Florida Department of
TRANSPORTATION

Hydroplaning Analysis

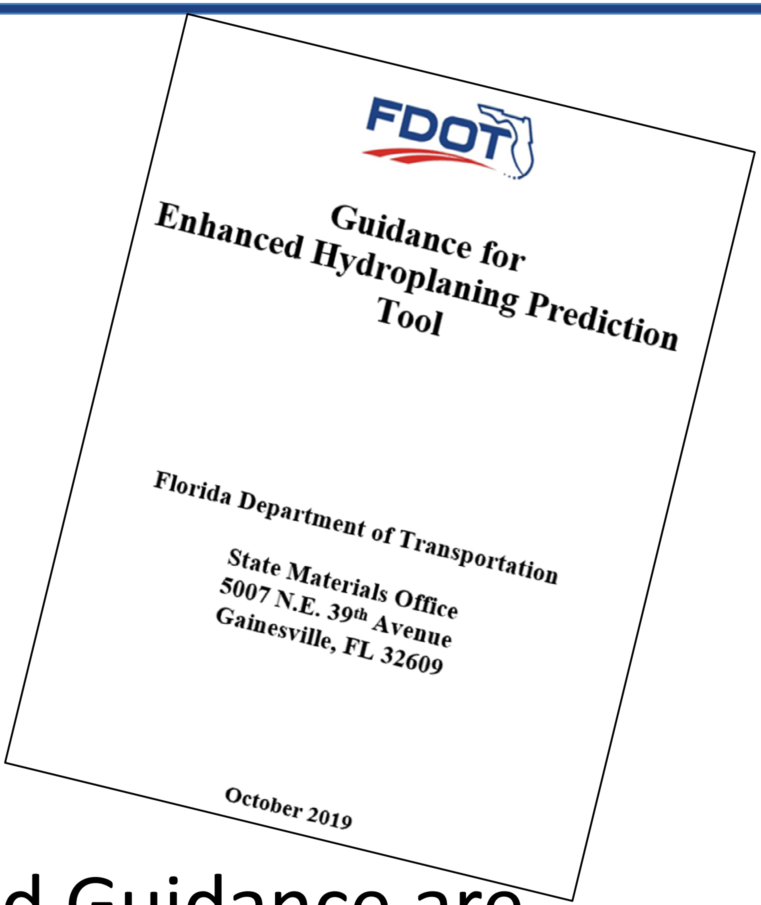
Computer Based Training Course

Outline

- Introduction
- Learning Objectives
- Hydroplaning Fundamentals
- Factors Affecting Hydroplaning
- Hydroplaning Prediction
- FDOT Hydroplaning Prediction Tool

FDOT Hydroplaning Guidance

- Quick reference document for those that will be using FDOT's new Hydroplaning Prediction Tool



Guidance for
Enhanced Hydroplaning Prediction
Tool

Florida Department of Transportation

State Materials Office
5007 N.E. 39th Avenue
Gainesville, FL 32609

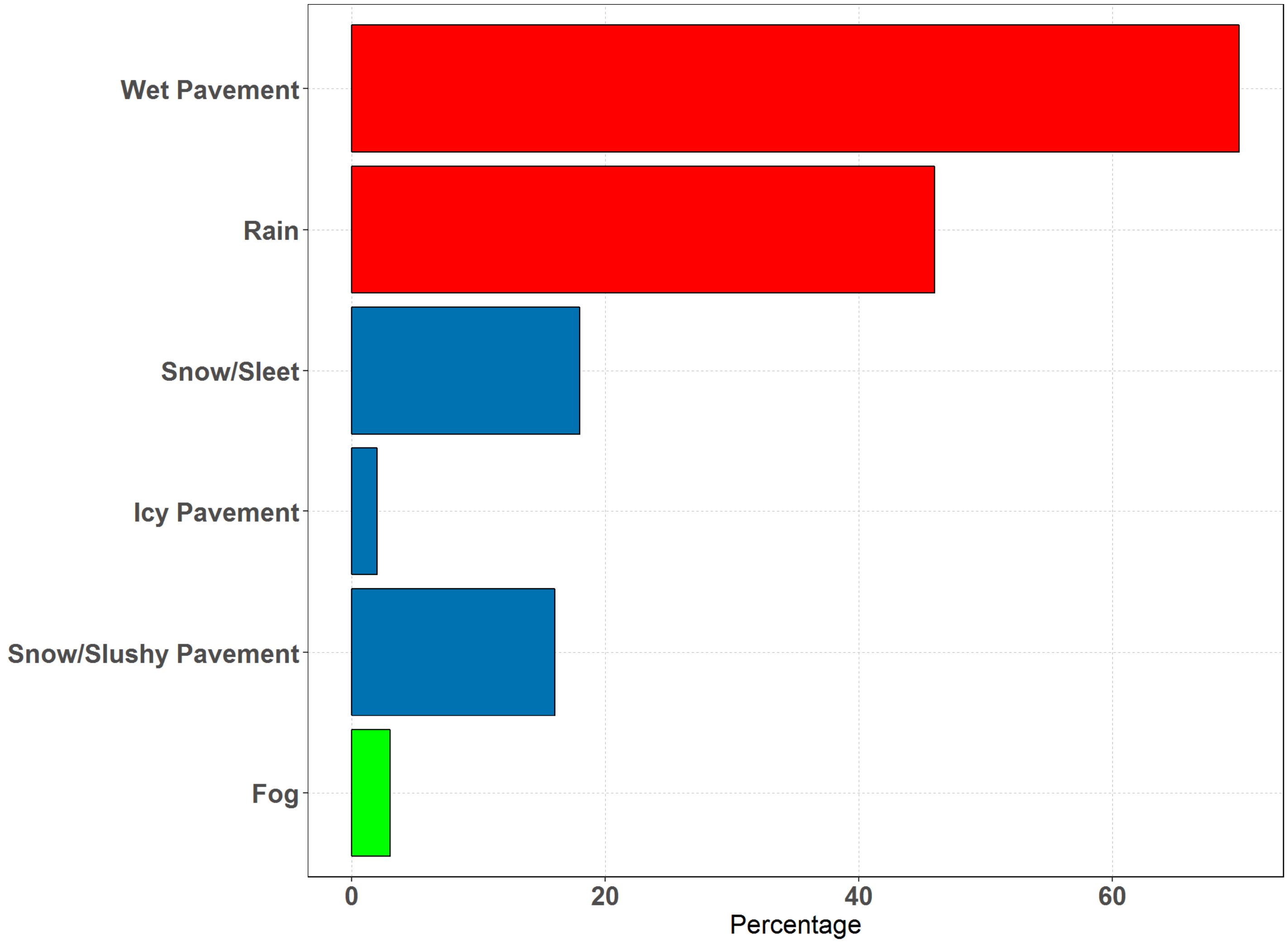
October 2019

- The Hydroplaning Tool and Guidance are available at [FDOT's Roadway Drainage Office Website]

Introduction

- Weather Related Crashes
  – Crashes that occur in the presence of adverse weather and/or slick pavement conditions
- National Highway Traffic Safety Administration Data (2007-2016)
  – Over 1.2M weather related crashes per year
  – Over 410K injuries per year
  – Over 5,000 fatalities per year

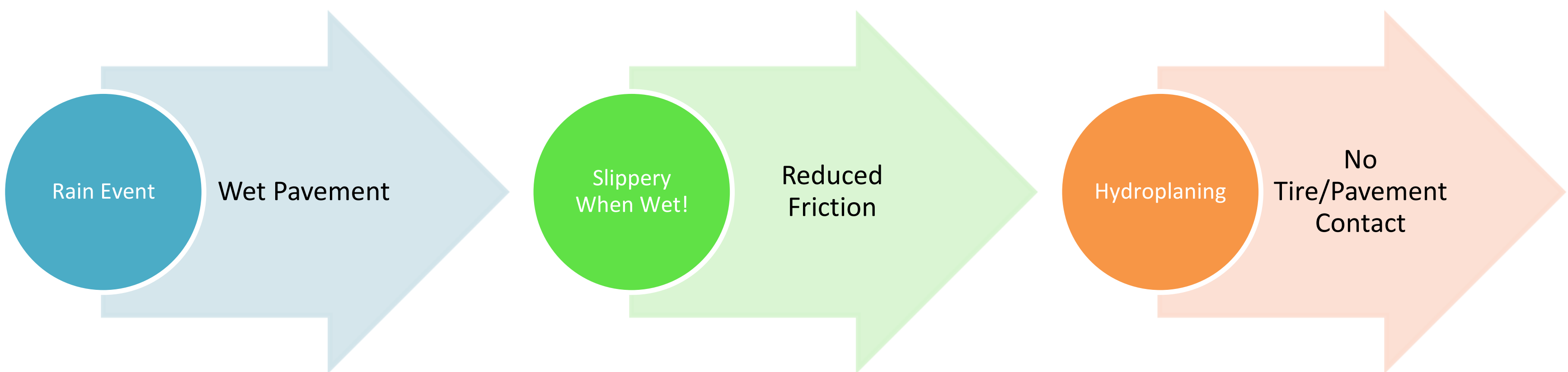
Weather Related Crashes



Source: Federal Highway Administration Office of Operations
https://ops.fhwa.dot.gov/weather/q1_roadimpact.htm

Water on Pavement Surface

- Slippery When Wet!
  - Water reduces friction between tire & pavement
  - Tire treads are designed to drain water
- Hydroplaning!
  - Under Severe Circumstances (More water than treads can handle)
  - Water pressure lifts the tire up from the pavement
  - Little to no traction
  - Affects driver’s control of the vehicle



Learning Objectives

Objective 1

- Understand Different Types of Hydroplaning and their Causes

Objective 2

- Understand the Factors Affecting Hydroplaning

Objective 3

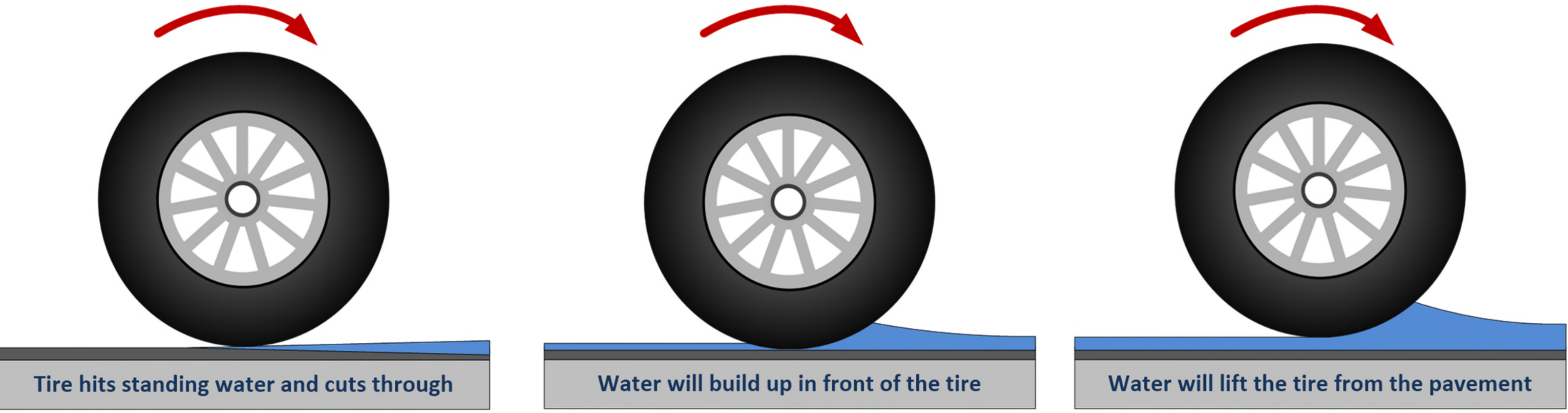
- Understand the Features of FDOT's Hydroplaning Tool
- Understand the Inputs for Hydroplaning prediction

Hydroplaning Fundamentals

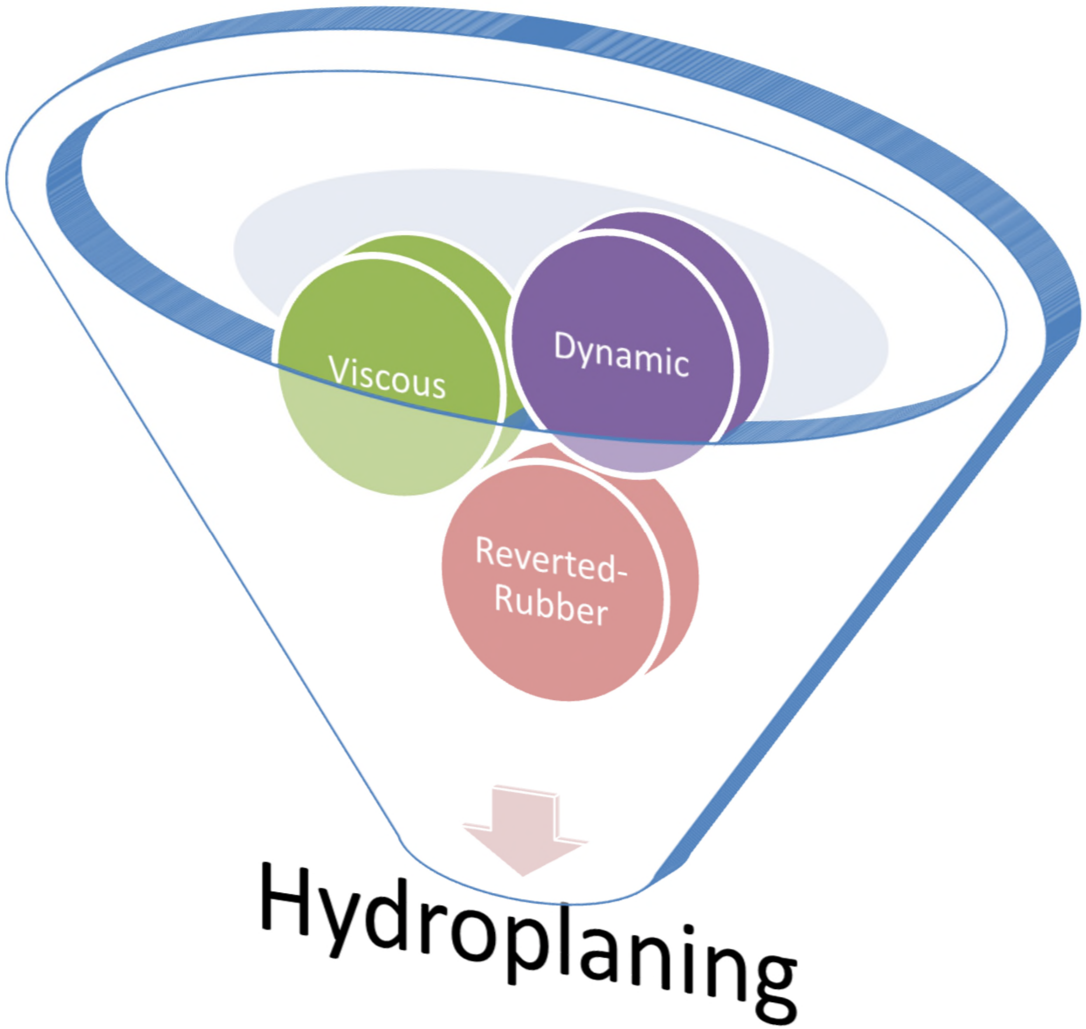
Definition

What is Hydroplaning?

- Condition that exists when a film of water or other contaminant is present at the tire/pavement interface and completely separates the tire from the pavement surface

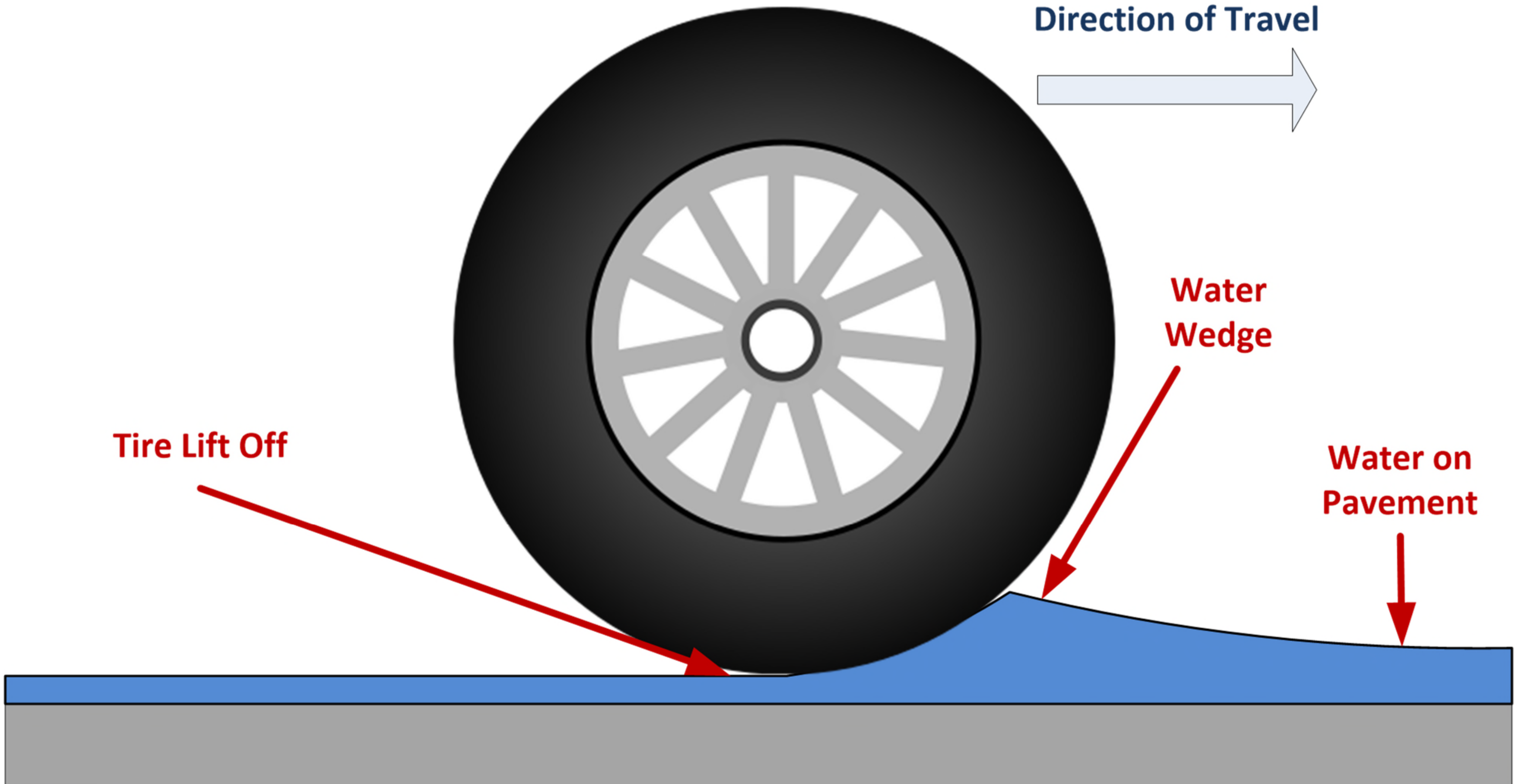


Hydroplaning Types



Dynamic Hydroplaning

- Occurs when there is more water than a tire can push away

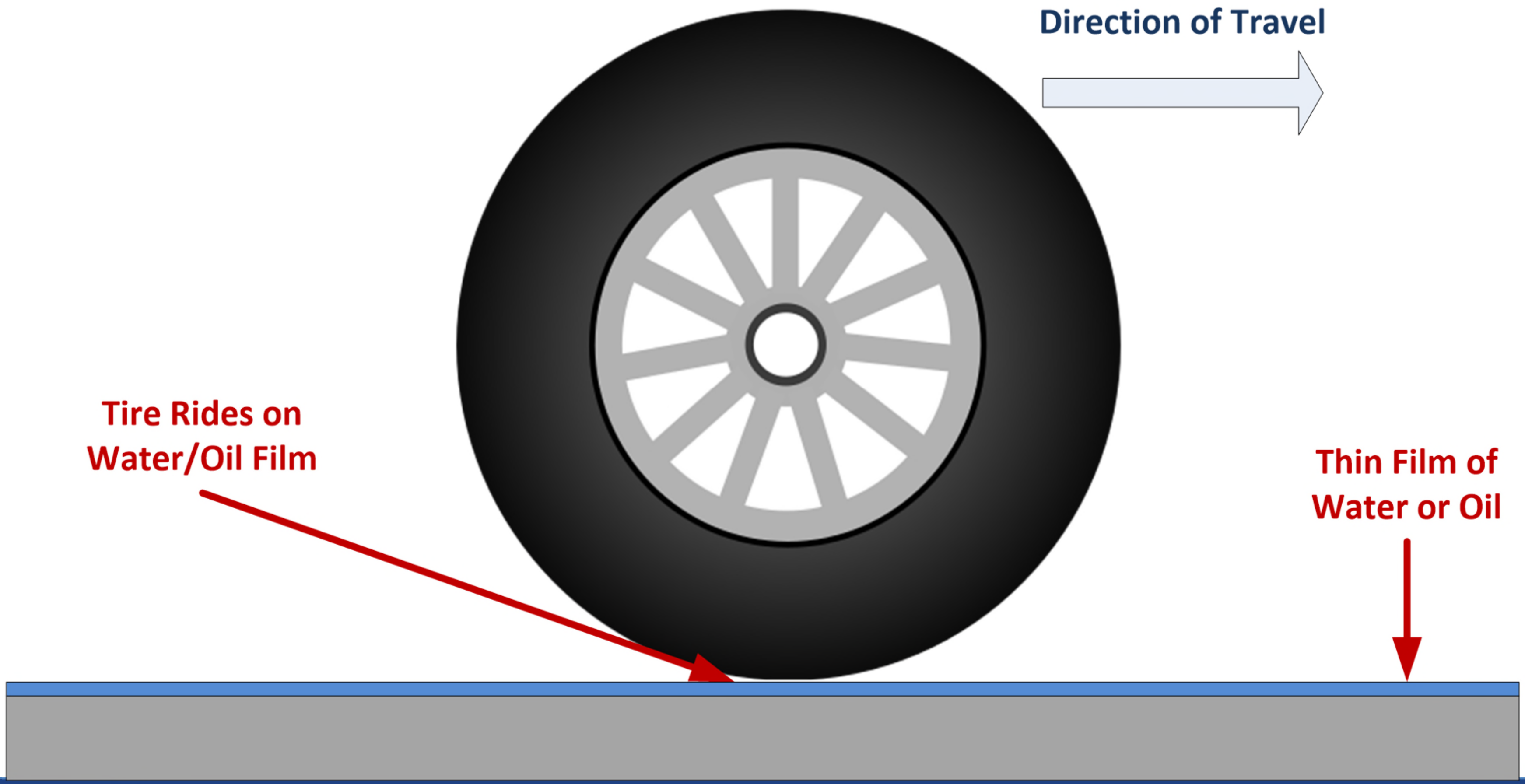


Dynamic Hydroplaning

- Most frequent type
- FDOT’s Hydroplaning Prediction Tool

Viscous Hydroplaning

- Occurs on pavements with little or no micro texture

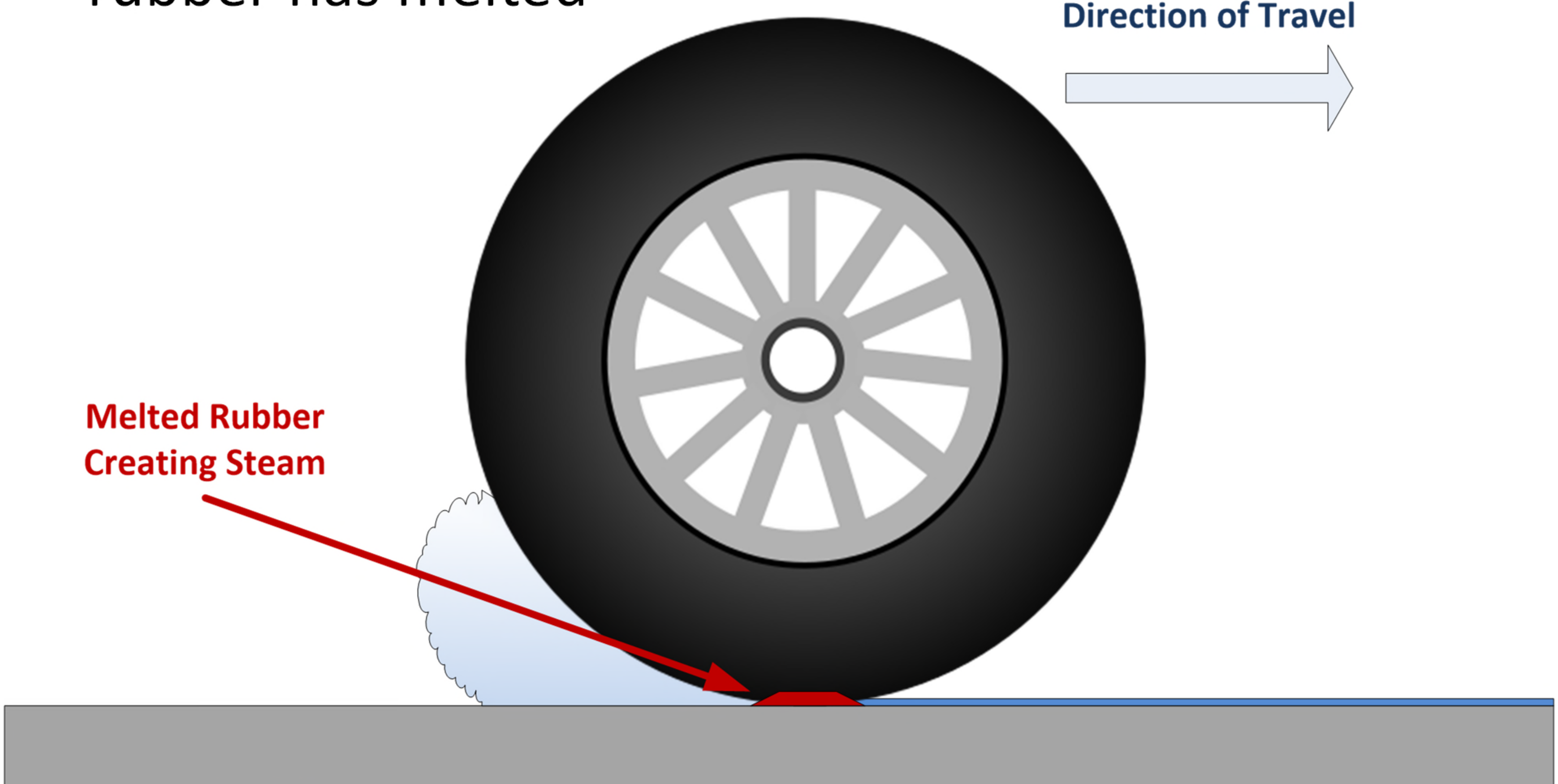


Viscous Hydroplaning

- Even a very thin film of water (less than 0.001 inch) may cause hydroplaning

Reverted-Rubber Hydroplaning

- Occurs when friction between tire and pavement generates excessive heat to the point where the tire rubber has melted



Reverted-Rubber Hydroplaning

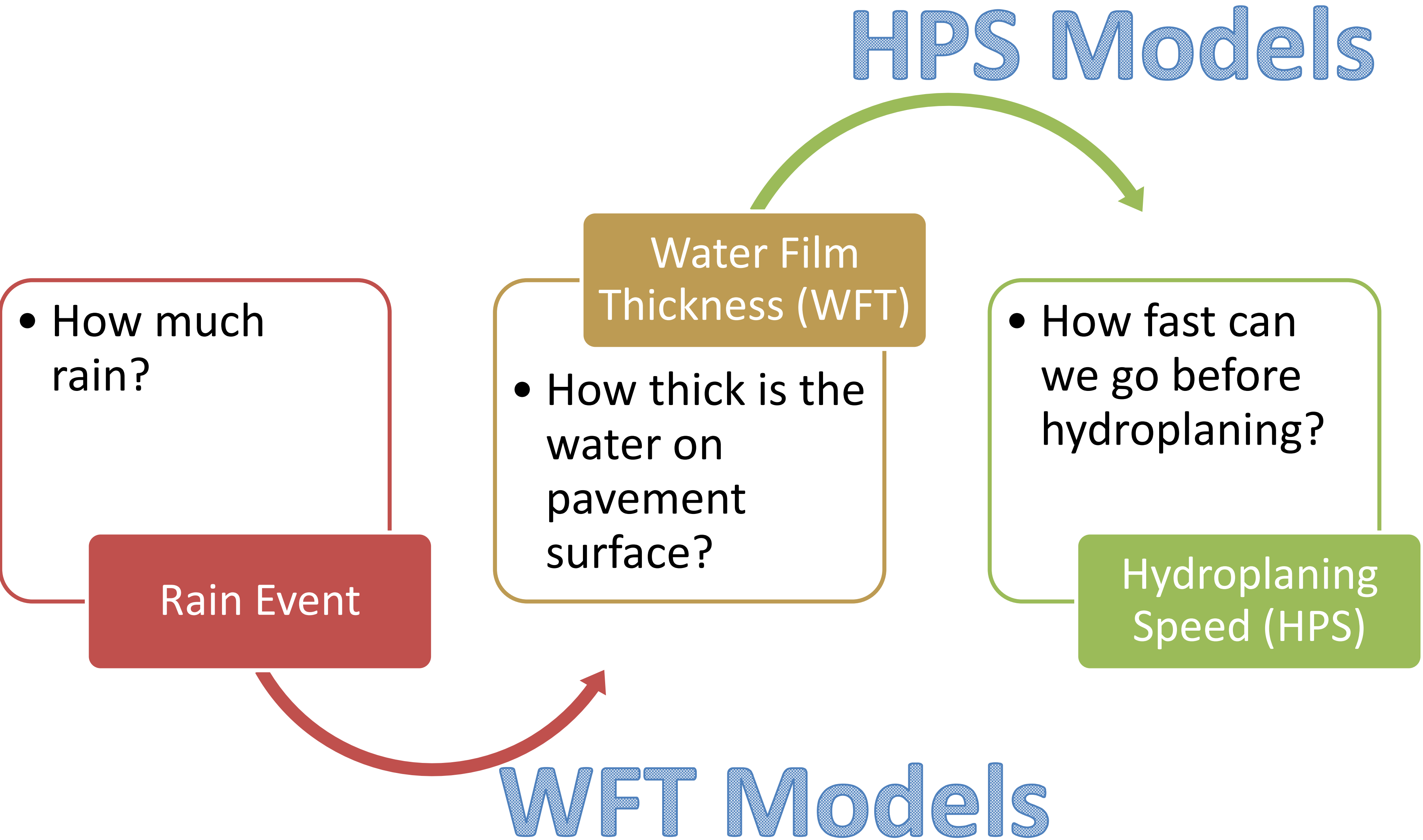
- Typically does not occur on roadways
- Rarely on runways with high speed aircrafts

What Affects Hydroplaning?

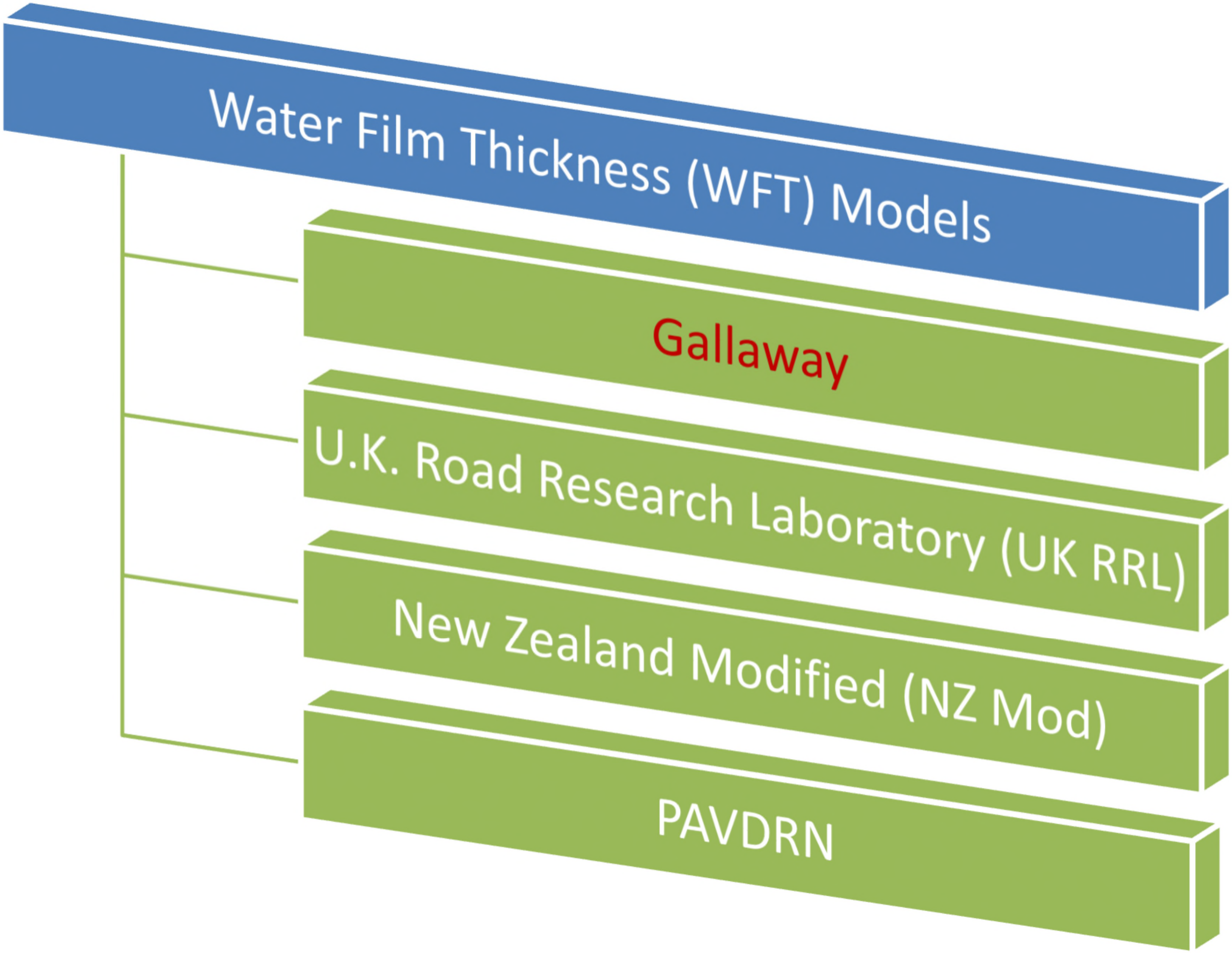
- Hydroplaning is a complicated phenomenon
- Improving Roadway and Pavement factors may help reduce hydroplaning

Roadway and Pavement	Environmental	Driver	Vehicle
☐ Surface Type	☐ Rainfall Intensity	☐ Speed	☐ Tire Tread Design
☐ Rut Depth	☐ Rainfall Duration	☐ Accelerating or Braking	☐ Tire Tread Depth
☐ Micro and Macro Texture	☐ Temperature	☐ Steering Maneuvers	☐ Tire Pressure
☐ Permeability			☐ Vehicle Type
☐ Cross Slope			☐ Vehicle Weight
☐ Longitudinal Grade			
☐ Pavement Width			
☐ Roadway Curvature			
☐ Pavement Depressions			

Hydroplaning Prediction



Water Film Thickness (WFT) Models



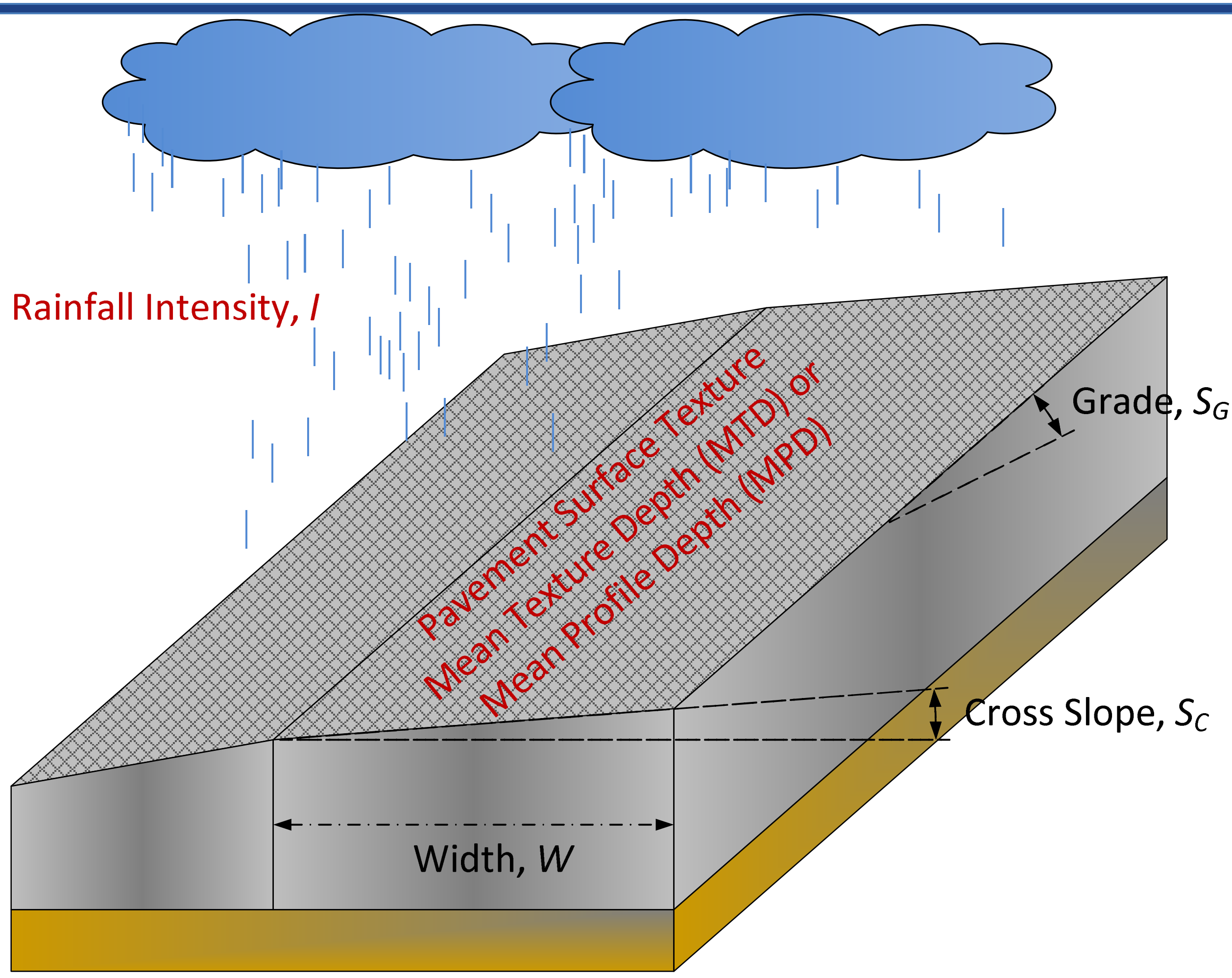
Gallaway WFT Model

$$WFT = \frac{0.003726 \cdot MTD^{0.125} \cdot L^{0.519} \cdot I^{0.562}}{S^{0.364}} - MTD$$

- *WFT*: Water Film Thickness (in.)
- *MTD*: Mean Texture Depth (in.)
- *L*: Drainage Path Length (ft.)
- *I*: Rainfall Intensity (in./hr.)
- *S*: Total Slope (dimensionless)

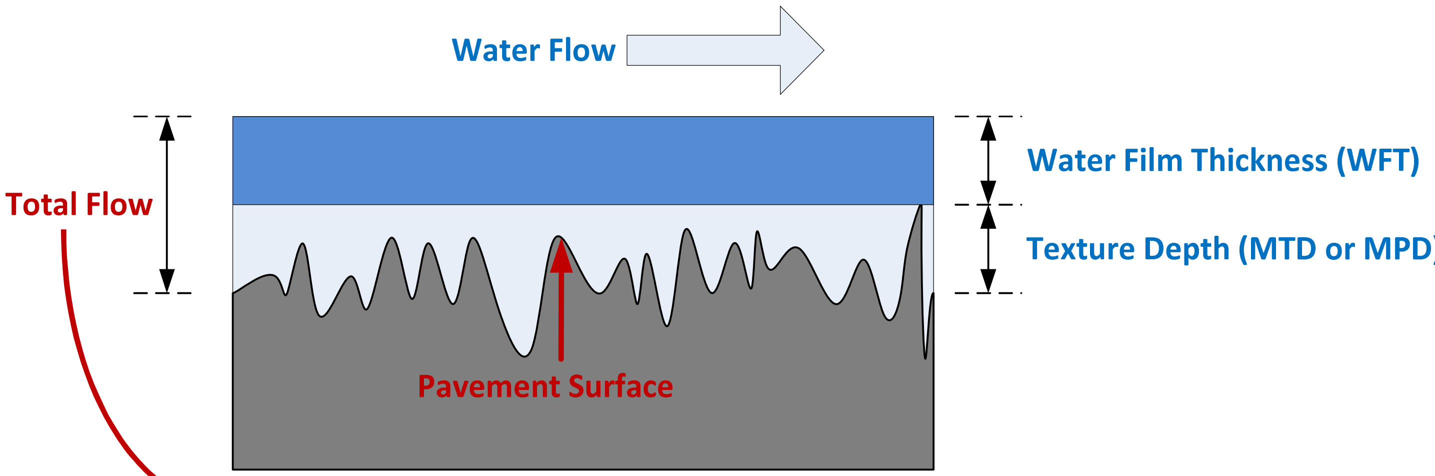
- You do NOT need to memorize the equation
  - Know the INPUTS and their importance

Inputs for WFT Equation



$$WFT = \frac{0.003726 \cdot MTD^{0.125} \cdot L^{0.519} \cdot I^{0.562}}{S^{0.364}} - MTD$$

Why is Texture Important?



$$WFT = \frac{0.003726 \cdot MTD^{0.125} \cdot L^{0.519} \cdot I^{0.562}}{S^{0.364}} - MTD$$

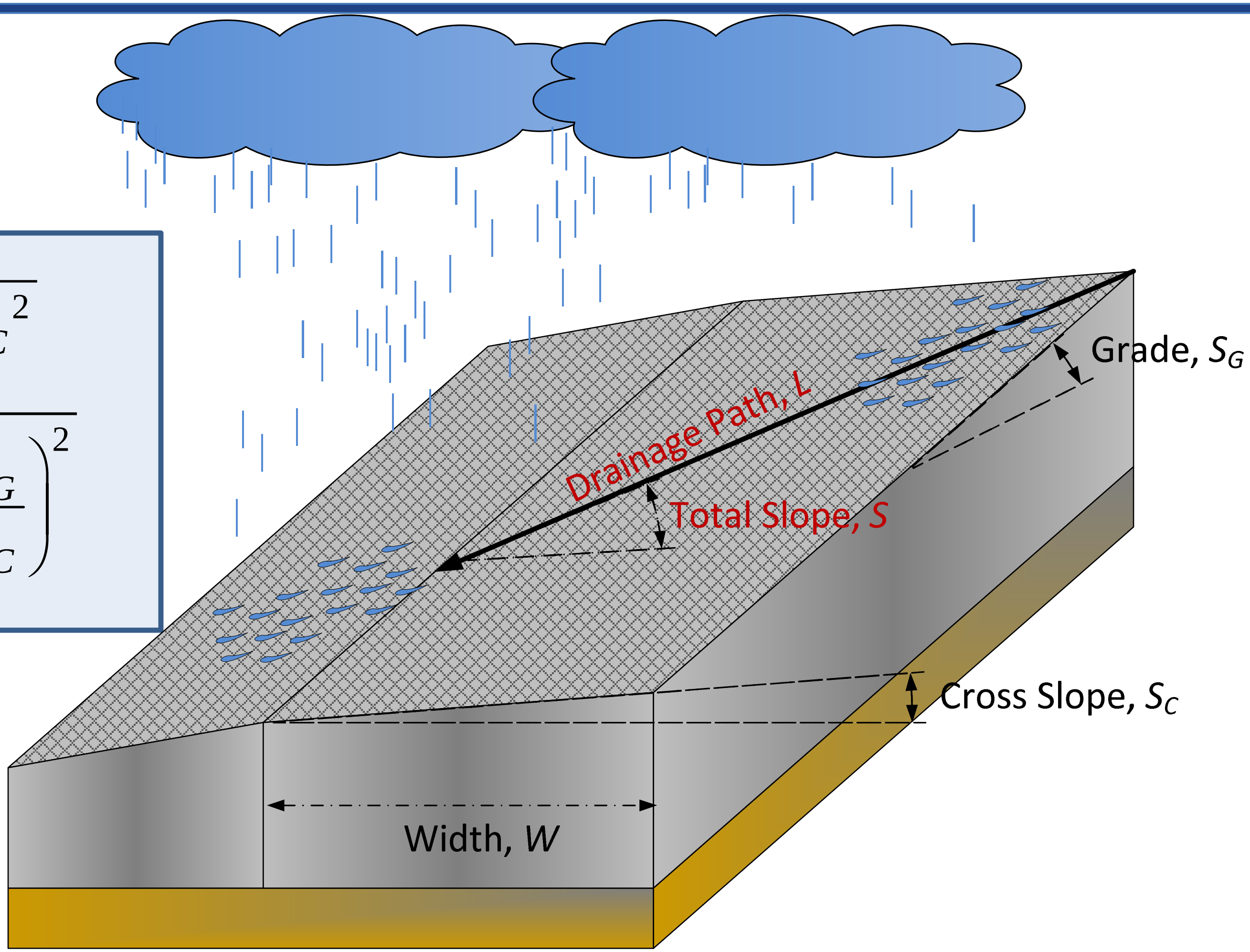
New Pavement

Old Pavement

Intermediate Variables

$$S = \sqrt{S_G^{\,2} + S_C^{\,2}}$$

$$L = W\sqrt{1 + \left(\frac{S_G}{S_C}\right)^2}$$



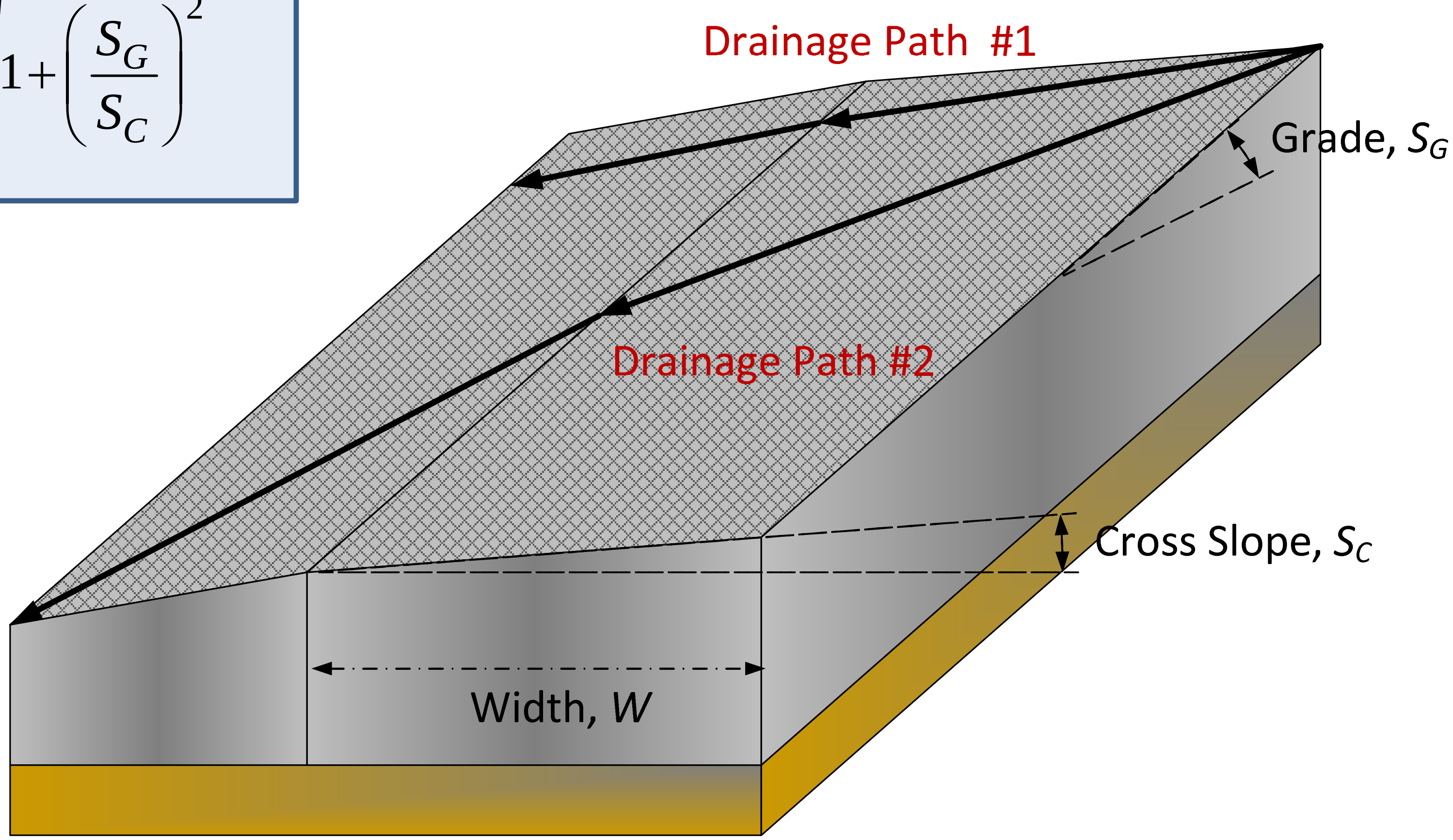
$$WFT = \frac{0.003726 \cdot MTD^{0.125} \cdot L^{0.519} \cdot I^{0.562}}{S^{0.364}} - MTD$$

Why Slope and Width of Pavement?

$$S = \sqrt{{S_G}^2 + {S_C}^2}$$

$$L = W\sqrt{1 + \left(\frac{S_G}{S_C}\right)^2}$$

$$WFT = \frac{0.003726 \cdot MTD^{0.125} \cdot L^{0.519} \cdot I^{0.562}}{S^{0.364}} - MTD$$



Hydroplaning Speed (HPS) Models

- Hydroplaning Speed (HPS) Models
  - PAVDRN
  - University of South Florida (USF)
  - Gallaway

PAVDRN HPS Model

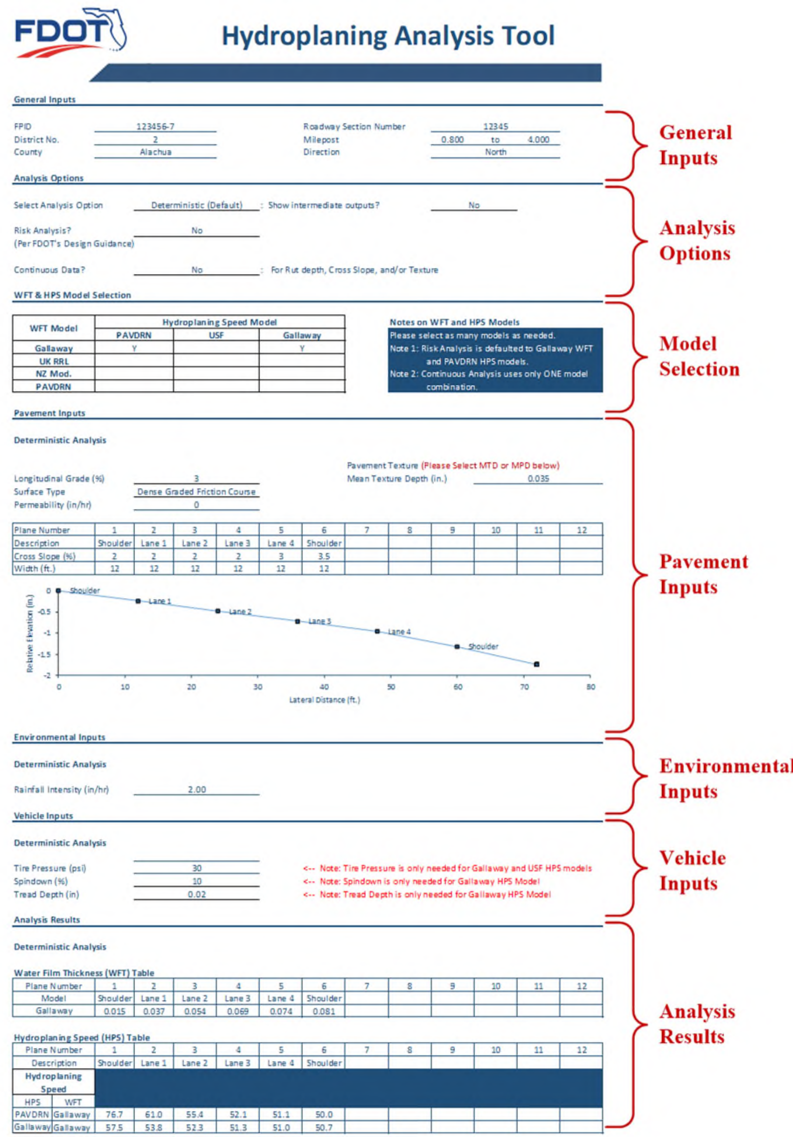
$$HPS = \begin{cases} 26.04 \cdot WFT^{-0.259} & \text{if } WFT < 0.094\,\text{in.} \\ 3.09 \cdot Max\left(\dfrac{10.409}{WFT^{0.06}} + 3.507, \left[\dfrac{28.952}{WFT^{0.06}} - 7.817\right] \cdot MTD^{0.14}\right) & \text{if } WFT \geq 0.094\,\text{in.} \end{cases}$$

– HPS: Hydroplaning Speed

- You do NOT need to memorize the equation
- FDOT's Hydroplaning Prediction (HP) Tool will do all the calculations for you

FDOT's Hydroplaning Prediction Tool

- Macro-enabled Excel (.xlsm file)
- User-Friendly
  - Select analysis option
  - Fill in the inputs
  - Get the outputs



FDOT

Hydroplaning Analysis Tool

General Inputs

FPID: 123456-7
District No.: 2
County: Alachua
Roadway Section Number: 12345
Milepost: 0.800 to 4.000
Direction: North

Analysis Options

Select Analysis Option: Deterministic (Default) : Show intermediate outputs? No
Risk Analysis? (Per FDOT's Design Guidance): No
Continuous Data?: No : For Rut depth, Cross Slope, and/or Texture

WFT & HPS Model Selection

WFT Model	Hydroplaning Speed Model		
	PAVDRN	USF	Gallaway
Gallaway	Y		Y
UK RRL			
NZ Mod.			
PAVDRN			

Notes on WFT and HPS Models
Please select as many models as needed.
Note 1: Risk Analysis is defaulted to Gallaway WFT and PAVDRN HPS models.
Note 2: Continuous Analysis uses only ONE model combination.

Pavement Inputs

Deterministic Analysis

Longitudinal Grade (%): 3
Surface Type: Dense Graded Friction Course
Permeability (in/hr): 0
Pavement Texture (Please Select MTD or MPD below)
Mean Texture Depth (in.): 0.035

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Description	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Cross Slope (%)	2	2	2	2	3	3.5						
Width (ft.)	12	12	12	12	12	12						

Environmental Inputs

Deterministic Analysis

Rainfall Intensity (in/hr): 2.00

Vehicle Inputs

Deterministic Analysis

Tire Pressure (psi): 30 <-- Note: Tire Pressure is only needed for Gallaway and USF HPS models
Spindown (%): 10 <-- Note: Spindown is only needed for Gallaway HPS Model
Tread Depth (in): 0.02 <-- Note: Tread Depth is only needed for Gallaway HPS Model

Analysis Results

Deterministic Analysis

Water Film Thickness (WFT) Table

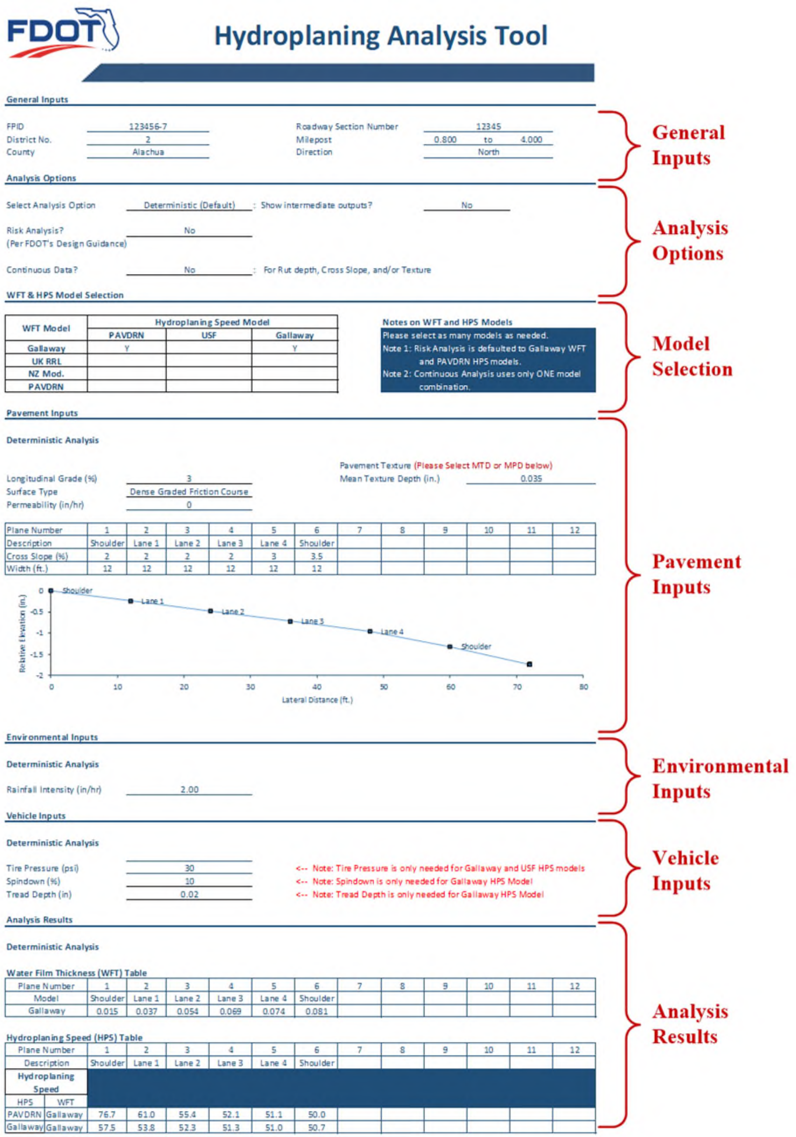
Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Model	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Gallaway	0.015	0.037	0.054	0.069	0.074	0.081						

Hydroplaning Speed (HPS) Table

Plane Number		1	2	3	4	5	6	7	8	9	10	11	12
Description		Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Hydroplaning Speed													
HPS	WFT												
PAVDRN	Gallaway	76.7	61.0	55.4	52.1	51.1	50.0						
Gallaway	Gallaway	57.5	53.8	52.3	51.3	51.0	50.7						

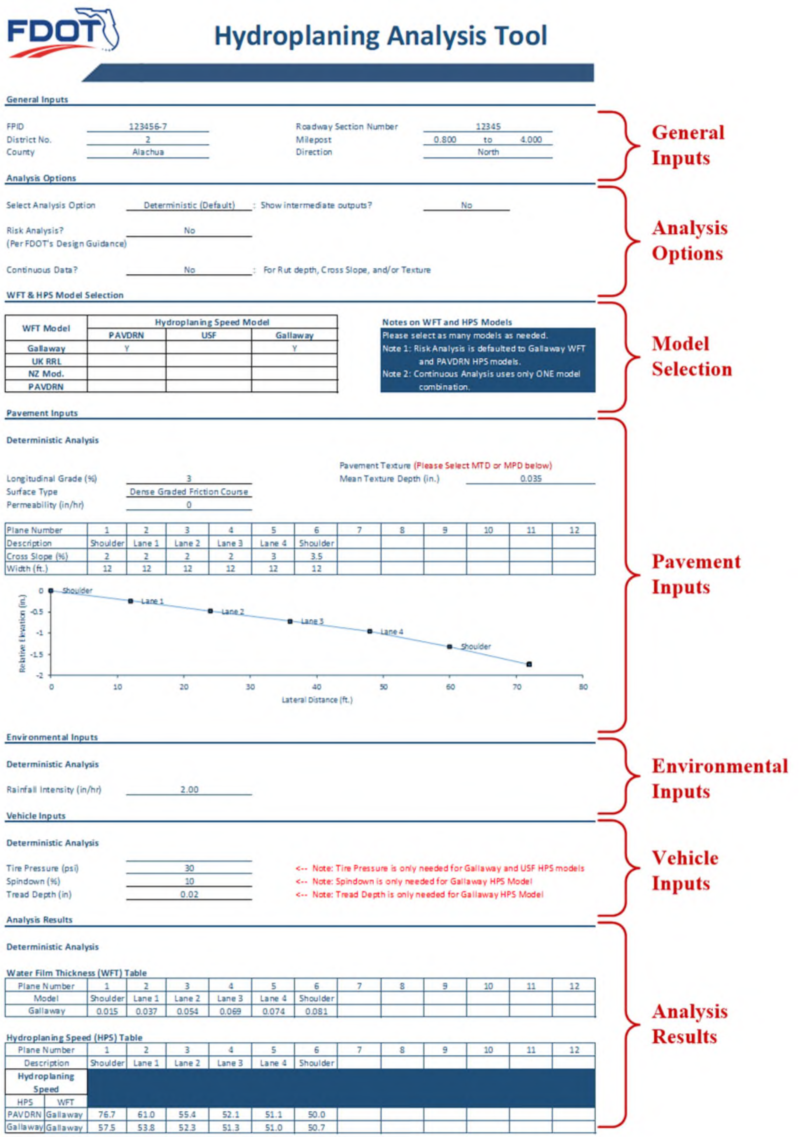
FDOT’s Hydroplaning Prediction Tool

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity
  - Probabilistic



FDOT's Hydroplaning Prediction Tool

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity
  - Probabilistic


FDOT

Hydroplaning Analysis Tool

General Inputs

FPID: 123456-7
District No.: 2
County: Alachua
Roadway Section Number: 12345
Milepost: 0.800 to 4.000
Direction: North

Analysis Options

Select Analysis Option: Deterministic (Default) ; Show intermediate outputs?: No

Risk Analysis? (Per FDOT's Design Guidance): No

Continuous Data?: No ; For Rut depth, Cross Slope, and/or Texture

WFT & HPS Model Selection

WFT Model	Hydroplaning Speed Model		
	PAVDRN	USF	Gallaway
Gallaway	Y		Y
UK RRL			
NZ Mod.			
PAVDRN			

Notes on WFT and HPS Models
Please select as many models as needed.
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Note 2: Continuous Analysis uses only ONE model combination.

Pavement Inputs

Deterministic Analysis

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Surface Type: Dense Graded Friction Course
Permeability (in/hr): 0
Pavement Texture (Please Select MTD or MPD below)
Mean Texture Depth (in.): 0.035

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Description	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Cross Slope (%)	2	2	2	2	3	3.5						
Width (ft.)	12	12	12	12	12	12						

Environmental Inputs

Deterministic Analysis

Rainfall Intensity (in/hr): 2.00

Vehicle Inputs

Deterministic Analysis

Tire Pressure (psi): 30 <-- Note: Tire Pressure is only needed for Gallaway and USF HPS models
Spindown (%): 10 <-- Note: Spindown is only needed for Gallaway HPS Model
Tread Depth (in): 0.02 <-- Note: Tread Depth is only needed for Gallaway HPS Model

Analysis Results

Deterministic Analysis

Water Film Thickness (WFT) Table

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Model	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Gallaway	0.015	0.037	0.054	0.069	0.074	0.081						

Hydroplaning Speed (HPS) Table

Plane Number		1	2	3	4	5	6	7	8	9	10	11	12
Description		Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Hydroplaning Speed													
HPS	WFT												
PAVDRN	Gallaway	76.7	61.0	55.4	52.1	51.1	50.0						
Gallaway	Gallaway	57.5	53.8	52.3	51.3	51.0	50.7						

Deterministic Analysis Options

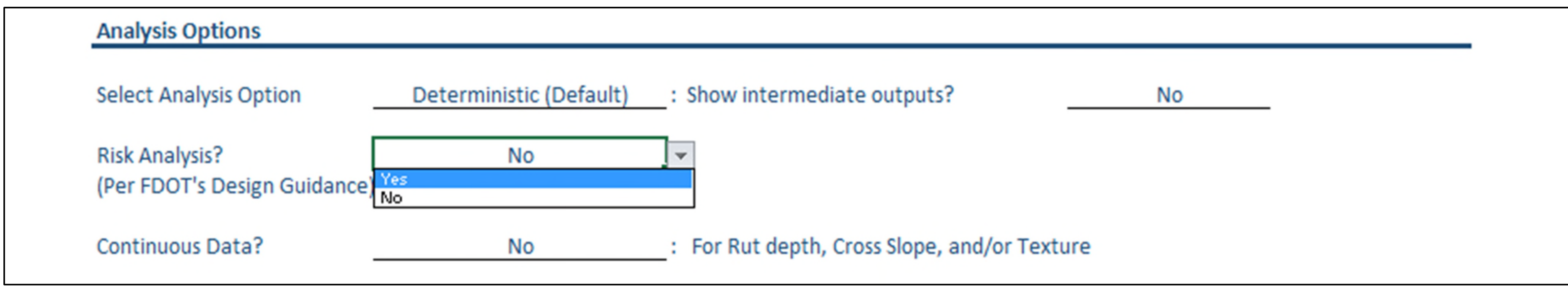
- Risk Analysis
- Basic Analysis
  - Select “No” for both “Risk” and “Continuous” analysis options
- Continuous Analysis

Analysis Options

Select Analysis Option	Deterministic (Default)	:	Show intermediate outputs?	No
Risk Analysis? (Per FDOT's Design Guidance)	No			
Continuous Data?	No	:	For Rut depth, Cross Slope, and/or Texture	

Deterministic → Risk Analysis

- Based on FDOT’s Design Guidance
- Expected driver speed vs. Hydroplaning speed
- Gallaway WFT & PAVDRN HPS models



Deterministic → Risk Analysis: Predicted Driver Speed

- Depends on Rainfall Intensity
- Minimum speed for Hydroplaning Analysis = 45 mph

Rainfall Intensity (in/hr)	Predicted Driver Speed (mph)
0.1	Design Speed – 0
0.25	Design Speed – 0
0.5	Design Speed – 6
1	Design Speed – 8
2	Design Speed – 12
3	45 mph
4	

Deterministic → Risk Analysis Inputs

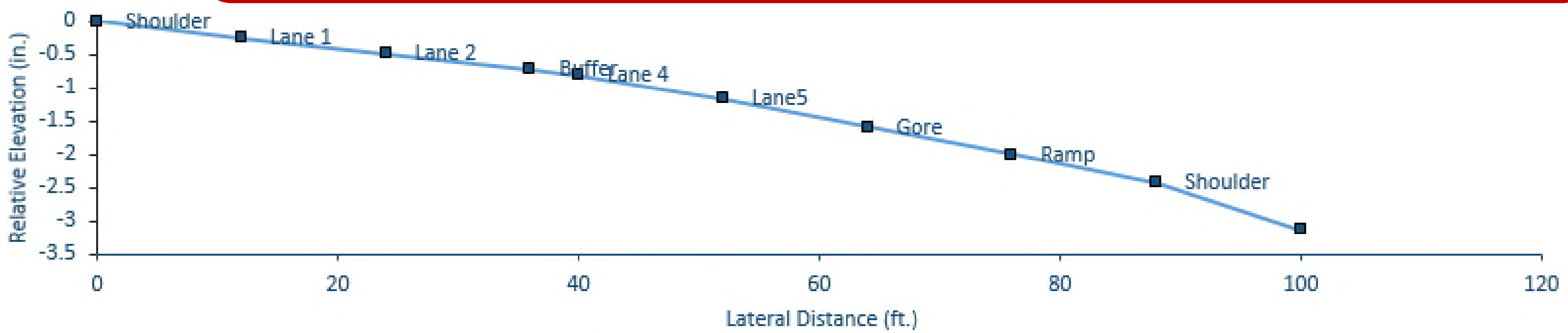
Pavement Inputs

Deterministic Analysis

Longitudinal Grade (%): 3
Surface Type: Open Graded Friction Course
Permeability (in/hr): 0

Pavement Texture (Please Select MTD or MPD below)
Mean Texture Depth (in.): 0.067
Mean Texture Depth (in.)
Mean Profile Depth (in.)

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Description	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
Design Speed (mph)		70	70	70	65	65		50				
Cross Slope (%)	2	2	2	2	3	3.5	3.5	3.5	6			
Width (ft.)	12	12	12	4	12	12	12	12	12			



Deterministic → Risk Analysis Results

- Lane 2, Buffer Area, and Lane 5
  - Not passing FDOT's Design Criteria

Predicted Driver Speed (mph)

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
0.1		70.0	70.0	70.0	65.0	65.0		50.0				
0.25		70.0	70.0	70.0	65.0	65.0		50.0				
0.5		64.0	64.0	64.0	59.0	59.0		45.0				
1		62.0	62.0	62.0	57.0	57.0		45.0				
2		58.0	58.0	58.0	53.0	53.0		45.0				
3		45.0	45.0	45.0	45.0	45.0		45.0				
4		45.0	45.0	45.0	45.0	45.0		45.0				

Predicted Hydroplaning Speed (mph)

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
0.1		999.0	999.0	999.0	999.0	999.0		999.0				
0.25		999.0	999.0	999.0	999.0	999.0		999.0				
0.5		999.0	999.0	999.0	999.0	999.0		110.5				
1		999.0	84.4	77.2	72.4	68.3		61.0				
2		67.1	57.3	55.4	53.9	52.3		49.0				
3		56.7	50.6	49.3	48.2	53.7		52.8				
4		51.8	53.7	53.3	53.0	52.7		51.8				

Deterministic → Basic Hydroplaning Analysis

- Select "No" for both Risk and Continuous options

Analysis Options

Select Analysis Option	Deterministic (Default)	: Show intermediate outputs?	No
Risk Analysis? (Per FDOT's Design Guidance)	No		
Continuous Data?	No	: For Rut depth, Cross Slope, and/or Texture	

- Up to 12 model combinations

WFT & HPS Model Selection

WFT Model	Hydroplaning Speed Model		
	PAVDRN	USF	Gallaway
Gallaway	Y	Y	Y
UK RRL	Y	Y	Y
NZ Mod.	Y	Y	Y
PAVDRN	Y	Y	Y

Notes on WFT and HPS Models

Please select as many models as needed.

Note 1: Risk Analysis is defaulted to Gallaway WFT and PAVDRN HPS models.

Note 2: Continuous Analysis uses only ONE model combination.

Deterministic → Basic Analysis Inputs

- Similar to Risk Analysis
- No Design Speed

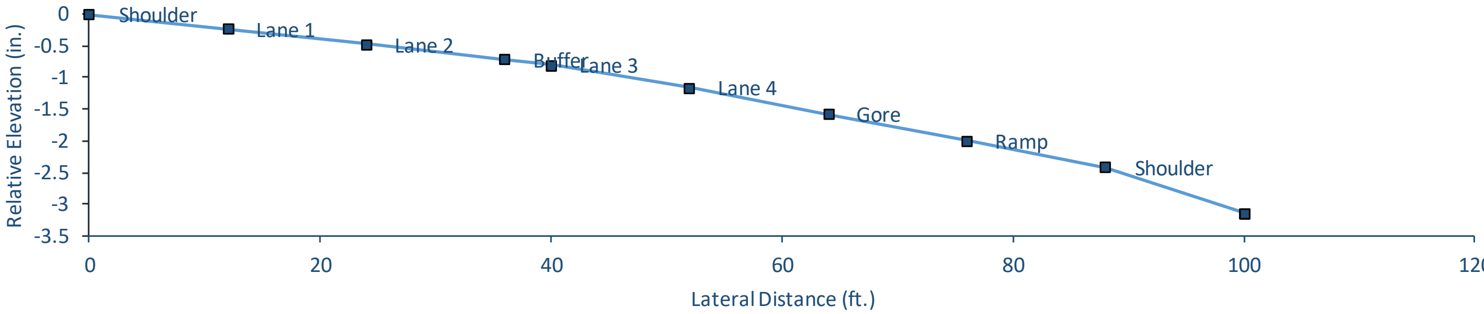
Pavement Inputs

Deterministic Analysis

Pavement Texture (Please Select MTD or MPD below)
Mean Texture Depth (in.) 0.067

Longitudinal Grade (%) 3
Surface Type Open Graded Friction Course
Permeability (in/hr) 0

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Description	Shoulder	Lane 1	Lane 2	Buffer	Lane 3	Lane 4	Gore	Ramp	Shoulder			
Cross Slope (%)	2	2	2	2	3	3.5	3.5	3.5	6			
Width (ft.)	12	12	12	4	12	12	12	12	12			



Deterministic → Basic Analysis Inputs

- Additional Inputs (Depending on Models)
  - Environmental & Vehicle Inputs

Environmental Inputs

Deterministic Analysis

Rainfall Intensity (in/hr)	2.00	
Temperature (deg. F)	70.0	<-- Note: Temperature is only needed for PAVDRN WFT Model

Vehicle Inputs

Deterministic Analysis

Axle Weight (lbs)	472.1	<-- Note: Axle Weight is only needed for USF HPS Model
Tire Pressure (psi)	30	<-- Note: Tire Pressure is only needed for Gallaway and USF HPS models
Spindown (%)	10	<-- Note: Spindown is only needed for Gallaway HPS Model
Tread Depth (in)	0.02	<-- Note: Tread Depth is only needed for Gallaway HPS Model

- If you do NOT see these inputs, do NOT worry about them

Deterministic → Basic Analysis Output

Water Film Thickness (WFT) Table (Units: in.)

Water Film Thickness Results

Plane Number	1	2	3							10	11	12
Model	Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
Gallaway	0.025	0.051	0.071	0.077	0.082	0.089	0.098	0.106	0.094			
UK RRL	0.029	0.056	0.077	0.083	0.092	0.100	0.109	0.117	0.113			
NZ Mod.	0.018	0.037	0.050	0.054	0.056	0.060	0.065	0.070	0.058			
PAVDRN	0.019	0.032	0.040	0.043	0.044	0.046	0.052	0.055	0.048			

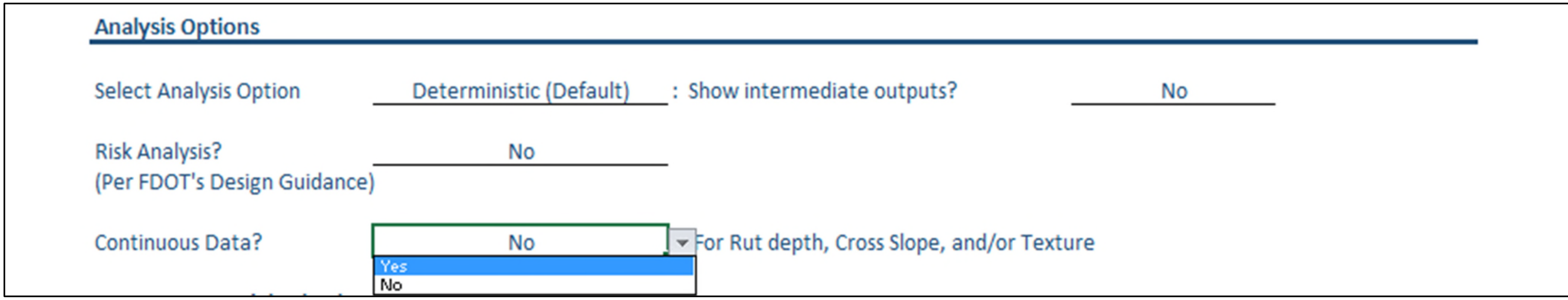
Hydroplaning Speed (HPS) Table (Units: mph)

Plane Number		1	2	3	4	5	6	7	8	9	10	11	12
Description		Shoulder	Lane 1	Lane 2	Buffer	Lane 4	Lane5	Gore	Ramp	Shoulder			
A Parameter													
WFT	Gallaway	17.72	16.77	16.34	16.23	16.14	16.05	15.93	15.83	15.98			
	UK RRL	17.48	16.63	16.24	16.14	16.01	15.90	15.79	15.70	15.75			
	NZ Mod.	18.14	17.19	16.77	16.68	16.63	16.56	16.45	16.35	16.58			
	PAVDRN	18.05	17.38	17.06	16.98	16.95	16.89	16.73	16.65	16.83			
Hydroplaning Speed													
HPS	WFT												
PAVDRN	Gallaway	67.8	56.4	51.7	50.6	49.7	48.7	49.2	48.9	48.1			
	UK RRL	64.9	54.9	50.7	49.7	48.4	49.1	48.8	48.5	48.7			
	NZ Mod.	73.5	61.3	56.5	55.4	54.9	54.1	52.9	51.9	54.3			
	PAVDRN	72.3	63.6	59.7	58.9	58.5	57.8	56.0	55.1	57.1			
USF	Gallaway	55.0	53.6	52.9	52.7	52.6	52.4	52.3	52.1	52.3			
	UK RRL	54.7	53.3	52.7	52.6	52.4	52.2	52.1	51.9	52.0			
	NZ Mod.	55.7	54.2	53.6	53.4	53.3	53.2	53.1	52.9	53.3			
	PAVDRN	55.5	54.5	54.0	53.9	53.8	53.7	53.5	53.4	53.7			
Gallaway	Gallaway	55.5	52.5	51.2	50.9	50.6	50.3	49.9	49.6	50.1			
	UK RRL	54.8	52.1	50.9	50.6	50.2	49.8	49.5	49.2	49.3			
	NZ Mod.	56.8	53.9	52.6	52.3	52.1	51.9	51.5	51.2	52.0			
	PAVDRN	56.6	54.4	53.5	53.2	53.1	52.9	52.4	52.2	52.8			

Hydroplaning Speed Results

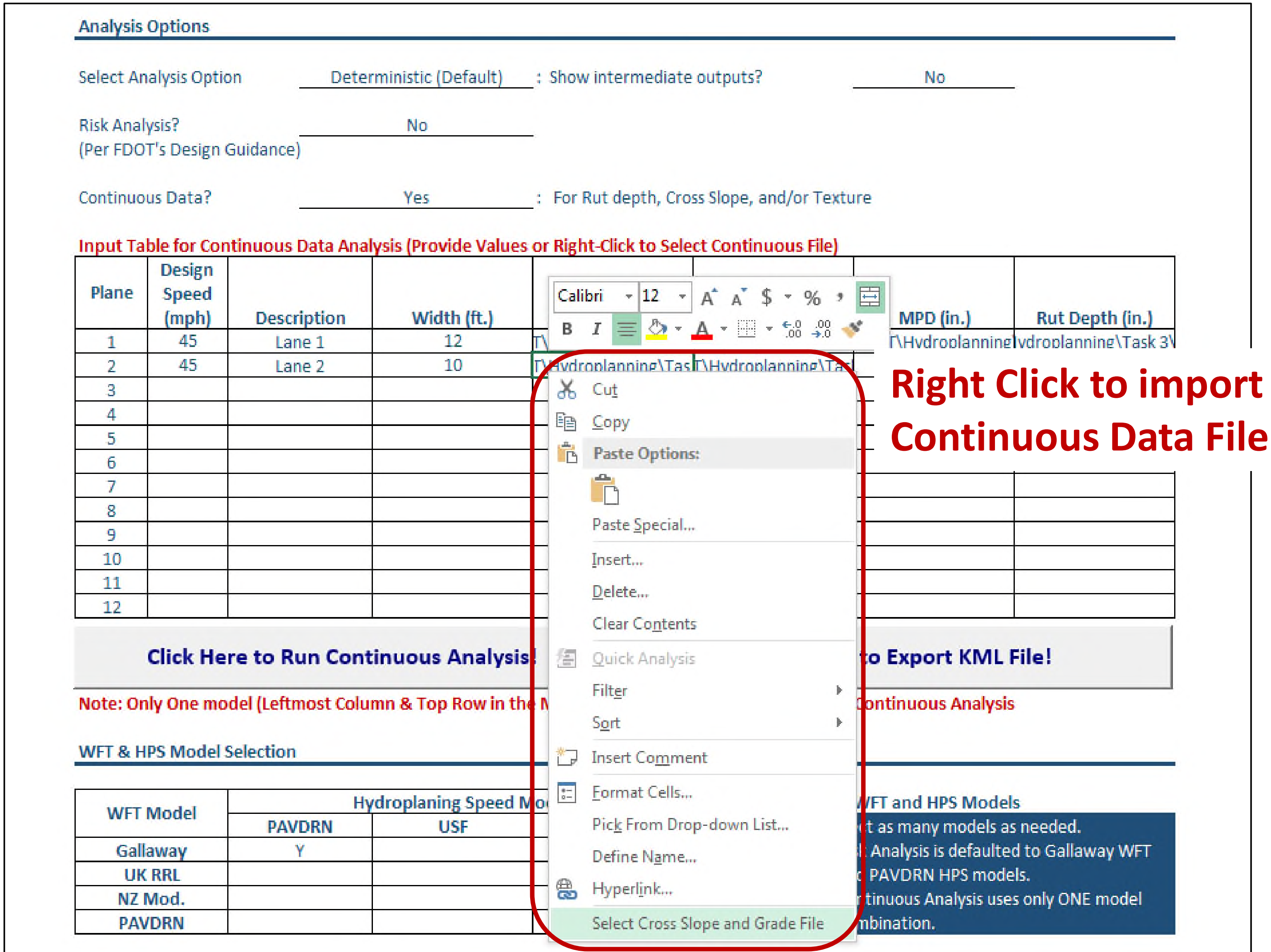
Deterministic → Continuous Analysis

- Pavement Cross-Slope, Grade, and Texture change from one location to another



- Can be used only if continuous measurements are available

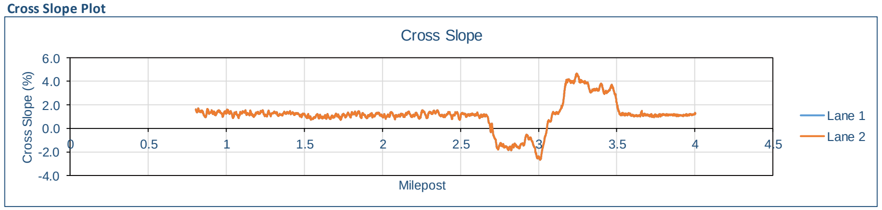
Deterministic → Continuous Analysis Inputs



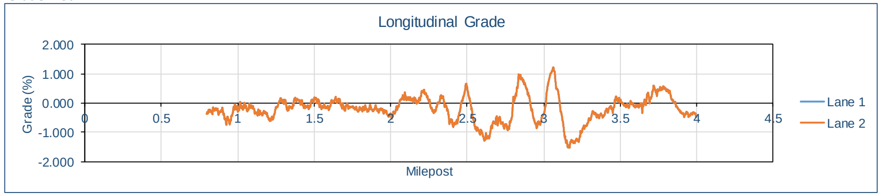
Deterministic → Continuous Analysis Results

Continuous Analysis Results

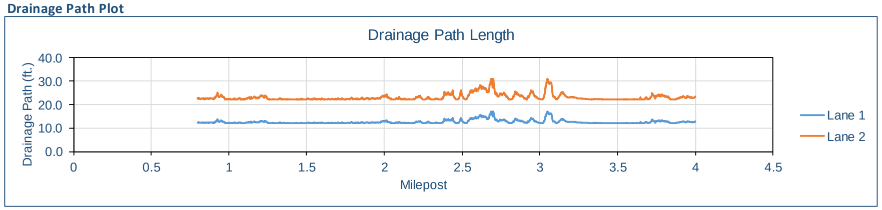
Cross Slope Plot



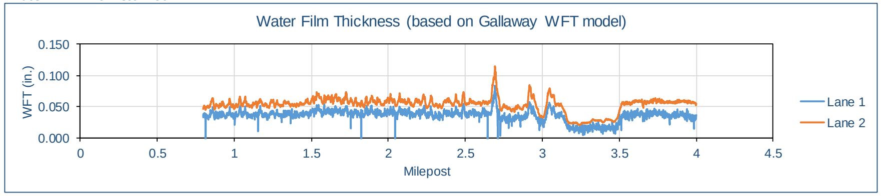
Grade Plot



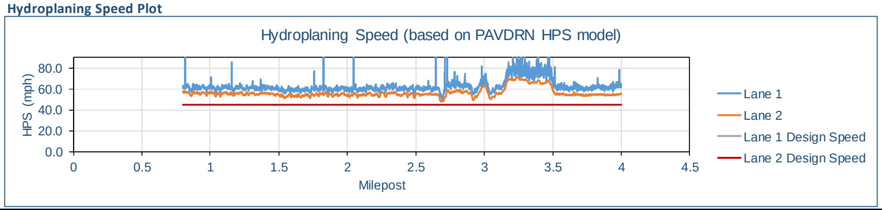
Drainage Path Plot



Water Film Thickness Plot



Hydroplaning Speed Plot



Cross Slope Inputs

Longitudinal Grade Inputs

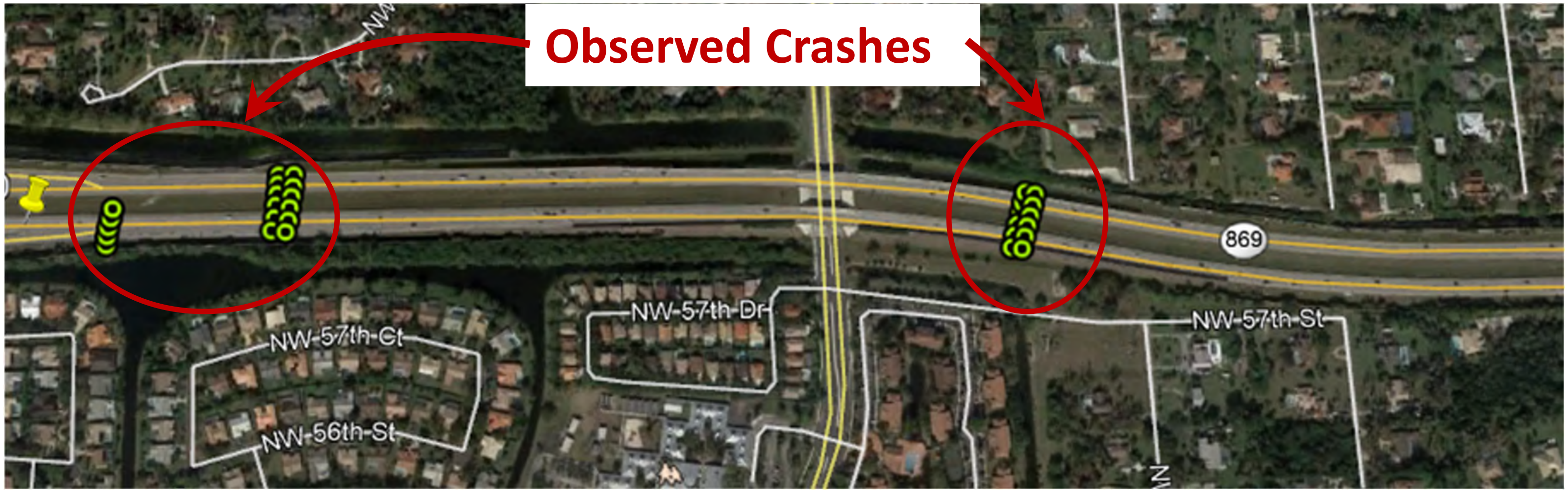
Drainage Path Results

Water Film Thickness Results

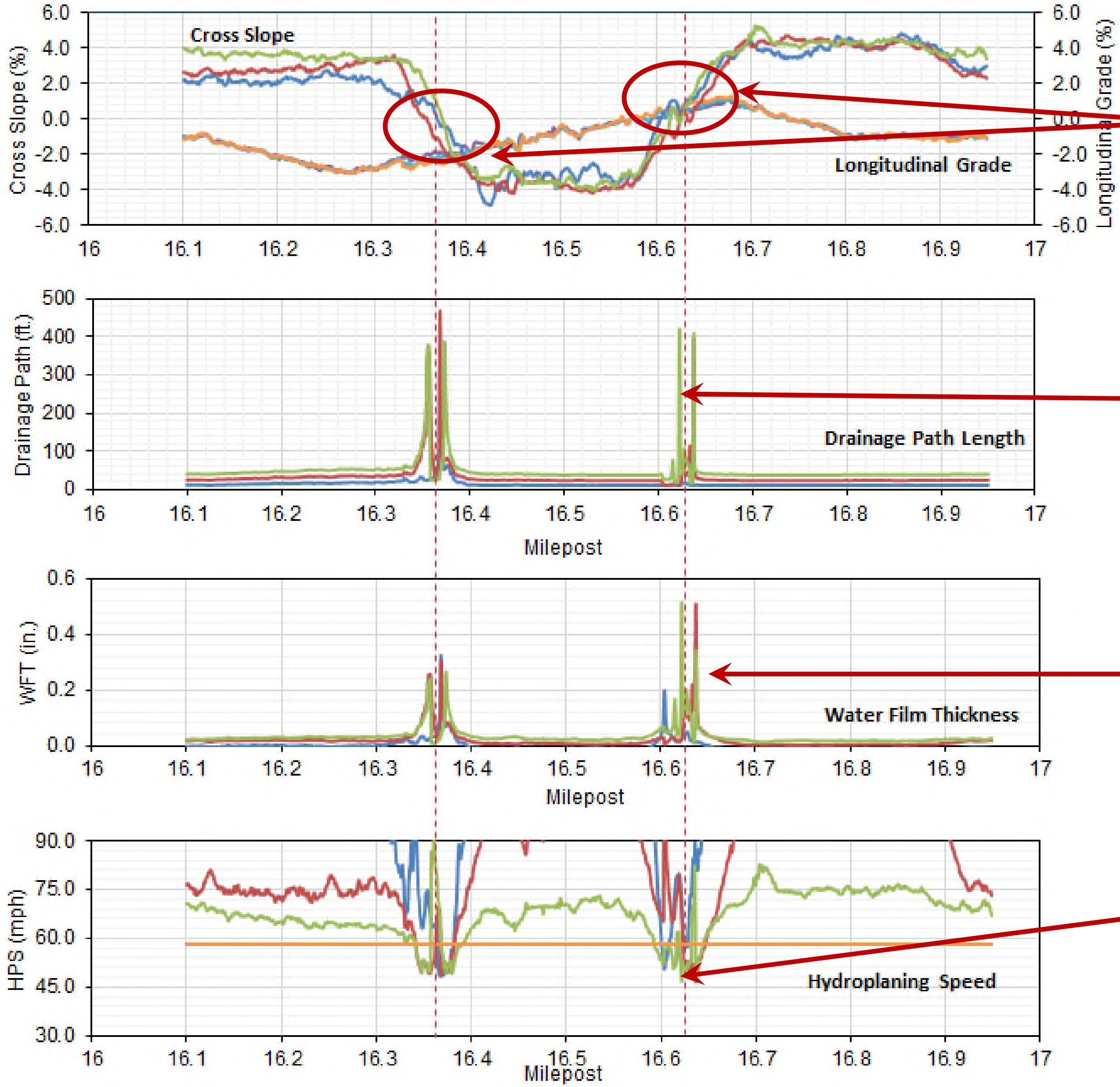
Hydroplaning Speed Results

Deterministic → Continuous Analysis Example

- Problem Statement
  - Increased number of crashes between mileposts 16.0 and 17.0 , especially under wet conditions
- Available Data
  - Continuous Cross Slope and Grade



Deterministic → Continuous Analysis Example Results



Cross Slope ≈ 0

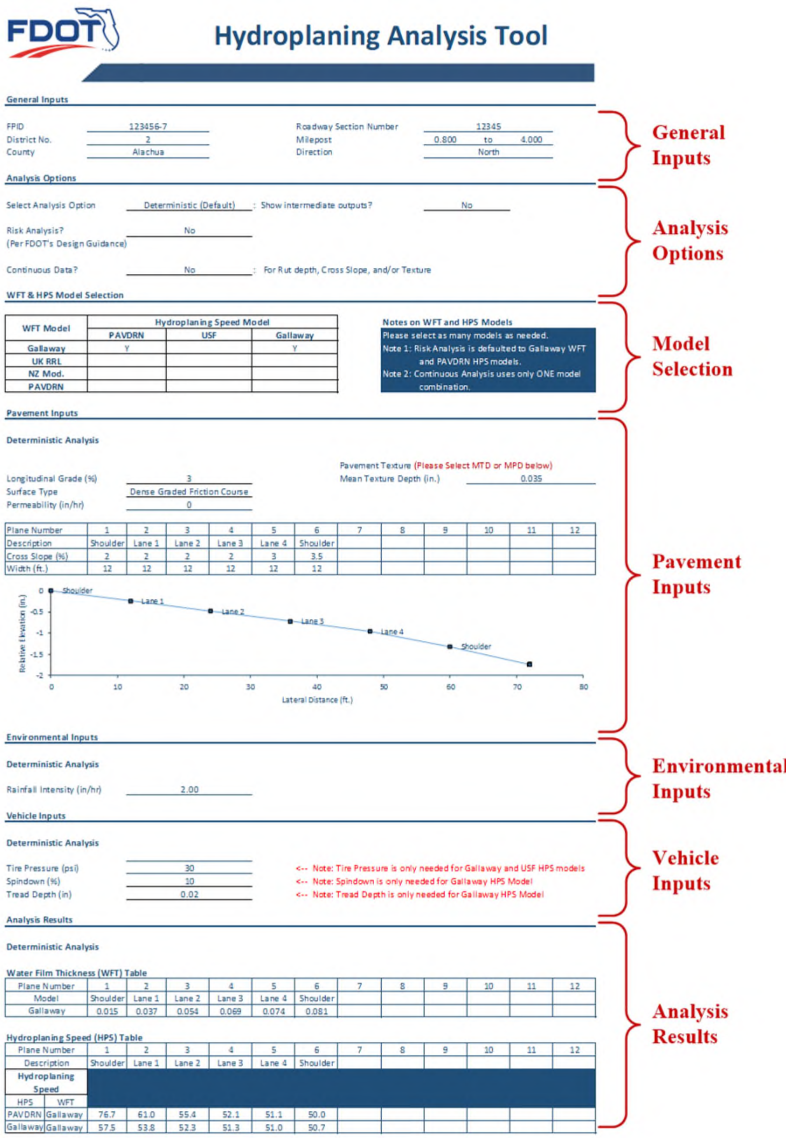
Increased Drainage Path Length

Increased Water Film Thickness

Hydroplaning Speed below Predicted Driver Speed !

FDOT's Hydroplaning Prediction Tool

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity
  - Probabilistic



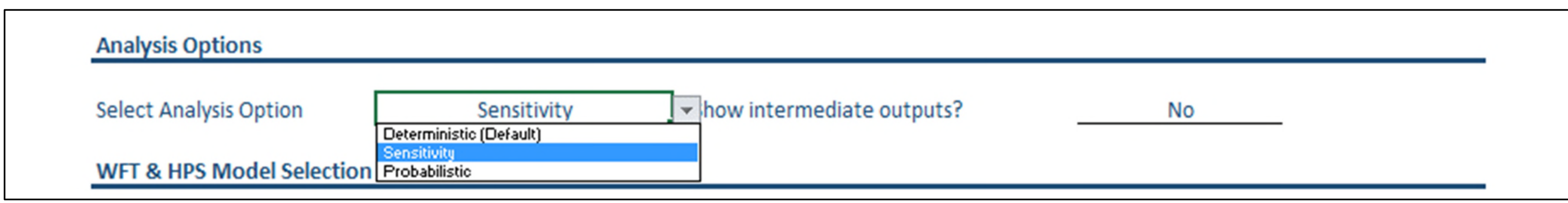
Sensitivity Analysis

- Batch run for Basic Analysis

EQUIVALENT !!

Single Sensitivity Analysis Run ⟷ **Total Number of Deterministic Analysis = 6×4×2 = 48**

- **Number of Rainfall Intensities = 6**
- **Number of MPD Values = 4**
- **Number of Cross Slope Values = 2**



Sensitivity Analysis Inputs

- Minimum, Maximum, and Increment

Pavement Inputs

Sensitivity Analysis

Select Surface Type (Y/N)

Dense Graded Friction Course	Y
Open graded Friction Course	
PCC (LGD)	
PCC (LGD+TGV)	

	Min	Max	Inc.
Longitudinal Grade (%)	1	2	
Permeability (in/hr)	0		
Mean Profile Depth (in.)	0.02	0.05	0.01

(Please Select MTD or MPD from above Cell)

Plane Number		1	2	3	4	5	6	7	8	9	10	11	12
Description		Lane 1	Lane 2										
Cross Slope (%)	Min	1	1										
	Max	2	2										
	Inc.	1											
Width (ft.)	Min	12	12										
	Max	14	14										
	Inc.												

Environmental Inputs

Sensitivity Analysis

	Min	Max	Inc.
Rainfall Intensity (in/hr)	0.5	3	0.5
Temperature (deg. F)	70	80	

Click Here to Run Sensitivity Analysis!

<-- Note: Temperature is only needed for PAVDRN WFT Model

Vehicle Inputs

Sensitivity Analysis

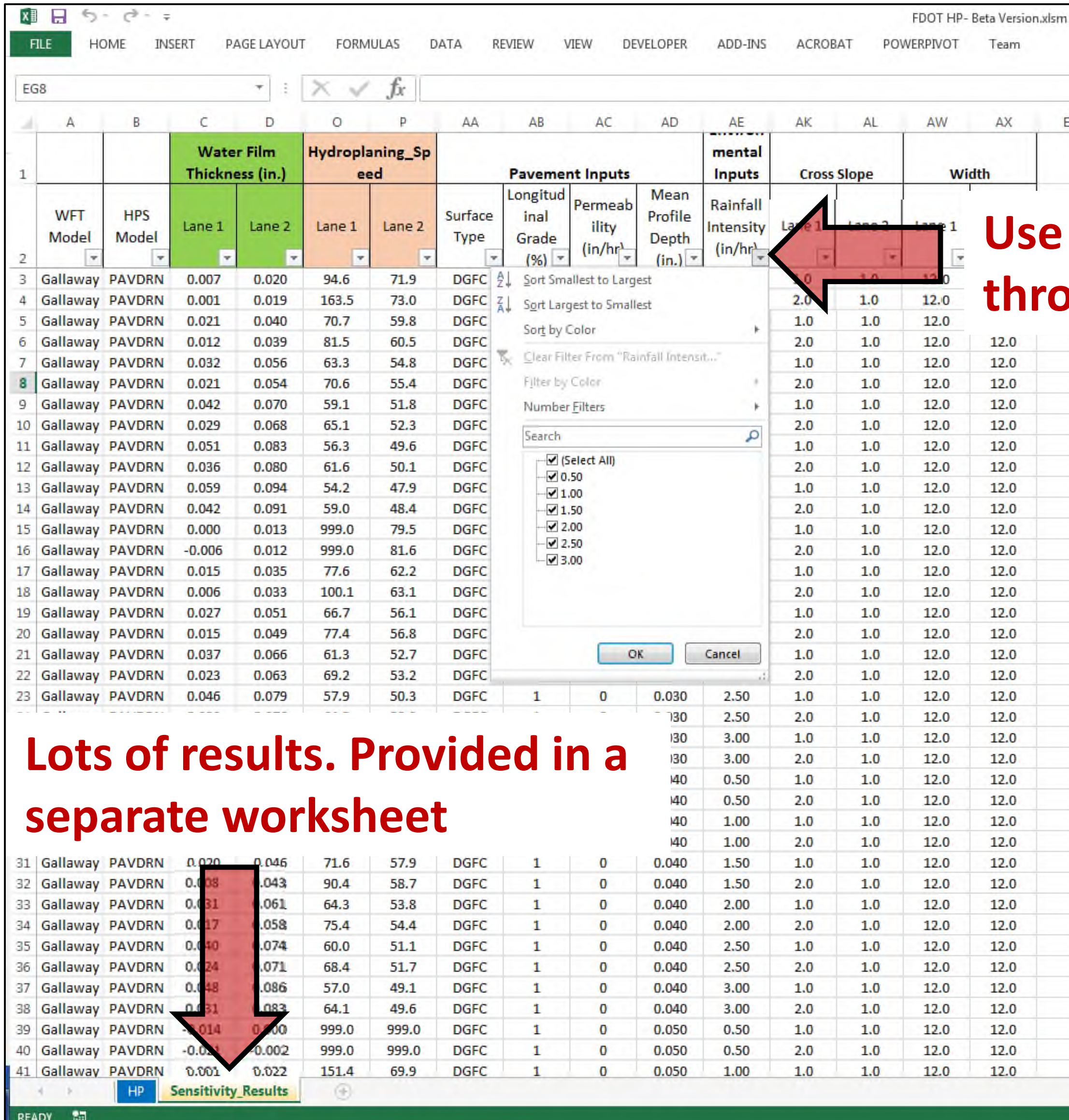
	Min	Max	Inc.	
Axle Weight (lbs)	450	550		<-- Note: Axle Weight is only needed for USF HPS Model
Tire Pressure (psi)	20	30		<-- Note: Tire Pressure is only needed for Gallaway and USF HPS models
Spindown (%)	10	10	0	<-- Note: Spindown is only needed for Gallaway HPS Model
Tread Depth (in)	0.02	0.02	0	<-- Note: Tread Depth is only needed for Gallaway HPS Model

Sensitivity Analysis Inputs

- Rainfall Intensity
  - Minimum: 0.5 in/hr
  - Maximum: 3.0 in/hr
  - Increment: 0.5 in/hr

- Equivalent to running Basic Analysis 6 times
  - With 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 in/hr rainfall intensities

Sensitivity Analysis Results



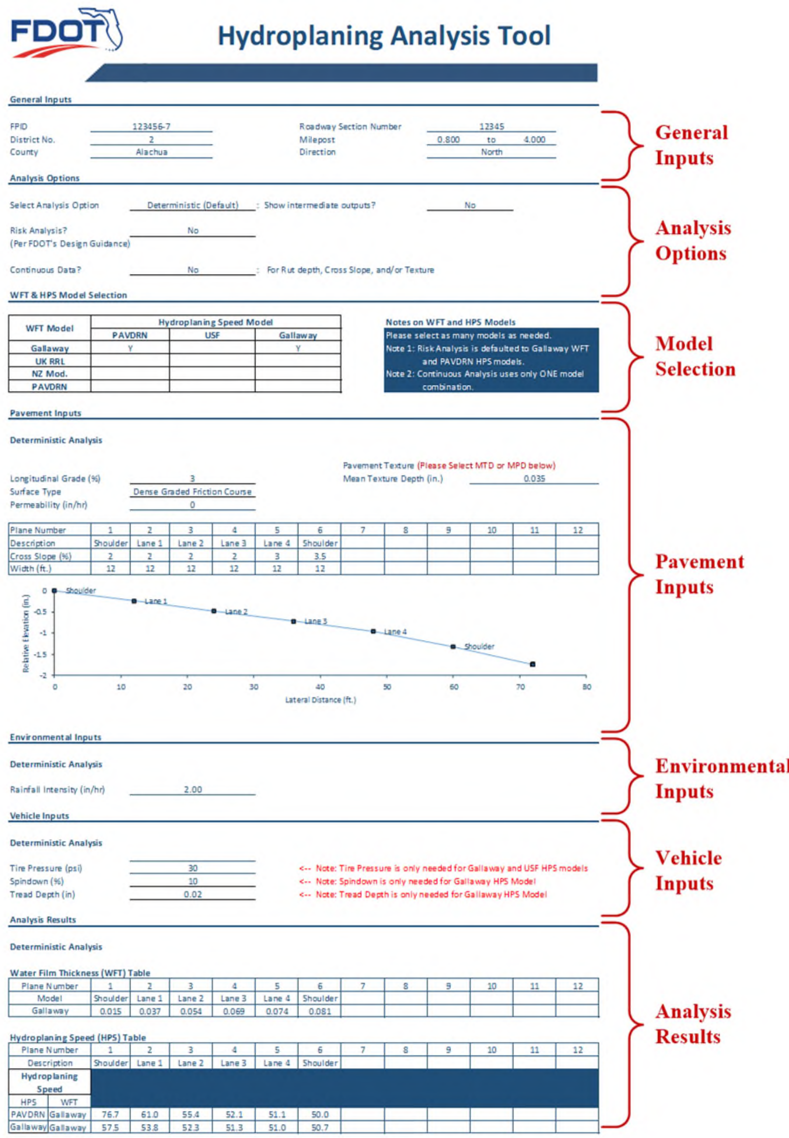
	A	B	C	D	O	P	AA	AB	AC	AD	AE	AK	AL	AW	AX
1			Water Film Thickness (in.)		Hydroplaning_Speed		Pavement Inputs				mental Inputs	Cross Slope		Width	
2	WFT Model	HPS Model	Lane 1	Lane 2	Lane 1	Lane 2	Surface Type	Longitudinal Grade (%)	Permeability (in/hr)	Mean Profile Depth (in.)	Rainfall Intensity (in/hr)	Lane 1	Lane 2	Lane 1	
3	Gallaway	PAVDRN	0.007	0.020	94.6	71.9	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Gallaway	PAVDRN	0.001	0.019	163.5	73.0	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	[illegible]
5	Gallaway	PAVDRN	0.021	0.040	70.7	59.8	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	[illegible]
6	Gallaway	PAVDRN	0.012	0.039	81.5	60.5	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
7	Gallaway	PAVDRN	0.032	0.056	63.3	54.8	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
8	Gallaway	PAVDRN	0.021	0.054	70.6	55.4	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
9	Gallaway	PAVDRN	0.042	0.070	59.1	51.8	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
10	Gallaway	PAVDRN	0.029	0.068	65.1	52.3	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
11	Gallaway	PAVDRN	0.051	0.083	56.3	49.6	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
12	Gallaway	PAVDRN	0.036	0.080	61.6	50.1	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
13	Gallaway	PAVDRN	0.059	0.094	54.2	47.9	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
14	Gallaway	PAVDRN	0.042	0.091	59.0	48.4	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
15	Gallaway	PAVDRN	0.000	0.013	999.0	79.5	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
16	Gallaway	PAVDRN	-0.006	0.012	999.0	81.6	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
17	Gallaway	PAVDRN	0.015	0.035	77.6	62.2	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
18	Gallaway	PAVDRN	0.006	0.033	100.1	63.1	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
19	Gallaway	PAVDRN	0.027	0.051	66.7	56.1	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
20	Gallaway	PAVDRN	0.015	0.049	77.4	56.8	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
21	Gallaway	PAVDRN	0.037	0.066	61.3	52.7	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	1.0	1.0	12.0	12.0
22	Gallaway	PAVDRN	0.023	0.063	69.2	53.2	DGFC	[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.0	12.0	12.0
23	Gallaway	PAVDRN	0.046	0.079	57.9	50.3	DGFC	1	0	0.030	2.50	1.0	1.0	12.0	12.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.50	2.0	1.0	12.0	12.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.00	1.0	1.0	12.0	12.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.00	2.0	1.0	12.0	12.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.50	1.0	1.0	12.0	12.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.50	2.0	1.0	12.0	12.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.00	1.0	1.0	12.0	12.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.00	2.0	1.0	12.0	12.0
31	Gallaway	PAVDRN	[illegible]	0.046	71.6	57.9	DGFC	1	0	0.040	1.50	1.0	1.0	12.0	12.0
32	Gallaway	PAVDRN	[illegible]	[illegible]	90.4	58.7	DGFC	1	0	0.040	1.50	2.0	1.0	12.0	12.0
33	Gallaway	PAVDRN	[illegible]	[illegible]	64.3	53.8	DGFC	1	0	0.040	2.00	1.0	1.0	12.0	12.0
34	Gallaway	PAVDRN	[illegible]	[illegible]	75.4	54.4	DGFC	1	0	0.040	2.00	2.0	1.0	12.0	12.0
35	Gallaway	PAVDRN	[illegible]	[illegible]	60.0	51.1	DGFC	1	0	0.040	2.50	1.0	1.0	12.0	12.0
36	Gallaway	PAVDRN	[illegible]	[illegible]	68.4	51.7	DGFC	1	0	0.040	2.50	2.0	1.0	12.0	12.0
37	Gallaway	PAVDRN	[illegible]	[illegible]	57.0	49.1	DGFC	1	0	0.040	3.00	1.0	1.0	12.0	12.0
38	Gallaway	PAVDRN	[illegible]	[illegible]	64.1	49.6	DGFC	1	0	0.040	3.00	2.0	1.0	12.0	12.0
39	Gallaway	PAVDRN	[illegible]	[illegible]	999.0	999.0	DGFC	1	0	0.050	0.50	1.0	1.0	12.0	12.0
40	Gallaway	PAVDRN	[illegible]	-0.002	999.0	999.0	DGFC	1	0	0.050	0.50	2.0	1.0	12.0	12.0
41	Gallaway	PAVDRN	0.001	0.022	151.4	69.9	DGFC	1	0	0.050	1.00	1.0	1.0	12.0	12.0

Use Excel filters to sort through the needed outputs

Lots of results. Provided in a separate worksheet

FDOT's Hydroplaning Prediction Tool

- Analysis Options
  - Deterministic
    - Risk Analysis
    - Basic Analysis
    - Continuous Analysis
  - Sensitivity
  - Probabilistic



Hydroplaning Analysis Tool

General Inputs

FPID: 123456-7
District No.: 2
County: Alachua
Roadway Section Number: 12345
Milepost: 0.800 to 4.000
Direction: North

Analysis Options

Select Analysis Option: Deterministic (Default) : Show intermediate outputs? No

Risk Analysis? (Per FDOT's Design Guidance): No

Continuous Data?: No : For Rut depth, Cross Slope, and/or Texture

WFT & HPS Model Selection

WFT Model	Hydroplaning Speed Model		
	PAVDRN	USF	Gallaway
Gallaway	Y		Y
UK RRL			
NZ Mod.			
PAVDRN			

Notes on WFT and HPS Models
Please select as many models as needed.
Note 1: Risk Analysis is defaulted to Gallaway WFT and PAVDRN HPS models.
Note 2: Continuous Analysis uses only ONE model combination.

Pavement Inputs

Deterministic Analysis

Longitudinal Grade (%): 3
Surface Type: Dense Graded Friction Course
Permeability (in/hr): 0

Pavement Texture (Please Select MTD or MPD below)
Mean Texture Depth (in.): 0.035

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Description	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Cross Slope (%)	2	2	2	2	3	3.5						
Width (ft.)	12	12	12	12	12	12						

Environmental Inputs

Deterministic Analysis

Rainfall Intensity (in/hr): 2.00

Vehicle Inputs

Deterministic Analysis

Tire Pressure (psi): 30 <-- Note: Tire Pressure is only needed for Gallaway and USF HPS models
Spindown (%): 10 <-- Note: Spindown is only needed for Gallaway HPS Model
Tread Depth (in): 0.02 <-- Note: Tread Depth is only needed for Gallaway HPS Model

Analysis Results

Deterministic Analysis

Water Film Thickness (WFT) Table

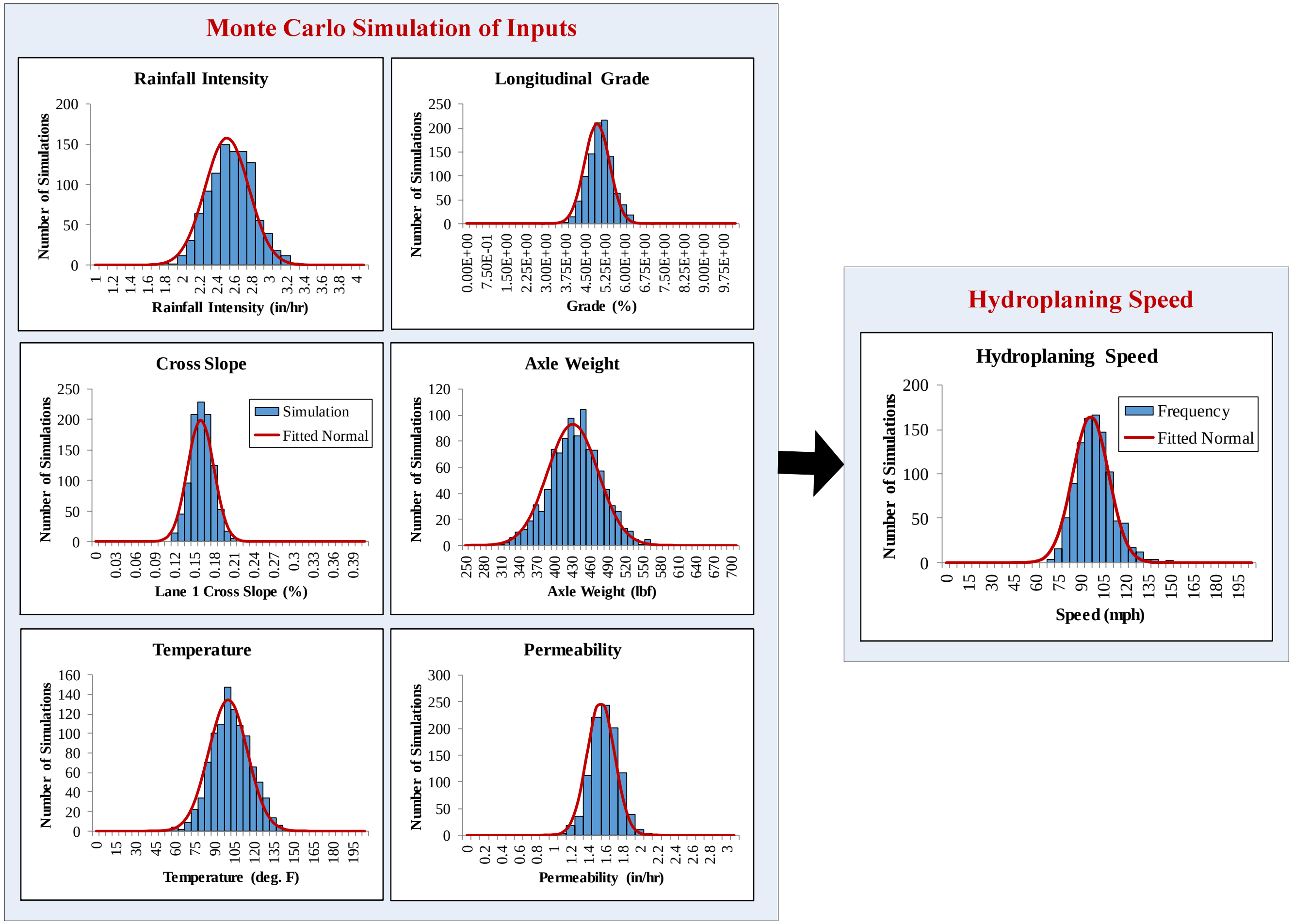
Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Model	Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Gallaway	0.015	0.037	0.054	0.069	0.074	0.081						

Hydroplaning Speed (HPS) Table

Plane Number		1	2	3	4	5	6	7	8	9	10	11	12
Description		Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Hydroplaning Speed													
HPS	WFT												
PAVDRN	Gallaway	76.7	61.0	55.4	52.1	51.1	50.0						
Gallaway	Gallaway	57.5	53.8	52.3	51.3	51.0	50.7						

Probabilistic Analysis

- Are you sure the Rainfall is exactly 2.0 in/hr?



Probabilistic Analysis Inputs

- In terms of Distribution
  - Average (or Mean) & Coefficient of Variation (COV)

Pavement Inputs

Probabilistic Analysis

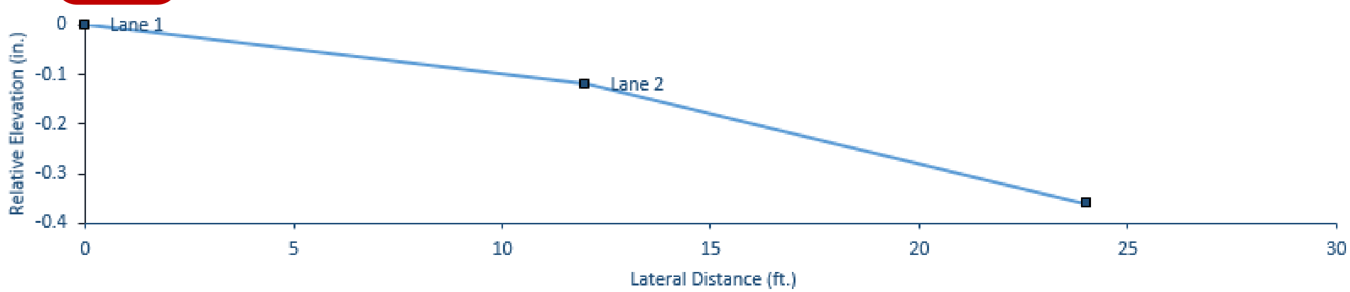
Surface Type: DGFC

Number of Runs: 100

	Avg.	COV (%)
Longitudinal Grade (%)	2	10
Permeability (in/hr)	0	
Mean Texture Depth (in.)	0.035	10

(Please Select MTD or MPD from above Cell)

Plane Number		1	2	3	4	5	6	7	8	9	10	11	12
Description		Lane 1	Lane 2										
Cross Slope	Avg.	1	2										
	COV (%)	10	10										
Width (ft.)	Avg.	12	12										
	COV (%)												



Environmental Inputs

Probabilistic Analysis

	Avg.	COV (%)
Rainfall Intensity (in/hr)	2	10

Click Here to Run Probabilistic Analysis!

Probabilistic Analysis Results

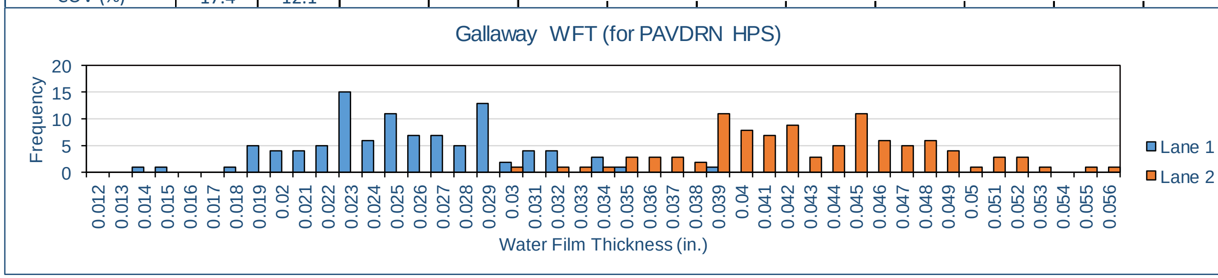
- Also in terms of Distribution

Probabilistic Analysis Results

Water Film Thickness (WFT) Results

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Description	Lane 1	Lane 2										
HPS / WFT												
PAVDRN / Gallaway												
Mean (in.)	0.025	0.043										
Stdev (in.)	0.004	0.005										
COV (%)	17.4	12.1										

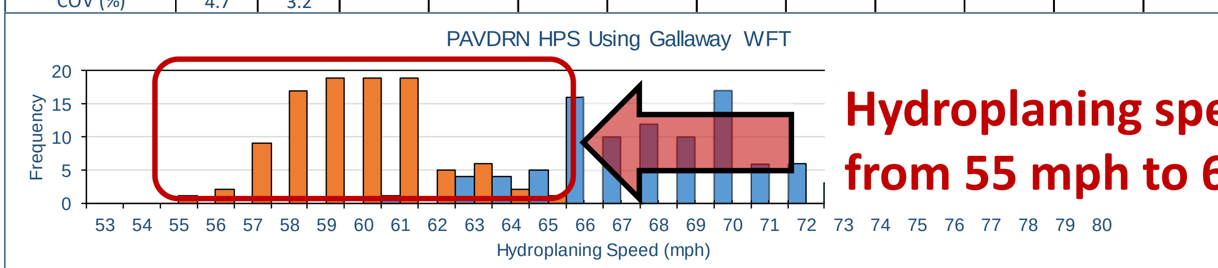
Water Film Thickness Results



Hydroplaning Speed (HPS) Results

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Description	Lane 1	Lane 2										
HPS / WFT												
PAVDRN / Gallaway												
Mean (mph)	68.0	59.1										
Stdev (mph)	3.2	1.9										
COV (%)	4.7	3.2										

Hydroplaning Speed Results



Hydroplaning speed may range from 55 mph to 65 mph

Summary

Dynamic Hydroplaning

- Occurs when there is more water than a tire can push away
- Tire is NOT in contact with pavement
- Most frequent on Roadways

What Affects Hydroplaning?

- Pavement / Roadway Geometry (e.g., Lane Width, Slopes)
- Environmental Conditions (e.g., Rainfall)
- Driver Behavior (e.g., Speed)
- Vehicle Condition (e.g., Tire Pressure, Weight, Tread)

Summary

FDOT’s Hydroplaning Prediction Tool

- Built in MS Excel
- User-Friendly
  - Select Analysis Option
  - Fill in the Inputs
  - Obtain the Results
- Different Analysis Options
  - Understand what you need when you need it
- Consult FDOT’s Hydroplaning Guidance for detailed information and Step-by-Step procedures
- Refer to FDOT’s Design Manual (Section 210.2.4.2) and Drainage Manual (Section 3.9.4) for additional information regarding FDOT’s criteria on calculating hydroplaning risk
- The Hydroplaning Tool and Guidance are available at FDOT’s Roadway Drainage Office Website

Hydroplaning Analysis

Computer Based Training Course

Quiz

Question 1

Q: When hydroplaning occurs, the tire is in contact with the pavement.

a) True

b) False

Question 2

Q: _____________ hydroplaning is the most frequent type of hydroplaning on roadways.

a) Dynamic

b) Viscous

c) Reverted-Rubber

Question 3

Q: Which of the following factors affect Hydroplaning Speed?

a) Pavement / Roadway Geometry

b) Environmental Conditions

c) Driver Behavior

d) Vehicle Condition

e) All of the above

Question 4

Q: FDOT's recommended model for Water Film Thickness is:

a) U.K. Road Research Laboratory Model
b) New Zealand Modified Model
c) Gallaway Model

Question 5

Q: FDOT's recommended model for Hydroplaning Speed is:

a) University of South Florida Model

b) PAVDRN Model

c) U.K. Road Research Laboratory Model

Question 6

Q: Based on FDOT's Design Guidance, Hydroplaning Risk Analysis compares the Hydroplaning Speed against the _______________.

a) Design Speed

b) Speed Limit

c) Predicted Driver Speed

Question 7

Q: You are running FDOT's Hydroplaning Risk Analysis. The results show that the Predicted Driver Speed 60 mph. The Hydroplaning Speed is found to be 50 mph. According to FDOT's Design Guidance, this pavement is safe and hence accepted.

a) True

b) False

Question 8

Q: Which of the following is NOT an input into the Hydroplaning Prediction tool?

a) Rainfall Intensity

b) Pavement Width

c) Pavement Cross-Slope

d) Speed Limit

Question 9

Q: Which of the following is NOT an output from the Hydroplaning Prediction tool?

a) Rainfall Intensity

b) Water Film Thickness

c) Hydroplaning Speed

d) Both (b) and (c)

Question 10

Q: Which Analysis Option in the Hydroplaning Prediction tool should you choose when you want to run a batch of Deterministic Inputs?

a) No Options available

b) Sensitivity Analysis Option

c) Probabilistic Analysis Option

End of CBT