

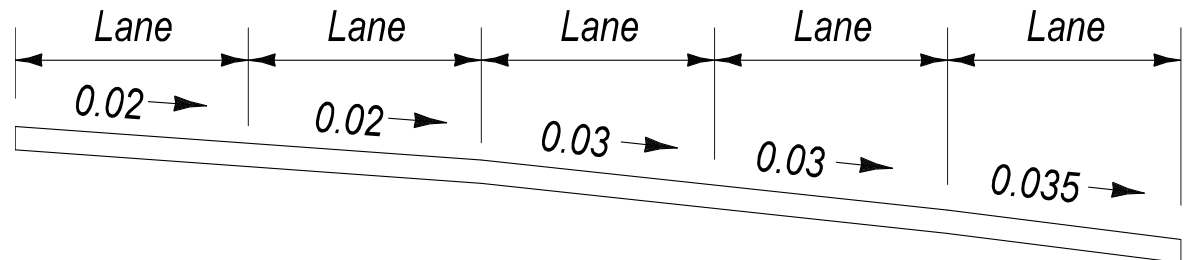
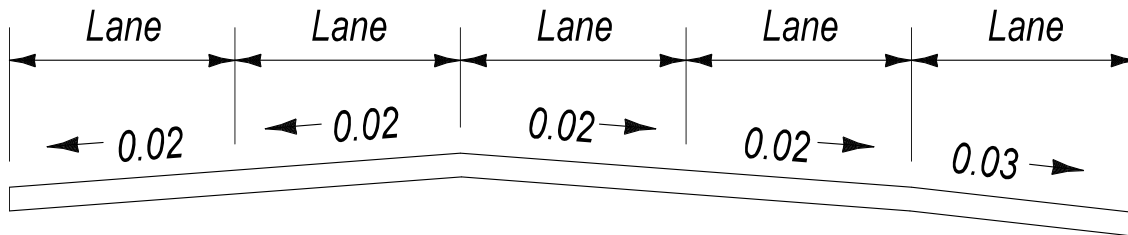
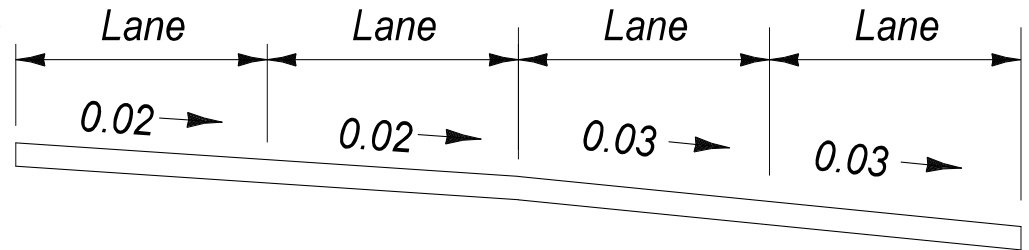
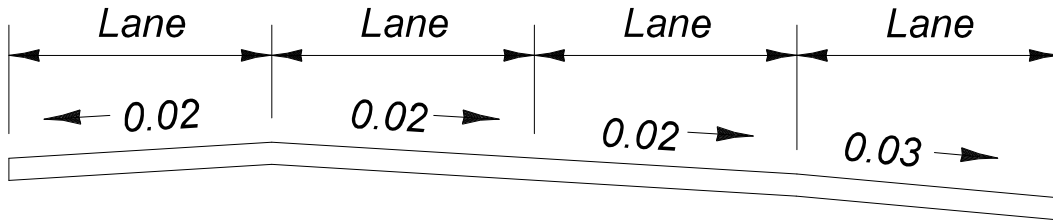
Analyzing Hydroplaning Potential on Wide Roadways



Catherine Earp, P.E.

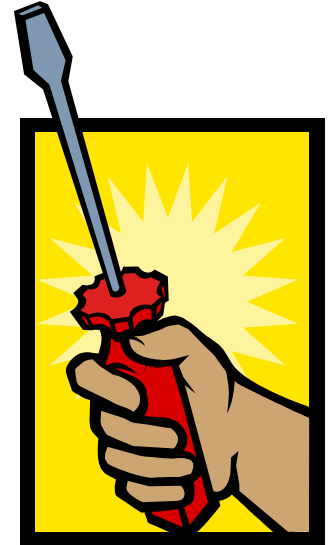
Rick Renna, P.E.

An Important Decision...



Hydroplaning Analysis Procedure

- ◆ NEW Design Guidance
- ◆ NEW Software Program
- ◆ NEW PPM Typical Sections



Elements of Hydroplaning Risk

Predicted
Hydroplaning
Speed

Expected
Driver
Speed



Rain
Pavement
Water Film Thickness

Design Speed
Driver Reaction

HP: Hydroplaning Speed Prediction Tool

- ◆ DOT & USF collaborated on Window-friendly program HP
- ◆ Predicts speed at which hydroplaning *could* occur.

HP

Rainfall Intensity in/h

Lane Geometry

Number of Planes 1

Longitudinal Slope 0 %

Plane #	CS Slope %	Pav. Width

Pavement Surf. Mat.

DGAC

OGFC

PCC

MTD mm

Permeability (k) 0 in/h

Manning's n Calculation

Pavement Temperature 32 F

Kinematic Viscosity (10⁻³)

Reynold's number

Calculate Manning's n value

Manning's Value

Calculate Water Film Thickness

Galloway Eq inches

RRL Eq inches

NZ modified Mannings Eq inches

PAVDRN (SI) Eq inches

Selection Criteria for Hydroplaning Speed

Galloway Eq RRL (UK) Eq NZ mod. Mannings Eq PAVDRN (SI) Eq Max. Min.

WFT (selected) mm

Tire Pressure 15 psi

Wheel Load 2100 N

Calculate Hydroplaning Speed

PAVDRN Eq mph

USF Eq mph

Galloway Eq mph

WFT Variation

Highest WFT plot

Results Summary

Exit

HP: User Defined Inputs

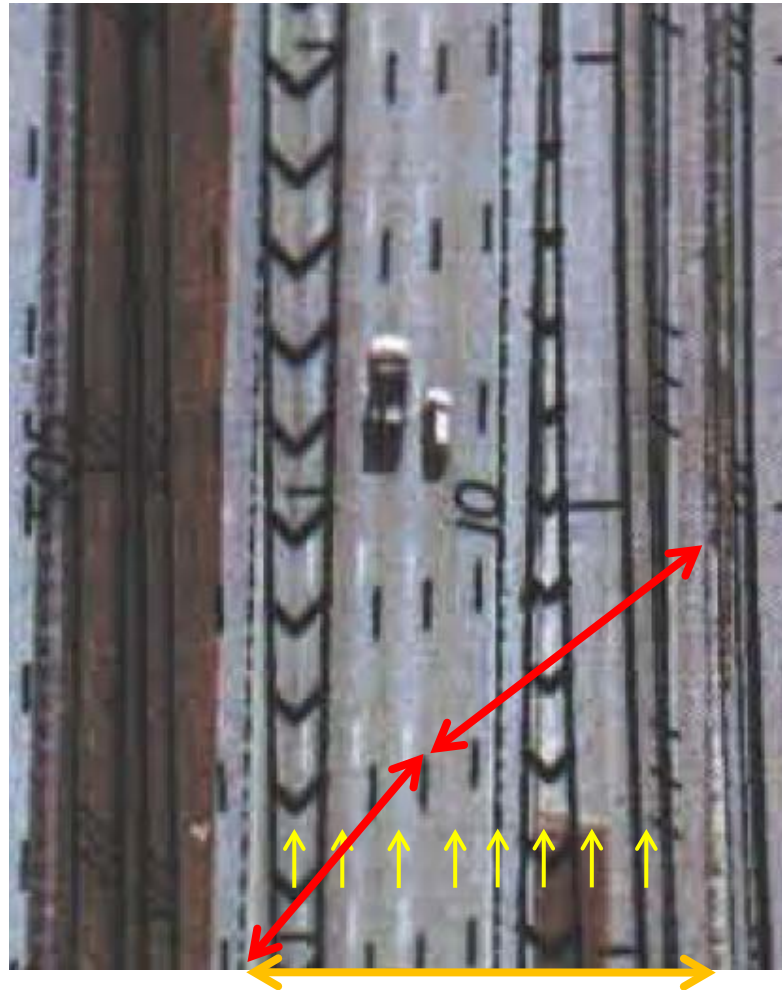
The screenshot shows the HP software interface with the following sections:

- Rainfall Intensity:** A text input field followed by "in/h".
- Lane Geometry:**
 - Number of Lanes:** A dropdown menu showing "1".
 - Longitudinal Slope:** A text input field followed by "%".
 - Table:** A table with 3 columns: LN, CS Slope %, and Pav. Width. It contains 4 empty rows.
- Pavement Surf. Mat.:**
 - Three radio buttons: DGAC, OGFC, and PCC.
 - MTD:** A text input field followed by "mm".
- Manning's n Calculation:**
 - Pavement Temperature:** A dropdown menu showing "32" followed by "F".
 - Kinematic Viscosity:** A text input field.
 - Reynold's number:** A text input field.
 - Calculate Manning's n value:** A button.
 - Manning's Value:** A text input field.
- Bottom Section:** Three text input fields followed by "mph", and four buttons: WFT Variation, Highest WFT plot, Results Summary, and Exit.

◆ Lane Width

Longitudinal Slope

- WFT Increases Along Flow Path
- Greater upstream contributing area
- Increase $S_L =$
Increase WFT



HP: Water Film Thickness

- ◆ Calculates the WFT using four different empirical formulas

HP

Rainfall Intensity in/h

Lane Geometry

Number of Planes

Longitudinal Slope %

Plane #	CS Slope %	Pav. Width

Pavement Surf. Mat.

DGAC

OGFC

PCC

MTD mm

Permeability (k) in/h

Manning's n Calculation

Pavement Temperature F

Kinematic Viscosity (10^{-3})

Reynold's number

Manning's Value

Gallaway Eq inches

RRL Eq inches

NZ modified Manings Eq inches

PAVDRN (SI) Eq inches

Selection Criteria for Hydroplaning Speed

Gallaway Eq RRL (UK) Eq NZ mod. Manings Eq PAVDRN (SI) Eq Max. Min.

WFT selected mm

Tire Pressure psi

Wheel Load N

HP: Hydroplaning Speed

- ◆ Calculates the Hydroplaning Speed using three different empirical formulas

The screenshot shows the HP software interface with the following fields and options:

- Rainfall Intensity: in/h
- Lane Geometry: Number of Planes: ; Longitudinal Slope: %
- Table:

Plane #	CS Slope %	Pav. Width
- Pavement Surf. Mat.: DGAC, OGFC, PCC
- MTD: mm
- Permeability (k): in/h
- Manning's n Calculation: Pavement Temperature: F; Kinematic Viscosity (10⁻³): ; Reynold's number: ; Calculate Manning's n value: ; Manning's Value:

Calculate Hydroplaning Speed

PAVDRN (SI) Eq

mph

USF

mph

TxDOT Eq

mph

Highest WFT plot

WFT Variation

Results Summary

Exit

Which Equations Should I Use?

- ◆ USF - Relative Accuracies with Relation to Florida's Wet Weather Crash Data
- ◆ Florida's 1,347 Miles of Interstate System
- ◆ CARS, PCS, GIS, VPD & Police Reports; 2006-2011
- ◆ National Climactic Data Centre (NCDC)

WFT: Galloway Equation

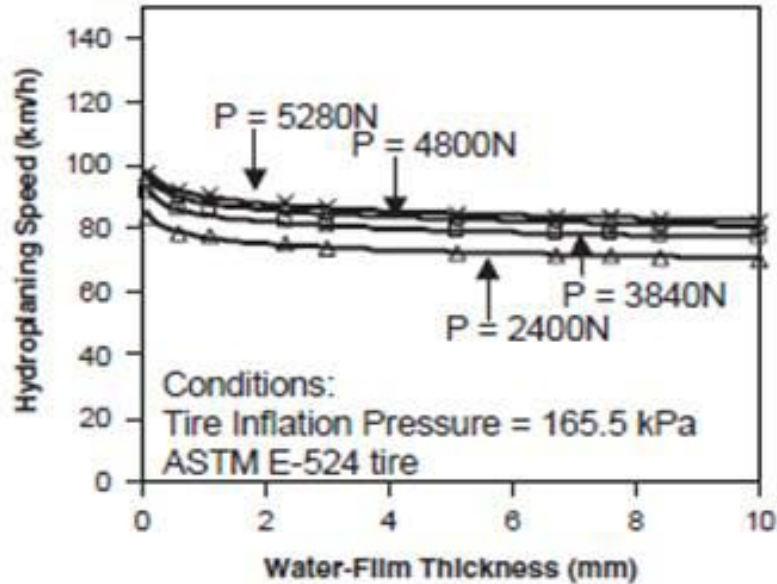
Hydroplaning Speed: PAVDRN

Assumptions

- ◆ PAVDRN Developed Through Testing
- ◆ Empirically Derived Formula
- ◆ ASTM E-524 Standard Tire Testing
 - ✓ Tire Pressure = 24 psi
 - ✓ Wheel Load = 4800 N
- ◆ Tire Tread Depth = 3/32 inches (TWI = 2/32")

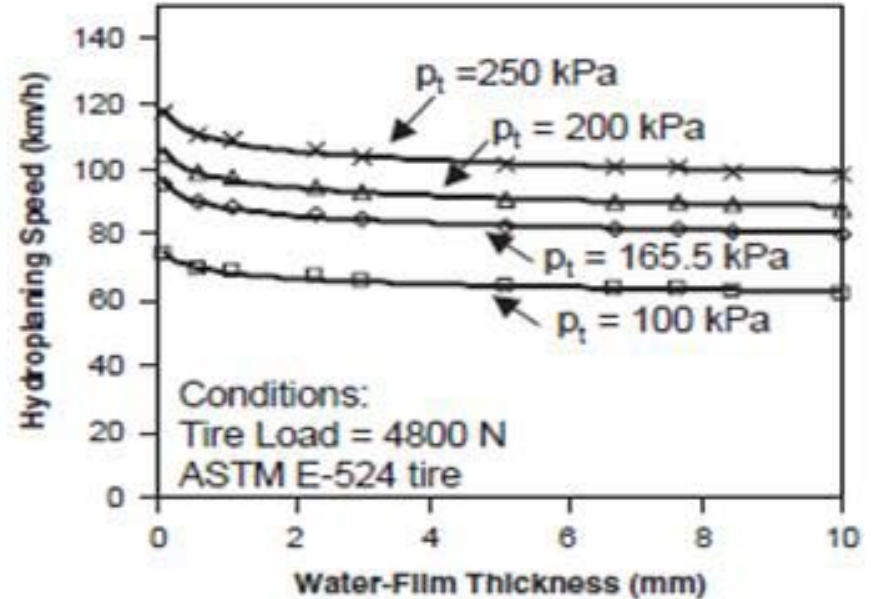
Hydroplaning Speeds Vary

Wheel Load



(a)

Tire Pressure



(b)

Analyzing the HP Results

- ◆ Gulf Coast University - *Evaluation of Driver Behavior to Hydroplaning in the State of Florida Using Drive Simulation*
 - ✓ PatrolSim: Driving Simulator at UCF
 - ✓ Driver Age, Gender

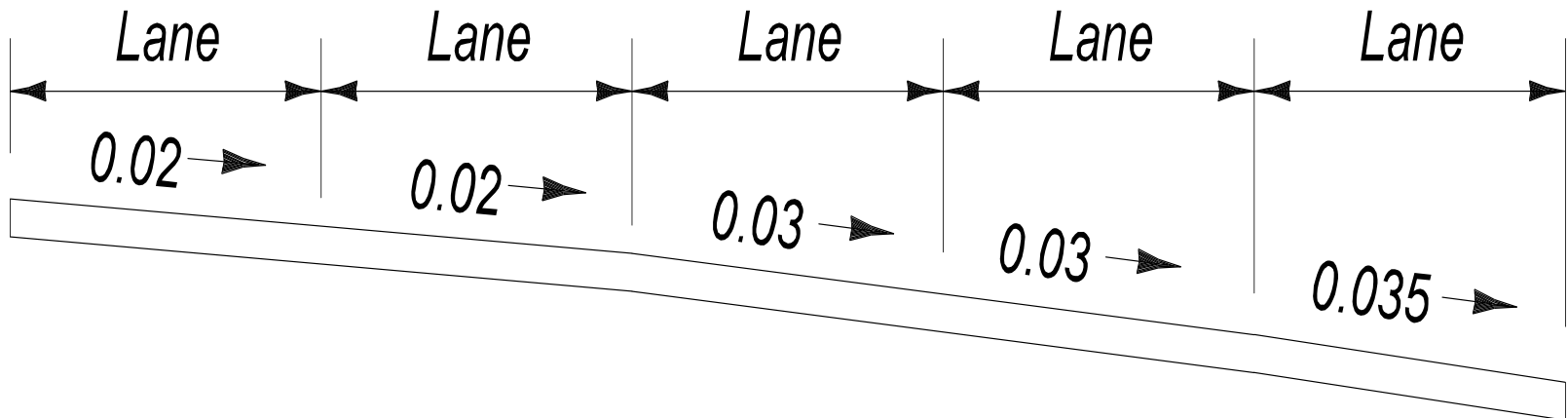
- ✓ Light rain (0.1-0.24in/hr) did not affect driver speed
- ✓ Heavy rain (+0.24in/hr) reduced speed by 6-12mph

Predicted Driver Response

<u>Intensity (in/hr)</u>	<u>Predicted Speed Reduction (mph)</u>	<u>Predicted Driver Speed (mph)</u>
0.1	0	Design Speed
0.25	0	Design Speed
0.5	6	Design Speed - 6
1.0	8	Design Speed - 8
2.0	12	Design Speed - 12
3.0	<i>below hydroplaning speed</i>	
4.0	<i>below hydroplaning speed</i>	

Example

- ◆ Design Speed = 60mph
- ◆ Longitudinal Slope = 5%
- ◆ Open graded friction course



Potential Hydroplaning Speed: Example

Design Speed = 60 mph

Cross Slope	0.02	0.02	0.02	0.03	0.03	0.035	Predicted Driver Speed
Rainfall Intensity <i>i</i> (in/hr)	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	
0.10	--					100 (n/a)	60
0.25	--					100 (n/a)	60
0.50	--					100 (n/a)	54
1.00	--					70	52
2.00	--					54	48
3.00	--					48	45
4.00	--					52	45

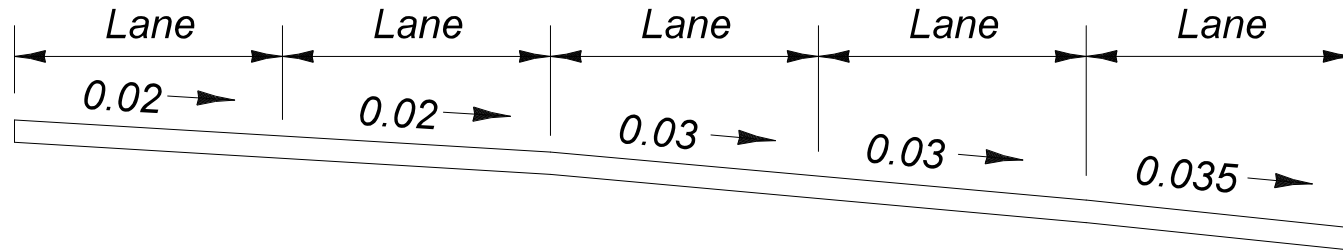
Potential Hydroplaning Speed: Example

Design Speed = 70 mph

Cross Slope	0.02	0.02	0.02	0.03	0.03	0.035	Predicted Driver Speed
Rainfall Intensity <i>i</i> (in/hr)	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	
0.10	--					100 (n/a)	70
0.25	--					100 (n/a)	70
0.50	--					100 (n/a)	64
1.00	--					70	62
2.00	--					54	58
3.00	--					48	45
4.00	--					52	45

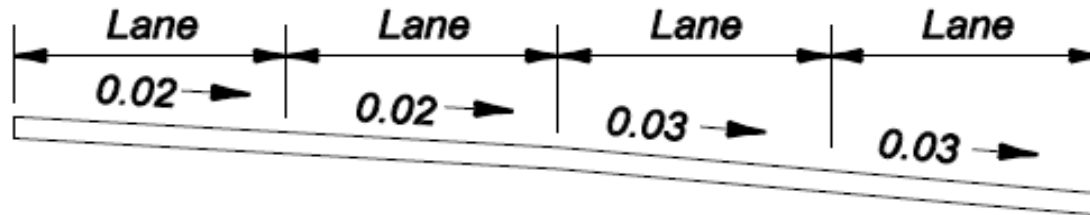
Potential Hydroplaning Speed: Example

Design Speed = 65 mph



Cross Slope	0.02	0.02	0.02	0.03	0.03	0.035	Predicted Driver Speed
Rainfall Intensity i (in/hr)	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	
0.10	--					100 (n/a)	65
0.25	--					100 (n/a)	65
0.50	--					100 (n/a)	59
1.00	--					70	57
2.00	--					54	53
3.00	--					48	45
4.00	--					52	45

PPM Typical Section: Design Speed = 70 mph

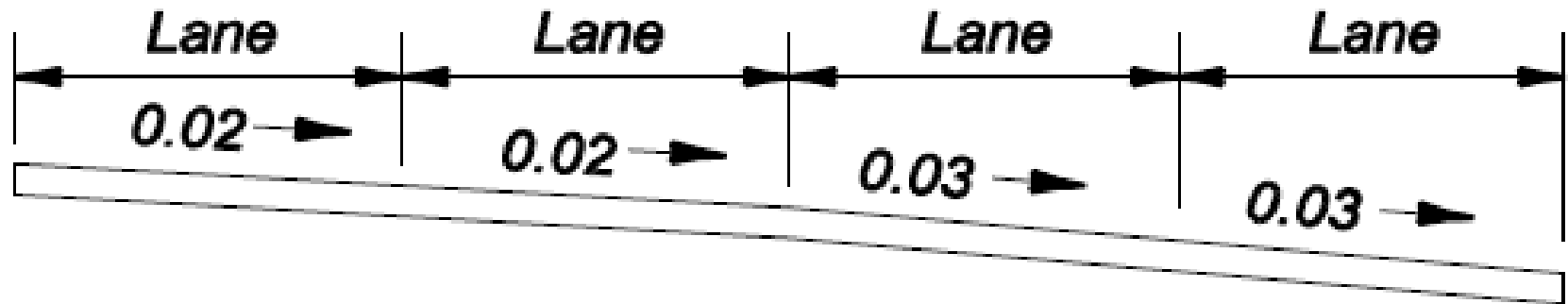


Cross Slope	0.02	0.02	0.02	0.03	0.03	Predicted Driver Speed
Rainfall Intensity <i>i</i> (in/hr)	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	
0.10	--				100 (n/a)	70
0.25	--				100 (n/a)	70
0.50	--				100 (n/a)	64
1.00	--				73	62
2.00	--				55	58
3.00	--				49	45
4.00	--				52	45

PPM Typical Section Modification

Design Speed ≤ 65 MPH

Longitudinal Slope $\leq 5\%$



Web Links:

- ◆ Roadway Design Bulletin

<http://www.dot.state.fl.us/rddesign/Bulletin/Default.shtm>

- ◆ Hydroplaning Tools

<http://www.dot.state.fl.us/rddesign/Drainage/ManualsandHandbooks.shtm>

QUESTIONS?

