MnDOT's Experience Using Paver-Mounted Thermal Profiling to Improve Mat Laydown Quality – and Experiences when Incentives are Part of the Contract

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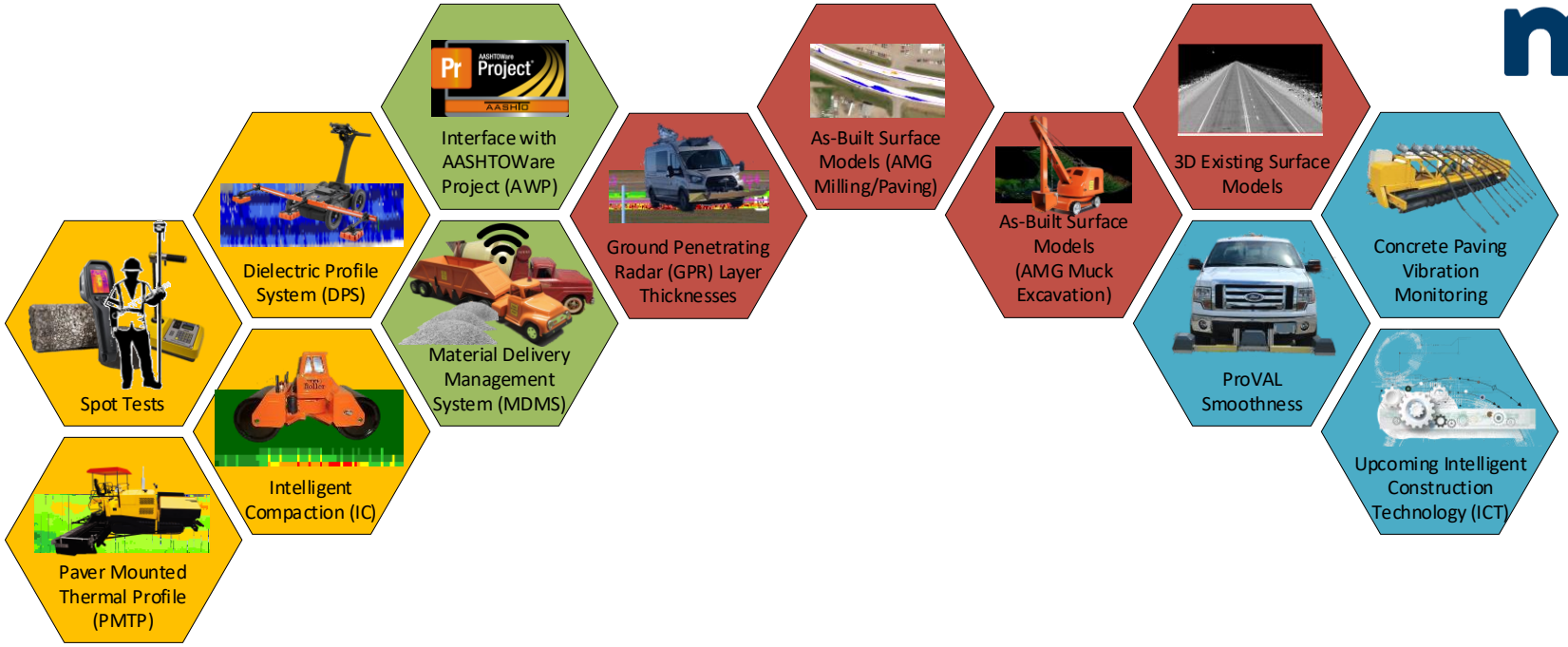
48th Annual Ohio Asphalt Paving Conference

February 1, 2023

DEPARTMENT OF TRANSPORTATION

http://www.dot.state.mn.us/materials/amt/index.html



DEPARTMENT OF TRANSPORTATION

Why are agencies using intelligent construction technologies (ICTs) on asphalt applications?

Paving construction causes of pavement failures

Why …. Why Me …

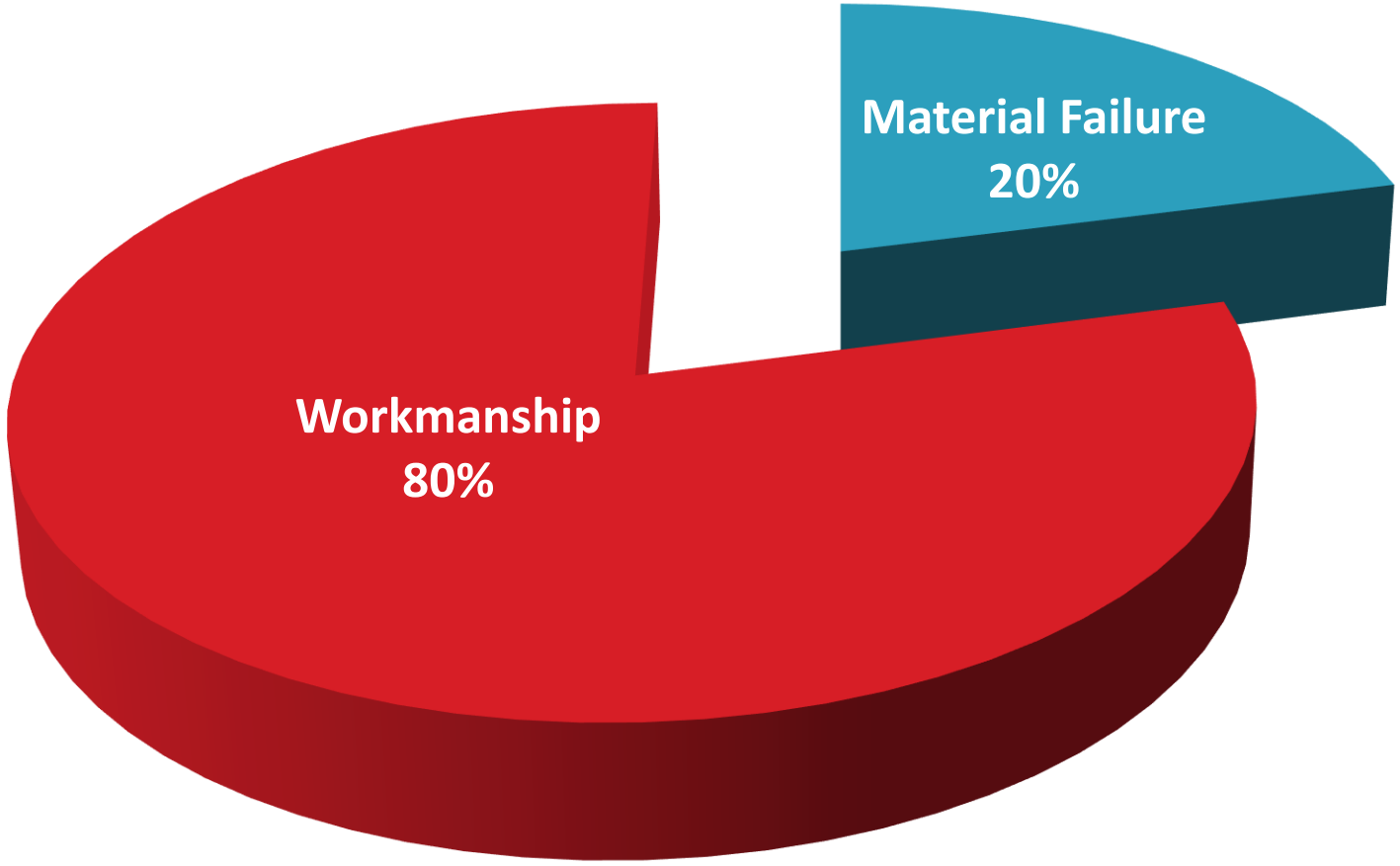
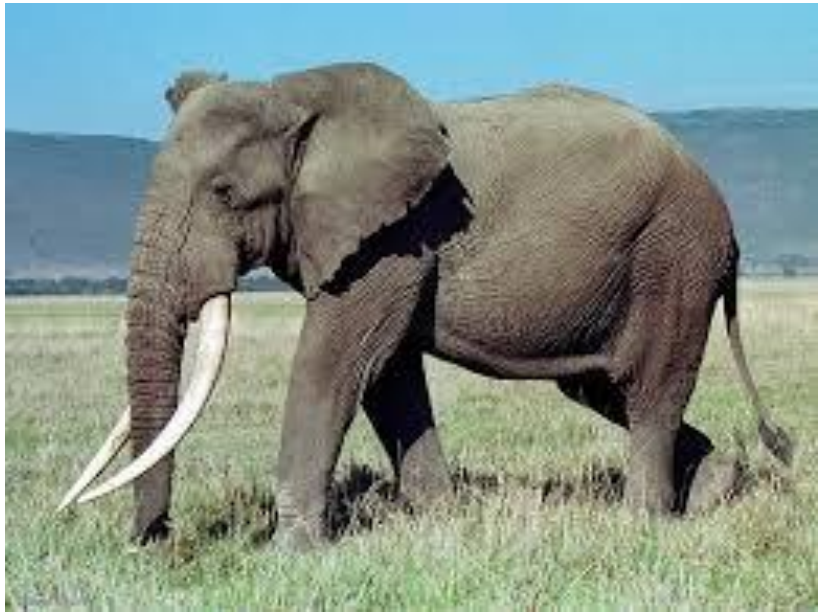


Figure Courtesy of Mark Woolaver, VAOT

Statistically valid sampling needed

It is unrealistic to collect the number of samples and tests required to statistically represent material properties

Not to scale



Elephant = 6 tons

Hedgehog < 1 pound

For every 100 elephants of mix, we sample and test two hedgehogs (cores)

THAT'S IT?

Analogy from the wise … Curt Turgeon, MnDOT State Pavement Engineer

Some stuff happens …

- …. with feeding paver,
- …. paver placing mat,
- …. rollers rolling,
- …. mat cooling
- ….
- ….then 24 hours later we take some cores

All we know is what we have seen in the mat.

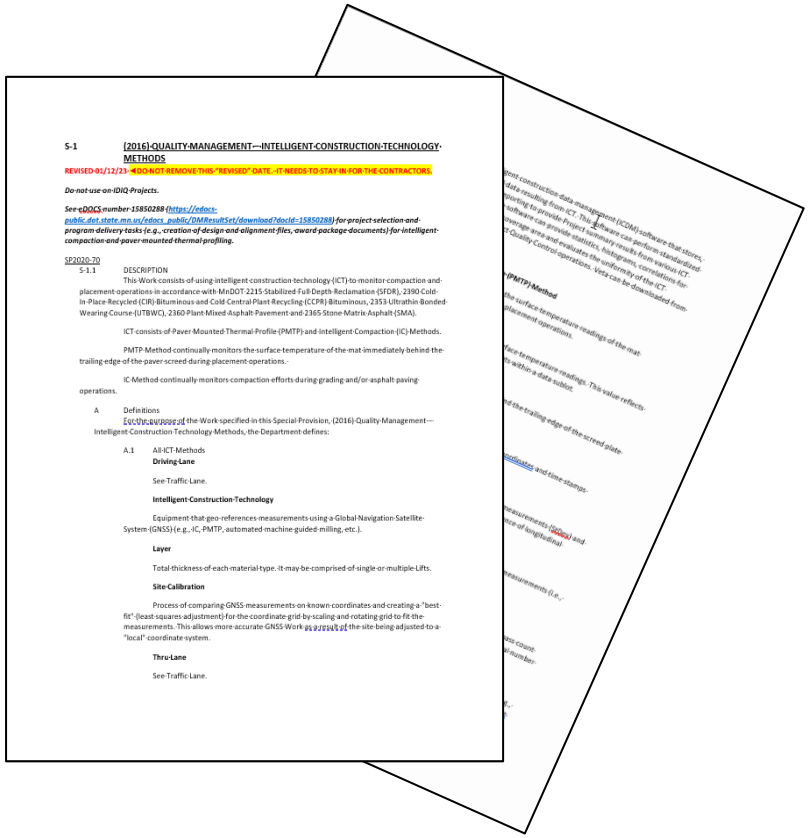
… If we have someone available.

Continuing hire of a strong workforce is getting difficult …

Quoted in Asphalt Pavement Magazine, pg. 51

"Technology is going to be a huge part of our industry going forward," said Jay. "Fleet tracking and optimization of equipment utilization has advanced and will continue to advance. Everything will continue to move toward real time. **We need to provide our young people with technology – they want the latest and the greatest.** And as fast as technology is moving, we need to ramp up our efforts regarding continuing education."

Jay Winford, Current Chairman of NAPA



S-1 (2016)-QUALITY-MANAGEMENT---INTELLIGENT-CONSTRUCTION-TECHNOLOGY-METHODS

REVISED-01/12/23- <DO-NOT-REMOVE-THIS-"REVISED"-DATE.-IT-NEEDS-TO-STAY-IN-FOR-THE-CONTRACTORS.

Do-not-use-on-IDIQ-Projects.

See-eDOCS-number-15850288-(https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=15850288)-for-project-selection-and-program-delivery-tasks-(e.g.,-creation-of-design-and-alignment-files,-award-package-documents)-for-intelligent-compaction-and-paver-mounted-thermal-profiling.

SP2020-70

S-1.1 DESCRIPTION

This-Work-consists-of-using-intelligent-construction-technology-(ICT)-to-monitor-compaction-and-placement-operations-in-accordance-with-MnDOT-2215-Stabilized-Full-Depth-Reclamation-(SFDR),-2390-Cold-In-Place-Recycled-(CIR)-Bituminous-and-Cold-Central-Plant-Recycling-(CCPR)-Bituminous,-2353-Ultrathin-Bonded-Wearing-Course-(UTBWC),-2360-Plant-Mixed-Asphalt-Pavement-and-2365-Stone-Matrix-Asphalt-(SMA).

ICT-consists-of-Paver-Mounted-Thermal-Profile-(PMTP)-and-Intelligent-Compaction-(IC)-Methods.

PMTP-Method-continually-monitors-the-surface-temperature-of-the-mat-immediately-behind-the-trailing-edge-of-the-paver-screed-during-placement-operations.-

IC-Method-continually-monitors-compaction-efforts-during-grading-and/or-asphalt-paving-operations.

A Definitions

For-the-purpose-of-the-Work-specified-in-this-Special-Provision,-(2016)-Quality-Management---Intelligent-Construction-Technology-Methods,-the-Department-defines:

A.1 All-ICT-Methods

Driving-Lane

See-Traffic-Lane.

Intelligent-Construction-Technology

Equipment-that-geo-references-measurements-using-a-Global-Navigation-Satellite-System-(GNSS)-(e.g.,-IC,-PMTP,-automated-machine-guided-milling,-etc.).

Layer

Total-thickness-of-each-material-type.-It-may-be-comprised-of-single-or-multiple-Lifts.

Site-Calibration

Process-of-comparing-GNSS-measurements-on-known-coordinates-and-creating-a-"best-fit"-(least-squares-adjustment)-for-the-coordinate-grid-by-scaling-and-rotating-grid-to-fit-the-measurements.-This-allows-more-accurate-GNSS-Work-as-a-result-of-the-site-being-adjusted-to-a-"local"-coordinate-system.

Thru-Lane

See-Traffic-Lane.

DEPARTMENT OF TRANSPORTATION

MnDOT PMTP Requirements

(2016) Quality Management – Intelligent Construction Technologies

Paver Mounted Thermal Profiling System (PMTP)

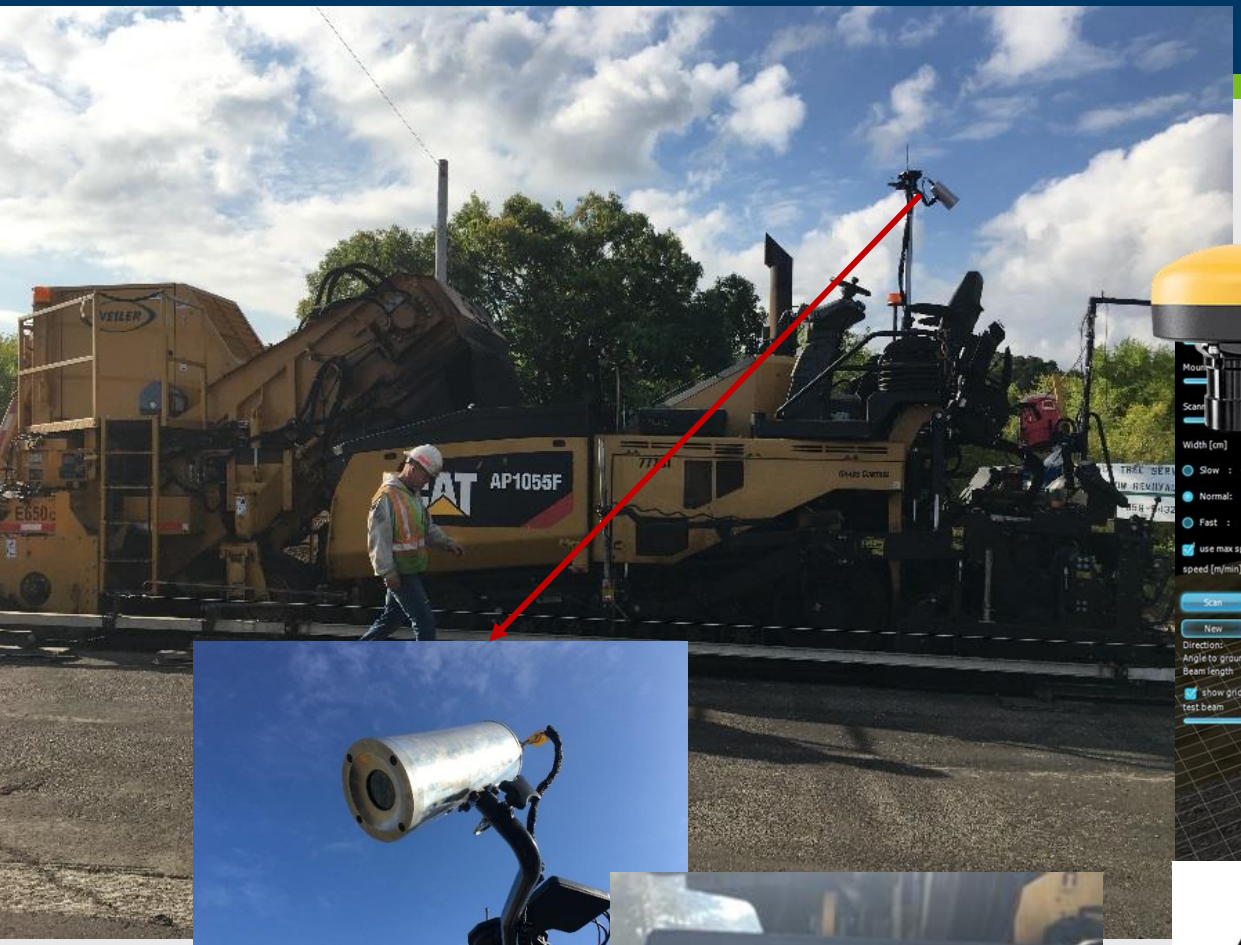


Photo Courtesy of TOPCON

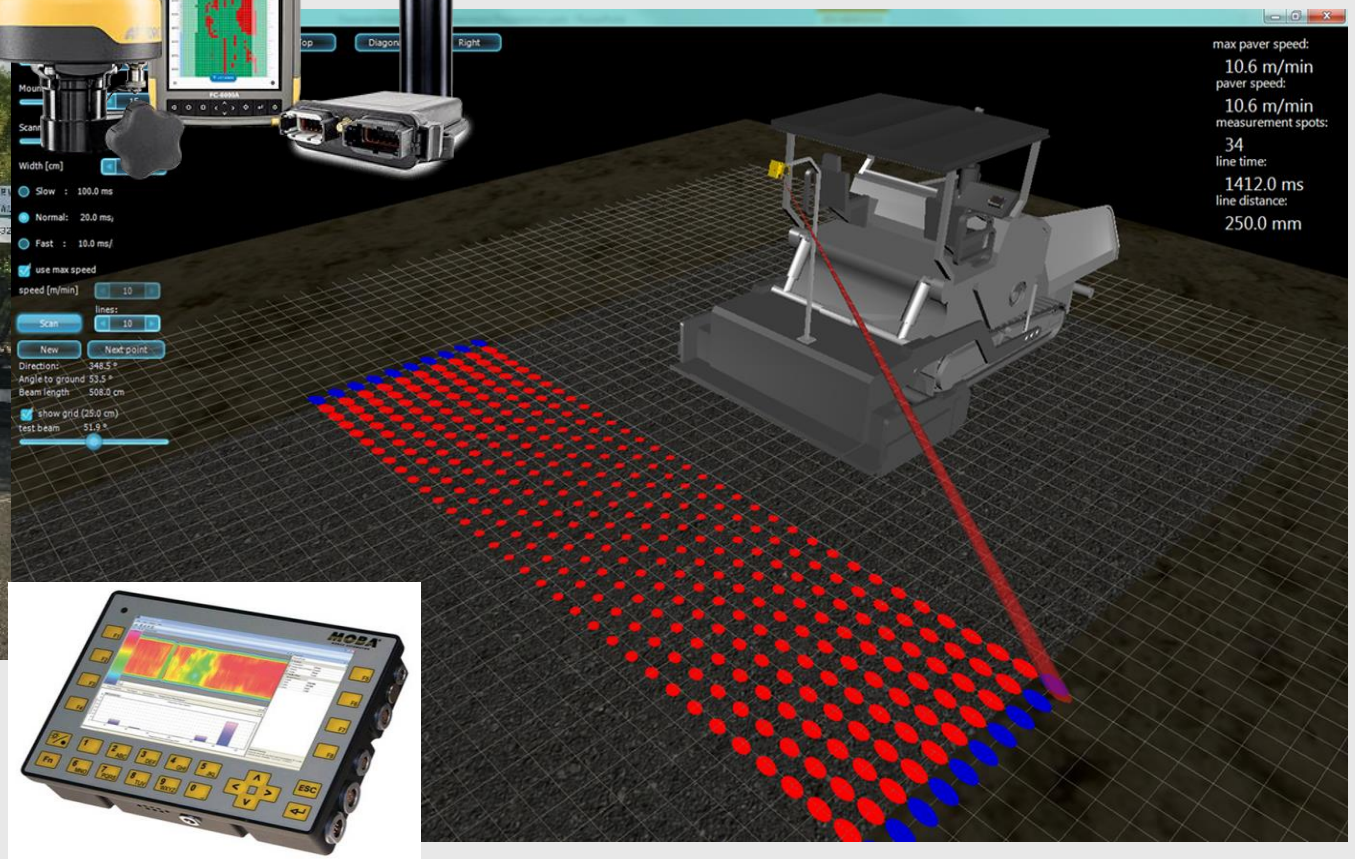
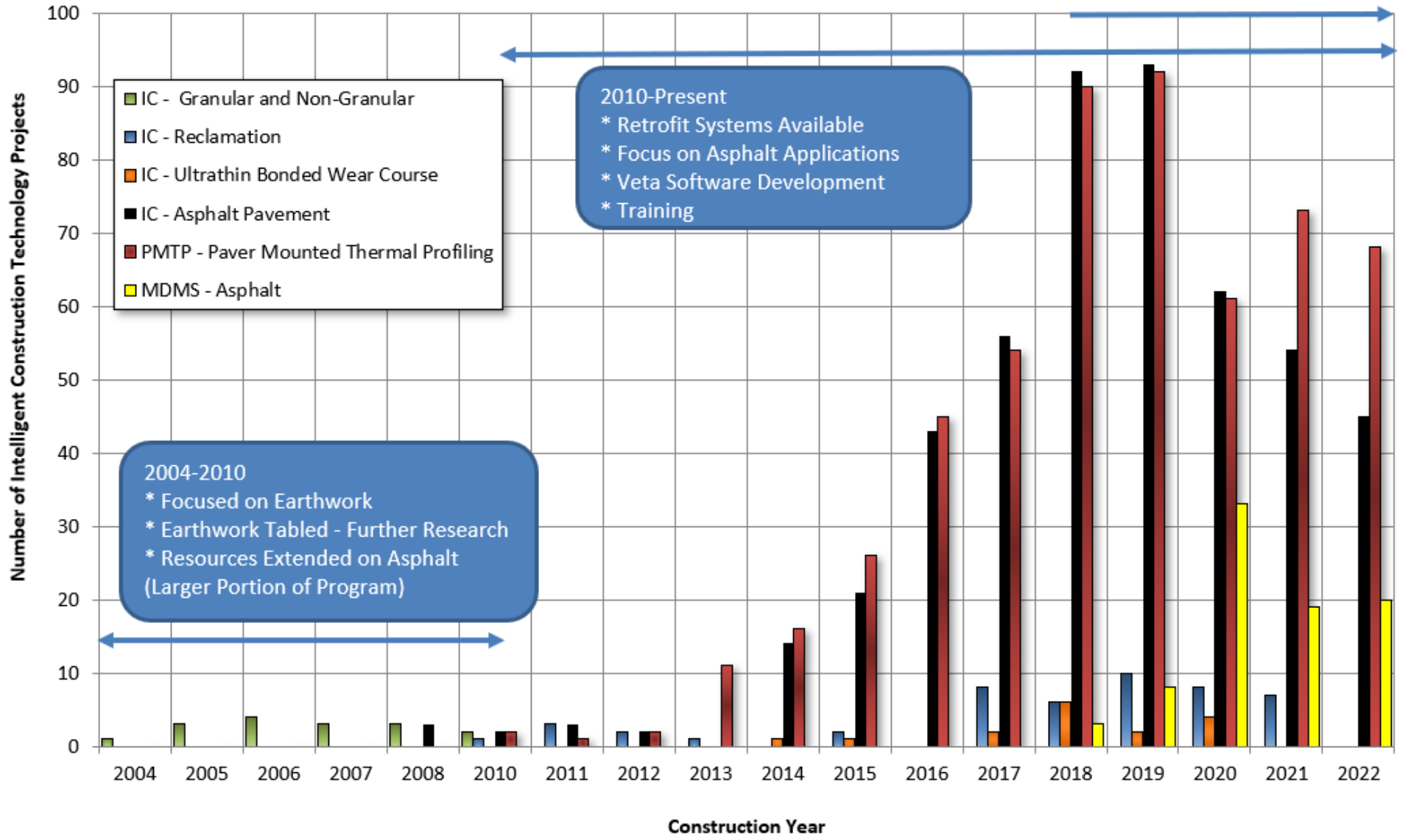


Photo Courtesy of Moba Corporation

~15 Million Tons (13.6 Million Metric Tons) Asphalt Paved Per Year

Total Number of IC Projects: **590** Total Number of MDMS Projects: **83**

Total Number of PMTP Projects: **541**



PMTP system requirements

S.xx.3.B.1.a

Parameter	Requirement
Longitudinal and Lateral Surface Temperature Readings	≤ 1-ft (300-mm) intervals **at all paving speeds** Tolerance: ± 1 in (25 mm)
Surface Temperature Readings Total Measurement Width	Traffic/required auxiliary lanes paved in one (1) pass.
Surface Temperature Readings	Range: 140°F (60°C) to 480°F (250°C) Accuracy: ± 3.6°F (2°C) or ± 2.0% of the sensor reading, whichever is greater.
GNSS	Accuracy of measurements on the asphalt mat: 2 inches (50 mm) in the horizontal direction

PMTP system setup on paver(s)

S.xx.3.B.1.b

Collect measurement at a distance no less than 3 feet and no greater than 12 feet of trailing edge of screed plate.

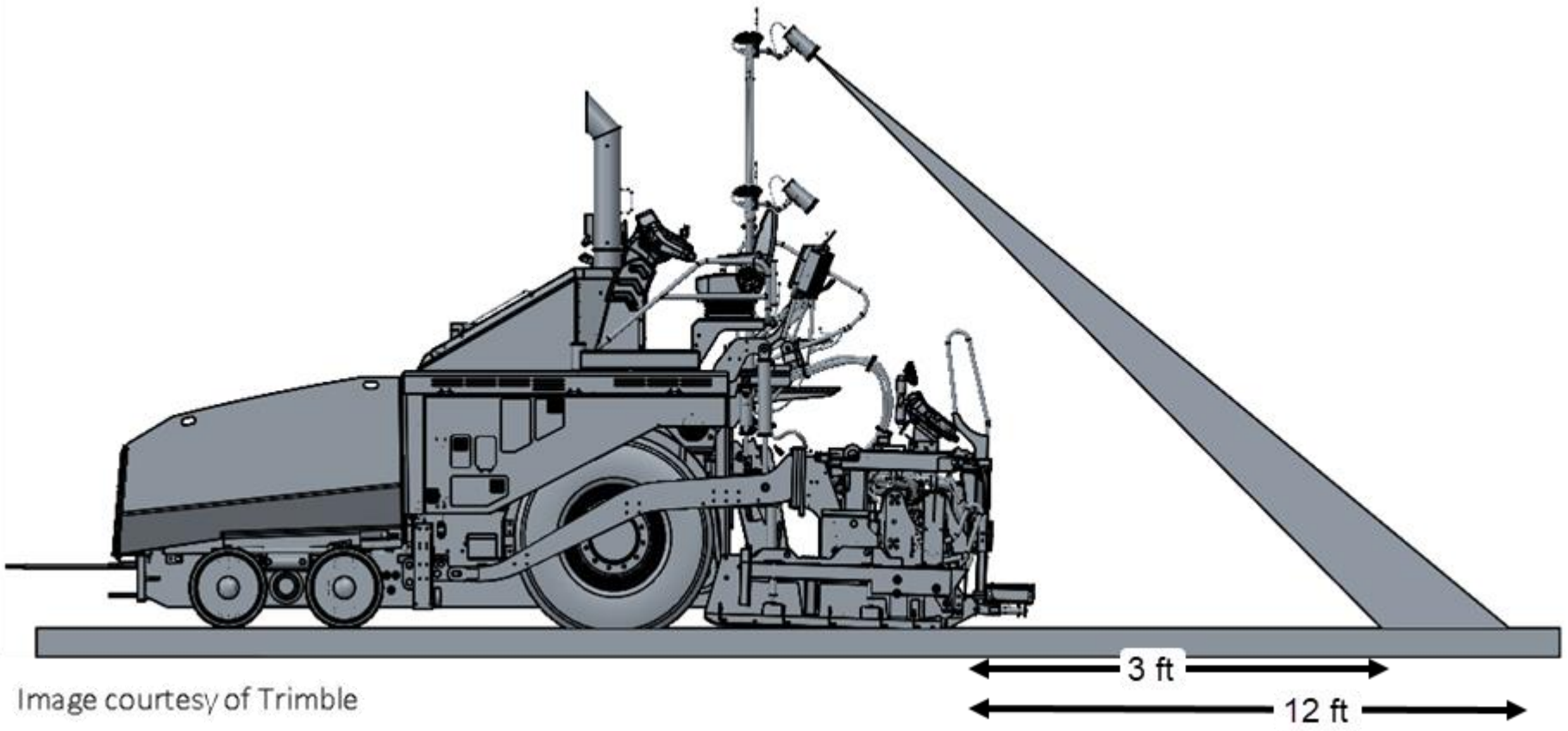
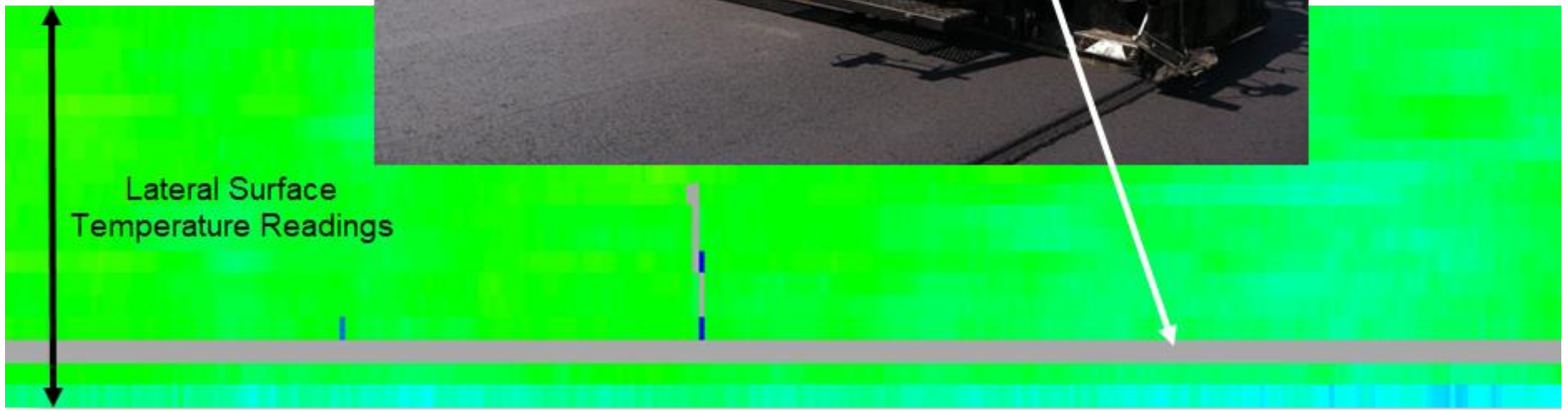


Image courtesy of Trimble

PMTP system setup on paver(s) – brackets for smoothness

S.xx.3.B.1.b

Ride brackets and plates used for smoothness will **not impede** later surface temperature readings for **more than 2, 10-inch-wide** lateral regions of surface temp. measurements.

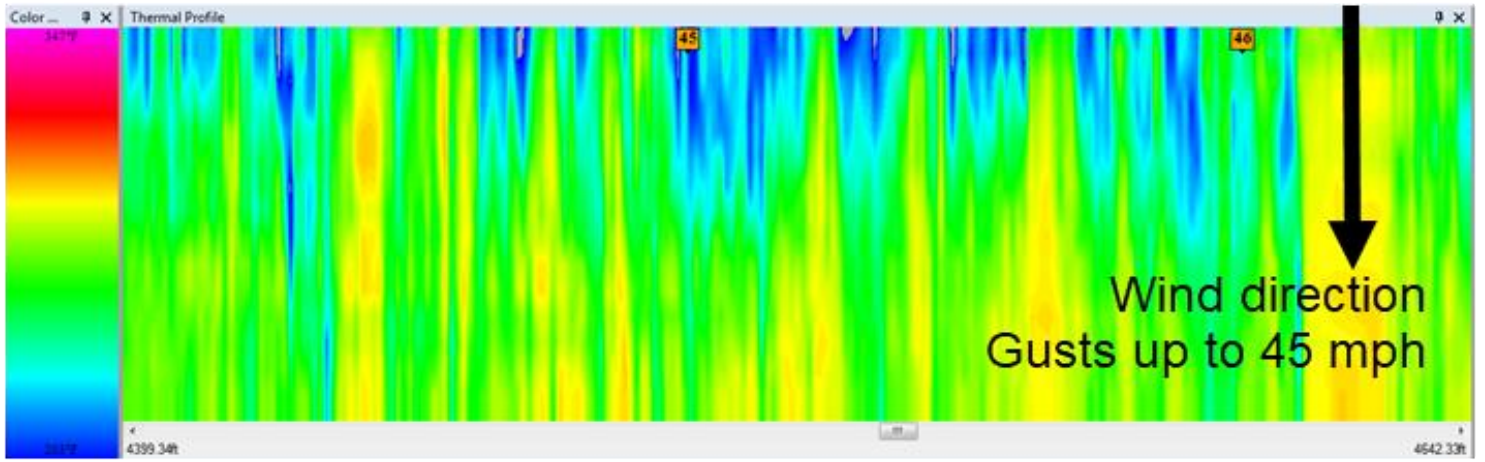


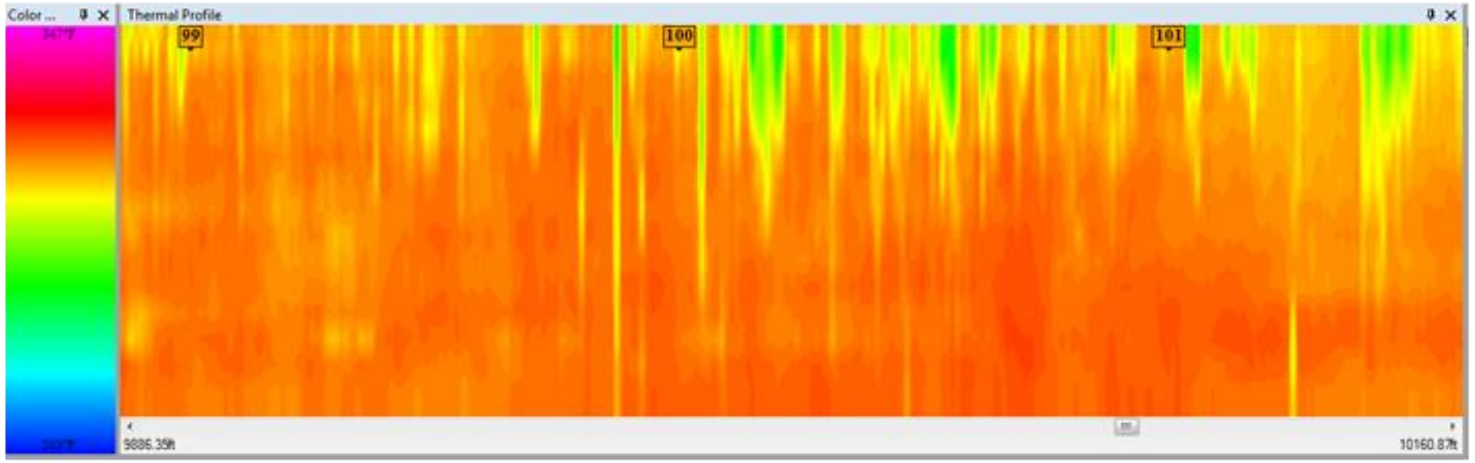
Required measurement locations

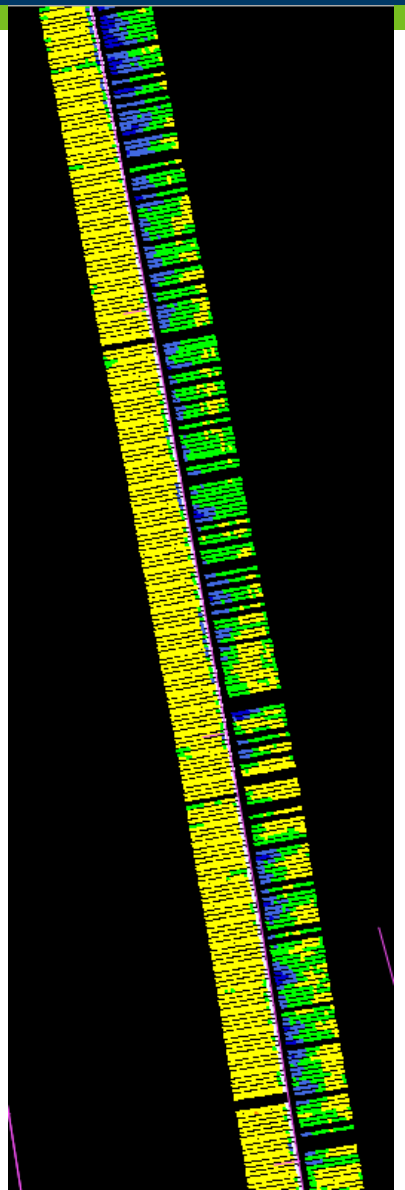
S-xx.3.A.1, S-xx.3.B.2

- Contract net length ≥ 2 miles
- 100% of each lift (≥ 1 inch thick)
  - Traffic lanes
  - E-ZPass Lanes
  - Continuous left turn lanes
  - Passing lanes

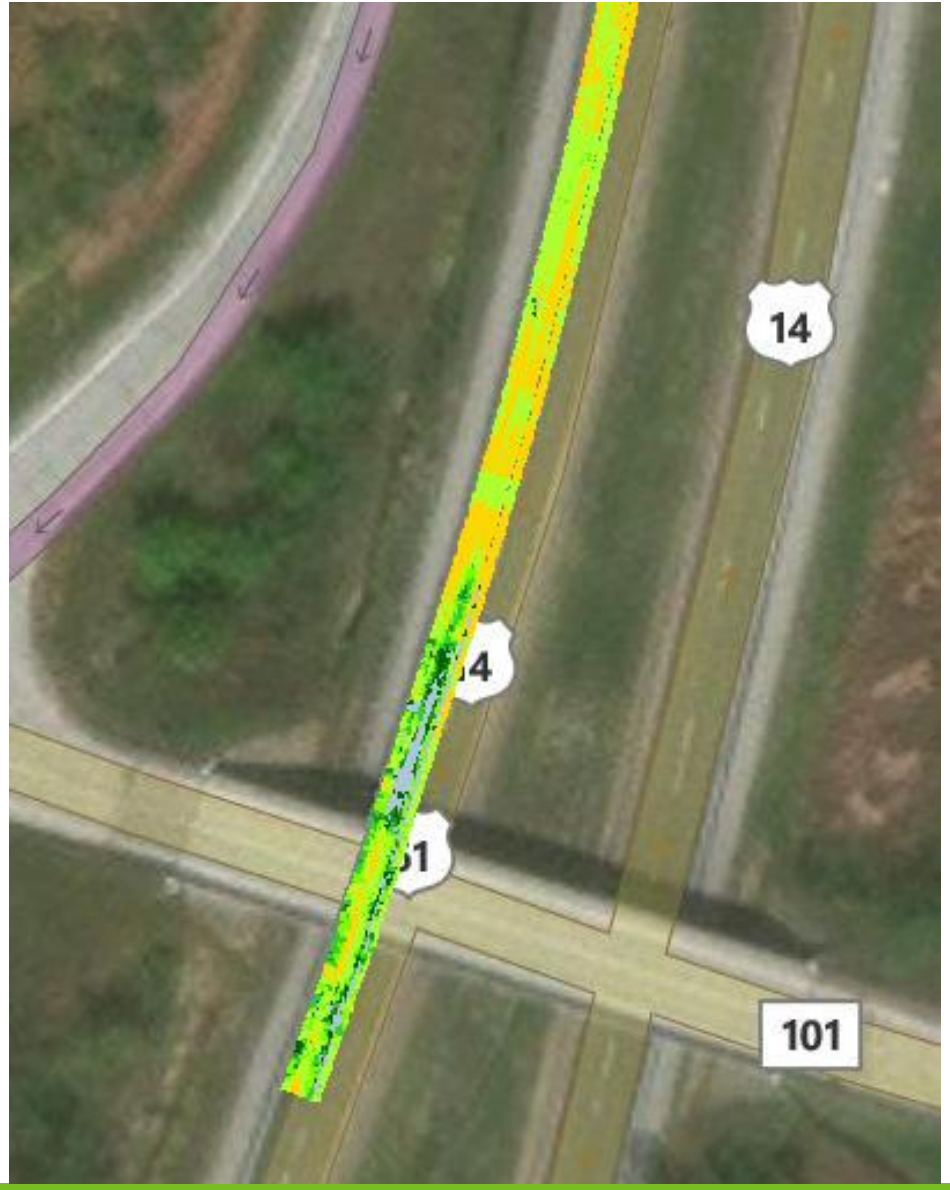
Effects of pavement thickness on PMTP measurements







- Wear course thickness = 5/8 inch (1.6 cm)
- Shoulder pavement edge max thickness = ½ inch (1.3 cm)



Example of PMTP measurements on scratch course
(lift less than 1 inch)

Establishment data sublots using Veta

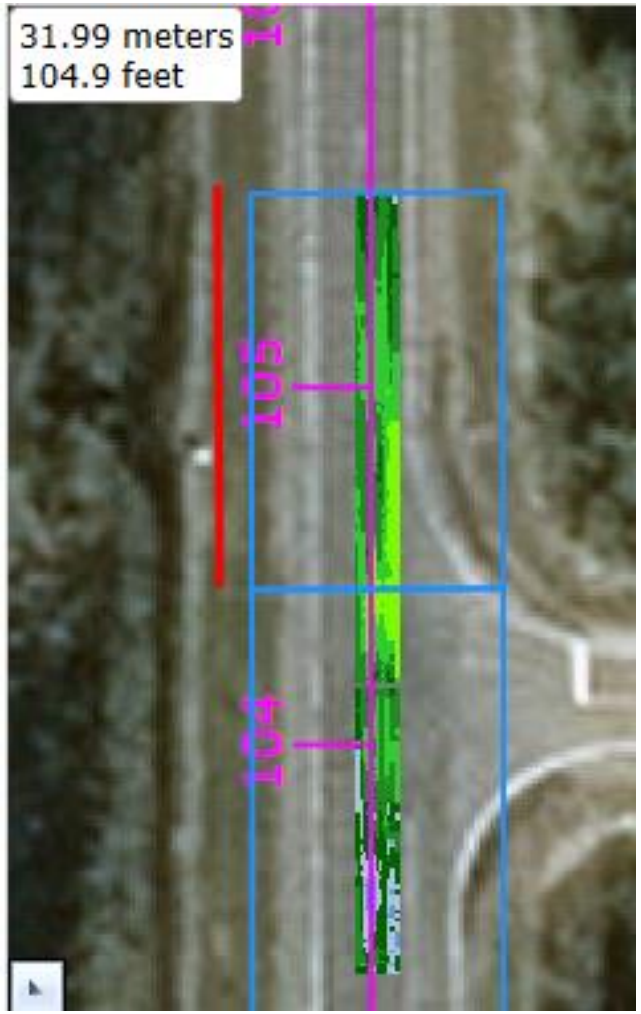
S-xx.3.B.3

Divide data into 150-linear ft data sublots using Veta

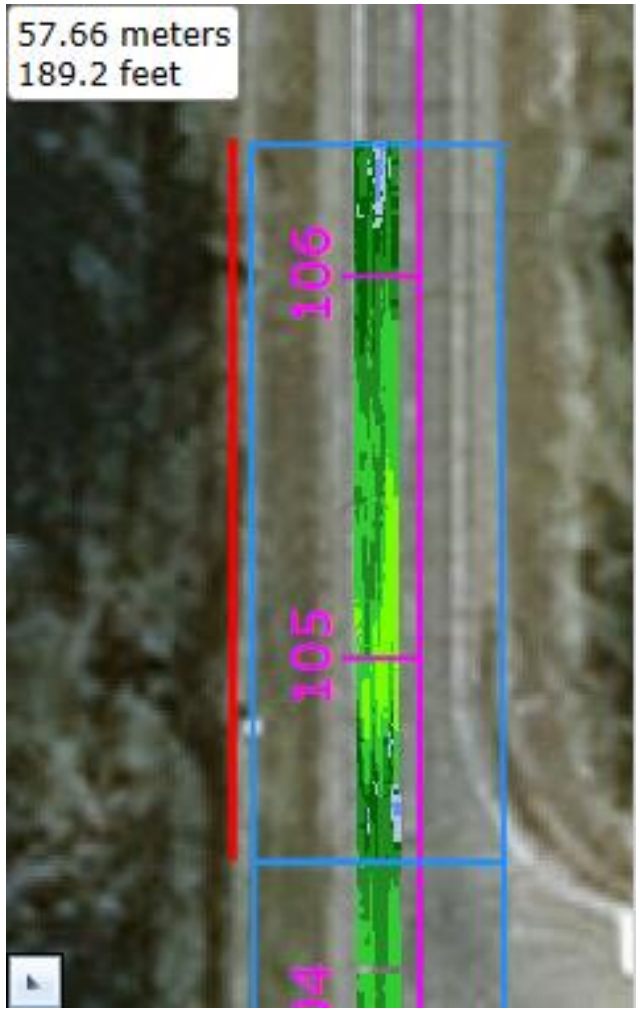
When last data sublot length is less than 150-feet

S-xx.3.B.3

≥ 75-ft Treat as data sublot

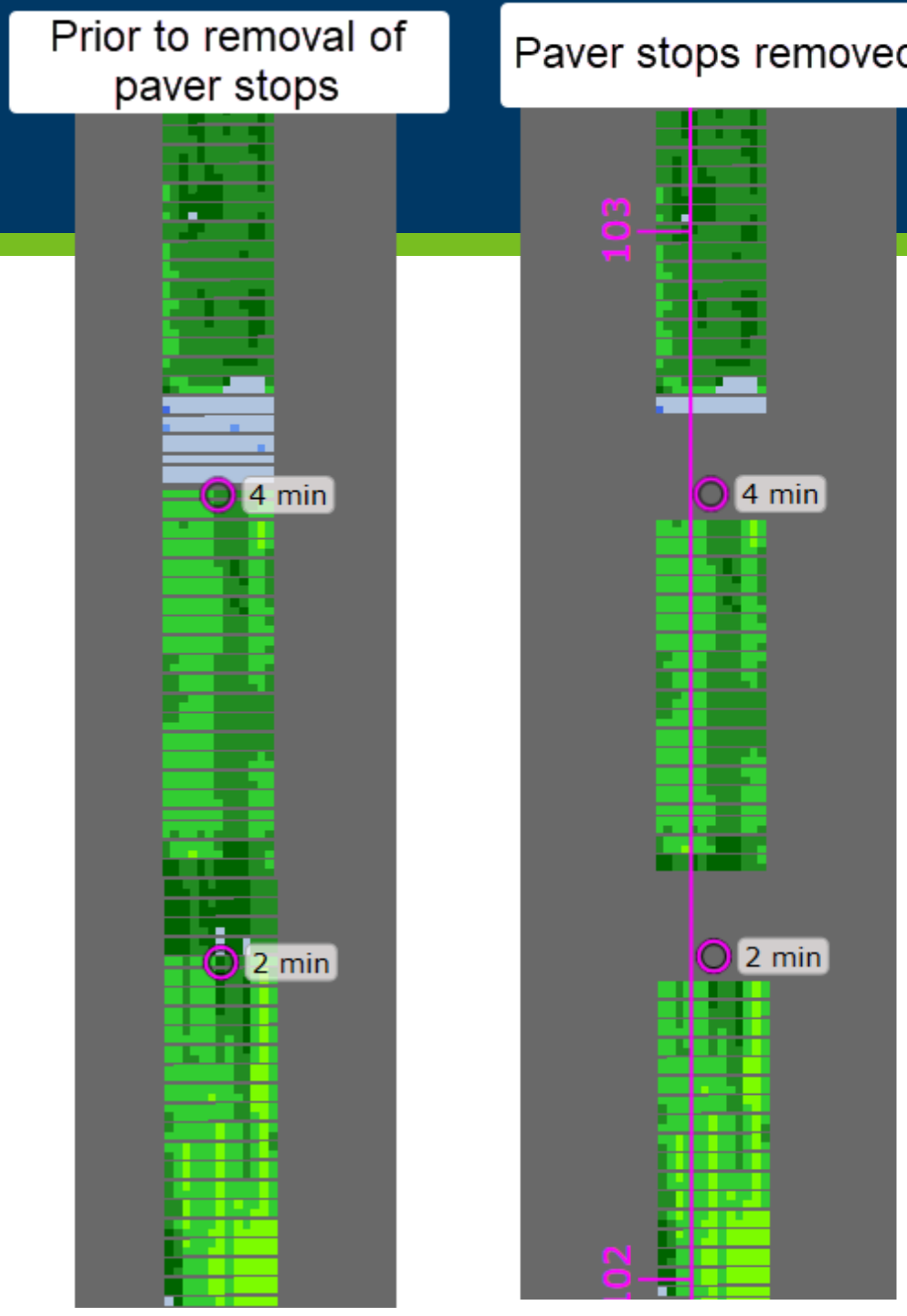


< 75 ft Combine with previous data sublot



Exclusion of paver stops

S-xx.3.B.5.a(1)

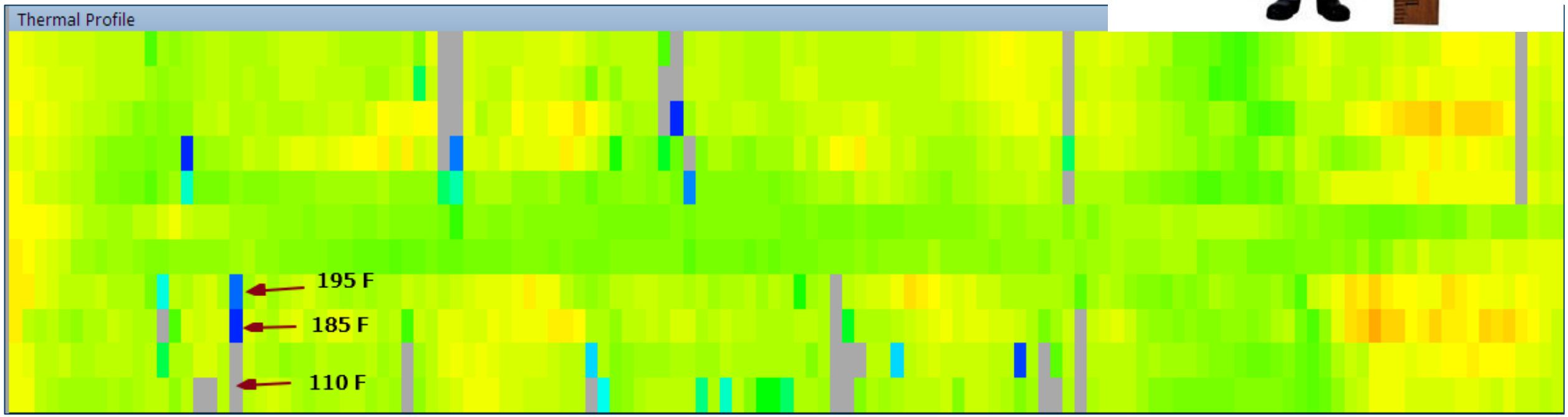


Exclude surface temperature readings within 2 feet prior to and 8 feet after paver stops that are greater than 1 minute in length

Exclusion of cold edges and temperatures less than 180F

S-xx.3.B.5.a(1), S-xx.3.B.4(6)

- Exclude surface temperature readings < 180°F
- Exclude cold edge and ride bracket data using designated operation filter.



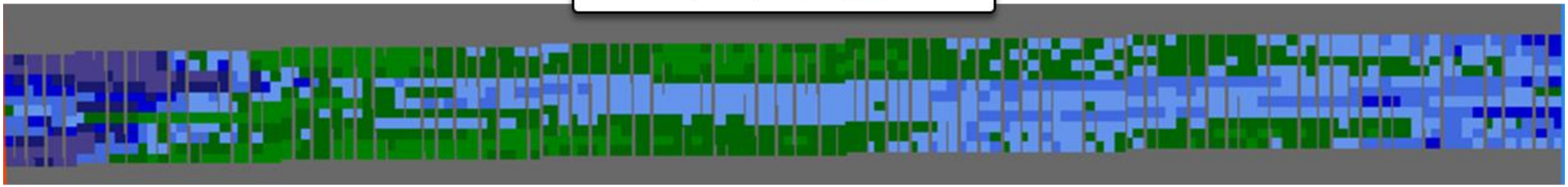
Breakdown roller drum and screed operator

Excessive walking on mat

Thermal Segregation Index (TSI)

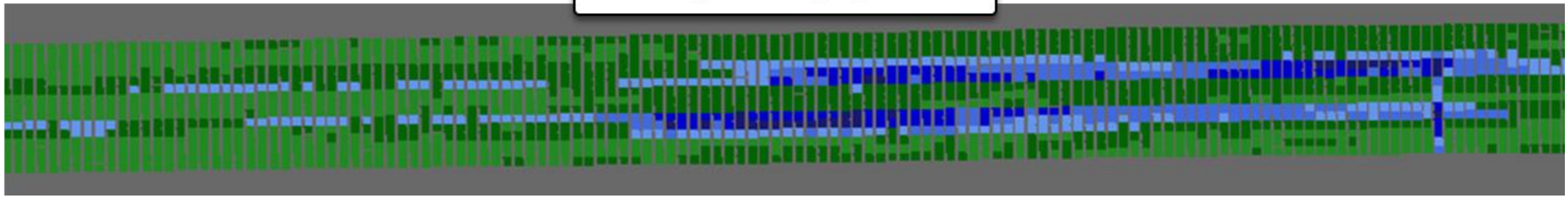
S-xx.3.B.5

Geo-spatial (X-Y) Segregation



+

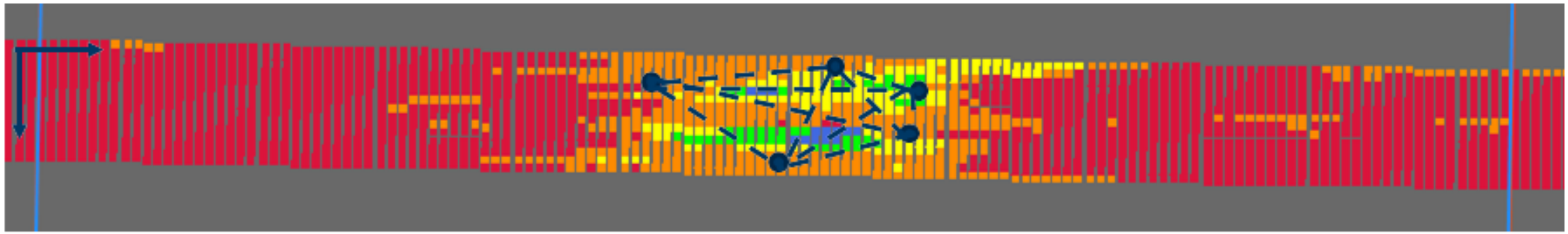
Longitudinal Segregation

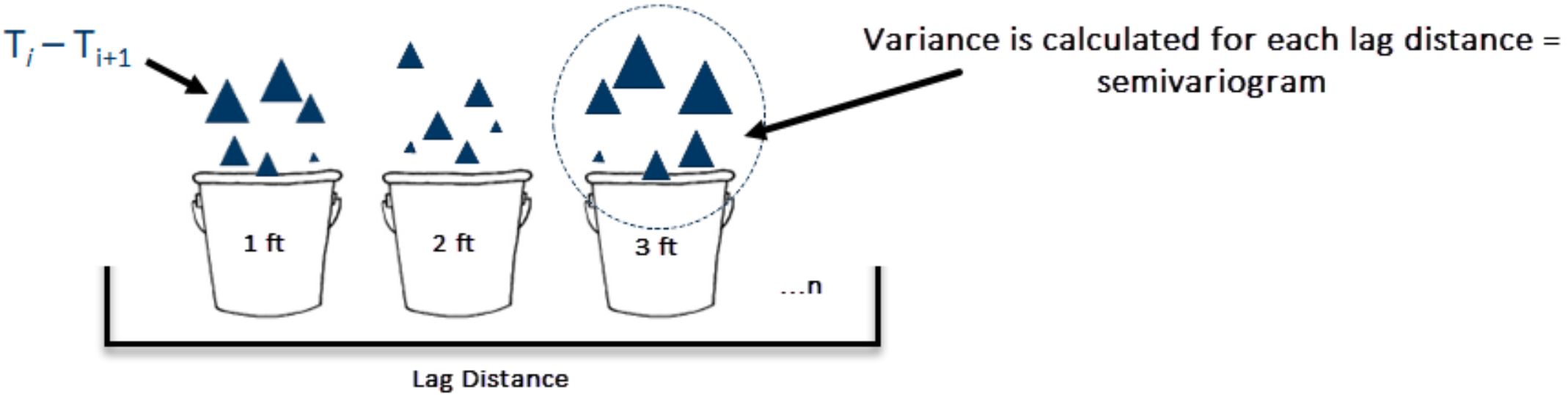


"…closer things are more predictable and have less variability… while distant things are less predictable and are less related…"

Geospatial Segregation

A semivariogram considers all points and their **distance** with respect to **temperature variance**.



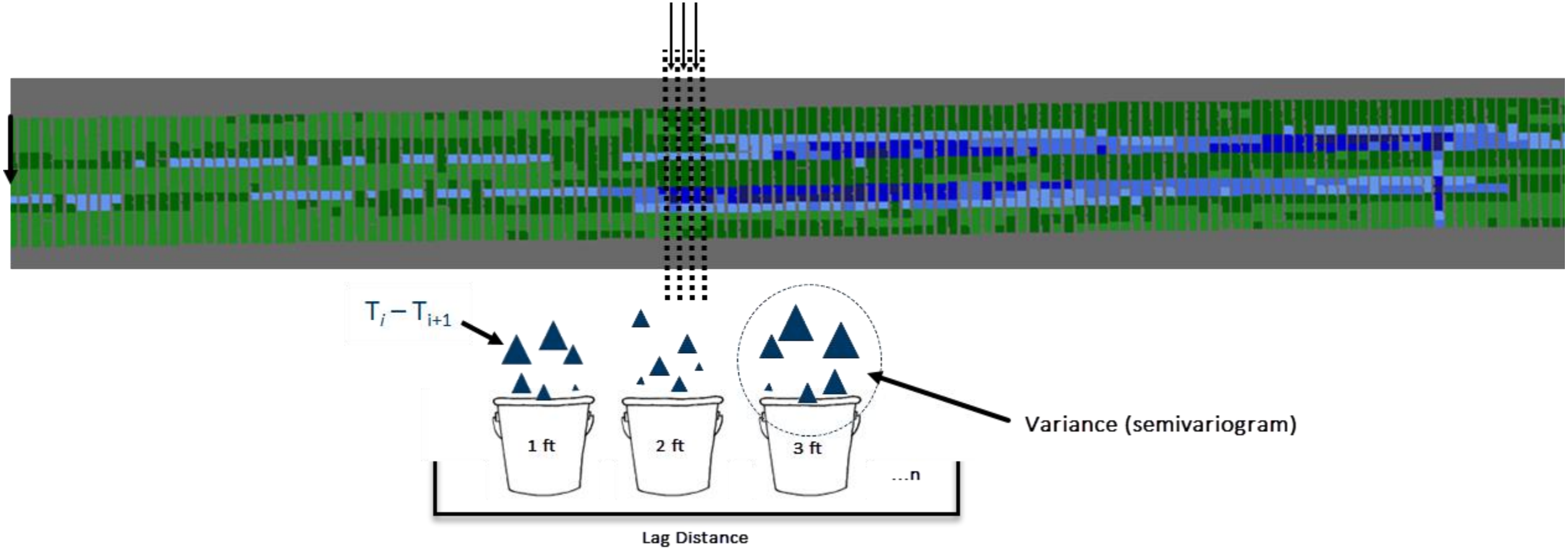


Geospatial Segregation

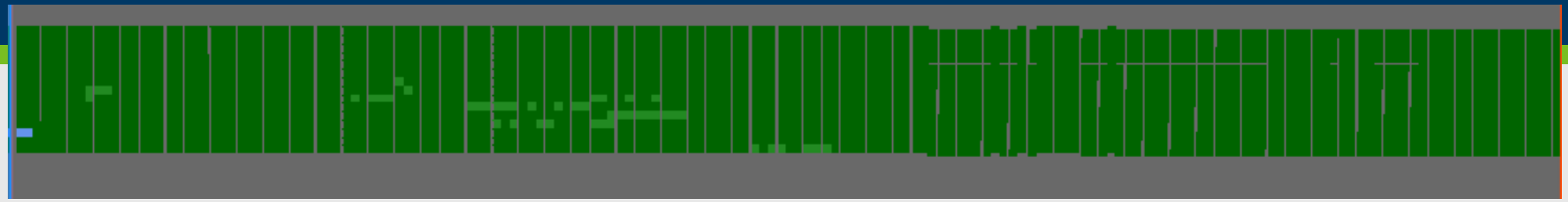
Standard Deviation

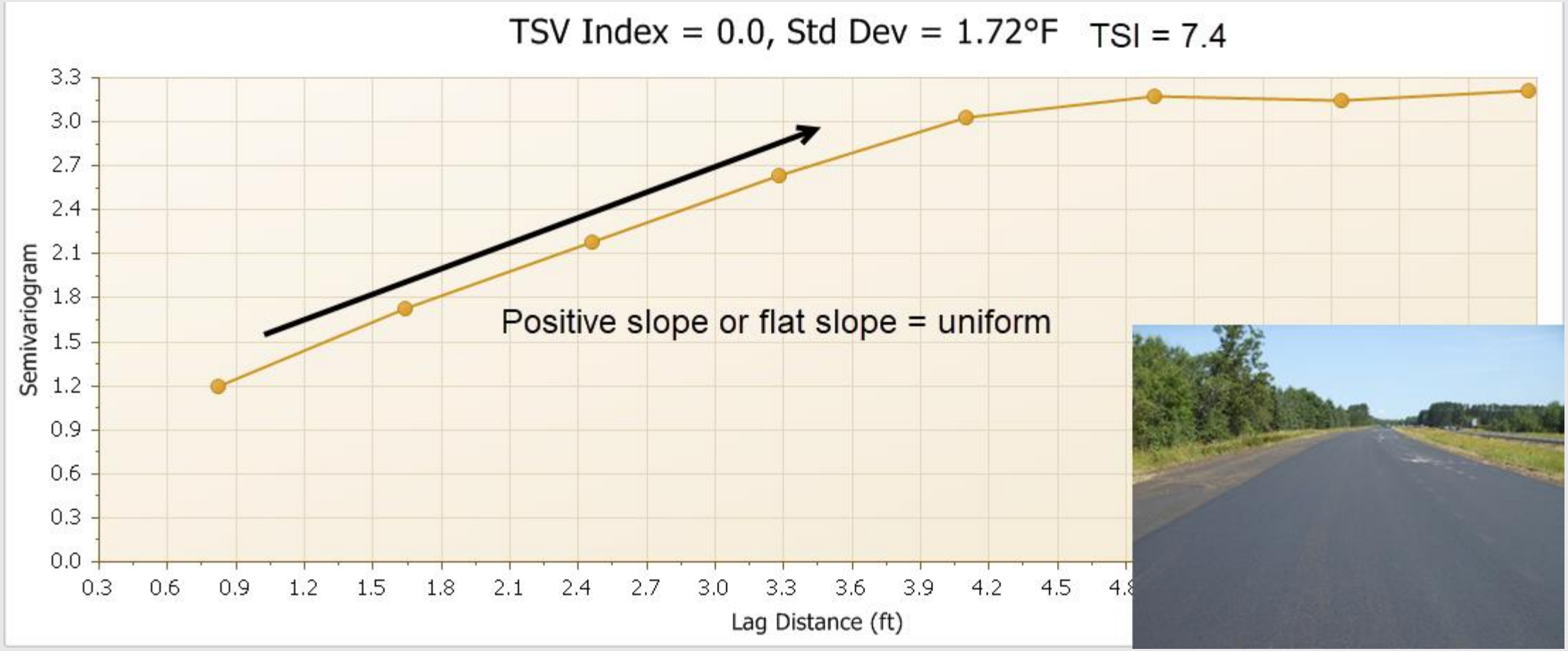
Standard Deviation $\cong$ Sill (semivarogram when variance plateaus)

Longitudinal segregation

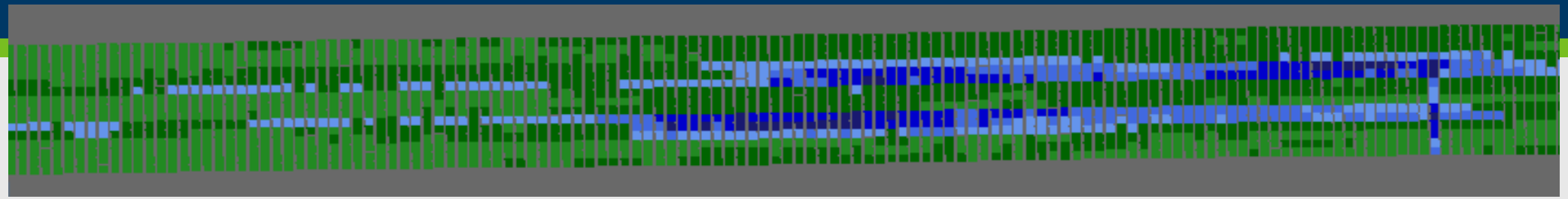


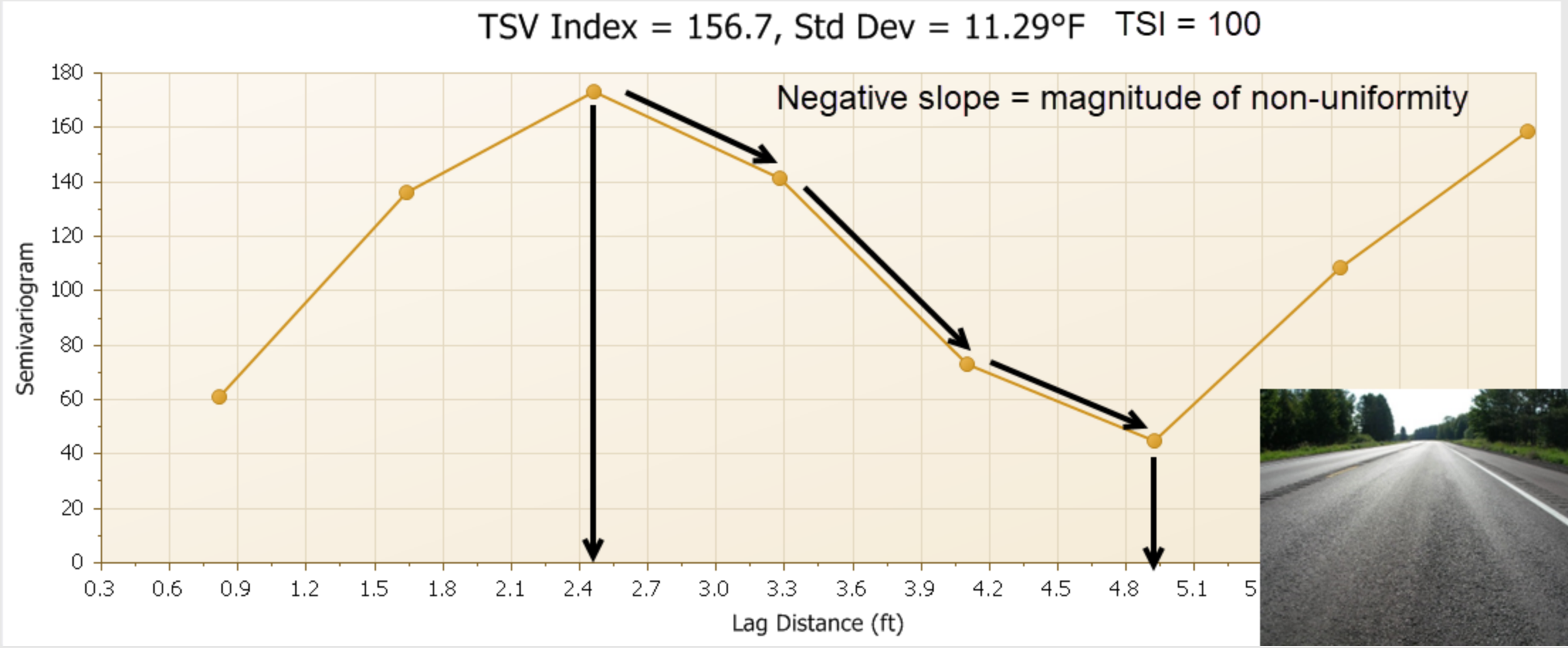
Longitudinal segregation – low severity





Longitudinal segregation – high severity





Longitudinal Segregation

Transverse Semivariogram (TSV) Index

TSV Index = Sum of the negative semivariogram slopes

Causes of geospatial (X-Y) segregation (standard deviation)

- Material segregation (material production, plant, trucking, paver)
- Plant temperature changes
- Stockpile moisture conditions
- Windrow placement
- Cycling hopper wings
- Hopper deck not covered
- Paver speeds and starting/stopping
- Material feed system
  - Level of mat'l at center of augur (feeder ratio dials)
  - Level of mat'l at the outboard ends of augers (feeder sensors)
  - Incorrect head of material at augers (ensure 1/2 auger)
  - Extension augers not used
- …

Causes of longitudinal segregation (stripes) (transverse semivariogram [TSV])

- Centerline
  - Missing or damaged deflector plates
  - Overloaded material feed system
  - Worn reversing augers
  - Low auger RPM
  - Mix dragging beneath gear box
- Outer auger bearing support
  - Excessive slow auger RPM
- Conveyors
  - Overloaded feeder system
  - Low auger RPM
  - Mix dragging beneath paver
- Outboard edge of mat
  - Insufficient material
  - Not enough auger extensions
- …

Thermal Segregation Index (TSI) equation

S-xx.B.5.a(2)

Equation 2016-1:

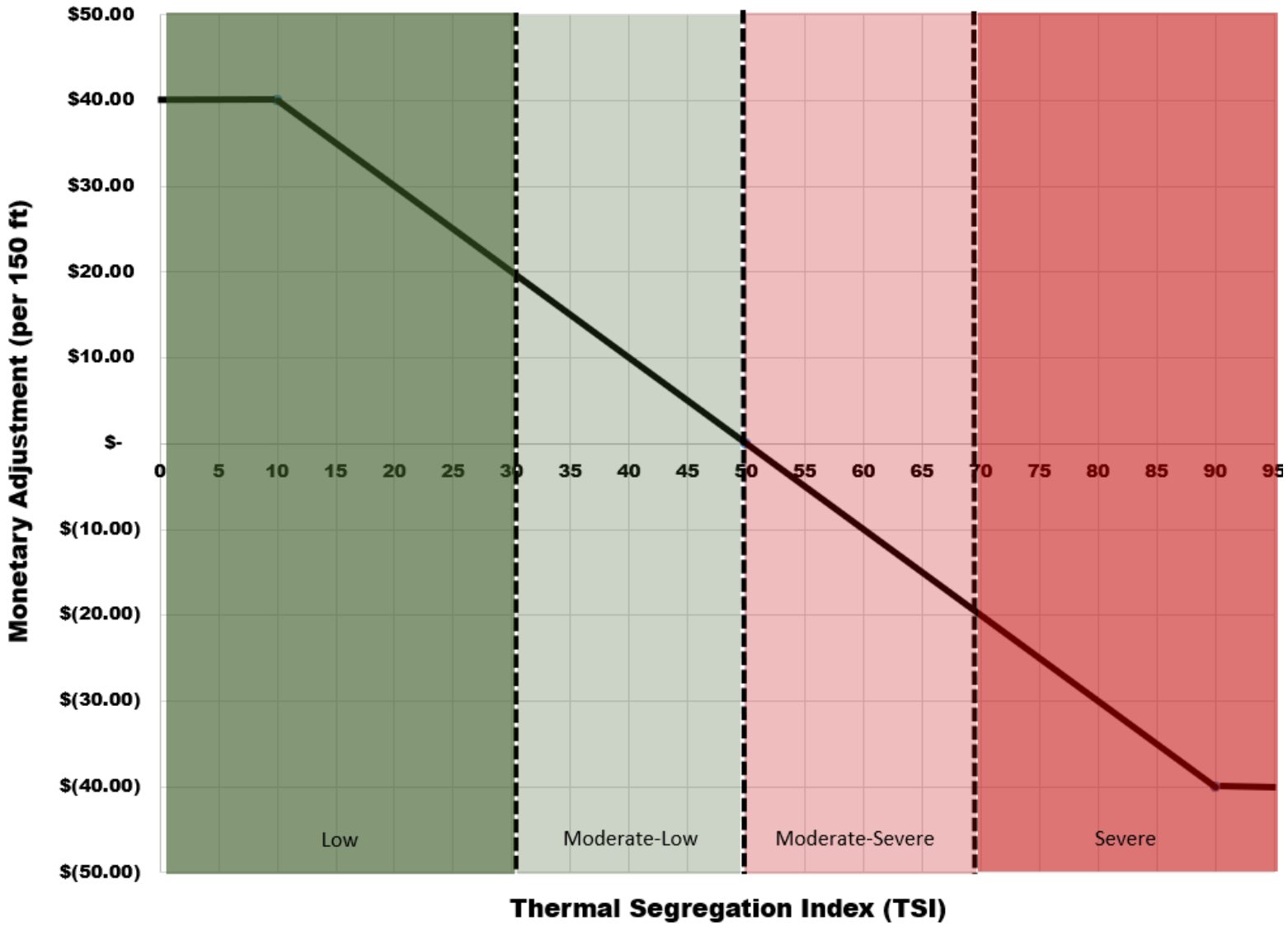
$$TSI_0 = 0.77\left[C \times \left(\frac{StDev}{StDev_{Severe\ Start}}\right) + (100 - C) \times \left(\frac{TSV}{TSV_{Severe\ Start}}\right)\right]$$

Equation 2016-2:

$$TSI = \begin{cases} TSI_0\ when\ TSI_0 < 100 \\ 100\ when\ TSI_0 \geq 100 \end{cases}$$

Where:
c = percent contribution of *Standard Deviation* to TSI_{Total} (ranges from 0 to 100, **default = 50**)

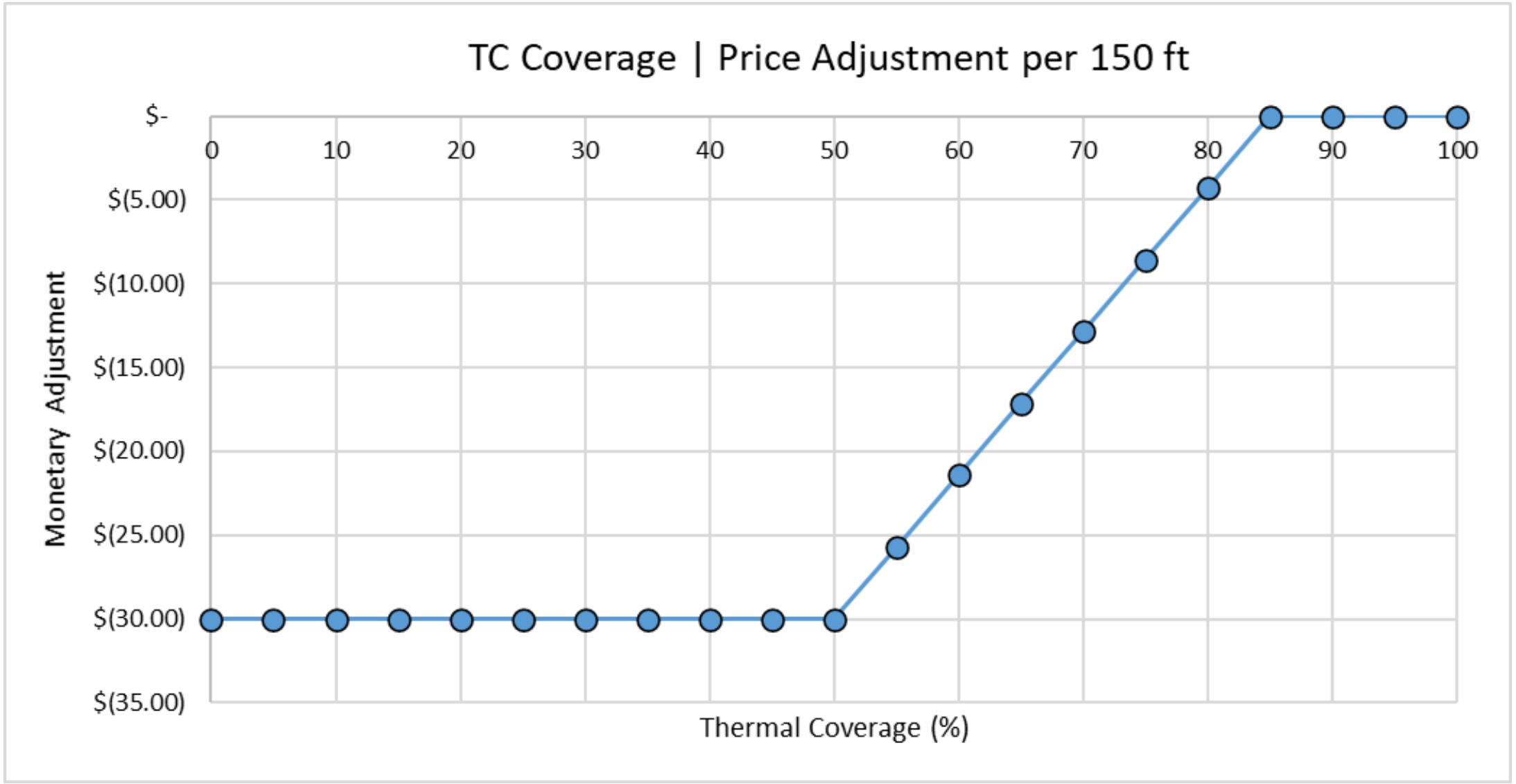
Monetary adjustments for thermal segregation



$$PA_{TSI} = \begin{cases} \$40 \ when \ TSI \ \leq 10 \\ \boldsymbol{PA_{TSI}} \ when \ 10 < TSI < 90 \\ -\$40 \ when \ TSI \ \geq 90 \end{cases}$$

$$PA_{TSI} = (50\text{-}TSI) \times 0.025 \times \$40$$

Thermal coverage monetary adjustments



ICT data submittals

S-xx.3.A.10

- Automatically transfer from ICT system to cloud storage within 15-minute intervals, or a minimum of once per day when limited satellite coverage
- Submit updated Veta projects and forms to Engineer at least 2 non-consecutive days per calendar week.

Price adjustment for Veta project and forms submittals

S-xx.3.5.A.1

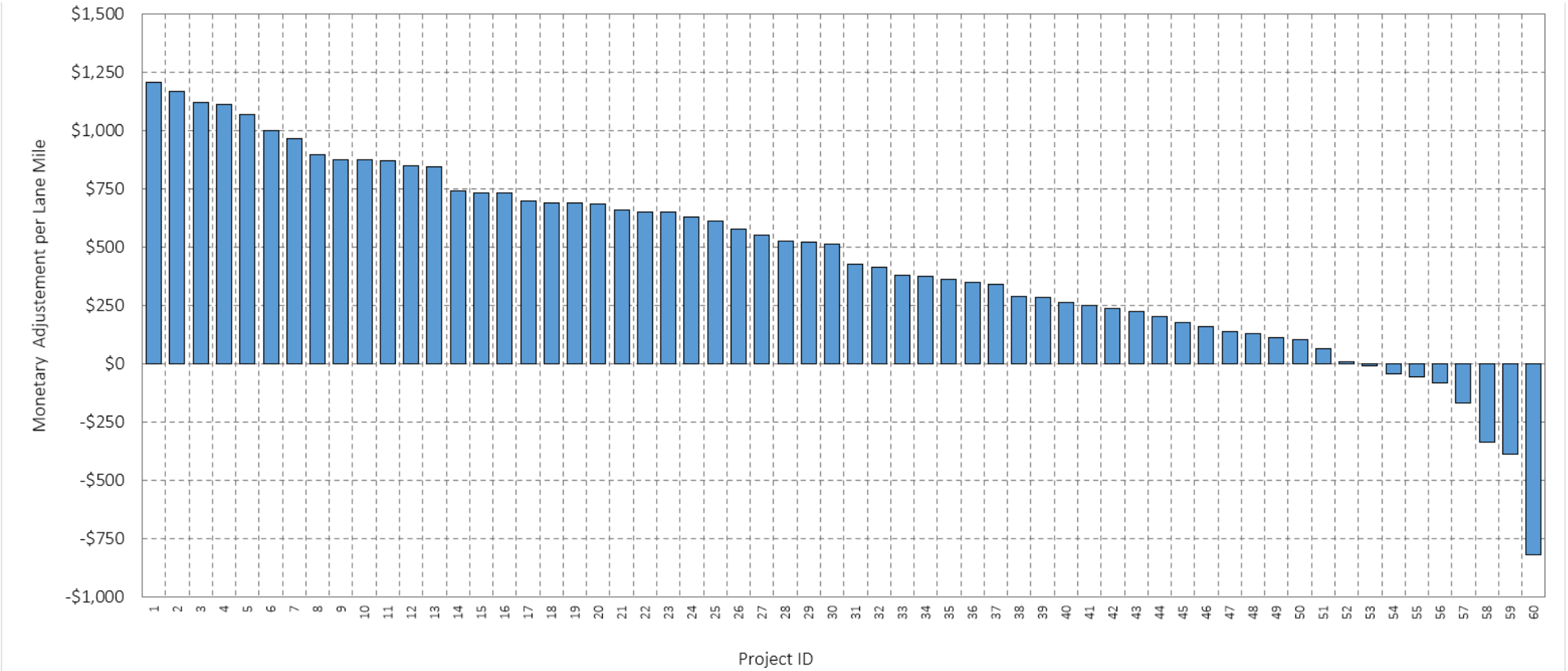
A monetary deduction of $500 per calendar day will be assessed for submitting the final version of the Veta project(s) and required forms later than 14-calendar days of completion of the ICT method.

S-xx.5 Basis of Payment

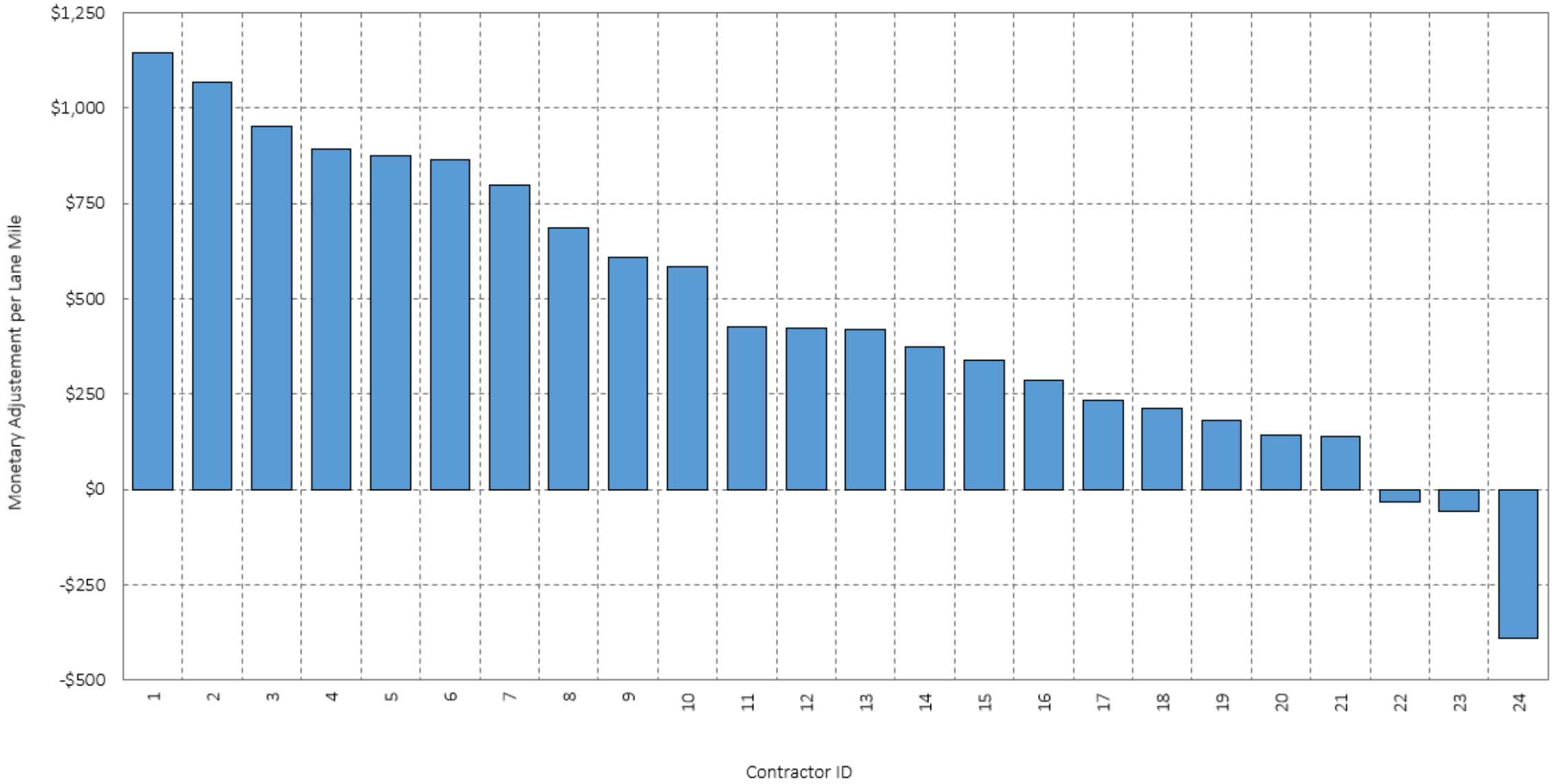
- 2016.601 Quality Management – PMTP Method …… Lump Sum
- 2016.601 Quality Management Special – IC Method …….. Lump Sum

DEPARTMENT OF TRANSPORTATION

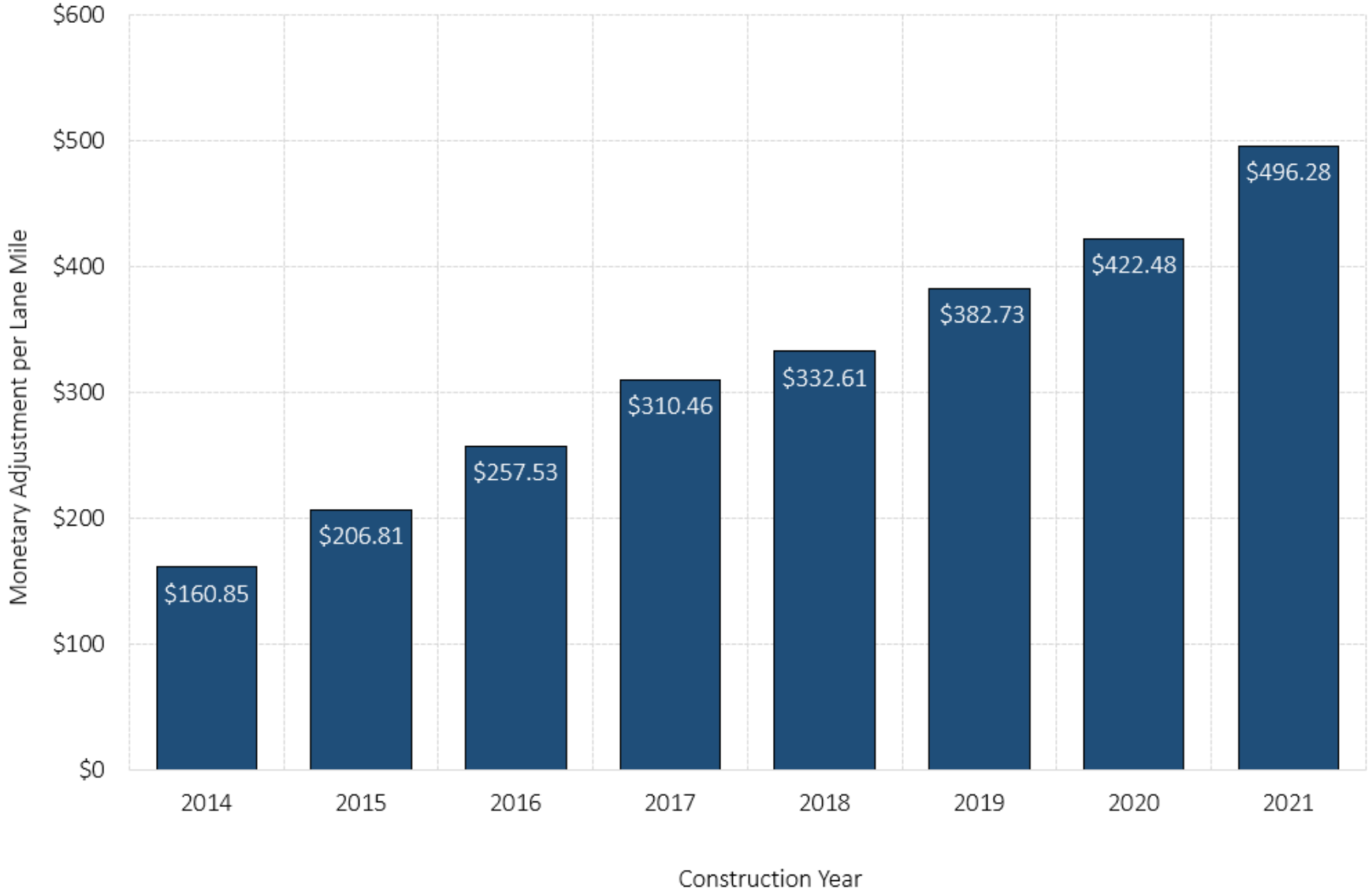
Use of Veta to identify workmanship issues



PMTP monetary adjustment per lane mile per project



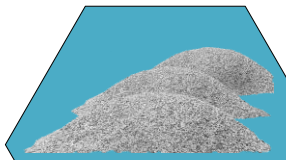
PMTP monetary adjustment per lane mile per contractor



PMTP monetary adjustments per lane mile per year

Equipment Considerations

Tarping Trucks



Monitoring Stock Piles

Report Cards Crew/Equipment Reviews

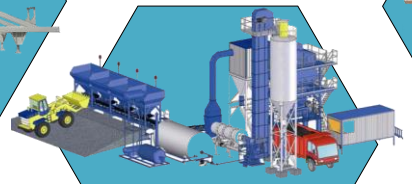
Guiding Belly Dumps

Proper Truck Loading

Real-Time Viewing of Data

Additional Rollers

Modifications to Paver Settings/ Maintenance

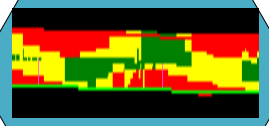


Monitoring Plant Temps

Reduced Paving Speeds

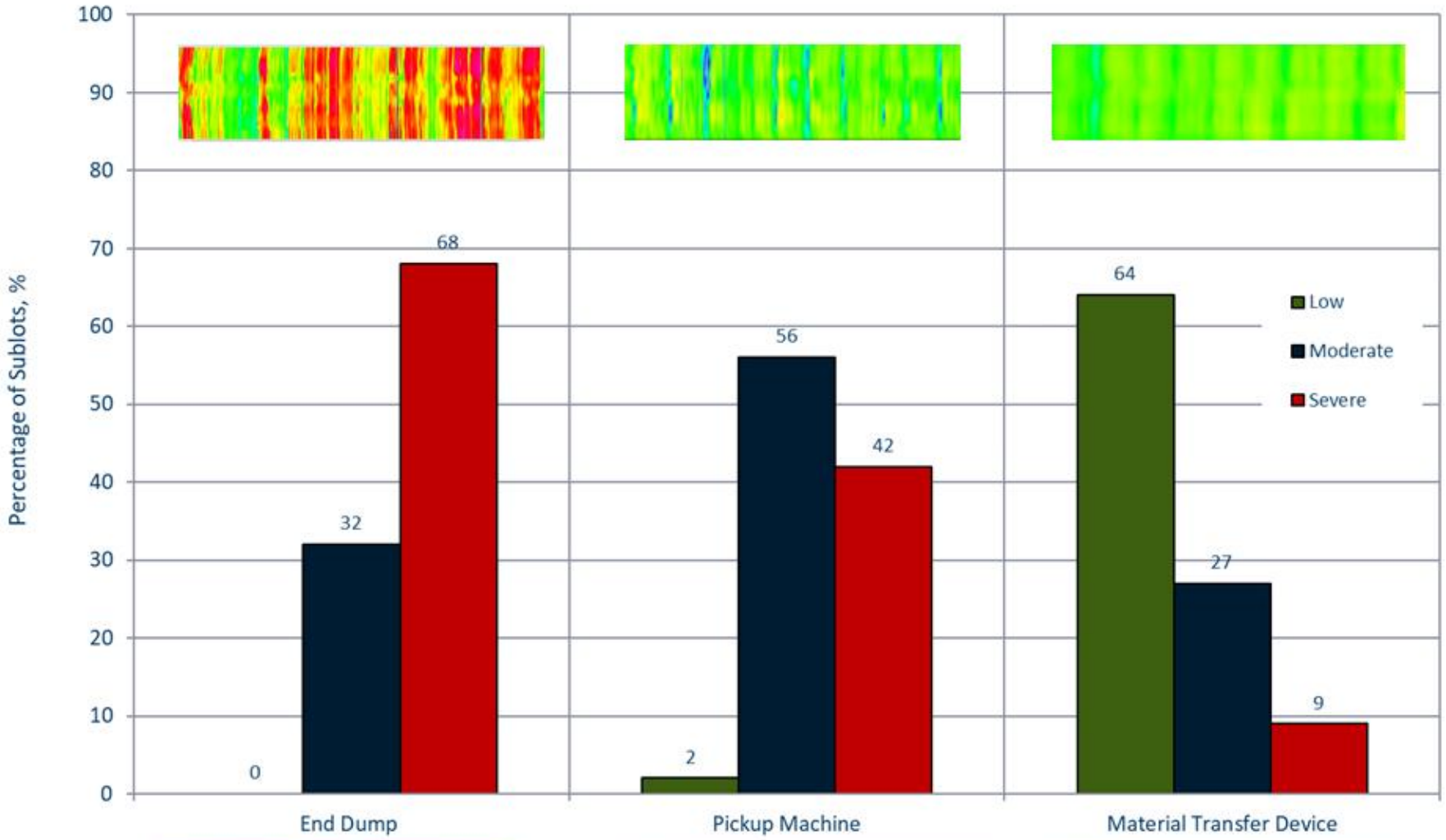
Increased Fleet Management

Off Season Training



Modification to Rolling Patterns

…some changes as a result of the technology

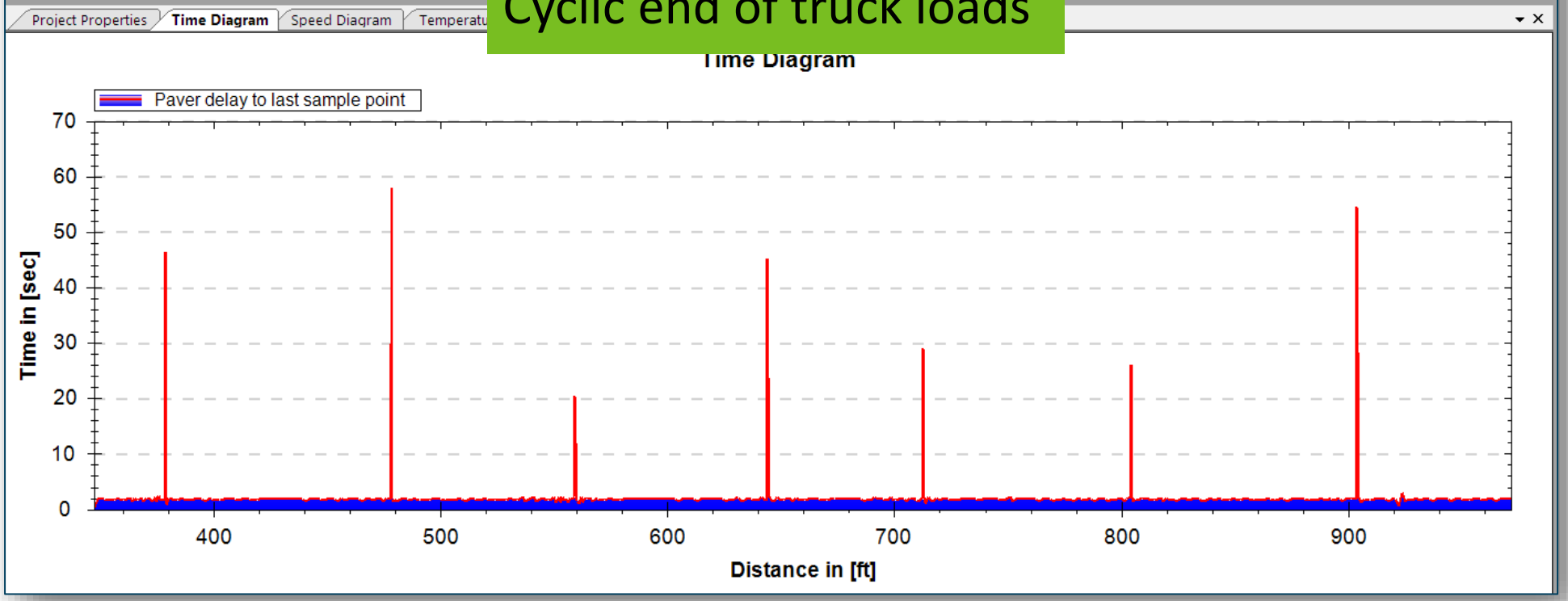


One Contractor –
One Project

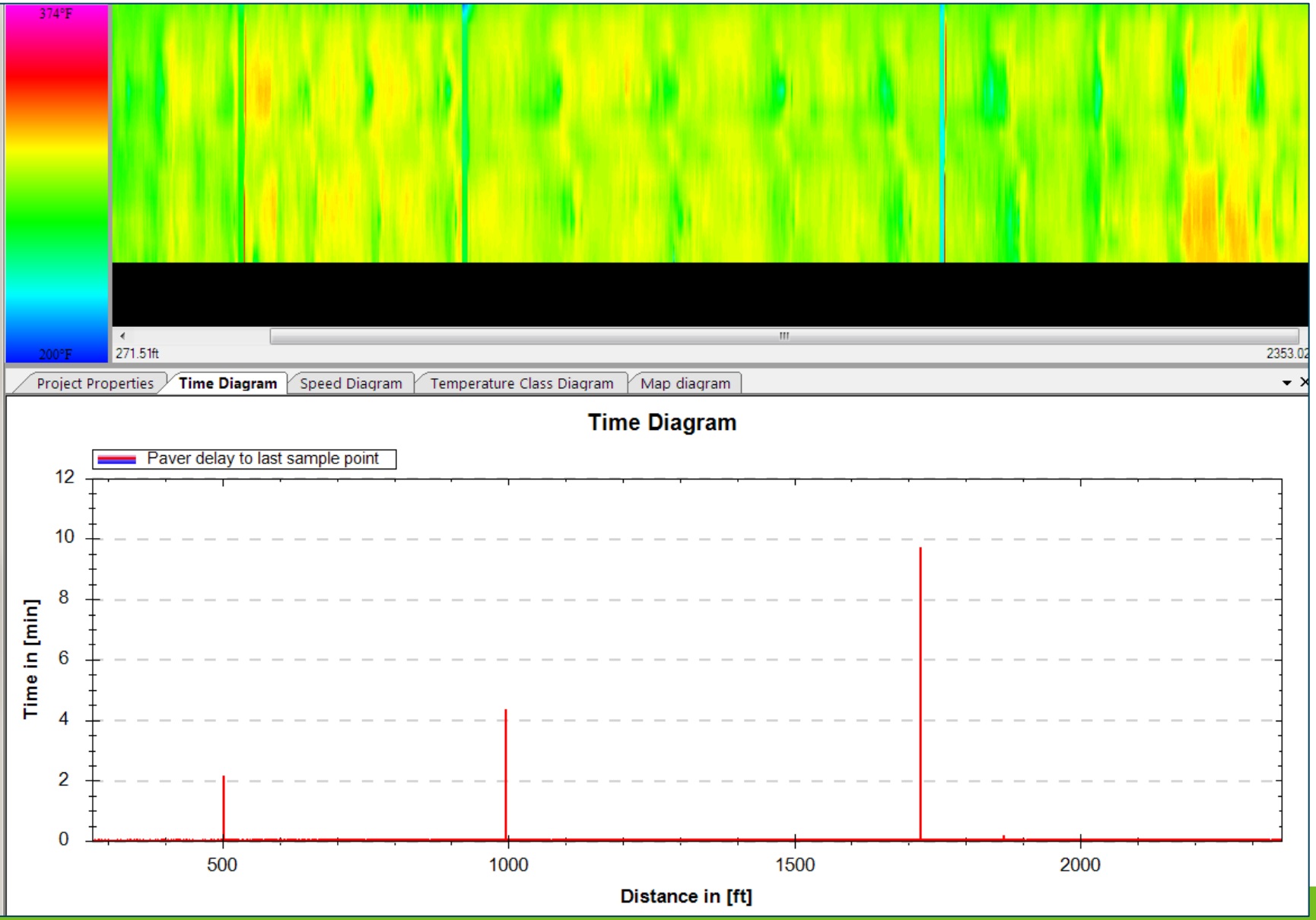
Raise box to allow mix to move against end-gate.
Then release end-gate to allow mix to drop in mass into the paver hopper to minimize material / thermal segregation.

End dump segregation

Cyclic end of truck loads

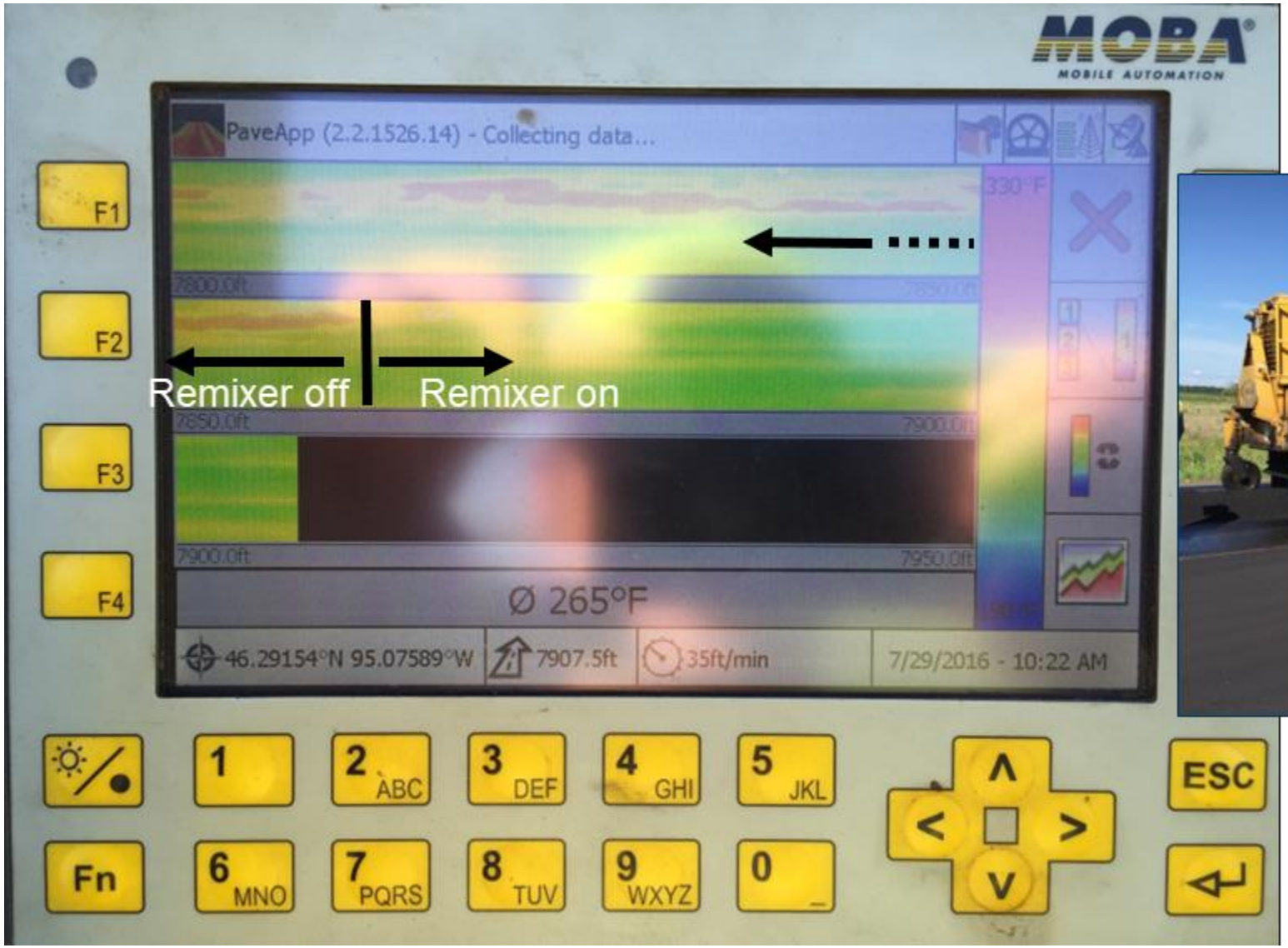


Thermal Segregation Category	Percent of Sublots
Low	0
Moderate	0
Severe	100



Thermal Segregation Category	Percent of Sublots
Low	0
Moderate	88
Severe	13

Reduced thermal segregation when using pickup machine

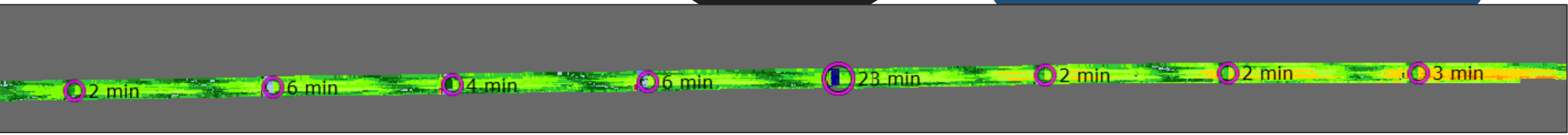


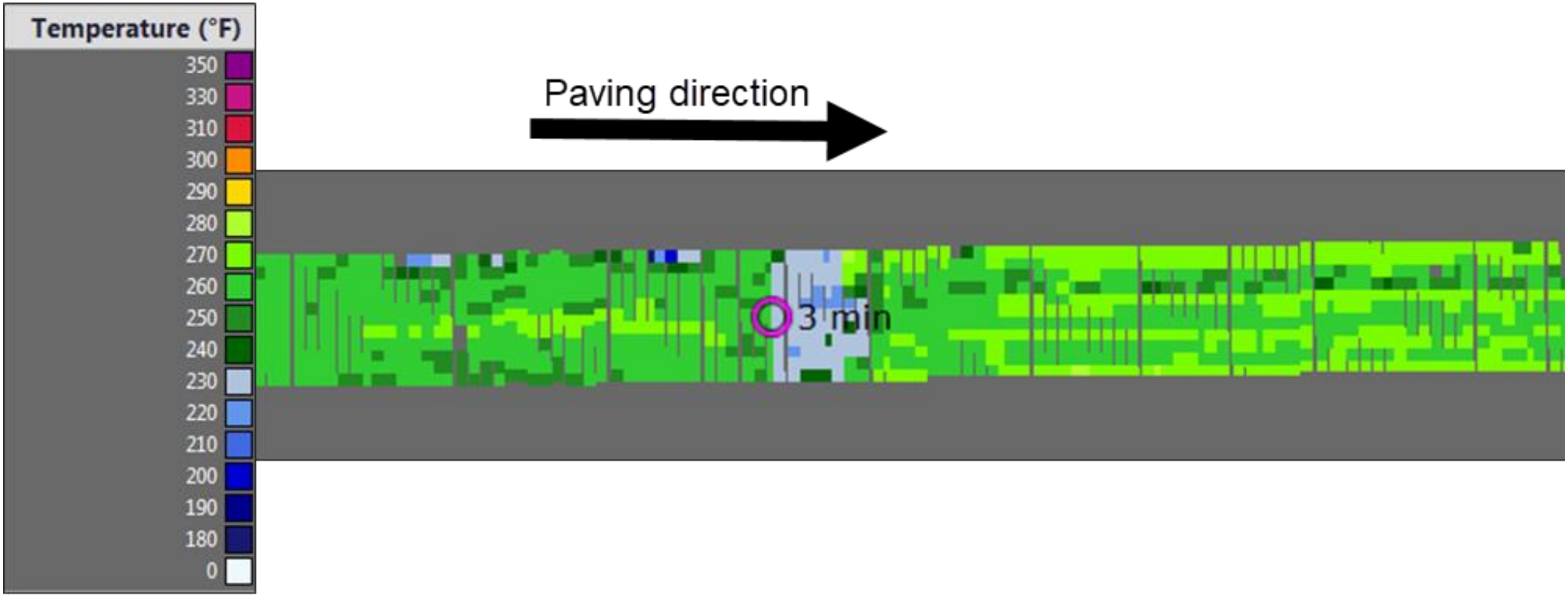
Consider equipment used during paving operation

Most paver stops are preventable with changes to operations.

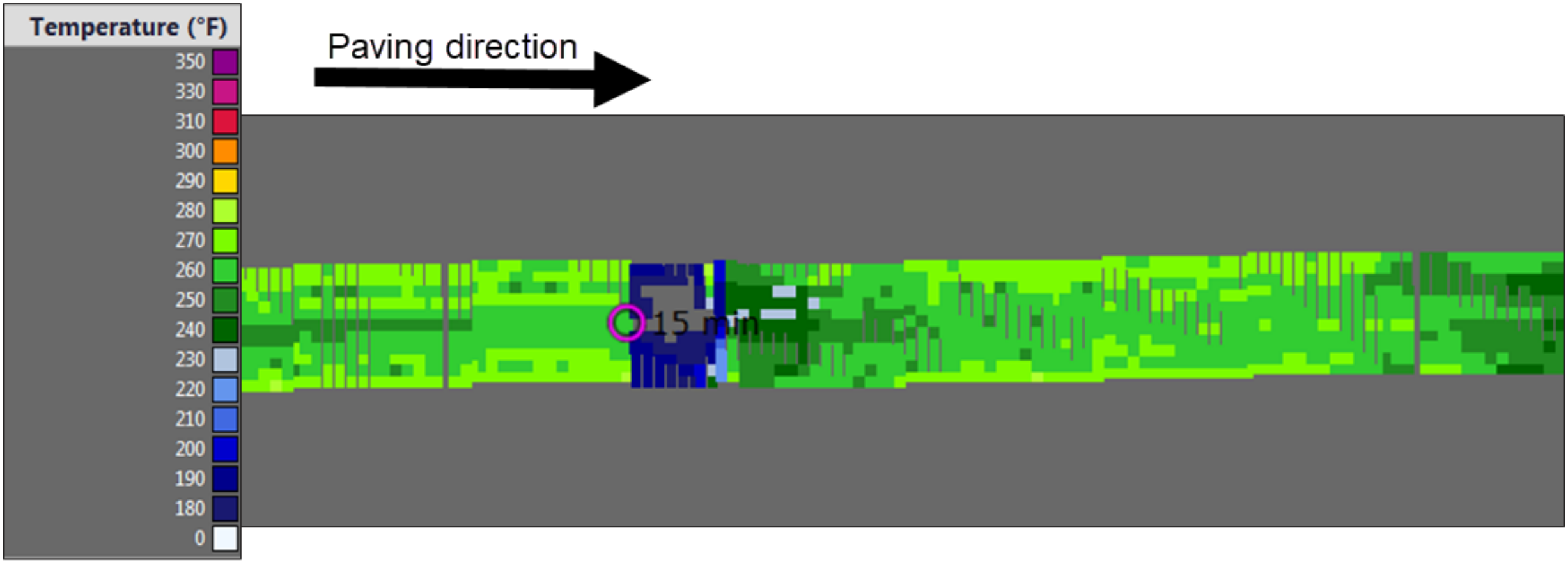
Negatively affects durability, density, ride, . . .

Too many paver stops

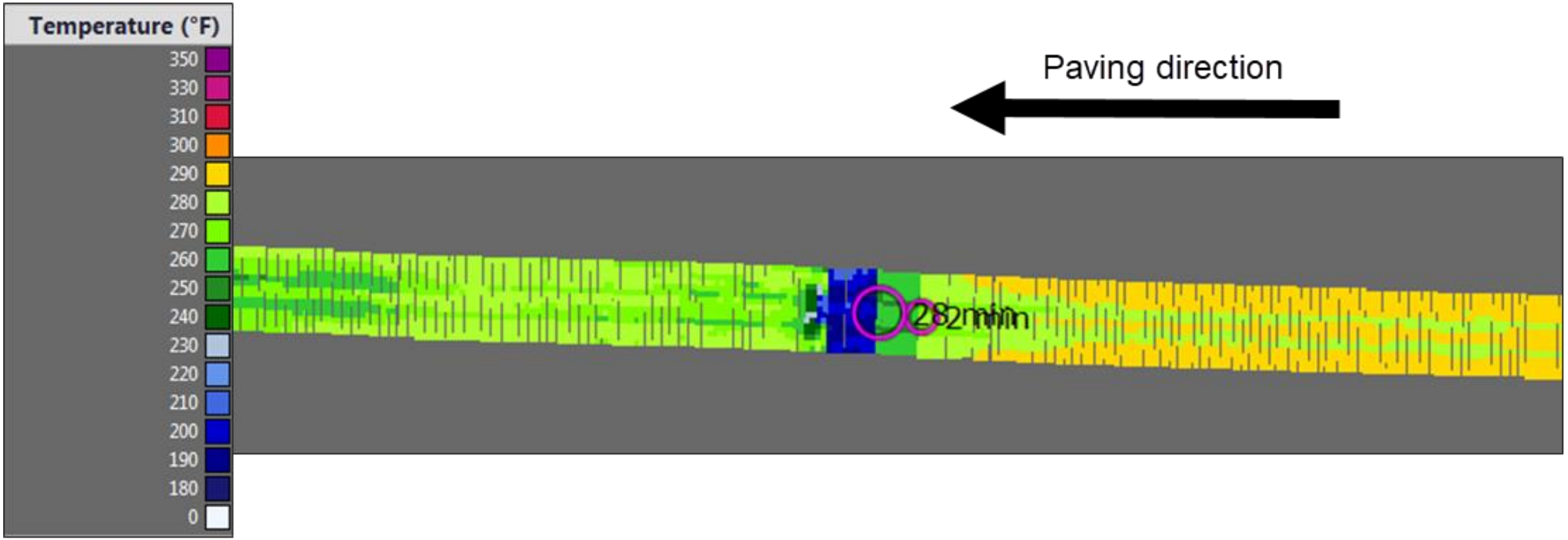




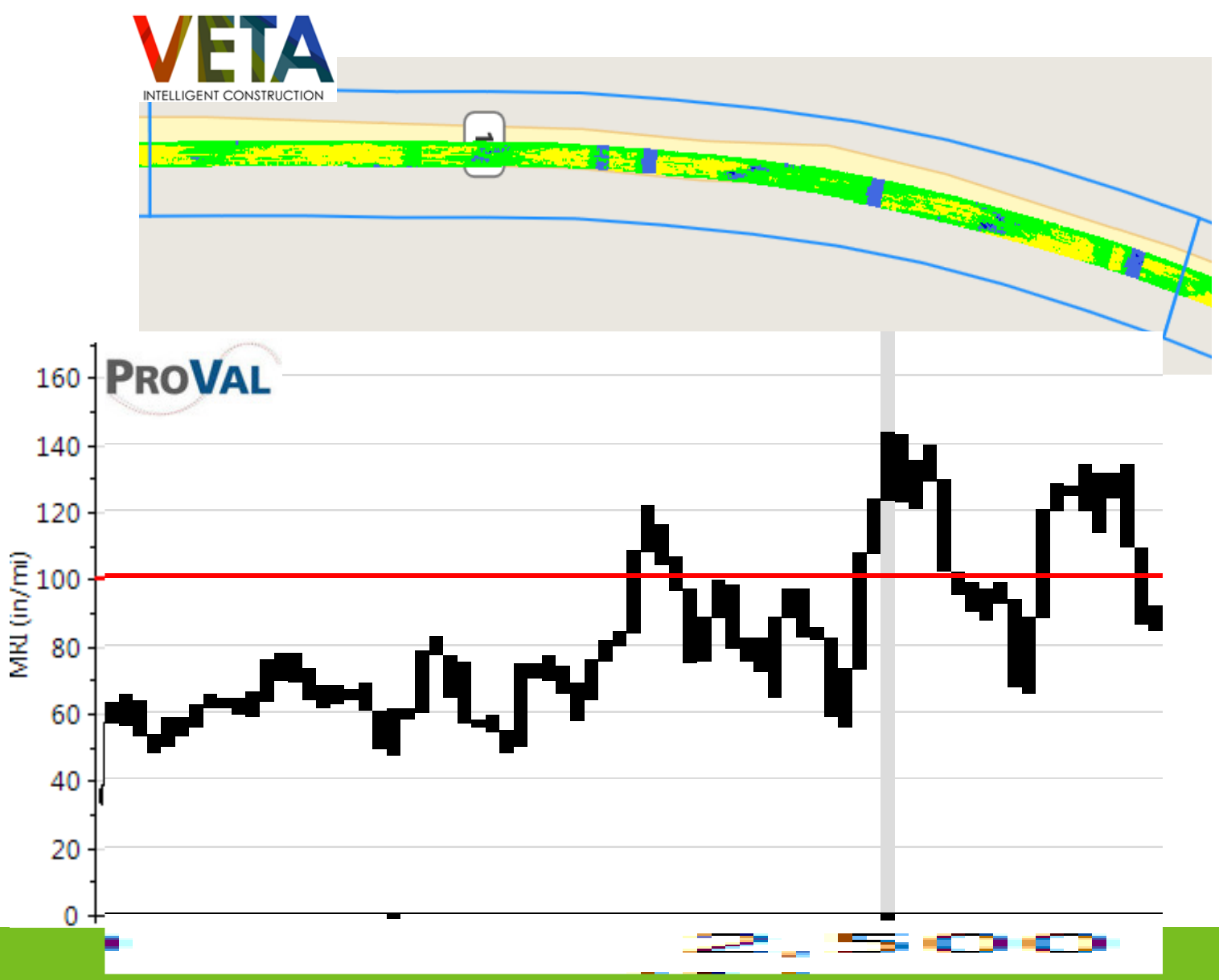
Thermal segregation after a 3-minute paver stop



Thermal segregation after a 15-minute paver stop



Thermal segregation after a 28-minute paver stop



Not all roughness is from paver stops.

…But…

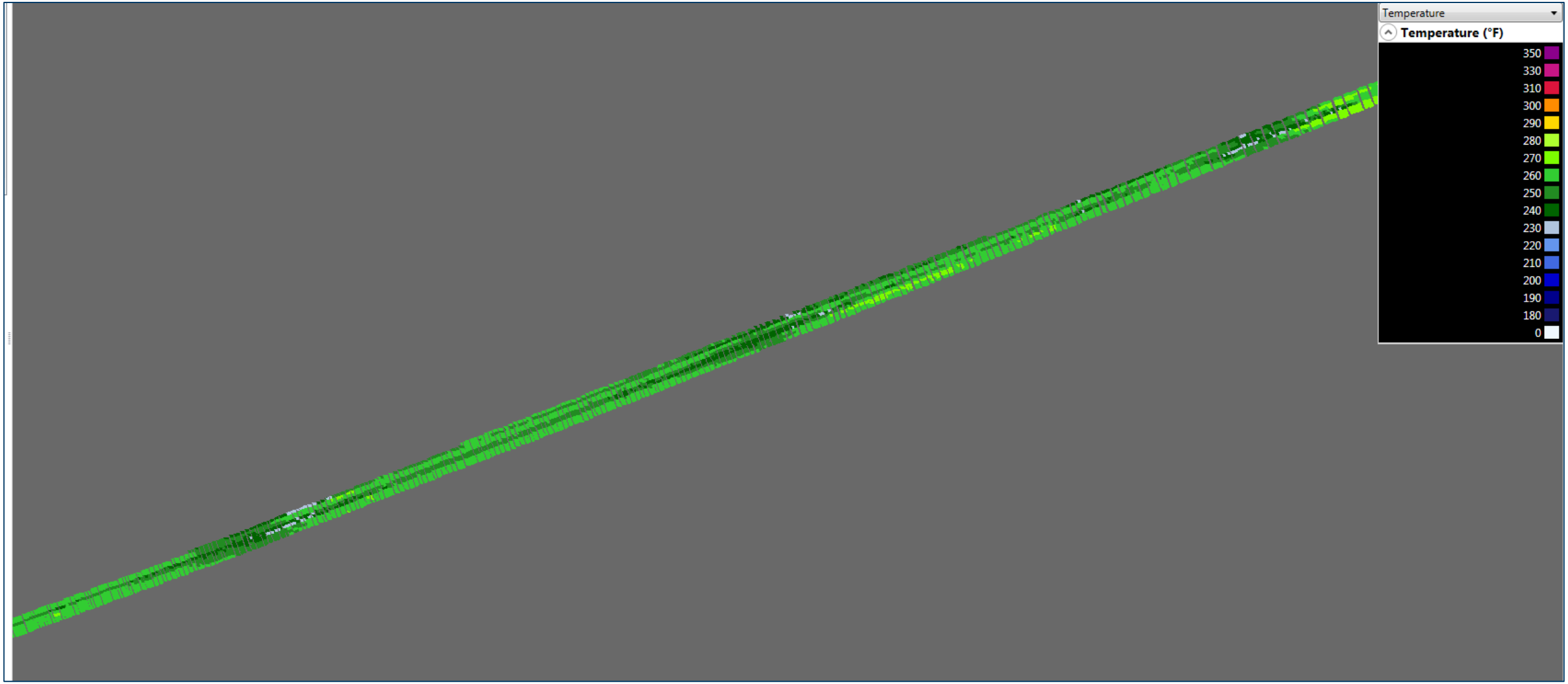
Fewer paver stops equals fewer opportunities to create roughness.

Increased roughness at paver stops

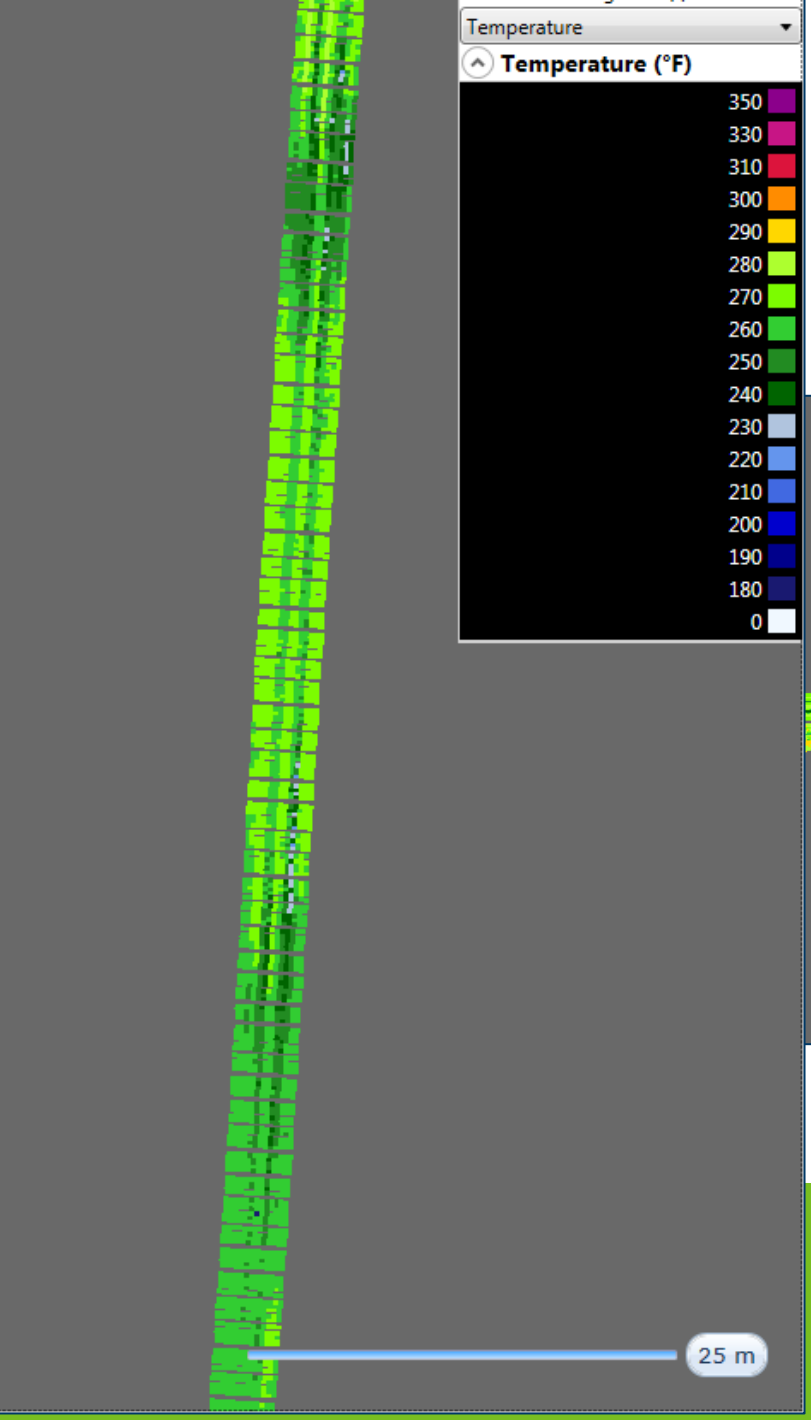
Windrows that are not overlapping

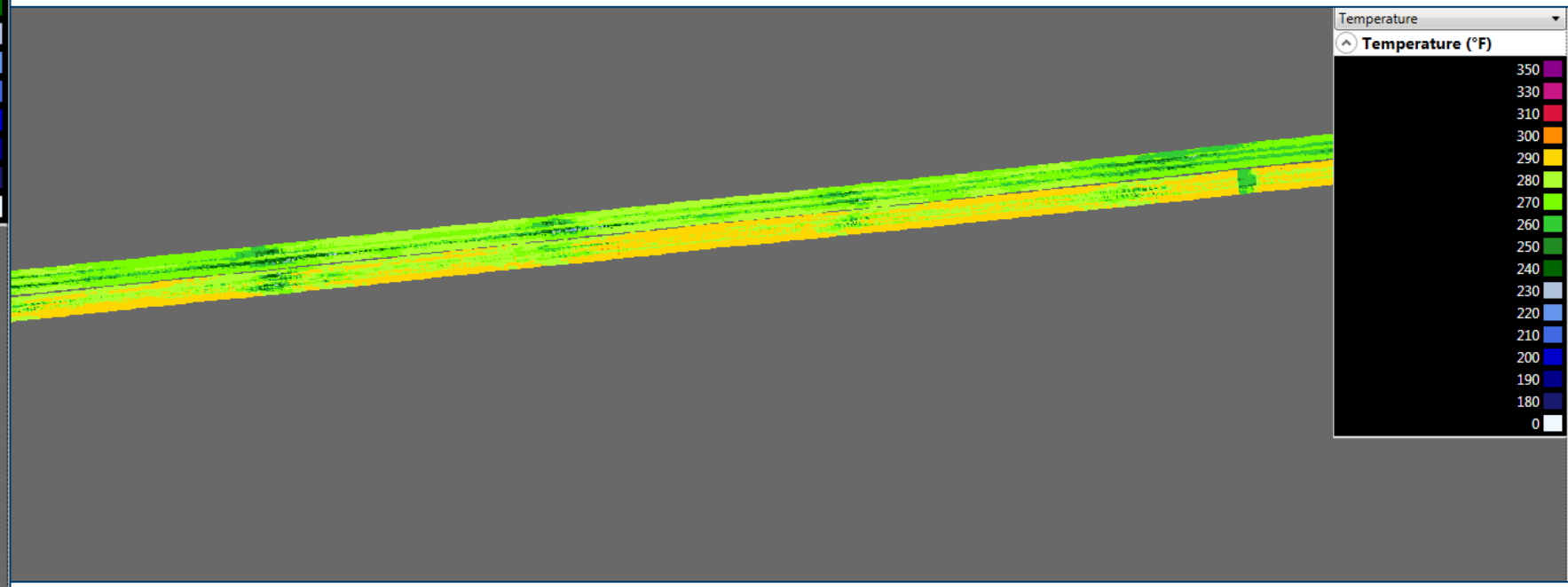
Trucks Driving on Windrows after Dump

Trucks driving on windrows can cause material and thermal segregation.

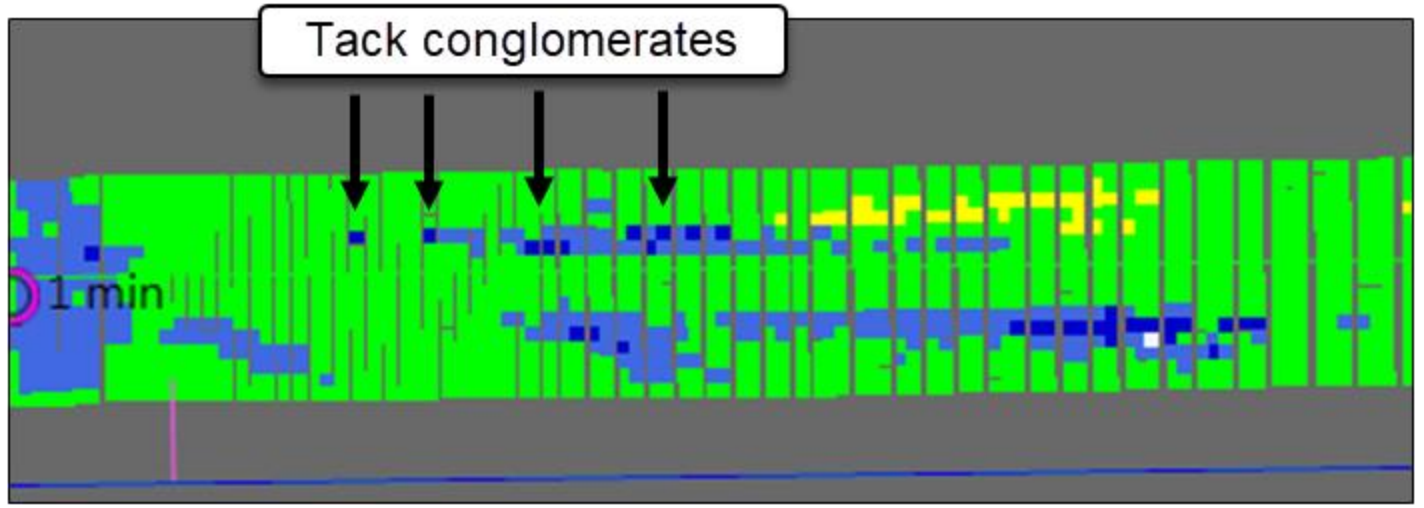


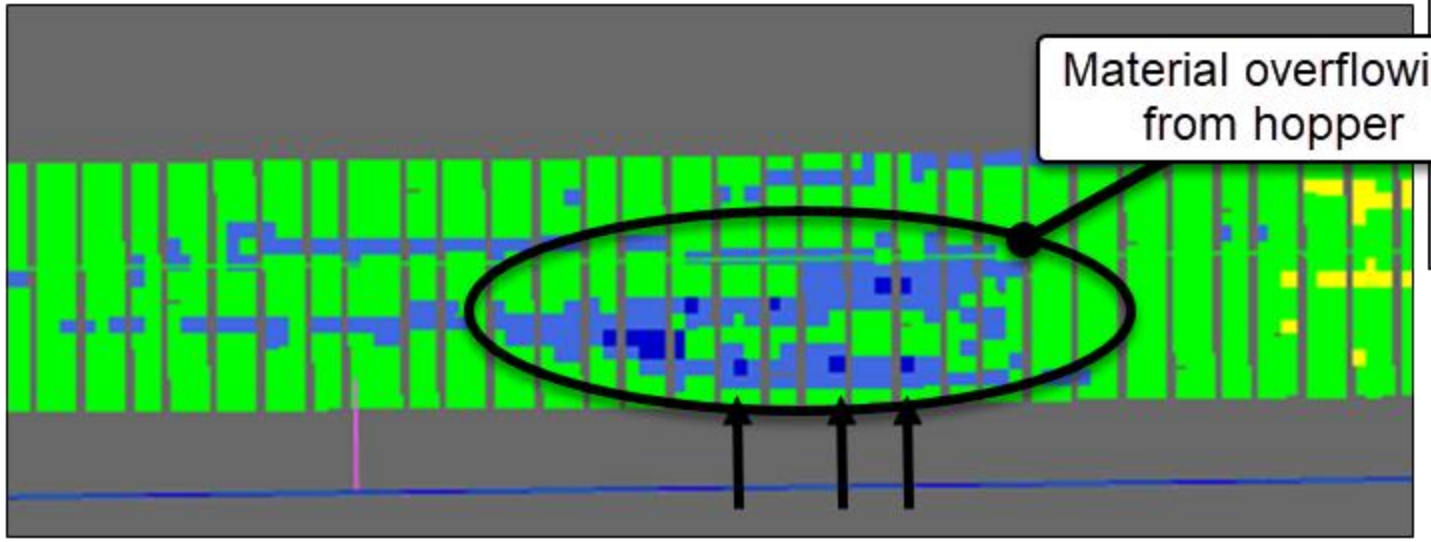
Segregation under gear box

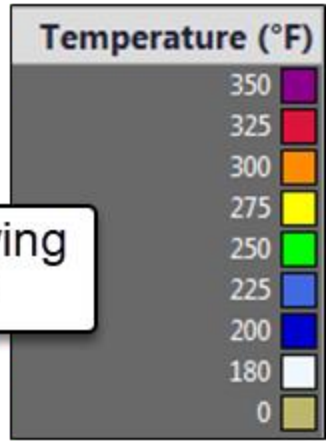




Thermal segregation under slat conveyors



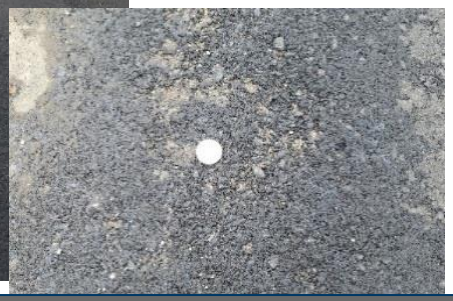


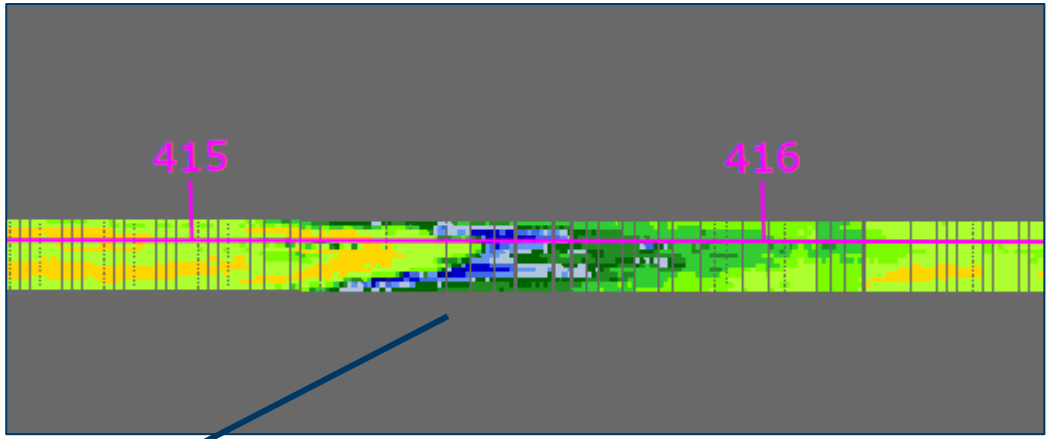


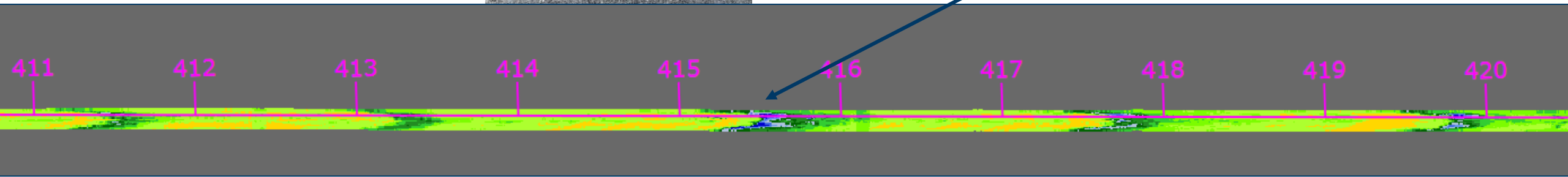
Ensure milled surface is kept clean and hopper is not overflowing

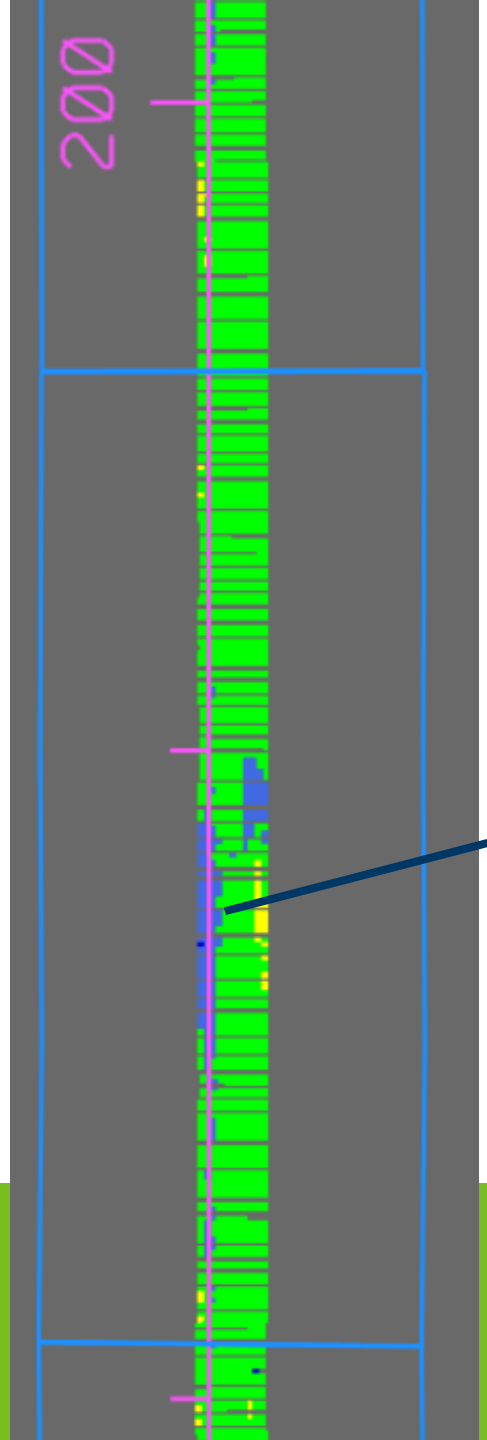
Folding hopper wings on paver

Do not fold the paver wings between trucks.
This will distribute cold, segregated mix on the roadway.

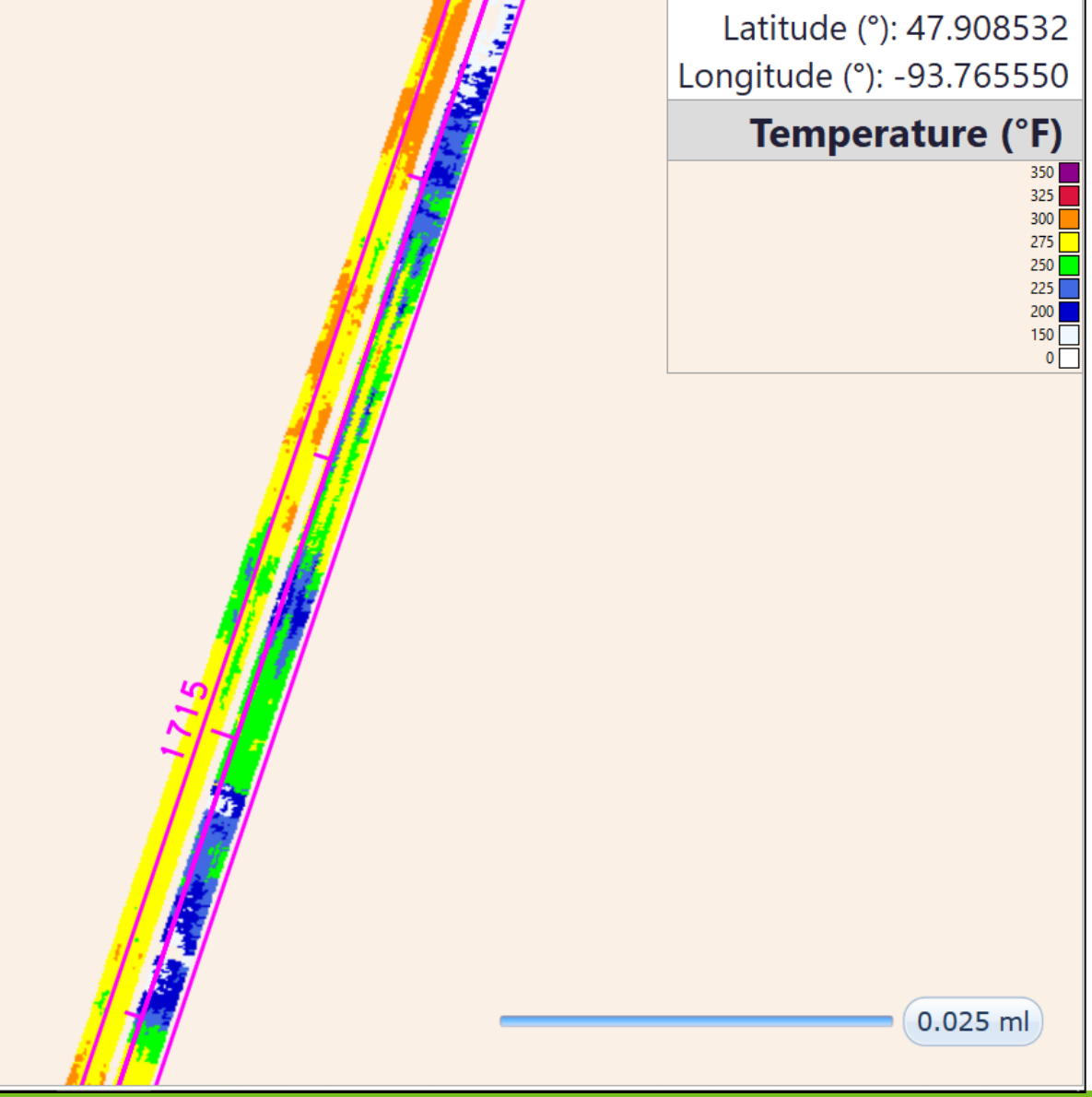


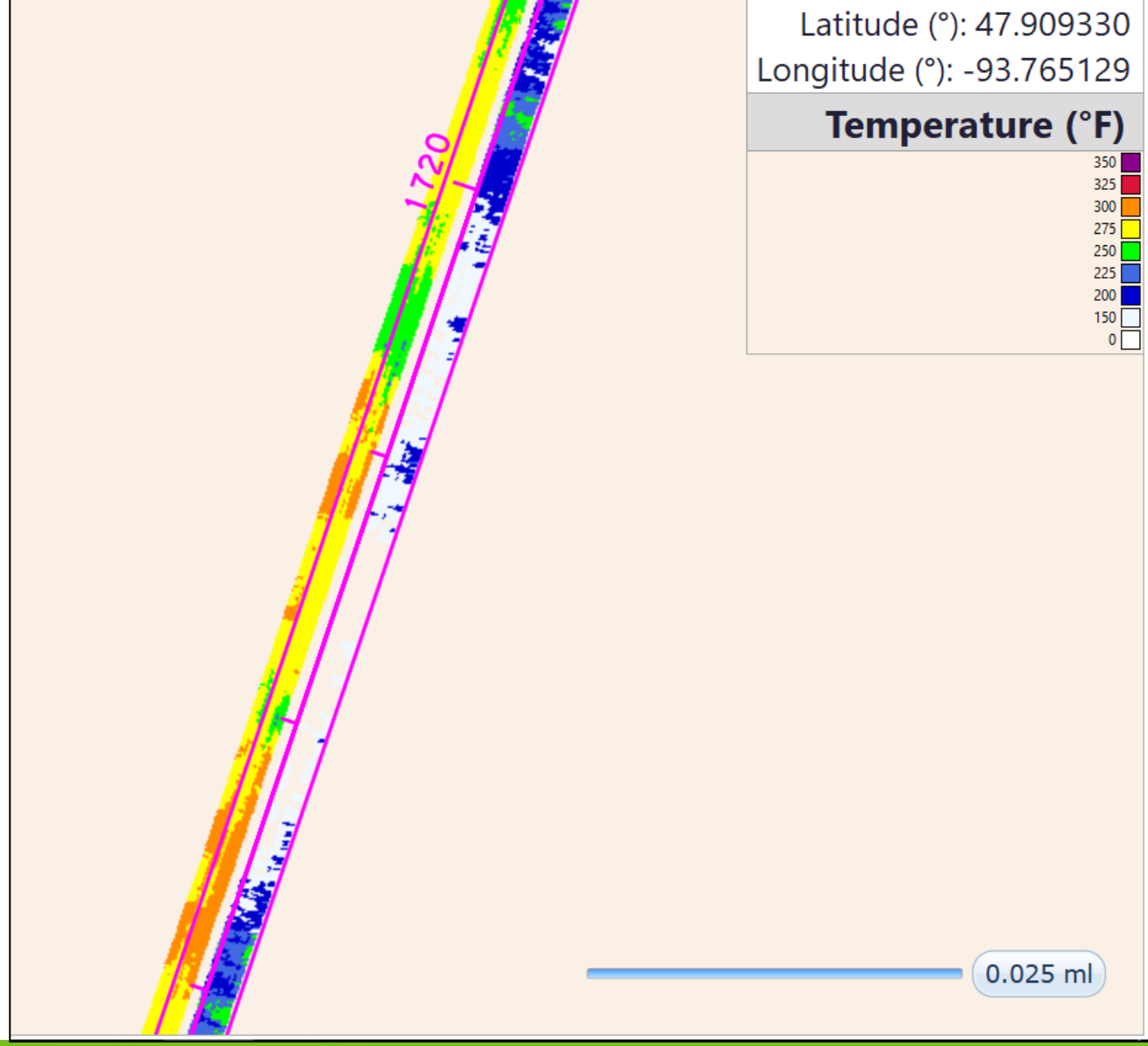






Material Segregation



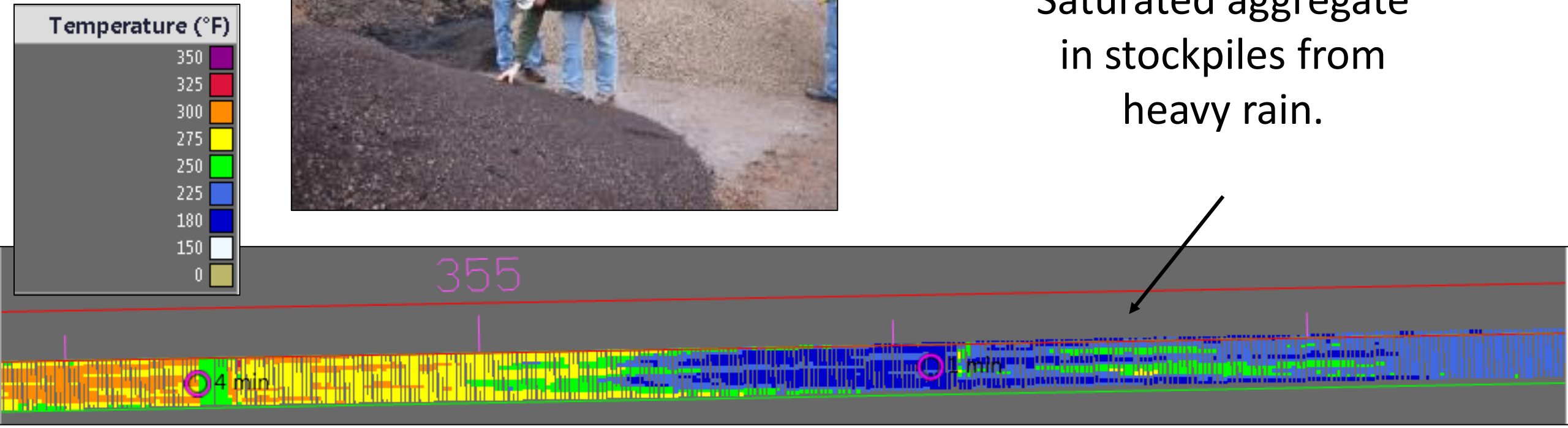


Rain event
Remove and replace

Monitor stockpiles for material changes, saturated aggregate, etc.

Failing density

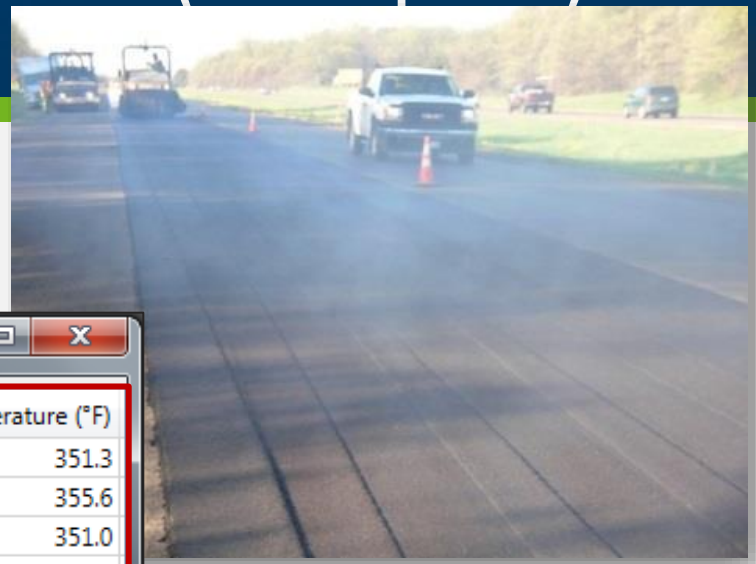
Saturated aggregate in stockpiles from heavy rain.



Detection of high temperatures (hot spots)

Temperature Changes at Plant

Mean Temperature = 280°F (138°C)



Search

Latitude (°) 45.010344

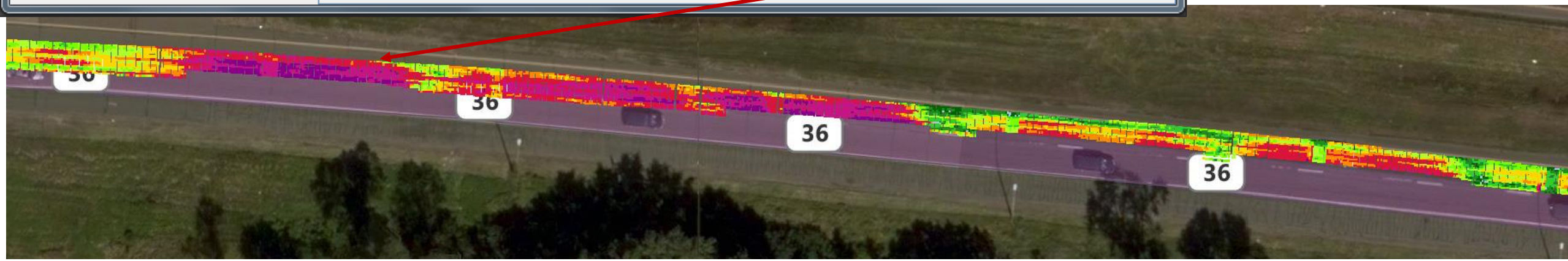
Longitude (°) -93.139949

Radius (ft) 1.0

Raw Data

Search

Timestamp	Machine ID	Latitude (°)	Longitude (°)	Sensor Location	Speed (ft/min)	Temperature (°F)
2016-09-16 18:09:46.033	20E4F396.EA8F0C03	45.0103435	-93.1399466	9	18.8	351.3
2016-09-16 18:09:46.033	20E4F396.EA8F0C03	45.0103457	-93.1399464	10	18.8	355.6
2016-09-16 18:09:47.012	20E4F396.EA8F0C03	45.0103435	-93.1399496	9	20.5	351.0
2016-09-16 18:09:47.012	20E4F396.EA8F0C03	45.0103457	-93.1399494	10	20.5	352.4
2016-09-16 18:09:47.932	20E4F396.EA8F0C03	45.0103435	-93.1399526	9	20.3	351.9



Improper mix placement – Unacceptable work

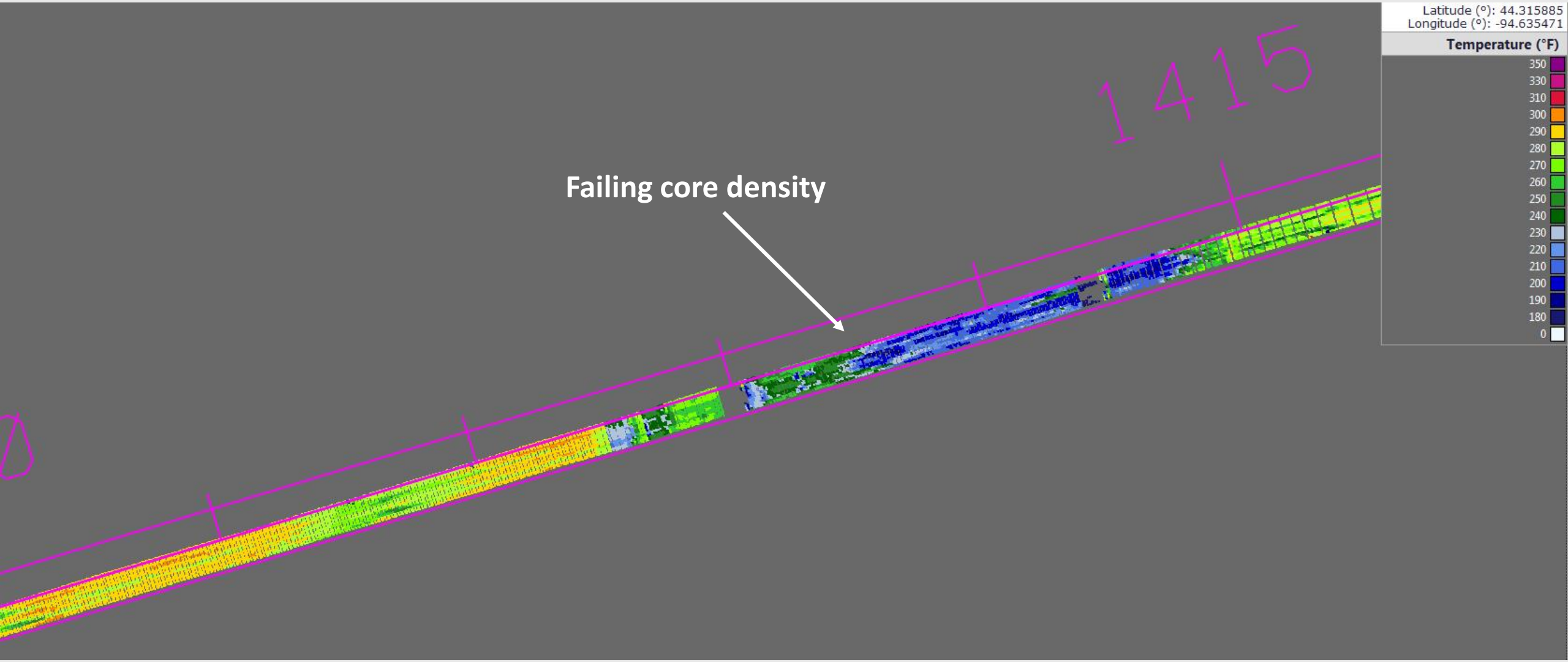
Pickup Machine Breakdown

- Continued to place mix on grade via belly dumps
- Paver driven over the cooled windrows
- Live dump loads loaded in paver hopper

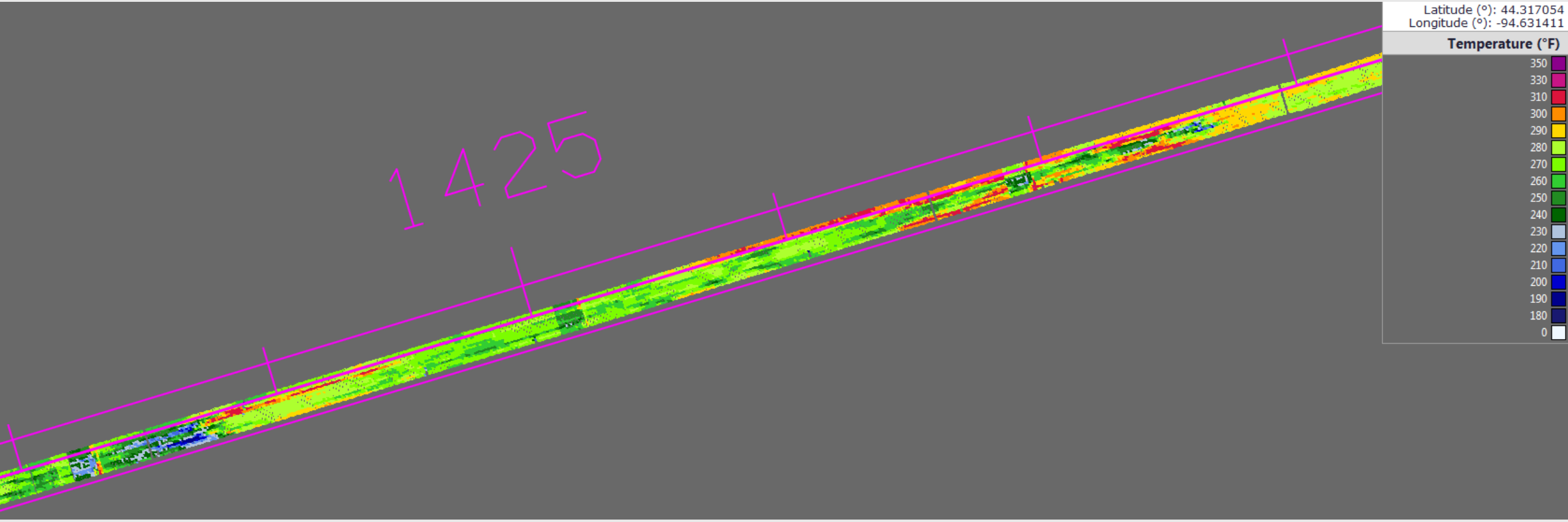
Field Results

- Material Segregation
- Severe Thermal Segregation
- Failing Core Densities (89.2%)

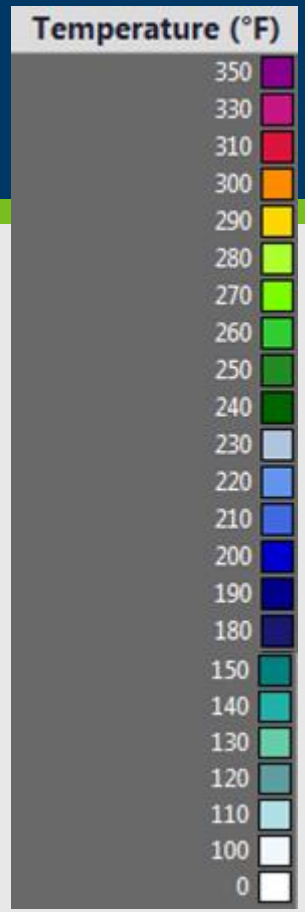
PMTP profile before and during pickup machine breakdown unacceptable work (cont)

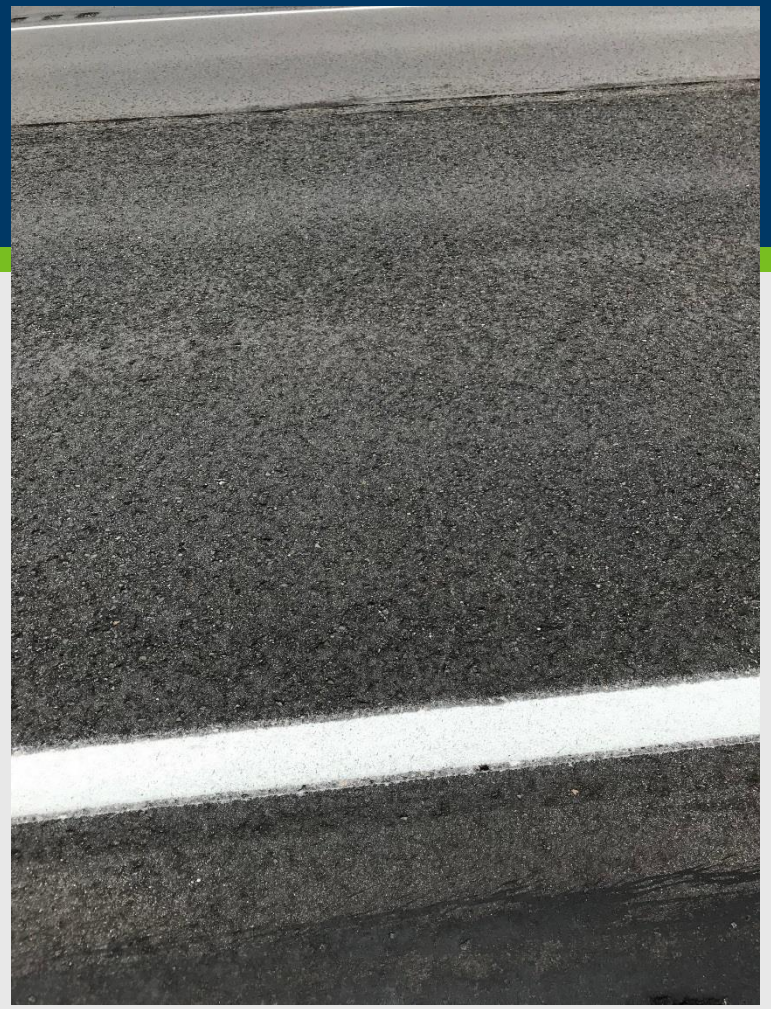


Segregation from hot material being loaded into hopper unacceptable work (cont)



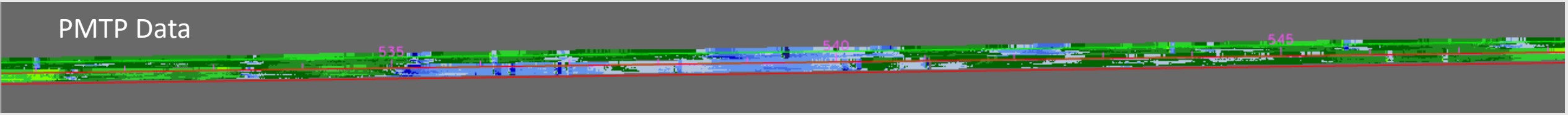
Placement and compaction of cold material



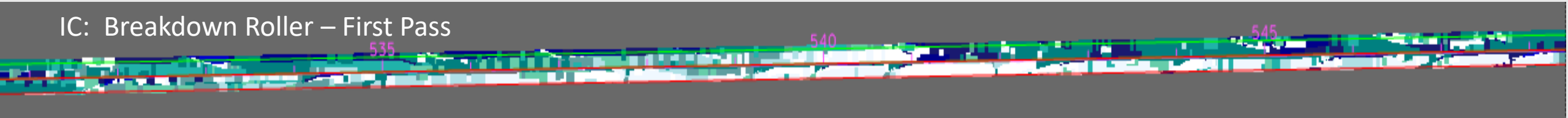


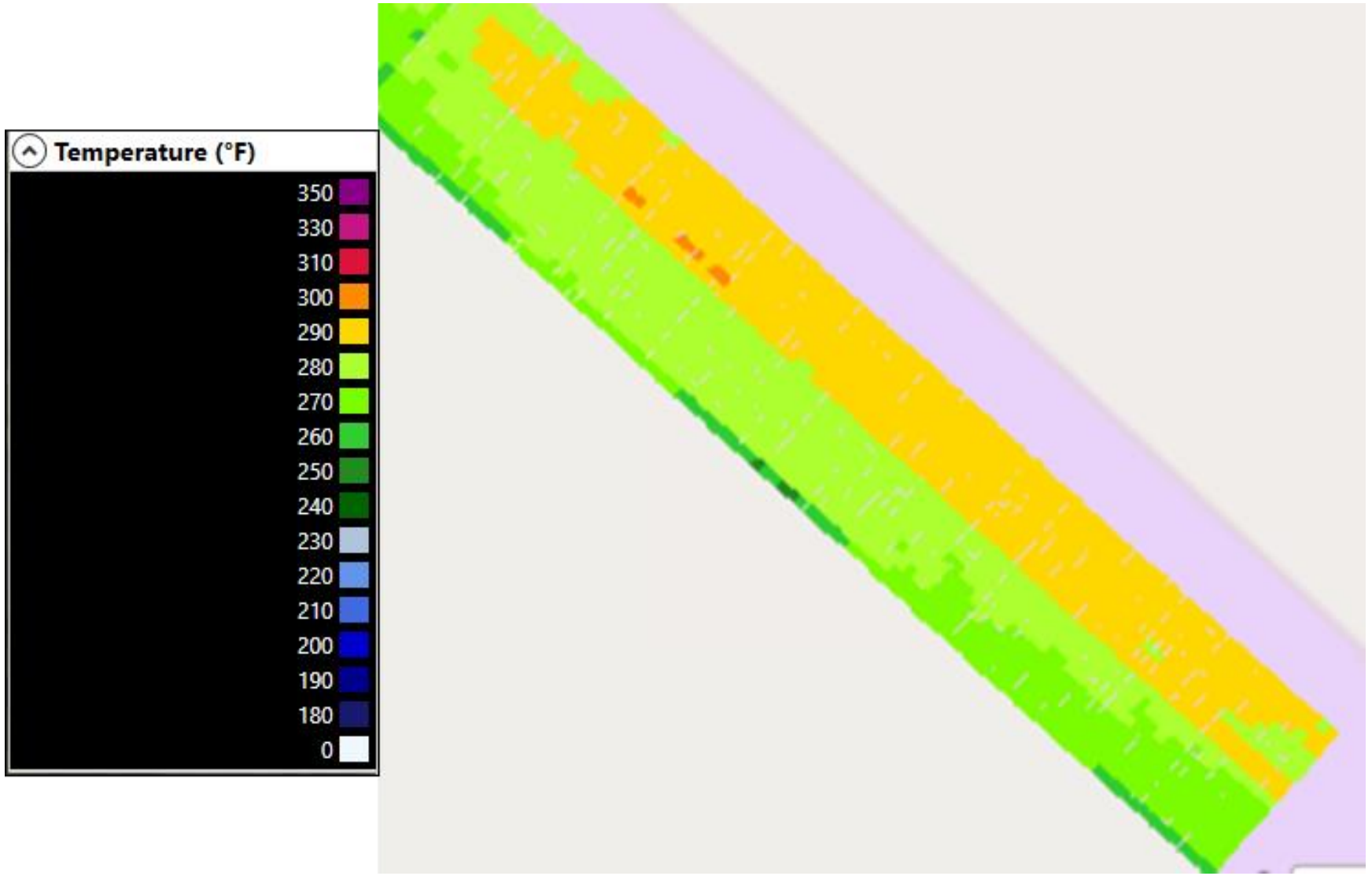
IC and PMTP data used to support cooler mat temperatures during compaction efforts at location.

PMTP Data

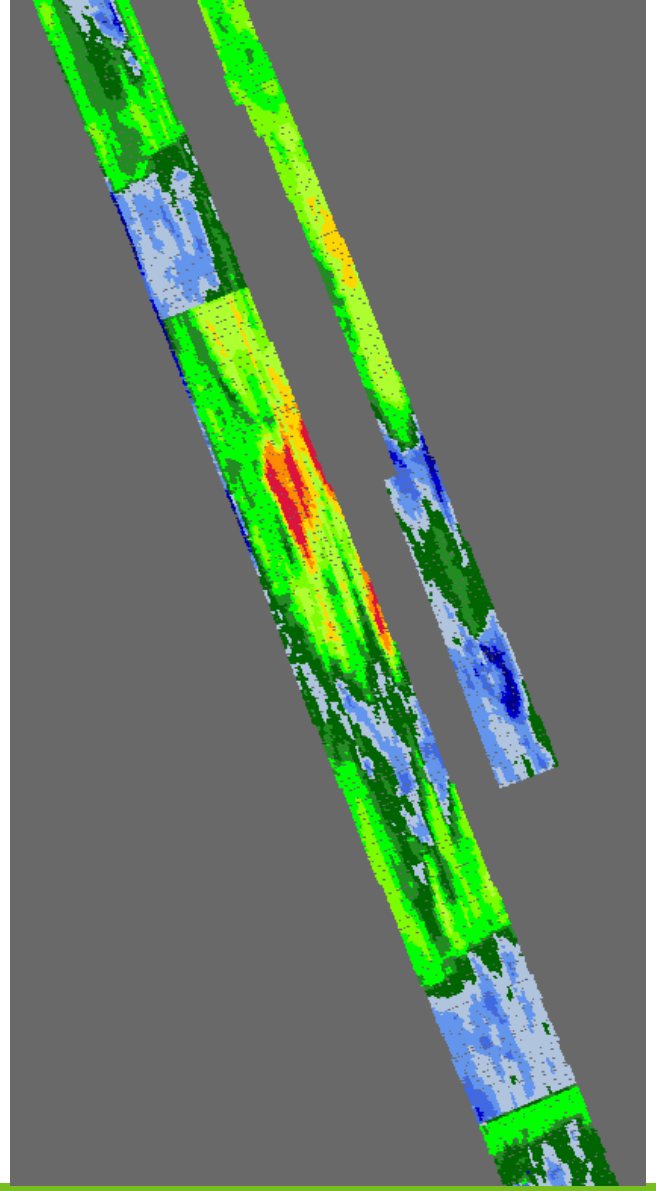


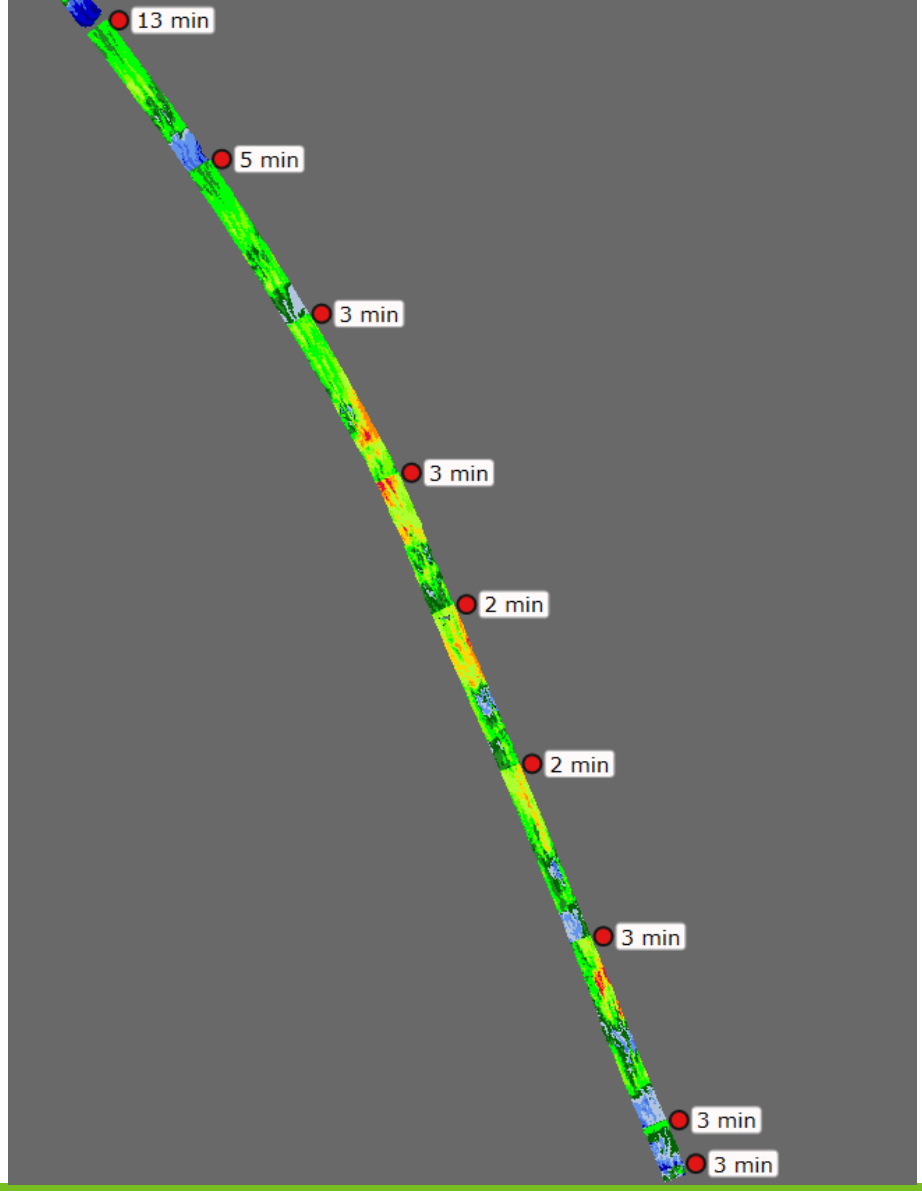
IC: Breakdown Roller – First Pass



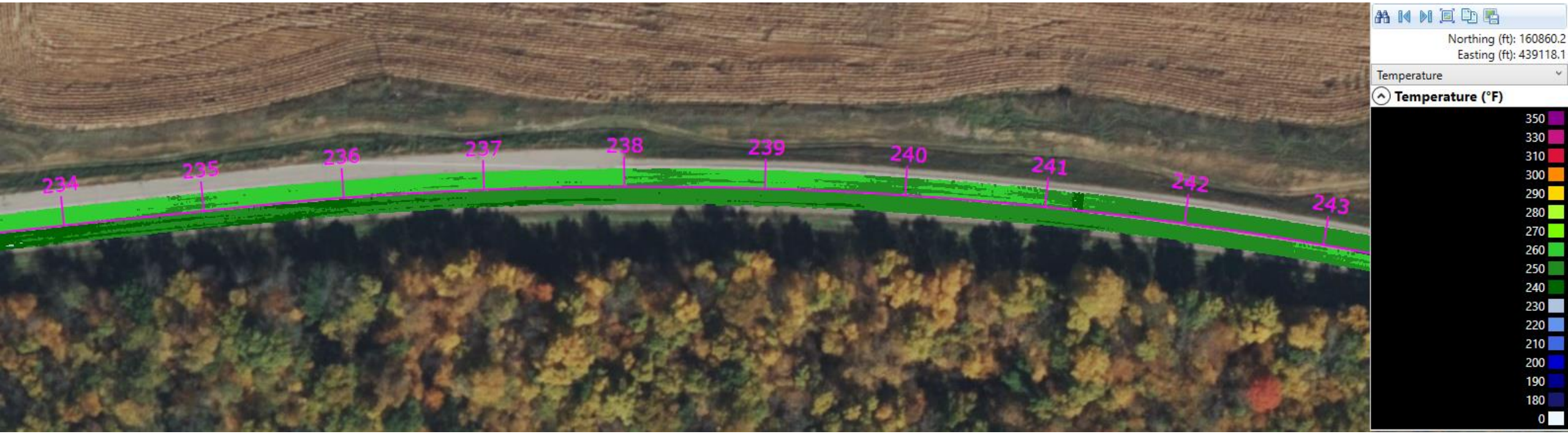


Effects of feed rates





. . . “stuff happens” . . .



It can be done

DEPARTMENT OF TRANSPORTATION

Thank You!

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