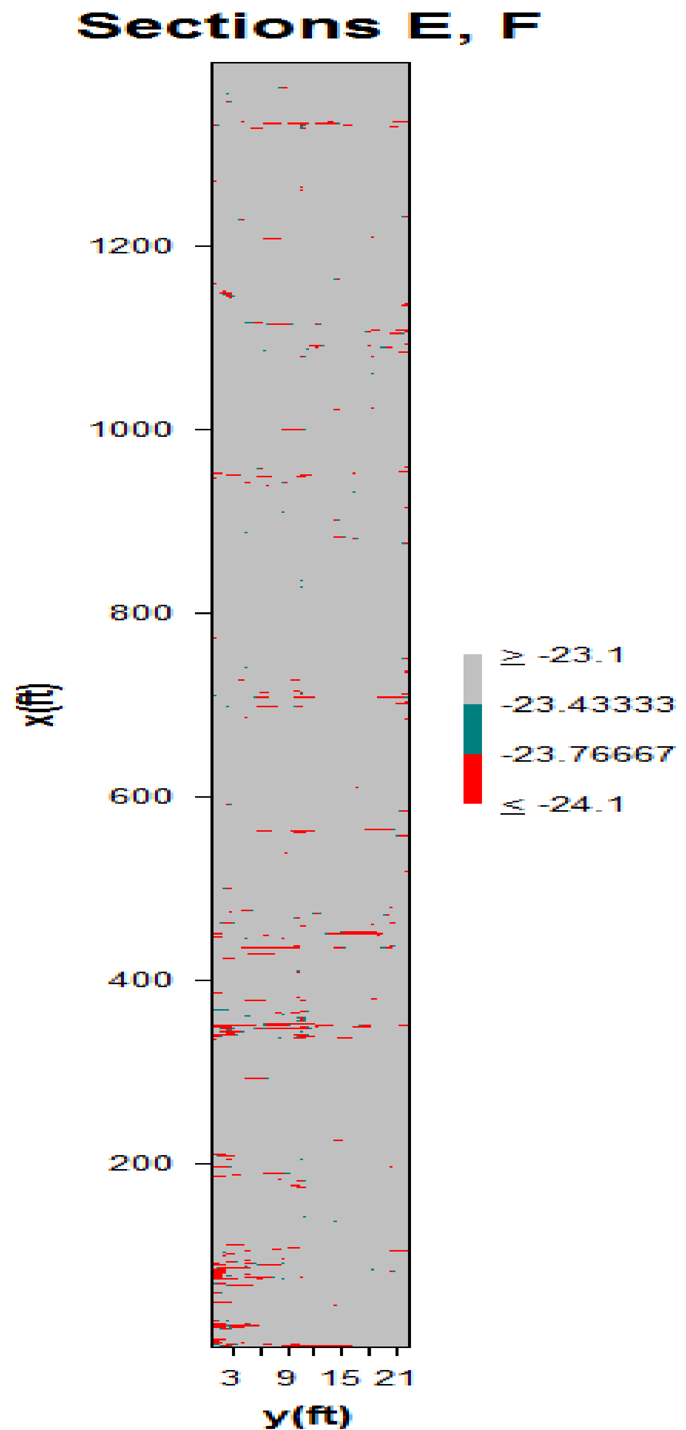




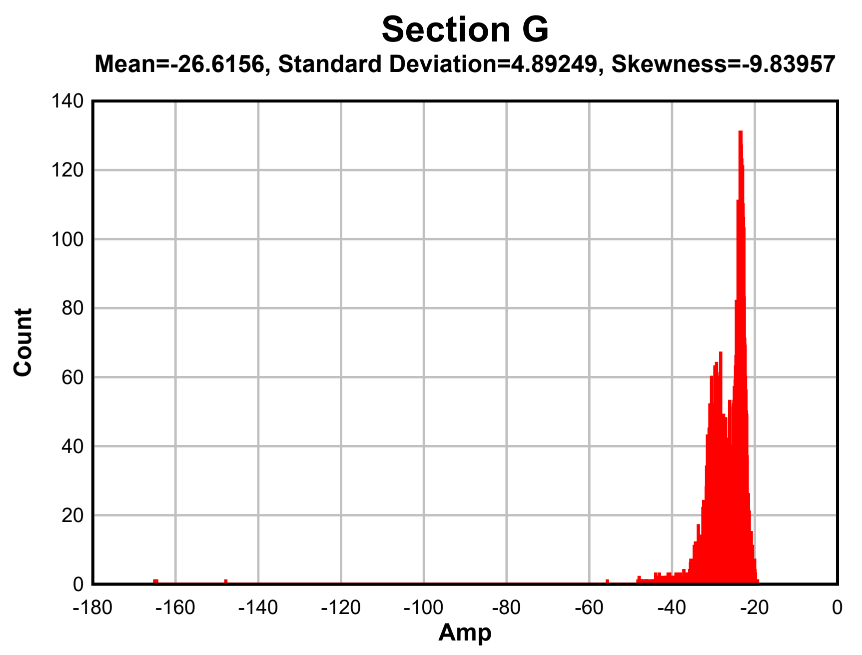
Section E, F: 3.5% +/- 5% deteriorated

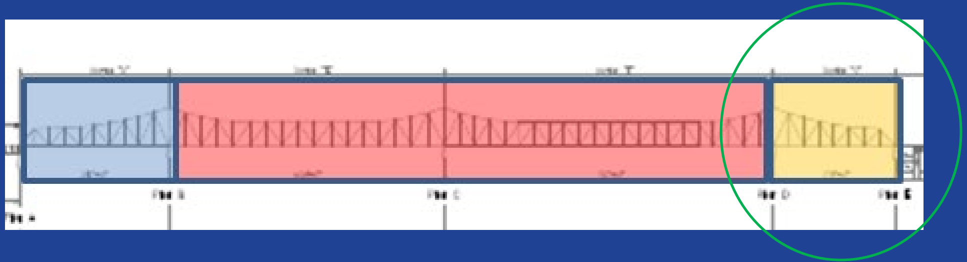


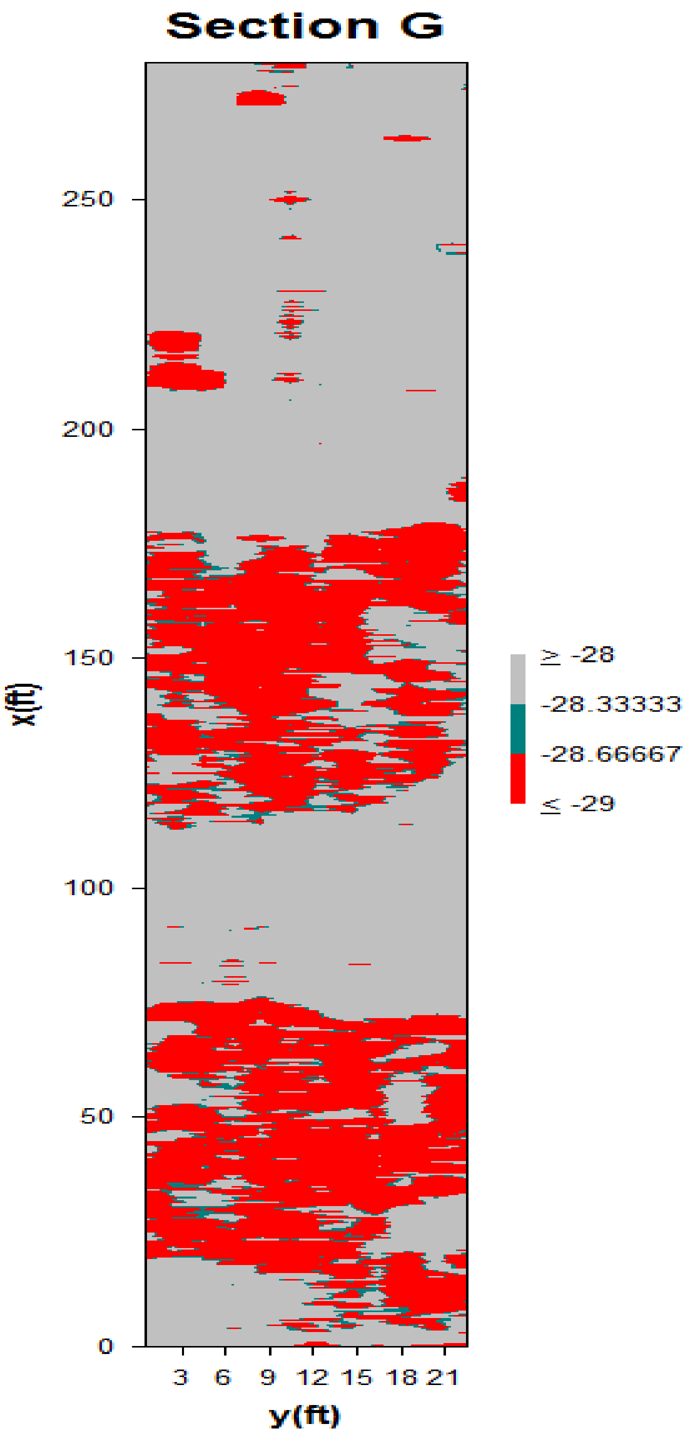




Section G: 36% +/- 5% deteriorated

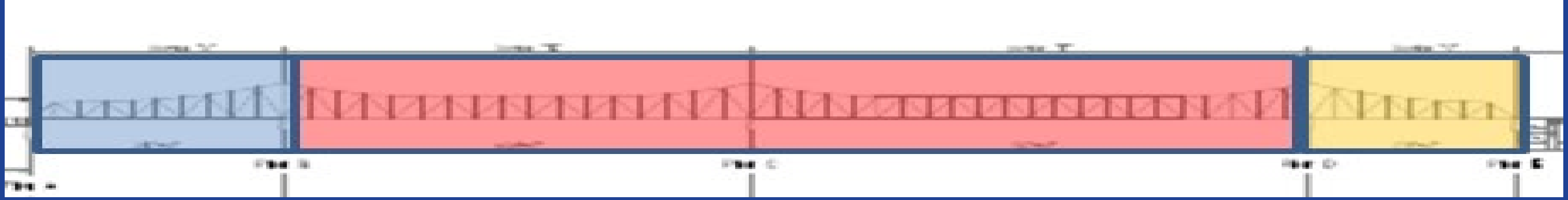




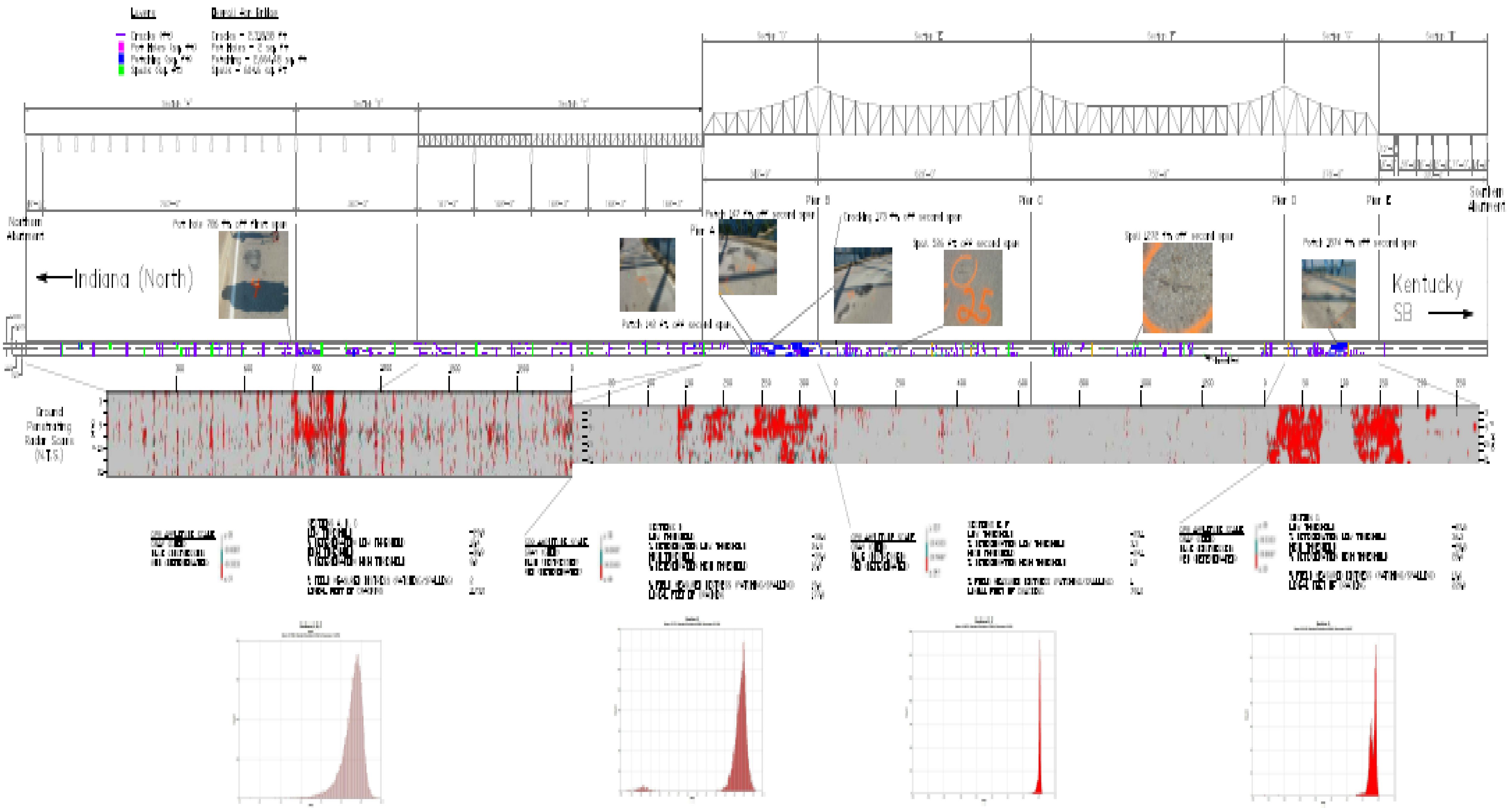


Distress comparison of Visual to GPR

Section	% deterioration Visual	% deterioration GPR +/- 5%
D	19.4	25
E, F	1	3.5
G	15.6	36



D E,F G


Indiana (North)
Kentucky
SB
Northern Abutment
Southern Abutment
Pier A
Pier B
Pier C
Pier D
Pier E
Ground Penetrating Radar Scans (N.T.S.)

Usefulness of Data

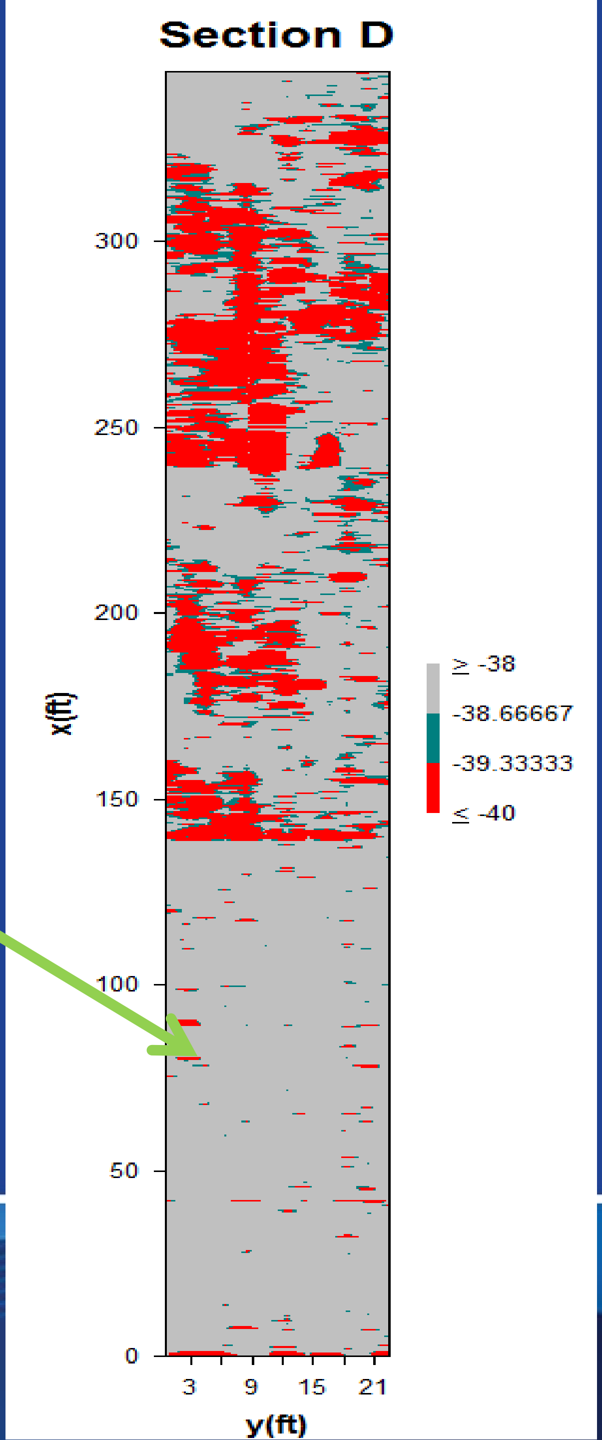
- Original visual distress questioned if the entire bridge deck needed to be replaced
  - Approximately 4,007 ft.
  - Approximate cost $17 million

- GPR results identified
  - Approximately 2,500 lineal feet needs replaced
  - Engineers Estimate $5 million, bid for $3 million

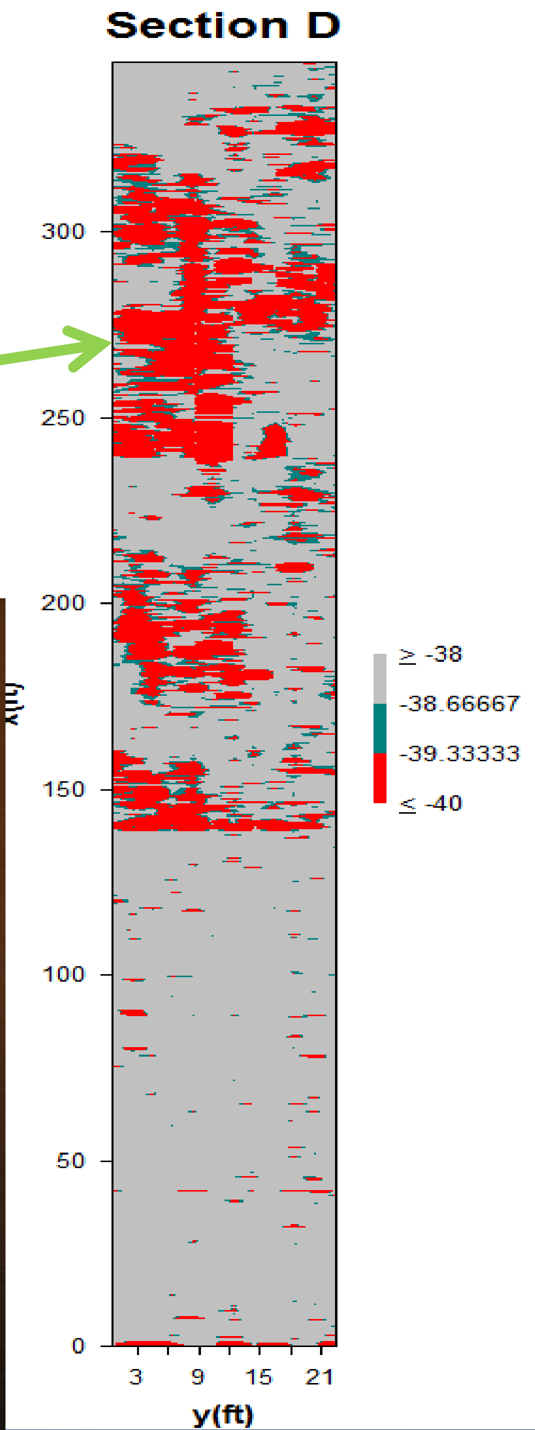
GPR compared to field conditions

- Do we believe in our data?


Genie
No Loss


Section D
x(ft)
y(ft)
300
250
200
150
100
50
0
3
9
15
21
≥ -38
-38.66667
-39.33333
≤ -40


50%
Loss


Section D
300
250
200
150
100
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3
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15
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y(ft)
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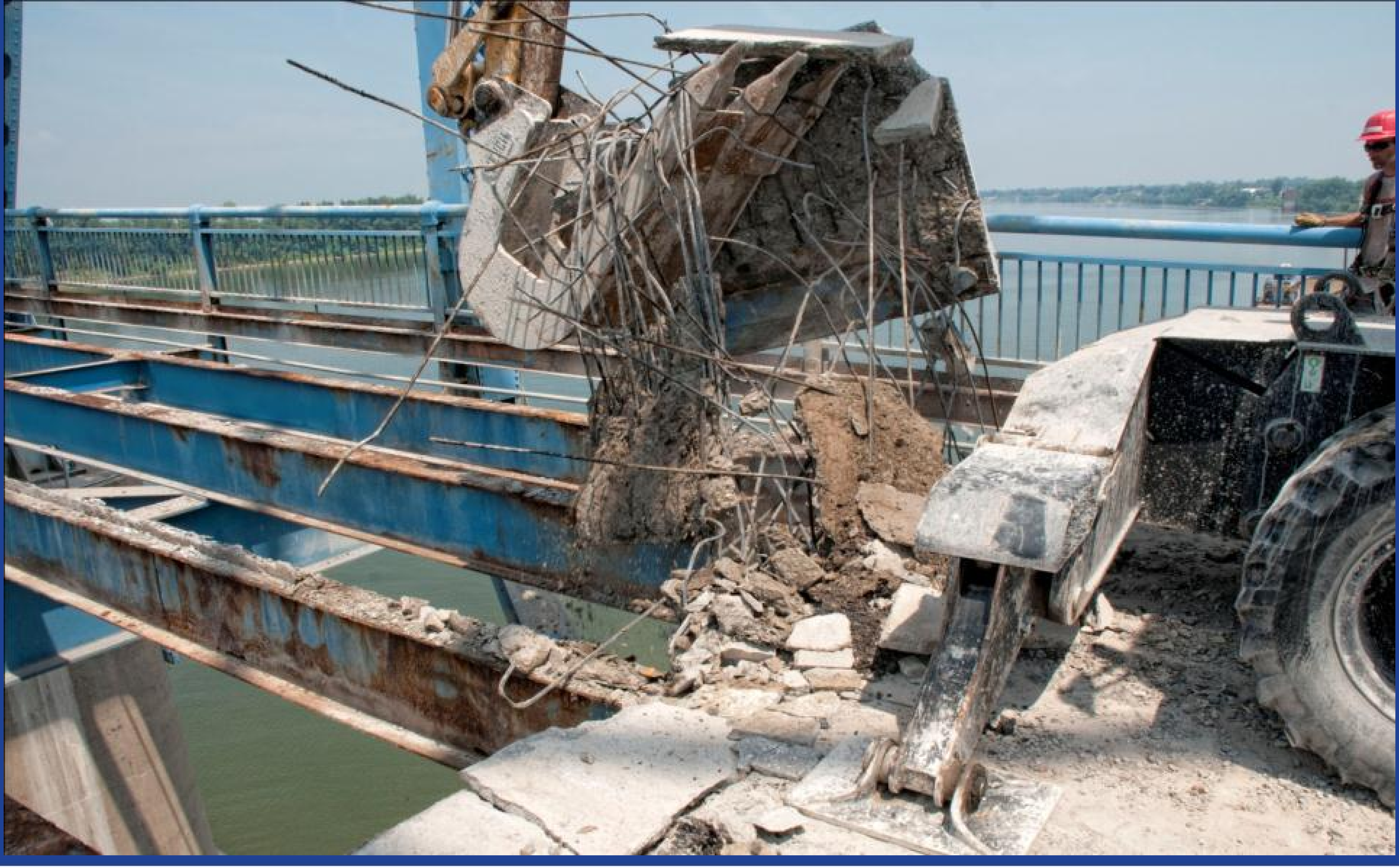
-38.66667
-39.33333
≤ -40

EXCELLENCE IN MOTION



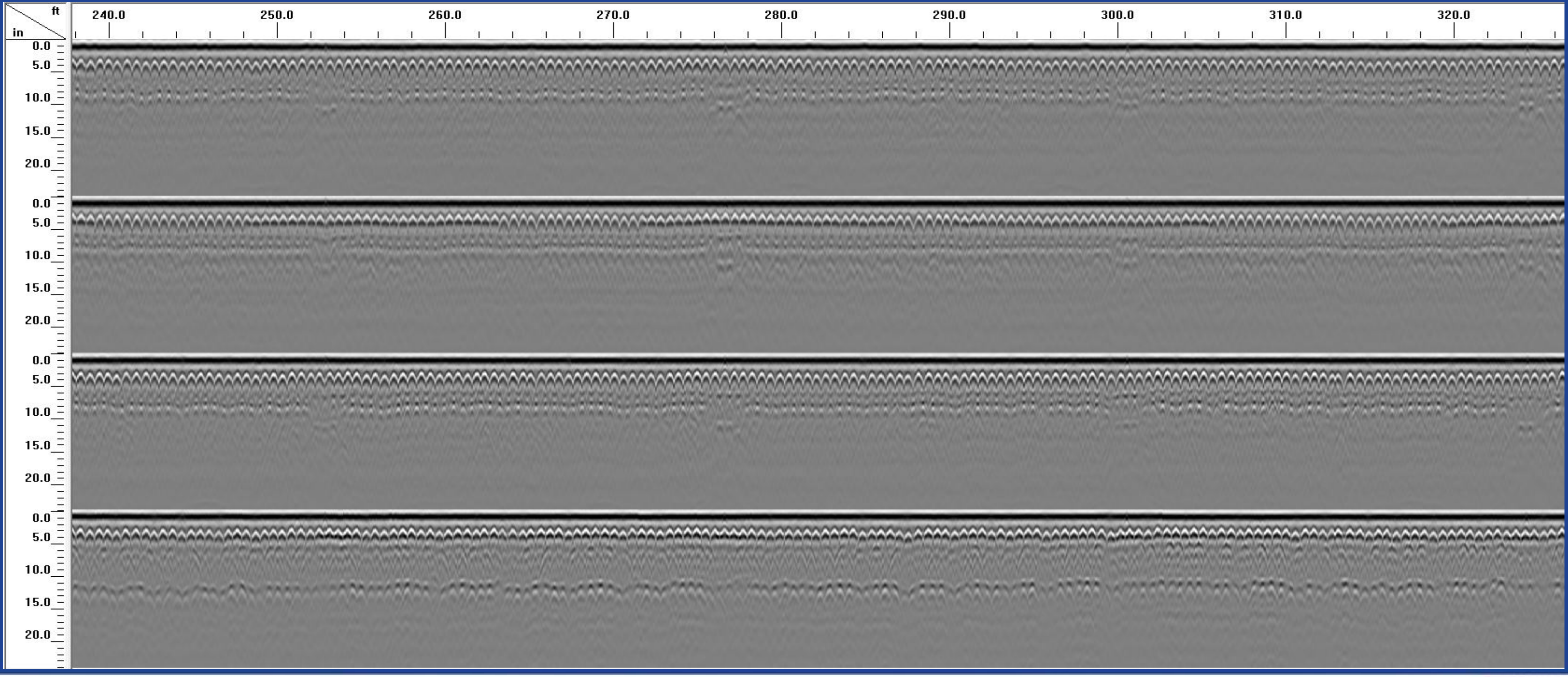
Case Study: Two

12th Street Bridge
Ashland, Kentucky

Methodology

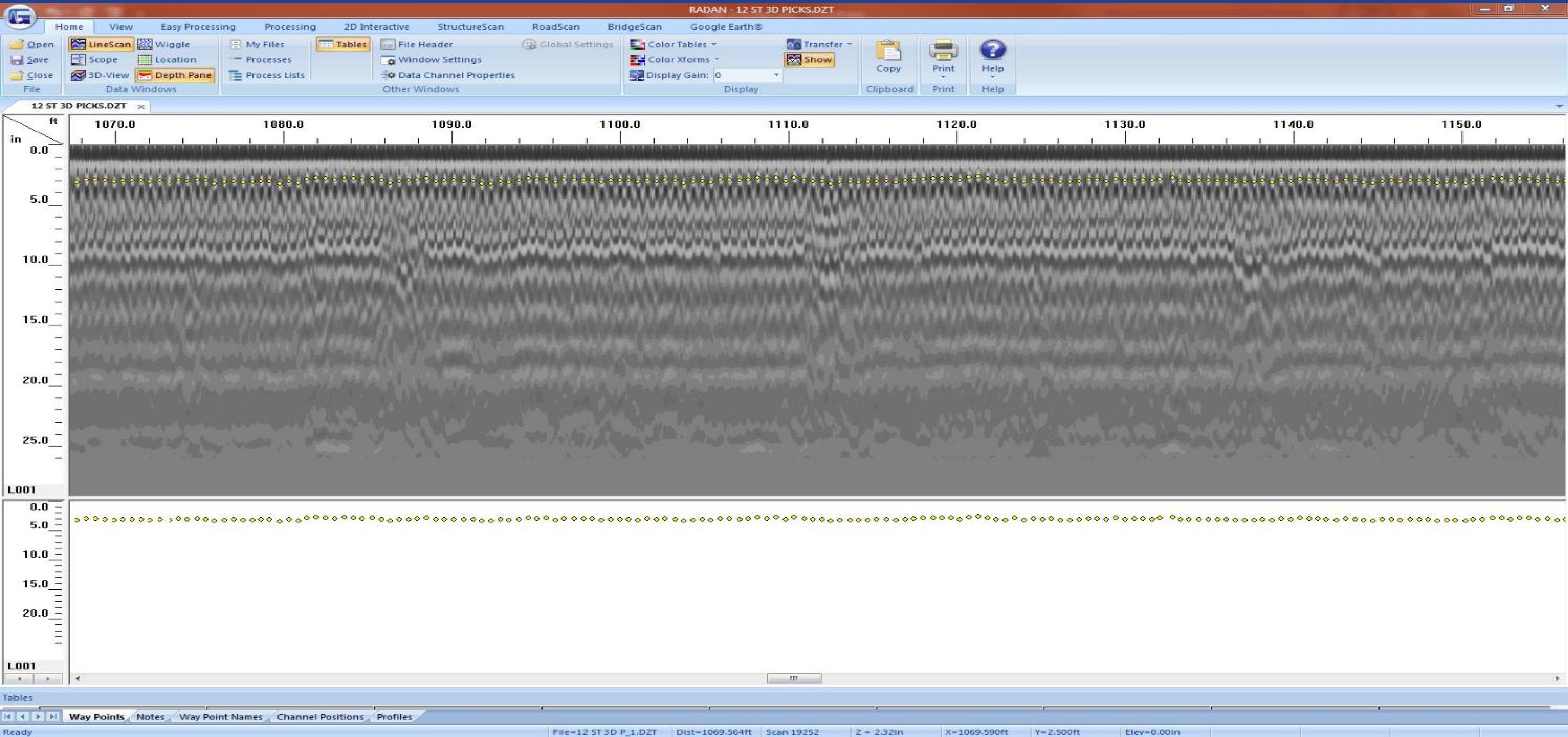
- 4 Channel collection
- Each antenna spaced 2ft apart
- 1-2 hours collection time

Example of Data During Collection

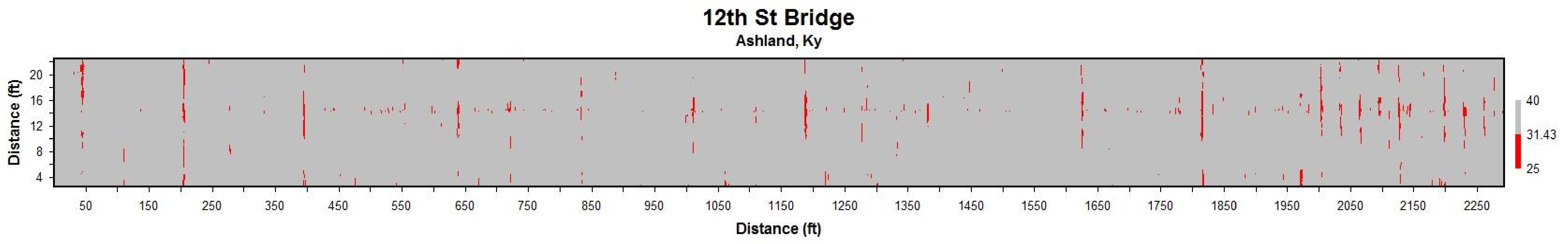


Processing the Data

- Each Rebar is Given a Data Point With Amplitudes Assigned to Each
- Low Amplitudes Indicate Deteriorated Rebar



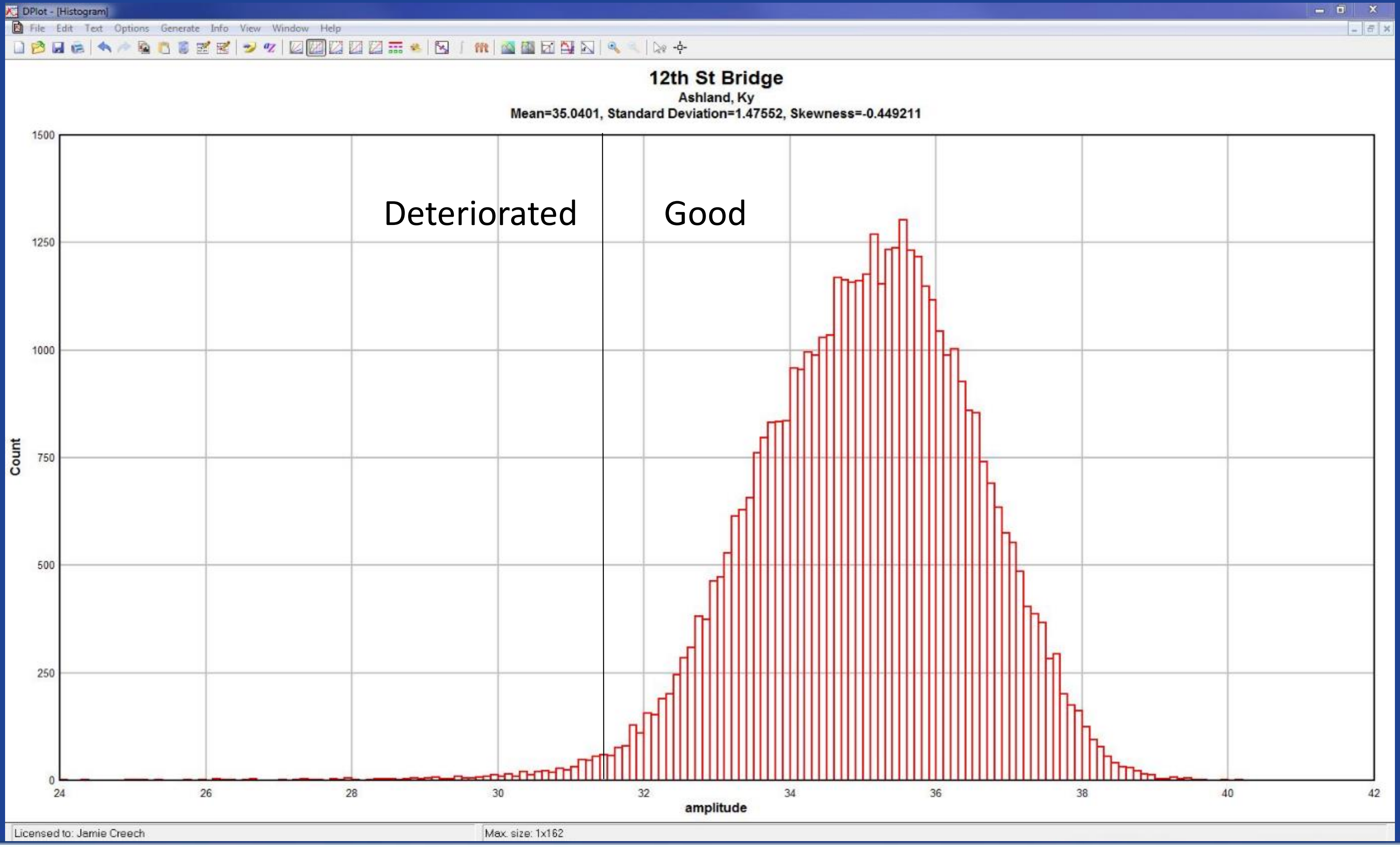
Contour Map Shows 1.1% of Rebar is Deteriorated



KENTUCKY TRANSPORTATION CABINET

EXCELLENCE IN MOTION

Histogram Showing Distribution of Deteriorated Rebar

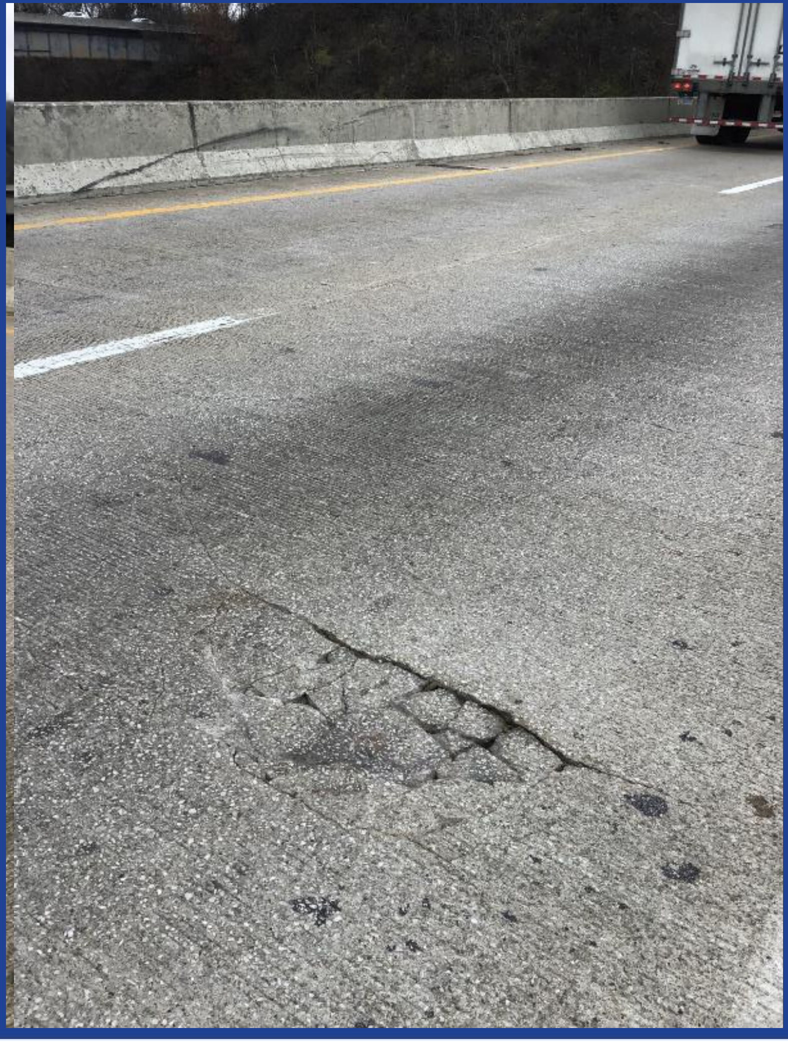


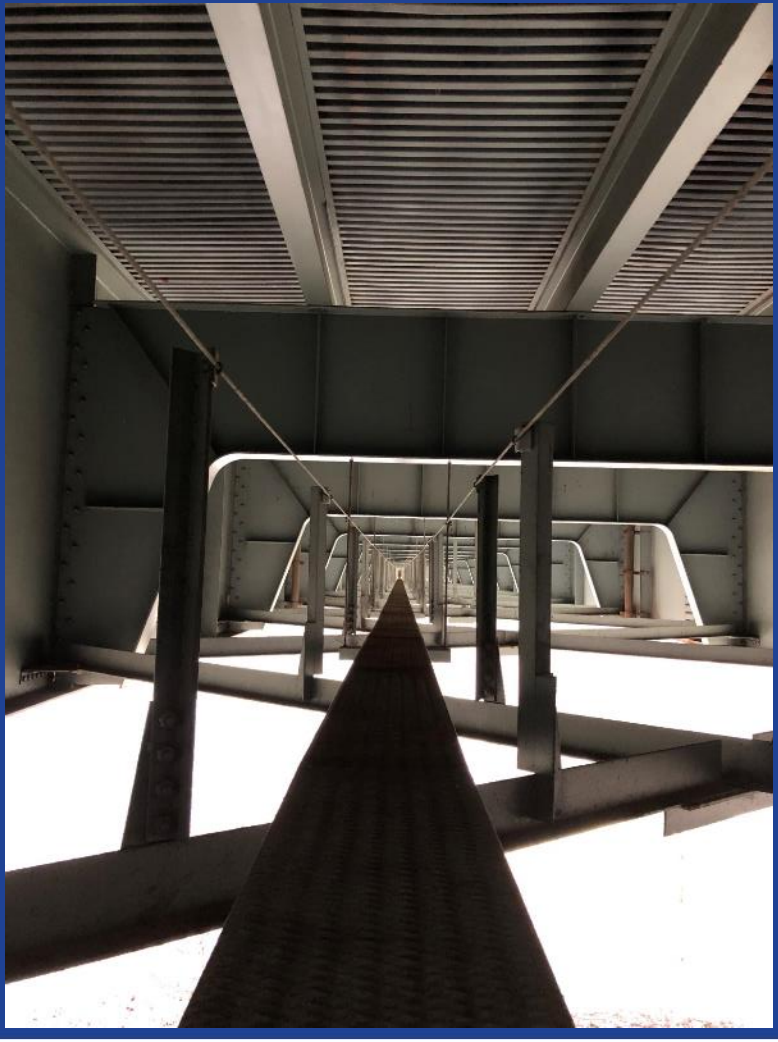
31.43


Exit Street View
© 2018 Google
© 2019 Google
Google Earth
Report a problem

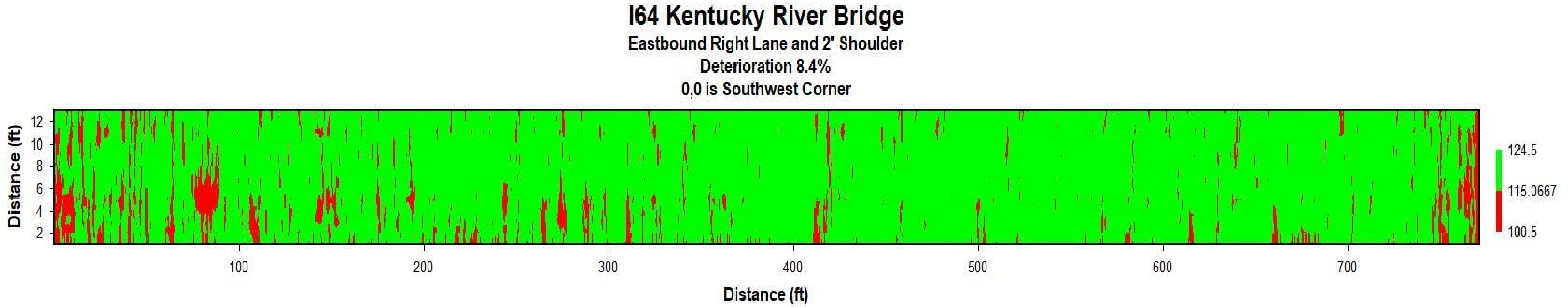
Case Study: Three
I-64 EB & WB
Over Kentucky River

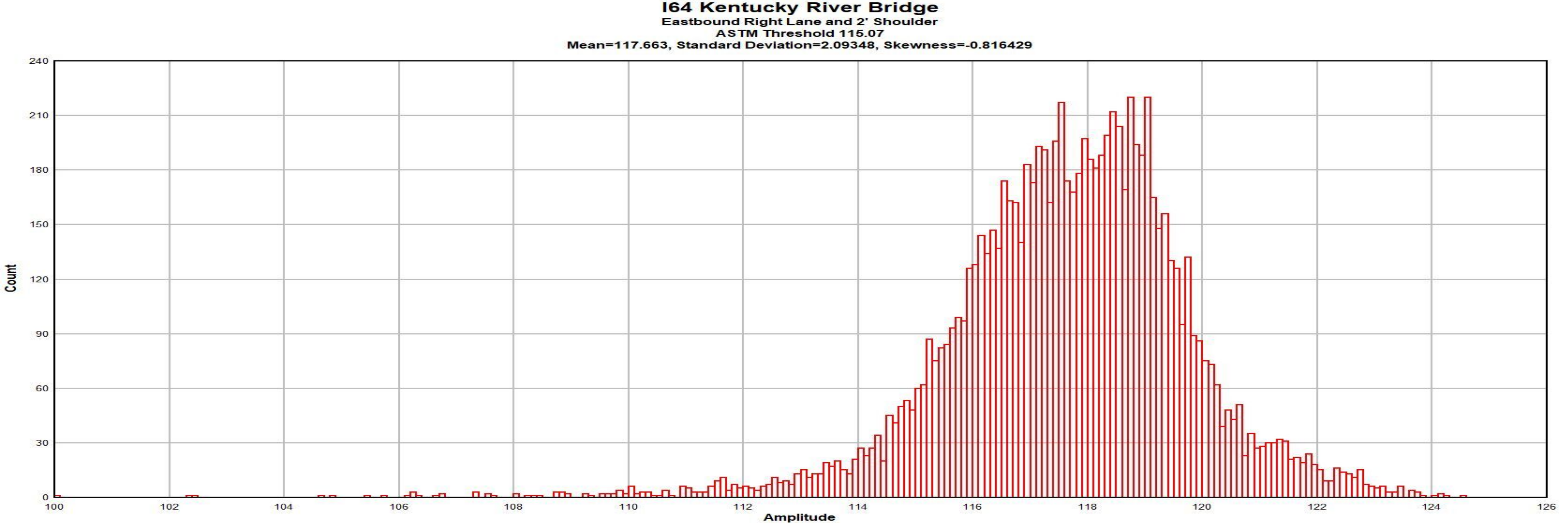
Why the concern





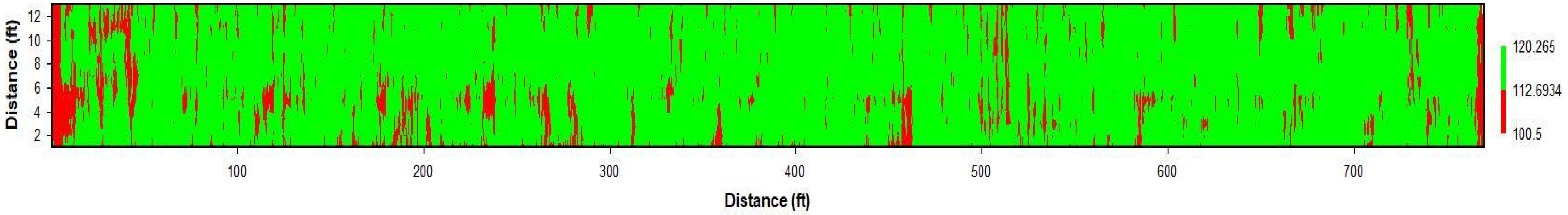

SUPER DUTY
Kentucky
W6727
OFFICIAL

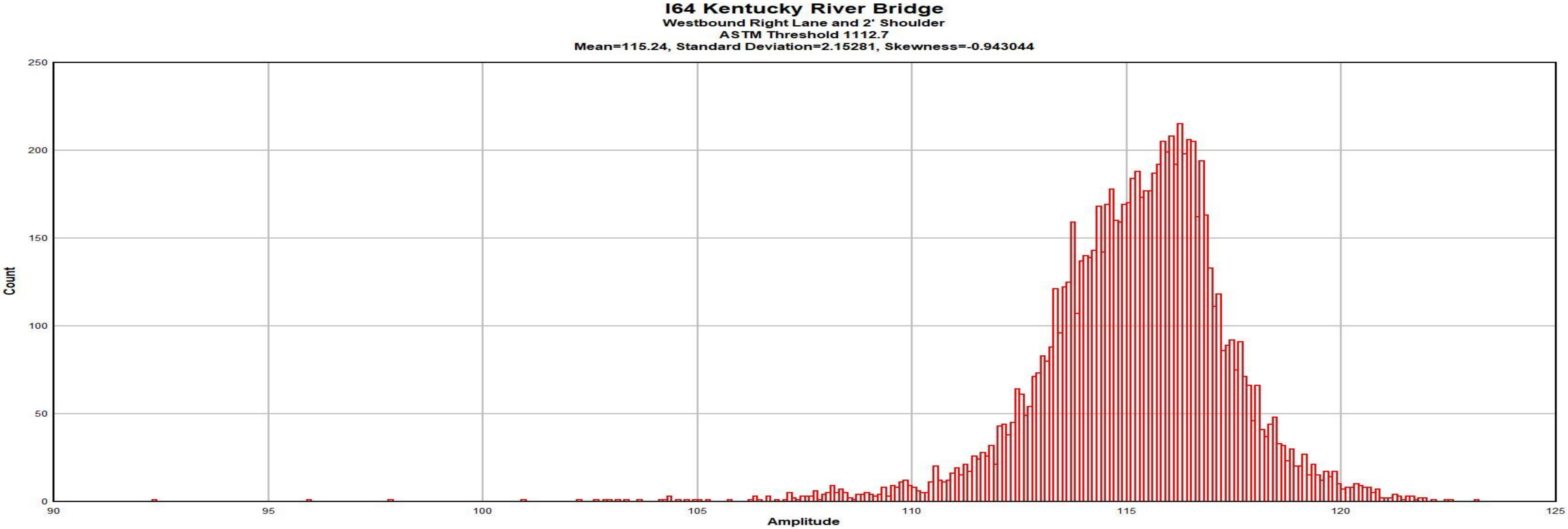

I64 Kentucky River Bridge
Eastbound Right Lane and 2' Shoulder
Deterioration 8.4%
0,0 is Southwest Corner
Distance (ft)
12
10
8
6
4
2
100
200
300
400
500
600
700
Distance (ft)
124.5
115.0667
100.5


I64 Kentucky River Bridge
Eastbound Right Lane and 2' Shoulder
ASTM Threshold 115.07
Mean=117.663, Standard Deviation=2.09348, Skewness=-0.816429
Count
240
210
180
150
120
90
60
30
0
100
102
104
106
108
110
112
114
116
118
120
122
124
126
Amplitude

I64 Kentucky River Bridge

Westbound Right Lane and 2' Shoulder
Deterioration 9.6%
0,0 is Northeast Corner





EB Core #1 (delaminated 2.5 inches)

EB Core #2 “low amplitude” (delaminated 1.625 inches)

EB Core #2 “low amplitude” (delaminated 1.625 inches)

WB1 Core “low amplitude” (delaminated 3 inches)

EXCELLENCE IN MOTION

WB1 Core: #5 bar section loss 7 +/- 1 %

WB2 Core (4-bar) (delaminated 3 inches)

Transverse Steel

Longitudinal Steel

Effects of delamination on capacity

Bridge Deck Capacity Loss based on Delaminated Depth

Deck Original Depth (in.)	8		
Delaminated at (in.)	Stress Increase (%)	Capacity Loss (%)	
1.0	48.8%	32.8%	
1.5	84.2%	45.7%	
2.0	128.6%	56.3%	
2.5	181.3%	64.5%	
3.0	236.8%	70.3%	
3.5	282.1%	73.8%	
4.0	300.0%	75.0%	

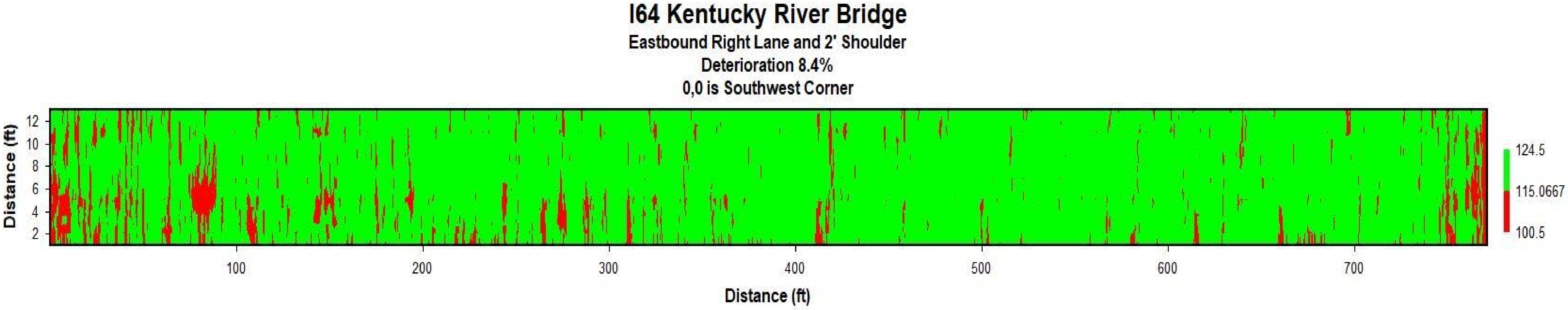
Delamination examples

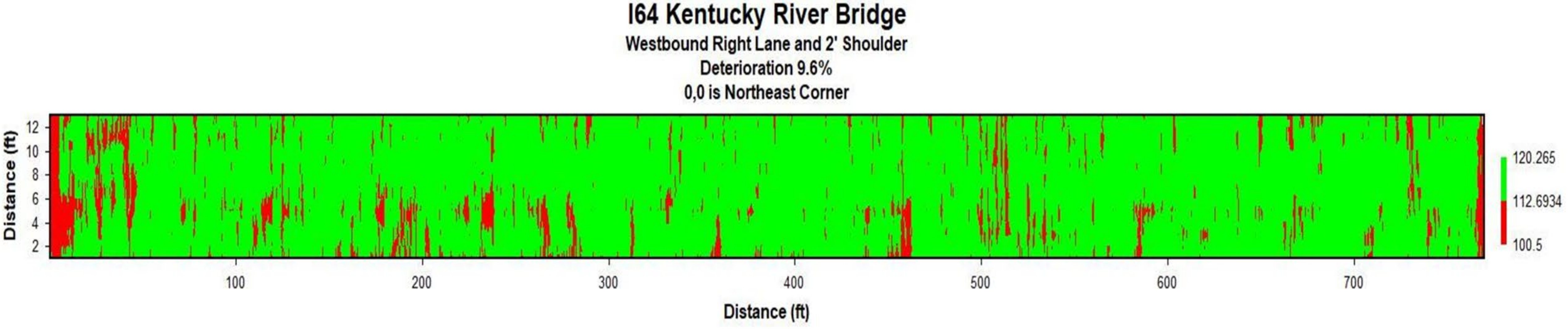
Non-delamination examples

Concern Areas (full depth)

Areas (ful

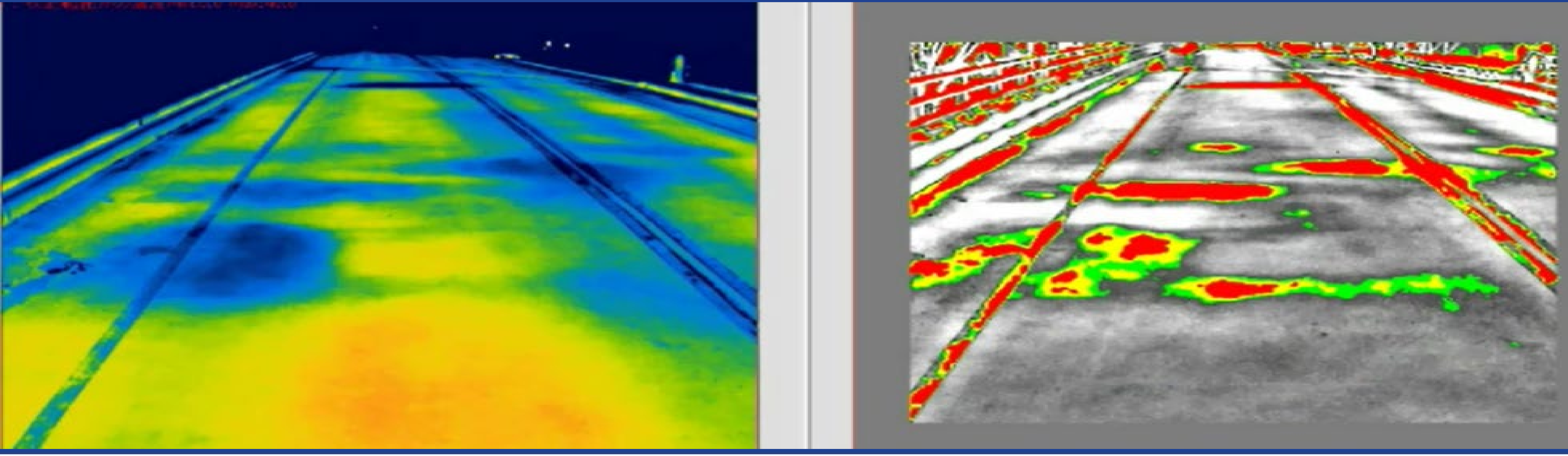
May consider red as full depth if entire bridge is to overlaid





Infrared Inspection of Concrete Bridge Deterioration

What we have tried



Discussion of Infrared Technology

- Thermal imaging can be used to detect and image subsurface damage (delamination's) in concrete. The technology can be applied to determine areas where repairs are needed in:
  - concrete bridge decks
  - soffits of overpass bridges
  - where there is potential for spalling concrete to fall into traffic below in FRP overlays

- A primary advantage of this technology is that it is non-contact and can be utilized from a distance, such that arms-length bridge access and traffic control are typically not required. A primary disadvantage of this technology is its dependence on certain environmental conditions that are necessary for the technology to be effective.

Discussion of Pooled Funded Study in Missouri

Study Detail View

Field Testing Hand-Held Thermographic Inspection Technologies Phase II

General Information

Study Number: TPF-5(247)
Status: Contract signed
Contract/Other Number: TRyy1144
Lead Agency: Missouri Department of Transportation
Last Updated: Feb 3, 2015
Contract Start Date: Nov 10, 2011
Est. Completion Date:
Contract End Date: Dec 31, 2015
Partners: FL , GA , IA , KY , MI , MN , MO , NY , OH , OR , PA , TX , WisDOT
Contractor(s): University of Missouri - Columbia

Contact Information:

Lead Agency Contact(s):

Jennifer Harper
Jennifer.Harper@modot.mo.gov
Phone: 573-526-3636

Investigator(s):

washerg@missouri.edu
Phone: 573-884-0320

What we learned from the pooled fund study

- Temperature differential of 15 degrees Fahrenheit prior to imaging
- The FLIR T650 thermographic camera can identify temperature differentials as little as 1 degree Fahrenheit
- Delamination's up to 3 inches are identifiable
  - Looking for where steel has corroded thus causing delamination in the concrete

- SUN EXPOSED AREAS (Generally)
  - Voided areas appear as hot spots in daytime
  - Voided areas appear as cold spots at nighttime
  - Optimal time to inspect is late afternoon after things have heated up
  - Wind speeds need to be less than 8 mph

- SHADED AREAS (Generally)
  - Voided areas appear as hot spots in daytime
  - Voided areas appear as cold spots at nighttime

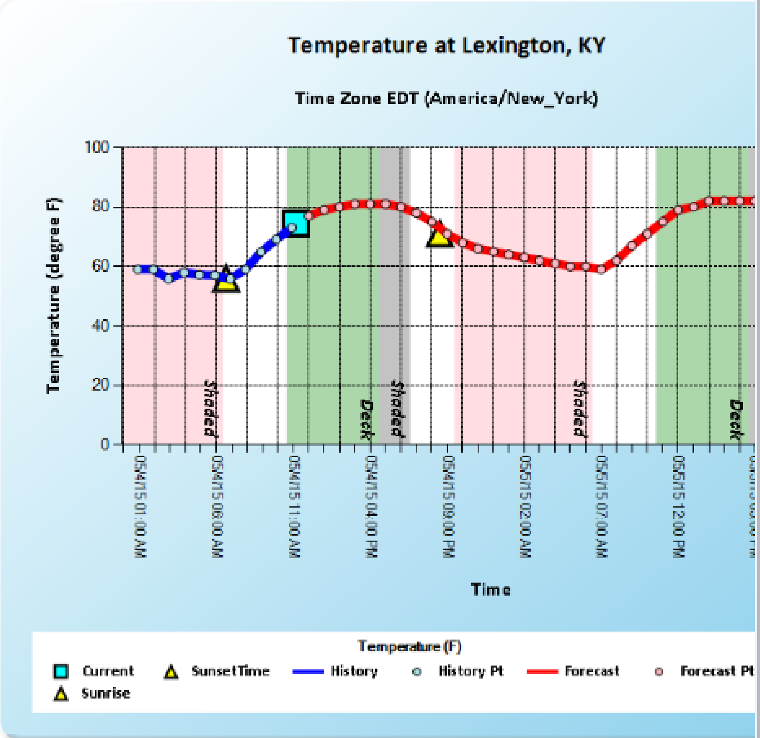
- Weather Link

IR Bridge Inspection Planner (IR BIP)

Auto Locate

Current Location: Lexington, KY

Current Conditions	Deck Daytime	Shaded Daytime
		
Inspection Window	5/4/2015 10:38:00 AM to 5/4/2015 4:38:00 PM	5/4/2015 10:38:00 AM to 5/4/2015 6:38:00 PM
Time until Inspection (hh:mm)	00:31	00:31
Time left to Inspect (hh:mm)	05:29	07:29
Temperature Increase/Decrease 6 Hr After/Before Sunrise/Sunset(Degree F)	N/A	+23.1
Past 3hr Temperature Change (degree F/Hr)	+4.0	+4.0
Temperature Change Maximum (degree F)	N/A	25.1
3 Hr Windspeed Average (mph)	+10.0	N/A



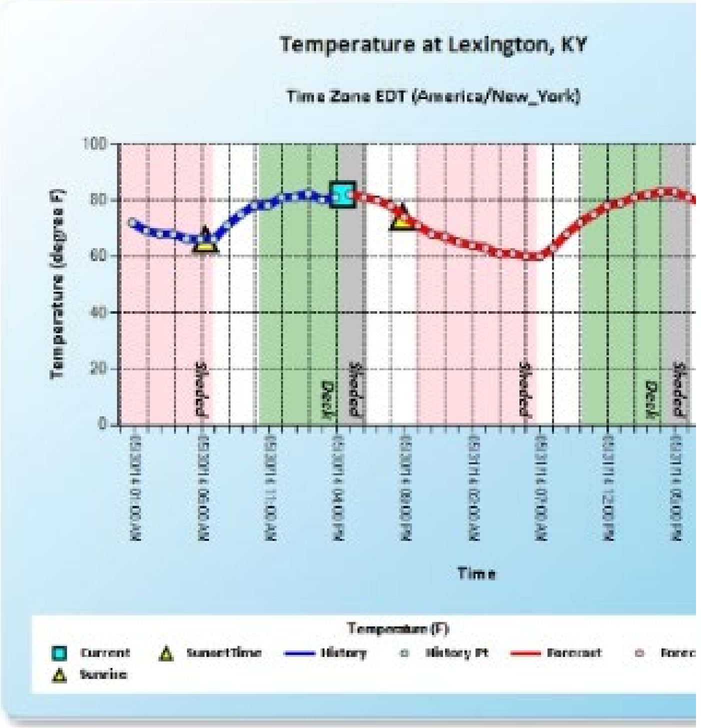
TPF-5(247) THERMOGRAPHY PROJECT PHASE II

IR Bridge Inspection Planner (IR BIP)

Auto Locate

Current Location: Lexington, KY

Current Conditions	Deck Daytime	Shaded Dayti
		
Inspection Window	5/30/2014 10:17:00 AM to 5/30/2014 4:17:00 PM	5/30/2014 10:17:00 5/30/2014 6:17:0
Time until Inspection (hh:mm)	06:13	06:13
Time left to Inspect (hh:mm)	00:00	01:47
Temperature Increase/Decrease 6 Hr After/Before Sunrise/Sunset(Degree F)	N/A	+15.0
Past 3hr Temperature Change (degree F/Hr)	-0.7	-0.7
Temperature Change Maximum (degree F)	N/A	16.4
3 Hr Windspeed Average (mph)	+7.7	N/A



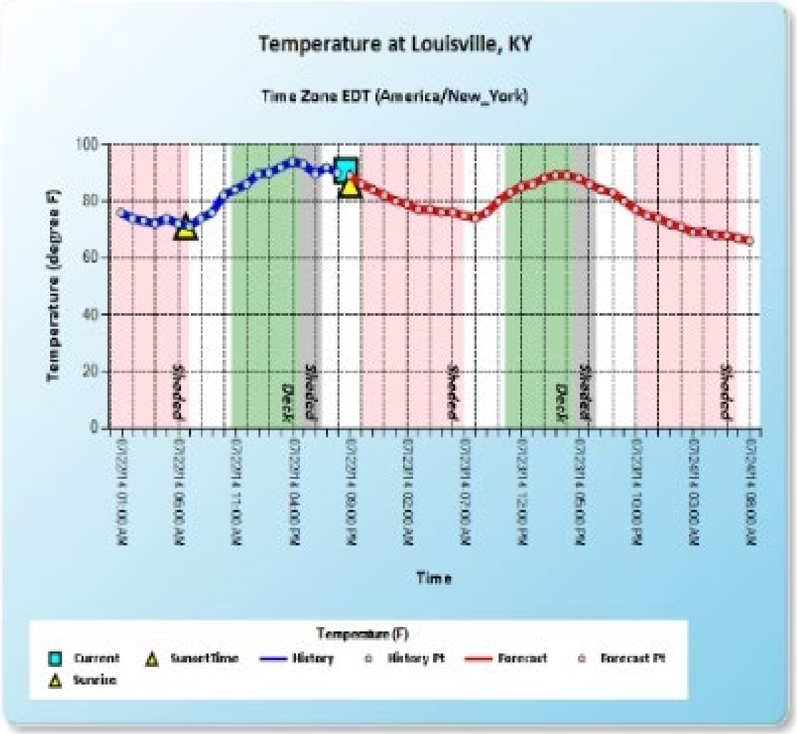
TPF-5(247) THERMOGRAPHY PROJECT PHASE II

IR Bridge Inspection Planner (IR BIP)

Auto Locate

Current Location: Louisville, KY

Current Conditions	Deck Daytime	Shaded Daytime	Shaded Nighttime
			
Inspection Window	7/22/2014 10:37:00 AM to 7/22/2014 4:37:00 PM	7/22/2014 10:37:00 AM to 7/22/2014 6:37:00 PM	7/22/2014 10:01:00 PM to 7/23/2014 7:01:00 AM
Time until Inspection (hh:mm)	10:00	10:00	01:24
Time left to Inspect (hh:mm)	00:00	00:00	09:00
Temperature Increase/Decrease 6 Hr After/Before Sunrise/Sunset(Degree F)	N/A	+18.5	-7.9
Past 3hr Temperature Change (degree F/Hr)	+0.2	+0.2	+0.2
Temperature Change Maximum (degree F)	N/A	22.8	-19.9
3 Hr Windspeed Average (mph)	+8.1	N/A	N/A



Problems

National Oceanic and Atmospheric Administration

U.S. Department of Commerce

The website you are trying to access is not available at this time due to a lapse in appropriation.

NOAA.gov and specific NOAA websites necessary to protect lives and property are operational and will be maintained during this partial closure of the U.S. Government.

See weather.gov for forecasts and critical weather information.

NOAA Federal Employees: Go to the NOAA Furlough information page for information, forms and other resources related to the shutdown.

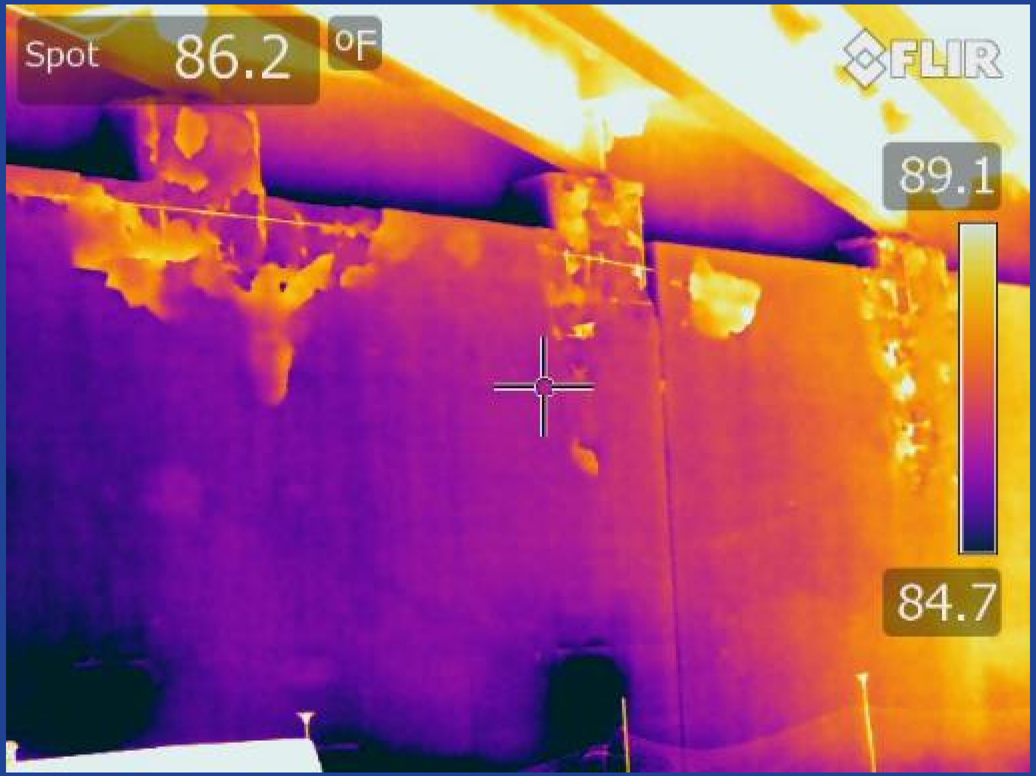
1.)NOAA can be closed ☹

2.) 30 years of historical weather data indicates IR would only work in Kentucky 62 days out of 365 days on average

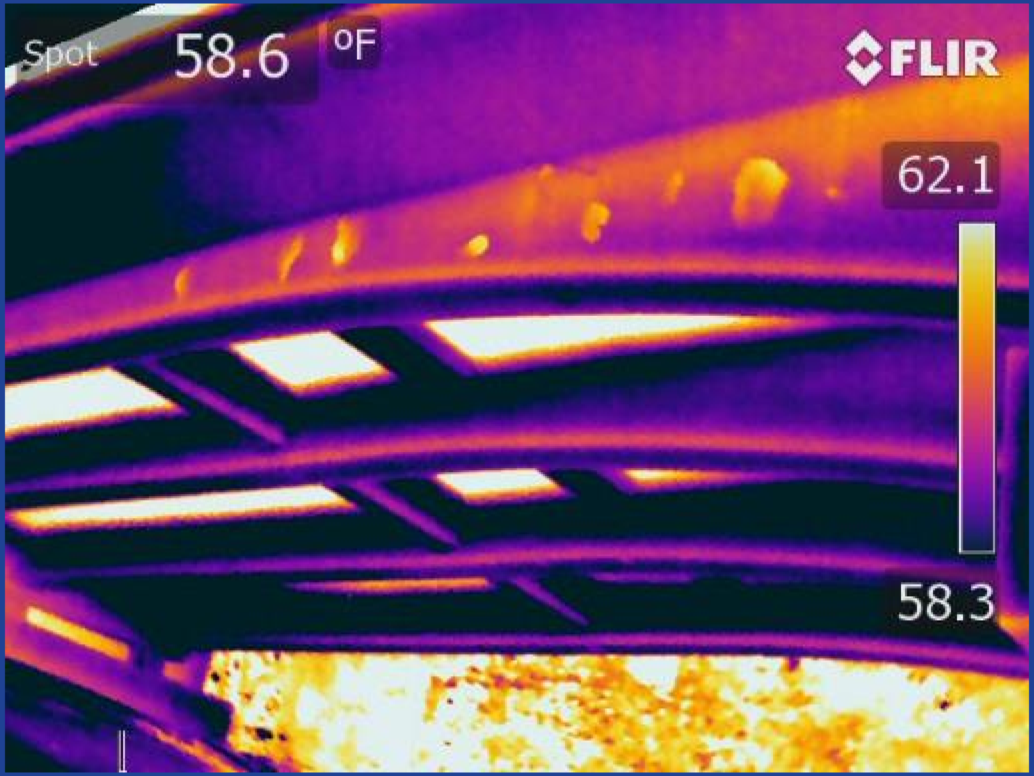
Application of Infrared Technology in Kentucky

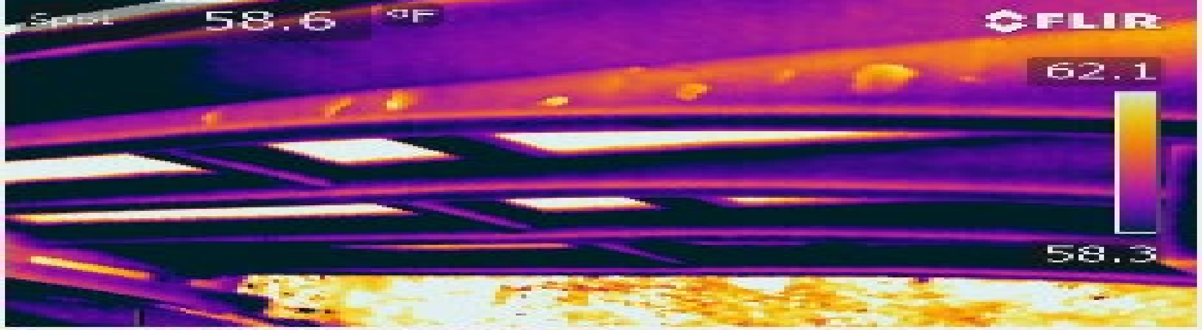
Arched Beams

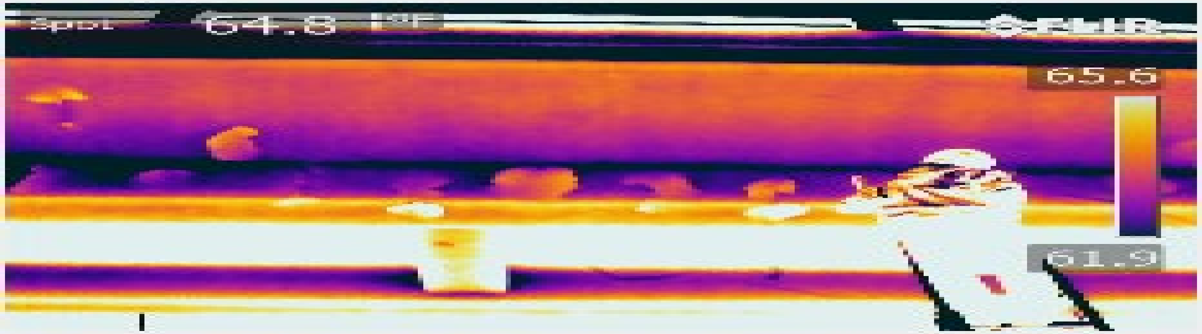
Abutments

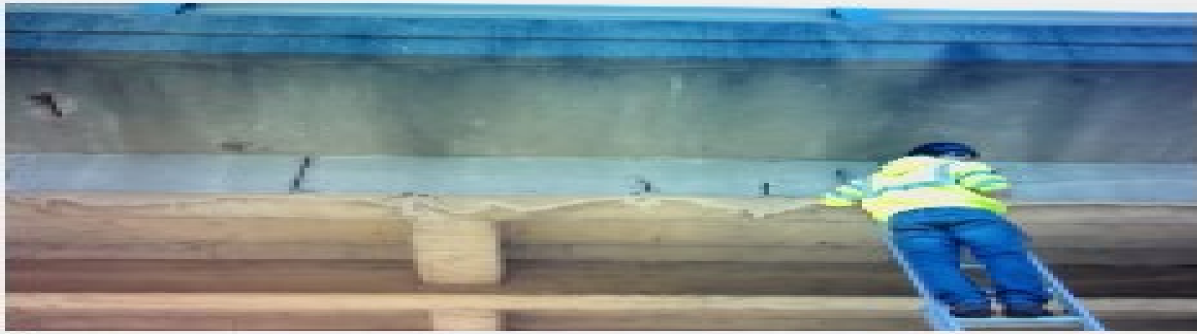


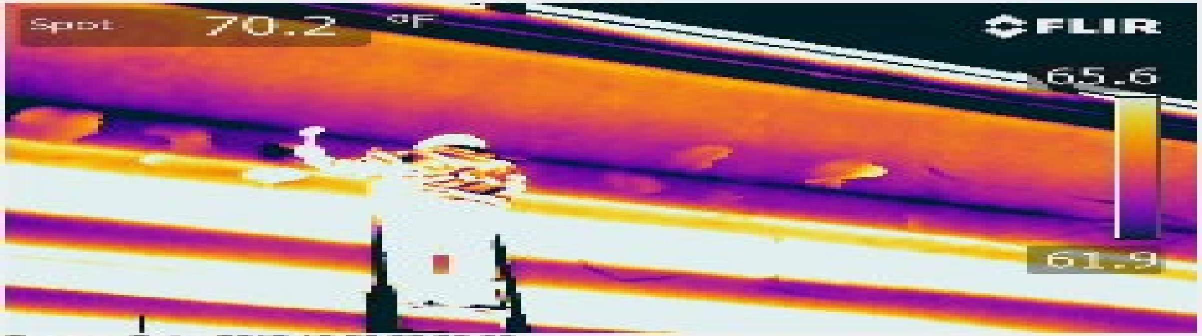
Soffit Areas

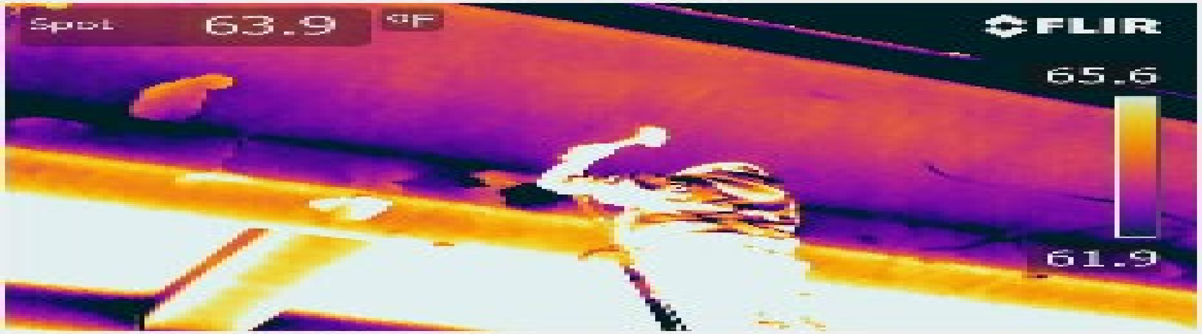



Spot 58.6 °F
FLIR
62.1
58.3


Spot 64.8 °F
FLIR
65.6
61.9

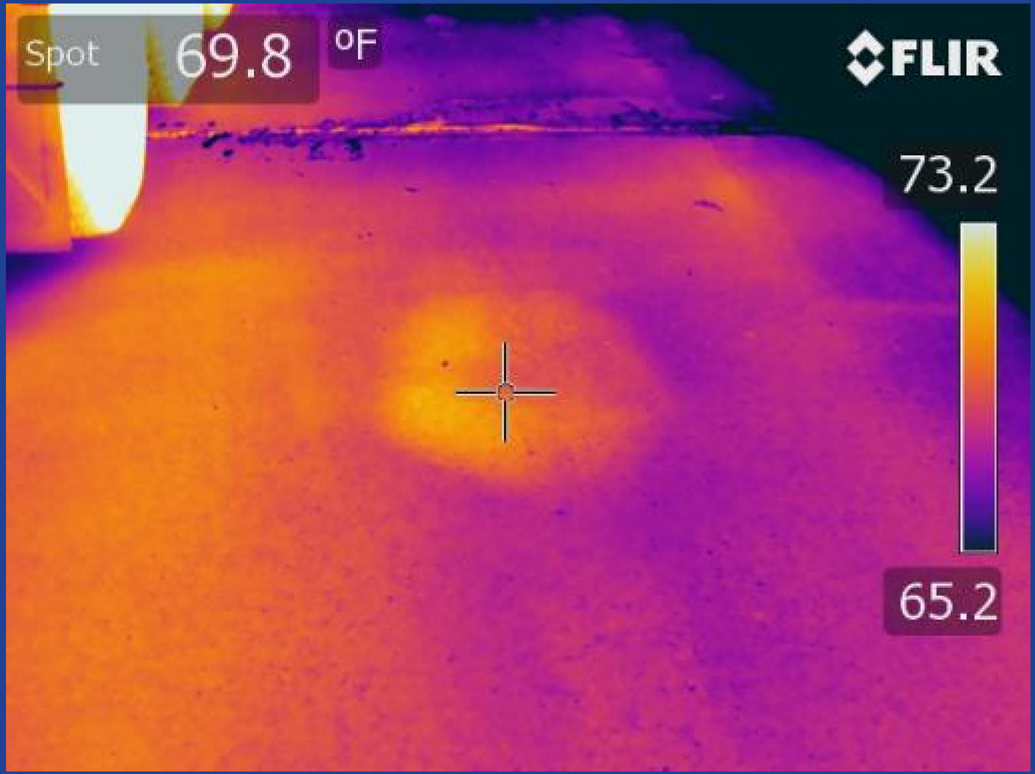


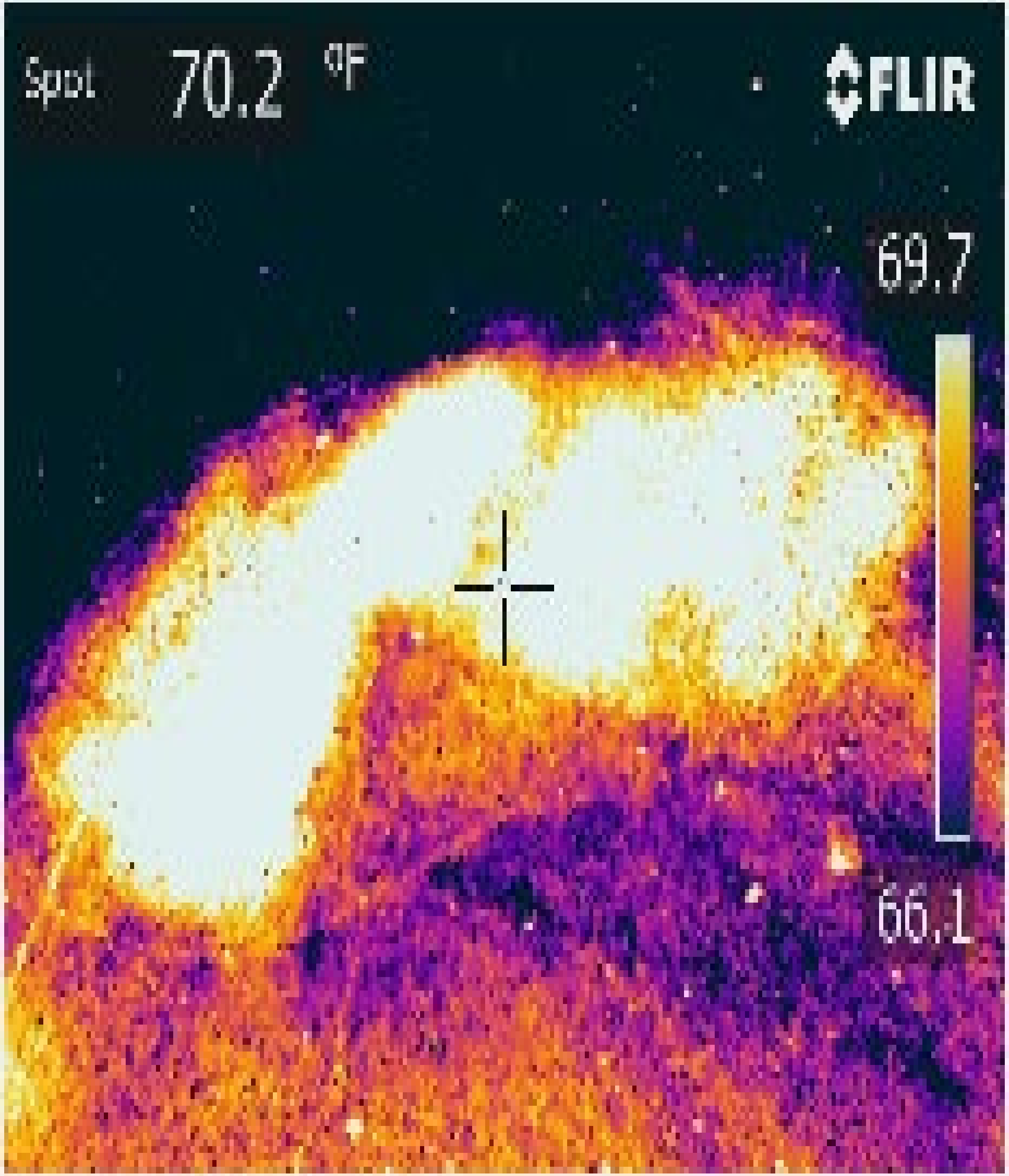

Spot 70.2 °F
FLIR
65.6
61.9


Spot 63.9 °F
FLIR
65.6
61.9

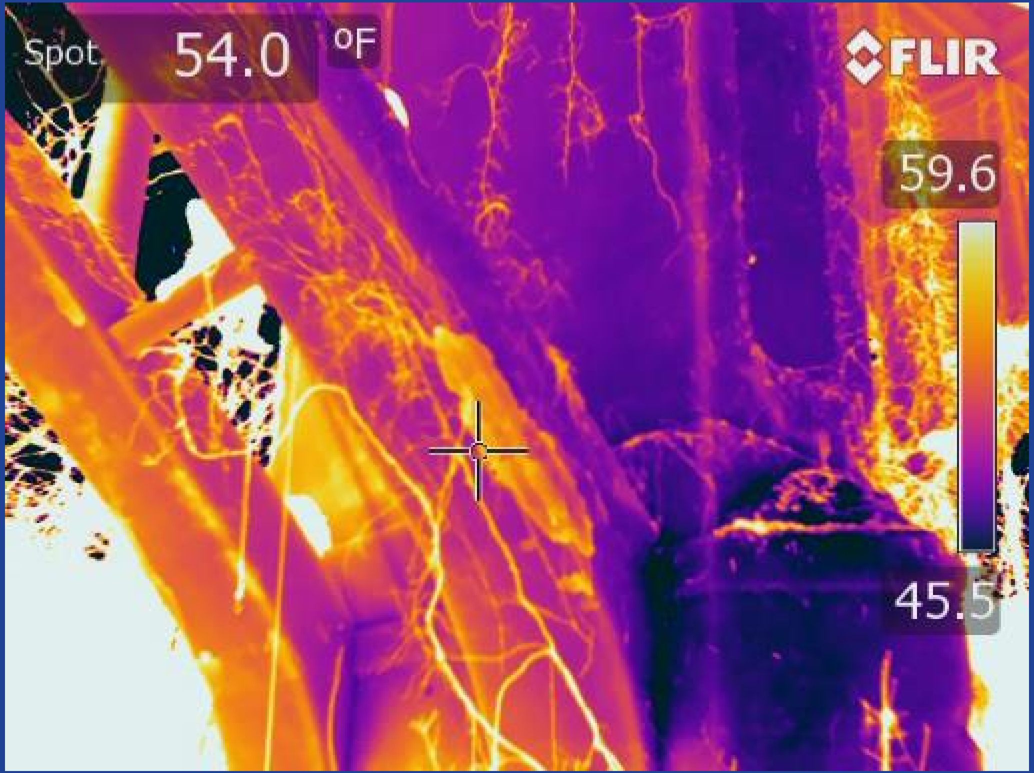
Voids in Cables

Bridge Decks

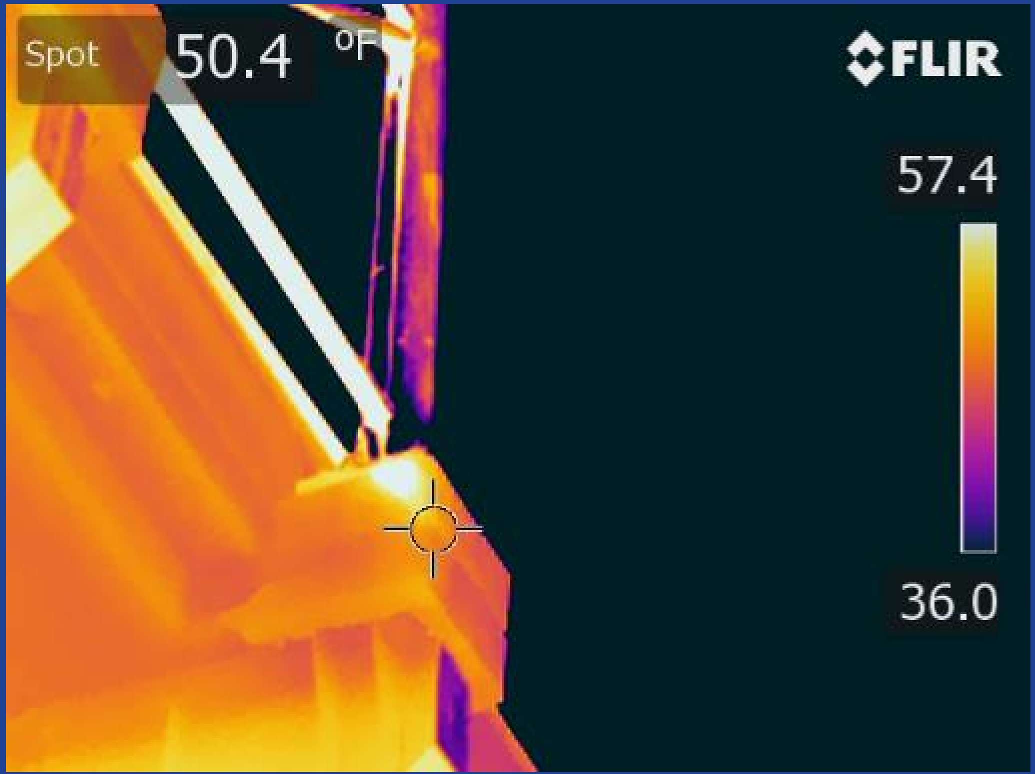



Spot
70.2 °F
FLIR
69.7
66.1

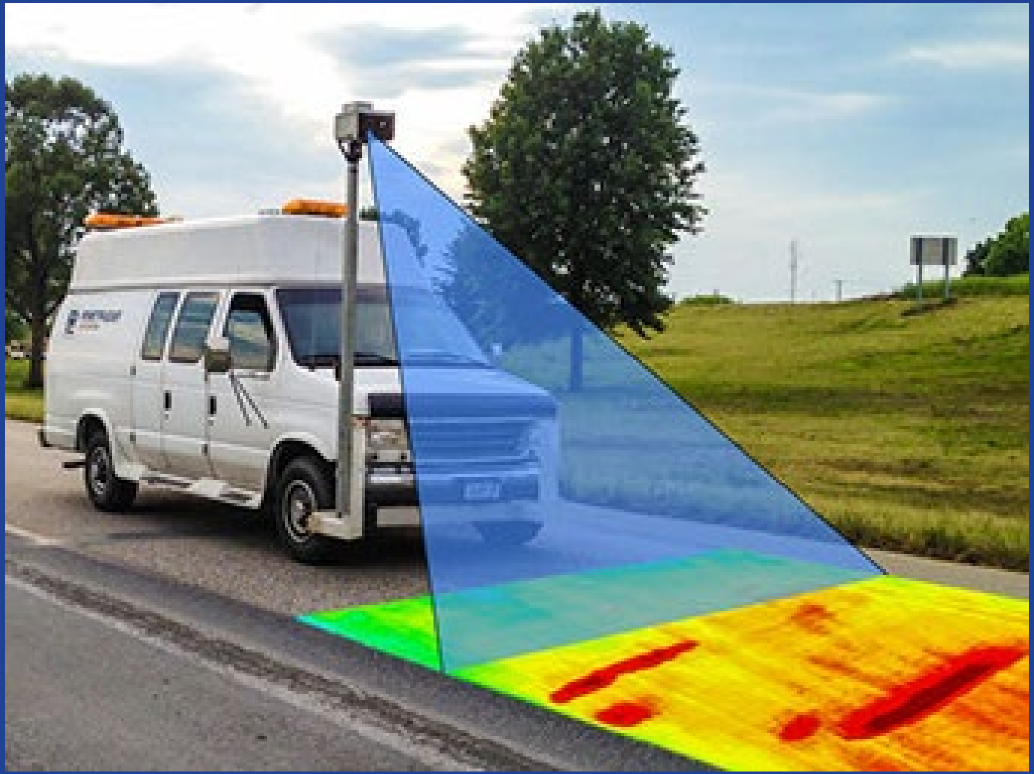
Problems with Vegetation



Sun exposed areas with shadowing can be misleading



Challenges


Penetrader 2018

- Depends on when you scan—Heat Transfer delamination's will grow/shrink throughout the day
- Truss shadow’s appear as cool spots
- Weather—When to scan
- Environmental conditions need to be evaluated prior to deployment (hence thermal effects from river system)
- If quantities are needed, best to mark deteriorated areas in field while using thermographic technology

Impact Echo

- Will be evaluated in February 2019

Financial items to consider

- Scanning bridge decks may cost between $.5 -$1.00 / s.f. depending on size
- Scanning small bridges may be cost prohibitive compared to potential change orders
- However, it may save $1,000’s dollars on large bridges.

Thank you