Re-Evaluation of Current TxDOT PVR Procedure with A New Suction-Based Approach

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August 10, 2005

TxDOT Project Background (2002-2004)

TTI Project Name: Design Procedure for Pavements on Expansive Soils (3 Volumes)

- *Volume I – Theoretical Background*
- *Volume II – Experimental Protocols, Case Studies Site Descriptions*
- *Volume III – Computer Programs Manuals*

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Co-PI: **Dr. Charles P. Aubeny**

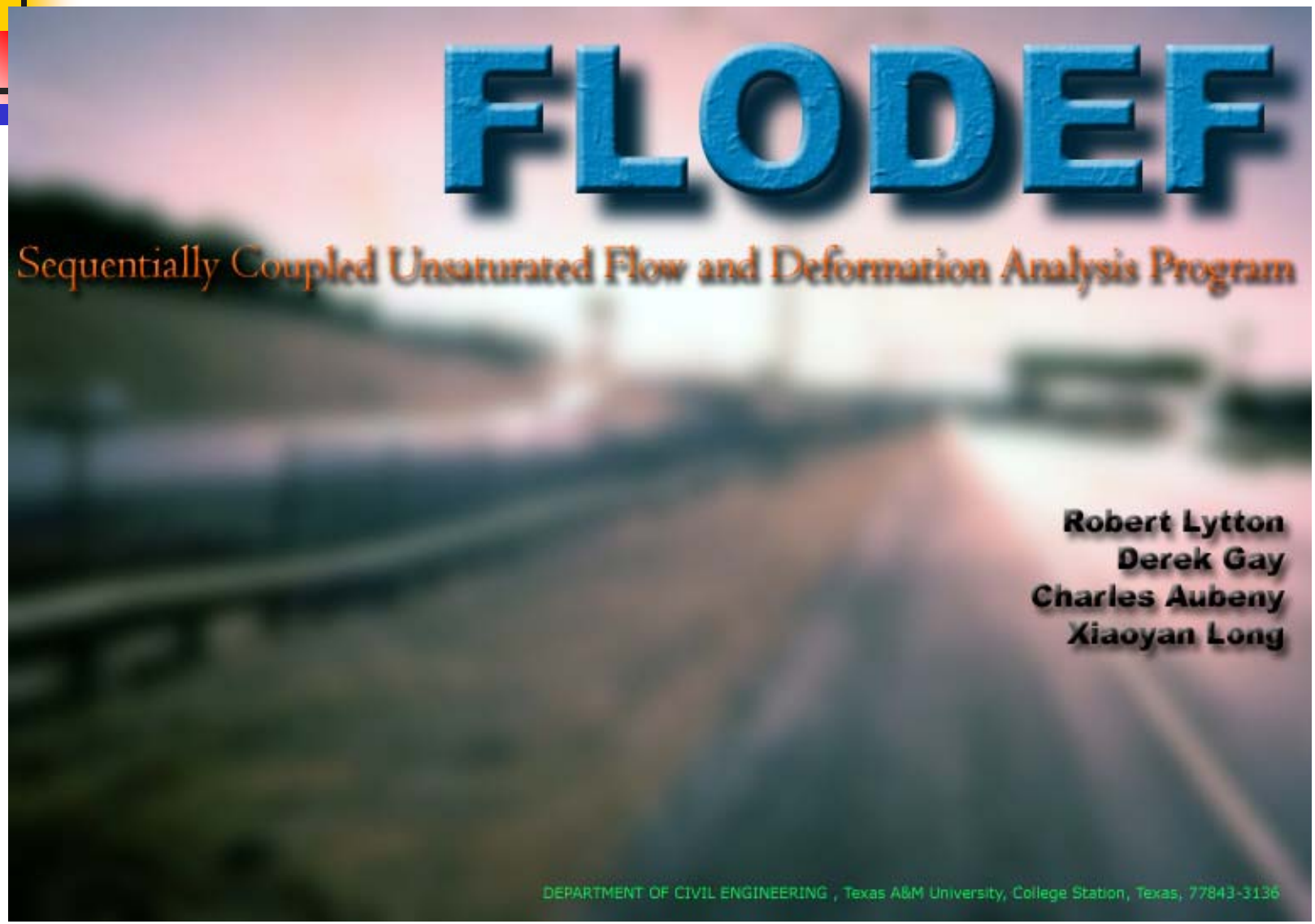
Outline

- *TxDOT PVR Assumptions*
- *Analysis Program (Flodef)*
- *Design Program (Winpres)*
- *Laboratory Testing (Diffusion Coefficient)*
- *TxDOT Case Studies*
- *PVR Comparison*
- *Implementation*

TxDOT PVR Tex-124-E Assumptions

- *Soil at all depths has access to water in capillary moisture conditions*
- *Vertical swelling strain is one-third of the volume change at all depths*
- *Remolded and compacted soils adequately represent soils in the field*
- *PVR of 0.5 inch produces unsatisfactory riding quality*
- *Volume change can be predicted by use of the plasticity index alone*

Analysis Program - Flodef



Analysis Program - Flodef

Two-Dimensional Transient Analysis
For the Effects of:

- ***Vertical Moisture Barrier***
- ***Subgrade Material (Lime Stabilized / Inert Soil)***
- ***Median Condition (Paved / Non-Paved)***
- ***Shoulder Condition (Paved / Bare)***

Analysis Program - Flodef

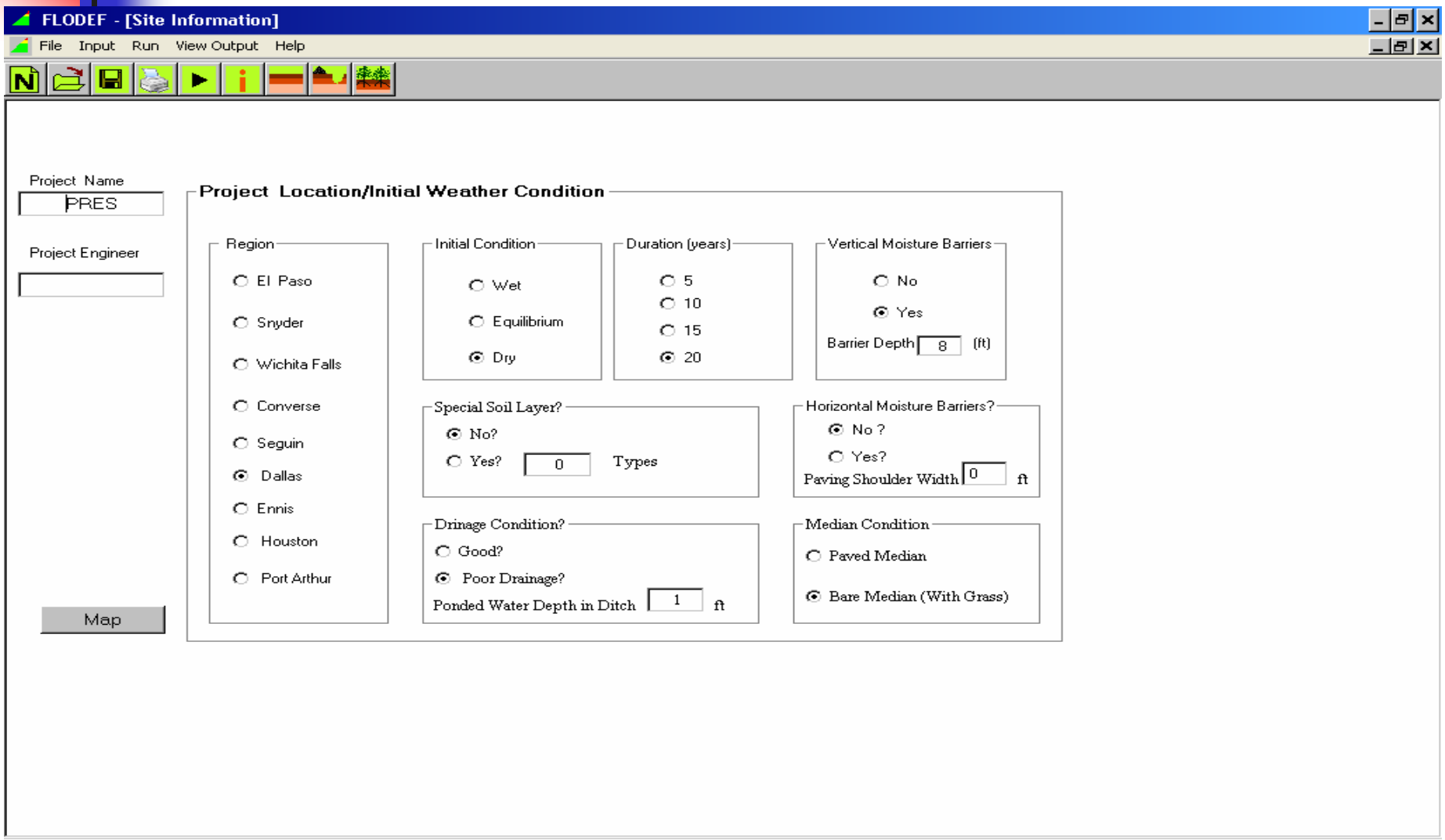
Input

- *2D Cross Section*
- *Soil Index Properties*
- *Geographic Location*
- *Vegetation*
- *Moisture Controls*
- *Drainage Conditions*

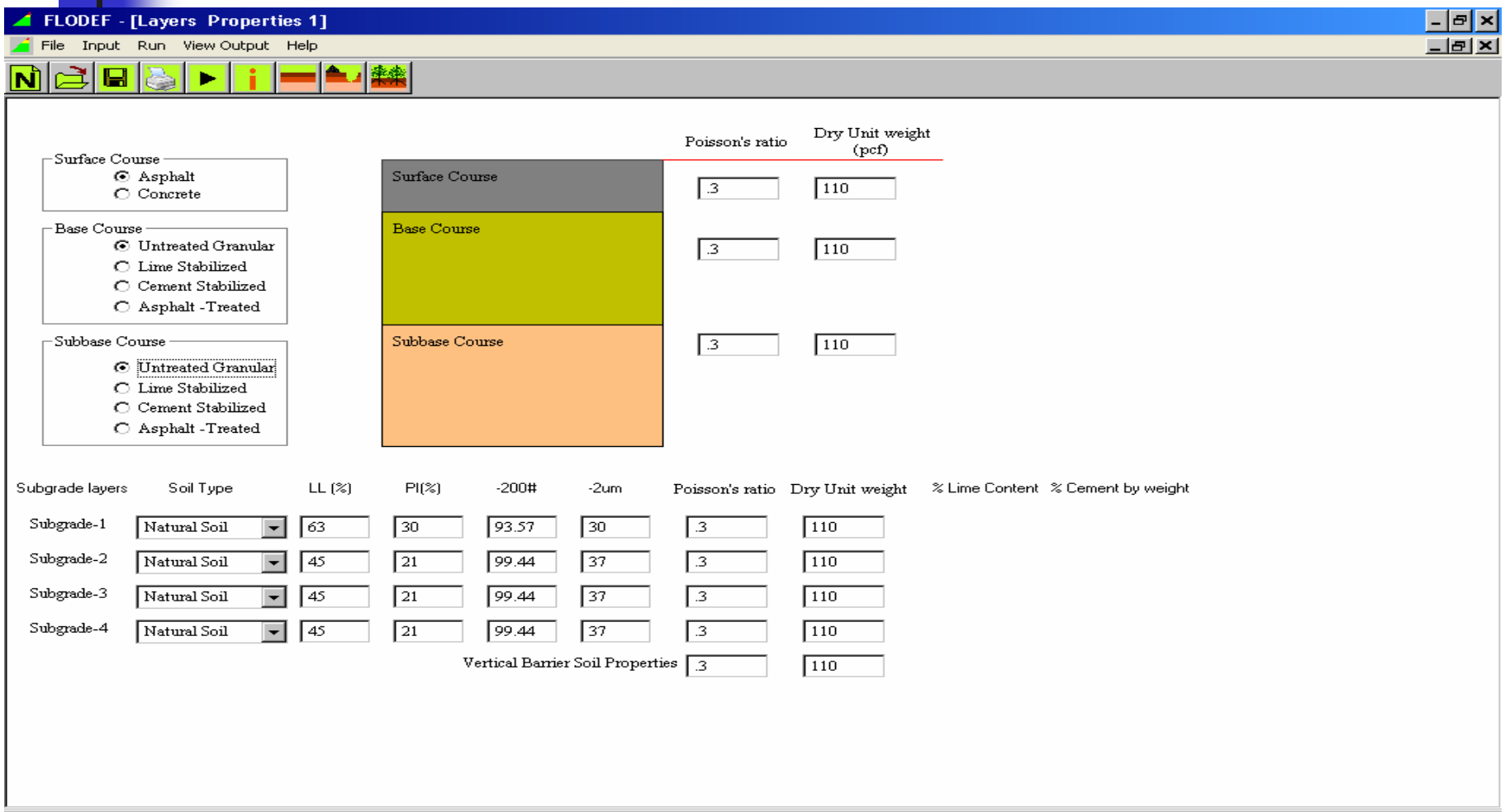
Output

- *Shrink-Swell versus Time*
- *Suction versus Time*

Analysis Program - Flodef



Analysis Program - Flodef



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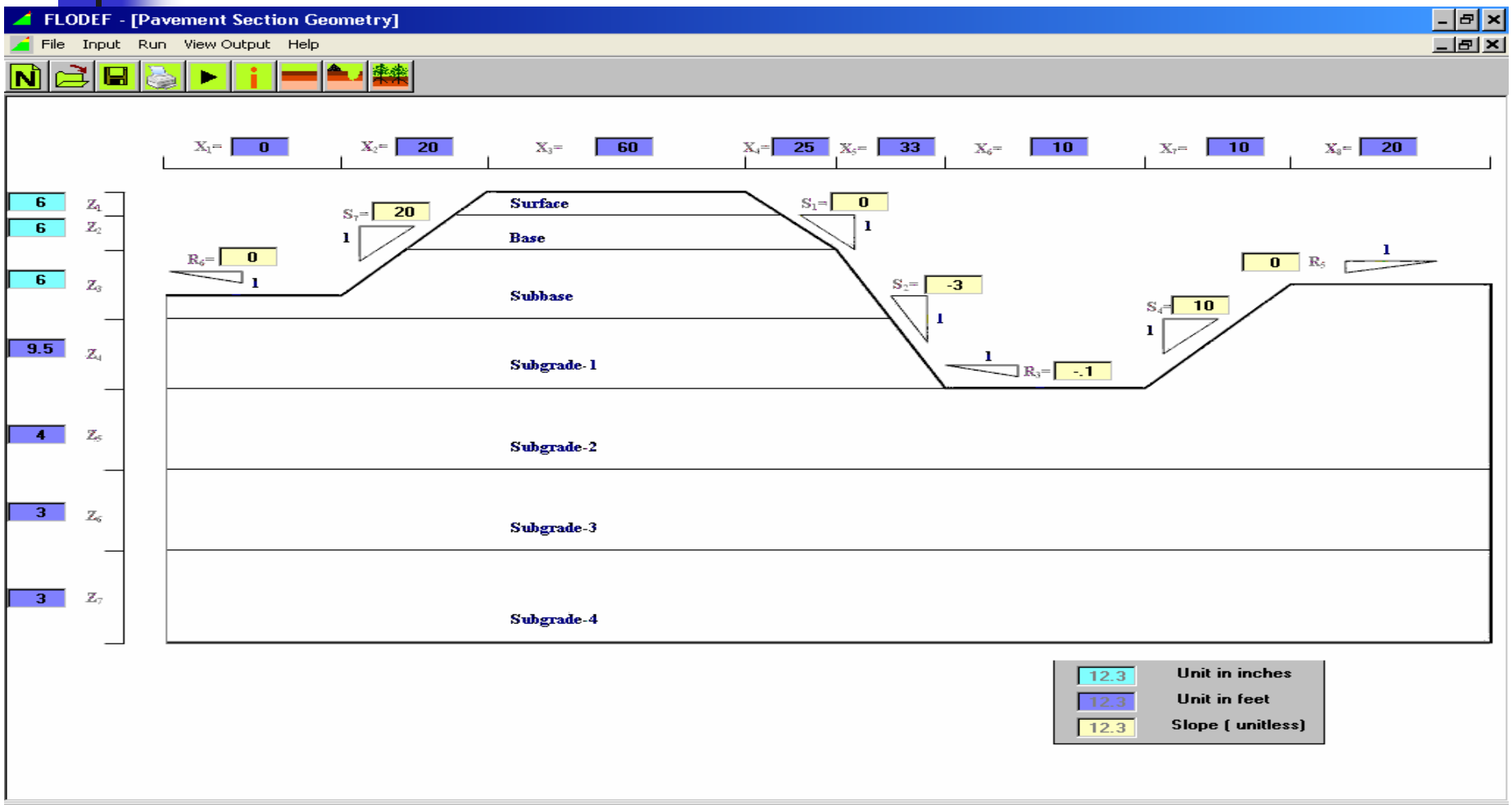

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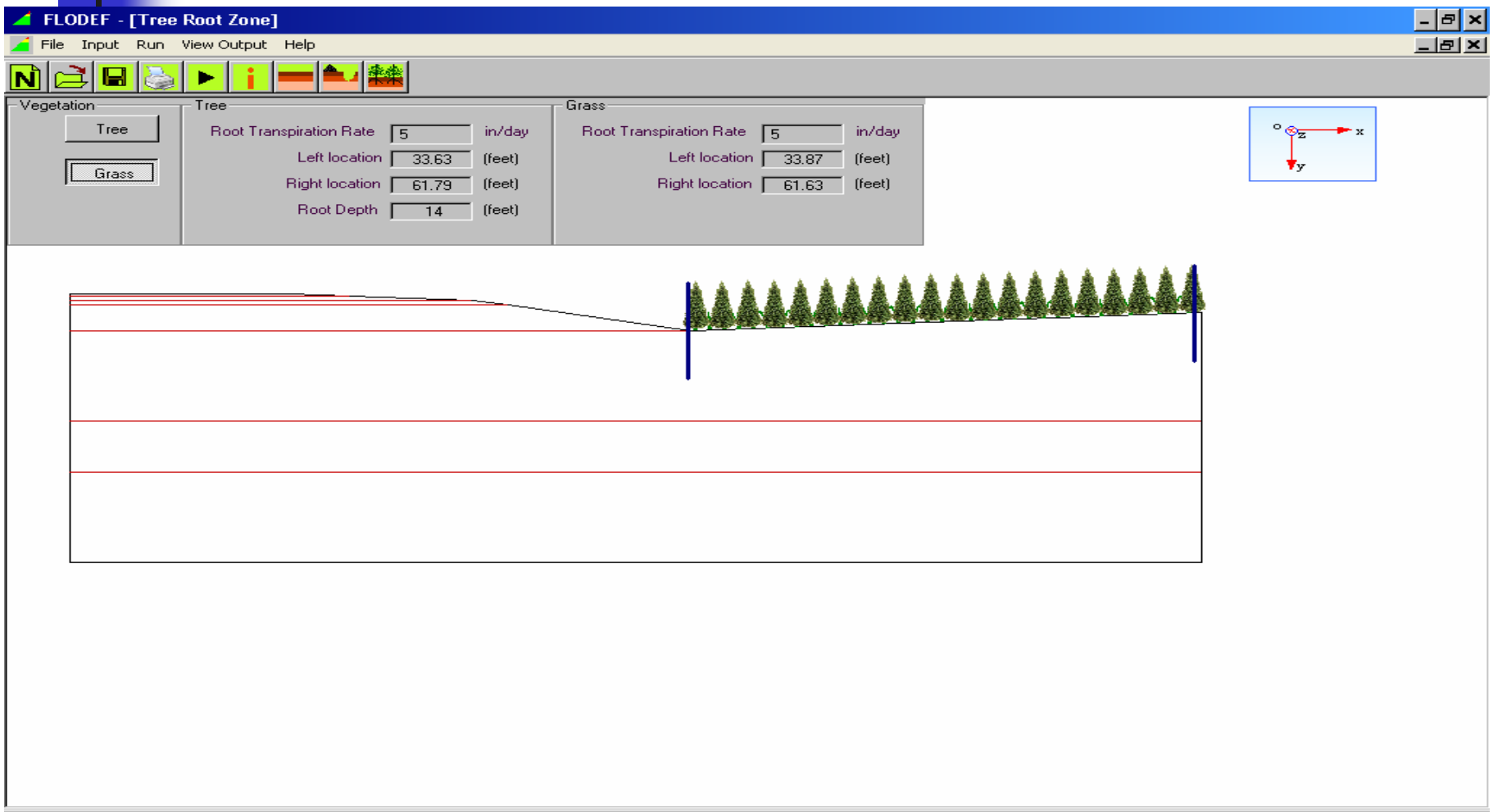

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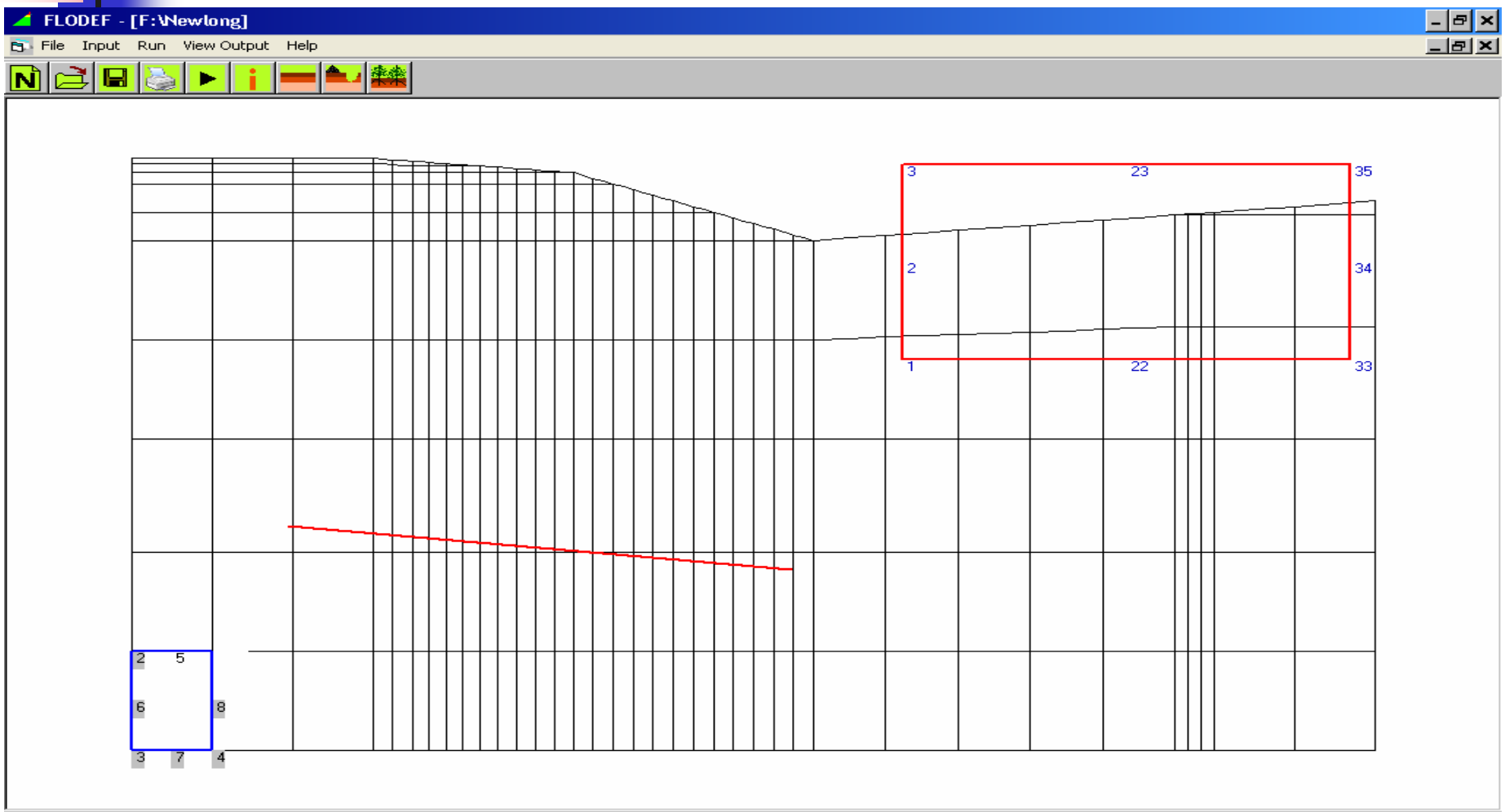

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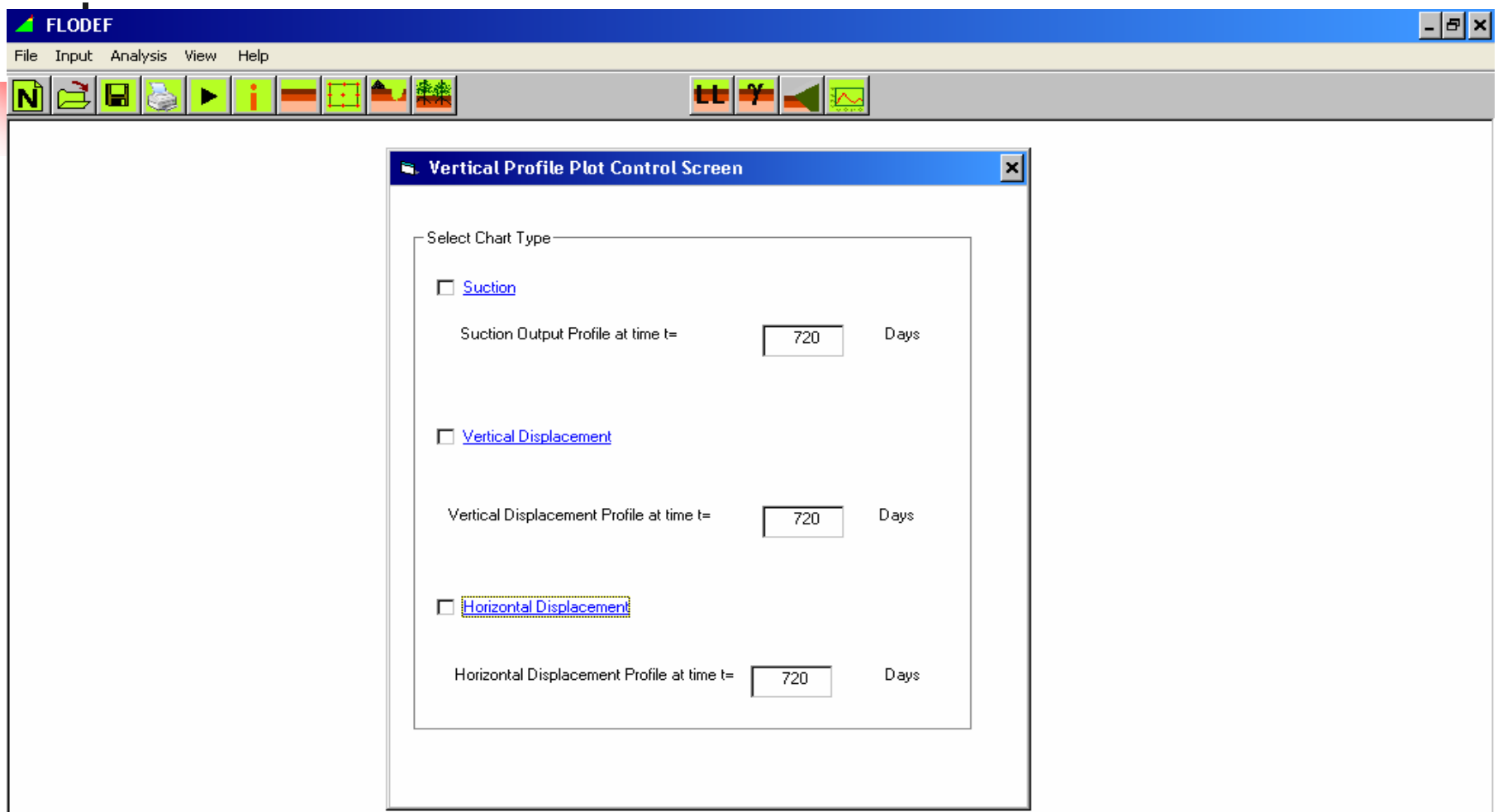

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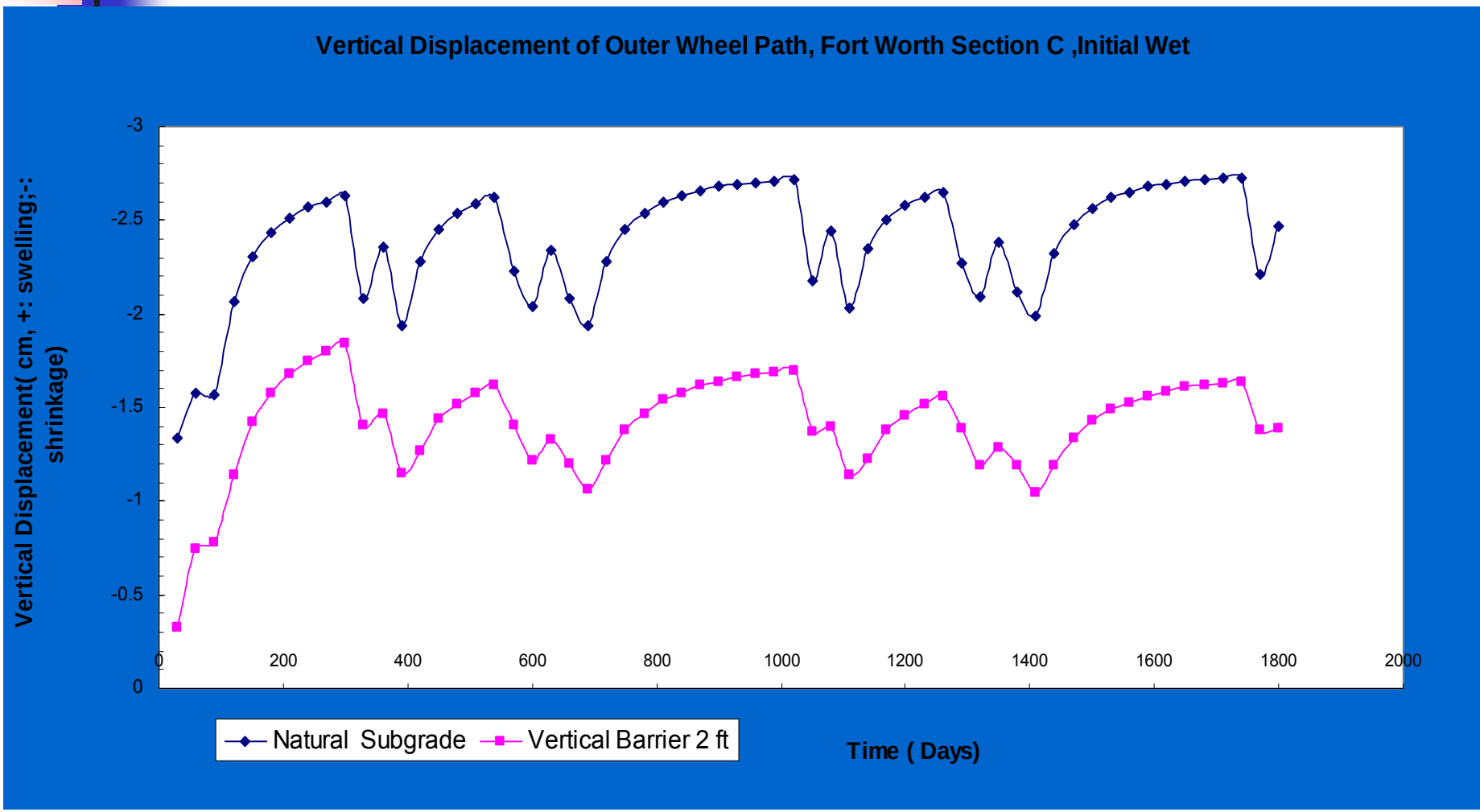

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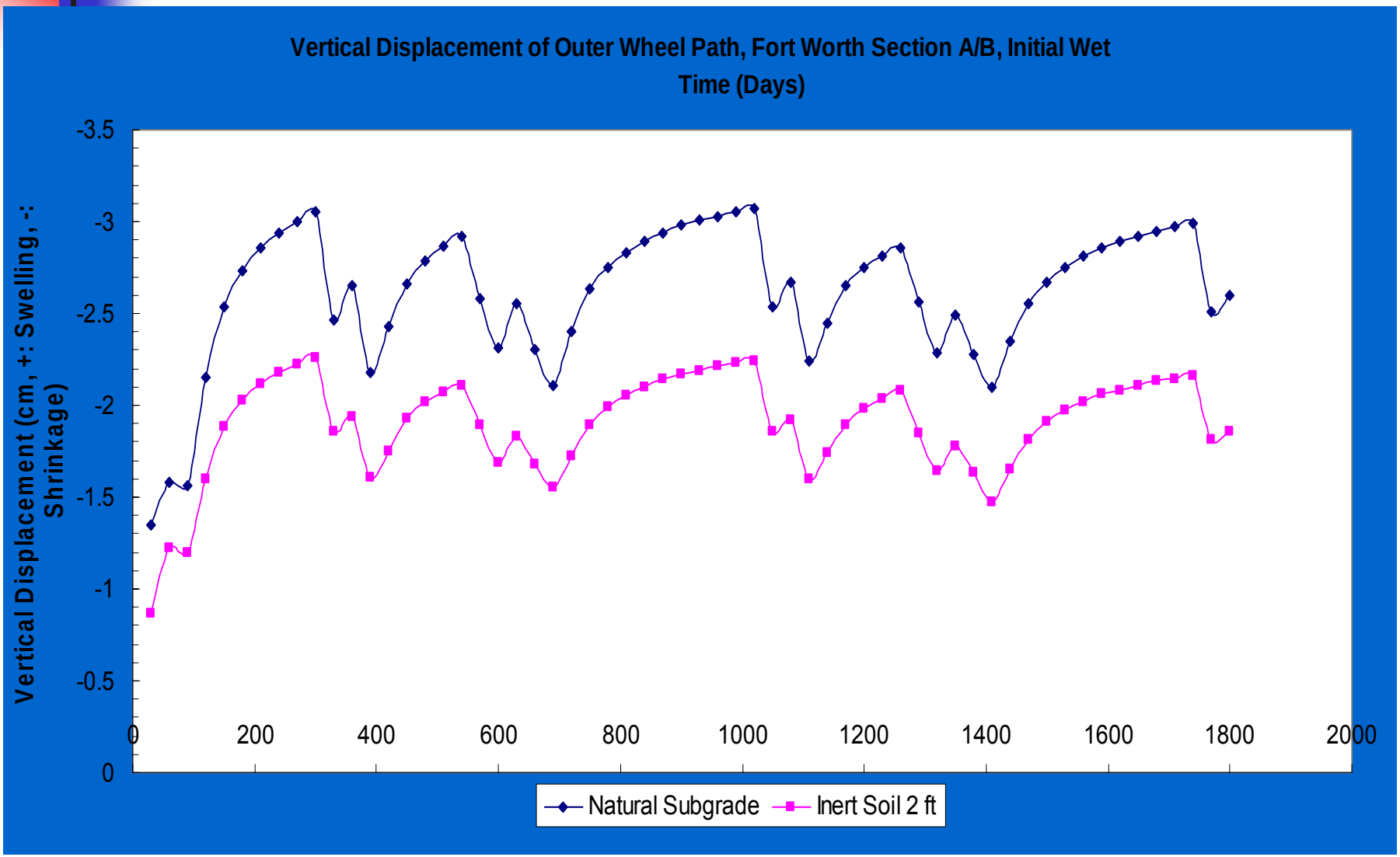


Design Program - Winpres

Design Program - Winpres

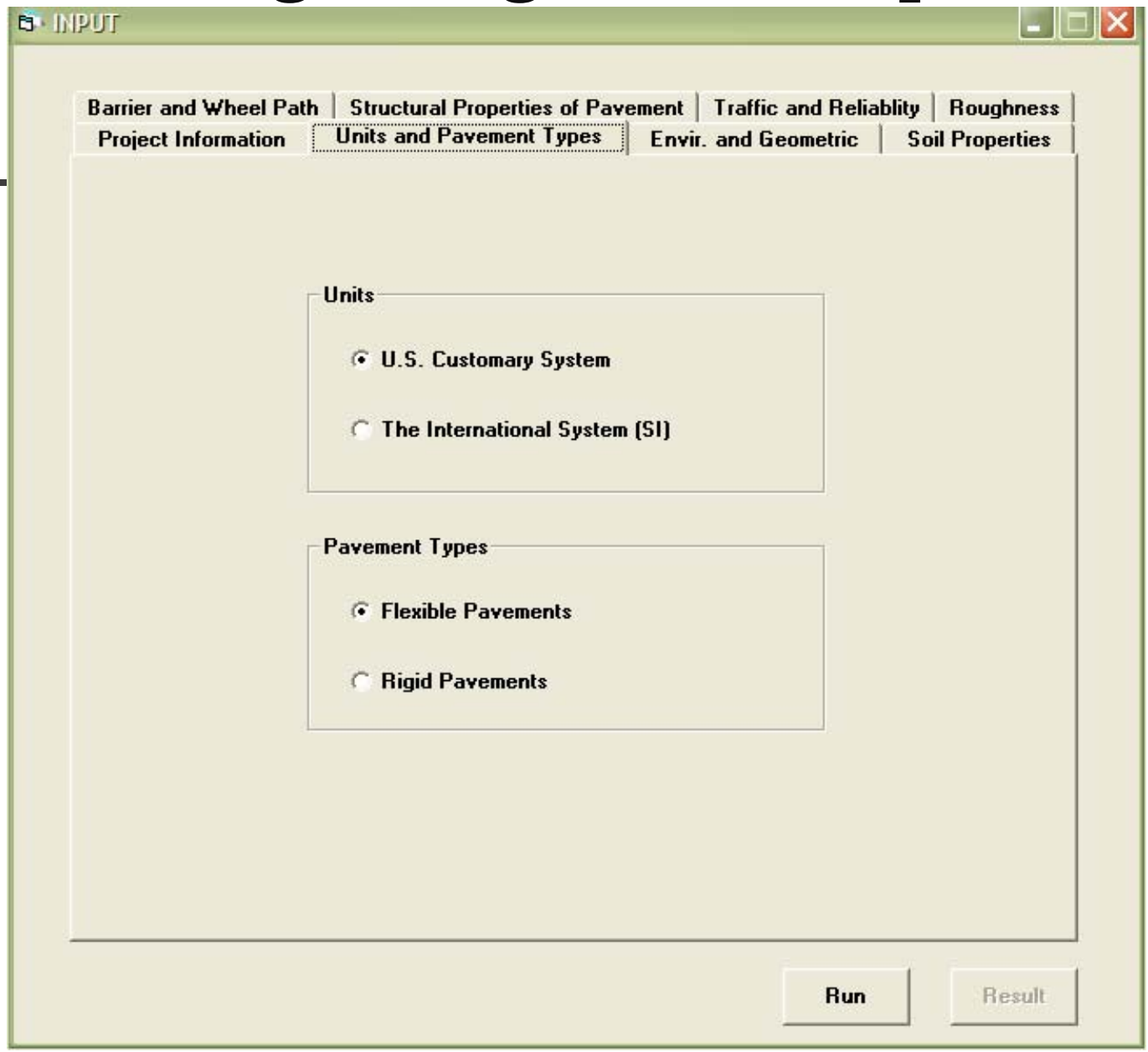
Input

- *Soil Index Properties*
- *Geographic Location*
- *Site Drainage and Vegetation*
- *Pavement Data*
- *Moisture Controls*
- *Traffic Data*
- *Reliability Level*

Output

- *Shrink-Swell versus Time*
- *PSI versus Time*
- *IRI versus Time*

Design Program - Winpres



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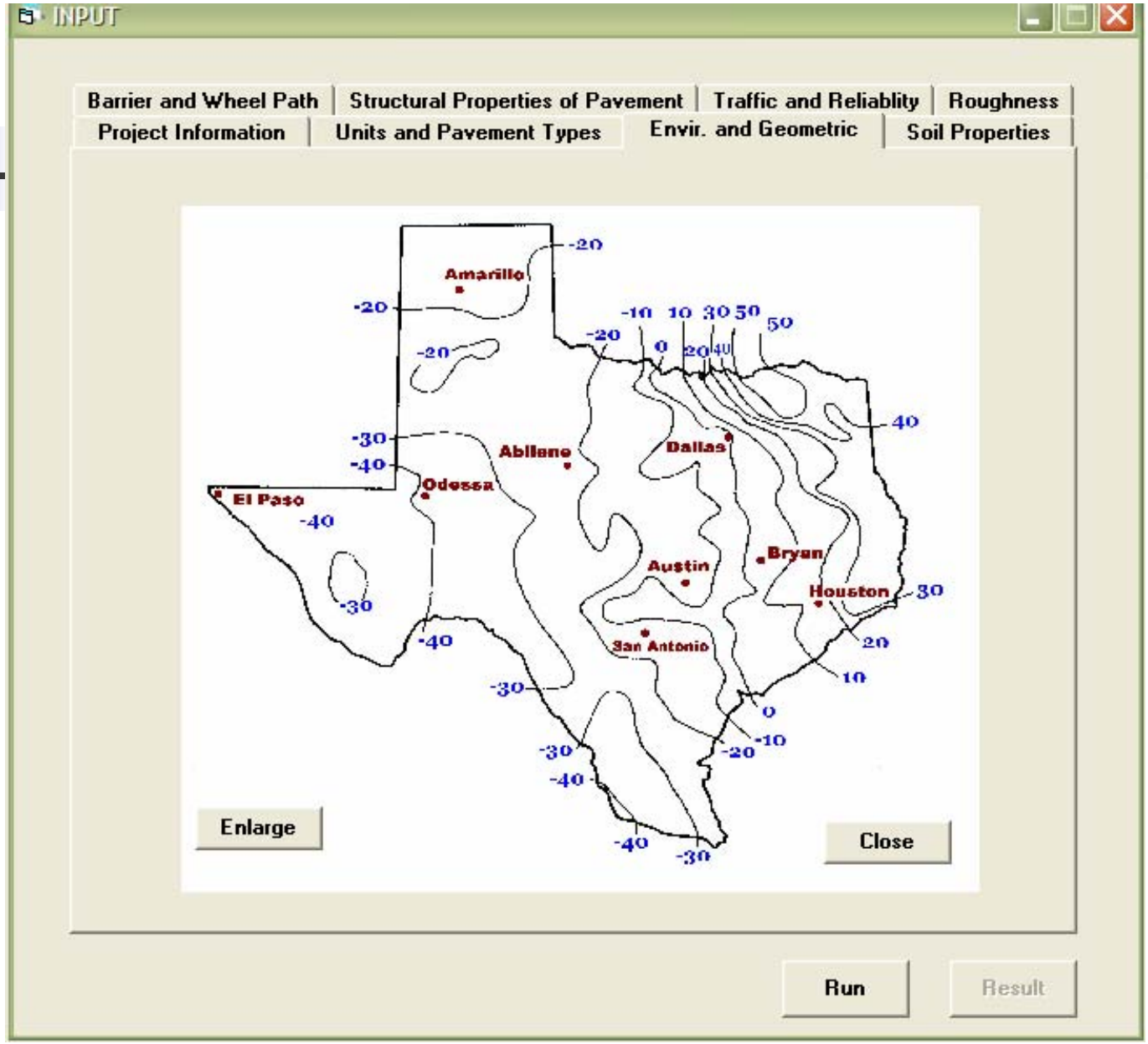

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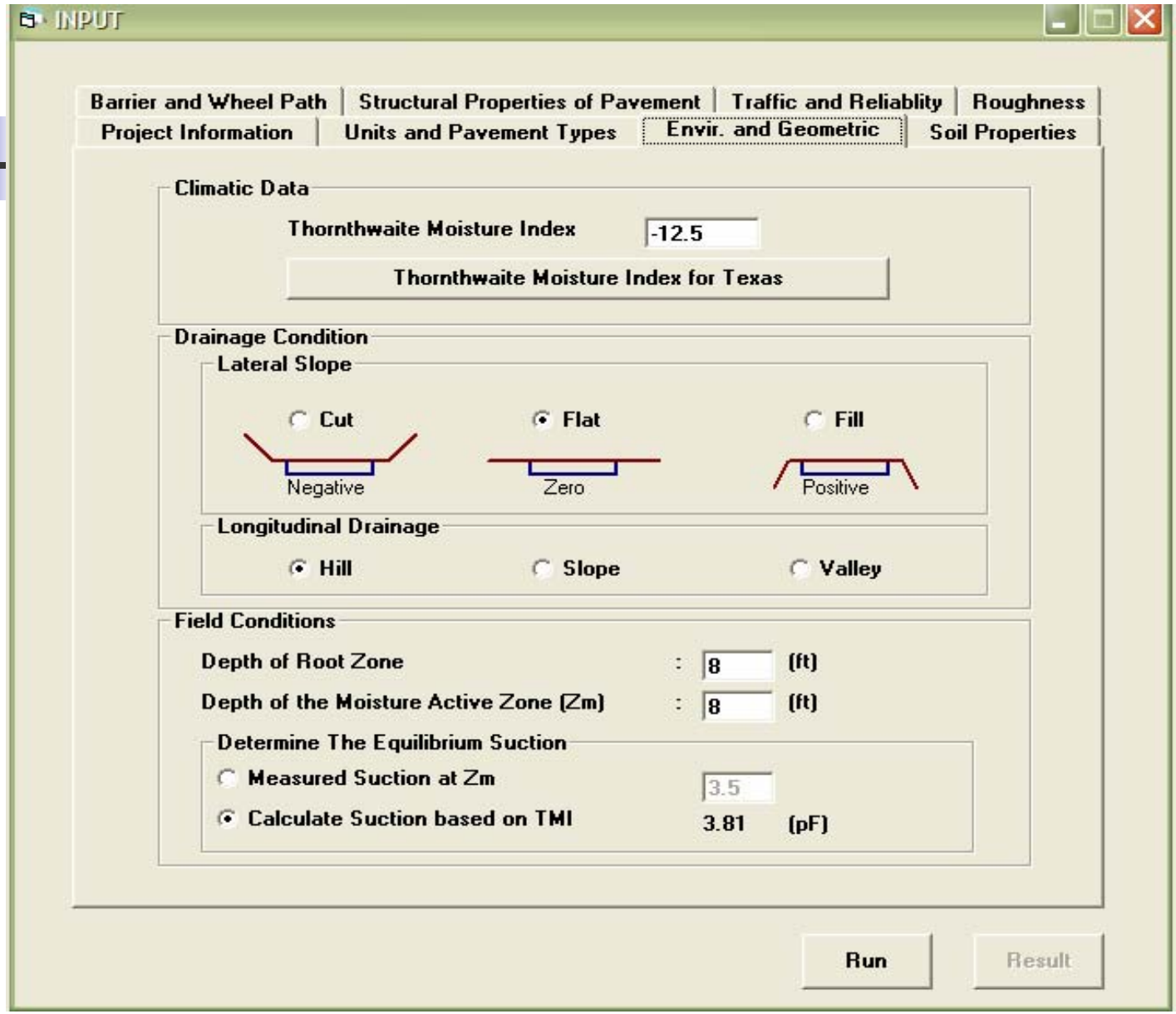

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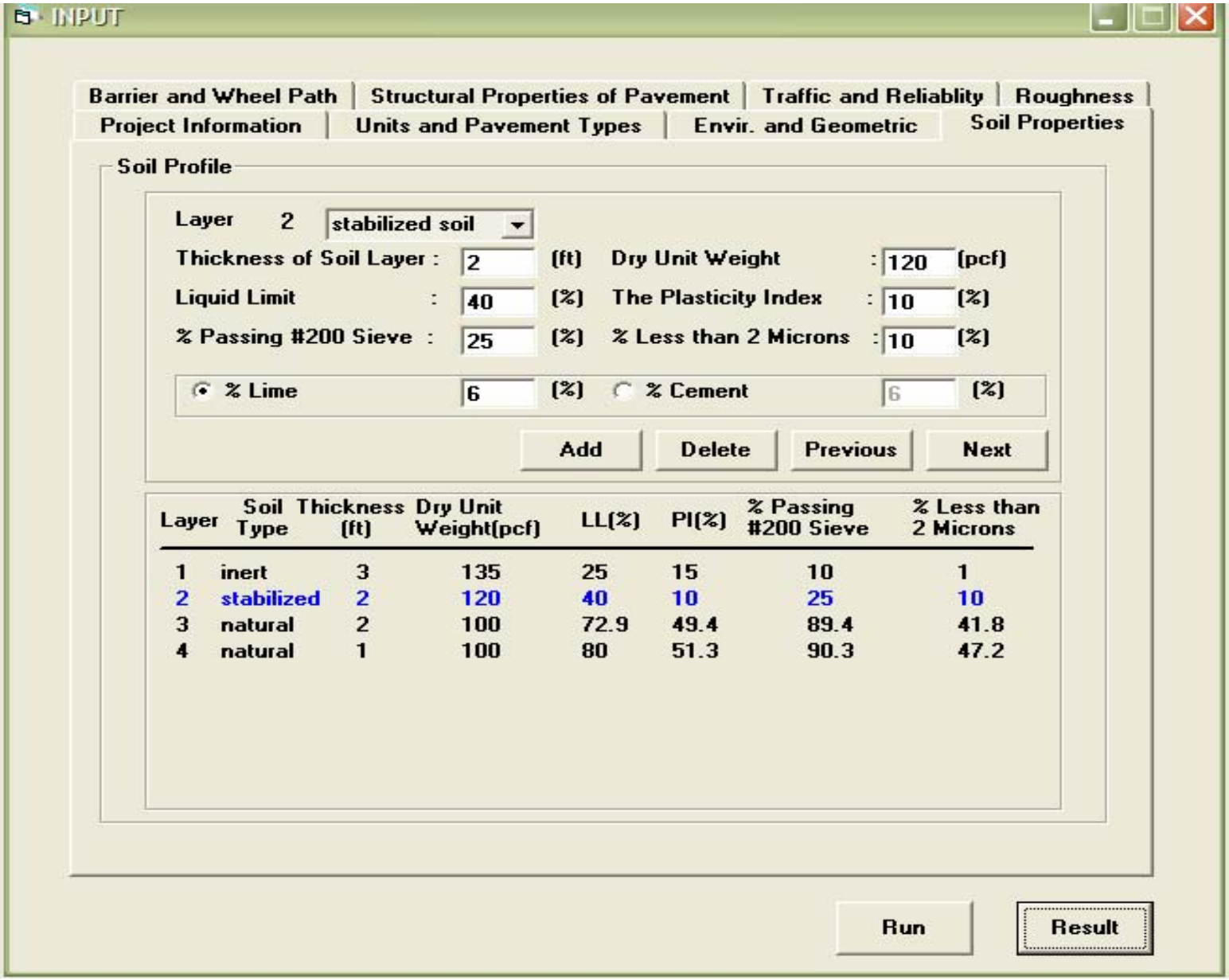
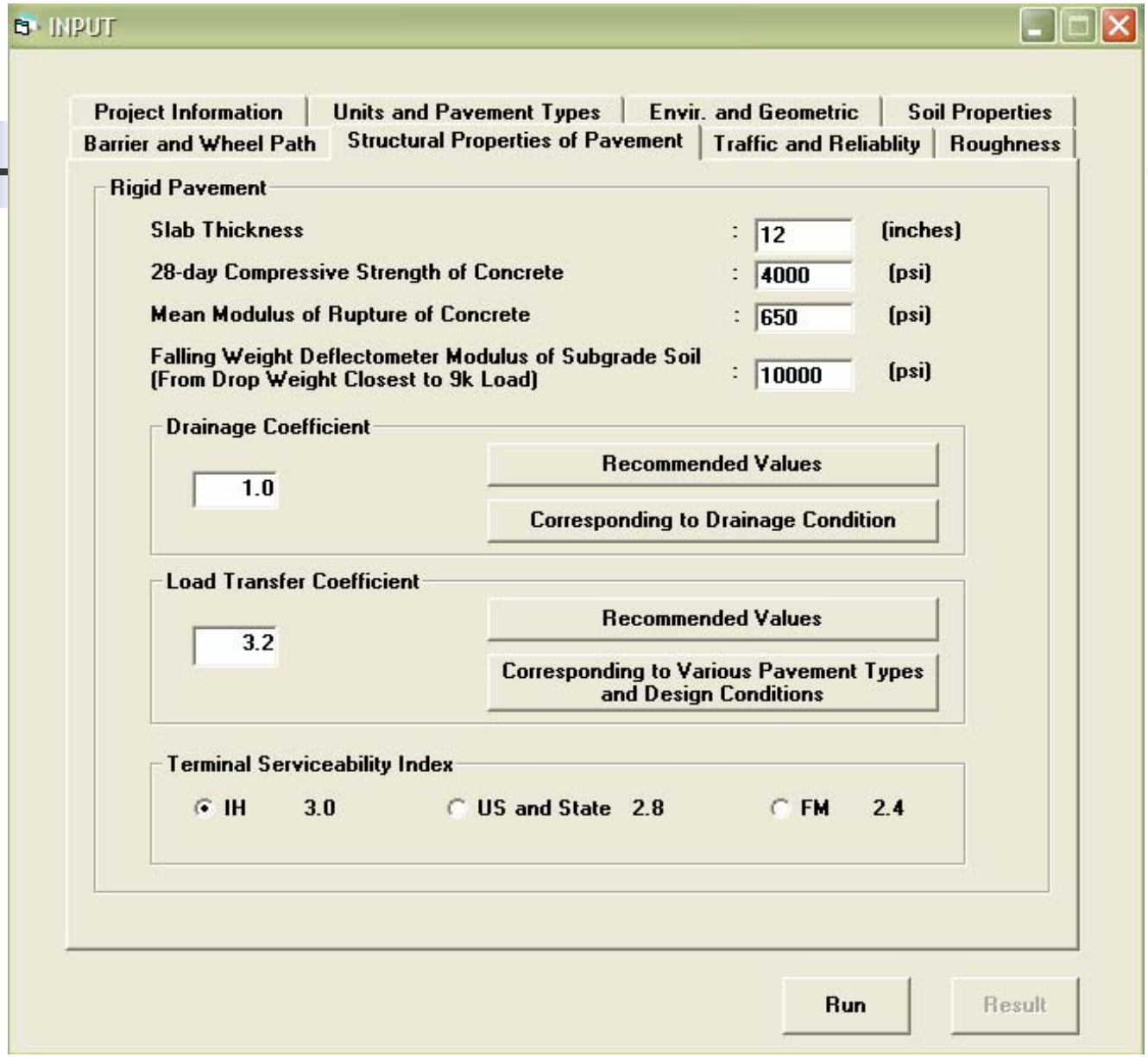


Layer	Soil Type	Thickness (ft)	Dry Unit Weight(pcf)	LL(%)	PI(%)	% Passing #200 Sieve	% Less than 2 Microns
1	inert	3	135	25	15	10	1
2	stabilized	2	120	40	10	25	10
3	natural	2	100	72.9	49.4	89.4	41.8
4	natural	1	100	80	51.3	90.3	47.2

Design Program - Winpres



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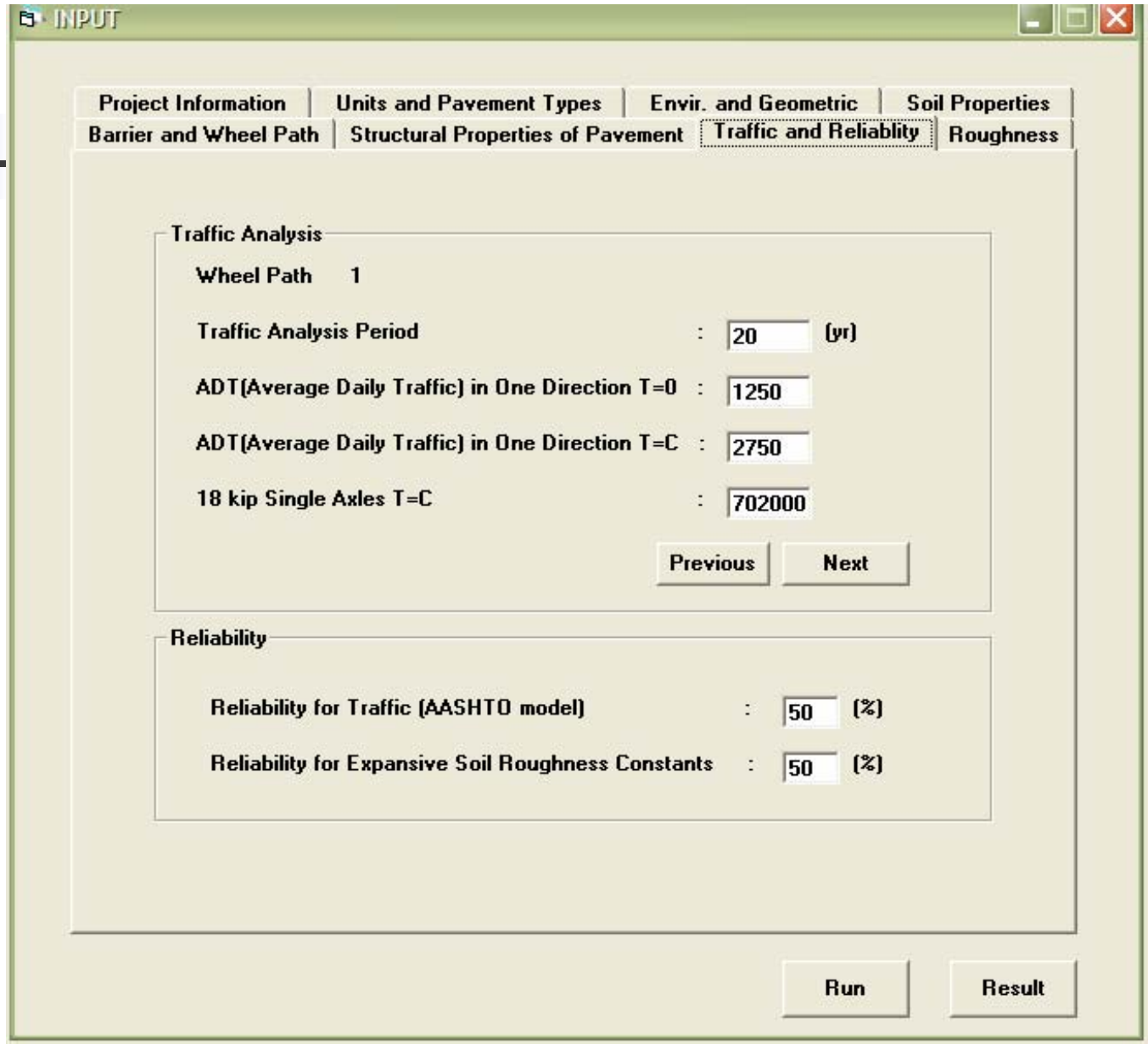

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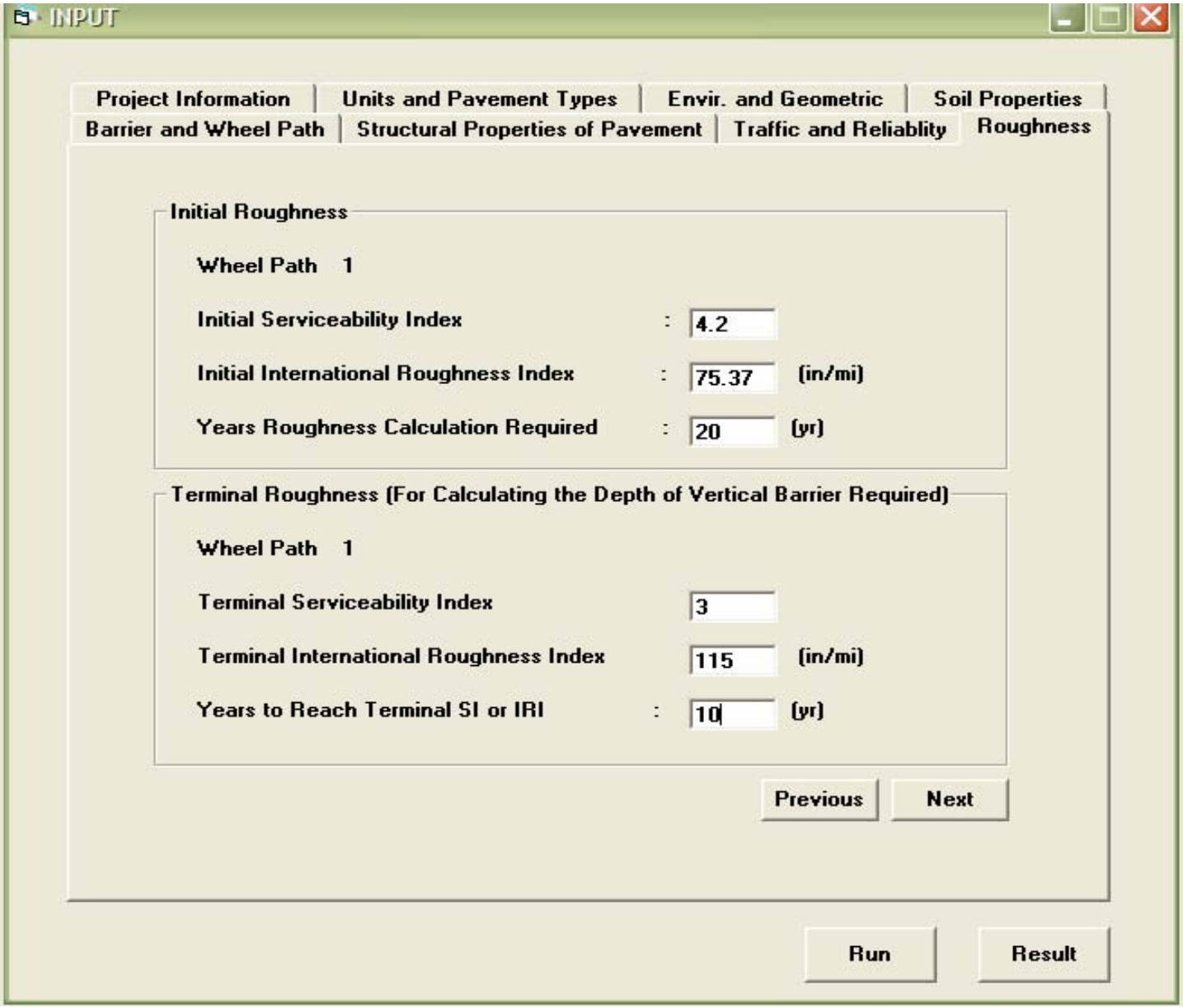

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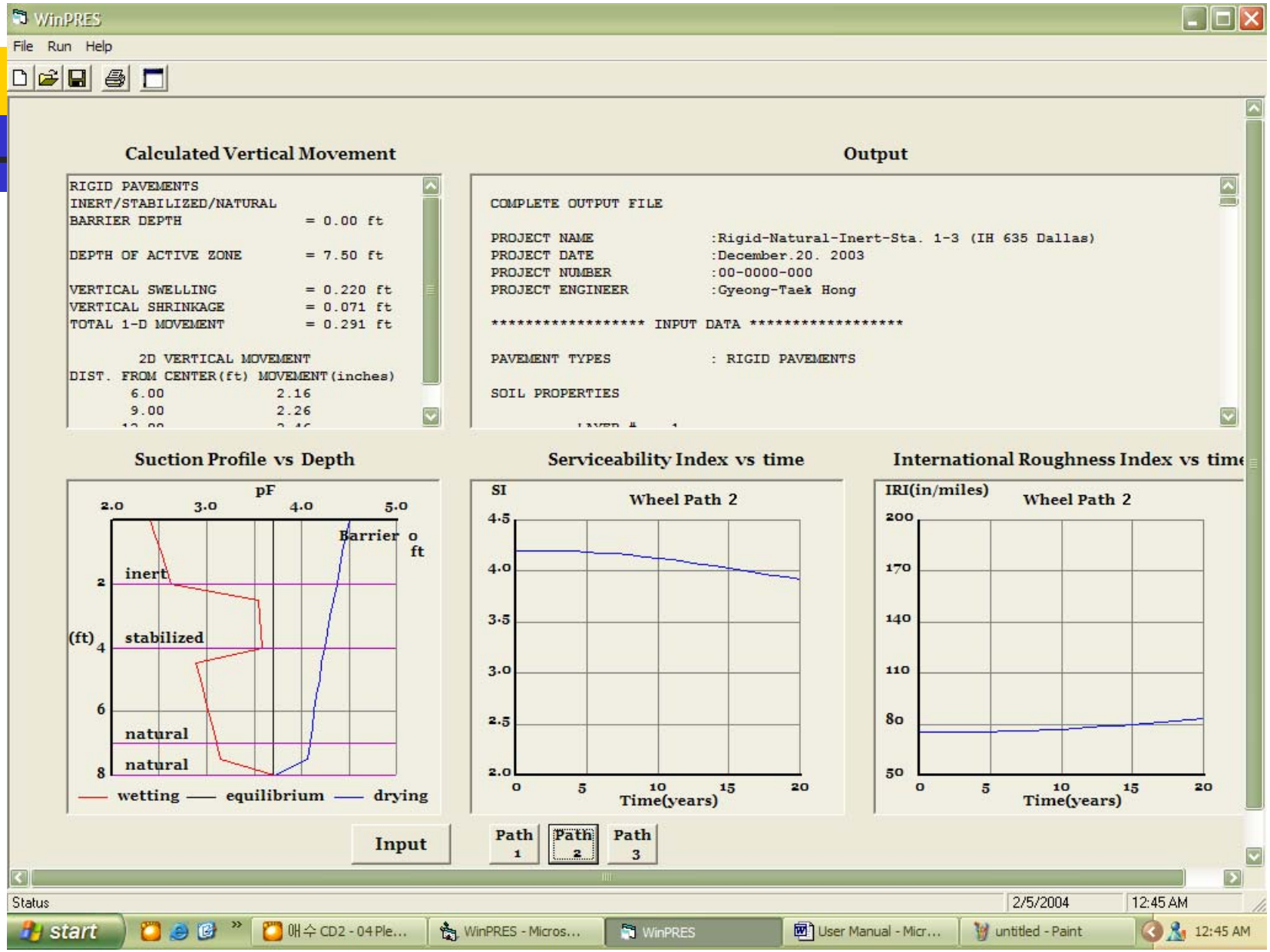
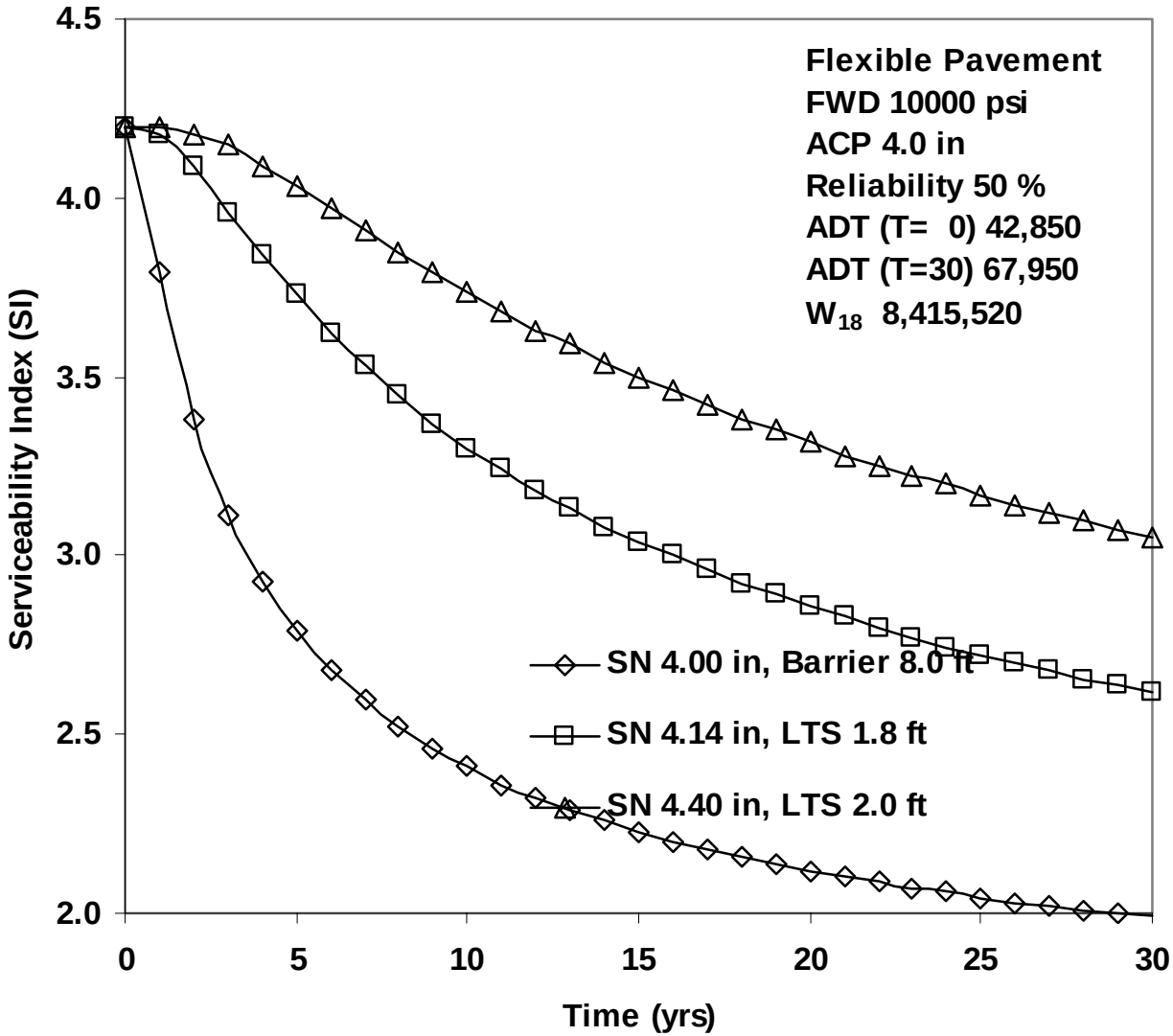


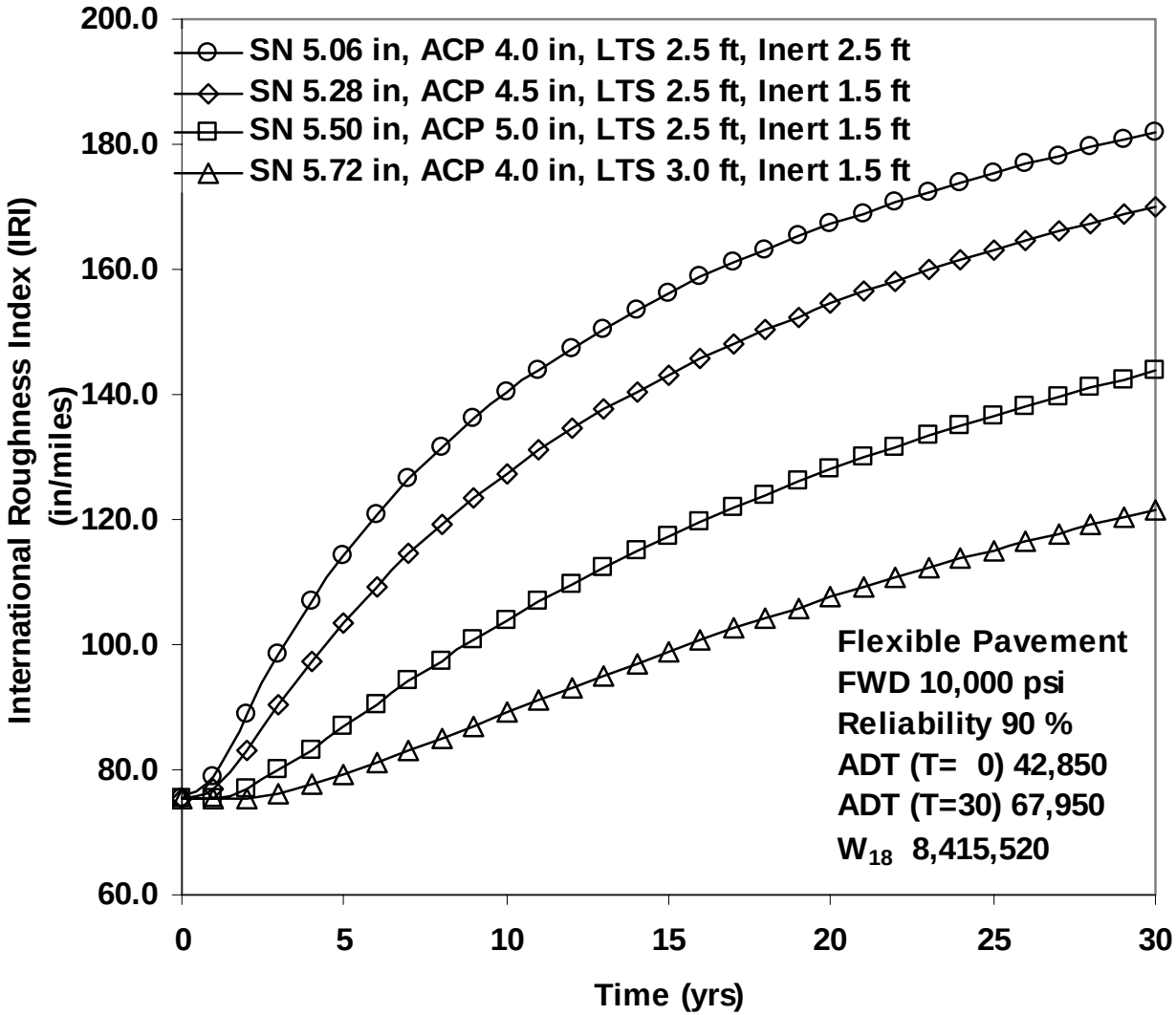
Design Program - Winpres

PSI versus Time



Design Program - Winpres

IRI versus Time



Laboratory Testing–Diffusion Coefficient

Apparatus

- *Thermocouple Psychrometers*
- *Sling Psychrometer*
- *Temperature Control Unit*
- *A drill-bit, knife, spatula, tape, sealing material (aluminum foil, plastic wrap, etc.)*

Laboratory Testing–Diffusion Coefficient

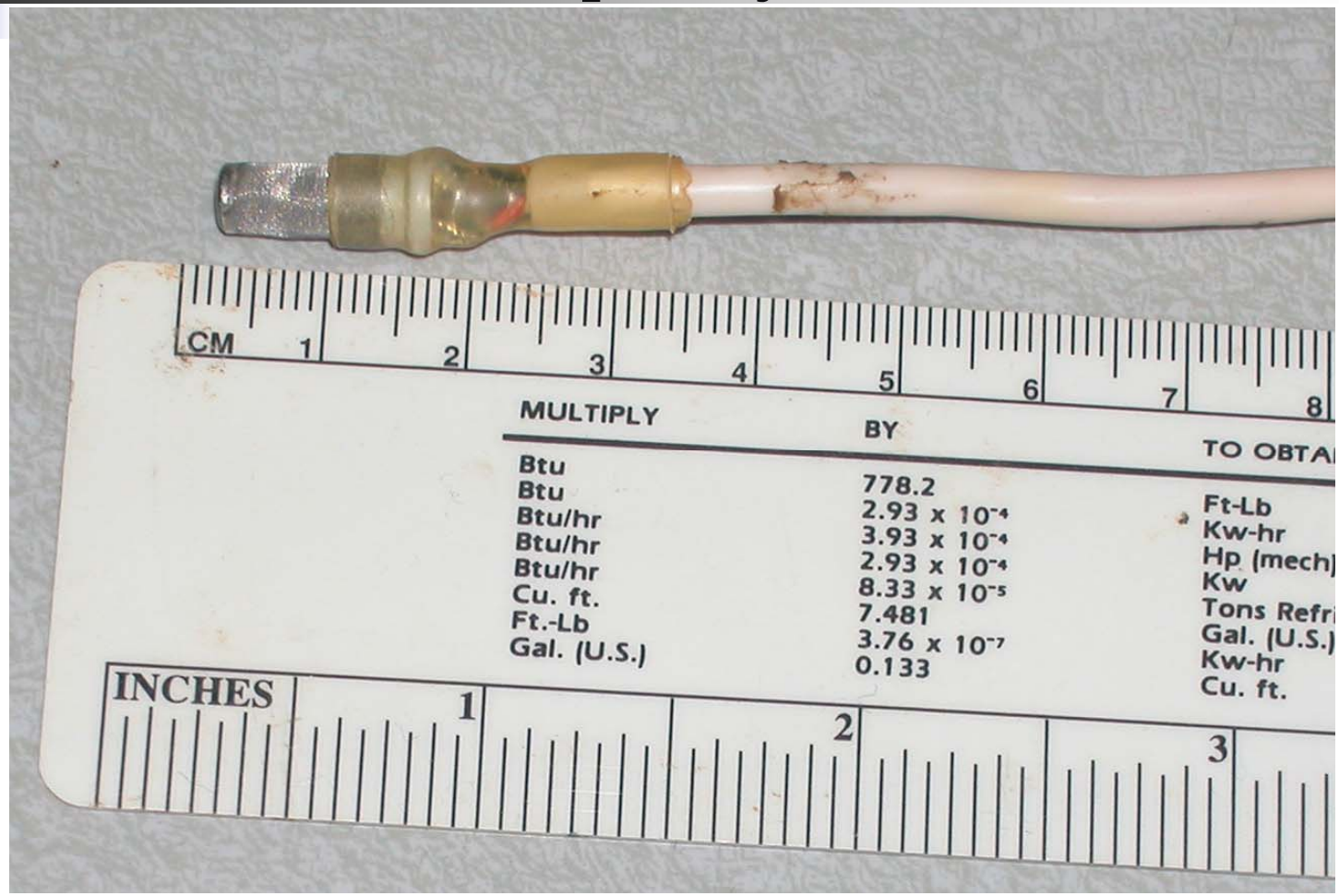
Laboratory Diffusion Test Setup

Laboratory Testing–Diffusion Coefficient

Temperature Control System

Laboratory Testing–Diffusion Coefficient

Thermocouple Psychrometer

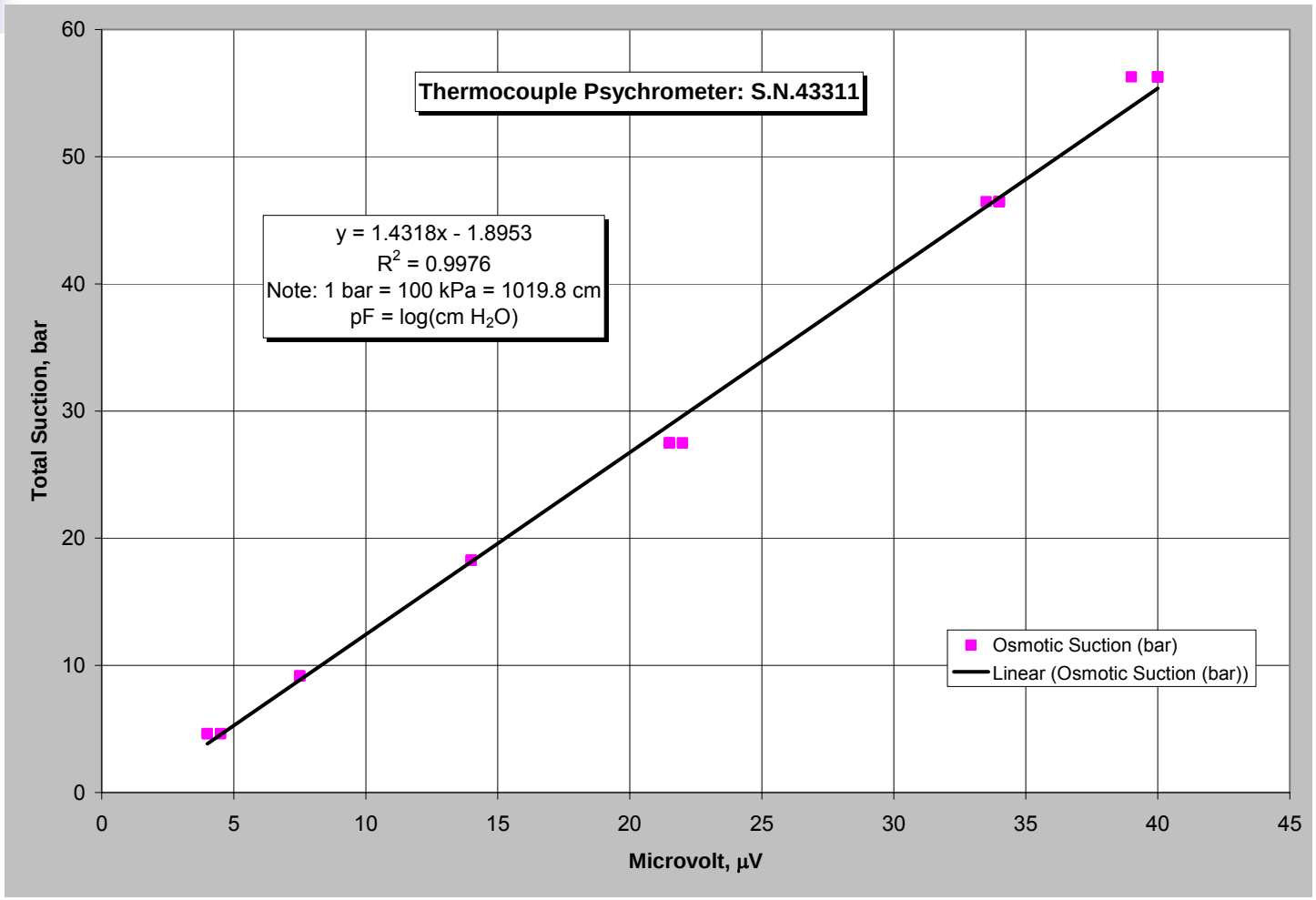


Laboratory Testing–Diffusion Coefficient

Psychrometer Calibration Solutions

Laboratory Testing–Diffusion Coefficient

Psychrometer Calibration Curve



Laboratory Testing–Diffusion Coefficient

Sling Psychrometer

Laboratory Testing–Diffusion Coefficient

Laboratory Testing–Diffusion Coefficient

CR 7 Datalogger

Laboratory Testing–Diffusion Coefficient

Laboratory Testing–Diffusion Coefficient

Laboratory Testing–Diffusion Coefficient

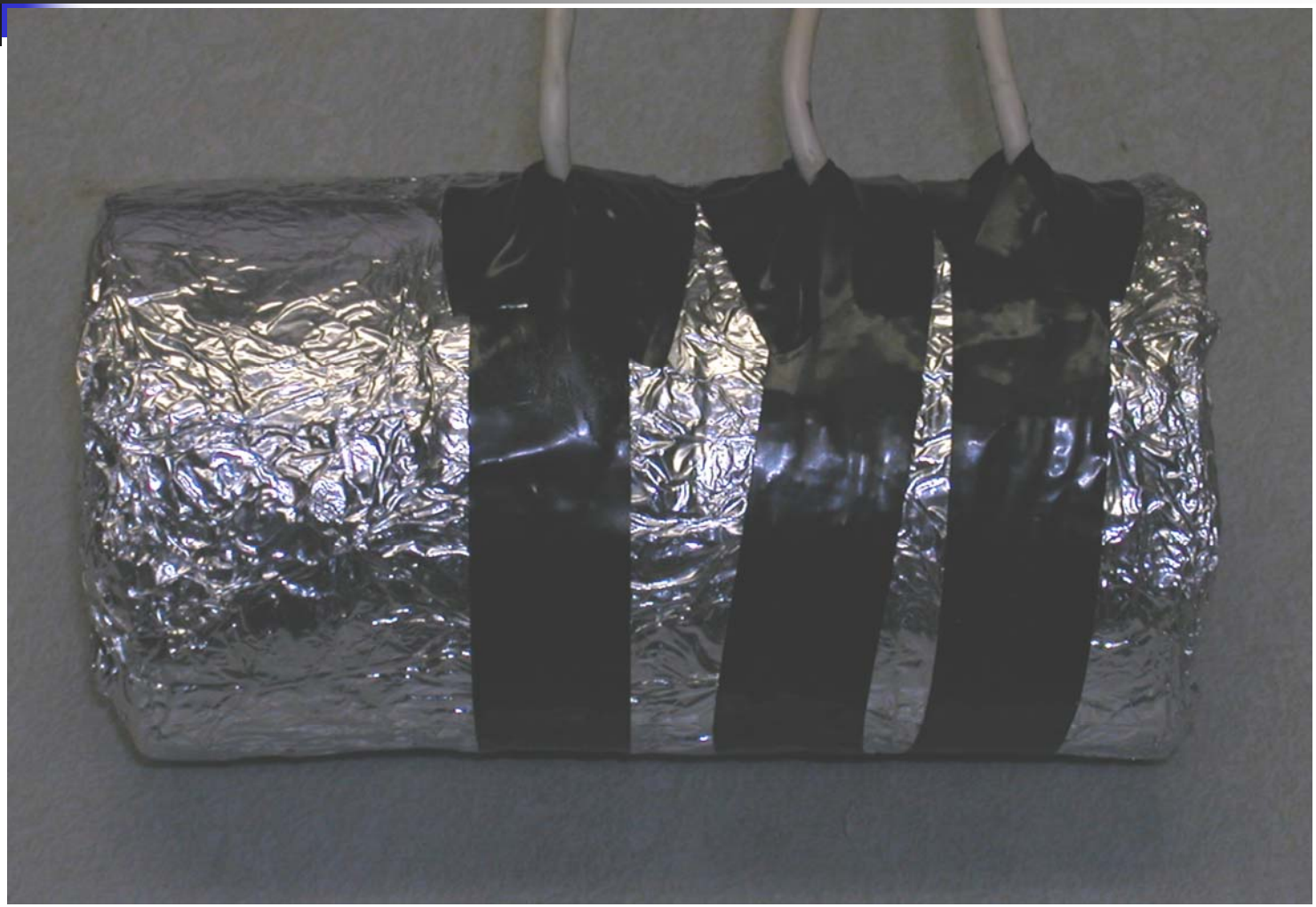
Laboratory Testing–Diffusion Coefficient

Laboratory Testing–Diffusion Coefficient

Laboratory Testing–Diffusion Coefficient

Laboratory Testing–Diffusion Coefficient

Laboratory Testing–Diffusion Coefficient



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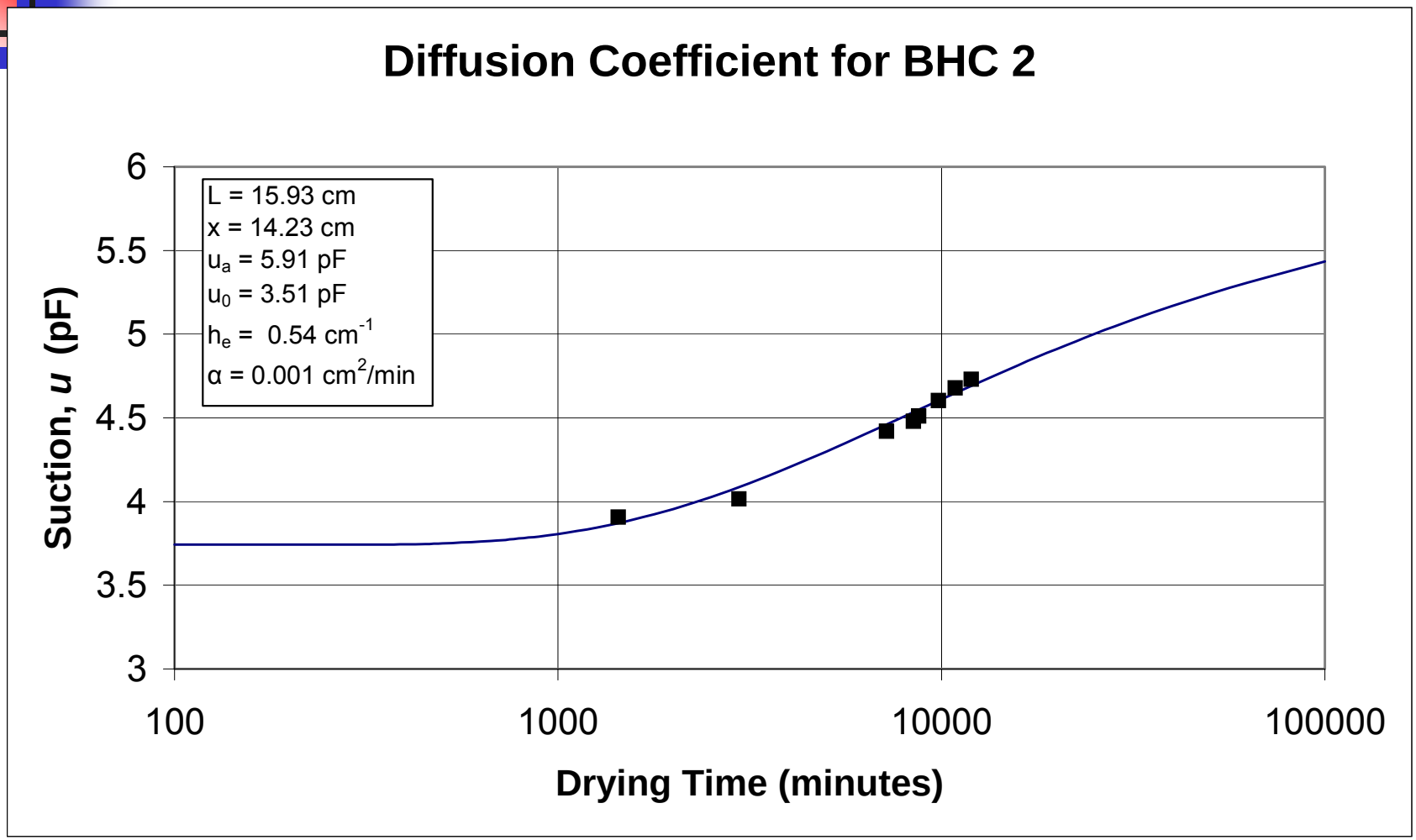


Laboratory Testing–Summary

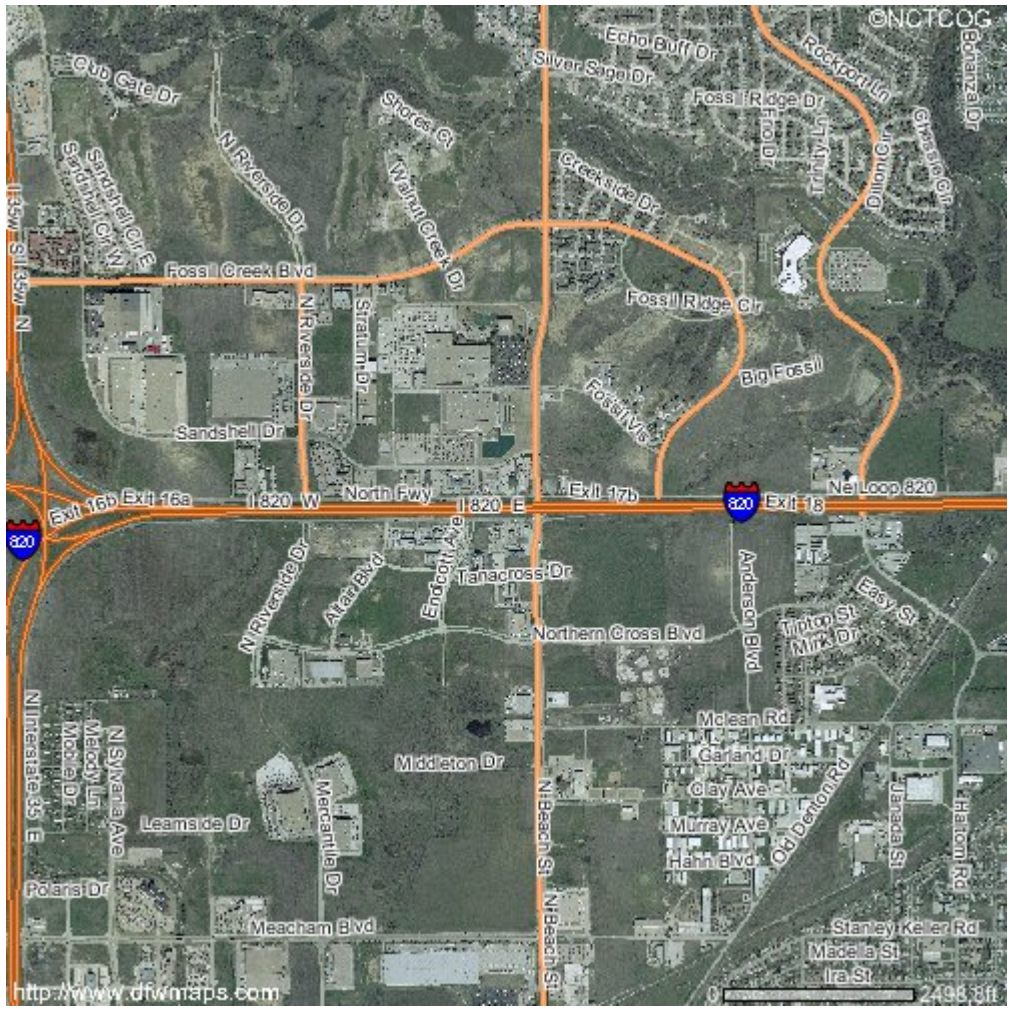
- Suction Measurements
  - Thermocouple Psychrometer
  - Filter Paper Method
- Diffusion Coefficient
- Atterberg Limits
- #200 Sieve
- -2 micron (Hydrometer Test)

TxDOT Case Studies

- ***Fort Worth District***
- ***Atlanta District***
- ***Austin District***

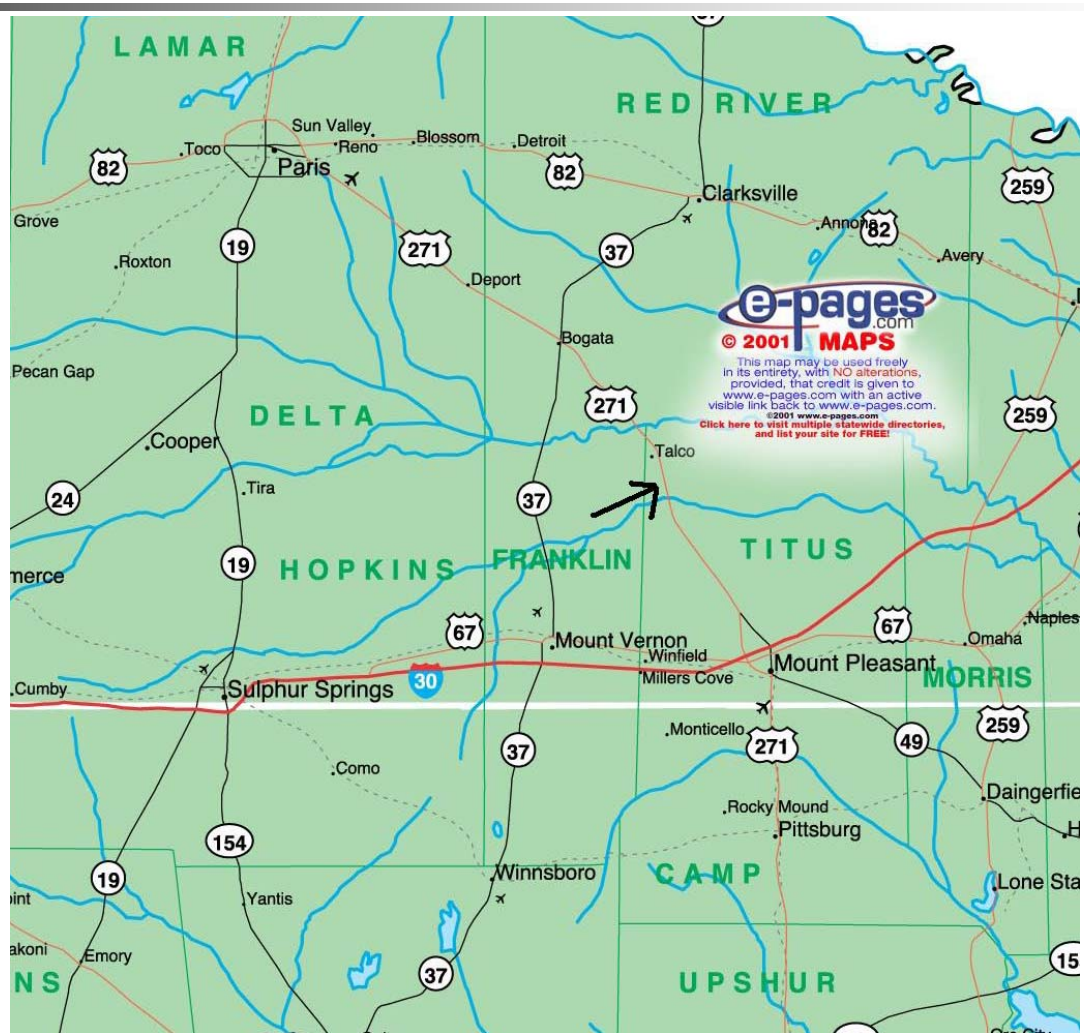
TxDOT Case Studies

Fort Worth District - North Loop 820



TxDOT Case Studies

Atlanta District - US 271



TxDOT Case Studies

Austin - Loop 360

TxDOT Case Studies

Index Properties

- **Atterberg Limits**
- **Clay Fraction (**Hydrometer analysis**)**
- **Fines Fraction (**Wet Sieve**)**

Suction

- **Initial**
- **Matric**

} From filter paper test

- **Water Content-Suction Curve**

(From filter paper test and pressure plate apparatus)

Moisture Diffusion Coefficient

- **Diffusion Test**

TxDOT Case Studies

Sample No.	Sample Depth (m)	Liquid Limit (%)	Plasticity Index (%)	Percent Fines (%)	Initial Total Suction (log kPa)	Atmospheric Total Suction (log kPa)	Laboratory Measurements α_{intact} (cm^2/sec)
1(A1)	3.35-3.66	45	22	84.2	2.38	5.06	5.90E-05
2(A5)	0.91-1.22	49	30	-	2.02	5.21	7.86E-05
3(B2)	3.35-3.66	53	32	-	2.30	4.93	9.66E-05
4(A1)	1.52-1.68	37	17	83.5	1.84	5.06	4.83E-05
5(C2)	2.74-3.35	37	15	89.9	2.43	4.76	13.1E-05
6(B1)	0.61-1.07	33	19	76.5	2.45	4.84	10.6E-05
7(B3)	2.89-3.35	50	29	95.9	2.77	4.76	4.66E-05

TxDOT Case Studies

Sample No.	Sample Depth (m)	Liquid Limit (%)	Plasticity Index (%)	Percent Fines (%)	Initial Total Suction (log kPa)	Laboratory Measurements α_{intact} (cm^2/sec)	Field Estimates α_{field} (cm^2/sec)
1(A3)	2.74-3.04	63	43	93.6	2.25	5.05E-05	3.67E-03
2(B4)	3.96-4.26	45	21	99.4	2.56	1.08E-05	3.90E-03
3(C1)	0.61-0.91	62	36	99.7	2.28	3.73E-05	3.49E-03
4(C5)	2.13-2.43	42	19	98.2	2.81	1.73E-05	4.01E-03
5(B1)	1.07-1.52	47	29	75.3	2.53	5.65E-05	4.11E-03
6(B2)	1.98-2.43	68	48	91.8	2.39	6.30E-05	3.69E-03
7(B2)	2.89-3.26	68	48	90.6	2.21	1.07E-04	3.82E-03
8(B3)	1.07-1.52	49	29	84.9	2.46	3.21E-05	4.05E-03

Subgrade Movements for the Pavement Design with Minimum Acceptable Predicted Performance, Austin, Loop 1

Case Study Location	Type of Pavement	Acceptable Pavement Design*	Movements at the Edge of Pavement (in)			Movements in outer Wheel Path (in)	PVR (in)	
			Swell	Shrink	Tot	Total	Edge	Outer+
Main Lanes	Flexible	ACP 4.0 in LTS 2.8 ft	0.78	0.66	1.44	0.93	2.40	1.93
	Rigid	CRCP 12.0 in LTS 2.0 ft	1.03	0.76	1.79	1.19	2.54	2.10
Frontage Road	Flexible	ACP 4.0 in LTS 2.0 ft Inert 2.0 ft	0.71	0.54	1.25	0.93	2.08	1.76
	Rigid	CRCP 11.0 in	2.03	1.00	3.03	2.28	2.97	2.37

Summary

- *Total movement controls the rate of increase in roughness*
- *Shrink prediction alerts the designer to longitudinal cracking*

Summary of Comparisons

PVR:

- **Over-predicts swell**
- **Neglects shrink**
- **Overly conservative designs**

IMPLEMENTATION

Three TxDOT Laboratories:

- **Dallas-Fort Worth**
- **Austin**
- **Bryan**

IMPLEMENTATION

- ✓ **Laboratory Testing Equipment**
  - **Filter Paper Method**
  - **Thermocouple Psychrometer**
  - **Transistor Psychrometer**

- ✓ **Training Courses**
  - **Computer Programs**
  - **Analysis and Design**

ACKNOWLEDGEMENTS!

- *Dr. Robert L. Lytton*
- *Dr. Charles P. Aubeny*
- *Ms. Xiaoyan Long*
- *Mr. Gyeong T. Hong*
- *Ms. Eeshani Sood*
- *Mr. Anshuman Thakur*

  and
- *TxDOT*

THANK YOU!

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