Lessons Learned from an *Intelligent Compaction (IC) and Thermal Imaging (TI)* Workshop and Demonstration

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Gallagher Asphalt Corporation

2014 IAPA Annual Meeting, March 10-11, 2014

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Agenda

- What is Intelligent Compaction?
- Why do we care about IC?
- IC Background
- IC/TI Workshop and Demo
- What did we learn about IC?
- Thermal Imaging

What is Intelligent Compaction?

What is Intelligent Compaction?

a) ***Integrated*** compaction ***measurement*** technology (and other machine parameters, e.g., temperature) *and optional* *<u>compaction control</u>*

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What is Intelligent Compaction?

a) ***Integrated*** compaction ***measurement*** technology (and other machine parameters, e.g., temperature) *and optional compaction control*

b) Jobsite ***positioning data*** tied to the measurements being recorded (via GPS)

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a) ***Integrated*** compaction ***measurement*** technology (and other machine parameters, e.g., temperature) *and optional compaction control*

b) Jobsite ***positioning data*** tied to the measurements being recorded (via GPS)

c) Ability to ***store and analyze the data*** collected for real time display for operator decision making and document for future use

HAMM Double Drum IC System

HCQ GPS Navigator

GPS Receiver

Temperature Sensors

Accelerometer

Control Panel

Why do we care about IC?

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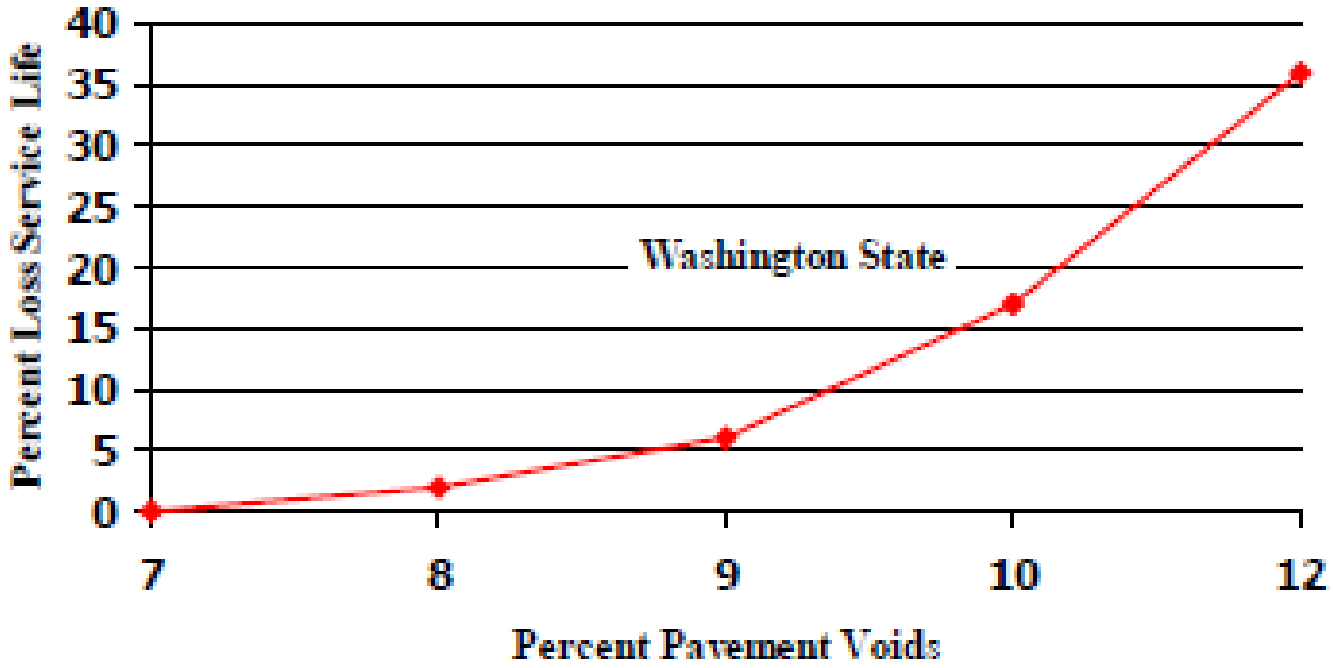
- We want to build long lasting, low life cycle cost asphalt pavements
- Compaction/density is key to asphalt pavement life
  - It increases interlocking of the aggregate particles, which is the primary factor in developing stability.
  - It retards the entrance of moisture, preventing excessive loss of stability under adverse service conditions.
  - It reduces the flow of air and water through bituminous mixtures and reduces damage from weathering and film stripping.

Basics of HMA Compaction

Effect of In-situ Air Voids on Life



Why do we care about IC?

- We want to build long lasting, low life cycle cost asphalt pavements
- Compaction/density is key to asphalt pavement life
- Conventional compaction techniques and QC procedures have some limitations…

Why do we care about IC?

- We want to build the best quality asphalt pavements we possibly can
- Compaction/density is key to asphalt pavement life
- Conventional compaction techniques and QC procedures have some limitations…
  - Relies on Operator judgement/performance
  - Small number of spot tests are run for evaluation

Trimble Study:
Roller Operator Blind Test

- Over a period of 20 hours of roller operation
  - 23% of the paved area was compacted **OVER** the target pass count
  - 40% of the paved area was compacted **UNDER** the target pass count
  - 37% of the paved area was compacted **AT** the target pass count

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- This leads to INCONSISTENT COMPACTION of the pavement

Spot tests cover only a small proportion of the quantities placed

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Why do we care about IC?

- We want to build long lasting, low life cycle cost asphalt pavements
- Compaction/density is key to asphalt pavement life
- Conventional compaction techniques and QC procedures have some limitations…
- Intelligent Compaction technology appears to offer the potential for improvement
  - Operator tool – pass count mapping for consistency
  - QC tool – view of entire mat stiffness and temperature

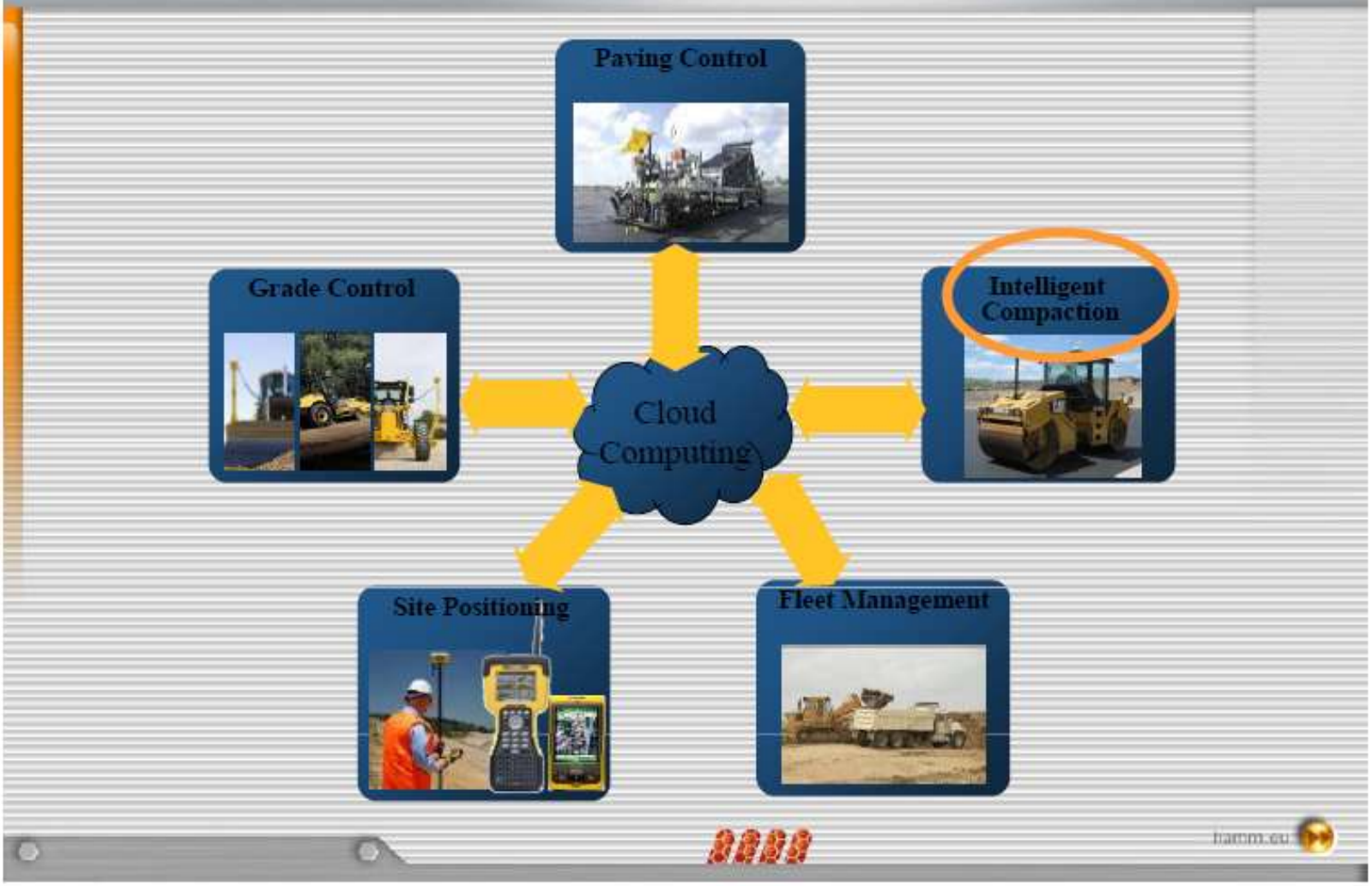
IC Background

- Originated in the 1970's and 80's
- Larger acceptance in Europe
- More focused on soils and base materials
- Began to gain US momentum in 2000's along with other intelligent construction activities

Intelligent Construction

WIRTGEN GROUP

HAMM



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IC Background

- Federal government has made IC a priority
- FHWA EDC2 program includes IC as an “Off-the-shelf technology” that we would benefit from rapid implementation
- TPF project with FHWA and 12 states demonstrating IC for soils/HMA through:
  - Field projects
  - Open house activities
  - Meetings and training

IC Background

- IC Workshops/Conferences
- IC Technical Support Service Center
- IC Retrofit Study Project
- FHWA IC-HMA Density Study
- IC TechBriefs
- IC Web-based training
- IC specs
- Most compaction equipment manufacturers are investing in IC technology for their equipment

IDOT IC/TI Workshop & Demo

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IDOT IC/TI Workshop & Demo

- In late 2012, IDOT expressed interest in doing an IC demonstration along with thermal imaging
- Through IAPA, Gallagher Asphalt agreed to participate in this effort
- Kicked off discussions at 2013 IAPA Annual Meeting
  - Dave Lippert (IDOT)
  - Matt Mueller (IDOT)
  - Larry Keach (Bomag)
  - Jim Trepanier (IDOT)
  - Hal Wakefield (FHWA)
  - Jim Trost (Gallagher)

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IDOT IC/TI Workshop & Demo

- Purpose:
  - Familiarize attendees with the fundamentals of intelligent compaction and thermal imaging
  - Demonstrate IC/TI equipment on an asphalt paving project and base material
  - Spread awareness of the potential benefits of IC/TI so attendees are more educated for their companies or organizations

IDOT IC/TI Workshop & Demo

- Date: September 25, 2013
- Format:
  - Educational sessions by all equipment manufacturers (5) at JFG Technical Center in Thornton, IL
  - 2 IC rollers set up to demonstrate in Thornton Yard
  - 3 IC rollers and Pave IR system set up on Gallagher jobsite
- Invitee's:
  - IAPA members, IDOT and FHWA personnel

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IDOT IC/TI Workshop & Demo

- Equipment Participating:
  - Bomag BW 278 AD roller with Asphalt Manager
  - Hamm HD120VVHF asphalt roller and 3410 Soils Compactor with HCQ IC System
  - Caterpillar CD54 asphalt roller with IC System
  - Trimble CCS Flex System on Gallagher roller
  - Moba Pave IR System

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IDOT IC/TI Workshop & Demo

- Location: Route 41 Relocation in Chicago
  - Extension of Lake Shore Drive
  - Former home of US Steel Southworks
  - Lakeside development project
  - Gallagher sub for Capital Cement
  - City of Chicago “Project of the Year”
- Gallagher Thornton Yard RAP pad

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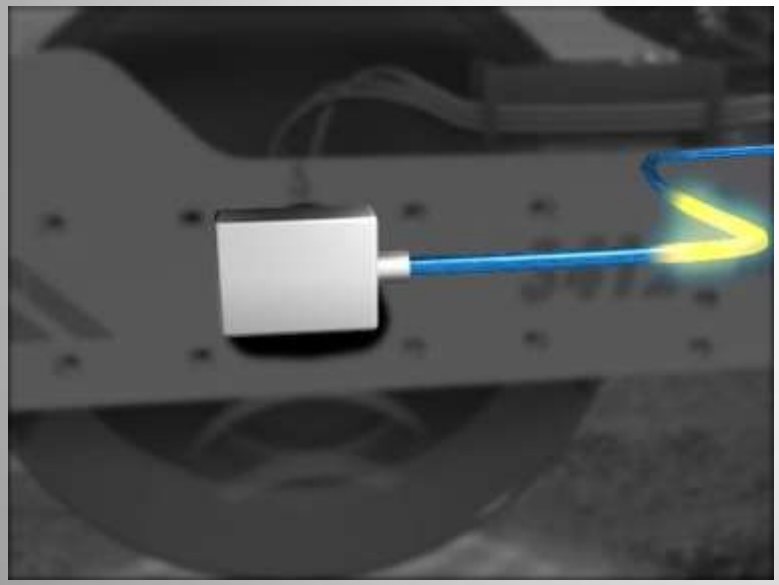
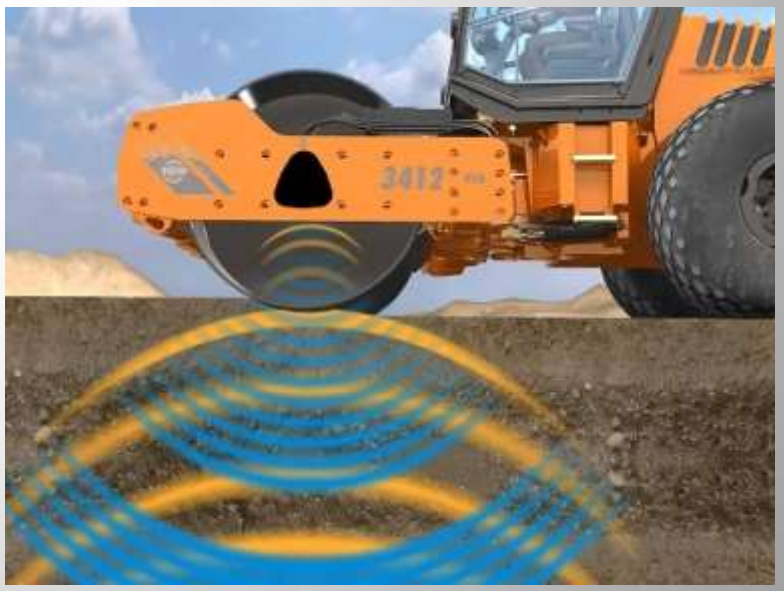
IDOT IC/TI Workshop & Demo

- Mix Information:
  - 2 inch Compacted Lift
  - IDOT 9.5 mm N90F Surface Course
    - Steel Slag Friction Aggregate
    - Polymer Modified PG 70-28 Asphalt Binder
    - RAP/RAS Recycled Materials

What did we learn?

Compaction Measurement - Stiffness





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Roller Measurement Values

Ammann

k_b

Caterpillar

CMV, MDP

HAMM/Wirtgen

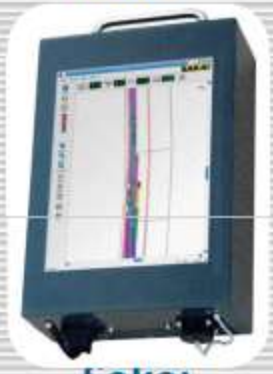
HMV

Bomag

E_{VIB}

Dynapac

CMV



Sakai

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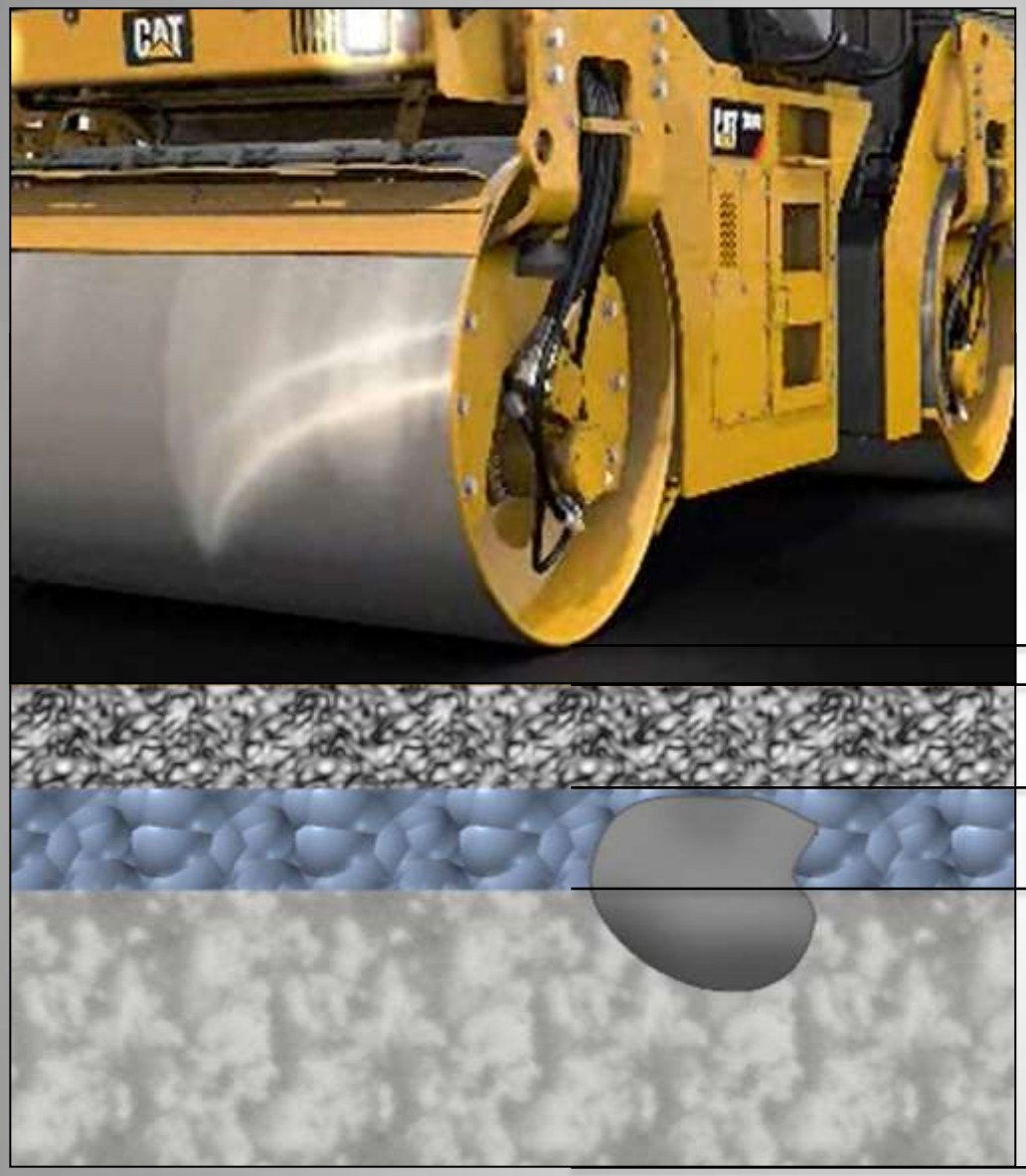
Stiffness ≠ Density

- Factors effecting stiffness readings:
  - Changing asphalt temperatures
  - Changing layer thickness
  - Non-homogeneous subbase
  - Accelerometers read deeper than the mat being compacted
- Other factors:
  - No static rollers
  - No oscillating drums



Accelerometer based technology measures deeper than the freshly laid lift of asphalt.

ICMV value is a ***composite of the current lift and the layers below it.***

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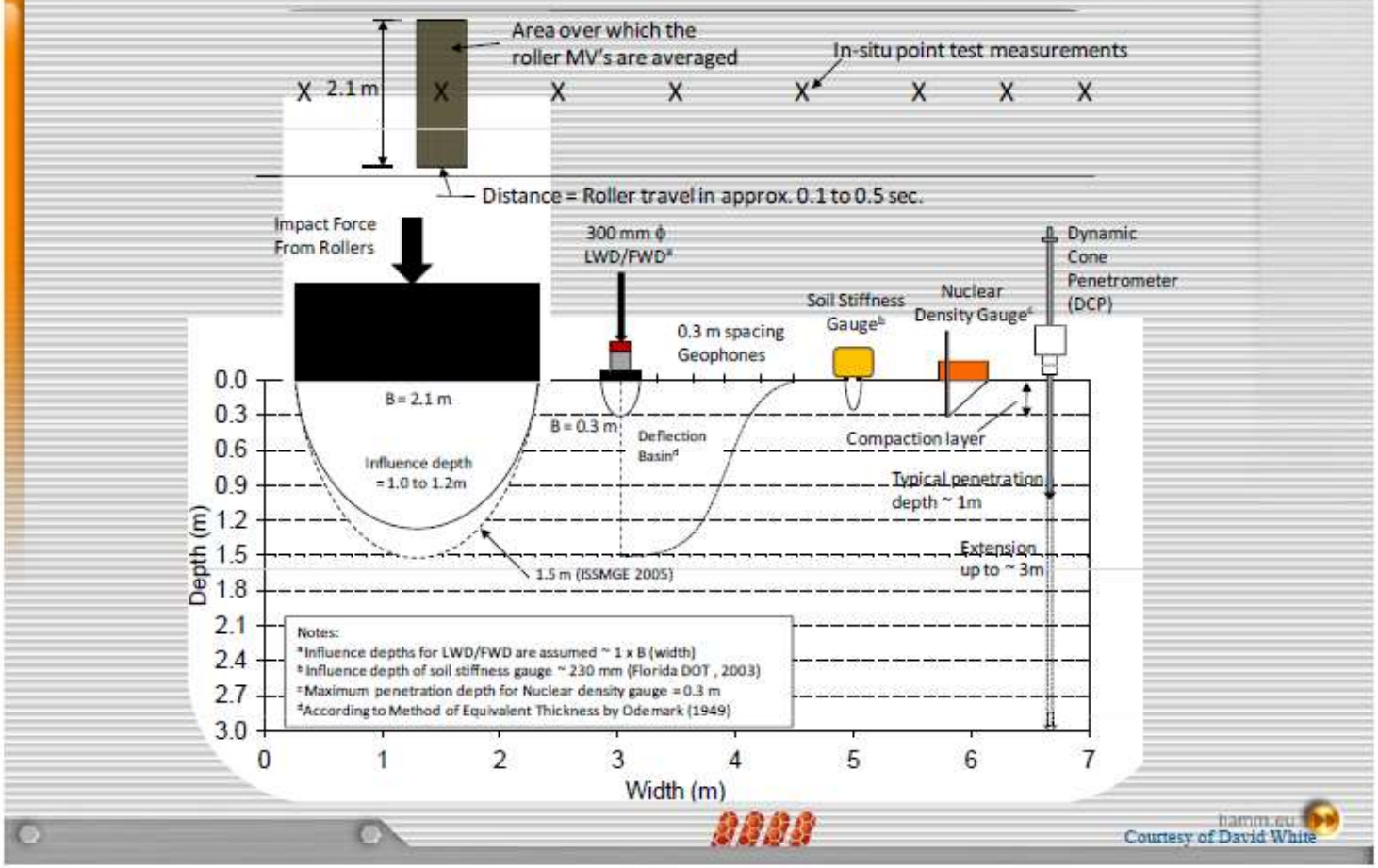
Correlation with In-Situ Testing



Courtesy of David White

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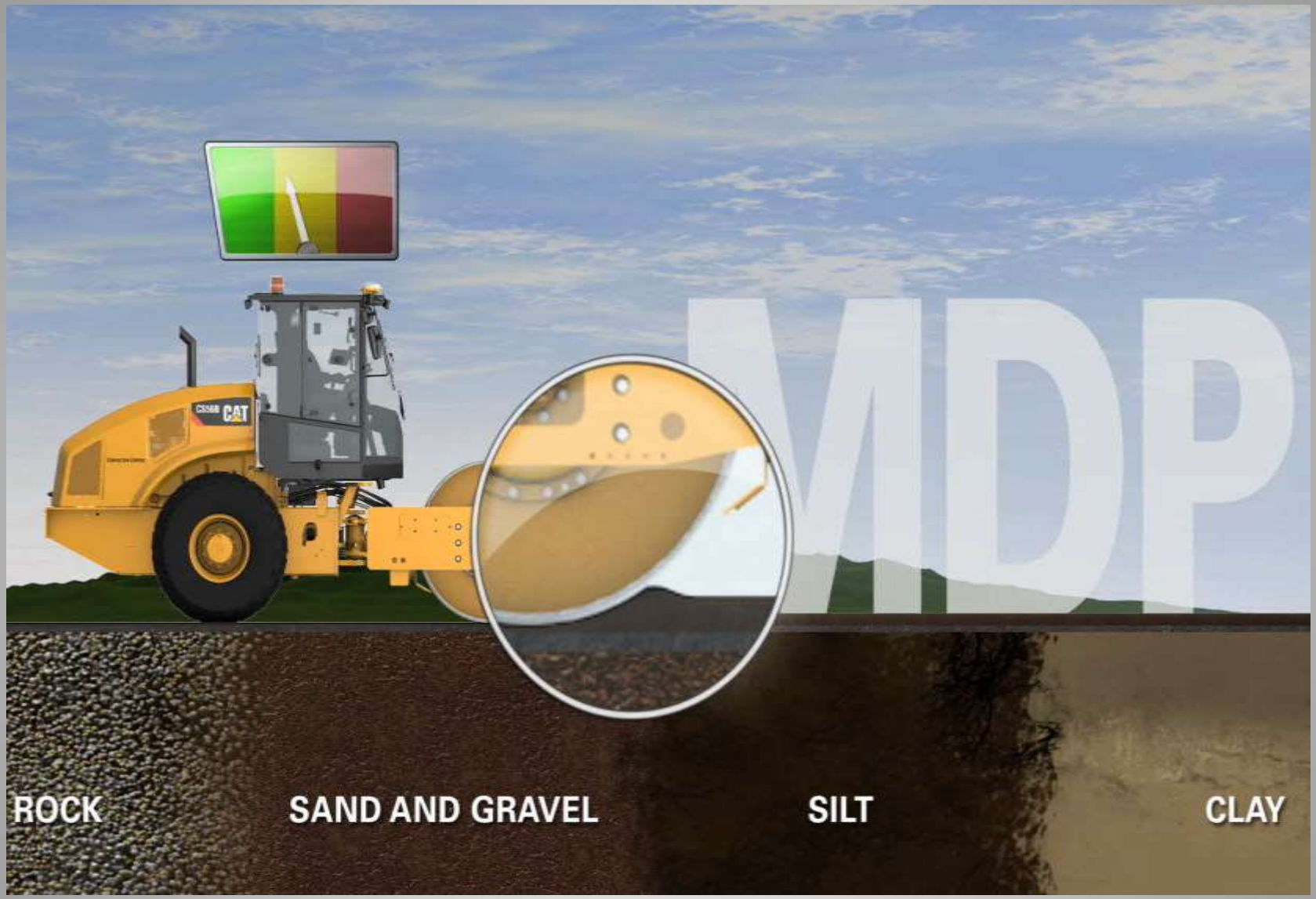
Stiffness ≠ Density

- Factors effecting stiffness readings:
- This is what we have to work with now
- FHWA trying to work on a correlation
- Roller mfg's are working on other methods
  - CAT using rolling resistance for soils/base rolling



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What else did we learn?

Roller Mfg Installed IC Systems vs. Retrofit Systems

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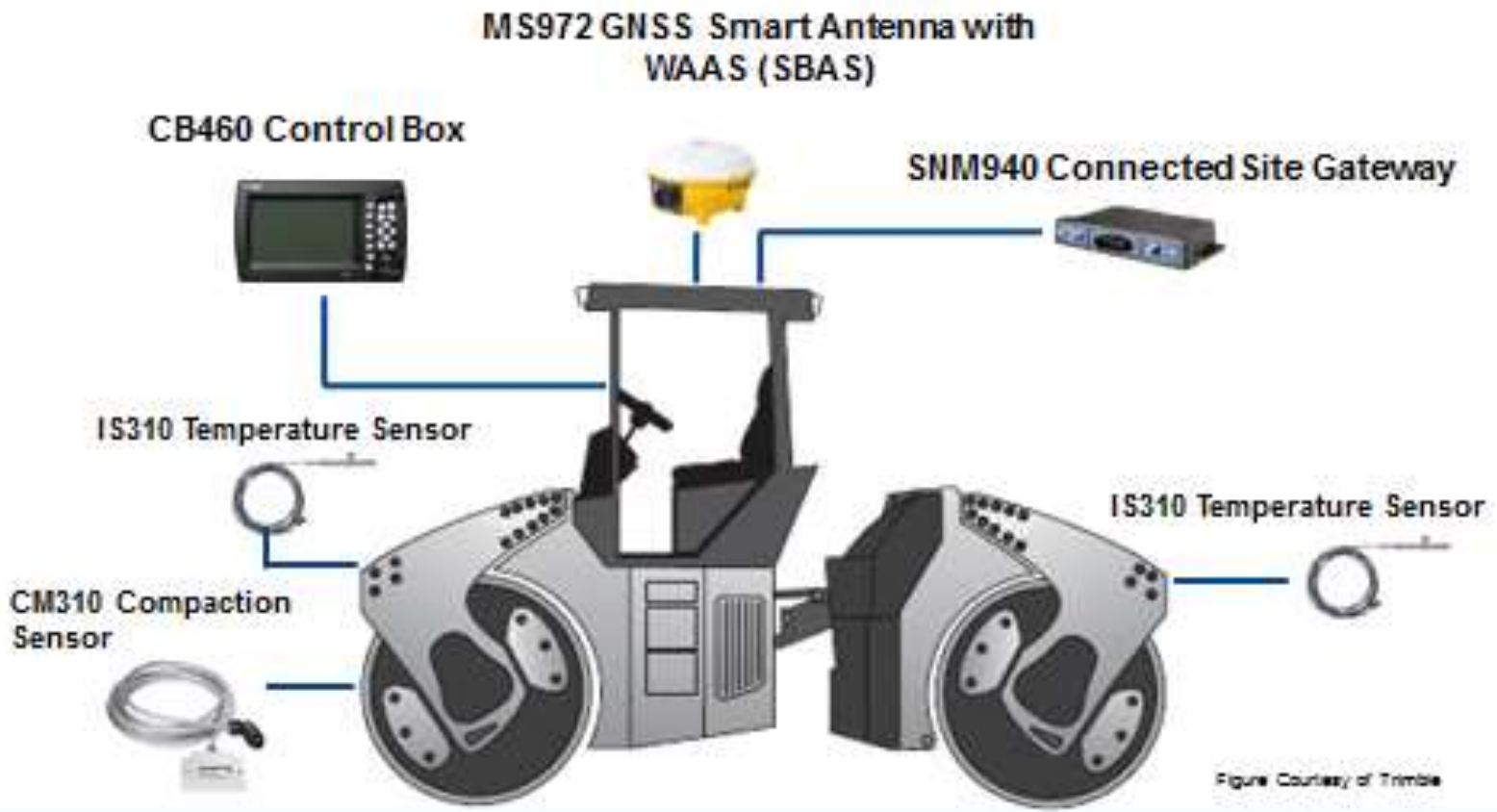
Roller Mfg Installed IC Systems vs. Retrofit Systems

- Trimble System was retrofit type

CCS900 Components Used for the Study

1. CB460 Control Box
2. SNM940 Connected Site Link
3. MS972 GPS Receiver with WAAS

Trimble IC Retrofit System Used
(CSS900 Components)



Roller Mfg Installed IC Systems vs. Retrofit Systems

- Trimble System was retrofit type
  - Not being designed into the machine created some nuisances for the operator
  - Screen was a bit small to easily read (4.3”)
  - Didn’t differentiate between vibe and static passes
  - System for pass count mapping cost is about $12k
  - Add temperature and stiffness capability and larger display moves it to upper $20k-$30k
  - Allows remote access through Trimble’s Vision Link system

Pass Count (20131001 180301) * - Veda

Close Project | Add File | Save | Report | Viewer | Editor | Layers | Point Tests | Analysis | Coordinate System | Screenshot | Options | Help | Add | Remove | Create Lots | Clear Lots | Layers

- Plan
- Design Files
- Sections
- Filters
- End Points

Fixed-Interval Sections

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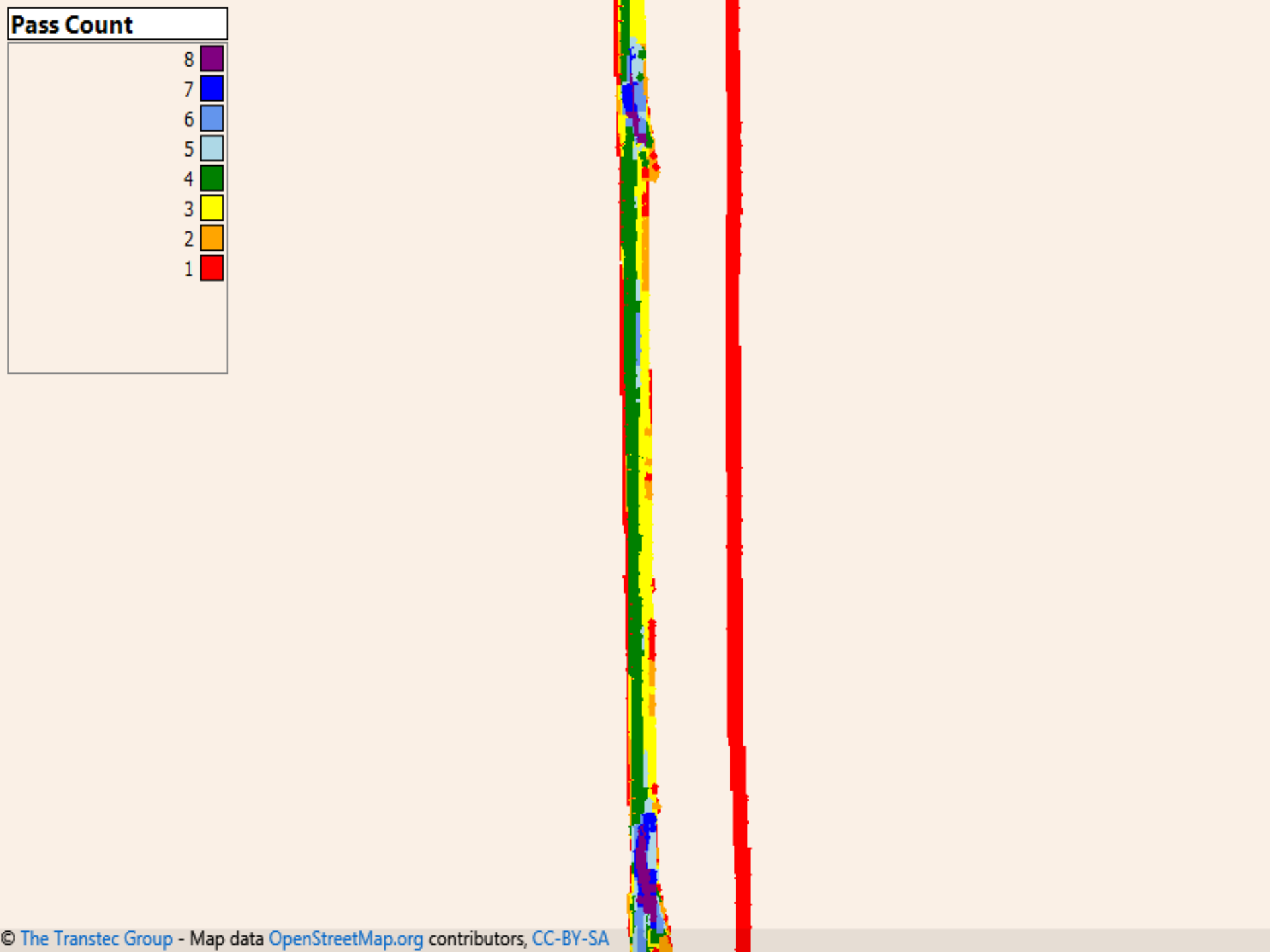
Stop	0	0

11:27 AM
2/24/2014



Roller Mfg Installed IC Systems vs. Retrofit Systems

- Trimble System was an Add-On type
- Other add-on systems out there

Roller Mfg Installed IC Systems vs. Retrofit Systems

- Trimble System was an Add-On type
- Other add-on systems out there
- FHWA study to evaluate the performance and reliability of these IC retrofit kits

Roller Mfg Installed IC Systems vs. Retrofit Systems

- Mfg installed IC systems:
  - Bomag
  - Hamm
  - Caterpillar
- Similarities and Differences

Mfg. Installed IC Systems

- Similarities:
  - All systems were easy to install, setup and get working

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Mfg. Installed IC Systems

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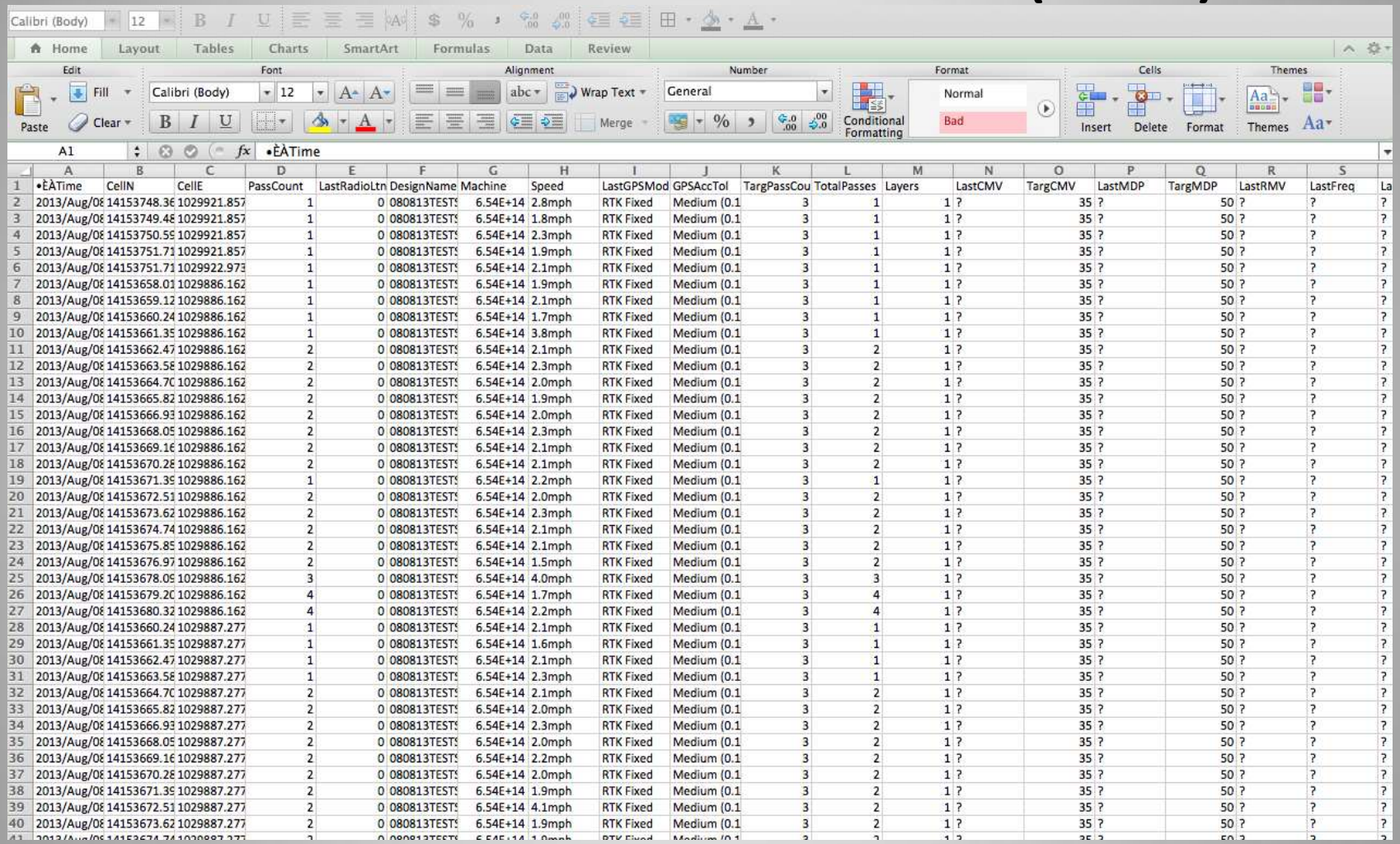
Mfg. Installed IC Systems

- Similarities:
  - All systems were easy to install, setup and get working
  - All systems have compaction measurement value displayed on the operator control panel
  - All systems have some flexibility in the setup of the graphical display
  - All systems generate data the same way

Data Files Generated (.csv)



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13	2013/Aug/08	14153664.70	1029886.162	2	0	080813TEST5	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
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28	2013/Aug/08	14153660.24	1029887.277	1	0	080813TEST5	6.54E+14	2.1mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
29	2013/Aug/08	14153661.35	1029887.277	1	0	080813TEST5	6.54E+14	1.6mph	RTK Fixed	Medium (0.1	3	1	1	?	35	?	50	?	?
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36	2013/Aug/08	14153669.16	1029887.277	2	0	080813TEST5	6.54E+14	2.2mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
37	2013/Aug/08	14153670.28	1029887.277	2	0	080813TEST5	6.54E+14	2.0mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
38	2013/Aug/08	14153671.39	1029887.277	2	0	080813TEST5	6.54E+14	1.9mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
39	2013/Aug/08	14153672.51	1029887.277	2	0	080813TEST5	6.54E+14	4.1mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?
40	2013/Aug/08	14153673.62	1029887.277	2	0	080813TEST5	6.54E+14	1.9mph	RTK Fixed	Medium (0.1	3	2	1	?	35	?	50	?	?

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Mfg. Installed IC Systems

- Similarities:
  - All systems were easy to install, setup and get working
  - All systems have compaction measurement value displayed on the operator control panel
  - All systems generate data the same way
    - Can be displayed in roller mfg's own software program or through VEDA or other software

Sample of Mfg. Installed IC System Output

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Sample of Mfg. Installed IC System Output

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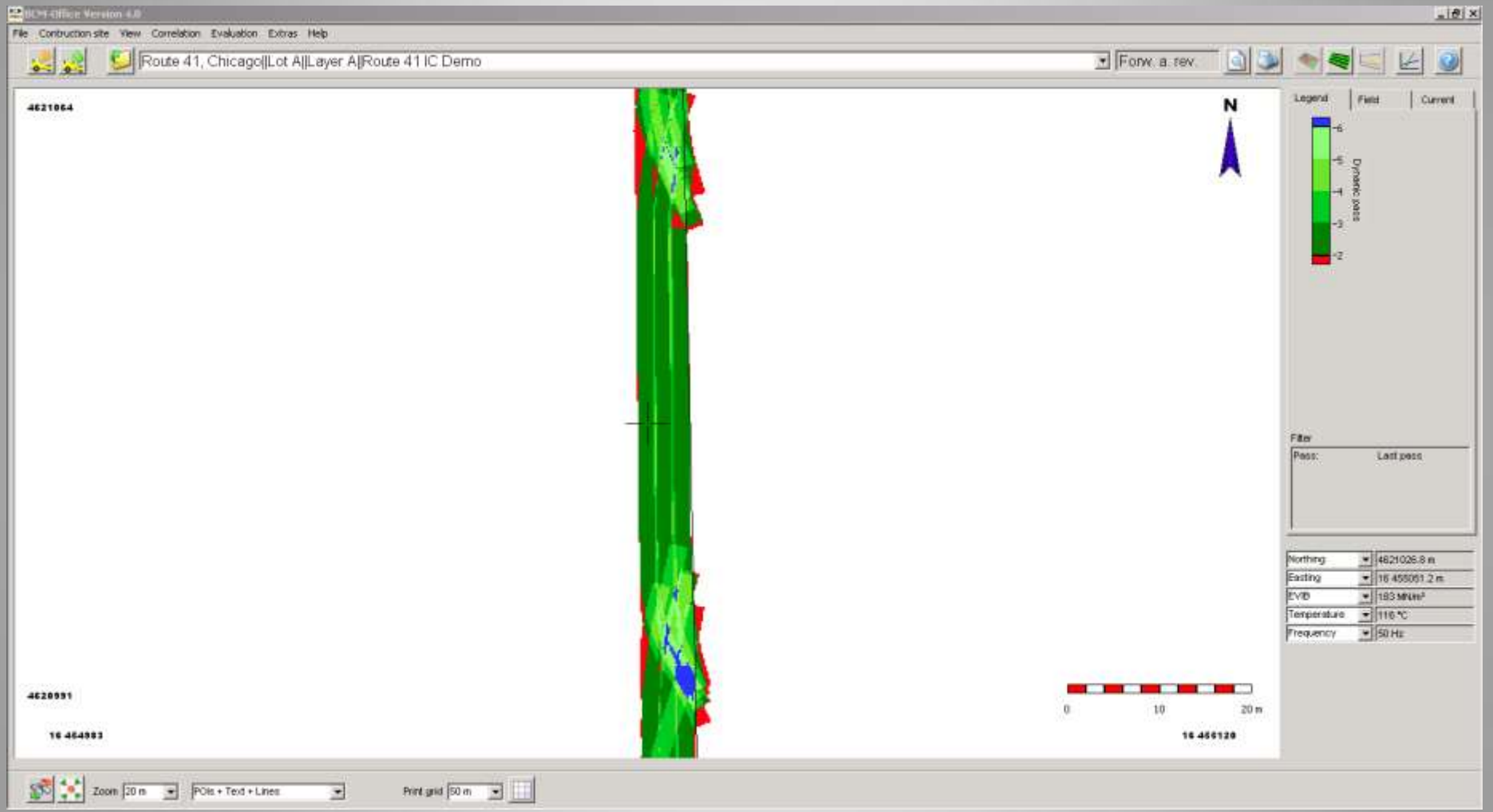
Sample of Mfg. Installed IC System Output



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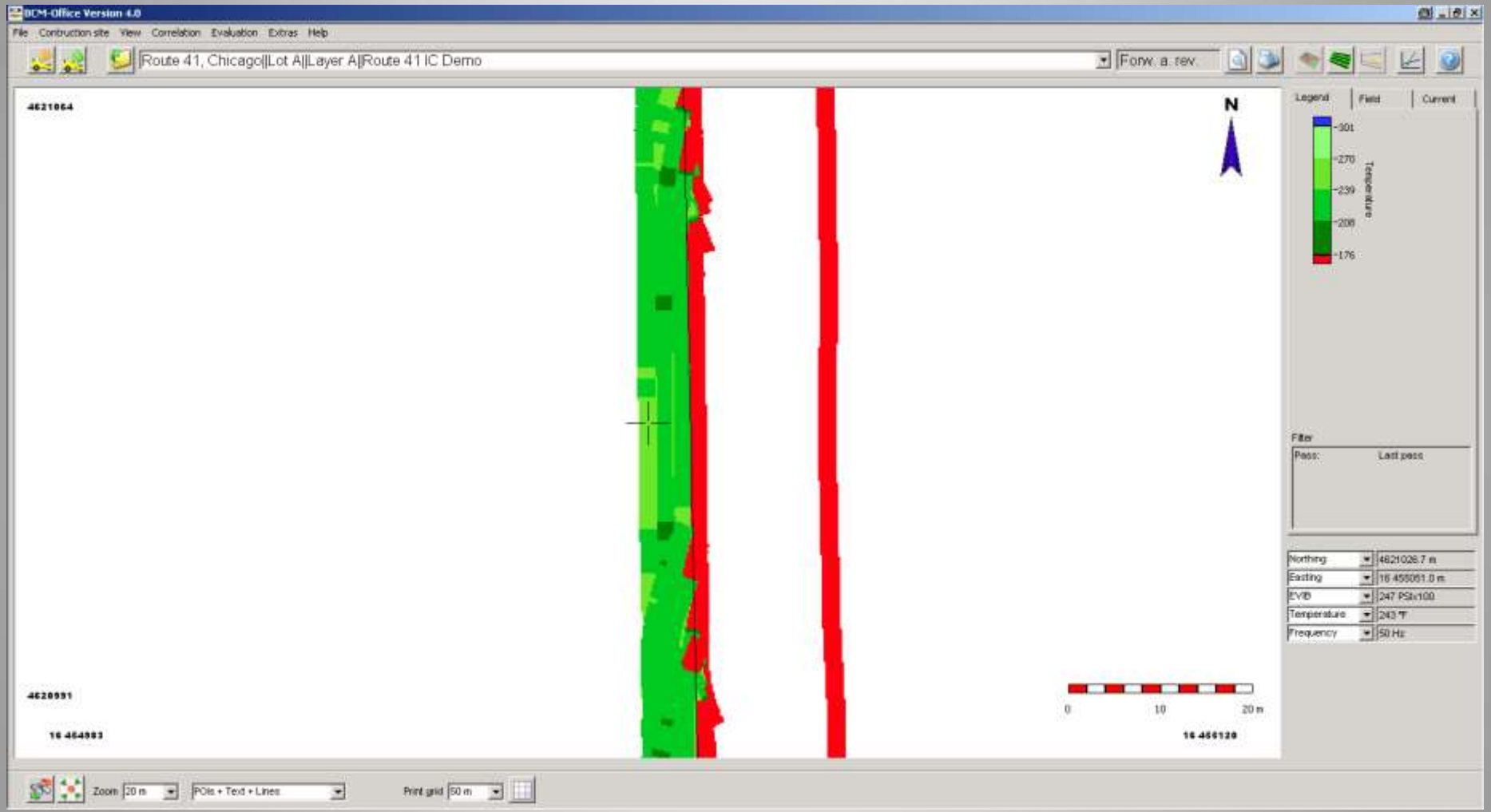
Sample of Mfg. Installed IC System Output



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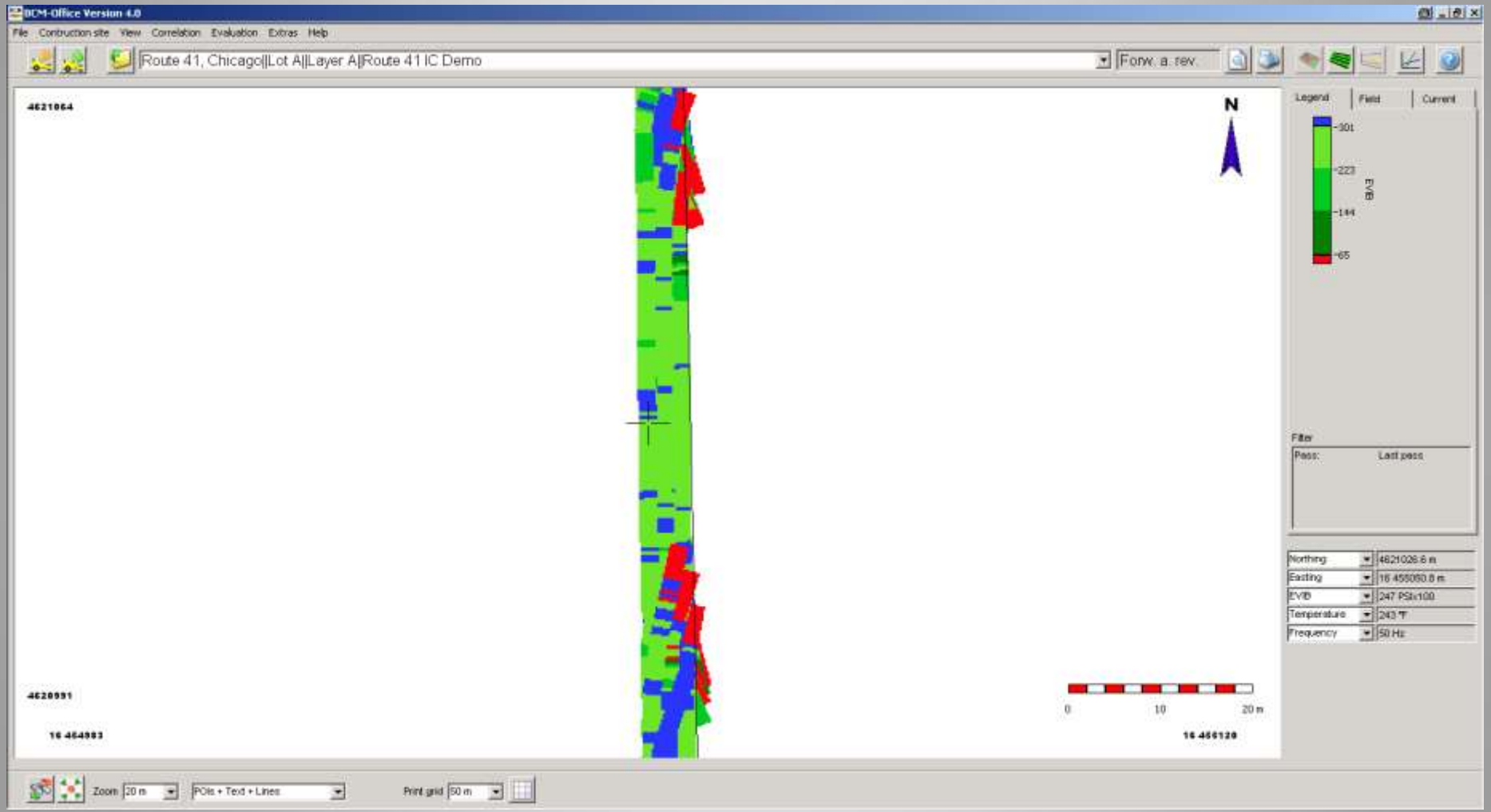
Sample of Mfg. Installed IC System Output



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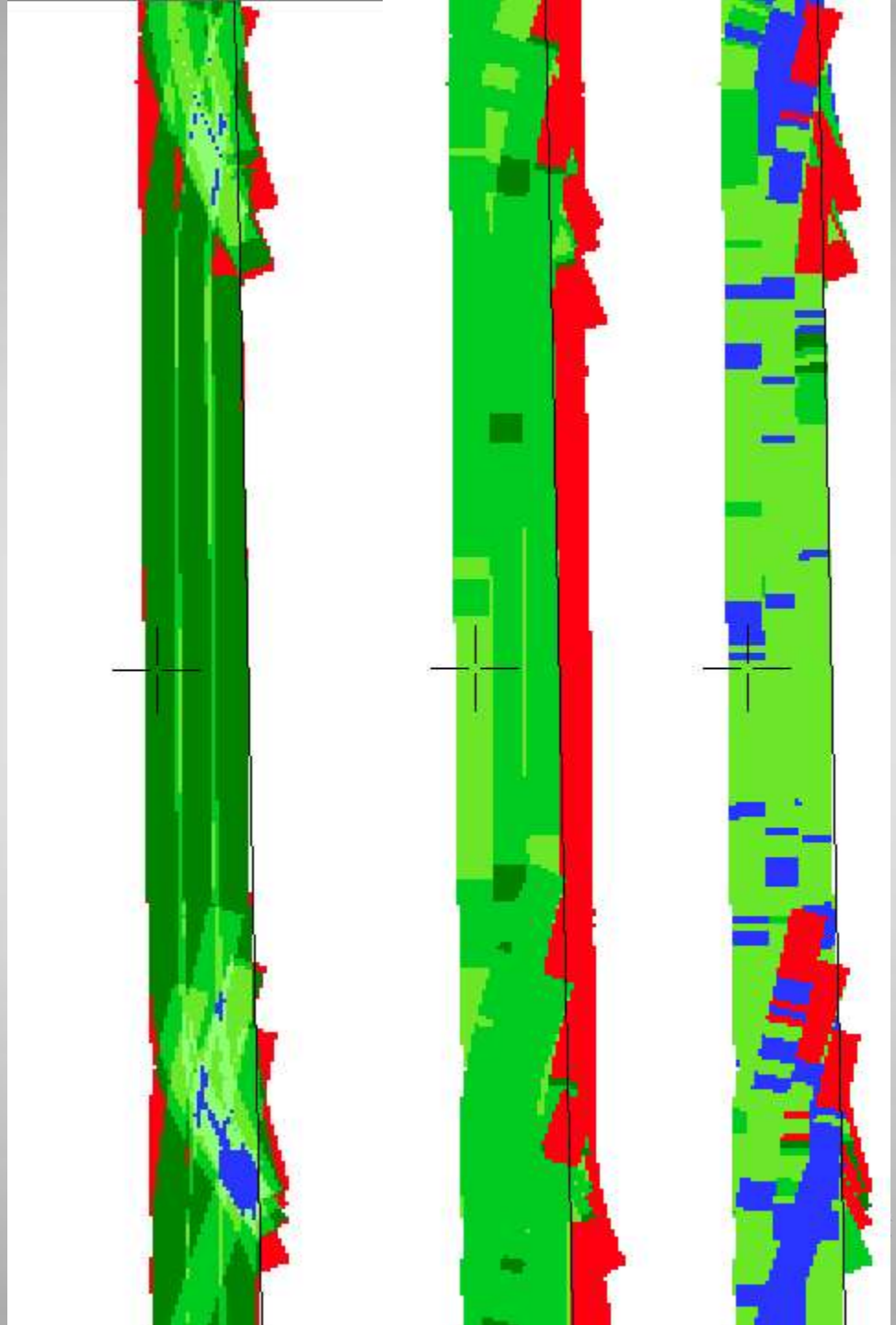

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Mfg. Installed IC Systems

- Similarities:
  - All systems were easy to install, setup and get working
  - All systems have compaction measurement value displayed on the operator control panel
  - All systems generate data the same way
  - Cost of a mfg. installed system is about $30-50k
    - Includes GPS and Panel PC for mapping/data logging

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  - All systems have compaction measurement value displayed on the operator control panel
  - All systems generate data the same way
  - Cost of a mfg. installed system is about $30-50k
  - Widely accepted by our roller operators and QC personnel

Mfg. Installed IC Systems

- Things that differentiated the systems:
  - No common compaction measurement value (stiffness)

Roller Measurement Values

Ammann

k_b

Caterpillar

CMV, MDP

HAMM/Wirtgen

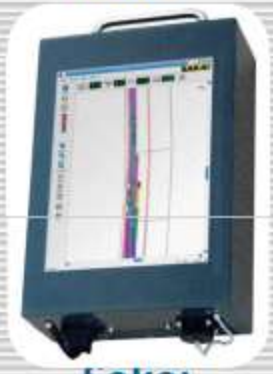
HMV

Bomag

E_{VIB}

Dynapac

CMV



Sakai

CCV

hamm.eu

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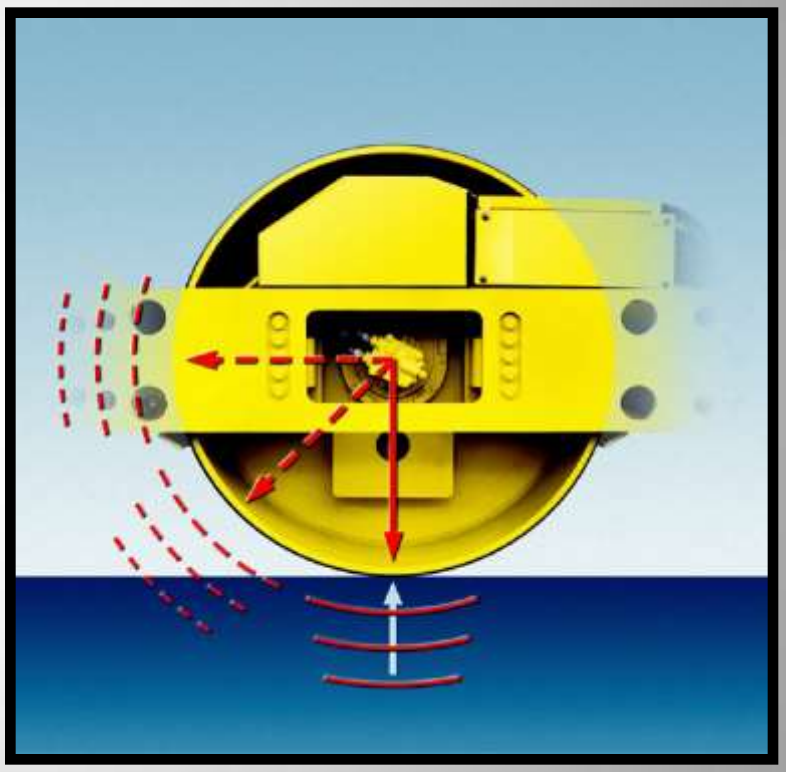
Mfg. Installed IC Systems

- Things that differentiated the systems:
  - No common compaction measurement value (stiffness)
  - Ability to control compaction energy based on measured stiffness readings (Bomag)


BOMAG


EVIB 279
0.4 mm
4.2 km/h



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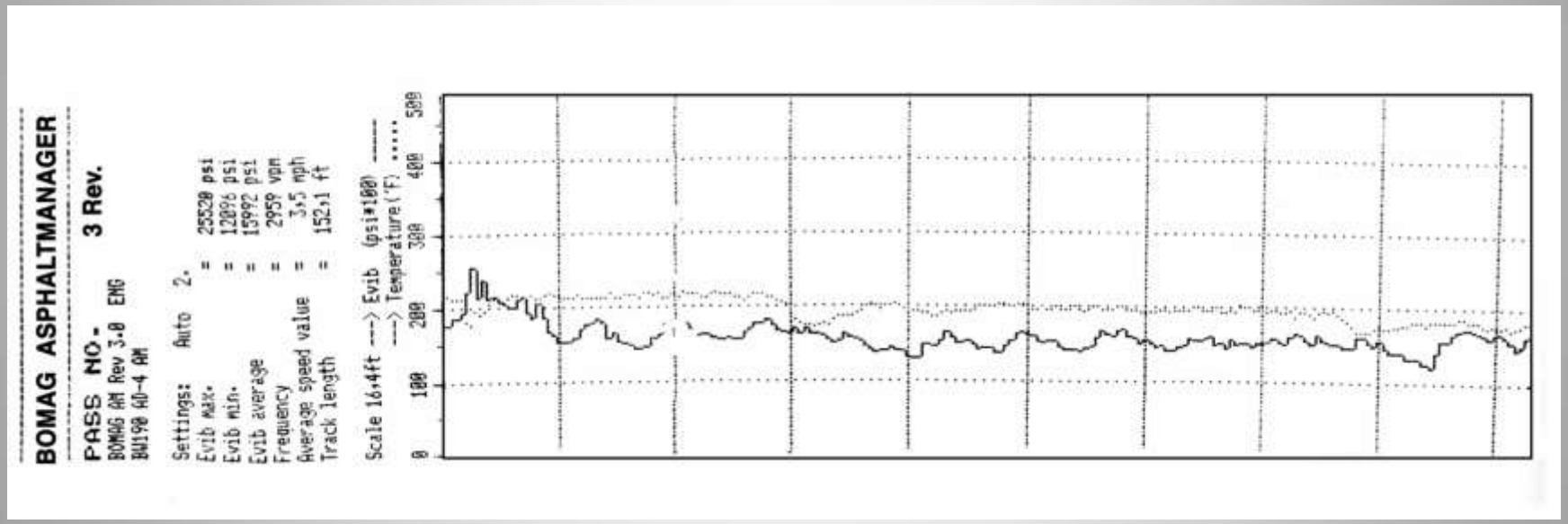
  - Ability to control compaction energy based on measured stiffness readings (Bomag)
  - Some rollers used 2 temperature probes vs. 1
  - Some systems have local printer capability

Local Printout of Stiffness & Temp



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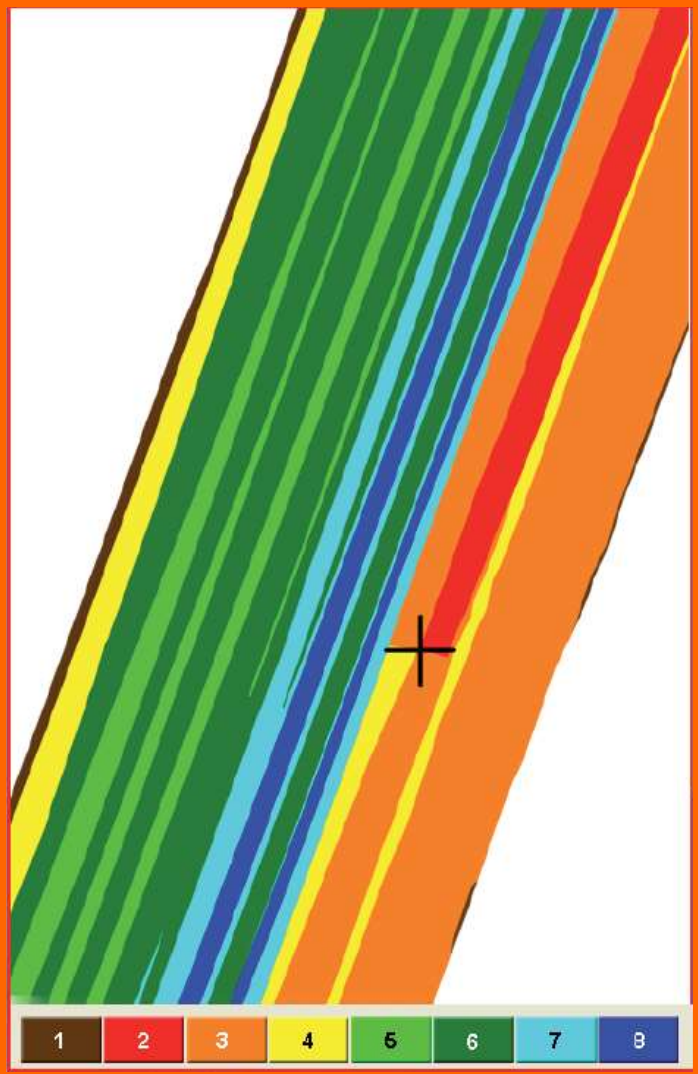
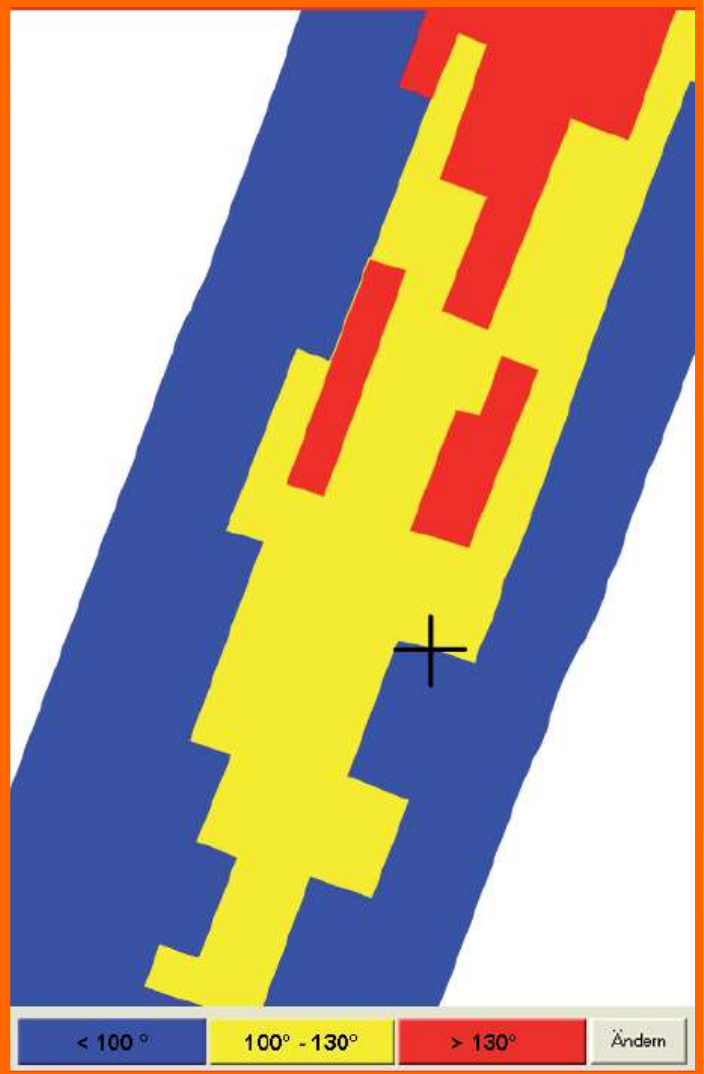
  - Ability to control compaction energy based on measured stiffness readings (Bomag)
  - Some rollers used 2 temperature probes vs. 1
  - Some systems have local printer capability
  - Some systems can push the current job data to the cloud for remote monitoring/evaluation

Mfg. Installed IC Systems

- Things that differentiated the systems:
  - Hamm system had several unique features:
    - Allows viewing multiple variables simultaneously

Passes	Temperature
	

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Mfg. Installed IC Systems

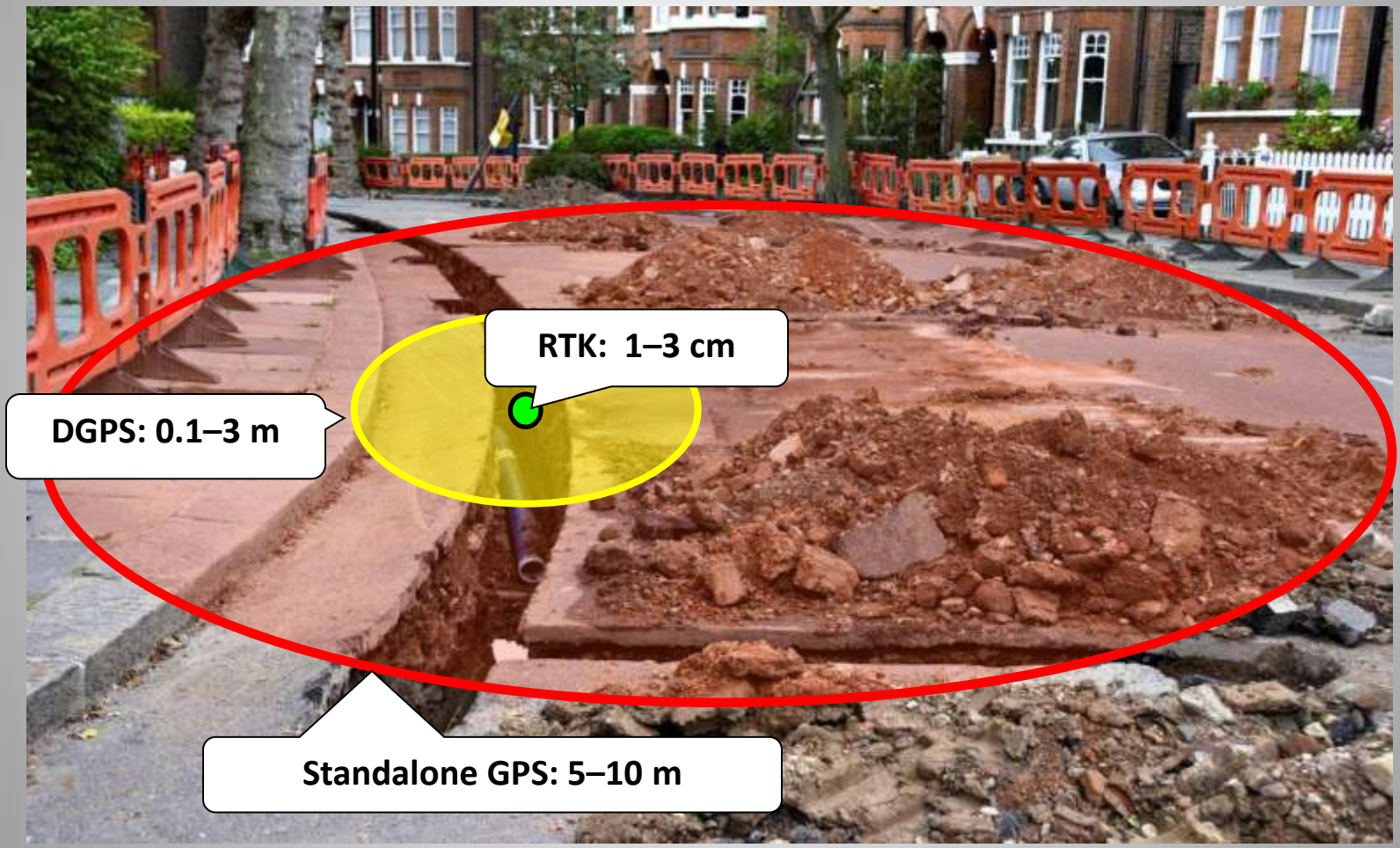
- Things that differentiated the systems:
  - Hamm system had several unique features:
    - Allows viewing multiple variables simultaneously
    - Multiple rollers can communicate via wifi (up to 3)
    - Steering sensor used to fill in the gaps when GPS is interrupted
    - GPS receiver and Panel PC can be swapped to another Hamm IC roller with no setup issues

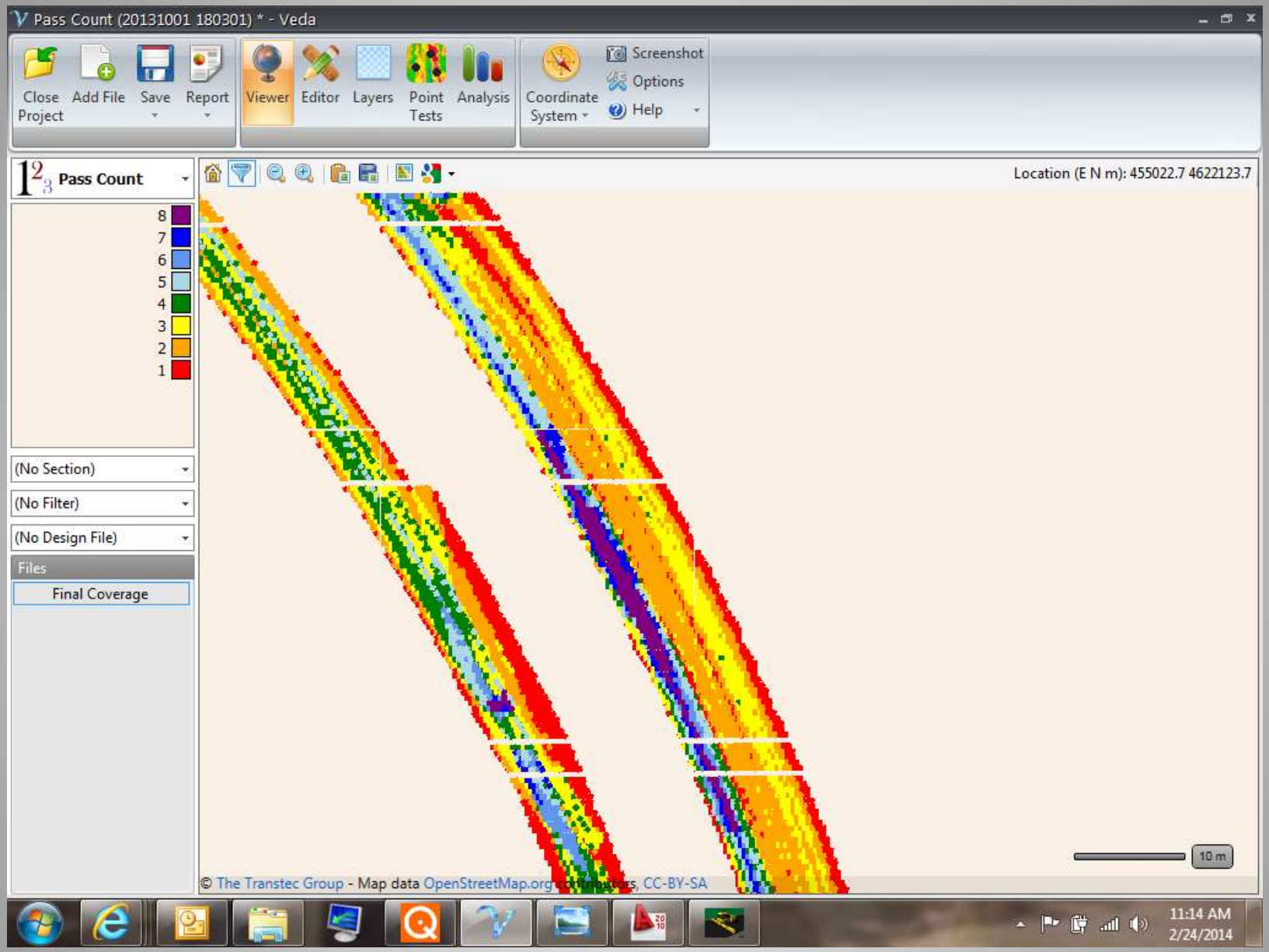
What else did we learn?

What else did we learn?

- Good quality GPS definitely helps

GPS Accuracy





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Thermal Imaging

The Problem

- Cooling of mix during transport is not remixed during the laydown process.
- Paver set-up and paving practices
- Results in erratic mat temperatures that are not apparent to the laydown crew.
- Concentrated areas of significantly cooler HMA generally result in lower than desirable compaction of those areas.
- Low compaction results in high in-place voids and reduced pavement life.

What is PaveIR?

- Paver mounted system used to identify thermal segregation in newly placed asphalt surfaces.
- Uses a series of infrared, GPS, and distance measuring sensors.
- Sensors are networked together and connected to a mobile computer with color display.
- Computer processes and displays data from all sensors.
- Areas where thermal segregation is present are displayed in real-time.
- Data stored on flash drive for post processing on PC

Pave-IR System Components

- The MOBA Operand™ computer attaches to sensor beam.
- Speed sensor
- GPS antenna mounts above the Operand™ computer.
- Memory drive connects directly to Operand™ computer
- System is powered by machine voltage (10-28 VDC).
- Sensor beam is hinged in center for easy setup and storage

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- First time setup approx. 1 hour
- Daily about 30 minutes

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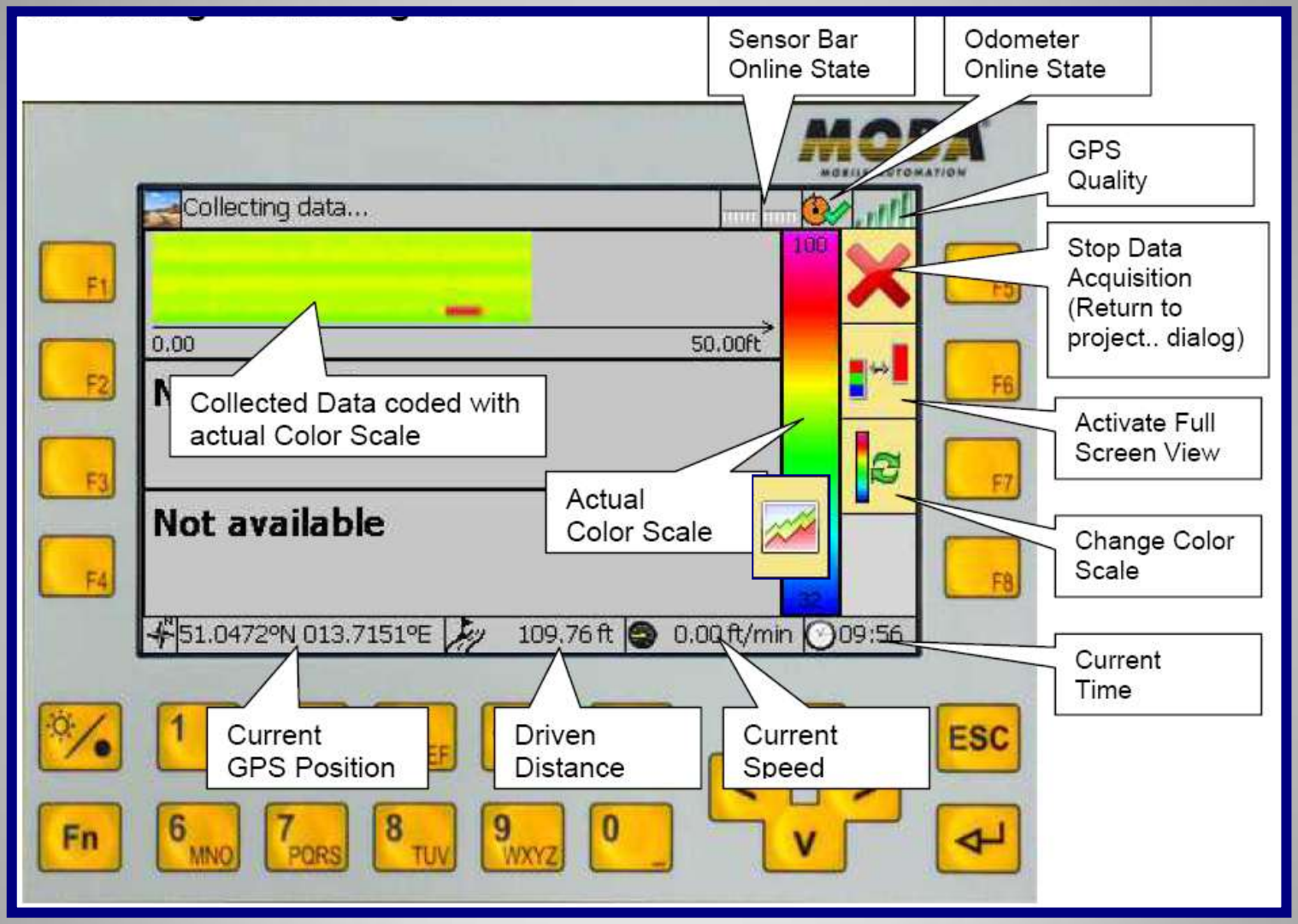
Our Project

- Ambient high temps in upper 50’s
- Average truck cycle time approx. 85 mins
- Heavy traffic
- Conventional paving (no MTD)



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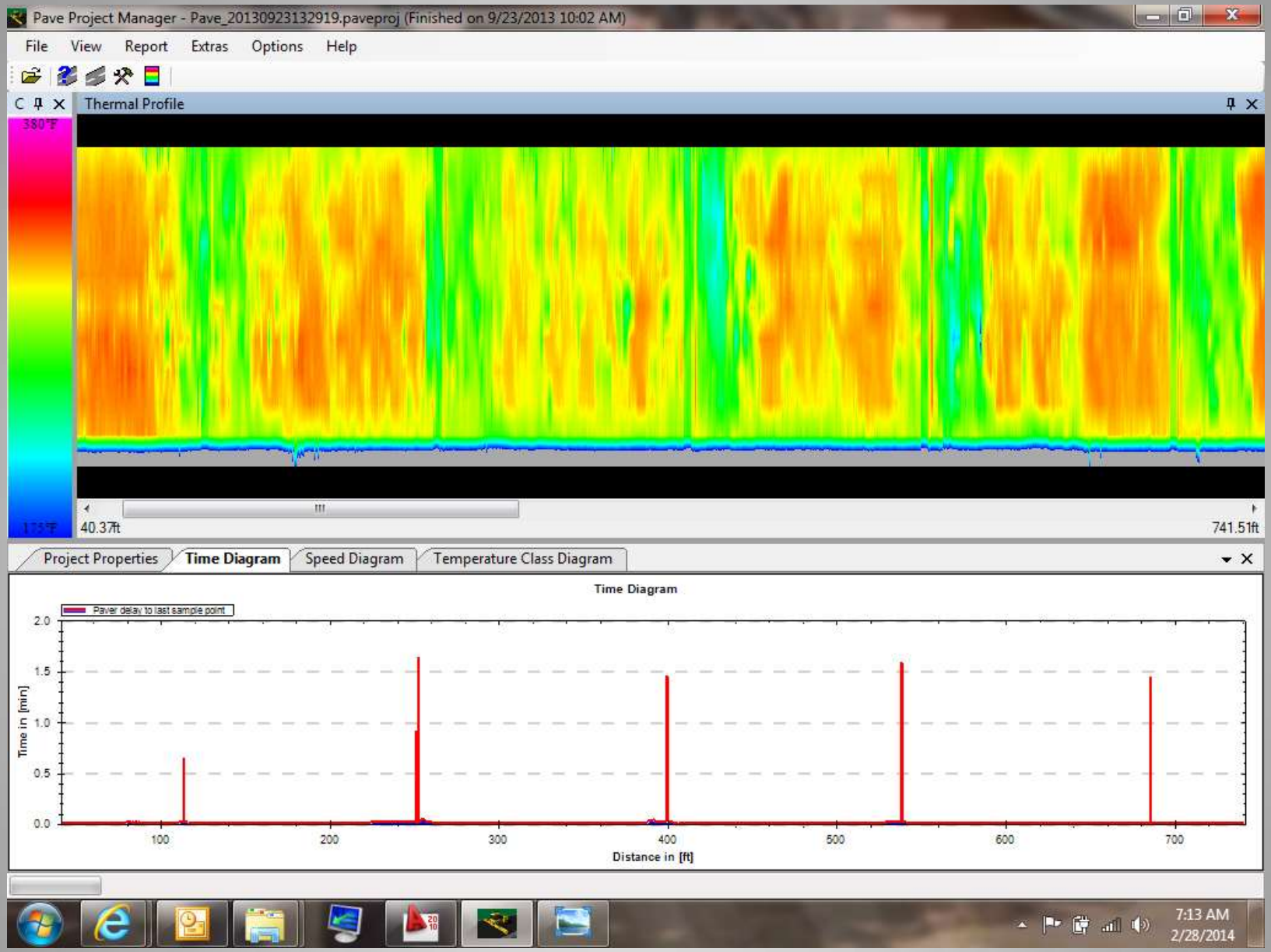

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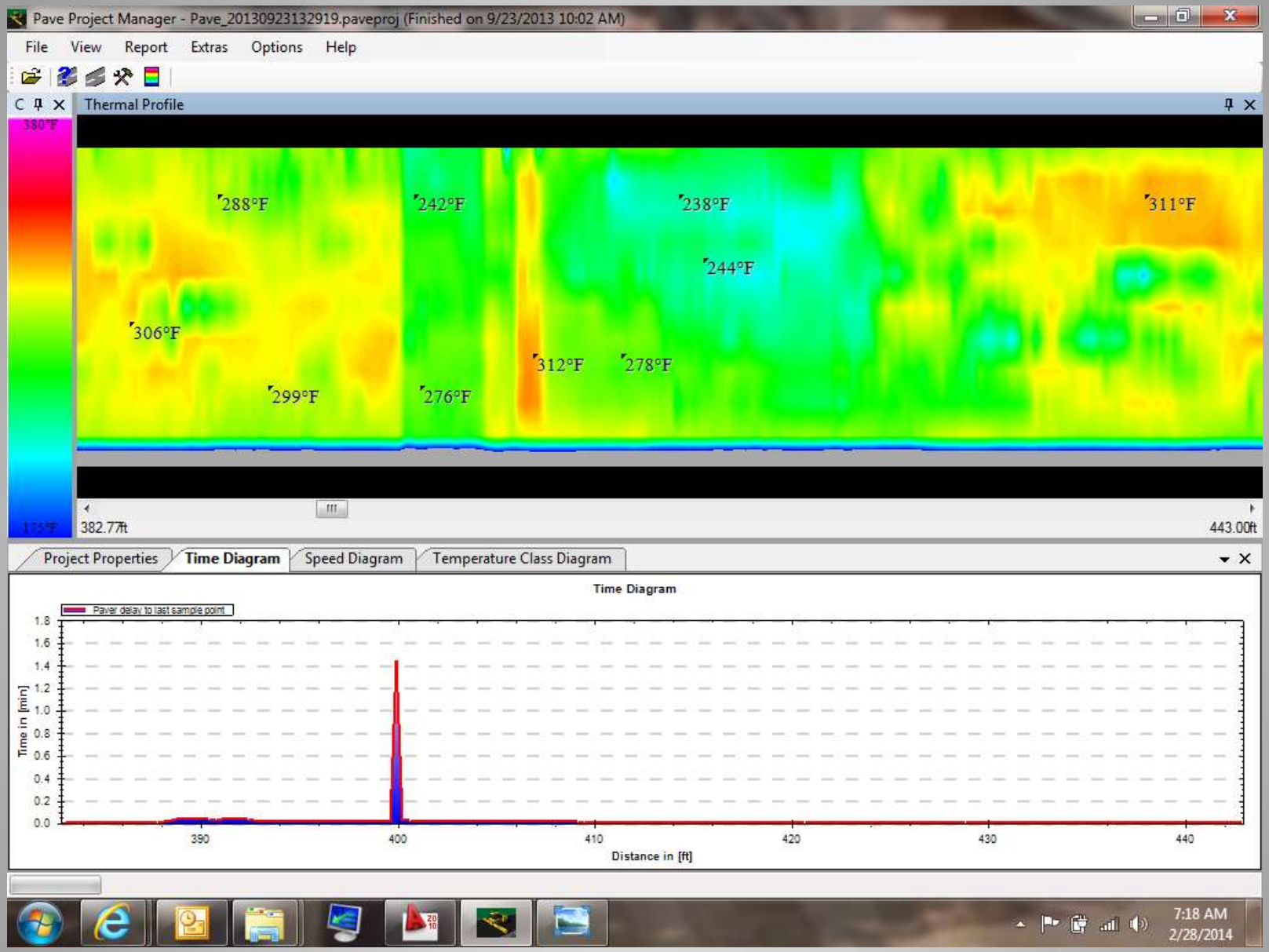

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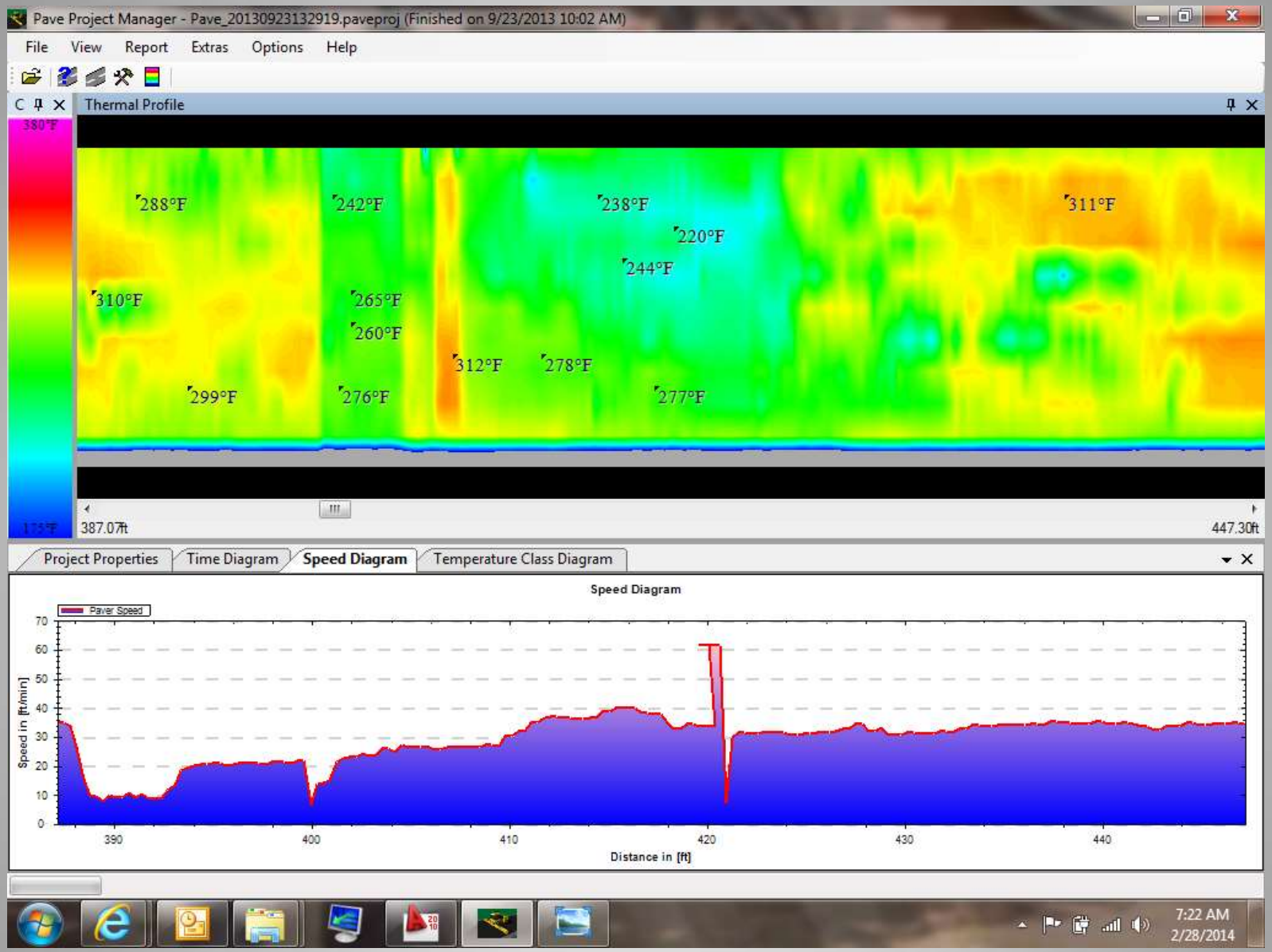

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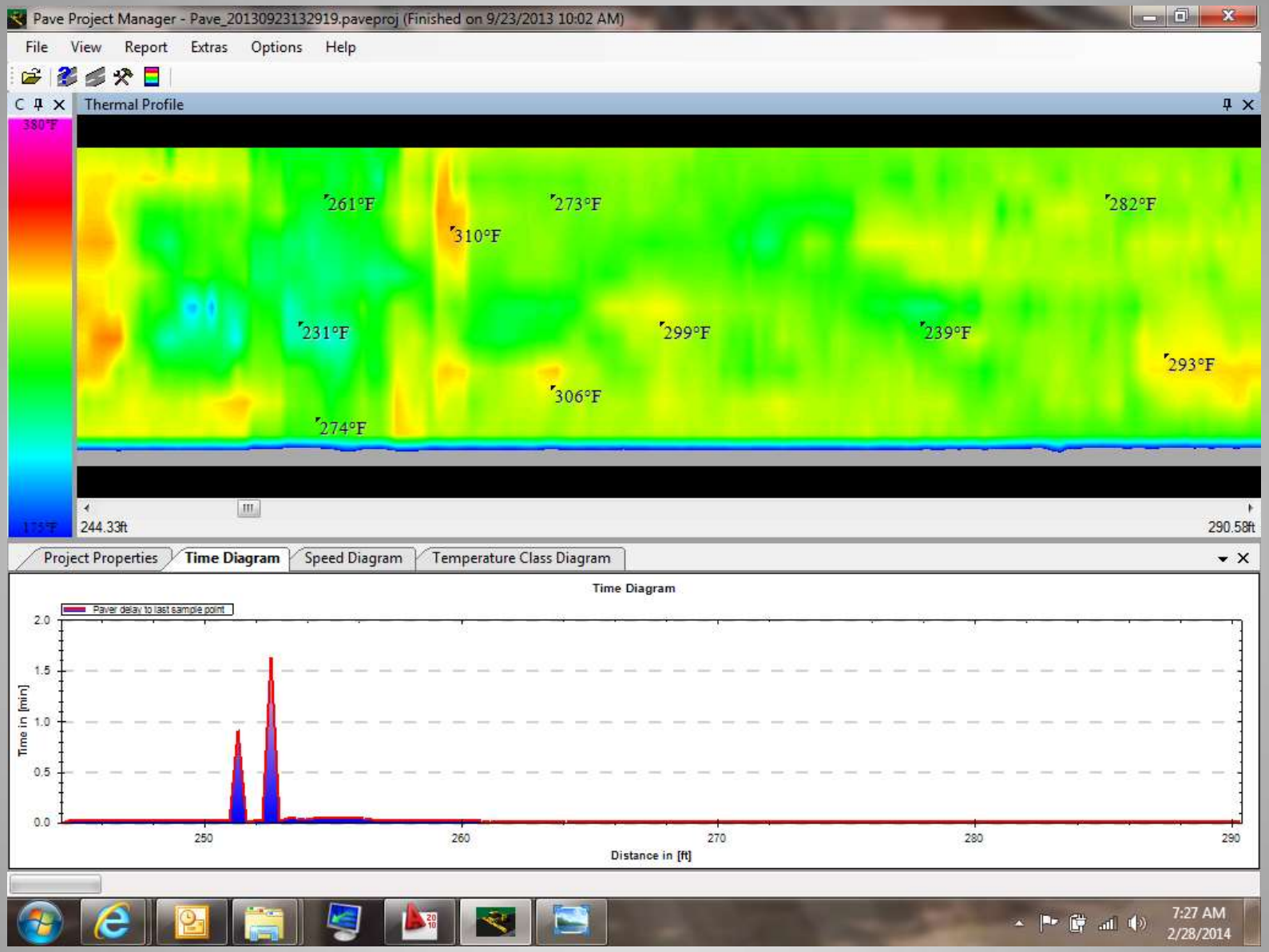

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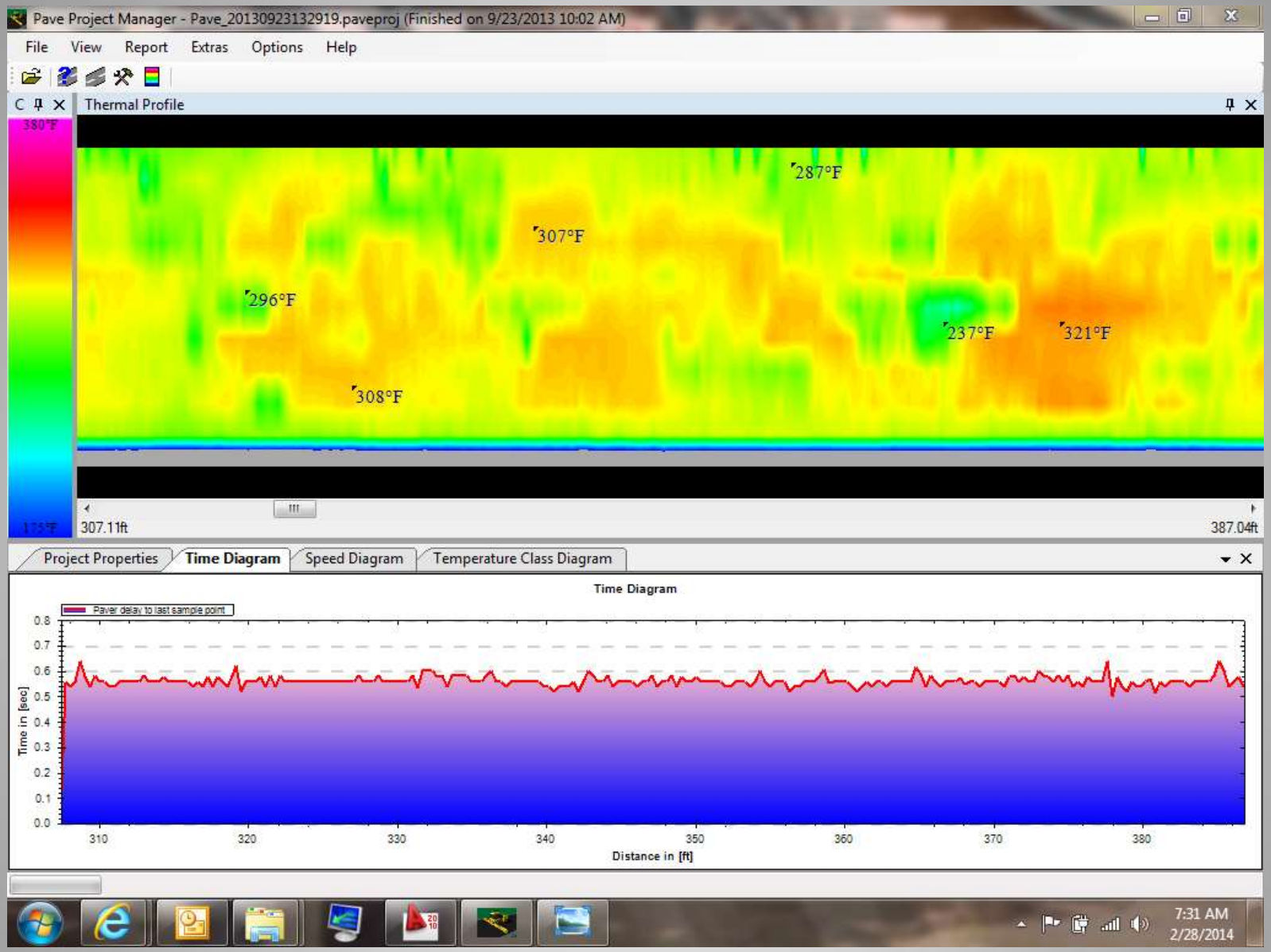

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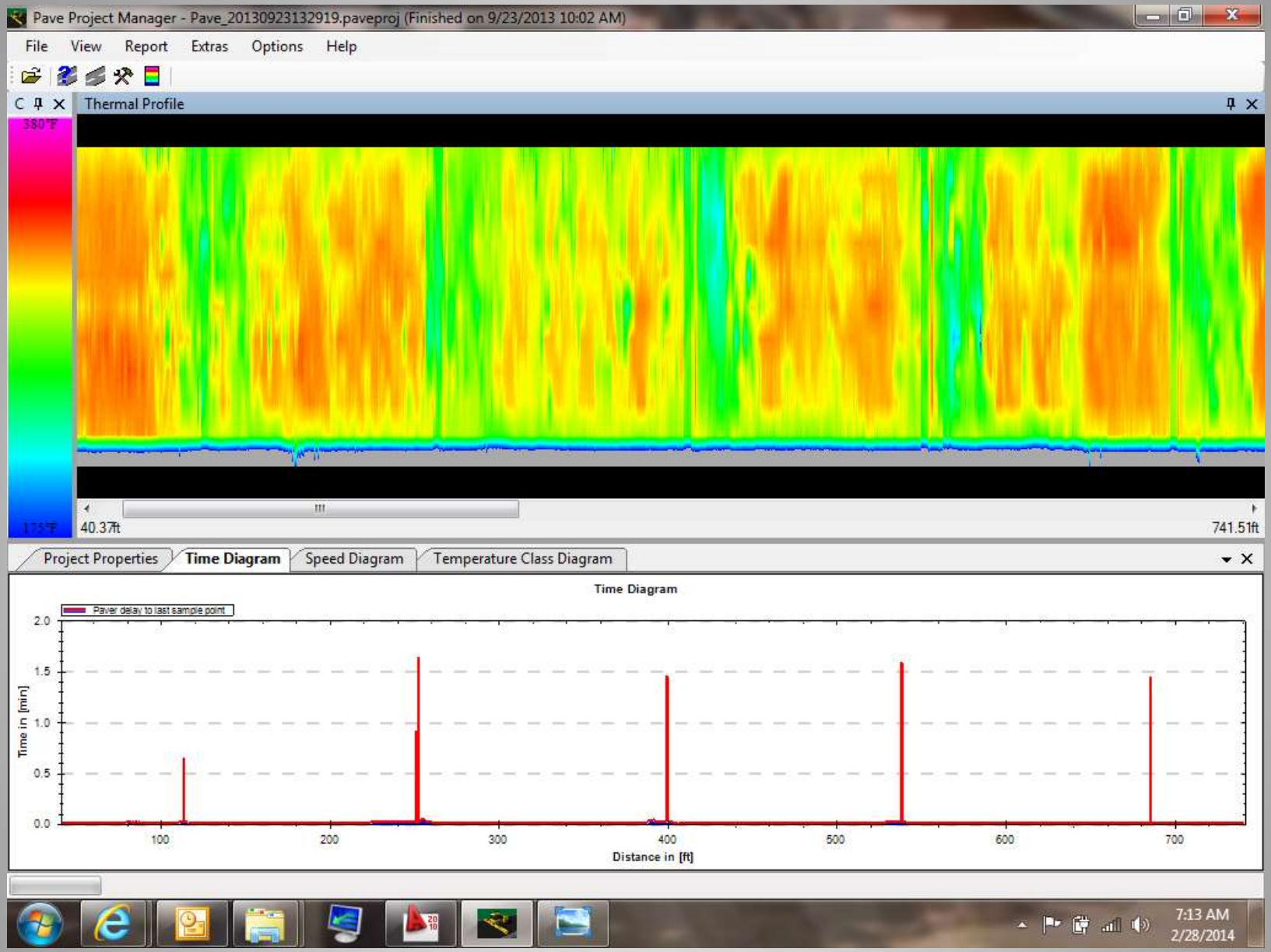

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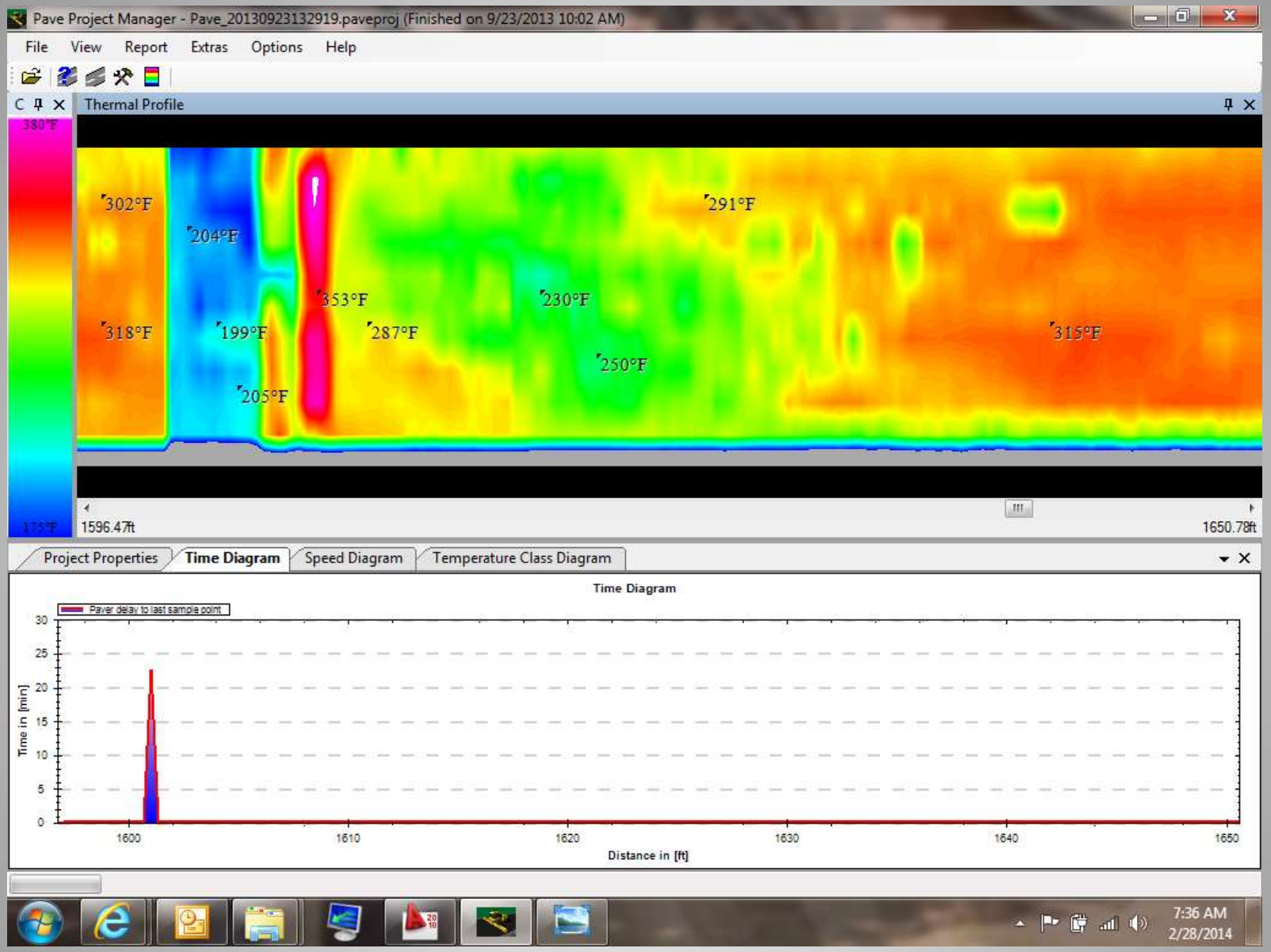

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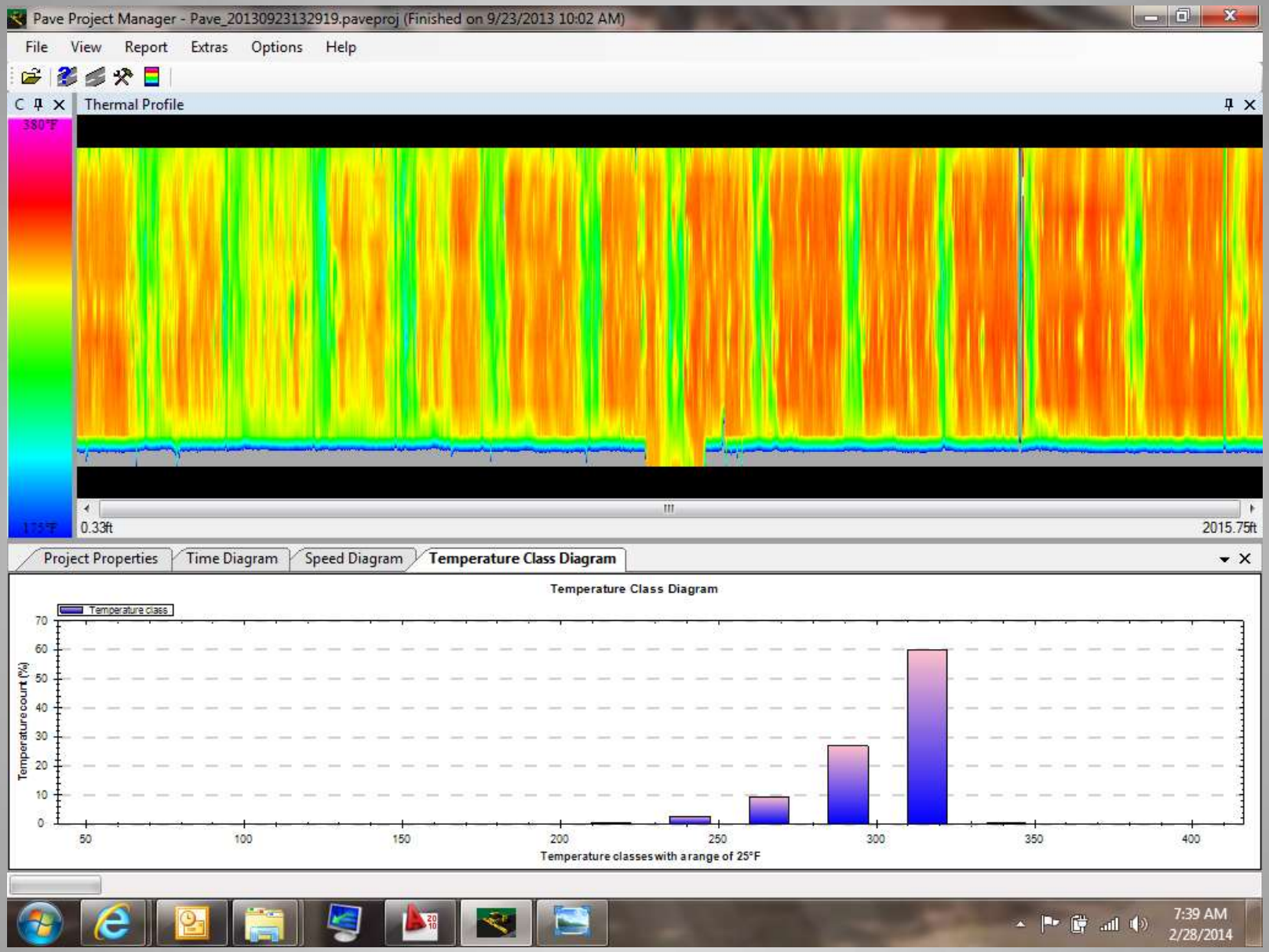

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PaveIR Reports

Rt41-Monday

Thermal Profile Summary Report

Profile ID:	41 recon	Profile Date:	9/23/2013 8:30:00 AM
Profile Number:		Letting Date:	
Status:		Controlling CSJ:	
County:		Spec Year:	
Tested By:		Spec Item:	
Test Location:	hwy	Special Provision:	
Material Code:		Mix Type:	
Material Name:			
Producer:			
Area Engineer:		Project Manager:	

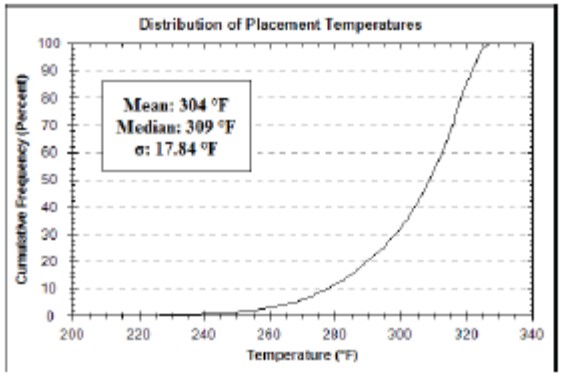
Course/Lift:	2	Temperature Differential Threshold:	25.0
Segment Length (ft):	150	Sensors Ignored:	1, 12

Thermal Profile Results Summary

Number of Profiles	Moderate 25.0°F < differential <= 50.0°F		Severe differential > 50.0°F	
	Number	Percent	Number	Percent
14	0	0	14	100

Summary of Locations with Thermal Segregation

Profile Nr	Beginning Location		Ending Location		Max Temp	Min Temp	Temperature Differential
	Distance (ft)	GPS in °	Distance (ft)	GPS in °			
1	0.33	87.5407 W, 41.74810833 N	149.93	87.5407 W, 41.74810833 N	322.7	250.0	72.7
2	150.50	87.5407 W, 41.74810833 N	300.20	87.5407 W, 41.74810833 N	318.7	251.8	67.0
3	300.52	87.5407 W, 41.74810833 N	450.13	87.54003833 W, 41.74630500 N	315.5	222.3	93.2
4	450.70	87.54003833 W, 41.74630500 N	600.30	87.54003833 W, 41.74630500 N	310.5	223.3	86.1
5	600.72	87.54003833 W, 41.74630500 N	750.00	87.54003833 W, 41.74630500 N	323.8	246.7	77.0
6	750.33	87.54003833 W, 41.74630500 N	900.03	87.54003833 W, 41.74630500 N	321.6	240.4	81.2
7	900.50	87.54003833 W, 41.74630500 N	1050.20	87.54057 W, 41.74440167 N	324.1	237.7	86.4
8	1050.52	87.54057 W, 41.74440167 N	1200.13	87.54057 W, 41.74440167 N	325.0	242.2	82.8
9	1200.70	87.54057 W, 41.74440167 N	1350.30	87.54057 W, 41.74440167 N	320.5	240.3	80.2
10	1350.72	87.54057 W, 41.74440167 N	1500.00	87.54057 W, 41.74440167 N	320.5	247.5	79.0
11	1500.33	87.54057 W, 41.74440167 N	1649.93	87.54057 W, 41.74440167 N	327.9	256.1	71.8
12	1650.50	87.54057 W, 41.74440167 N	1800.20	87.54053167 W, 41.74268333 N	320.4	266.0	63.4
13	1800.52	87.54053167 W, 41.74268333 N	1950.13	87.54053167 W, 41.74268333 N	327.0	258.8	68.2
14	1950.70	87.54053167 W, 41.74268333 N	2018.70	87.54053167 W, 41.74268333 N	326.7	269.1	57.6



Location of Paver Stops greater than One Minute	
Location (ft)	Duration (h:min:sec)
252.30	0:1:38
300.01	0:1:27
538.30	0:1:35
685.70	0:1:20
1000.72	0:22:45
1048.40	0:5:1

PaveIR System

- Worked very well to identify HMA temperature segregation during paving
- Easier than we thought to install, use and study the data
- Plan to do further evaluation
- Cost: $31,500
- Next Generation - single IR temperature scanner

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Questions?

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