# Recalibration of the Asphalt Layer Coefficient

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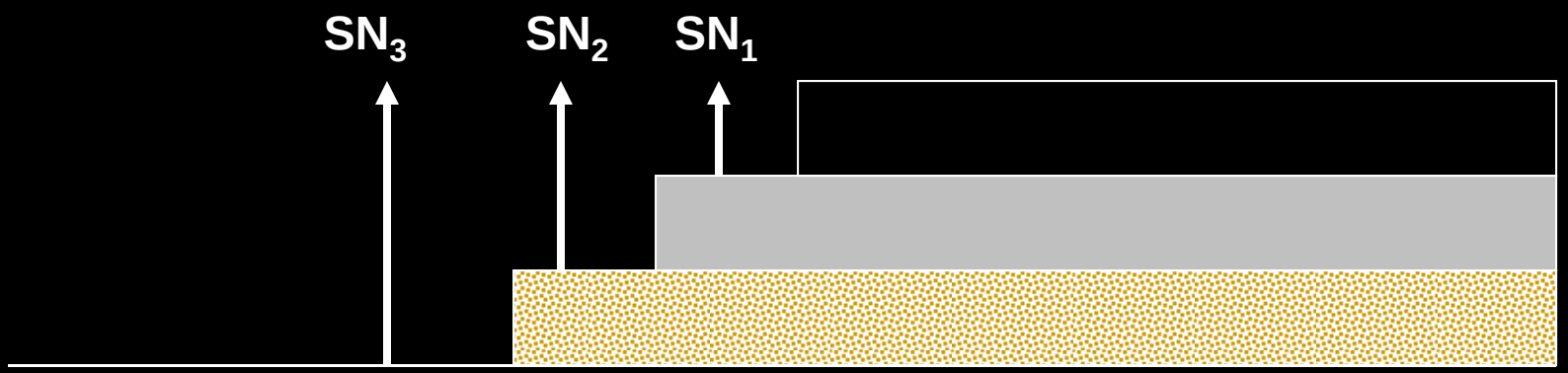
NCAT Pavement Test Track

# Overview

- Current ALDOT pavement design based on AASHO Road Test
- Structural coefficients ($a_i$) are key inputs
  - Express relative “strength” of component layers
  - Used to determine required thicknesses of layers
- Current ALDOT asphalt coefficients were officially set in 1990
  - No changes since then

# Structural Coefficient in Design




$SN_1 = a_1D_1$

$SN_2 = a_1D_1 + a_2D_2$

$SN3 = a_1D_1 + a_2D_2 + a_3D_3$

$$D_1 = SN_1/a_1$$

# AASHTO Design Equation

Traffic

Reliability & Variability

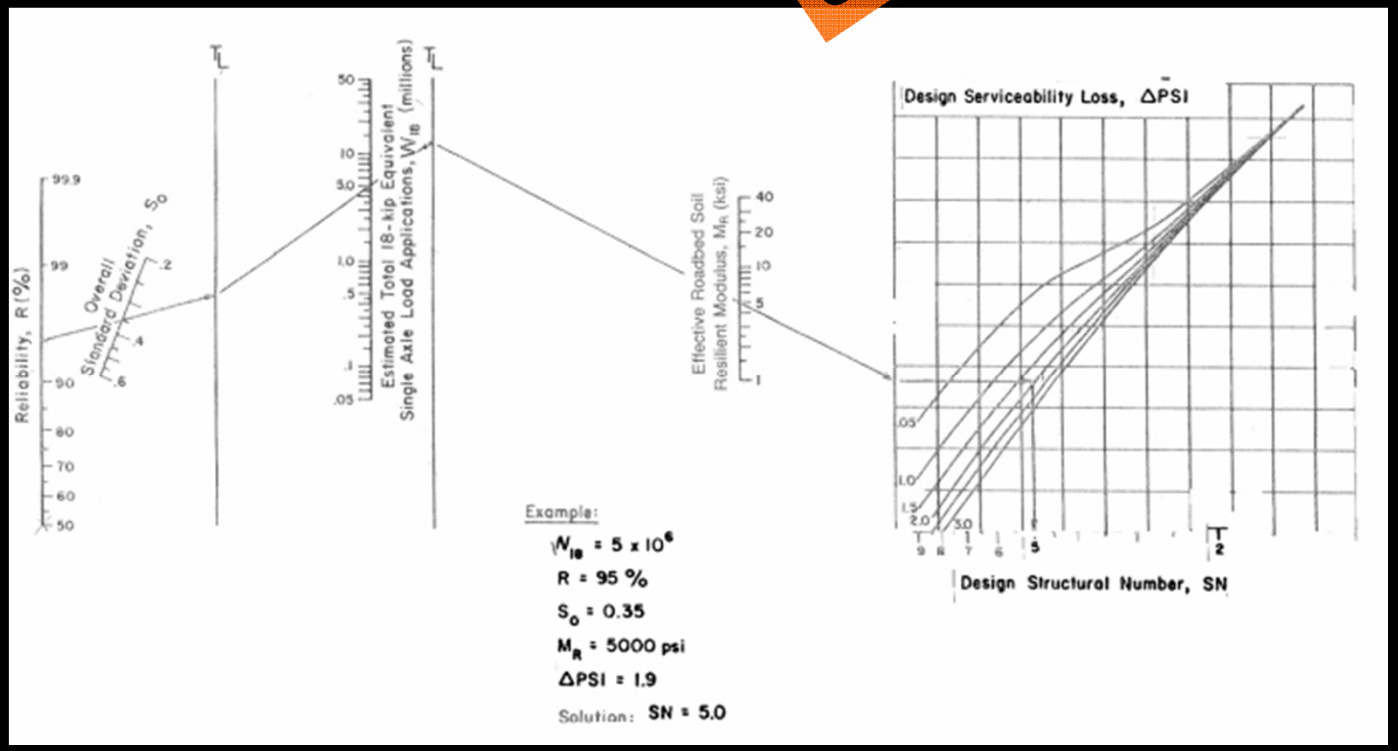
Structure

Performance

Structure

Soil Strength

$$\log_{10}(W_{18}) = Z_R S_o + 9.36 \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \log_{10}(M_R) - 8.07$$



# AASHO HMA Coefficients

| Loop | Layer Coefficient ($a_1$) | Test Sections | $R^2$ |
|---|---|---|---|
| **2** | 0.83 | 44 | 0.80 |
| **3** | 0.44 | 60 | 0.83 |
| **4** | 0.44 | 60 | 0.90 |
| **5** | 0.47 | 60 | 0.92 |
| **6** | 0.33 | 60 | 0.81 |

# Current ALDOT Asphalt Coefficients

| Pavement Material | Structural Coefficient |
|---|---|
| Hot Mix Asphalt | 0.44 |
| Sand Asphalt | 0.40 |
| Road Mix (Low Stability) | 0.20 |
| Limestone Agg. Base | 0.14 |
| Granite Agg. Base | 0.12 |

# Problem Statement

- Given new advances in mixture technology (Superpave, SMA, polymer-modification), there is a need to update the structural coefficient to reflect ***actual*** performance in Alabama

# Objectives

1. Quantify sensitivity of design equation
2. Recalibrate equation to match observed performance

# Scope of Work

- Literature Review
  - Past recalibration efforts
- Sensitivity Analysis
  - Rank variables from most to least important
- Recalibration using NCAT Test Track performance data
  - 2003 and 2006 Test Sections

# Past Recalibration Efforts

- Many studies, few changes
- Most studies focus on computing $a_1$ from deflection data
- Previous values range from 0.44 to 0.60
- Previous Test Track study found 0.59 using very thick sections from 2000 experiment
  - Calibrated to deflection ***not*** performance

# Sensitivity Analysis

- 3-layer pavement (HMA, aggregate base, soil)
- 5,120 thicknesses calculated
- Determined correlation coefficients between HMA thickness and input parameters

| Parameter | Range |
|---|---|
| Layer coefficient ($a_1$) | 0.20 – 0.60 |
| Traffic level ($W_{18}$) | 1e6 – 1e9 ESALs |
| Resilient modulus ($M_R$) | 3,000 – 30,000 psi |
| Reliability (R) | 50% – 99% |
| Change in serviceability ($\Delta$PSI) | 1 – 2.5 |
| Variability ($S_o$) | 0.20 – 0.60 |

# Results of Sensitivity Analysis

| Parameter | Correlation Coefficient |
|---|---|
| Layer coefficient ($a_1$) | -0.518 |
| Traffic level ($W_{18}$) | 0.483 |
| Resilient modulus ($M_R$) | -0.425 |
| Reliability (R) | 0.157 |
| Change in serviceability ($\Delta$PSI) | -0.141 |
| Variability ($S_o$) | 0.083 |

# Recalibration Procedure

Actual Traffic
(Loads, Repetitions)

Actual Performance
(weekly IRI measurements)

AASHTO ESAL
Equation

$$PSI = 5e^{(-0.0041 \cdot IRI)}$$

Measured Traffic

$a_1$

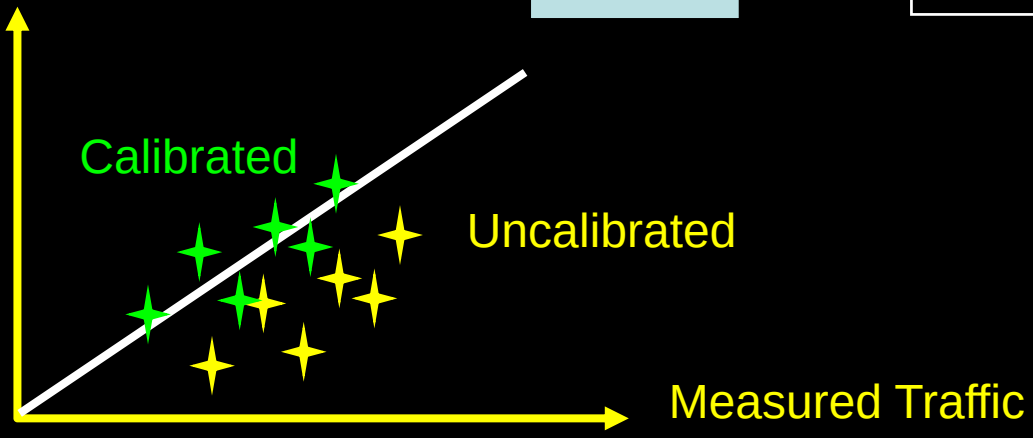
$p_t$

$\Delta PSI$

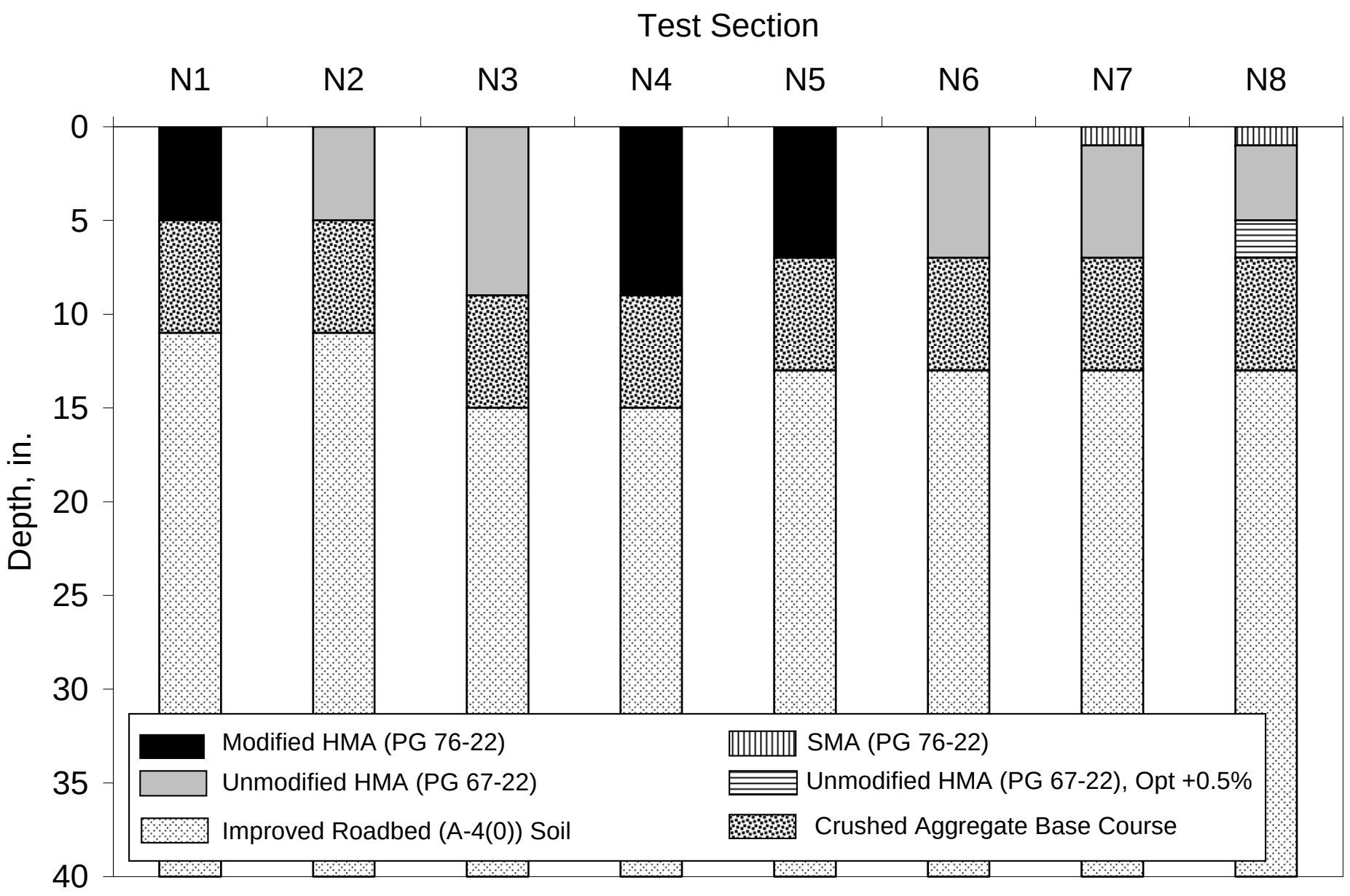
SN

AASHTO Design
Equation

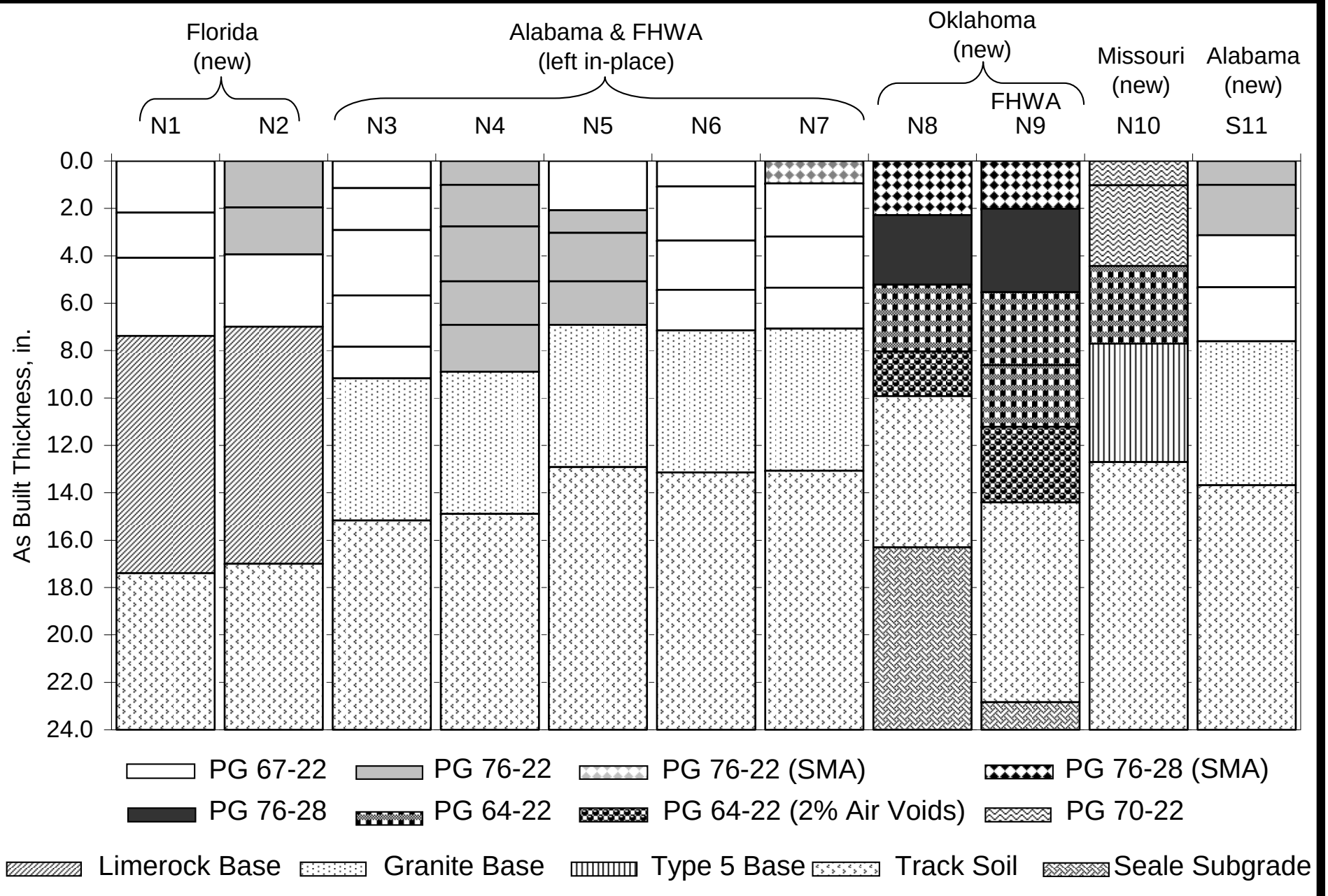
Predicted Traffic



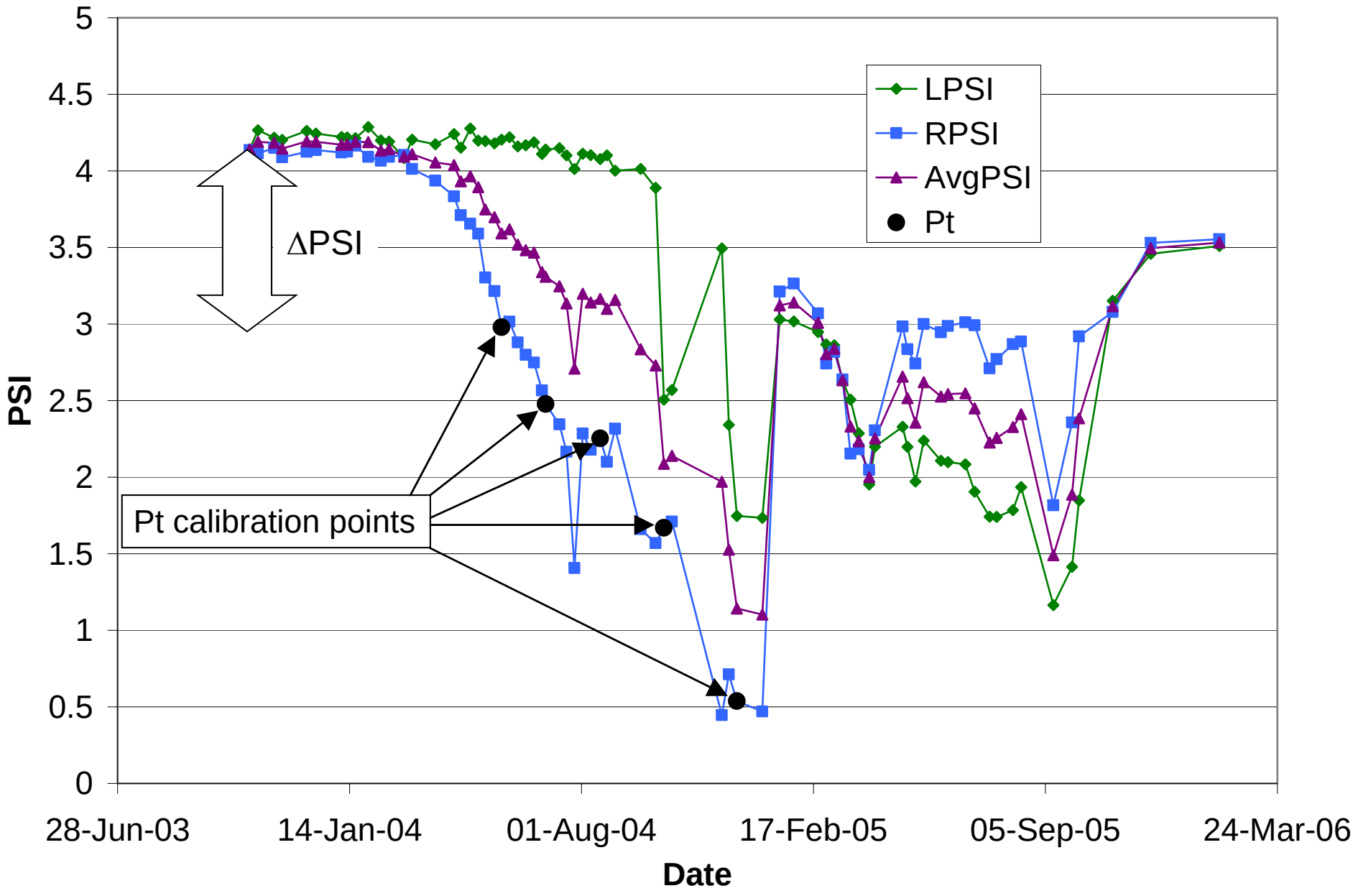
# 2003 Test Sections



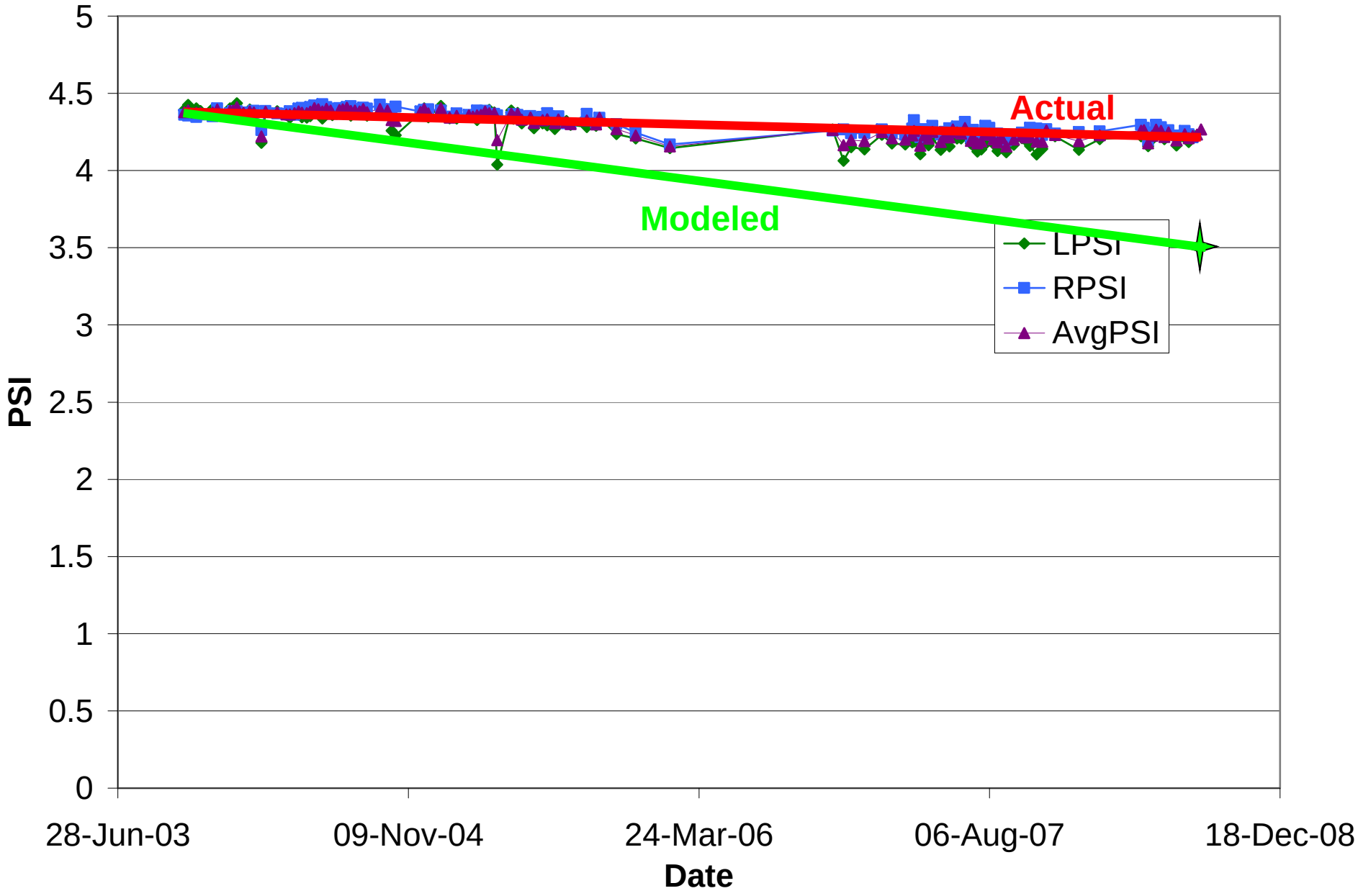
# 2006 Test Sections



# N1 PSI vs Date



# N3 PSI vs. Date



# N1 – Predicted and Measured Traffic

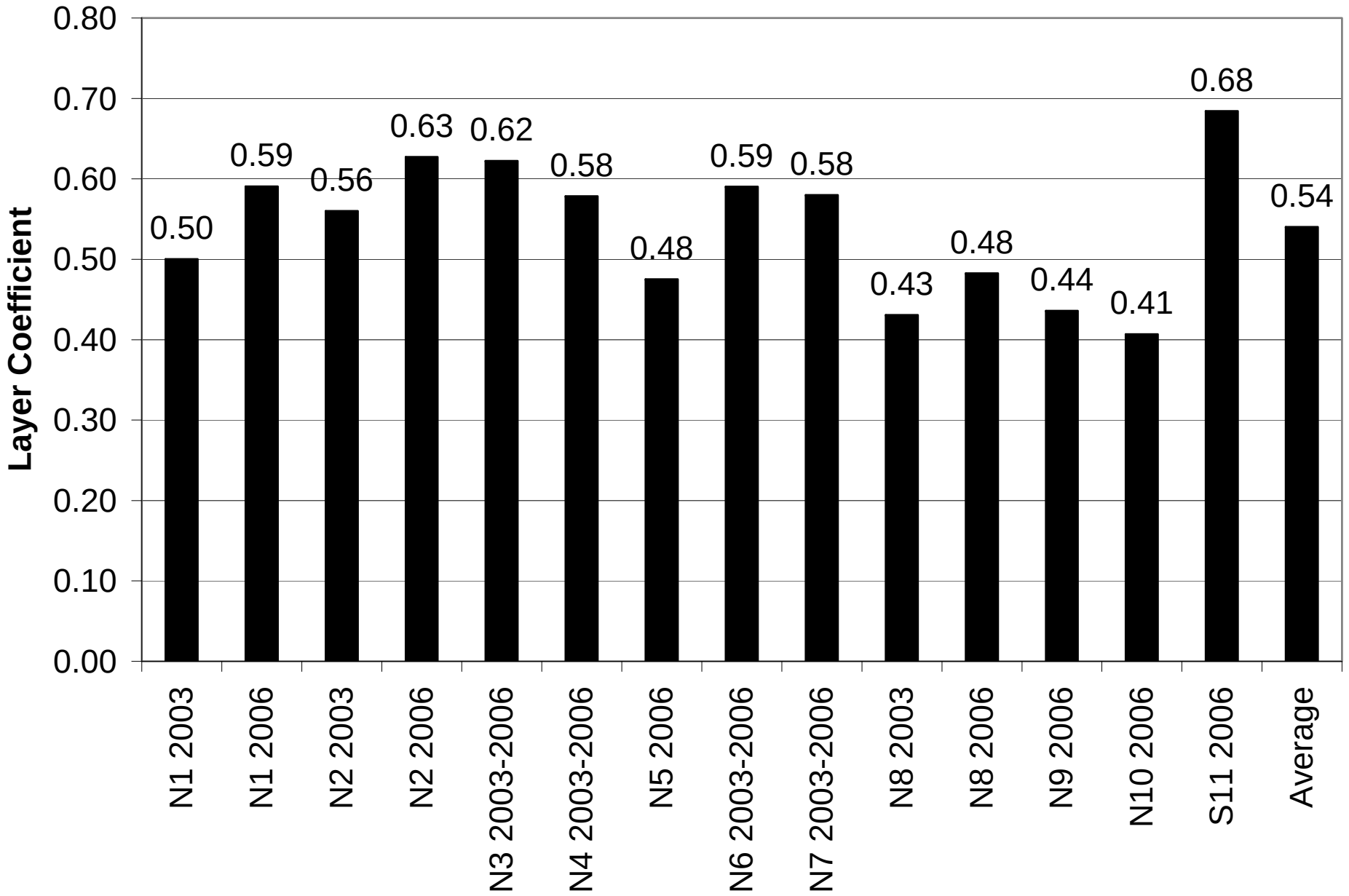
## $a_1 = 0.44$ ($R^2 = 0.08$)

| Predicted ESALs | Measured ESALs | Difference | % Error |
|---|---|---|---|
| 802,367 | 2,267,922 | 1,465,555 | 65% |
| 1,126,574 | 2,837,091 | 1,710,517 | 60% |
| 1,270,712 | 2,963,064 | 1,692,352 | 57% |
| 1,638,661 | 3,212,141 | 1,573,480 | 49% |
| 2,340,290 | 4,321,771 | 1,981,481 | 46% |

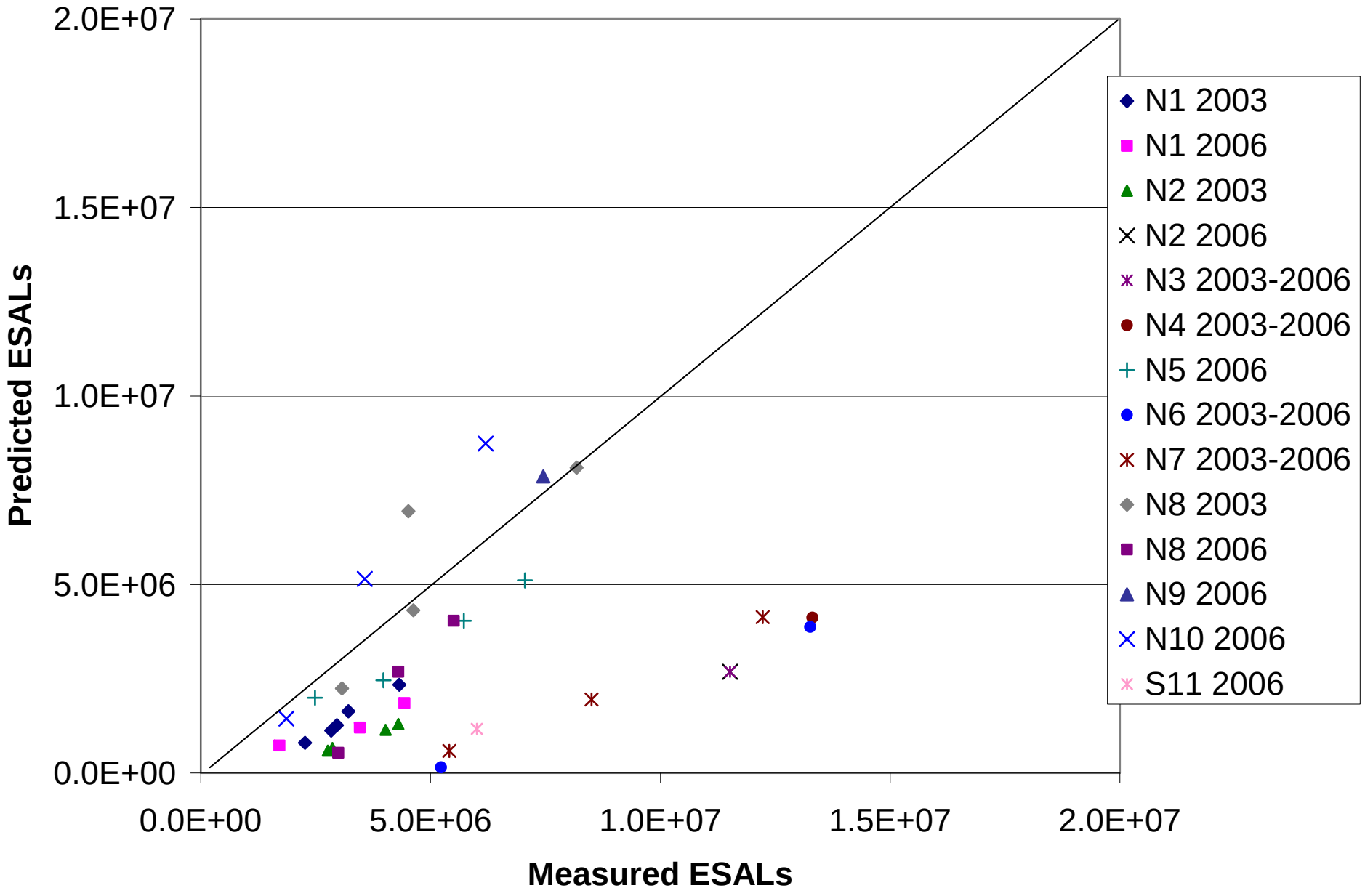
## $a_1 = 0.55$ ($R^2 = 0.74$)

| Predicted ESALs | Measured ESALs | Difference | % Error |
|---|---|---|---|
| 1,314,680 | 2,224,691 | 910012 | 41% |
| 2,007,491 | 2,806,554 | 799065 | 28% |
| 2,332,763 | 2,939,906 | 607145 | 21% |
| 3,203,489 | 3,207,147 | 3661 | 0% |
| 4,996,650 | 4,353,456 | 643194 | 15% |

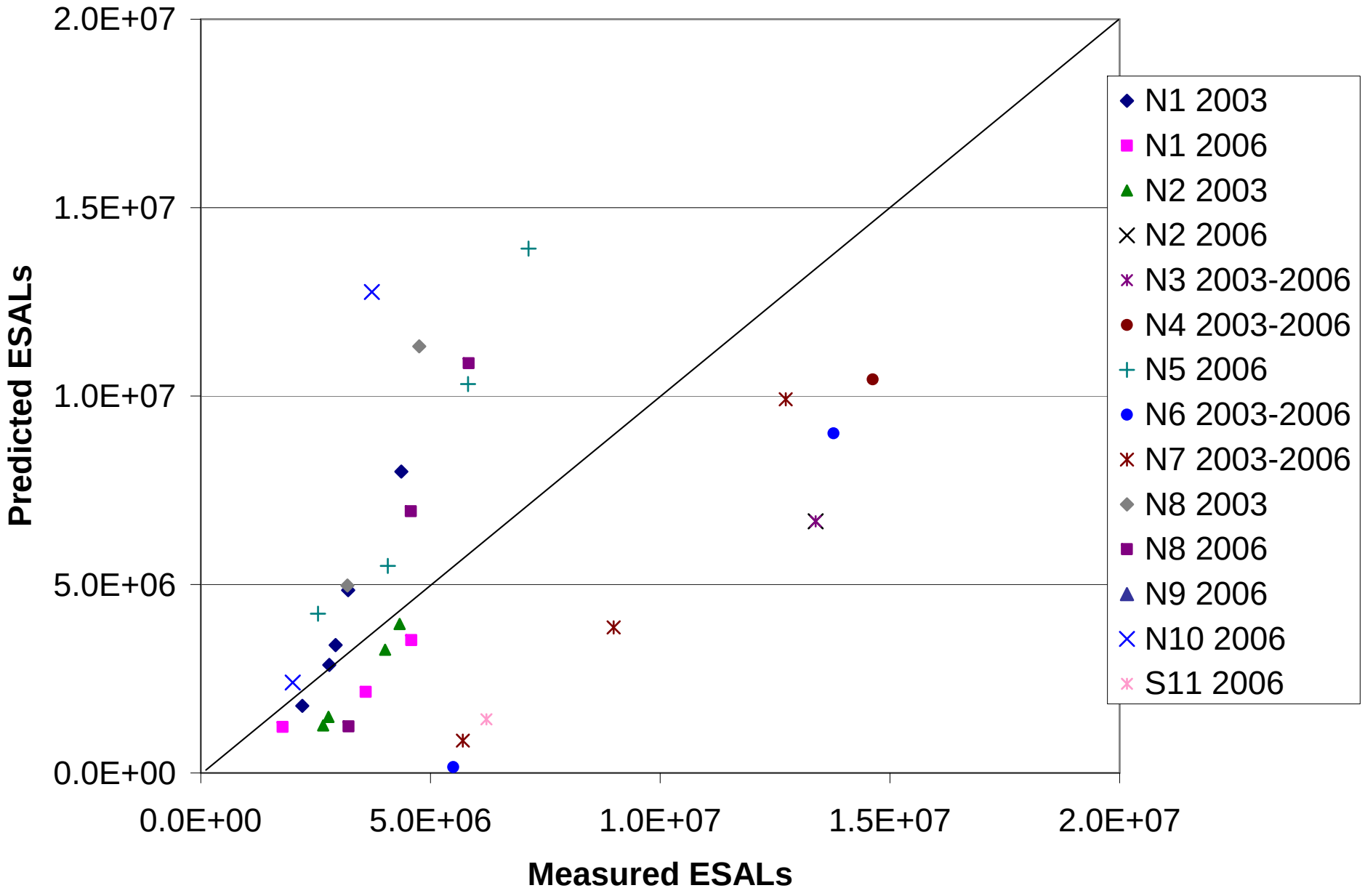
# $a_1$ Summary


Layer Coefficient
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.50
0.59
0.56
0.63
0.62
0.58
0.48
0.59
0.58
0.43
0.48
0.44
0.41
0.68
0.54
N1 2003
N1 2006
N2 2003
N2 2006
N3 2003-2006
N4 2003-2006
N5 2006
N6 2003-2006
N7 2003-2006
N8 2003
N8 2006
N9 2006
N10 2006
S11 2006
Average

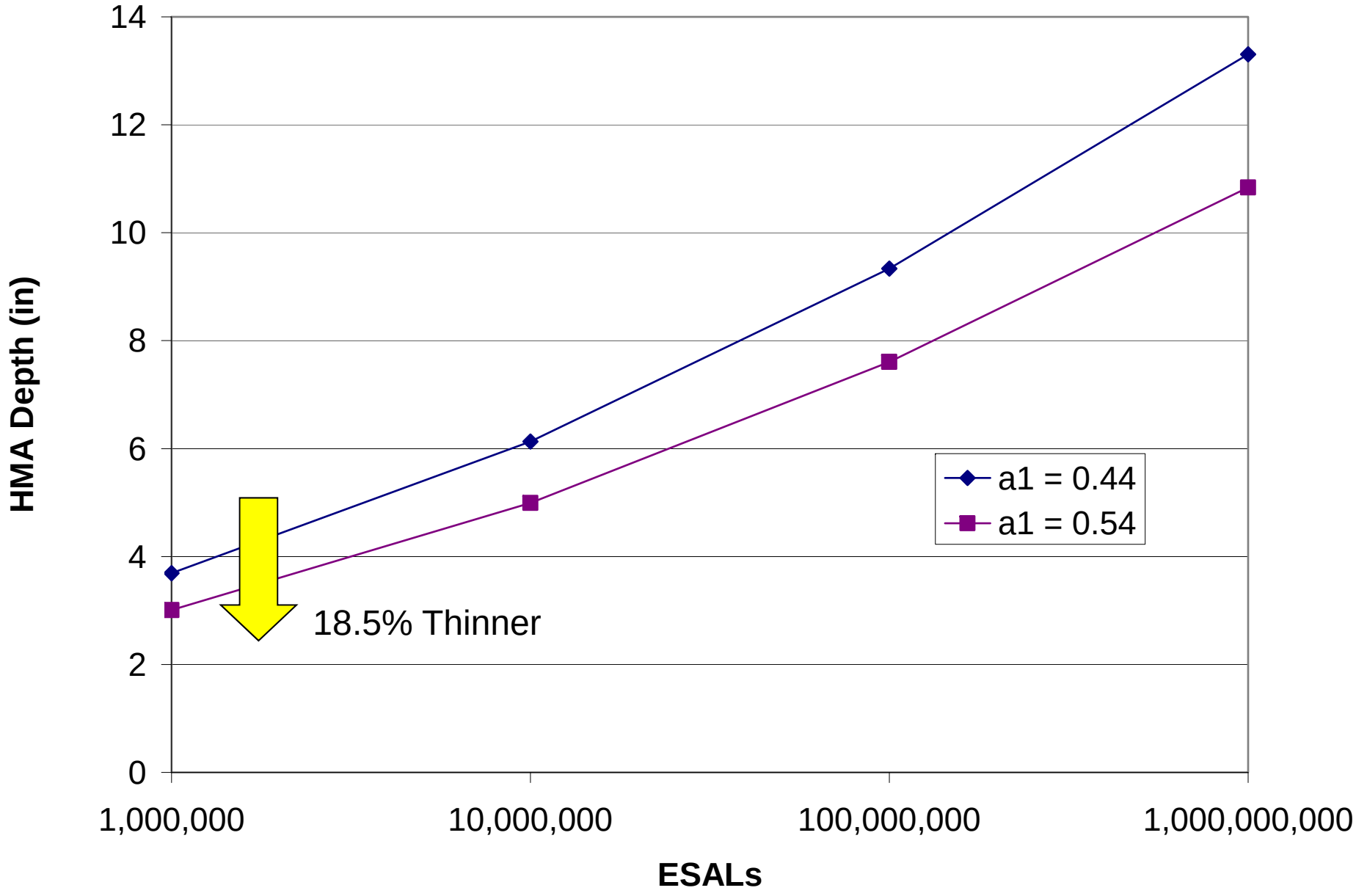
# UnCalibrated



# Calibrated


2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
Predicted ESALs
0.0E+00
5.0E+06
1.0E+07
1.5E+07
2.0E+07
Measured ESALs
N1 2003
N1 2006
N2 2003
N2 2006
N3 2003-2006
N4 2003-2006
N5 2006
N6 2003-2006
N7 2003-2006
N8 2003
N8 2006
N9 2006
N10 2006
S11 2006

# Effect on Pavement Design



# Minimum Thickness

- Not calibrated for thicknesses < 5”
- Need recommendation for thinner sections
- Lower volume recommendation
  - If new coefficient (0.54) results in thickness < 5”, use old coefficient (0.44)
    - If resulting thickness > 5”; use 5”

# Conclusions

- New advances in mix design technology warrants recalibrating structural coefficient of HMA
- Structural coefficient has greatest impact of all design variables on pavement thickness
- Recalibration using NCAT Test Track data resulted in average $a_1 = 0.54$
  - Believed to be conservative estimate
- Using 0.54 instead of 0.44 yields 18.5% reduction in HMA thickness

# Structural Coefficient Status

- ALDOT has implemented new coefficient for rehabilitation/overlay design
- ALDOT will soon implement new coefficient on all new construction

# Washington State DOT Design Table

**Table 5.1. Flexible and Rigid Pavement Layer Thicknesses for New or Reconstructed Pavements**

| Design Period ESALs | Layer Thicknesses, ft. | | | | |
|---|---|---|---|---|---|
| | Flexible Pavement | | Rigid Pavement | | |
| | HMA | CSBC Base | PCC Slab | Base Type and Thickness | |
| ≤ 5,000,000 | 0.50 | 0.50 | 0.67 | CSBC only | 0.35 |
| 5,000,000 to 10,000,000 | 0.67 | 0.50 | 0.75 | HMA over CSBC | 0.35 + 0.35 |
| 10,000,000 to 25,000,000 | 0.75 | 0.50 | 0.83 | HMA over CSBC | 0.35 + 0.35 |
| 25,000,000 to 50,000,000 | 0.92 | 0.58 | 0.92 | HMA over CSBC | 0.35 + 0.35 |
| 50,000,000 to 100,000,000 | 1.00 | 0.67 | 1.00 | HMA over CSBC | 0.35 + 0.35 |
| 100,000,000 to 200,000,000 | 1.08 | 0.75 | 1.08 | HMA over CSBC | 0.35 + 0.35 |

# Acknowledgements