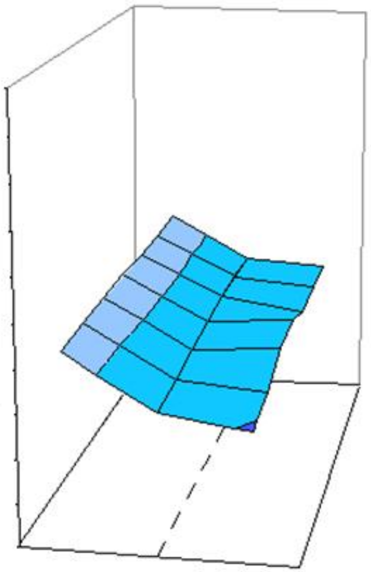


Automated Cross-Slope and Drainage Path Method

Presentation Outline:

- Contributing factors to Hydroplaning
- Traditional and Automated Survey Methods
- Multi-Purpose Survey Vehicle (MPSV) and Subsystems
- Automated Cross-Slope Analysis Program (ACAP)
- Field Validation
- Examples
- Conclusion

Factors that contribute to hydroplaning:

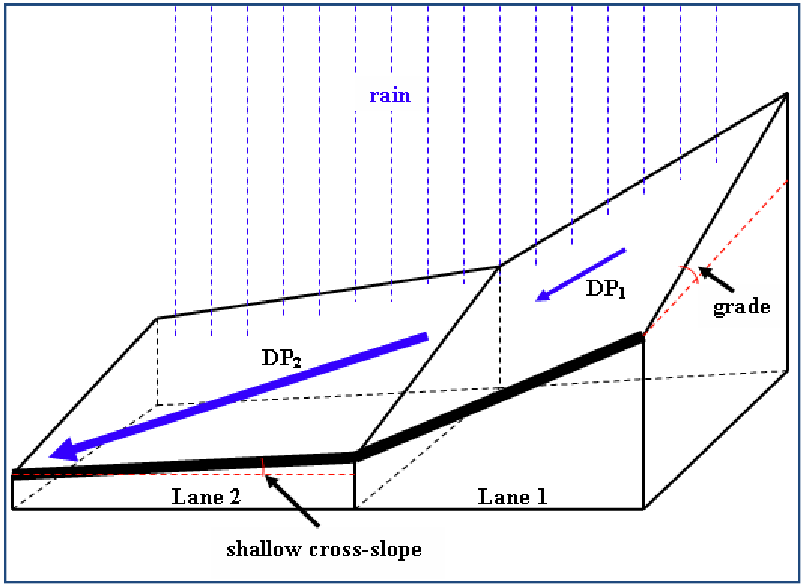
- Driver
- Vehicle
- Environment
- Pavement Surface (geometry, condition, drainage)

Pavement

- **Cross-slope**
  Facilitates/hampers drainage

- **Grade**
  Affects drainage path (DP)

- **Rutting**
  Increases water retention



Traditional Survey Methods

- Slow and labor intensive
- Expose crew to hazardous conditions
- Require traffic control
- Cause inconvenience to traveling public
- Costly

Automated Survey Methods

- Fast (highway speed)
- Safe (no traffic control required)
- Efficient
  (simultaneous data collection)
- Cost-Effective

Automated Cross-Slope and Drainage Path Method

- Multi-Purpose Survey Vehicle (MPSV) to collect pavement data, and
- Automated Cross-Slope Analysis Program (ACAP) to analyze data

Multi-Purpose Survey Vehicle (MPSV)

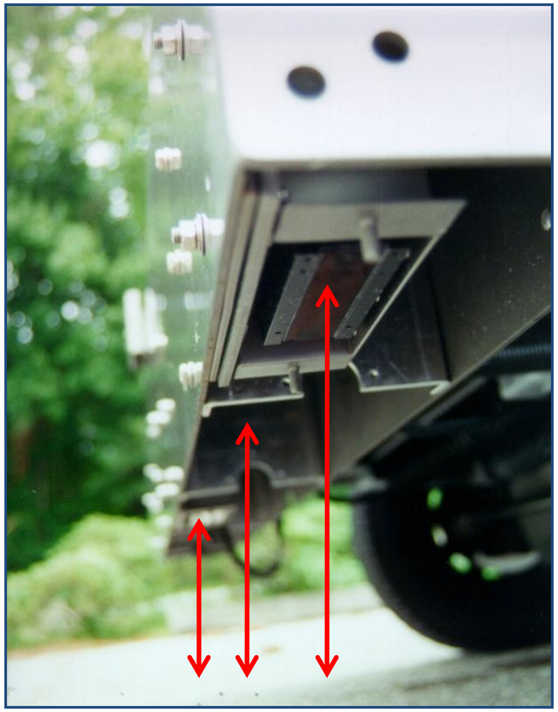
- Inertial Profiling System
- Position and Orientation System (POS)

Multi-Purpose Survey Vehicle (MPSV)

- **Inertial Profiling System**
- **Position and Orientation System (POS)**

Inertial Profiling System

- Three height laser sensors
- Two accelerometers
- Distance Measurement Indicator (DMI)
- Automatic Trigger System



Multi-Purpose Survey Vehicle (MPSV)

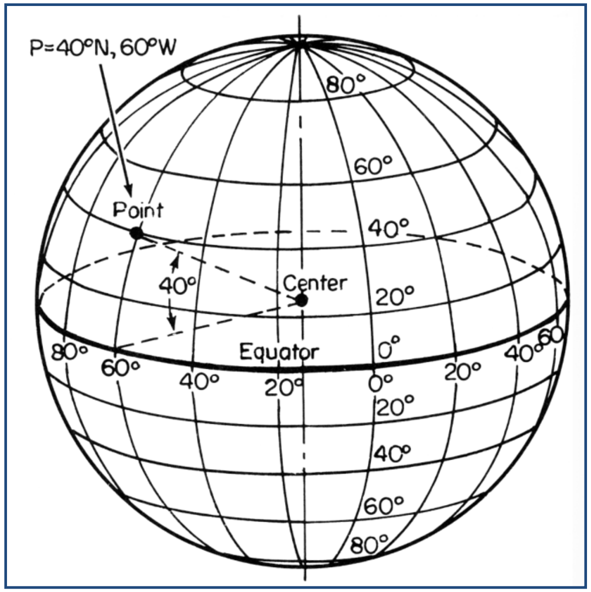
- Inertial Profiling System
- **Position and Orientation System (POS)**

Position and Orientation System (POS)

- Differential Global Positioning System (DGPS)
- Inertial Measurement Unit (IMU)
- Distance Measurement Indicator (DMI)
- POS Computer

Differential Global Position System (DGPS)

- Roof antennas
- Receiver (12 channel)
- Differential correction signal



Inertial Measurement Unit (IMU)

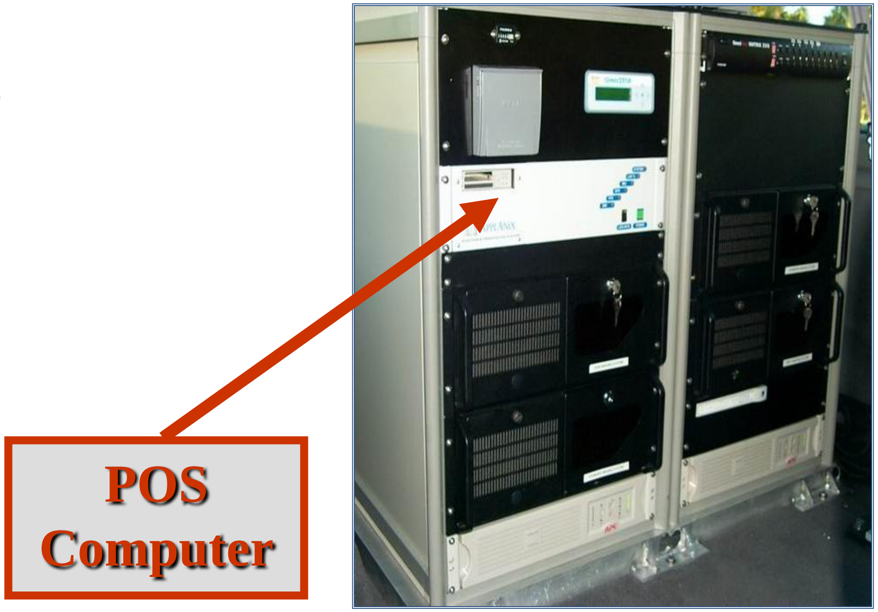
- Generates tilt, roll and yaw data
- 3 accelerometers
- 3 gyroscopes

Distance Measuring Indicator (DMI)

- **Linear distance referencing**

POS Computer

- Data storage and processing



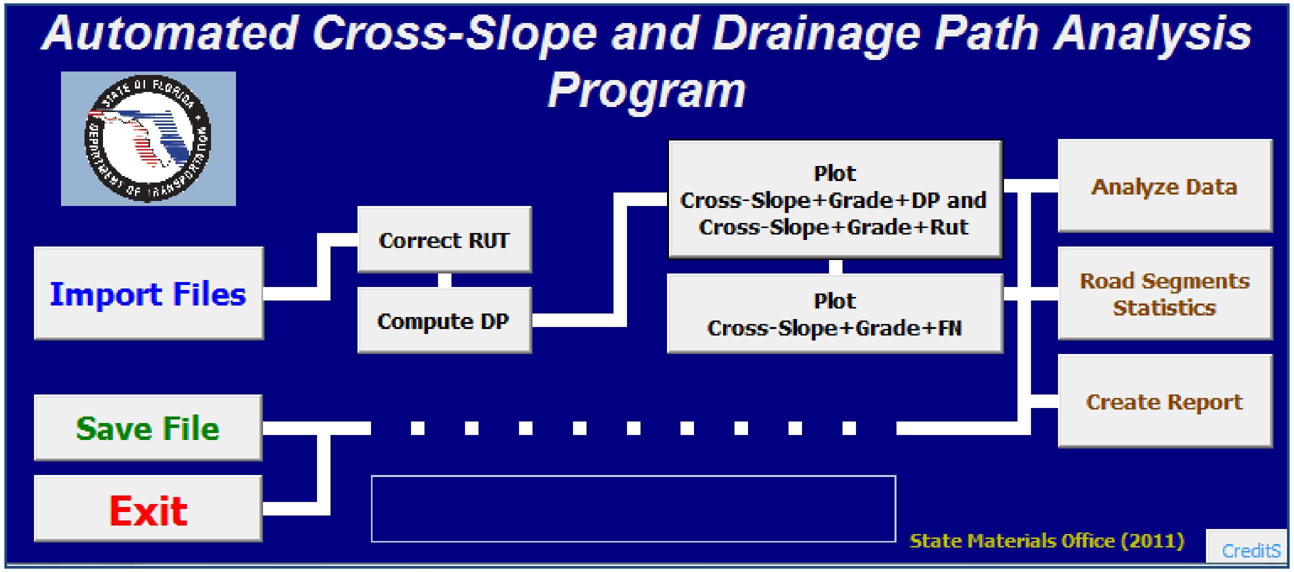
Input Data from MPSV

- Cross-Slope
- Grade
- Rutting
- Linear Reference (Distance)

Automated Cross-Slope Analysis Program (ACAP)

- Imports MPSV data (cross-slope, grade, rutting, distance)
- Calculates drainage path length
- Generates outputs (tabular and graphical)

Automated Cross-Slope Analysis Program (ACAP)



Drainage Path Length Calculation

$$DP^2 = (W_C^2)[1+(S_G/S_C)^2]$$ [1]

W_C = pavement width (ft)

S_G = grade (ft/ft)

S_C = cross-slope (ft/ft)

[1] **John C. Glennon: "Hydroplaning – The Trouble With Highway Cross-Slope" (January 2003)**

Automated Cross-Slope Analysis Program (ACAP) Text Report

REPORT

Road Number	72280	**Project Limit (Start)**	4.3
Road Name and County	SR-9, DUVAL Co	**Project Limit (End)**	2.3
Direction	Southbound	**Note**	0.01-mile interval reporting
FIN Number	213274-1-52-01	**Survey Date**	3/24/2010

Section: 2 (MP 3.95 to MP 3.2), L1, L2, and L3. L4 decceleration lane begins at MP 3.458 and ends at MP 3.358:

Super-Elevation.

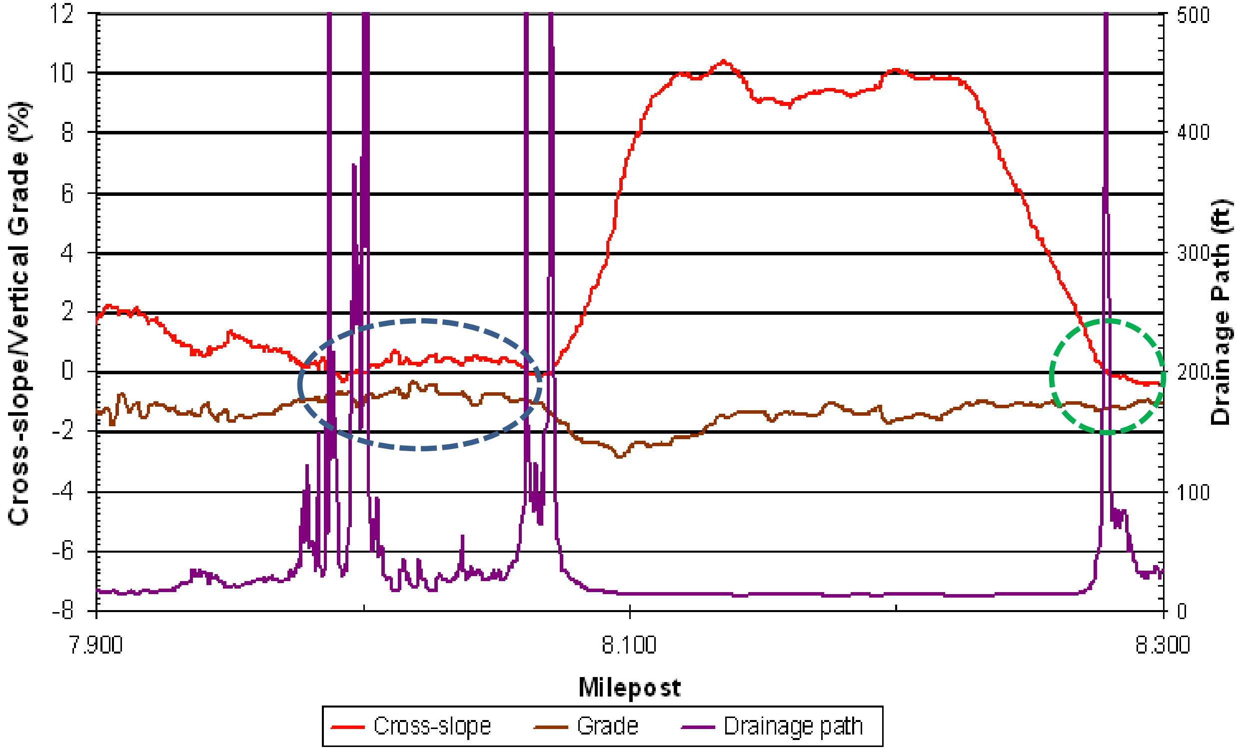
L1 Cross-slope: Min= -3.2 %, Max= 2.3 %, Mean= -2.1 %, St.Dev.= 1.4 %.
L1 Drainage Path: Min= 12 ft, Max= 1130.2 ft, Mean= 40 ft.
L1 Rutting: Min= 0.00 inch, Max= 0.21 inch, Mean= 0.13 in, St.Dev.= 0.05 in.
L2 Cross-slope: Min= -3.4 %, Max= 1.8 %, Mean= -2 %, St.Dev.= 1.23 %.
L2 Drainage Path: Min= 13.6 ft, Max= 1200.1 ft, Mean= 29.8 ft.
L2 Rutting: Min= 0.00 inch, Max= 0.37 inch, Mean= 0.21 in, St.Dev.= 0.05 in.
L3 Cross-slope: Min= -2.4 %, Max= 2.8 %, Mean= -1.1 %, St.Dev.= 0.93 %.
L3 Drainage Path: Min= 12 ft, Max= 1092.1 ft, Mean= 21.7 ft.
L3 Rutting: Min= 0.00 inch, Max= 0.3 inch, Mean= 0.18 in, St.Dev.= 0.07 in.
L4 Cross-slope: Min= 0.6 %, Max= 4.4 %, Mean= 3.2 %, St.Dev.= 1.02 %.
L4 Drainage Path: Min= 12.2 ft, Max= 29.2 ft, Mean= 13.4 ft.
L4 Rutting: Min= 0.07 inch, Max= 0.48 inch, Mean= 0.17 in, St.Dev.= 0.12 in.
L4 Average Vertical Grade= -1.1 %.

User Note: L3 lane is not fully superelevated (Cross-slope is between 1% and 2%). Rutting in all lanes is up to 0.25 inch with L2 up to 0.35 inch. Cross-slope in L3 steadily rises from 0.5% up to 6% and splits off L3 lane which has negative Cross-slope.

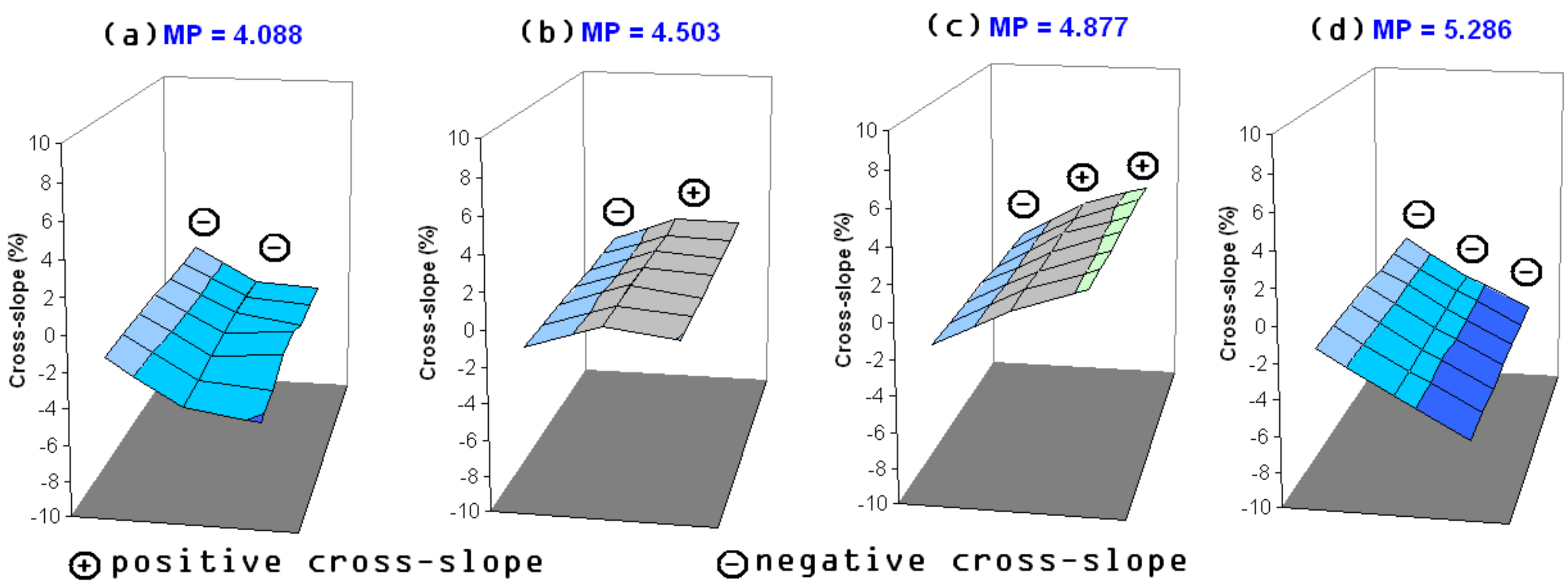
Automated Cross-Slope Analysis Program (ACAP) Tabular Output

Milepost (MP)		Cross-slope (%)	Longitudinal Grade (%)	Drainage Path (ft)
6.32		2.36	-2.37	17
6.33		2.62	-1.61	14
6.34		3.11	-0.87	12
6.35		3.29	-0.56	12
6.36		3.44	-0.51	12
6.37		2.74	-0.40	12
6.38		4.24	-1.22	12
6.39		3.34	-0.59	12
6.4		3.53	-1.03	13
6.41		2.93	-0.61	12
6.42		1.81	-0.45	12
6.43		2.80	-0.68	12
6.44		2.66	-0.89	13
6.45		2.97	-0.82	12
6.46		2.78	-0.94	13
6.47		3.10	-0.96	13
6.48		2.62	-0.79	13
6.49		3.50	-0.91	12

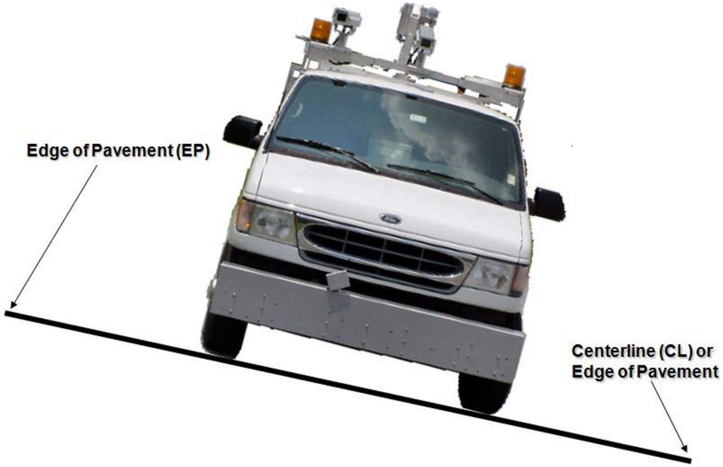
Automated Cross-Slope Analysis Program (ACAP) 2D Graphical Output



Automated Cross-Slope Analysis Program (ACAP) 3D Graphical Output (work in progress)

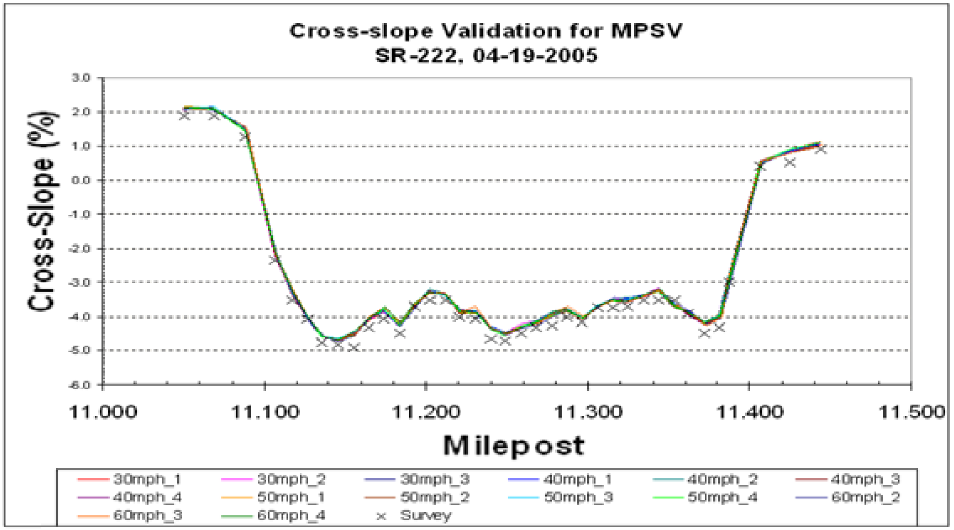


Field Validation



MPSV Cross-Slope Precision

- **Repeatability: 0.06%**
- **Accuracy: ± 0.13 %**



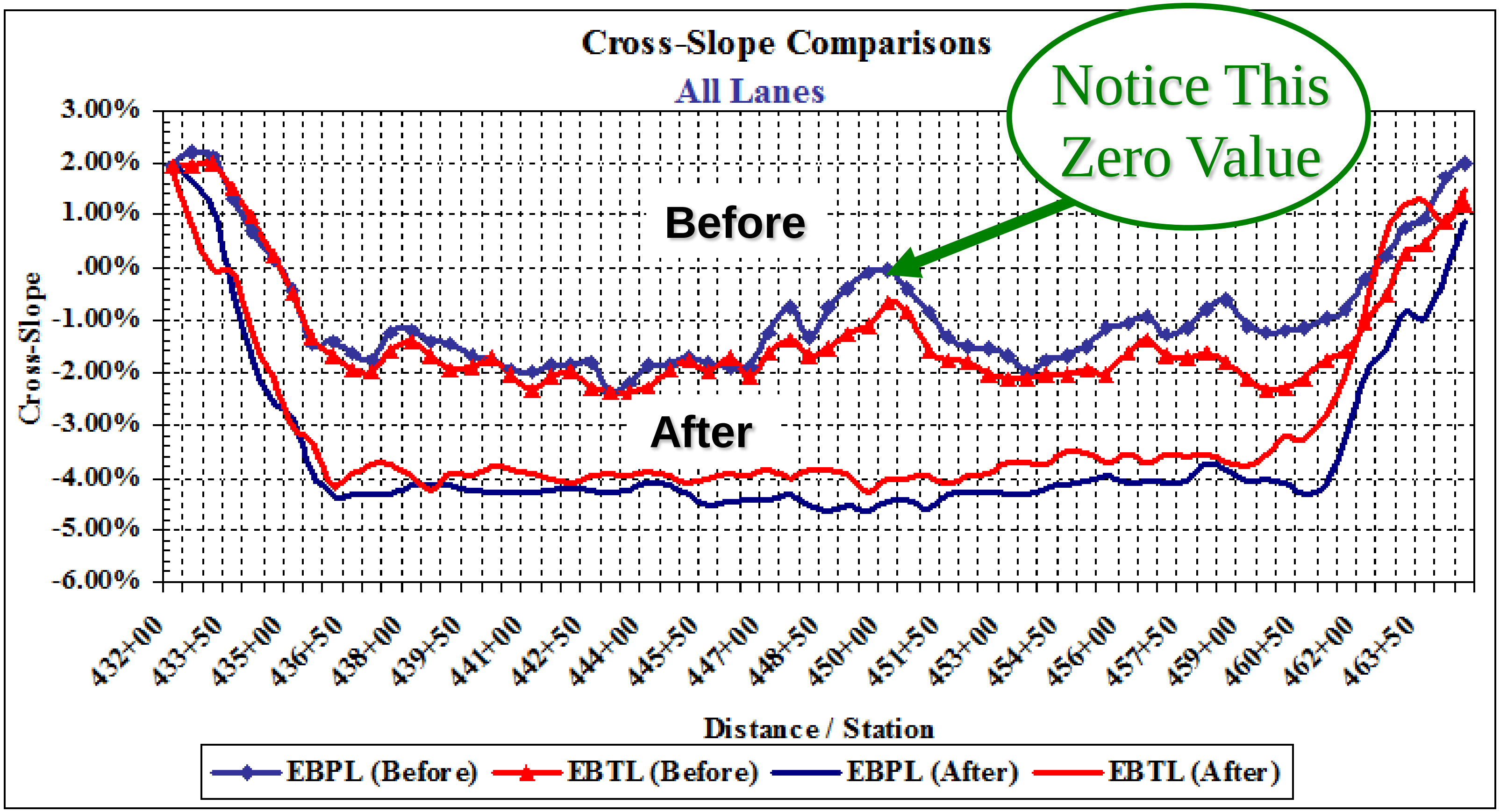
Case Example 1

Problem:

Shallow cross-slope within super elevation of interstate

Consequence:

Vehicle departures reported


Cross-Slope Comparisons
All Lanes
Notice This Zero Value
Before
After
3.00%
2.00%
1.00%
.00%
-1.00%
-2.00%
-3.00%
-4.00%
-5.00%
-6.00%
Cross-Slope
432+00
433+50
435+00
436+50
438+00
439+50
441+00
442+50
444+00
445+50
447+00
448+50
450+00
451+50
453+00
454+50
456+00
457+50
459+00
460+50
462+00
463+50
Distance / Station
EBPL (Before)
EBTL (Before)
EBPL (After)
EBTL (After)

Case Example 2

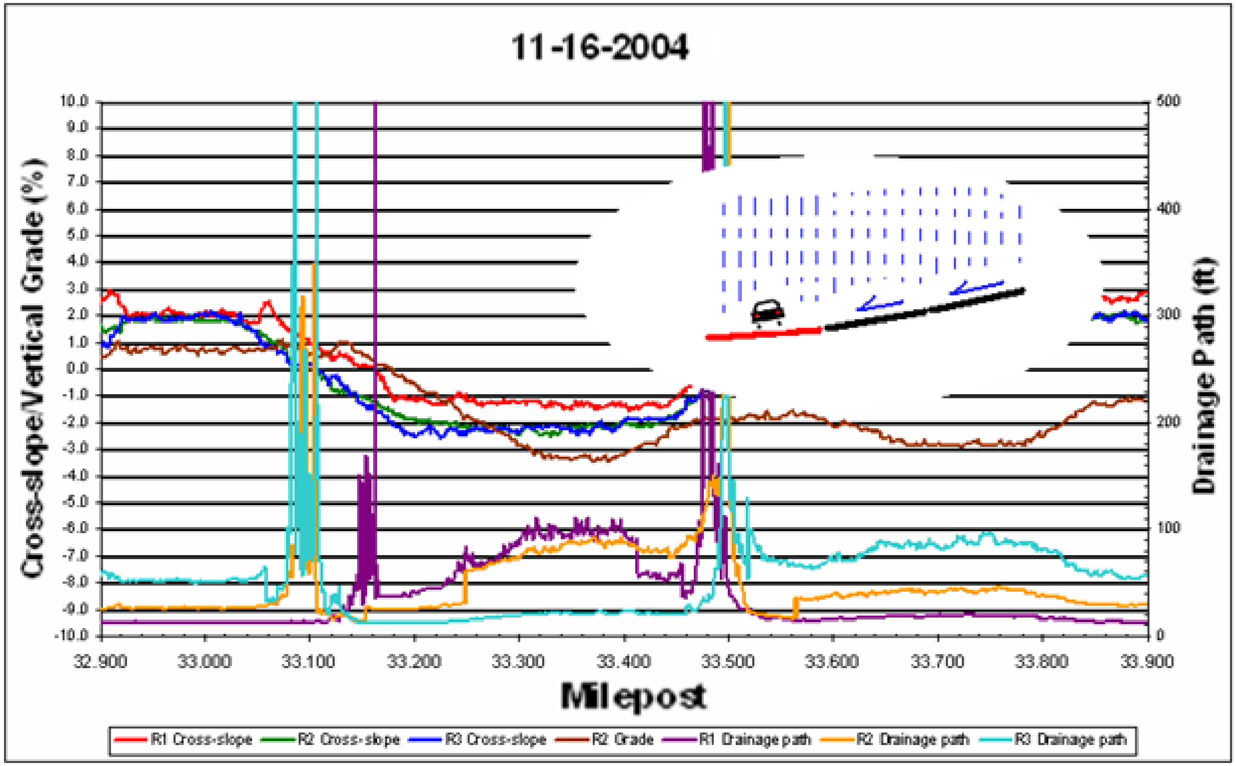
Problem:

Poor pavement drainage reported on 6-lane rural interstate

Consequence:

Roadway departures reported

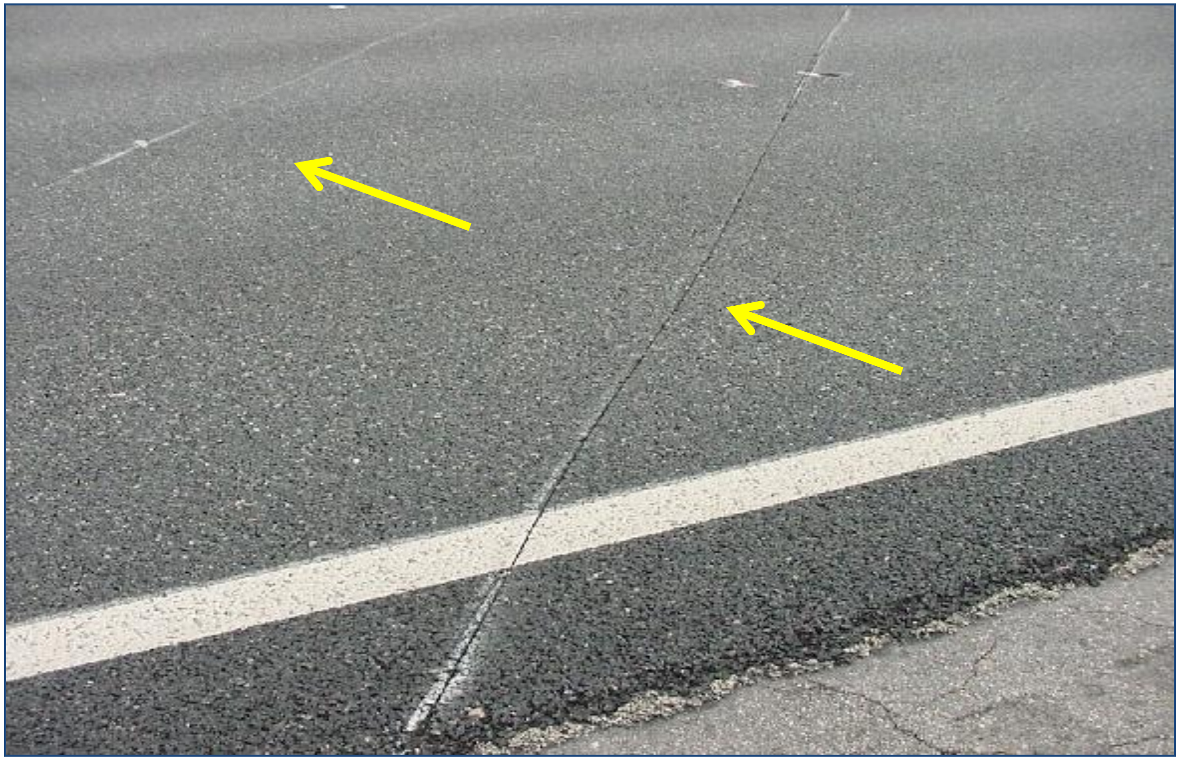
Before Corrective Action



Short-Term Preventive Action

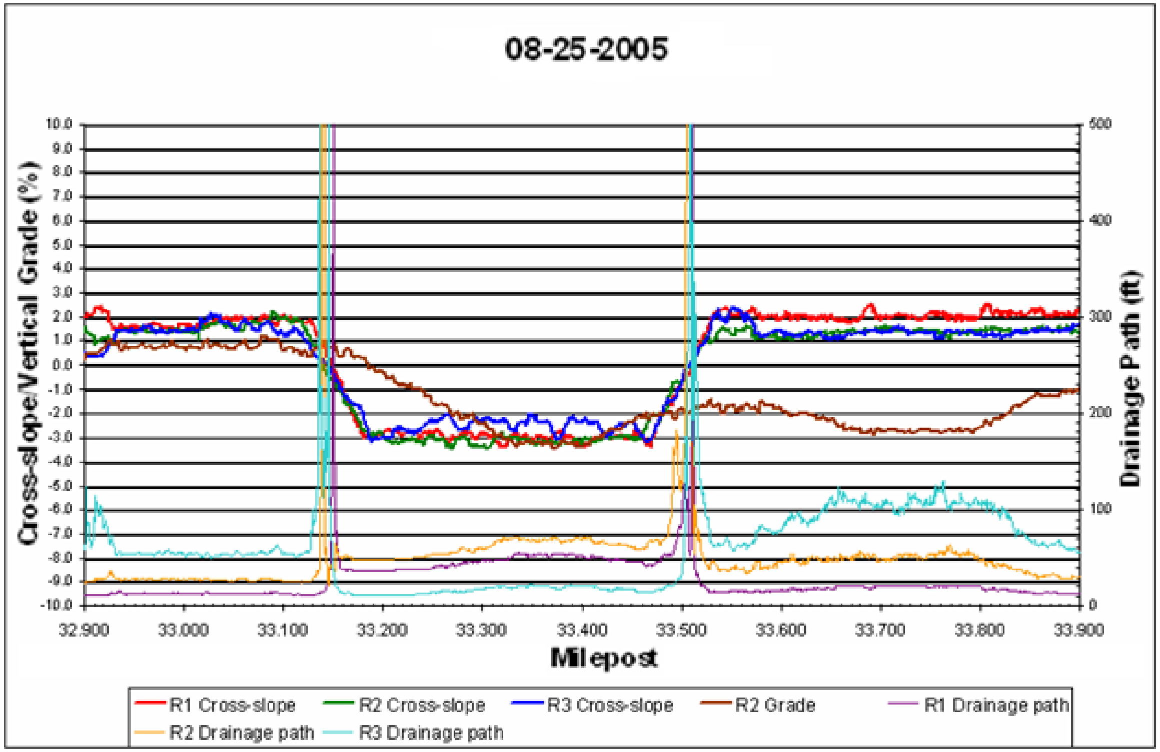
Short-Term Preventive Action

Short-Term Solution



Long-term Solution

- Milling
- Overbuild



Observations

- Substantial cross-slope improvement
- Smoother transition in and out of super-elevation
- Elimination of surface drainage problem
- No new roadway departures reported

Automated Cross-Slope and Drainage Path Method

- Identifies areas of pavement prone to hydroplaning
- For design, construction and safety projects
- Assists in developing short and long term solutions
- Safe, fast and very effective

Thank You !