Evaluation of Non-Nuclear Density Gauges for Measuring In-Place Density of Hot Mix Asphalt

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Outline

- Background
- Objectives
- Research Approach
- Results
- Cost Analysis
- Findings
- Recommended further studies

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Background

- The density of in-place may be the single factor that most affects the performance of a properly designed pavement.
  - Hot mix asphalt

Background

- Hot mix asphalt (HMA)
  - Lab - Maximum theoretical specific gravity
  - Field acceptance
    - Nuclear Gauge
    - Cores (true)

Background

- Core for HMA
  - Accurate
  - Destructive
  - Time consuming
- Nuclear gauge
  - Fast
  - Less accurate
  - Radiation
  - Strict regulation

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Objectives

- Evaluate non-nuclear density gauges
- Compare performance of non-nuclear density gauges with nuclear gauges
  - Determine potential factors influencing gauge measurements
- Make recommendations

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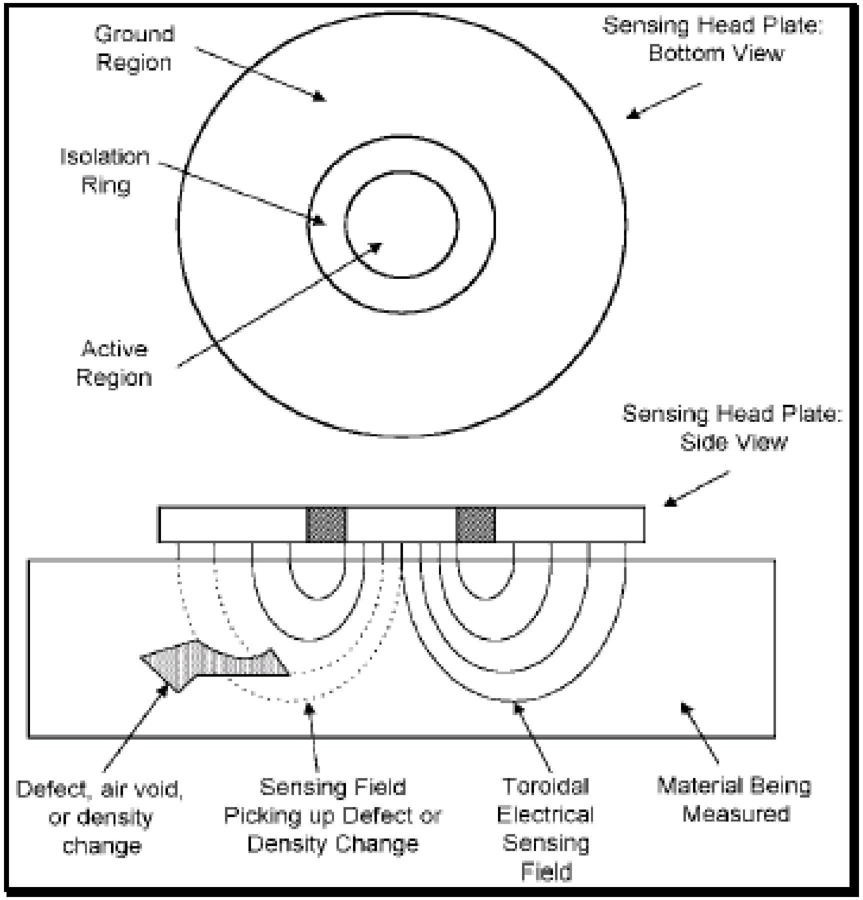
Research Approach

- HMA Devices
  - Trans Tech Pavement Quality Indicator (PQI) 301
  - Troxler PaveTracker (PT) Plus

Research Approach

- Theory
- Measures bulk dielectric constant of pavement/soil
  - Aggregates
  - Air
  - Asphalt Binder or Moisture



From Romero, 2002

Research Approach

- Potential Factors Influencing Accuracy
  - Global factors – different paving operations
    - HMA Classes
    - Nominal Maximum Aggregate Size
    - Aggregate Source
    - Percent Aggregate Absorption
    - Mat Thickness

Research Approach

- Potential Factors Influencing Accuracy
  - Local factors – one paving operation
    - Temperature
    - Moisture (high dielectric constant)
    - Presence of Fines/Debris: with and without fines
    - Presence of Paint/Marking: with and without spray
    - Change of density with Roller Passes
    - Gauge movement
  - Accuracy at the paving joints

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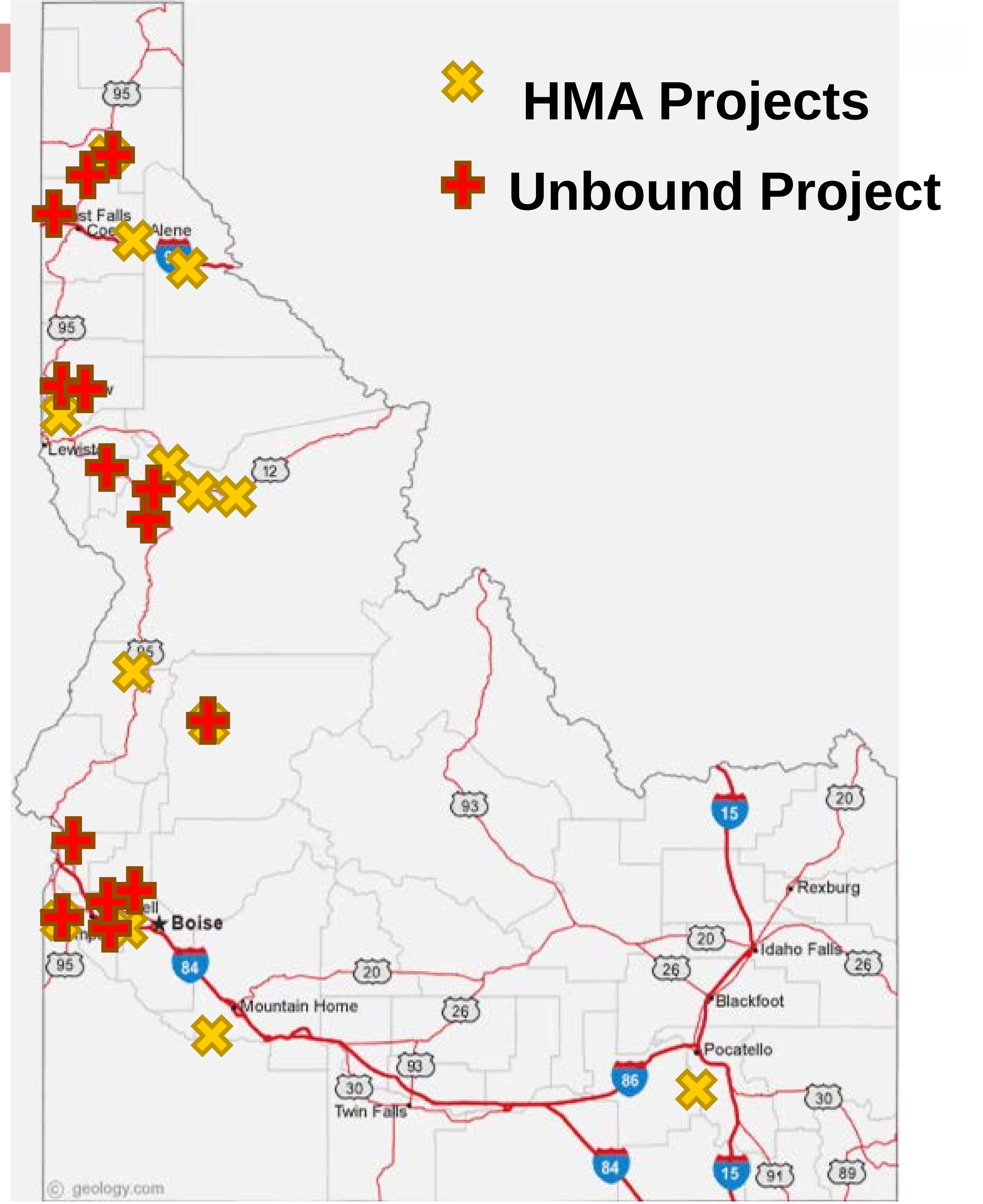
Map of Projects



HMA

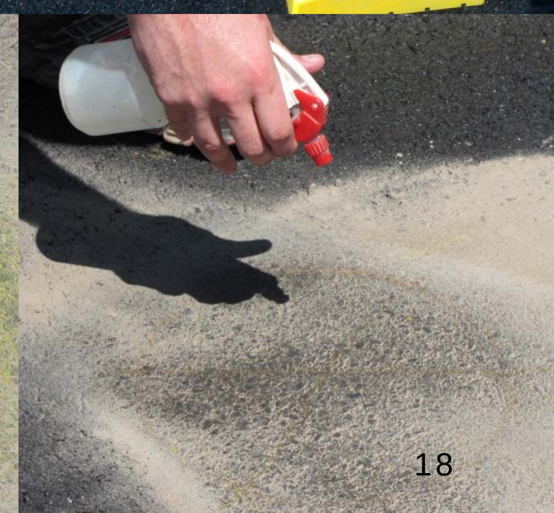
- Testing
  - 16 Test Strips
    - HMA Classes (SP 2 to SP 6)
    - Nominal Maximum Aggregate Size (1/2” and 3/4”)
    - Aggregate Source (Alluvial, Basalt, Quartz)
    - Percent Aggregate Absorption
    - Mat thickness: thin and thick (1.8” to 3.12”)

HMA

- Testing
  - Nuclear Gauge, PQI and PaveTracker
  - Continuous reading for roller pattern
  - 5 shot average for each device at core locations
  - Moisture, fines, paint, and temperature study
  - Five 4" or 6" cores in test strip for ITD correction
  - Up to seven additional locations for tests and cores for validation
  - Nuclear, non-nuclear shots, and/or cores at additional locations on joints.

HMA Field Work

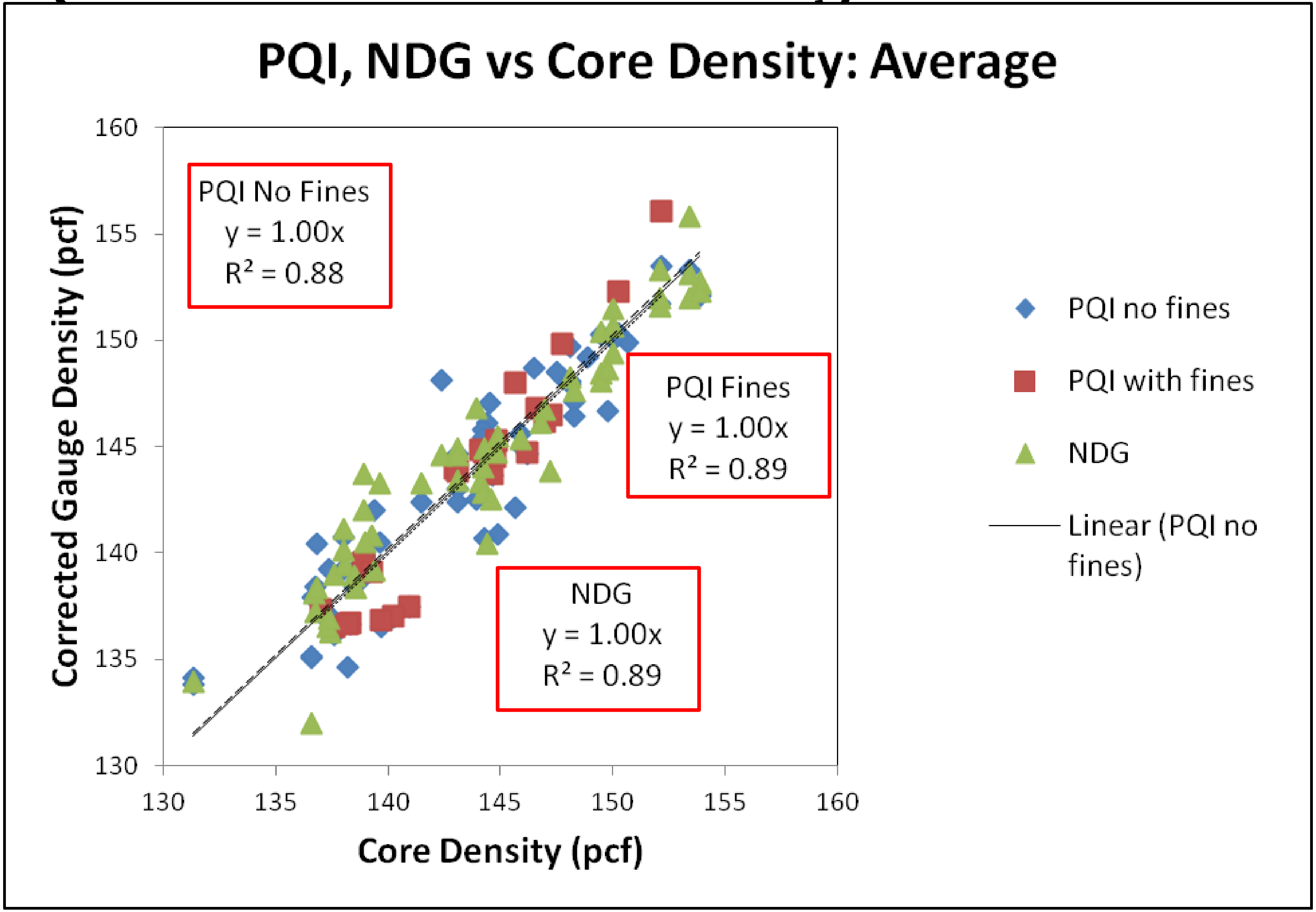
- Testing
  - Local Factors
    - Plain HMA
    - Roller pattern
    - Fines
    - Moisture
    - Temperature
    - Paint



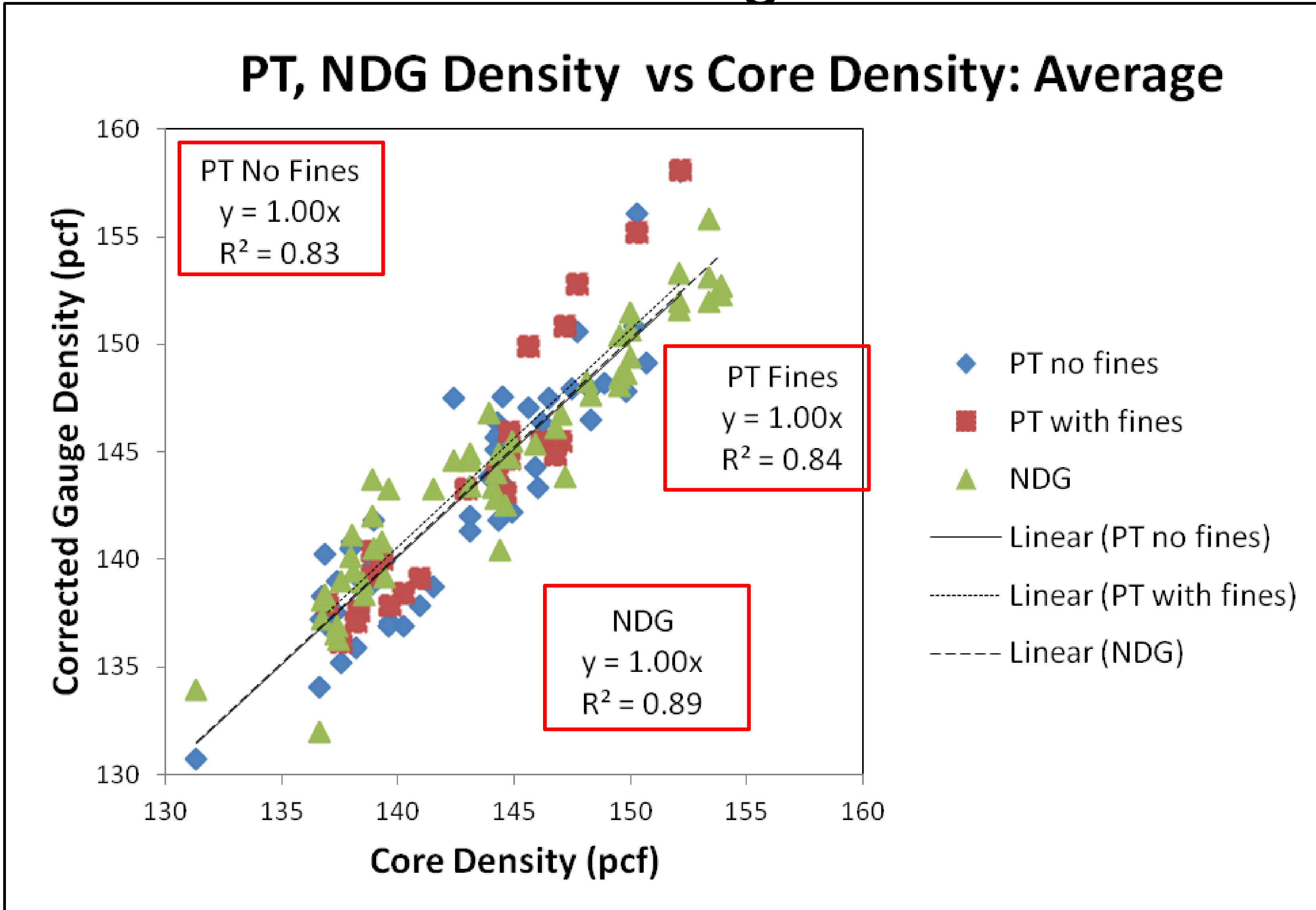
Results

- Analysis Procedure
  - Obtain correction factors from first 5 cores
  - Verify accuracy with additional cores

PQI Correlation: Average Correction

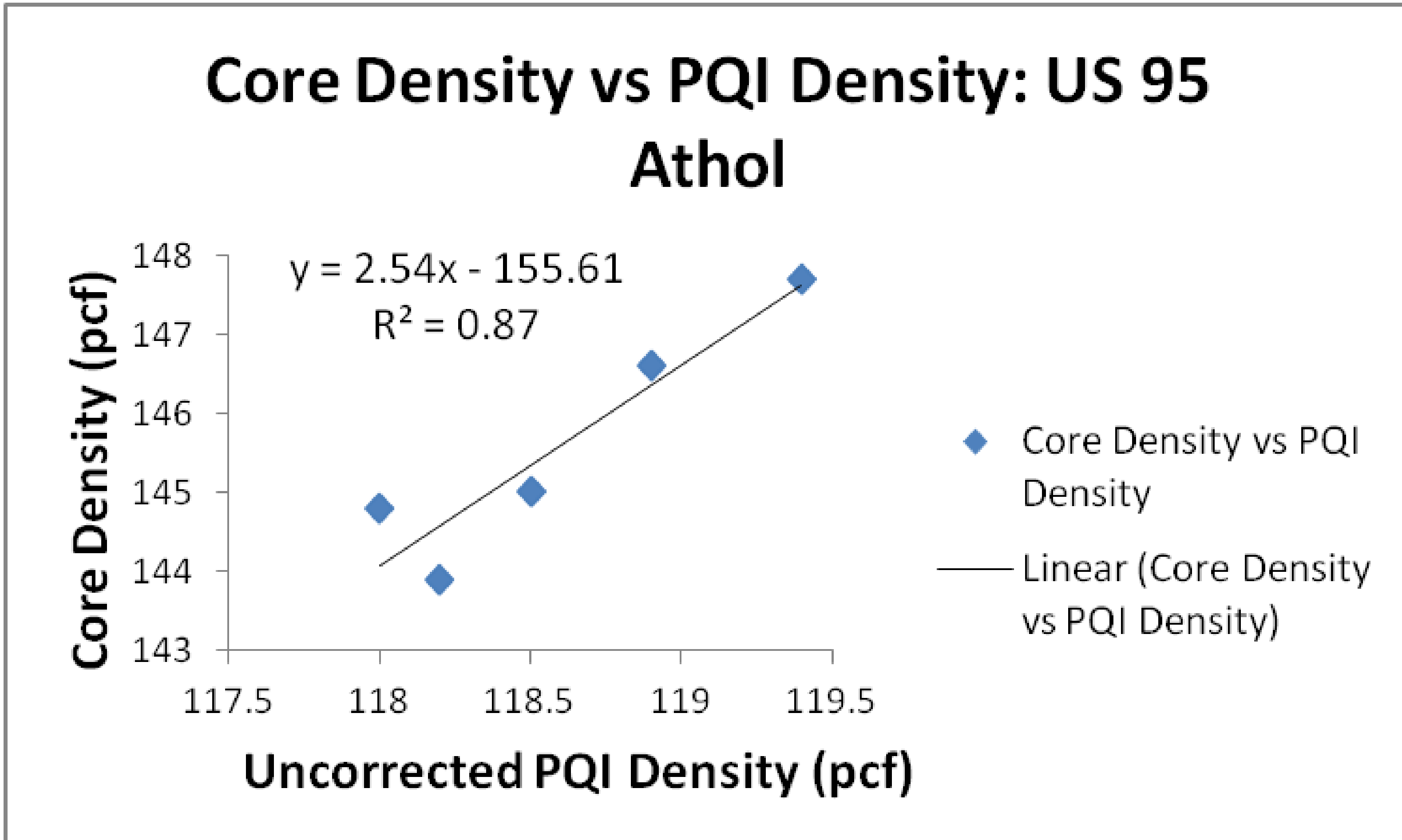


PT Correlation: Avg. Correction



Slope Correction: PQI

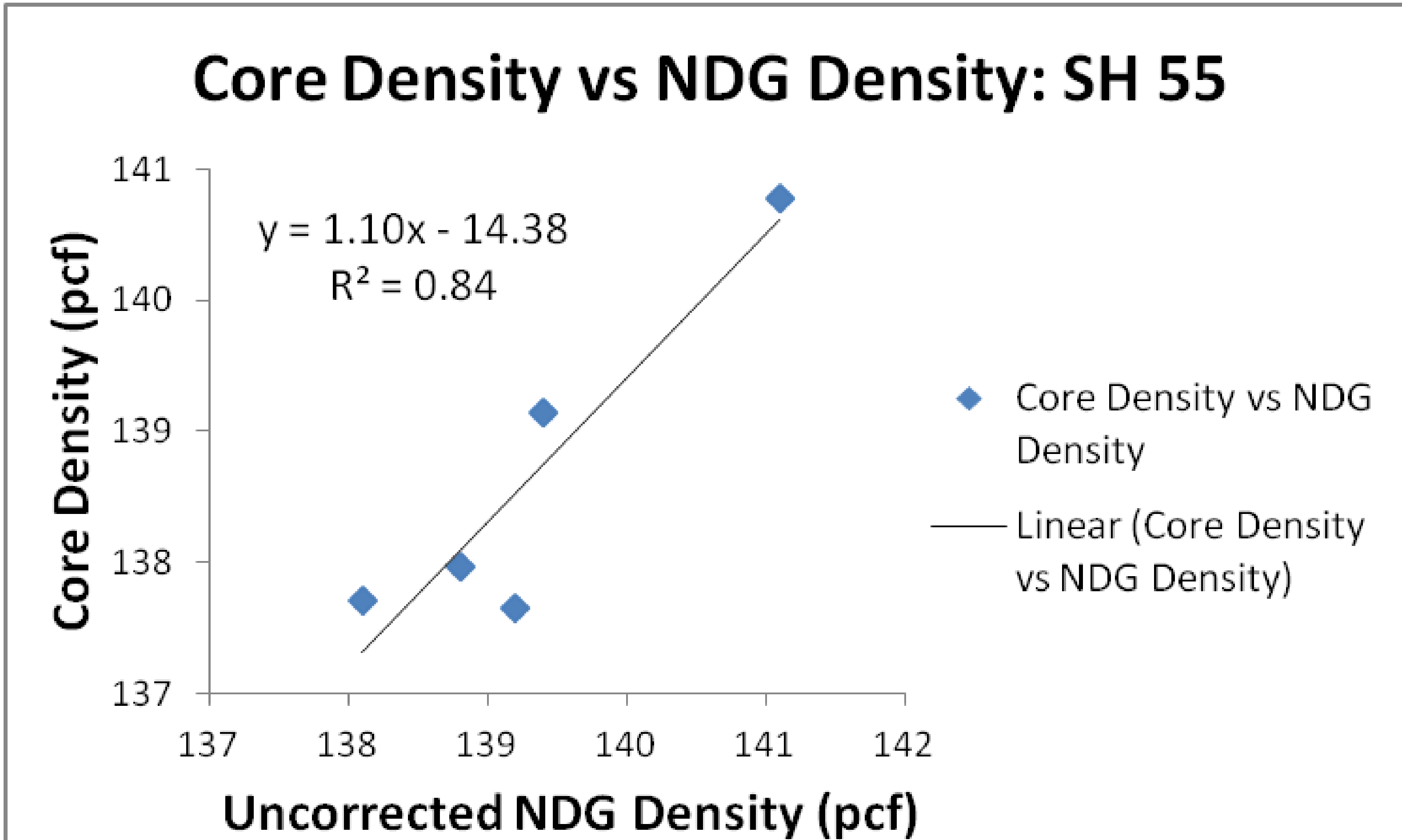
- Offset not constant



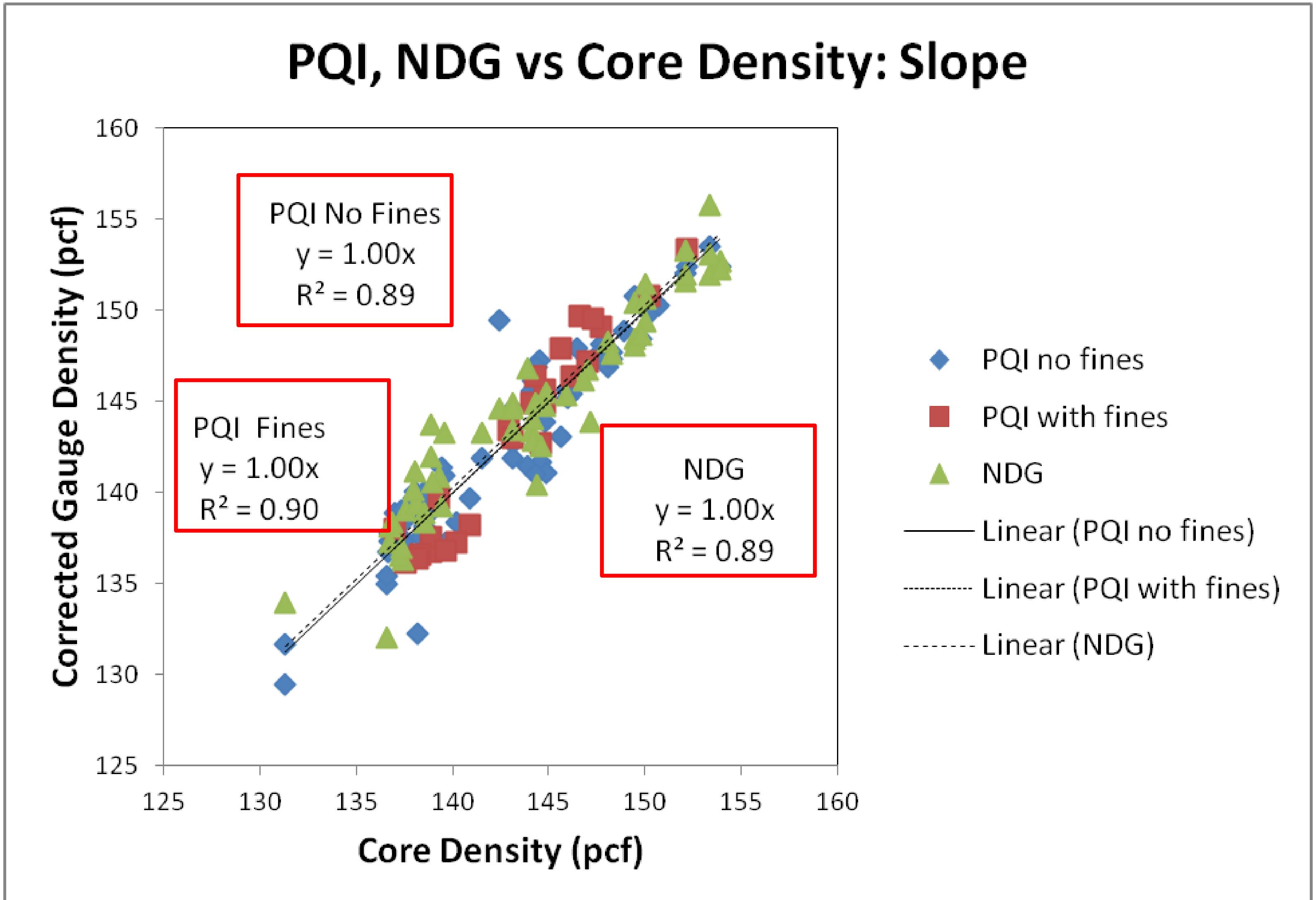
Slope Correction

- Develop best-fit trendline for each project using calibration cores from test strip
  - Both PQI and PT
- NDG results
  - NDG also has this slope
  - Continued to use average method in accordance with ITD specifications,

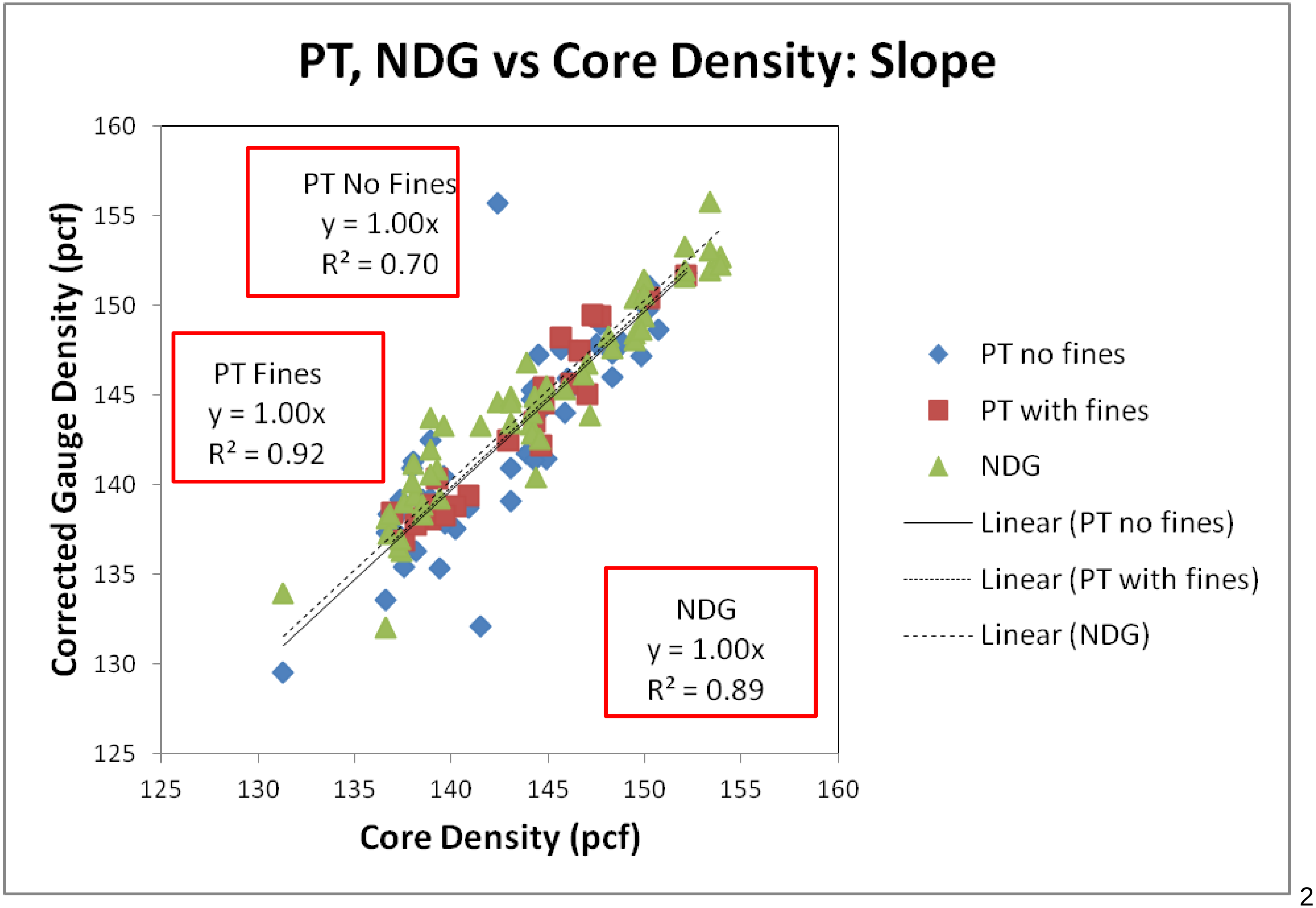
NDG Slope


Core Density vs NDG Density: SH 55
y = 1.10x - 14.38
R² = 0.84
Core Density (pcf)
141
140
139
138
137
137
138
139
140
141
142
Uncorrected NDG Density (pcf)
Core Density vs NDG Density
Linear (Core Density vs NDG Density)

PQI Correlation: Slope Correction

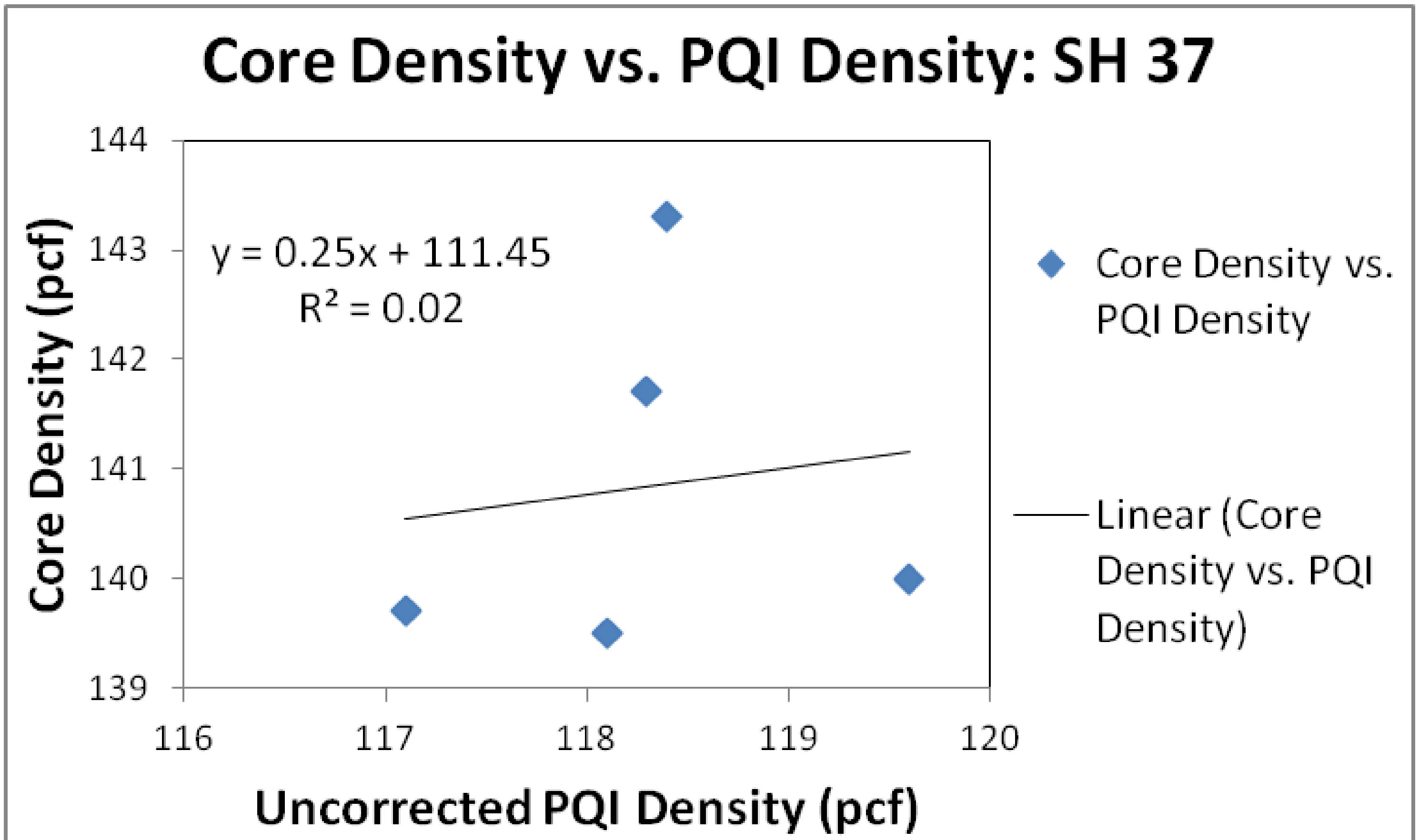


PT Correlation: Slope Correction



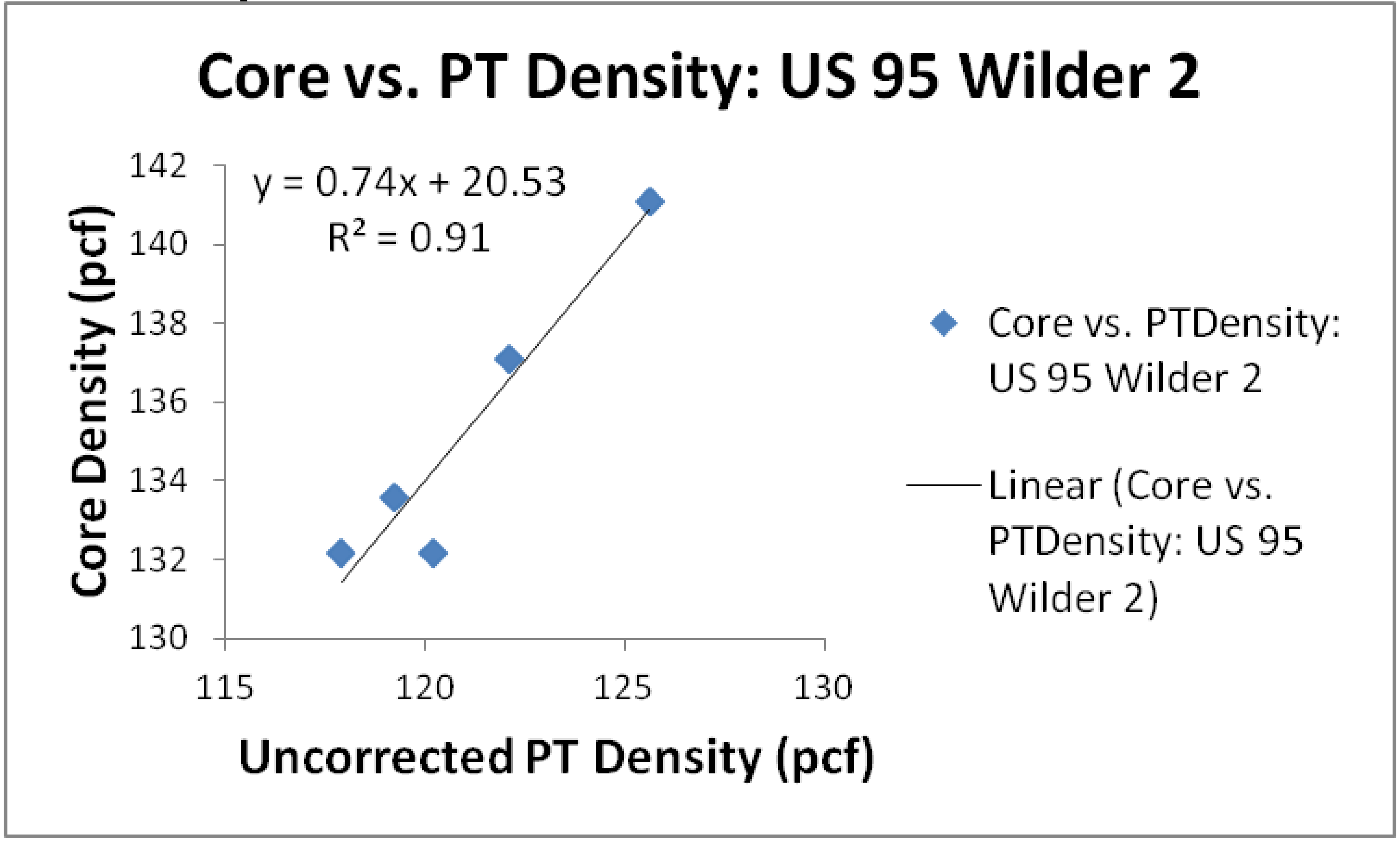
Slope Correction Method

- Good slopes not always possible



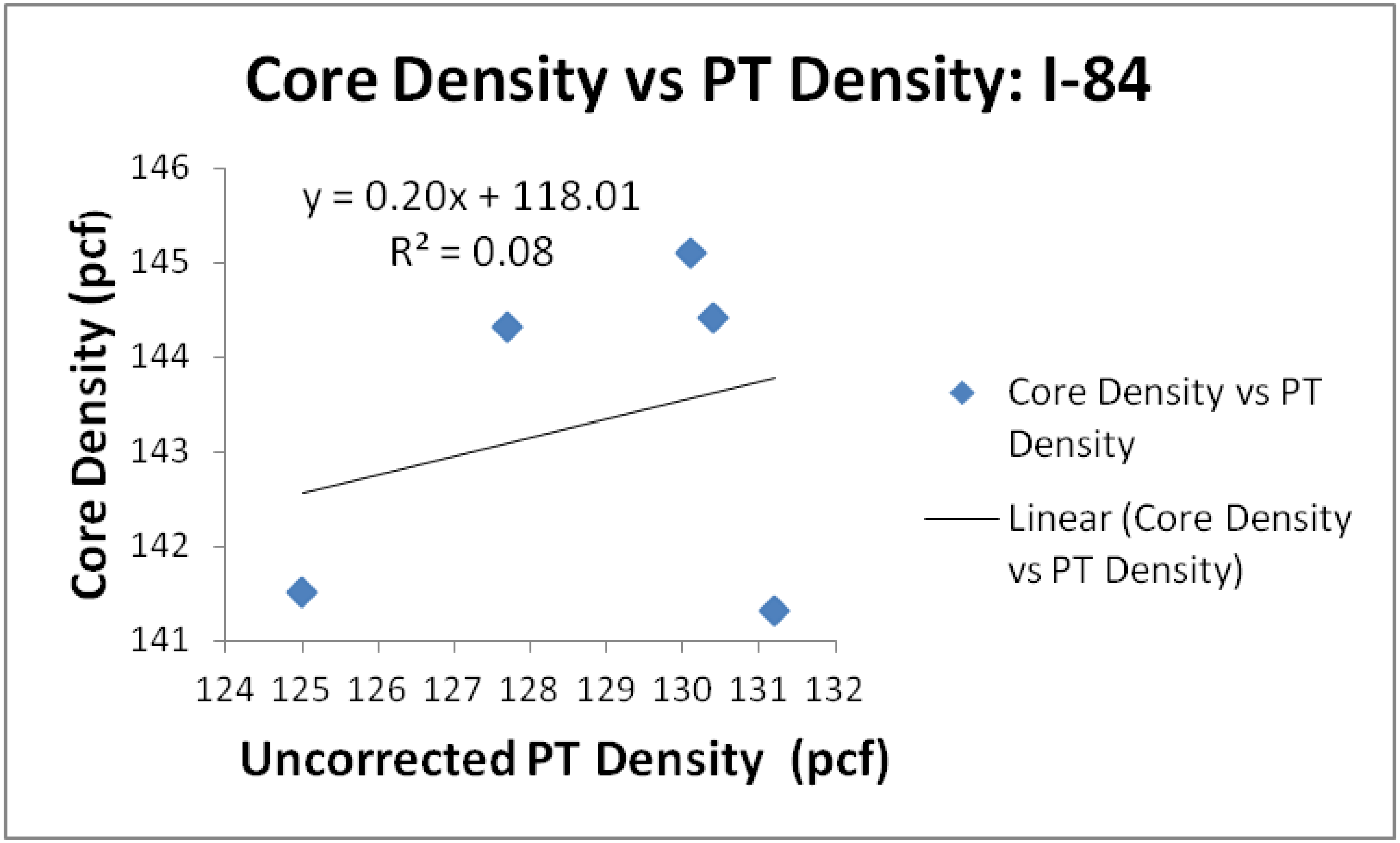
Hybrid Method

- Use slope correction if R^2 >0.5

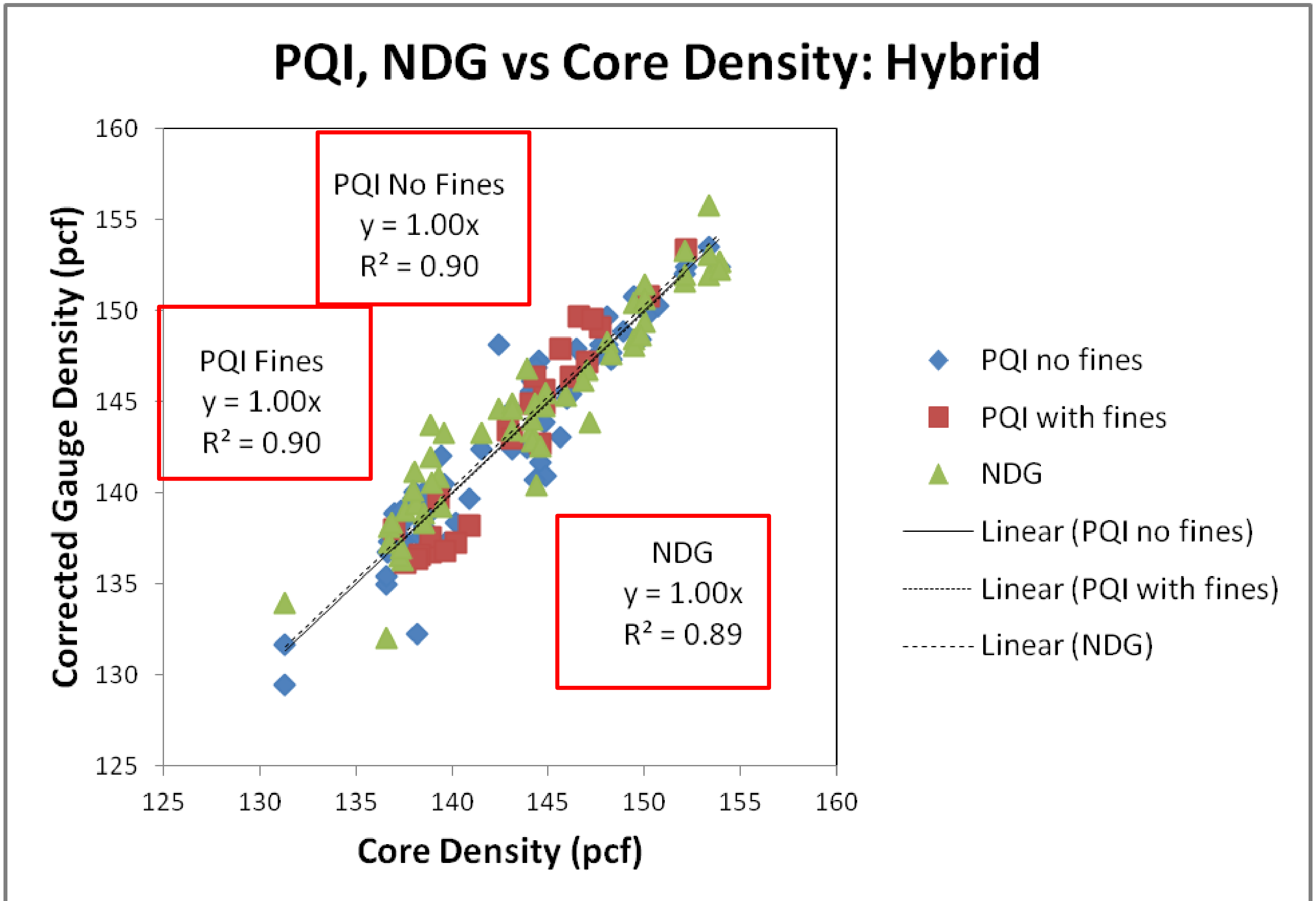


Hybrid Method

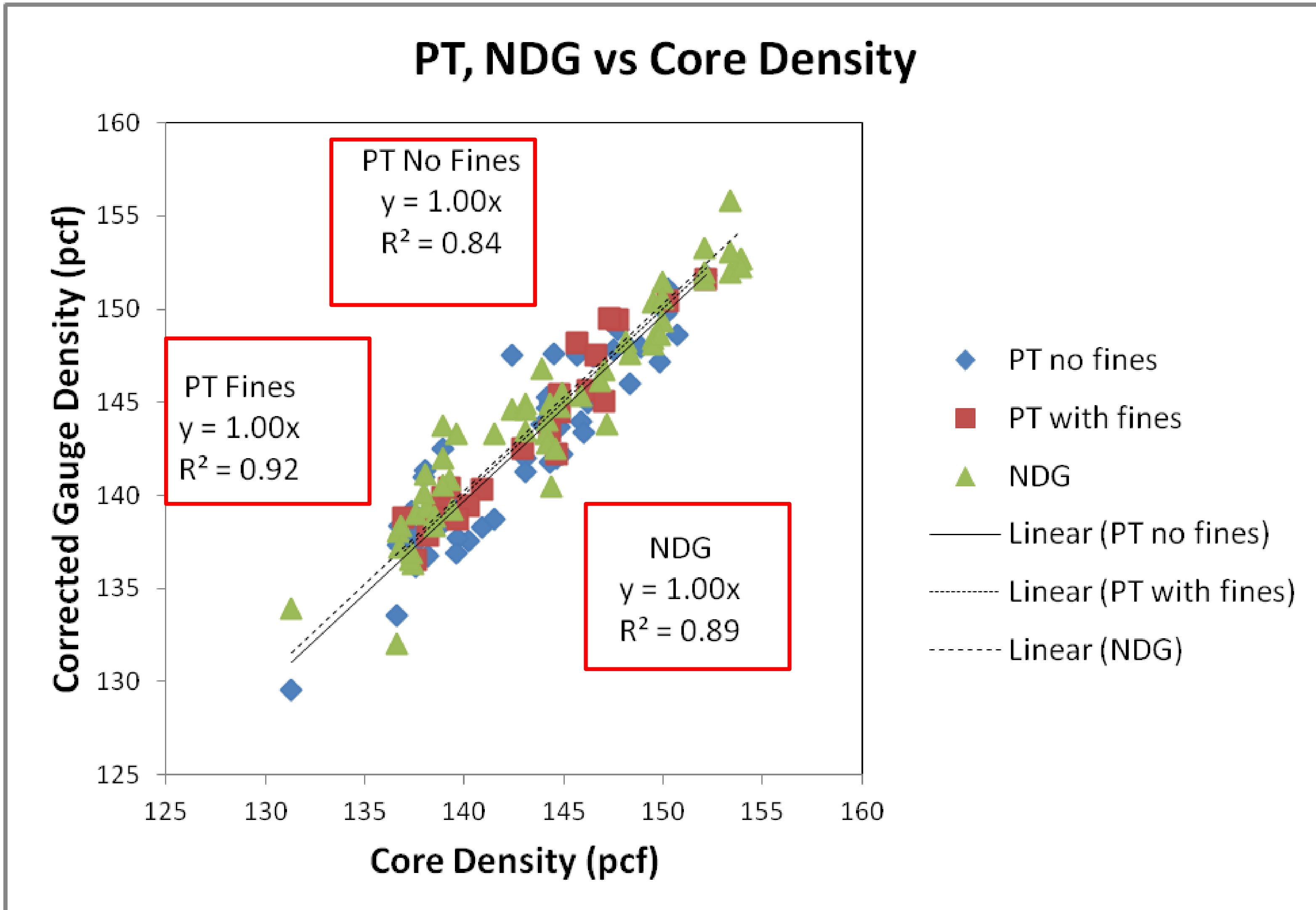
- If R^2 <0.5, use average correction method



PQI Correlation: Hybrid Method



PT Correlation: Hybrid Method



Potential Factors

- Global Factors
  - HMA Classes
  - Nominal Maximum Aggregate Size
  - Aggregate Source
  - Percent Aggregate Absorption
  - Mat Thickness
- Local Factors
  - Moisture
  - Temperature
  - Paint
  - Fines

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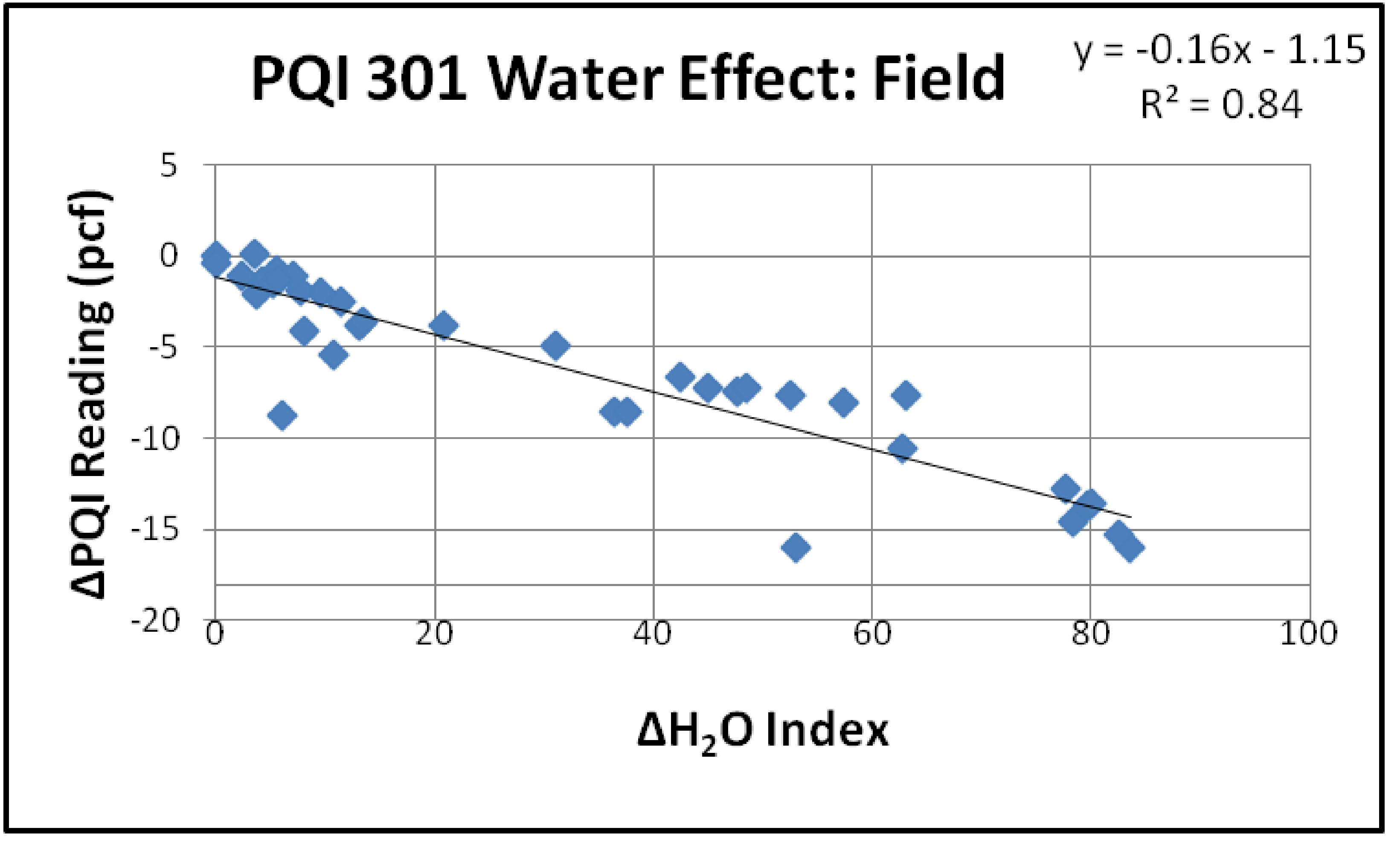
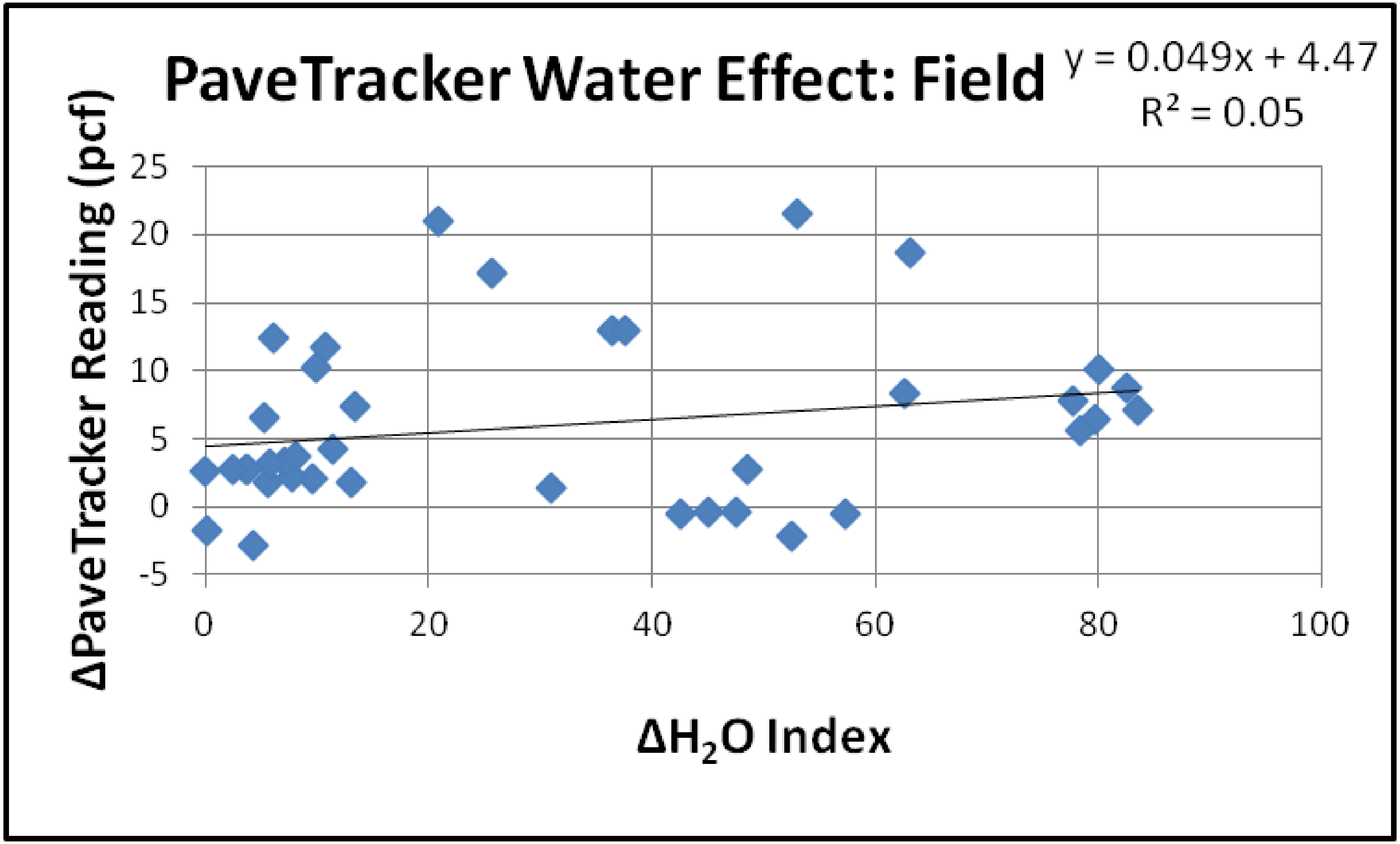
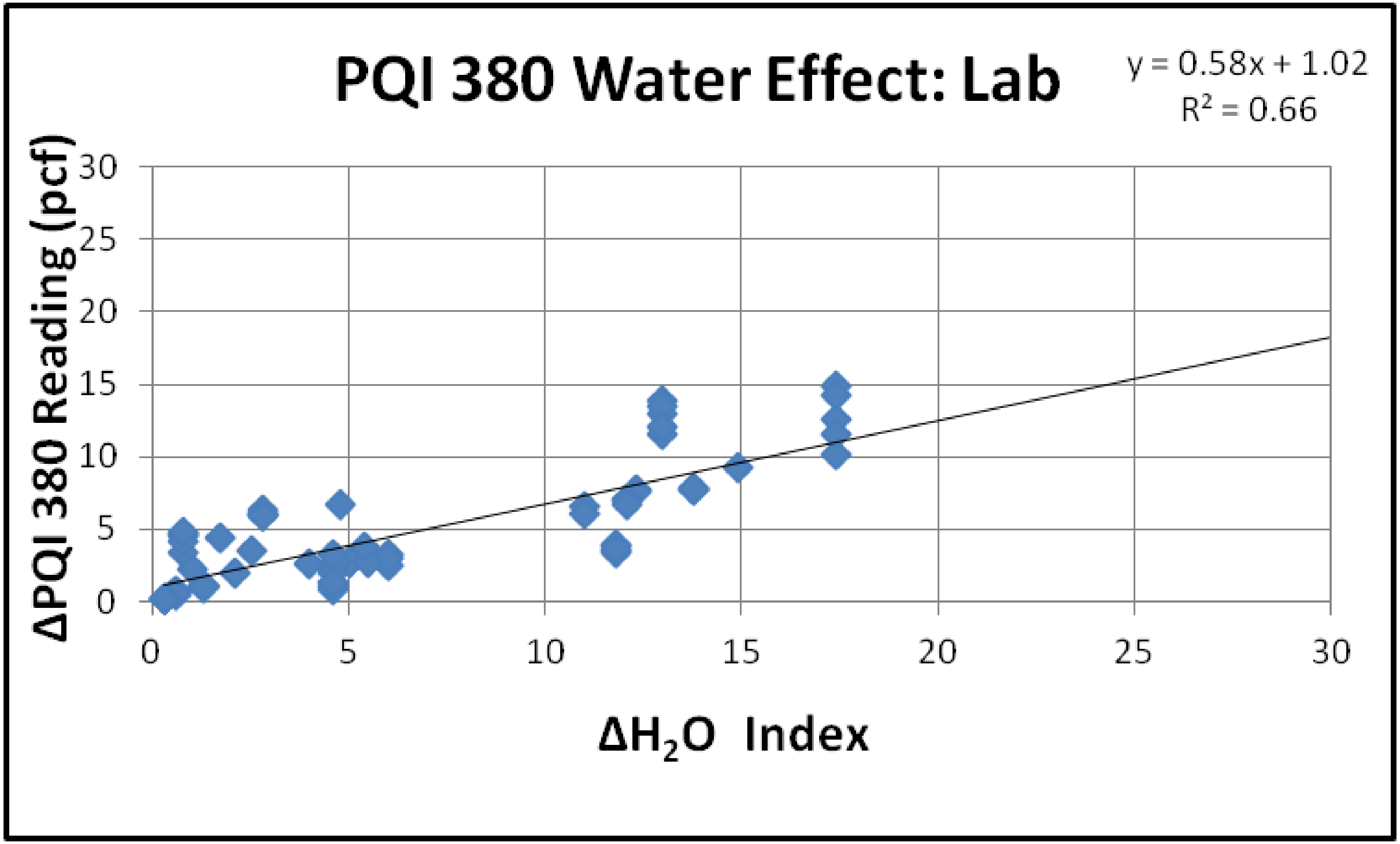
Moisture Field Data: PQI



Moisture Field Data: PT

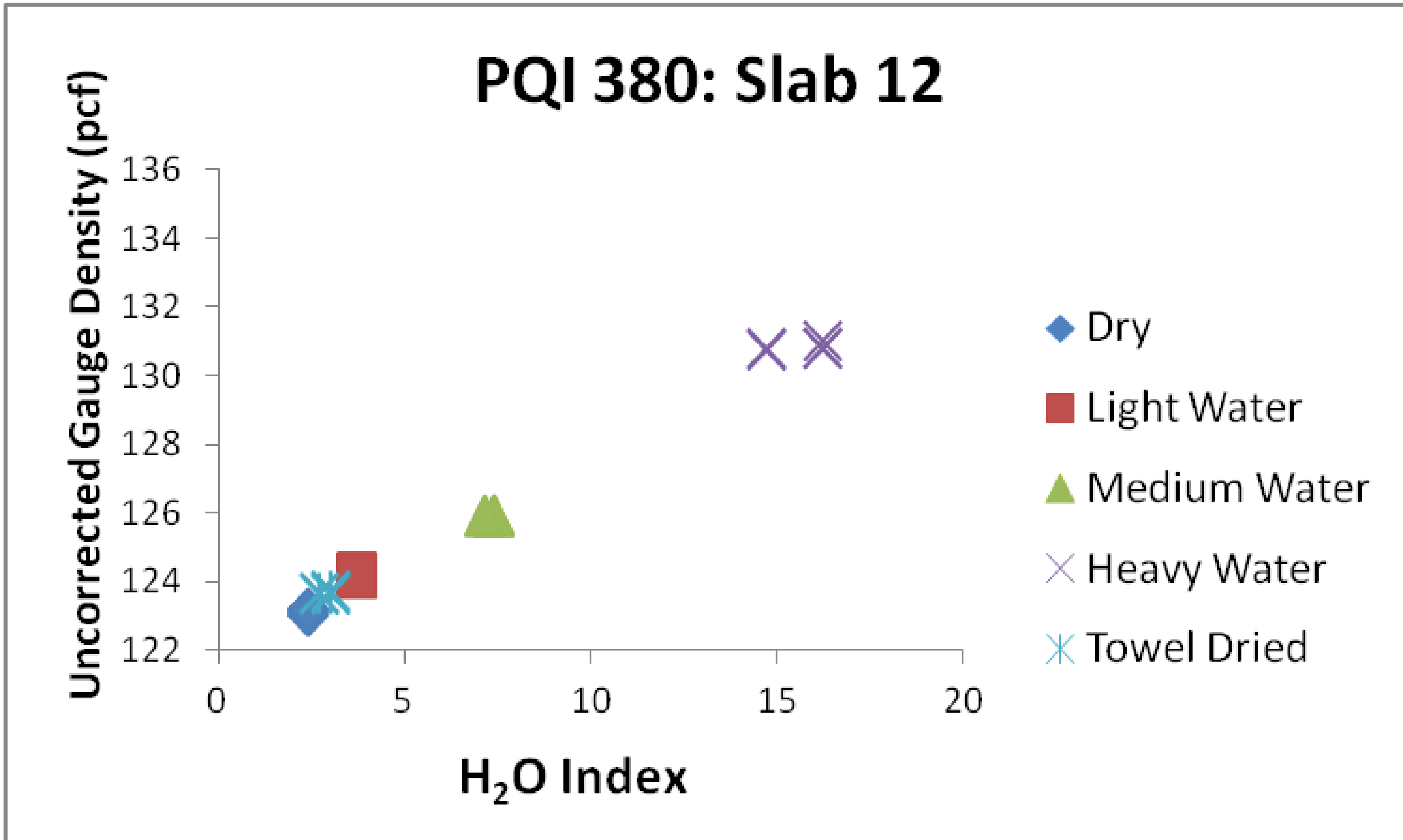


2013 Moisture Lab Data: PQI 380



Moisture Study: Solution

- Towel drying works reasonably well



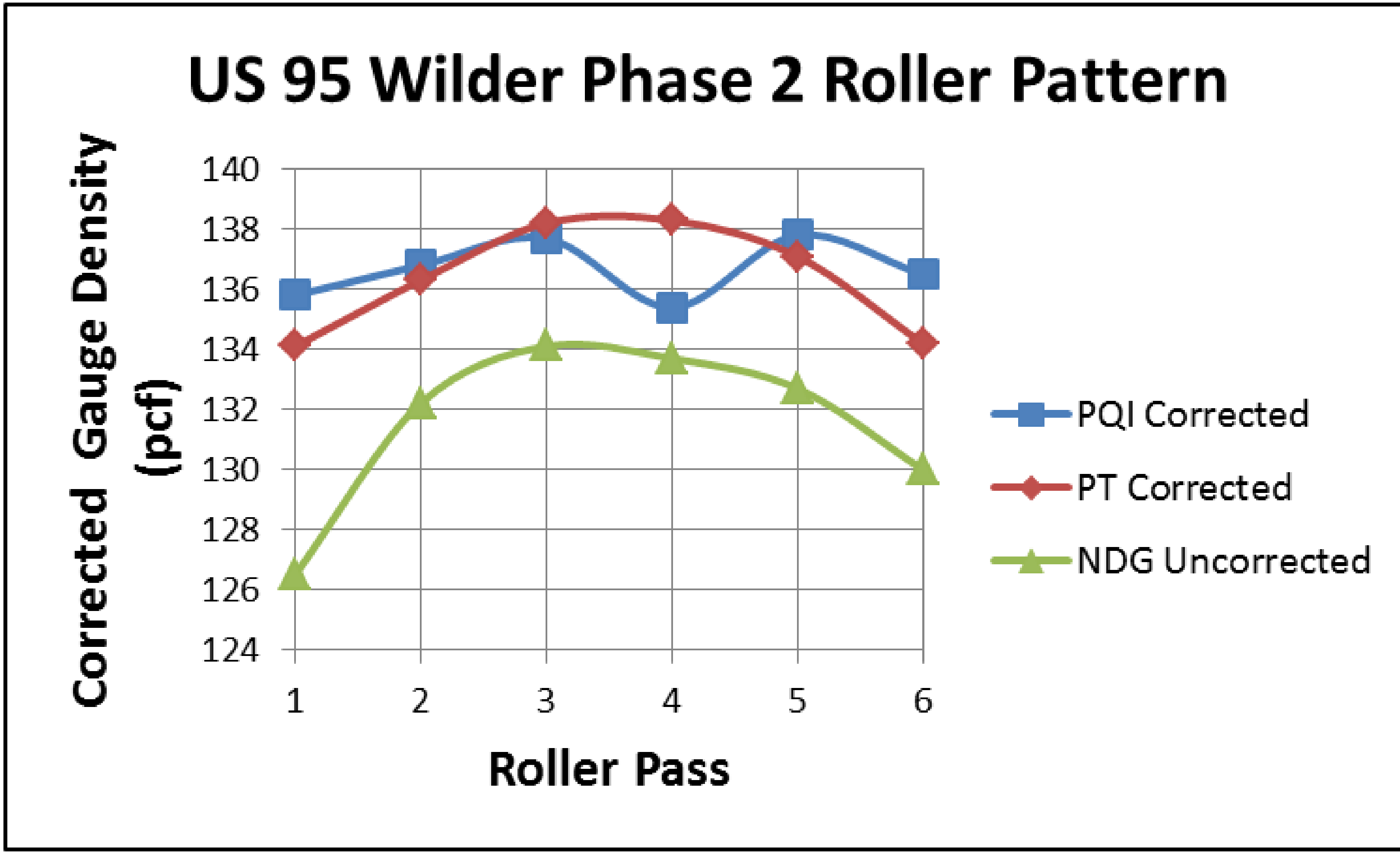
Moisture Investigation

- All electromagnetic gauges affected by surface moisture
  - PQI 301, PT, PQI 380
- Used PQI 301 H_2O Index to quantify moisture for all gauges
  - Otherwise difficult to quantify
- Dry the surface with towel if moisture is present

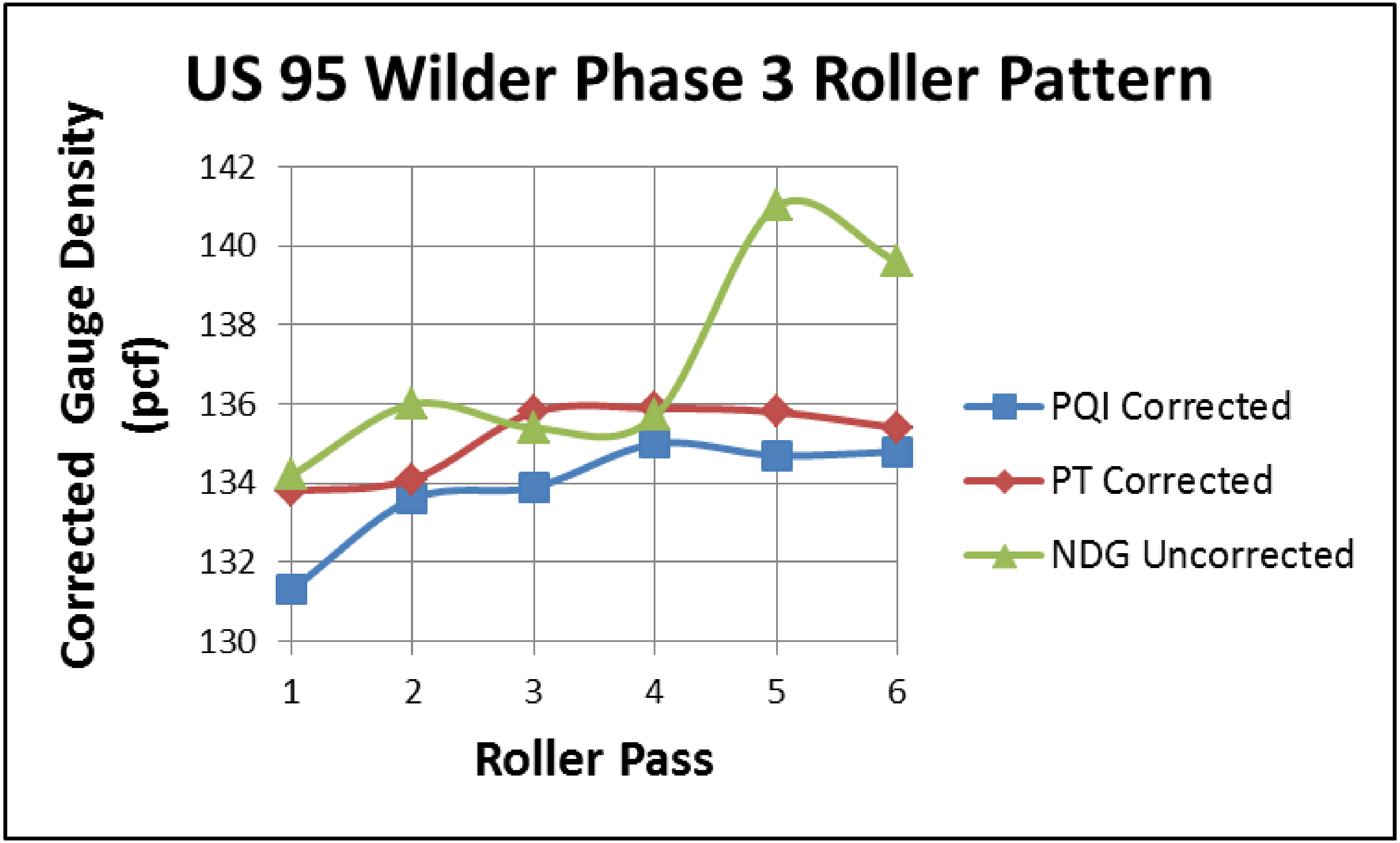
Roller Pattern Use

- How do NNDGs compare to NDGs on a roller pattern setup
  - 3 case studies

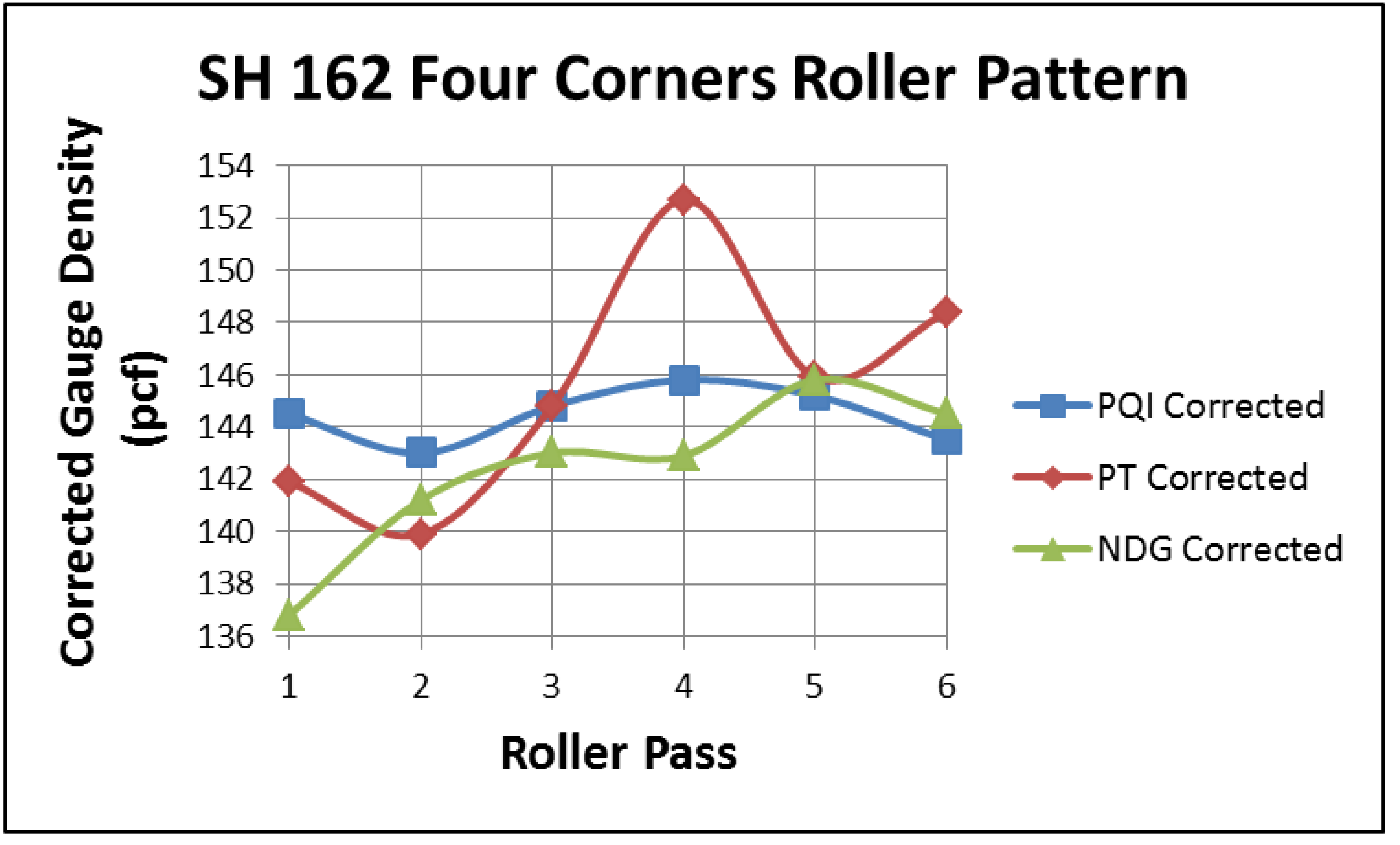
Roller Pattern: Example 1



Roller Pattern: Example 2



Roller Pattern: Example 3



Asphalt NNDGs Findings

- PQI and PT have similar core correlations compared to NDGs.
  - PQI generally has a better correlation to cores than PT
- Slope correction recommended unless the correlation coefficient is low (R^2 <0.5)
  - Average method recommended if R^2 <0.5
- No global factors causing error with statistical significance

Asphalt NNDGs Findings

- Paint and fines do not cause error with statistical significance
  - Clean surface recommended
- Moisture effect gauge readings
  - Keep surface dry, use towel if necessary

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Life Cycle Cost

Device	Initial Cost	Annual Cost	Lifetime (10 years) Cost
NDG (Troxler 3430)	$8,000	$1,652.30	**$24,523**
PQI 301	$9,150	$475	**$13,900**
PQI 380	$8,900	$525	**$14,150**
PT	$8,800	$500	**$13,800**
EDG	$9,060	$315	**$12,210**
SDG	$8,900	$525	**$14,150**

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Asphalt NNDG Implementation

- NNDGs can be used to replace NDG for QA/QC
- Use hybrid correction method
  - Slope correction when $R^2 > 0.5$
  - Average correction when $R^2 < 0.5$
- Surface shall be dry or dried with towel
- Use 6” cores for calibration
- Revised ITD FOP for AASHTO 343

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Further Studies

- Temperature effects in the field
- NNDG production paving repeatability
  - This study only examined data from test strips, not production paving
- Longitudinal joints
  - Both NNDGs and NDGs

Acknowledgements

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Thank You

QUESTIONS?