TTI: 0-6896

Developing a Surface Drainage Rating for Inclusion in TxDOT's Asset Management System: Presentation

Technical Report 0-6896-P1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/documents/0-6896-P1.pdf

DEVELOPING A SURFACE DRAINAGE RATING FOR INCLUSION IN TXDOT'S ASSET MANAGEMENT SYSTEM: PRESENTATION

by

Charles F. Gurganus
Associate Research Engineer
Texas A&M Transportation Institute

Product 0-6896-P1
Project 0-6896
Project Title: Developing a Surface Drainage Rating for Inclusion in TxDOT's Asset Management System

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: January 2019

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The authors thank the project director, members of the Project Monitoring Committee, and state and federal sponsors.

Developing a Surface Drainage Rating for Inclusion in TxDOT's Asset Management System
TxDOT Project 0-6896

Project Close Out Meeting

November 21, 2017

Abstract

Develop a drainage rating system aided by the collection of data through automated means. Test this system on a range of TxDOT's network to determine adequacy. Illustrate the use of drainage information at both the network and project levels.

Project Evolution

- Mobile LiDAR returns a measurement when it impacts a surface
- Roadway design balances safety and drainage with safety held paramount
  - Design standards are used as a baseline for rating
  - Design standards do not always benefit drainage
- A surface drainage project by its nature becomes a surface geometric project
  - Can include an evaluation of design compliance

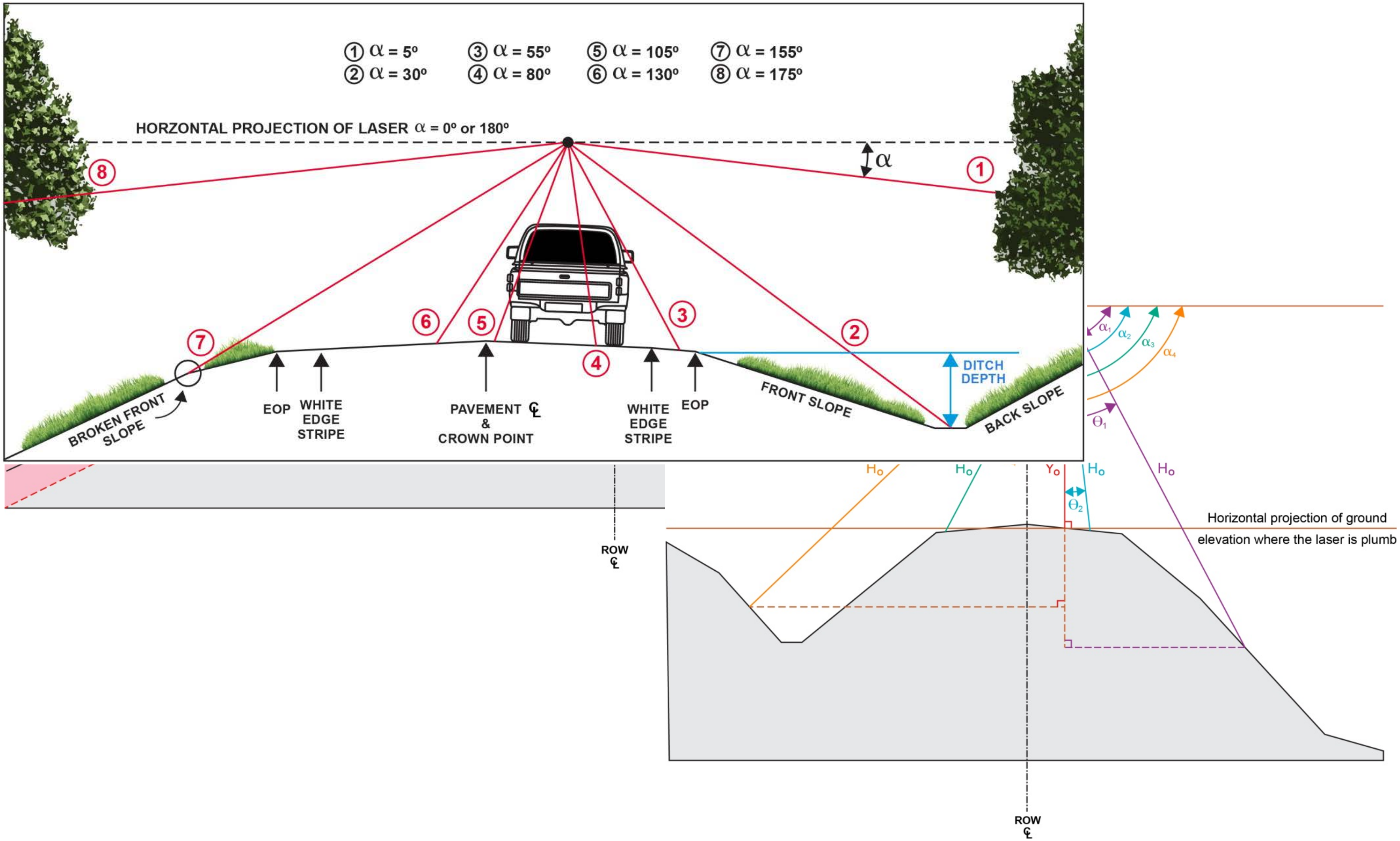
Mobile LiDAR Systems

- Components
  - Vehicle: in-vehicle computer and software, laser, GPS, inertial measurement unit (IMU), accelerometer, camera, DMI
  - Desktop: post-processing software

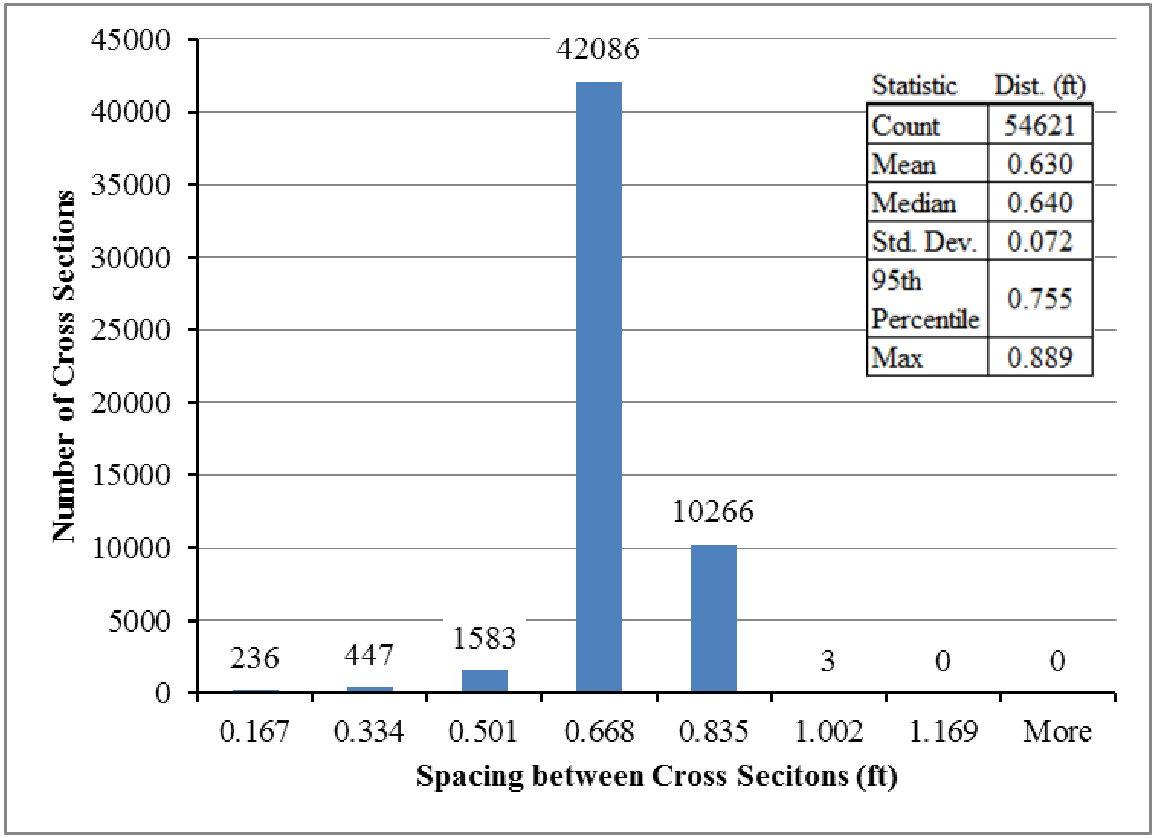
TTI Mobile LiDAR Unit

- Hardware and software manufactured by Roadscanners Oy of Finland

Mobile LiDAR Data Collection Basics



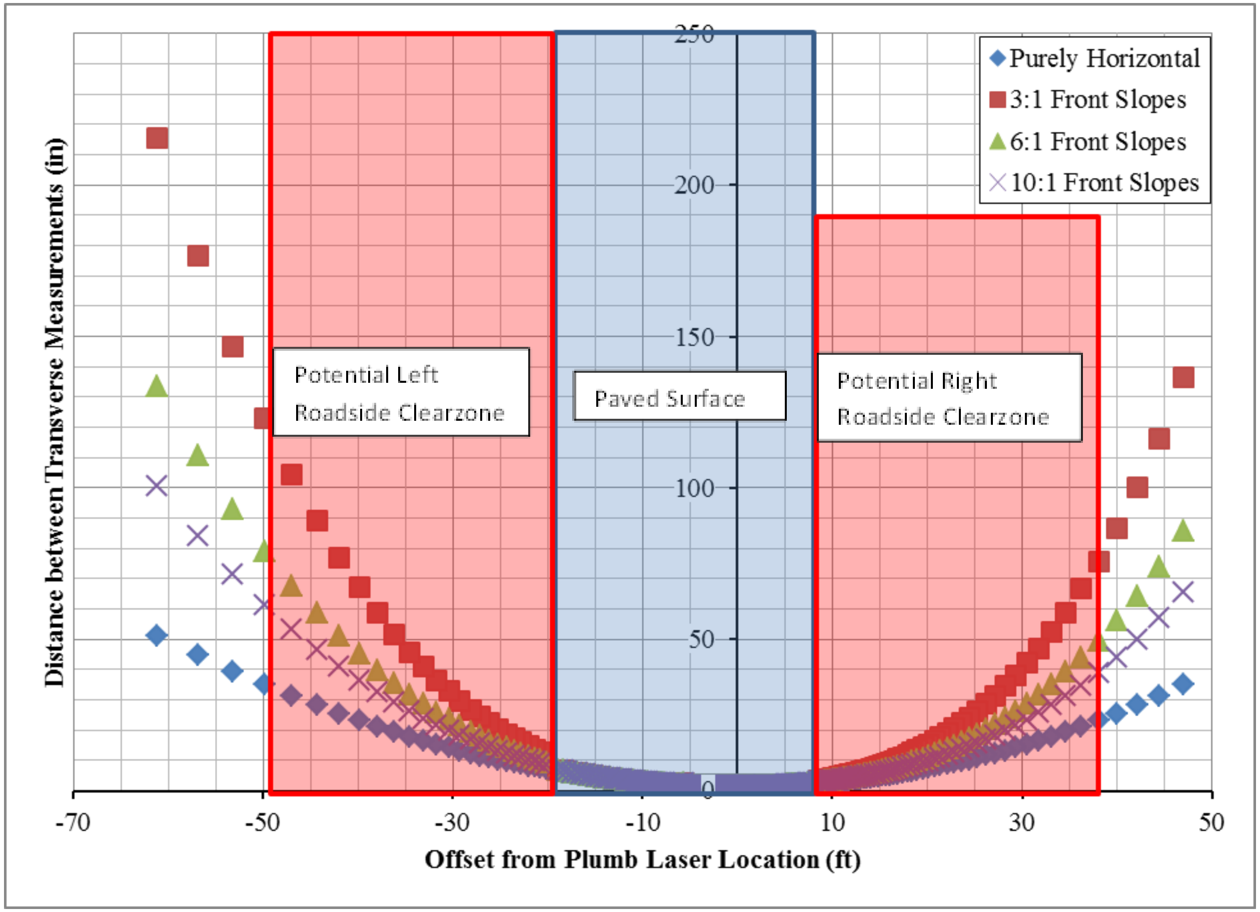
Longitudinal Spacing



Statistic	Dist. (ft)
Count	54621
Mean	0.630
Median	0.640
Std. Dev.	0.072
95th Percentile	0.755
Max	0.889

- Spacing between strings of data at approximately 8 inches at 45 mph

Transverse Spacing



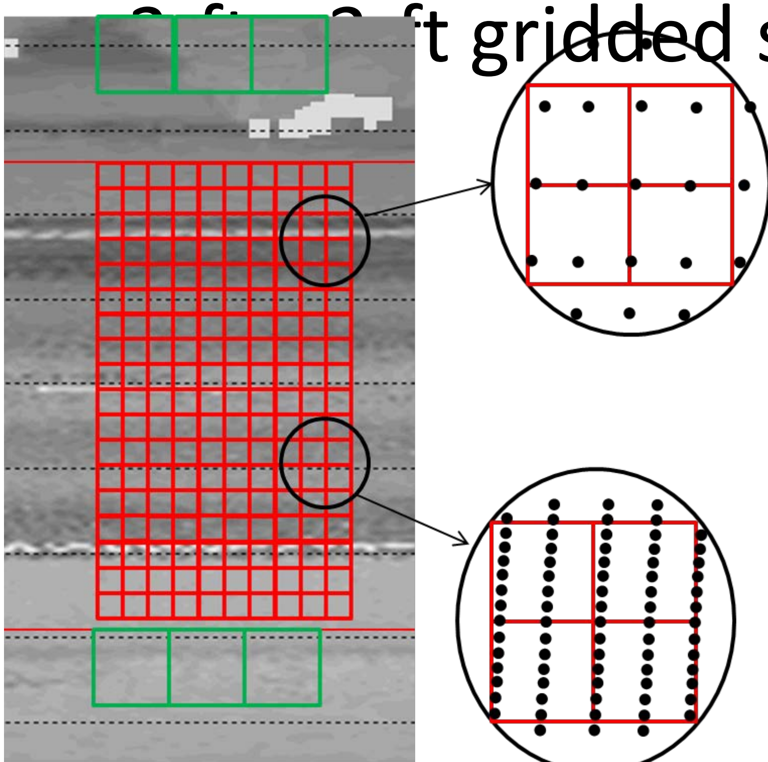
- Transverse spacing on paved surface is typically less than 10 inch spacing.
- Spacing is less than 3 inches across the data collection lane
- Adjacent to the data collection direction spacing between point is typically within 4-ft

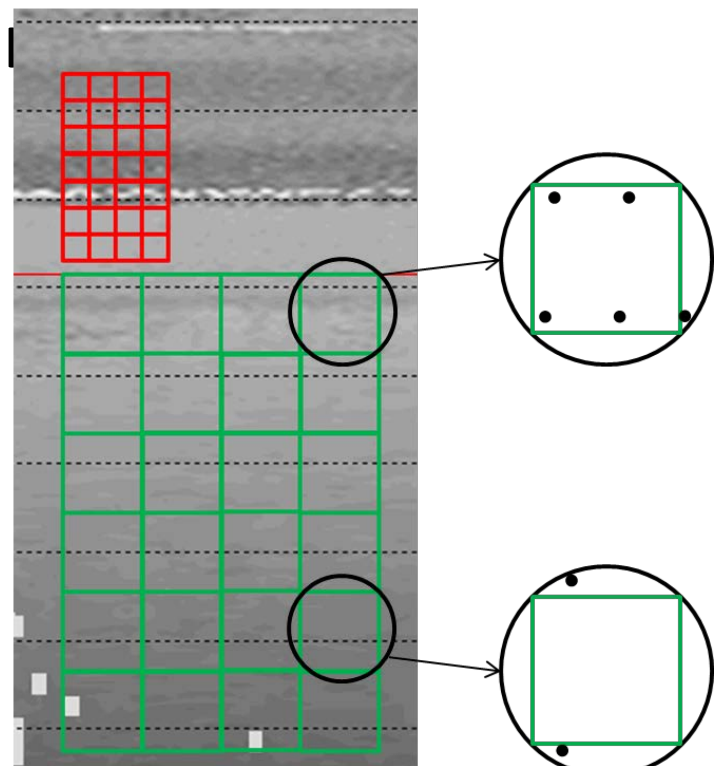
Transverse Spacing on Different Paved Geometry

No. Thru Lanes	Potential Roadway Type	Paved Width (ft)	Lane Configuration	Data Collection Lane	Distance between Transverse Measurments at Specific Locations (inches)		
					LT Edge of Pavement	Middle of Lanes	RT Edge of Pavement
2	One roadbed of a divided hwy	38	4'/12'/12'/10' (Shld./2 Lanes/Shld.)	Outside Lane	7.75	3.70/1.50	4.60
4	Opposing traffic with no median or single direction multi-lane facility	56	4'/48'/4' (Shld./4 Lanes/Shld.)	Outside Lane	25.37	18.08/9.50/3.70/1.50	2.77
4	Opposing traffic with no median; 4 lane single direction multi-lane facility	56	4'/48'/4' (Shld./4 Lanes/Shld.)	Inside Lane	14.8	8.57/3.46/1.50/3.47	7.21
3	Super-2 or passing lane in a single direction; 3 lane single direction facility	50	10'/36'/4' (Shld./3 Lanes/Shld.)	Outside Lane	21.26	9.00/3.70/1.50	2.77
3	Super-2 or passing lane in a single direction; 3 lane single direction facility	50	10'/36'/4' (Shld./3 Lanes/Shld.)	Inside Lane	10.7	3.46/1.50/3.47	7.21
3	Super-2 or passing lane in a single direction; 3 lane single direction facility	50	10'/36'/4' (Shld./3 Lanes/Shld.)	Single lane direction	14.8	8.57/3.46/1.50	4.6
5	5 lane single direction facility; two-way traffic with a flush median or turn lane.	74	4'/60'/10' (Shld./5 Lanes/Shld.)	Middle Lane	18.59	10.62/3.70/1.50/3.47/9.32	28.51
5	5 lane single direction facility; two-way traffic with a flush median or turn lane.	74	4'/60'/10' (Shld./5 Lanes/Shld.)	Outside Lane	54.36	36.86/22.07/10.62/3.70/1.50	4.77
5	Crowned two-way traffic with flush median or turn lane	82	10'/24'/14'/24'/10' (Shld./2 Lanes/Turn Lane/2 Lanes/Shld)	Inside Lane	33.49	19.16/10.39/4.05/1.50/3.47	11.1

Conversion of Raw LiDAR Data to Gridded Data

- 1-ft x 1-ft gridded surface for paved area
- ft gridded surface for





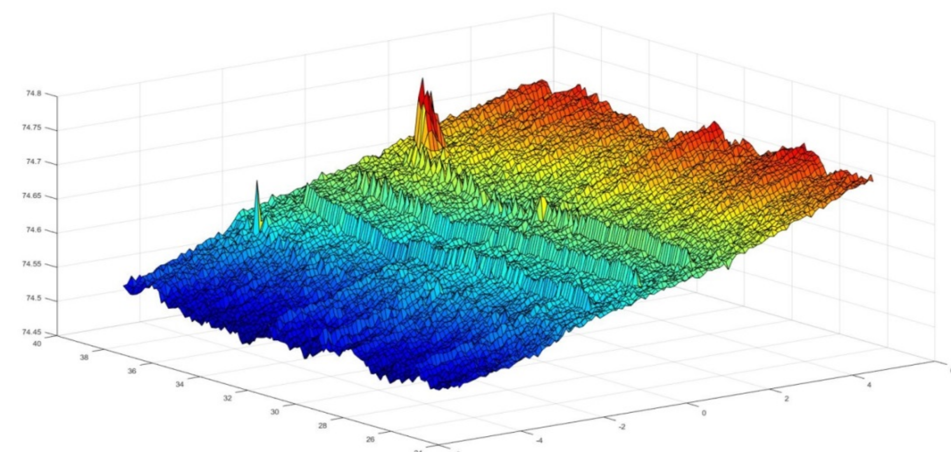
Mobile LiDAR Accuracy within Study

- Individual components, such as the inner workings of the laser, are certified as accurate and precise by the manufacturer
- Focus of accuracy is on roadway elements
- Often requires some processing of the data

Mobile LiDAR Accuracy for Rated Elements

- Longitudinal length: within± ±0.15% of actual length
  - ± 1.8 inches in every 100-ft
- Data collection lane cross slope: ± 0.05% and ±0.10%
- Adjacent lane cross slope: ± 0.20%
- Adjacent to data collection lane front slope steepness: ±0.5H:1V
  - Typically flatter
  - More variable on the opposite roadside
- Ditch offsets are measured within the 3-ft window of the grid
- Ditch depths are typically more shallow due to vegetation. Depth differences can typically be explained by vegetation height on roadside adjacent to data collection lane
- Rut depth in data collection lane: ±0.05 inches

Example of Accuracy Check



Network Level Elements

- Traveled way width
- Travel lane cross slope
- Hydroplaning potential
- Front slope steepness
- Ditch depth
- Ditch flowline steepness

Requires additional processing (manual)

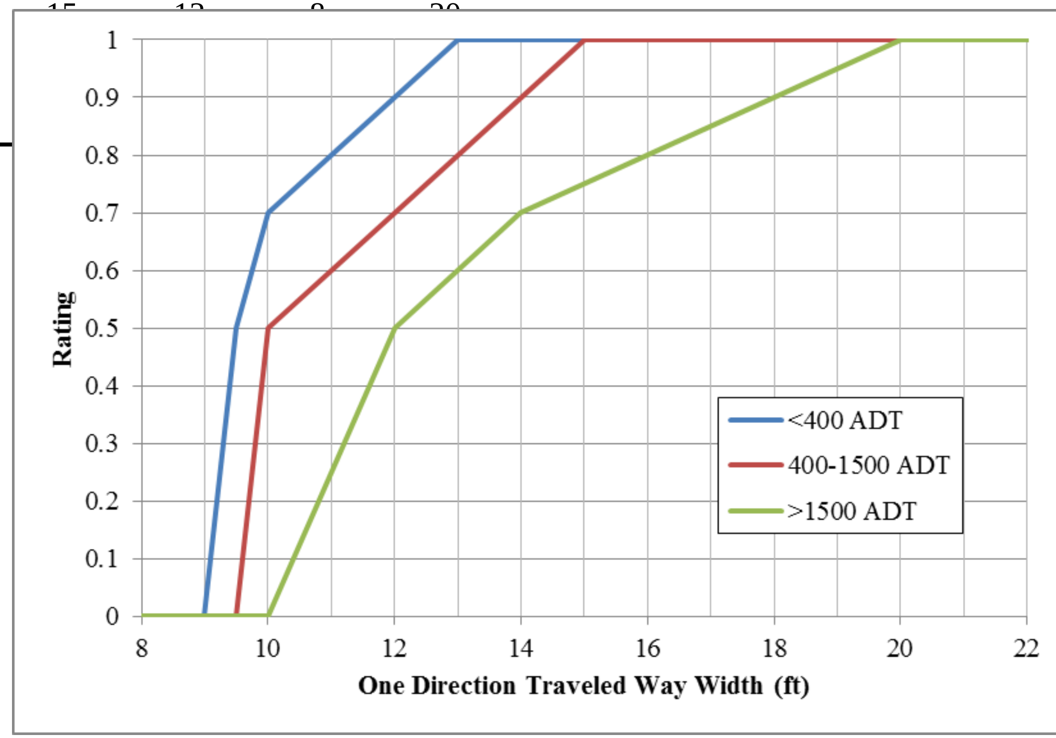
- Curb height (if applicable)
- Outside lane ponding in C&G sections
- Edge condition
- Intersection radii
- Non-uniform cross section
- Inlet condition

Parallel and cross structures require manual inspection.

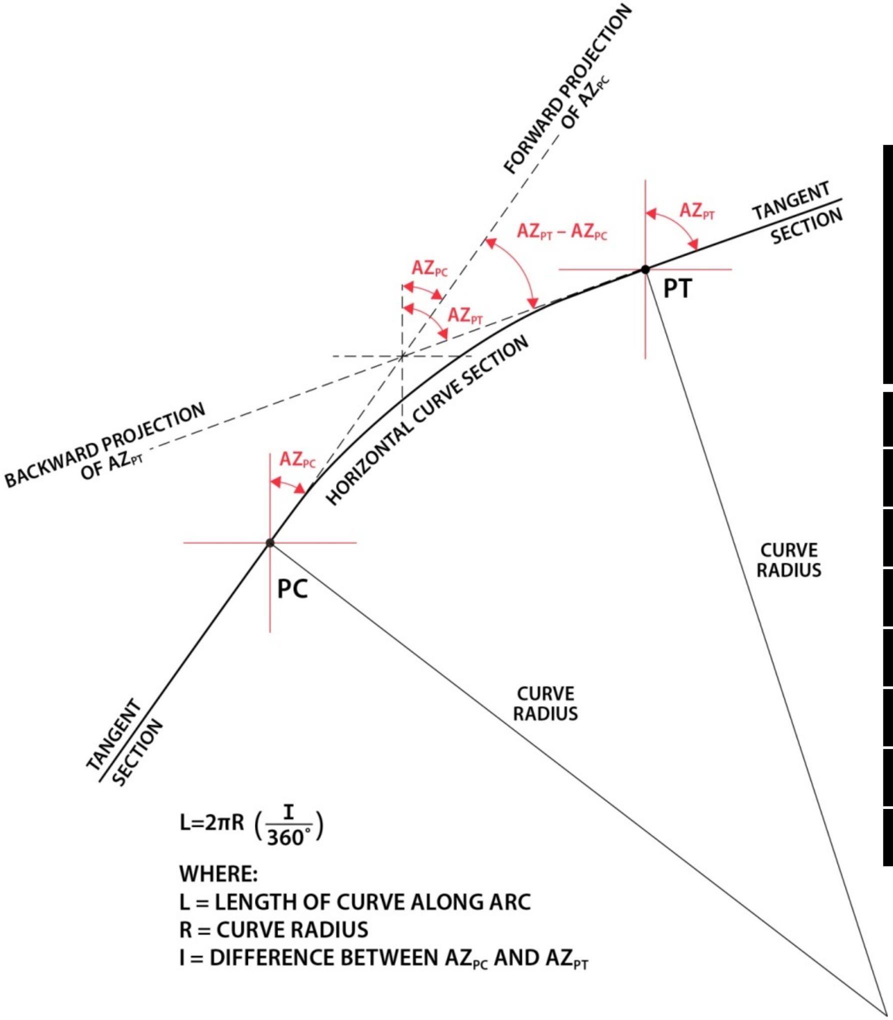
Network Level Elements: Lane Width

- Based on 3R and 4R design requirements

Rating	<400 ADT			400-1500 ADT			>1500 ADT		
	Lane Width (ft)	Shld. Width (ft)	Tot. Width (ft)	Lane Width (ft)	Shld. Width (ft)	Tot. Width (ft)	Lane Width (ft)	Shld. Width (ft)	Tot. Width (ft)
1.0	11	2	13	11	4	[illegible]	[illegible]	[illegible]	[illegible]
0.7	10	0	10	11	1	[illegible]	[illegible]	[illegible]	[illegible]
0.5	9.5	0	9.5	10	0	[illegible]	[illegible]	[illegible]	[illegible]
0.0	9	0	9	9.5	0	[illegible]	[illegible]	[illegible]	[illegible]



Network Level Elements: Cross Slope



$$L=2\pi R\left(\frac{I}{360^\circ}\right)$$

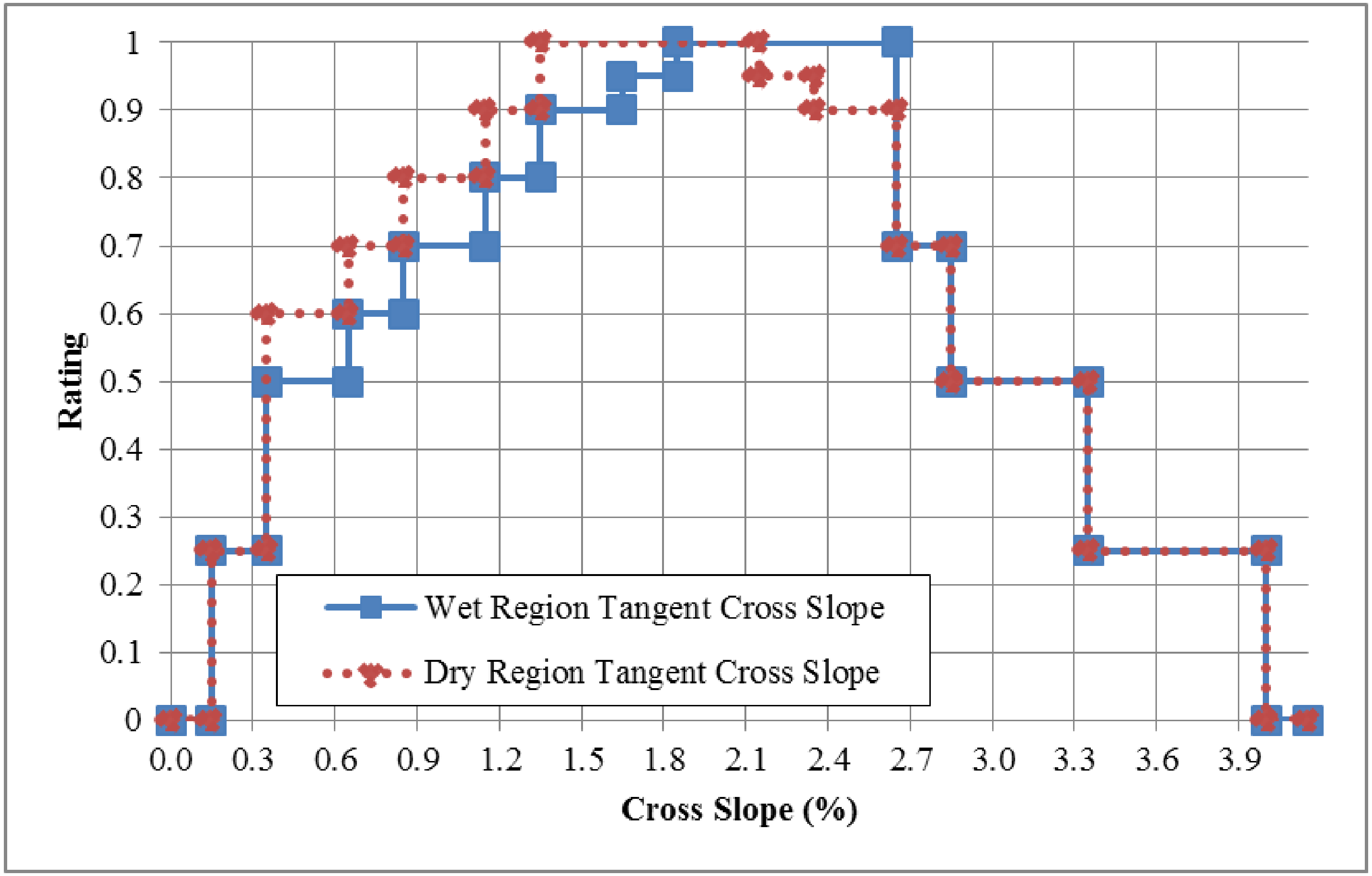
WHERE:
L = LENGTH OF CURVE ALONG ARC
R = CURVE RADIUS
I = DIFFERENCE BETWEEN AZ_{PC} AND AZ_{PT}

Design Speed	6% Superelevation		8% Superelevation	
	Min. Radius (ft)	Azimuth Δ in 528 ft	Min. Radius (ft)	Azimuth Δ in 528 ft
45	6,480	4.67	6,710	4.51
50	7,870	3.84	8,150	3.71
55	9,410	3.21	9,720	3.11
60	11,100	2.73	11,500	2.63
65	12,600	2.40	12,900	2.35
70	14,100	2.15	14,500	2.09
75	15,700	1.93	16,100	1.88
80	17,400	1.74	17,800	1.70

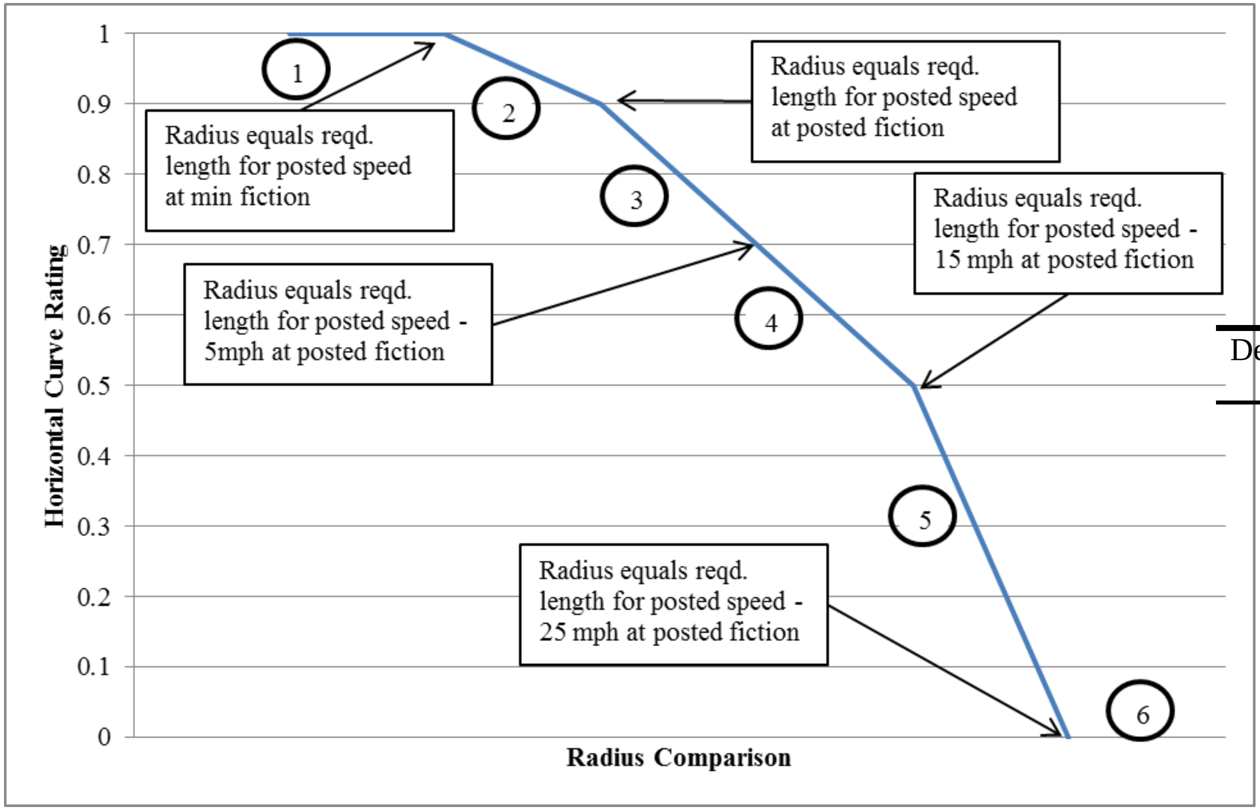
Network Level Elements: Cross Slope

- Within a 0.1-mile data collection section, 528 cross sections exist
- Check the expected location of the highpoint to determine if the section is in-shape
  - Out of shape sections receive a 0.0 rating
- A 50% threshold is required to classify a section as in-shape

Network Level Elements: Tangent Cross Slope



Network Level Elements: Curve Cross Slope

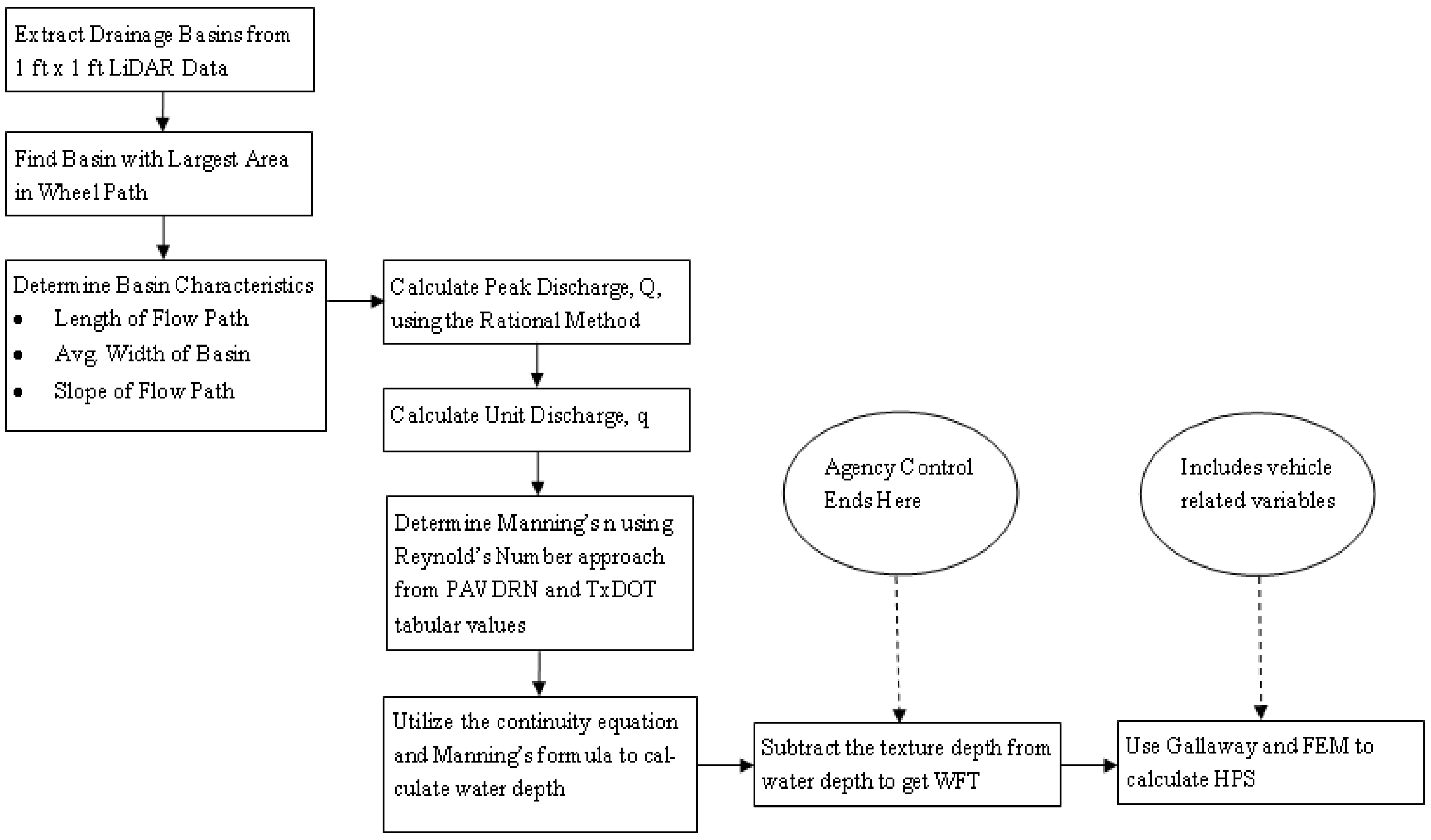


$$e + f = \frac{V^2}{15R}$$

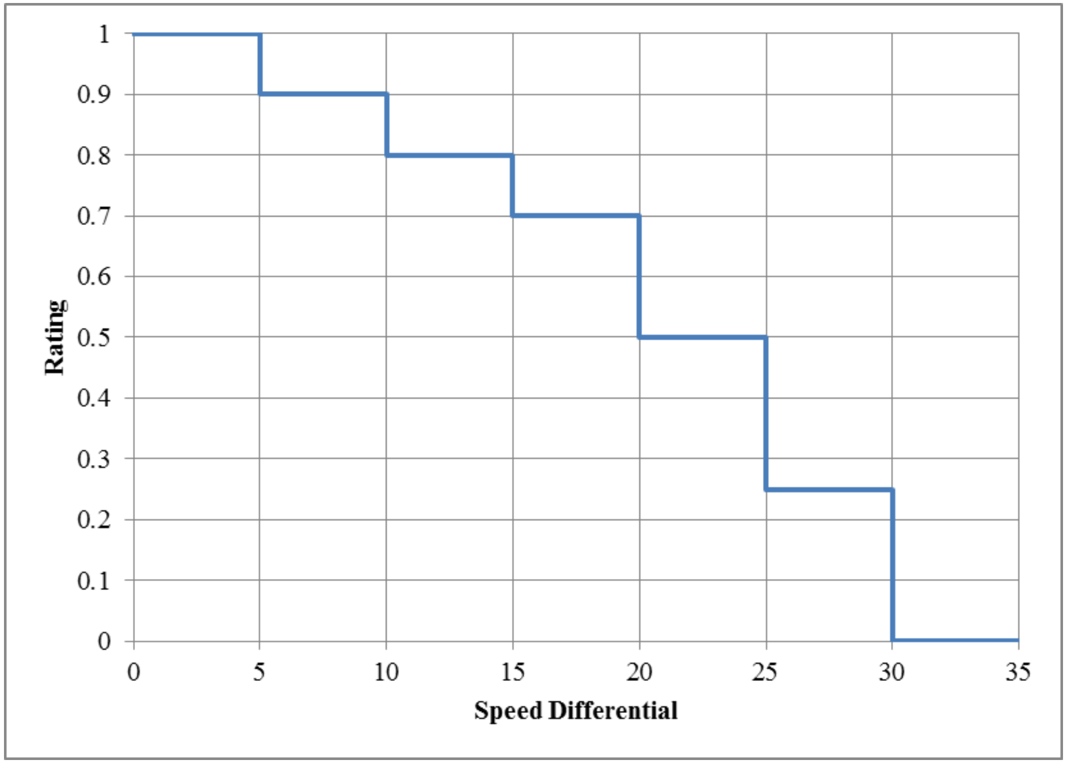
$$L = 2\pi R\left(\frac{I}{360°}\right)$$

Design Speed (mph)	Max Side Friction factor, ***f***
45	0.15
50	0.14
55	0.13
60	0.12
65	0.11
70	0.10
75	0.09
80	0.08

Network Level Elements: Hydroplaning Potential

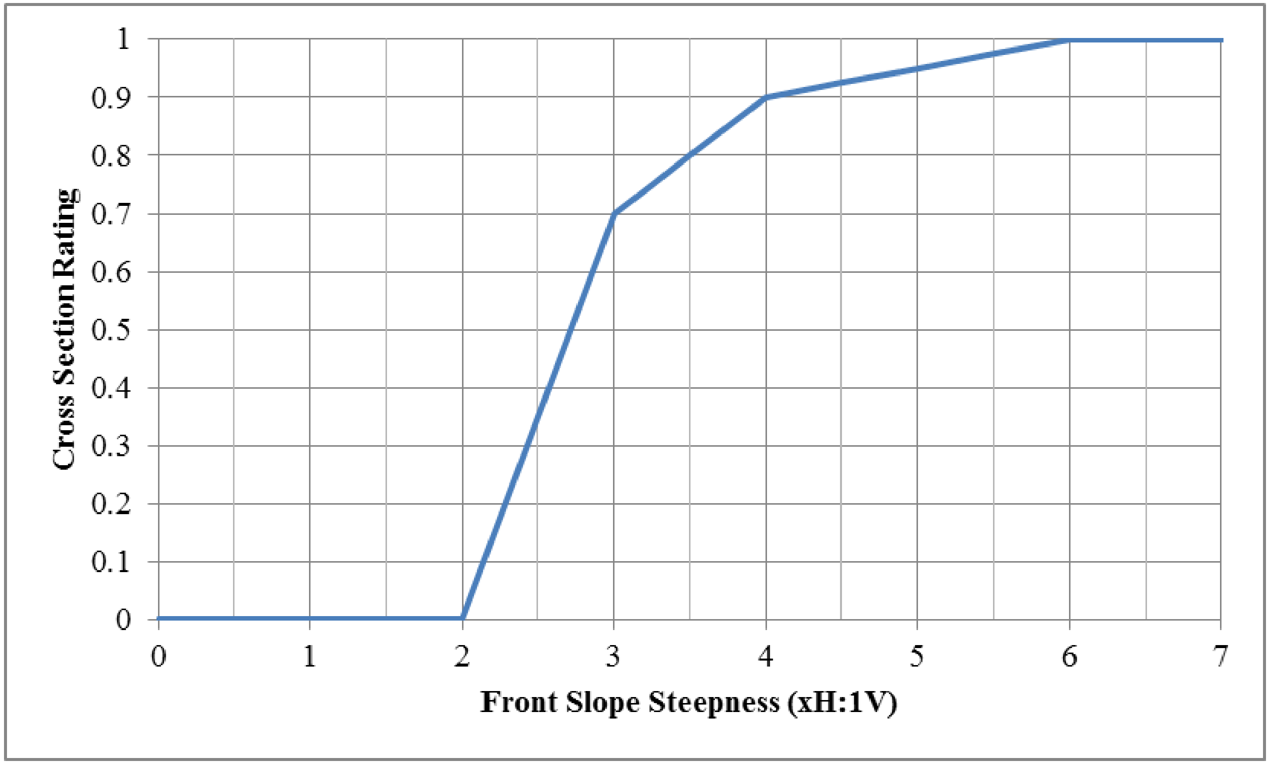


Network Level Elements: Hydroplaning Potential



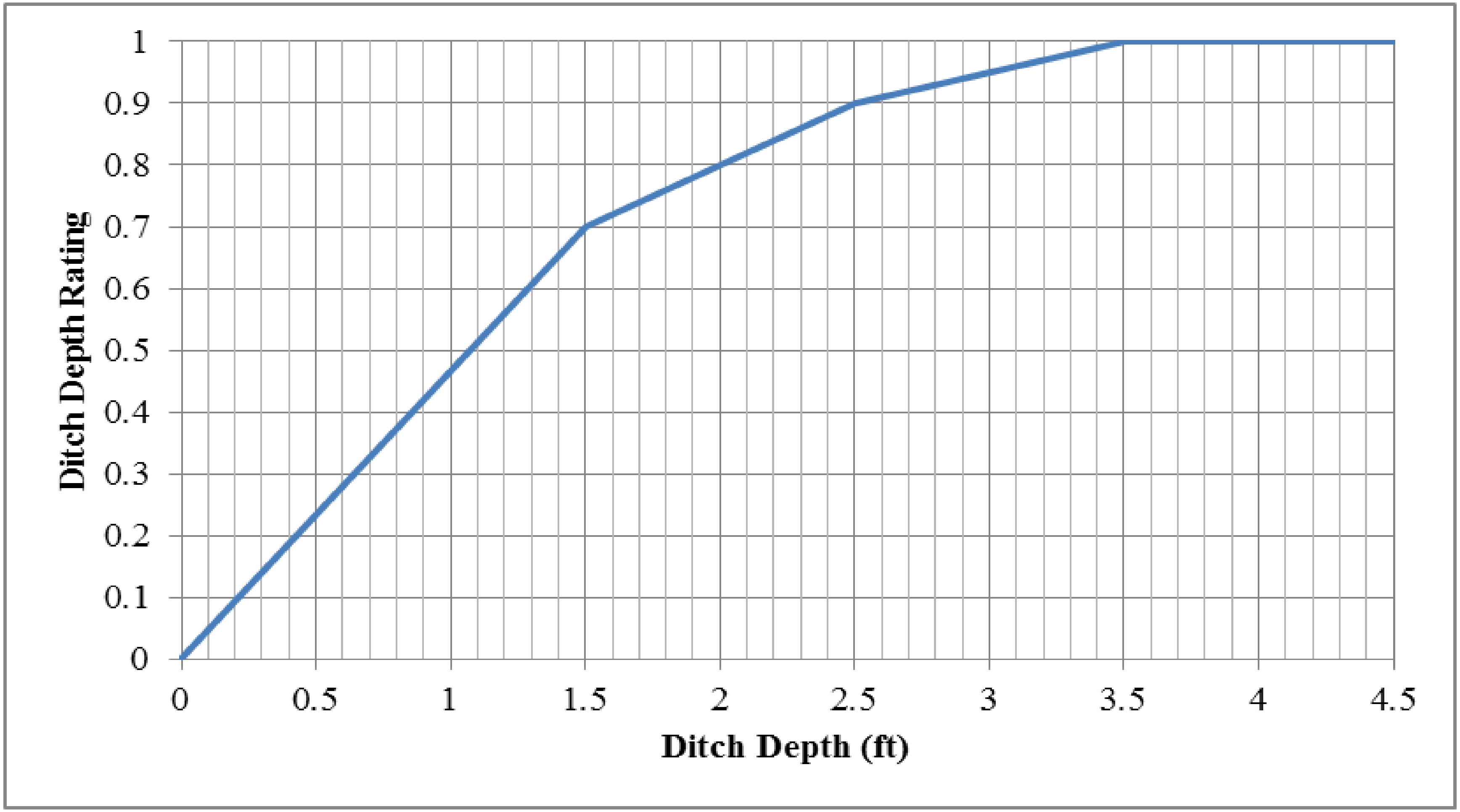
- Monte Carlo simulation for variables within HPS equations
  - AADT used for number of iterations
- Compare against posted speed limit
- Potential reduction in speed of 3 mph to 6 mph in heavy rain

Network Level Elements: Front Slope Steepness

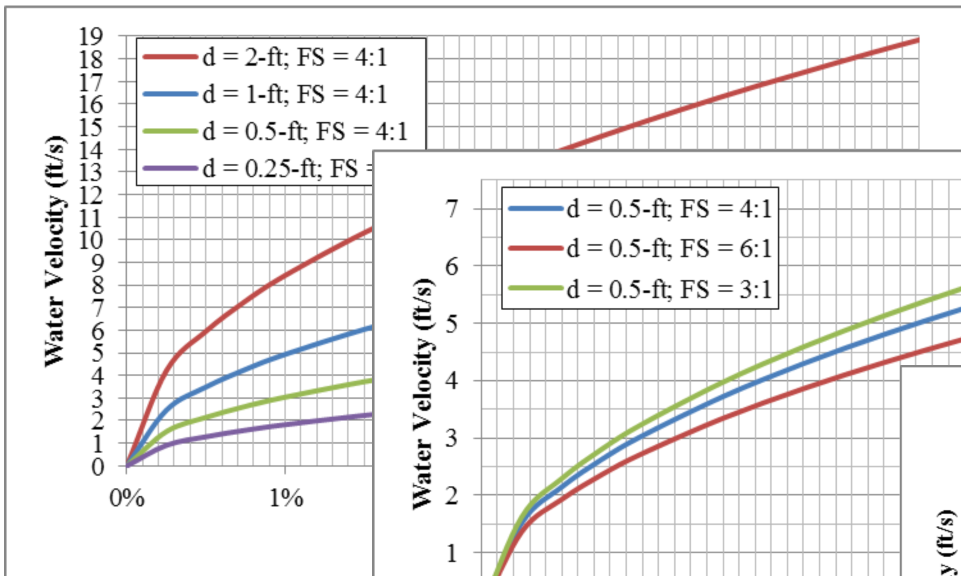


- TxDOT Roadway Design Manual: 1/3 of fatalities associated with single vehicle run-off-the-road
- AASHTO Roadside Design Guide:
    - 1V:4H considered recoverable
    - 1V:3H considered traversable but non-recoverable
    - Steeper considered critical
- 1V:6H is a typical slope within TxDOT

Network Level Elements: Ditch Depth

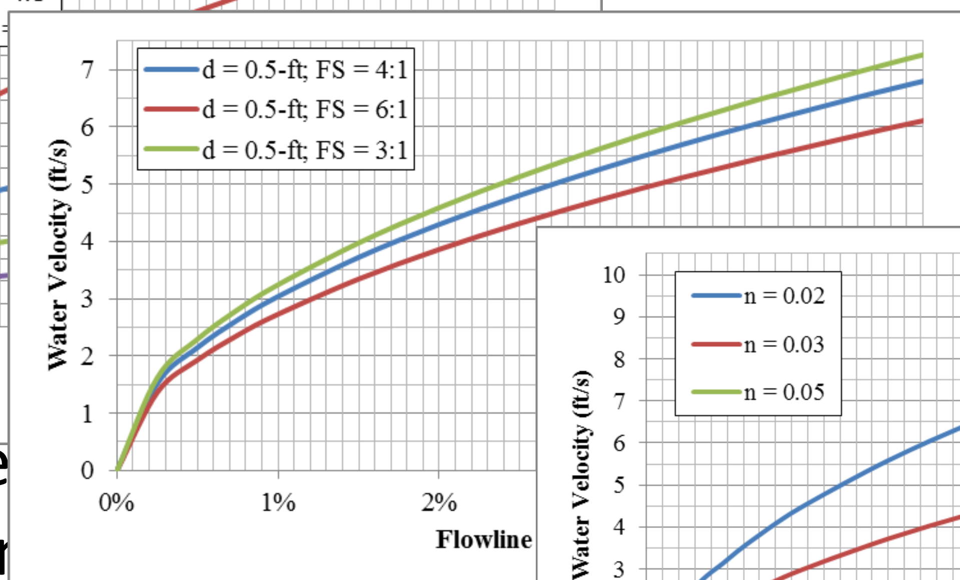


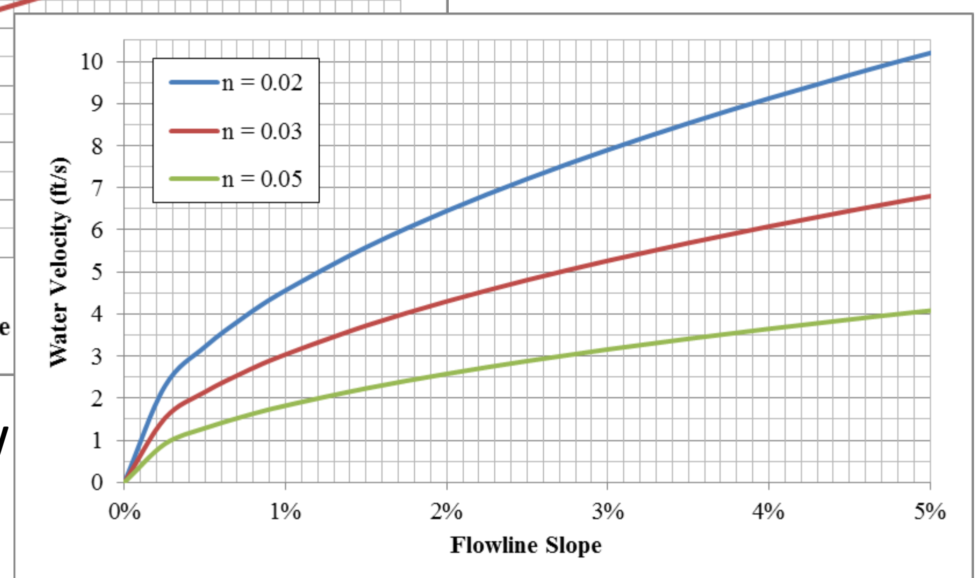
Network Level Elements: Ditch Flowline Grade



…ly based on “too

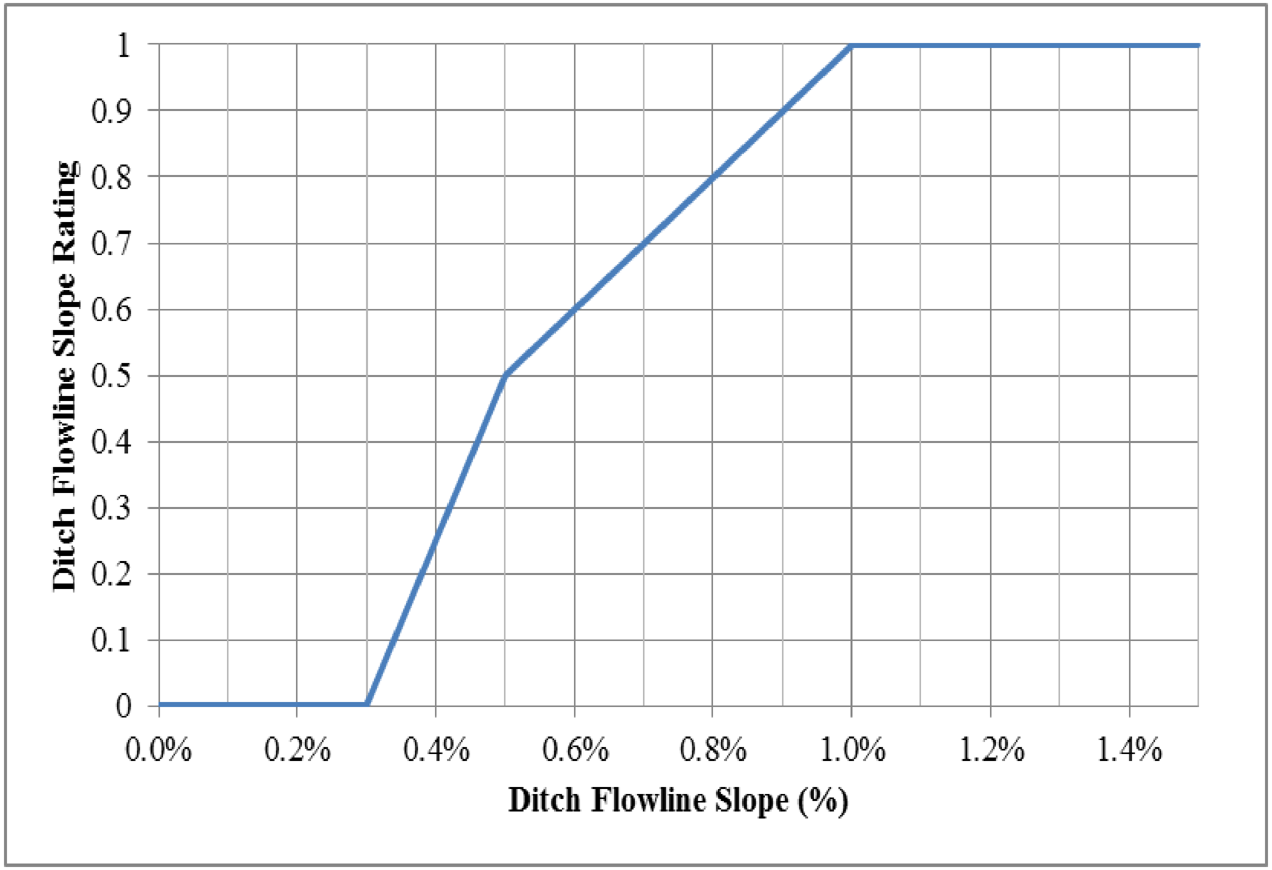
…en a





– Stee…
quar…
- Amount of water flow … unknown

Network Level Elements: Ditch Flowline Grade



Surface Drainage Rating Summary

					Roadway Surface				Roadside Surface						
Begin TRM	End TRM	Section	Alignment Classificaiton	Section Shape	RT Width Rating	RT Cross Slope Rating	RT Hydro-planing Rating	RT Roadside Shape	RT Front Slope Rating	RT Ditch Depth Rating	RT Ditch Slope Rating	Combined Paved Surface Rating	Combined Roadside Rating	Overall Drainage Rating	**Overall Rating Normalized to 100**

Each contribute 1/3 (RT Width Rating, RT Cross Slope Rating, RT Hydro-planing Rating → Combined Paved Surface Rating)

Each contribute 1/3 (RT Front Slope Rating, RT Ditch Depth Rating, RT Ditch Slope Rating → Combined Roadside Rating)

Overall Drainage Rating: Evenly constructed from Roadway and Roadside

Application of Surface Drainage Rating

- Applied to rural sections with both roadway and roadside elements
- Applied only in the data collection direction
- Proof of concept code developed to create the rating with little manual intervention
  - This is a primary reason for application only to rural roadways
- Applied to 73.5 miles of roadway in the Atlanta, Bryan, Corpus Christi, and Tyler Districts

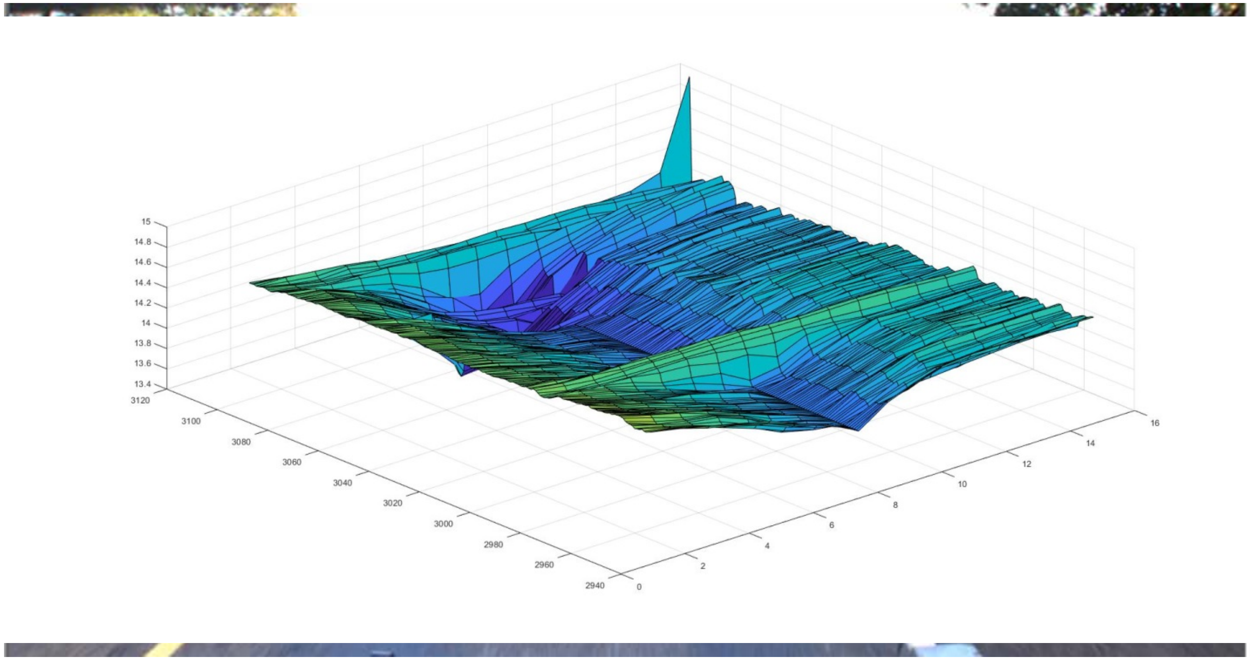
FM 31 Example Rating Sheet

Section 26:

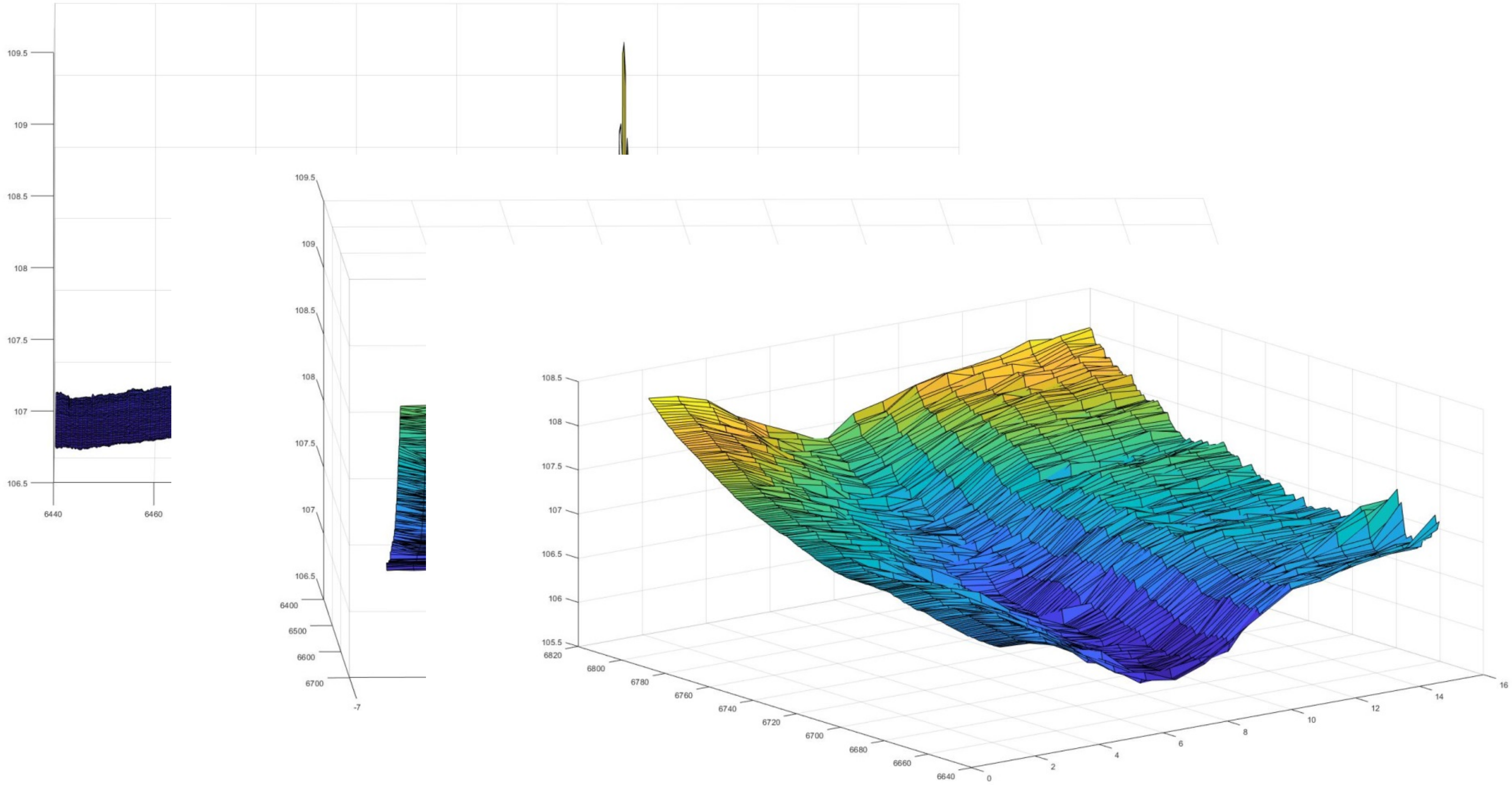
- 68 Overall Rating
  - 60 paved surface rating
  - 75 roadside rating
- Paved surface rating affected by out of shape section and narrowness
- Roadside rating affected by shallow ditch with flat flowline slope

					Roadway Surface				Roadside Surface						
Begin TRM	End TRM	Section	Alignment Classificaiton	Section Shape	RT Width Rating	RT Cross Slope Rating	Hydro-planing Rating	RT Roadside Shape	RT Front Slope Rating	RT Ditch Depth Rating	RT Ditch Slope Rating	Combined Paved Surface Rating	Combined Roadside Rating	Overall Drainage Rating	Overall Rating Normalized to 100
280.0	280.1	1	TANGENT	TANGENT	0.86	0.93	1.00	Primarily Ditch	1.00	0.90	1.00	0.93	0.97	0.95	95
280.1	280.2	2	TANGENT	TANGENT	0.86	0.87	1.00	Primarily Ditch	1.00	0.86	1.00	0.91	0.95	0.93	93
280.2	280.3	3	RTCURVE	OUT OF SHAPE	0.85	0.00	1.00	Primarily Ditch	1.00	0.82	1.00	0.62	0.94	0.78	78
280.3	280.4	4	TANGENT	TANGENT	0.84	0.90	1.00	Primarily Ditch	1.00	0.99	1.00	0.91	1.00	0.96	96
280.4	280.5	5	TANGENT	TANGENT	0.86	0.79	1.00	Primarily FS	1.00	0.93	1.00	0.88	0.97	0.93	93
280.5	280.6	6	TANGENT	TANGENT	0.82	0.80	1.00	Primarily FS	1.00	1.00	1.00	0.87	1.00	0.94	94
280.6	280.7	7	TANGENT	TANGENT	0.81	0.67	1.00	Primarily Ditch	0.94	1.00	1.00	0.83	0.98	0.90	90
280.7	280.8	8	TANGENT	TANGENT	0.84	0.76	1.00	Primarily Ditch	1.00	0.72	1.00	0.87	0.91	0.89	89
280.8	280.9	9	TANGENT	OUT OF SHAPE	0.91	0.00	1.00	Primarily Ditch	1.00	0.98	1.00	0.64	0.99	0.82	82
280.9	281.0	10	TANGENT	OUT OF SHAPE	0.81	0.00	1.00	Primarily Ditch	1.00	0.97	1.00	0.60	0.99	0.80	80
281.0	281.1	11	TANGENT	OUT OF SHAPE	0.88	0.00	1.00	Primarily Ditch	1.00	0.87	1.00	0.63	0.96	0.79	79
281.1	281.2	12	TANGENT	OUT OF SHAPE	0.81	0.00	1.00	Primarily Ditch	0.99	0.70	1.00	0.60	0.90	0.75	75
281.2	281.3	13	TANGENT	OUT OF SHAPE	0.85	0.00	1.00	Primarily Ditch	0.99	0.91	1.00	0.62	0.97	0.79	79
281.3	281.4	14	LTCURVE	OUT OF SHAPE	0.88	0.00	1.00	Primarily Ditch	1.00	0.85	1.00	0.63	0.95	0.79	79
281.4	281.5	15	TANGENT	TANGENT	0.90	0.60	1.00	Primarily Ditch	1.00	0.81	0.94	0.83	0.92	0.87	87
281.5	281.6	16	TANGENT	TANGENT	0.95	0.90	1.00	Primarily Ditch	0.99	0.72	1.00	0.95	0.91	0.93	93
281.6	281.7	17	TANGENT	OUT OF SHAPE	0.89	0.00	1.00	Primarily Ditch	1.00	0.92	1.00	0.63	0.97	0.80	80
281.7	281.8	18	TANGENT	TANGENT	0.88	0.83	1.00	Primarily Ditch	0.98	0.97	1.00	0.90	0.98	0.94	94
281.8	281.9	19	TANGENT	OUT OF SHAPE	0.89	0.00	1.00	Primarily Ditch	1.00	0.79	1.00	0.63	0.93	0.78	78
281.9	282.0	20	TANGENT	TANGENT	0.86	0.52	1.00	Primarily Ditch	1.00	0.86	1.00	0.79	0.95	0.87	87
282.0	282.1	21	TANGENT	TANGENT	0.86	0.76	1.00	Primarily Ditch	1.00	0.78	1.00	0.87	0.93	0.90	90
282.1	282.2	22	TANGENT	OUT OF SHAPE	0.86	0.00	1.00	Primarily Ditch	1.00	0.80	0.83	0.62	0.88	0.75	75
282.2	282.3	23	TANGENT	OUT OF SHAPE	0.96	0.00	1.00	Primarily Ditch	0.99	0.78	0.99	0.65	0.92	0.79	79
282.3	282.4	24	TANGENT	OUT OF SHAPE	0.76	0.00	1.00	Primarily Ditch	1.00	0.76	0.83	0.59	0.86	0.73	73
282.4	282.5	25	TANGENT	OUT OF SHAPE	0.83	0.00	1.00	Primarily Ditch	0.99	0.81	0.56	0.61	0.79	0.70	70
282.5	282.6	26	TANGENT	OUT OF SHAPE	0.81	0.00	1.00	Primarily Ditch	0.99	0.71	0.54	0.60	0.75	0.68	68
282.6	282.7	27	TANGENT	OUT OF SHAPE	0.82	0.00	1.00	Primarily Ditch	0.99	0.84	1.00	0.61	0.95	0.78	78
282.7	282.8	28	TANGENT	CURVE TRANS	0.78	0.50	1.00	Primarily Ditch	0.98	0.90	1.00	0.76	0.96	0.86	86
282.8	282.9	29	TANGENT	CURVE TRANS	0.81	0.50	1.00	Primarily Ditch	0.97	0.76	1.00	0.77	0.91	0.84	84
282.9	283.0	30	RTCURVE	RT CURVE	0.70	1.00	1.00	Primarily Ditch	0.99	1.00	1.00	0.90	1.00	0.95	95
283.0	283.1	31	TANGENT	CURVE TRANS	0.72	0.50	1.00	Primarily Ditch	1.00	0.73	1.00	0.74	0.91	0.83	83
283.1	283.2	32	TANGENT	OUT OF SHAPE	0.70	0.00	1.00	Primarily Ditch	1.00	0.90	1.00	0.57	0.97	0.77	77
283.2	283.3	33	TANGENT	CURVE TRANS	0.73	0.50	1.00	Primarily Ditch	1.00	0.77	1.00	0.74	0.92	0.83	83
283.3	283.4	34	LTCURVE	LT CURVE	0.78	1.00	1.00	Primarily Ditch	0.99	0.87	1.00	0.93	0.96	0.94	94
283.4	283.5	35	TANGENT	CURVE TRANS	0.76	0.90	1.00	Primarily Ditch	1.00	0.71	1.00	0.89	0.90	0.89	89
283.5	283.6	36	TANGENT	TANGENT	0.75	0.79	1.00	Primarily Ditch	0.90	1.00	1.00	0.85	0.97	0.91	91
283.6	283.7	37	TANGENT	CURVE TRANS	0.64	0.90	1.00	Primarily Ditch	0.93	0.76	1.00	0.84	0.90	0.87	87
283.7	283.8	38	LTCURVE	LT CURVE	0.72	1.00	1.00	Primarily Ditch	1.00	0.75	1.00	0.91	0.92	0.91	91
283.8	283.9	39	LTCURVE	LT CURVE	0.77	1.00	1.00	Primarily Ditch	0.99	0.92	1.00	0.92	0.97	0.95	95
283.9	284.0	40	TANGENT	CURVE TRANS	0.79	1.00	1.00	Primarily Ditch	0.94	0.62	0.92	0.93	0.83	0.88	88
284.0	284.1	41	TANGENT	CURVE TRANS	0.82	1.00	1.00	Primarily Ditch	0.99	0.98	1.00	0.94	0.99	0.97	97
284.1	284.2	42	TANGENT	CURVE TRANS	0.76	1.00	1.00	Primarily Ditch	0.88	0.76	0.71	0.92	0.78	0.85	85
284.2	284.3	43	TANGENT	CURVE TRANS	0.74	1.00	1.00	Primarily Ditch	1.00	0.87	1.00	0.91	0.96	0.93	93
284.3	284.4	44	RTCURVE	RT CURVE	0.71	1.00	1.00	Primarily Ditch	1.00	0.64	1.00	0.90	0.88	0.89	89
284.4	284.5	45	TANGENT	CURVE TRANS	0.76	0.78	1.00	Primarily Ditch	1.00	0.72	1.00	0.84	0.91	0.88	88
284.5	284.6	46	TANGENT	TANGENT	0.80	0.55	1.00	Primarily Ditch	0.98	0.90	1.00	0.78	0.96	0.87	87
284.6	284.7	47	TANGENT	TANGENT	0.72	0.45	1.00	Primarily Ditch	1.00	0.58	1.00	0.72	0.86	0.79	79
284.7	284.8	48	TANGENT	TANGENT	0.73	0.60	1.00	Primarily Ditch	1.00	0.57	0.54	0.78	0.70	0.74	74
284.8	284.9	49	TANGENT	TANGENT	0.82	0.92	1.00	Primarily Ditch	1.00	0.78	1.00	0.91	0.92	0.92	92
284.9	285.0	50	TANGENT	TANGENT	0.80	0.93	1.00	Primarily Ditch	0.99	0.91	1.00	0.91	0.97	0.94	94
285.0	285.1	51	TANGENT	CURVE TRANS	0.73	0.97	1.00	Primarily Ditch	1.00	0.92	1.00	0.90	0.97	0.93	93
285.1	285.2	52	TANGENT	CURVE TRANS	0.70	0.97	1.00	Primarily Ditch	1.00	0.91	1.00	0.89	0.97	0.93	93
285.2	285.3	53	RTCURVE	RT CURVE	0.70	1.00	1.00	Primarily Ditch	1.00	0.78	1.00	0.90	0.93	0.91	91
285.3	285.4	54	RTCURVE	RT CURVE	0.70	1.00	1.00	Primarily Ditch	1.00	0.81	1.00	0.90	0.94	0.92	92

FM 31 Example, cont.



Section 41 ON FM 2625



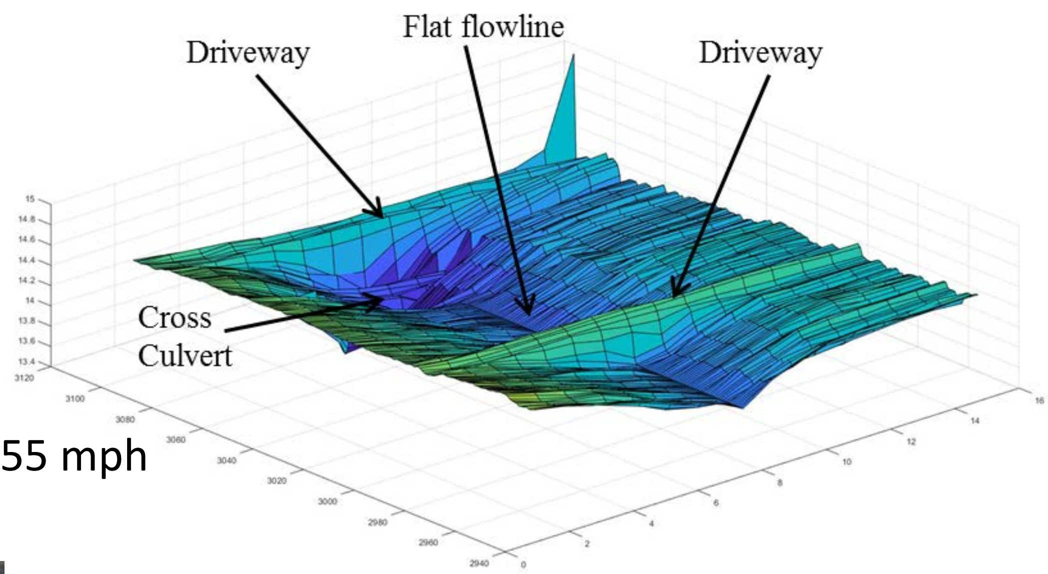
Curve Ratings – FM 2983

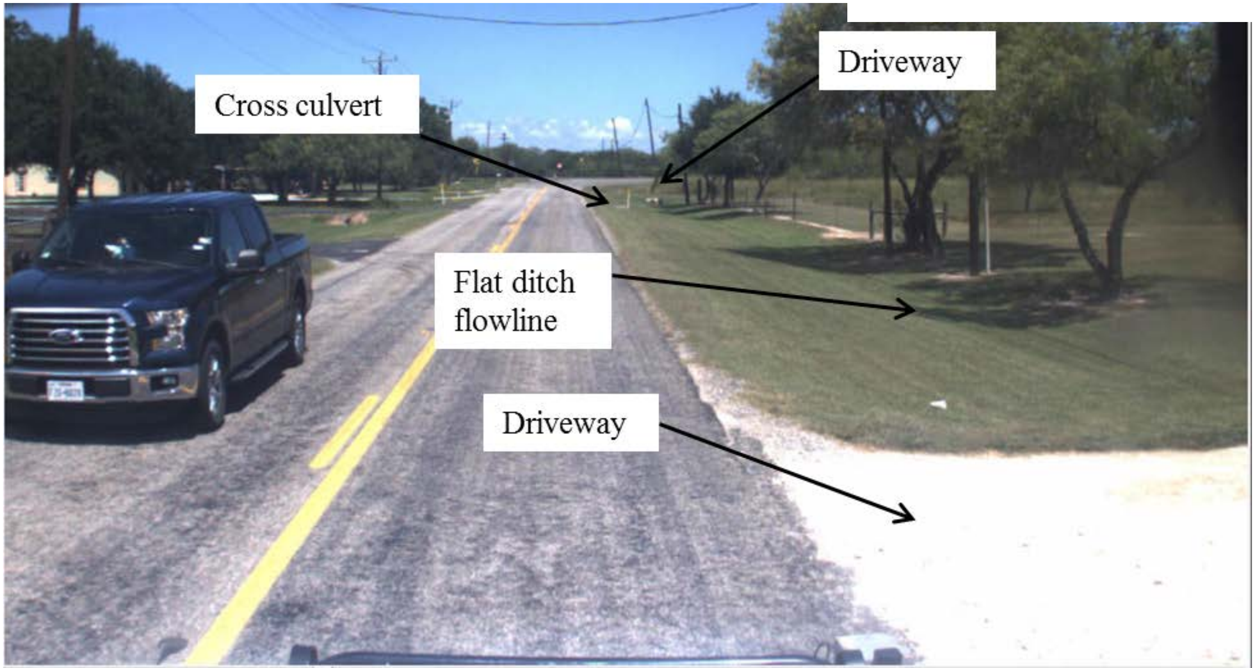
Cross Slope rating of 0.0, not because its out of shape, but because of the curve

- 463-ft radius
- 4.12% superelevation
- At 4.12% super:
    - 1980-ft radius required for 1.0
    - 1489-ft radius required for 0.9
    - 837-ft radius requires -15 mph advisor
    - 507-ft radius requires -25 mph advisory

Section 10 on FM 136

- Overall rating of 67
  - Paved rating of 51
    - Narrow (9.8-ft)
    - Poor cross slope (1.3%)
    - High hydroplaning potential (55 mph with 70 mph posted





- Roadside rating of 83
  - 2.6-ft ditch depth
  - 0.6% flowline slope
  - 13.5:1 average front slope steepness

Network Level Difficulty

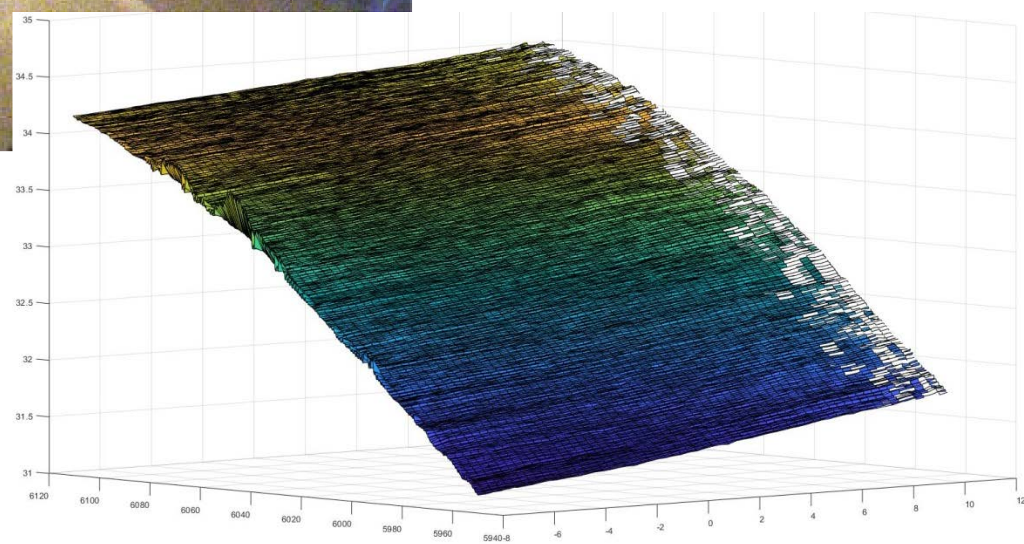
Metro Sections

- Should be treated more similar to project level analysis than network level
  - Need to define the parameters of interest
  - Can easily collect lane width and cross slope
  - Extreme widths limit the ability to collect the necessary data in one data collection run
    - Merging data proves difficult and manually exhausting
    - Hydroplaning potential can be limited by extreme widths
  - Elements such as guard rail and barrier height can be measured if they are specifically needed

Texas A&M Transportation Institute

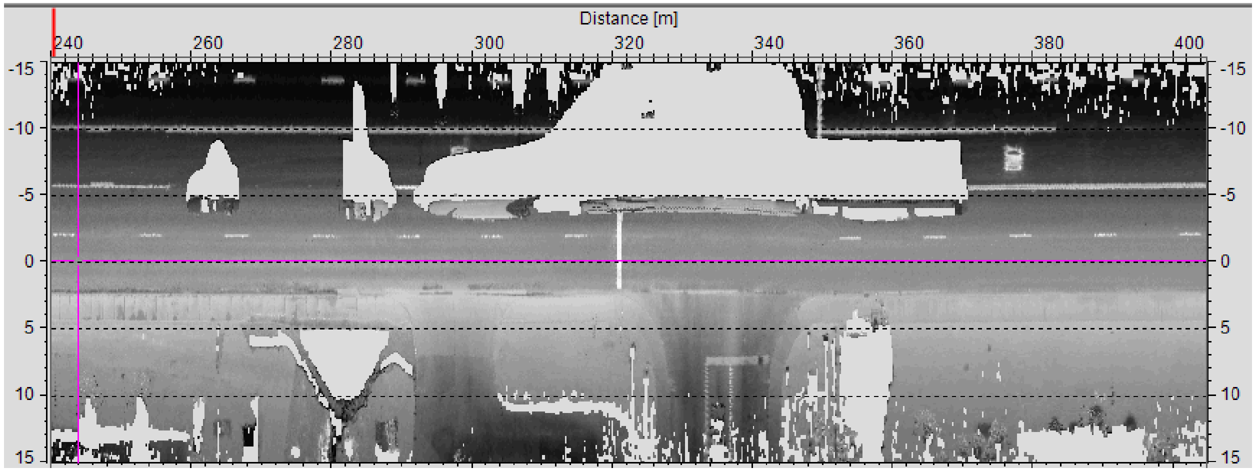
Lives, Time and Resources

Metro Sections – IH 45 Houston



Urban Sections

- Should be treated more similarly to project level analysis than network level analysis
  - Little to no roadside elements
  - Data collection can be impacted by other vehicles

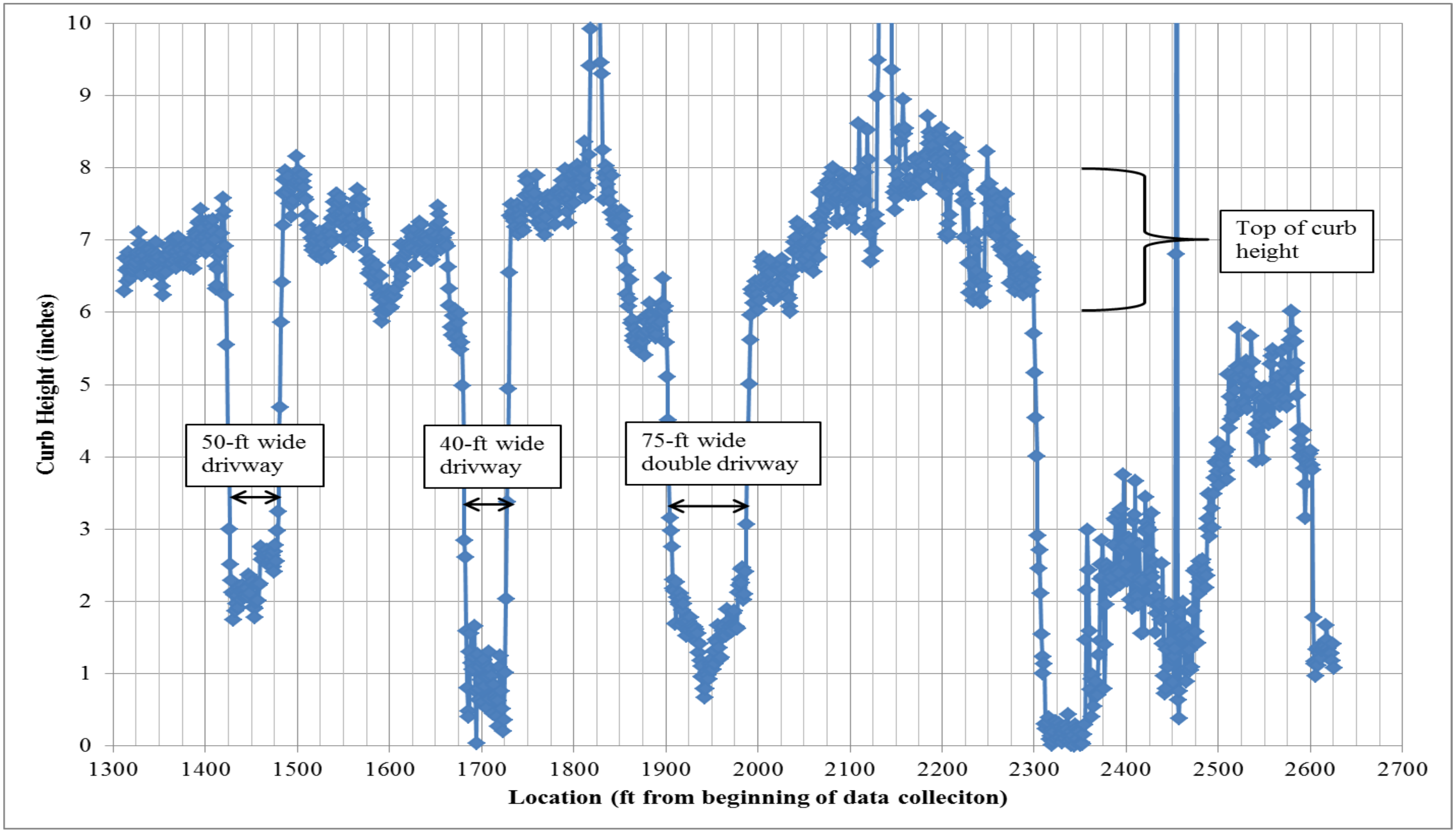


Urban Sections

- More time is spent writing code for exceptions than the actual network level analysis
- Information can be gathered on curb height, location of driveways, and inlets
  - Often requires manual processing and analysis
  - Drainage basins can be developed from automated data collection and gridded data
    - Additional hydraulic calculations can then be performed to evaluate inlet size and outside lane ponding

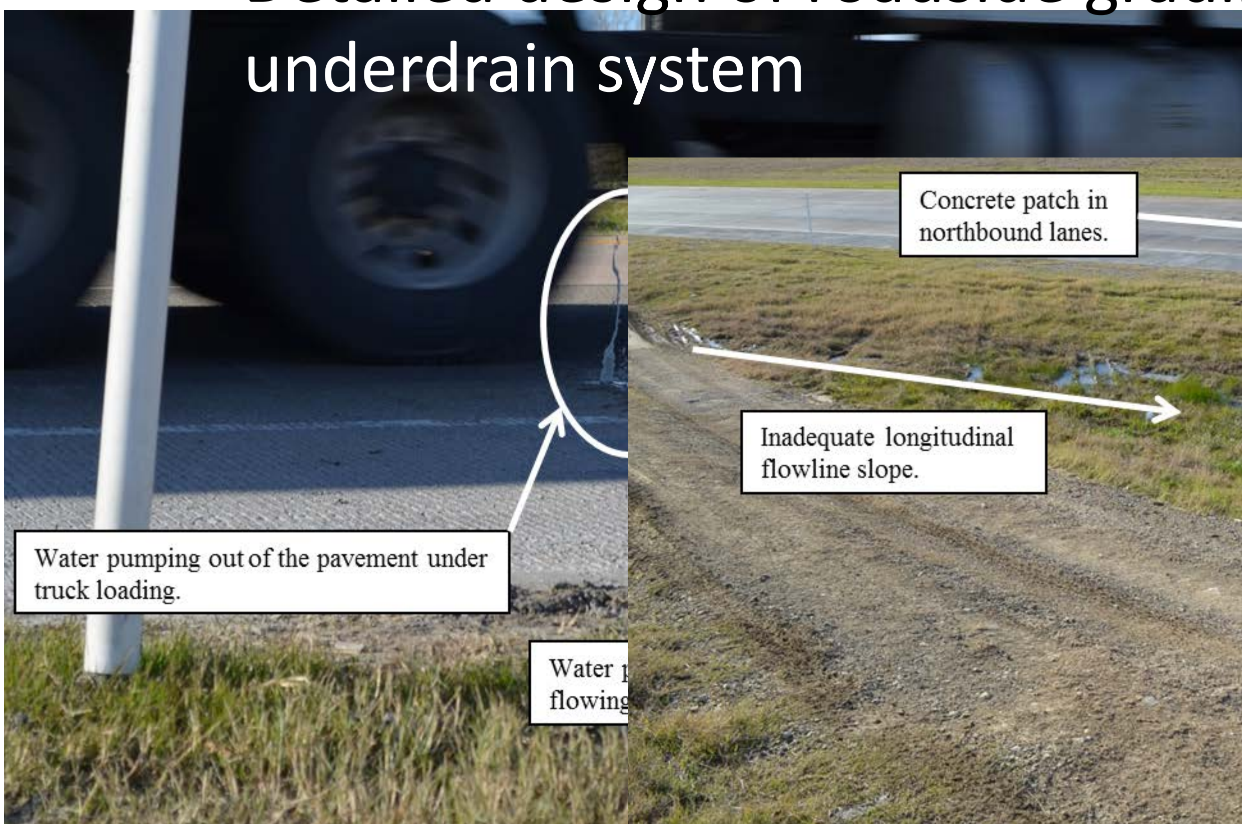
Texas A&M Transportation Institute

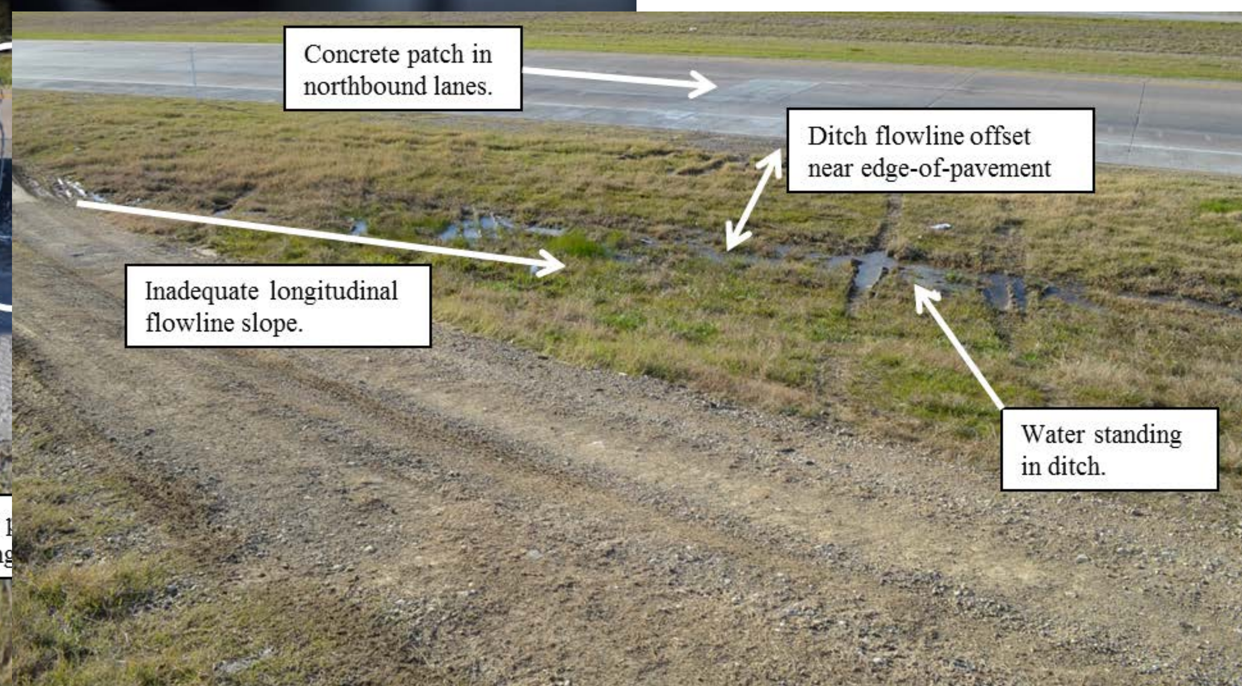
Urban Section – SH 30 Bryan District



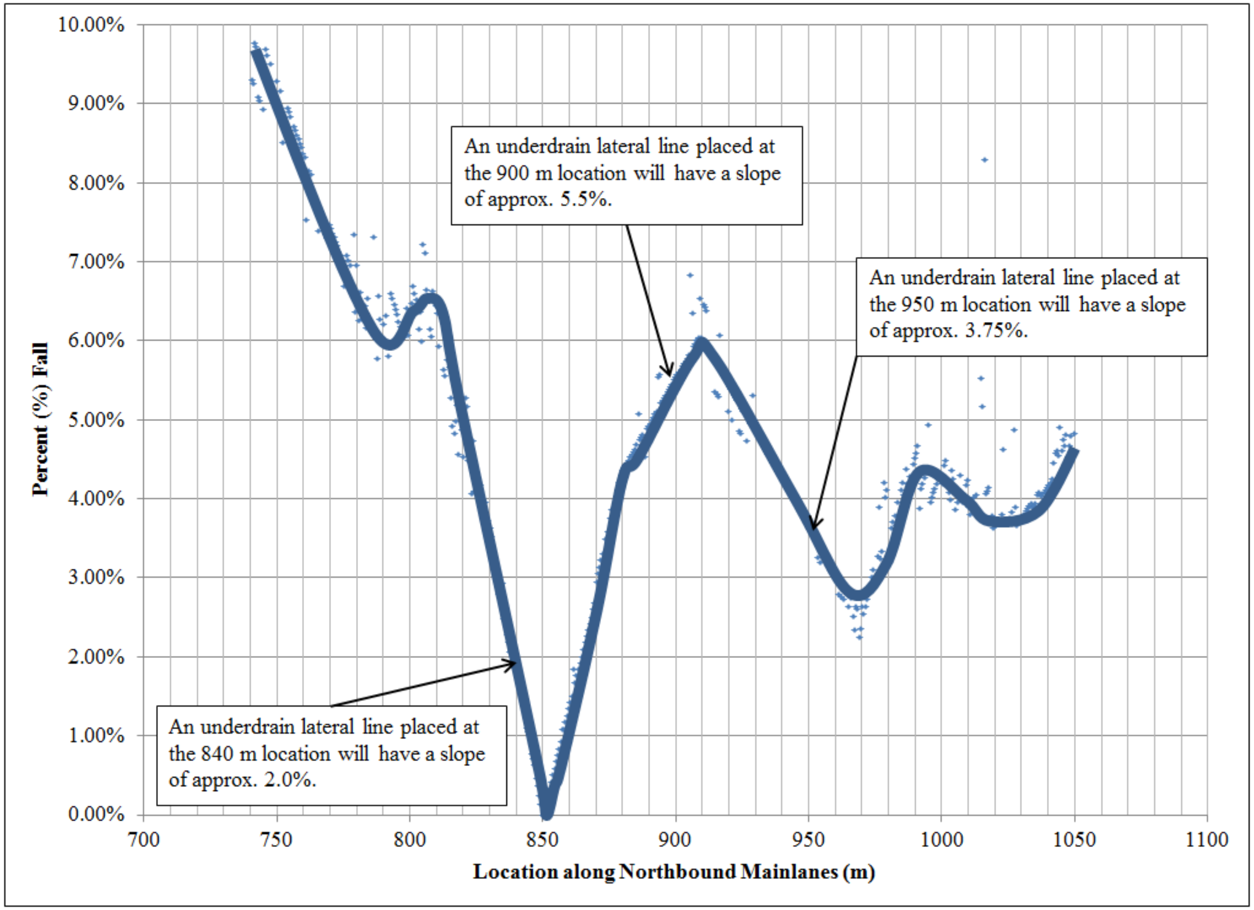
Project Level Analysis

- US 75 – Paris District
  - Detailed design of roadside grading and underdrain system





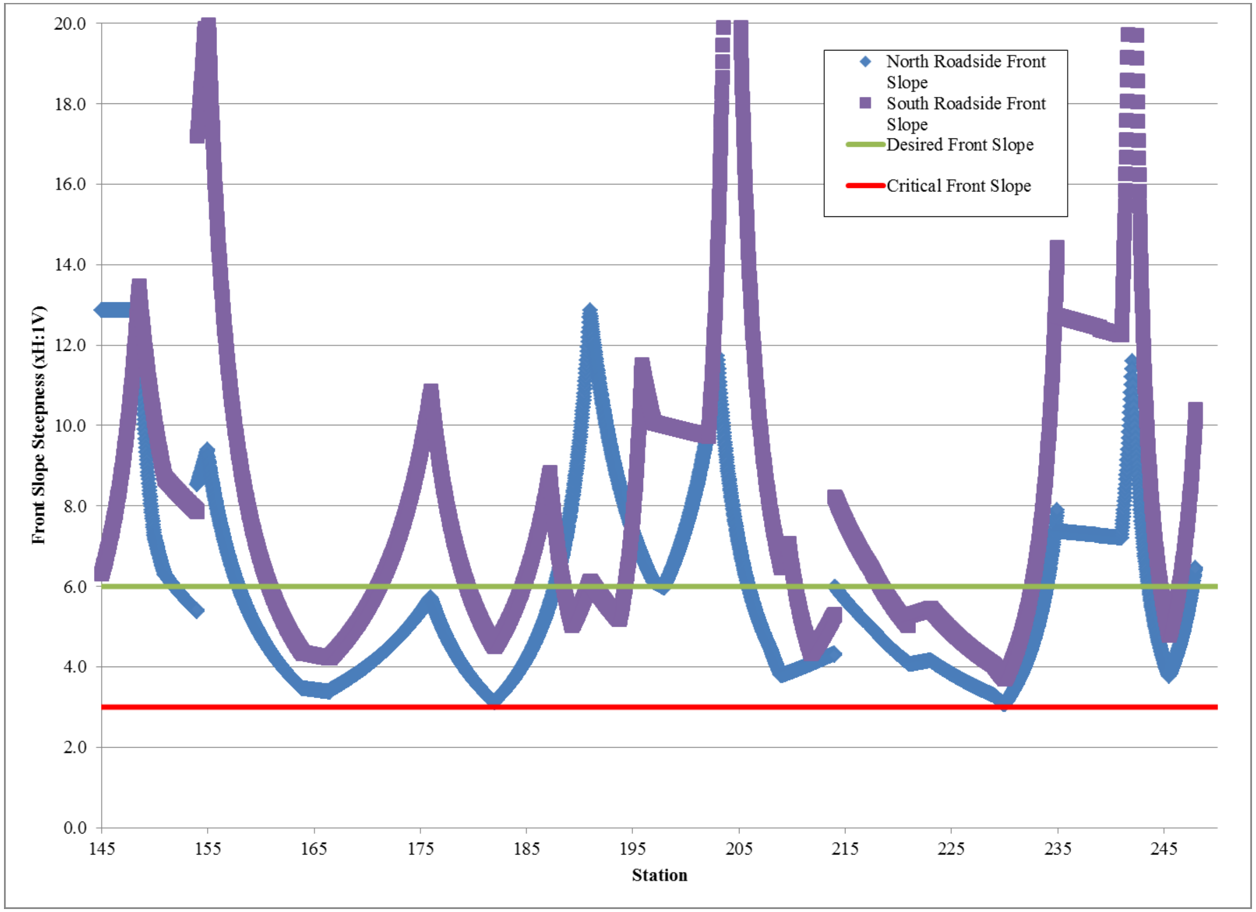
US 75 – Project Level Analysis



FM 652 – Project Level Analysis

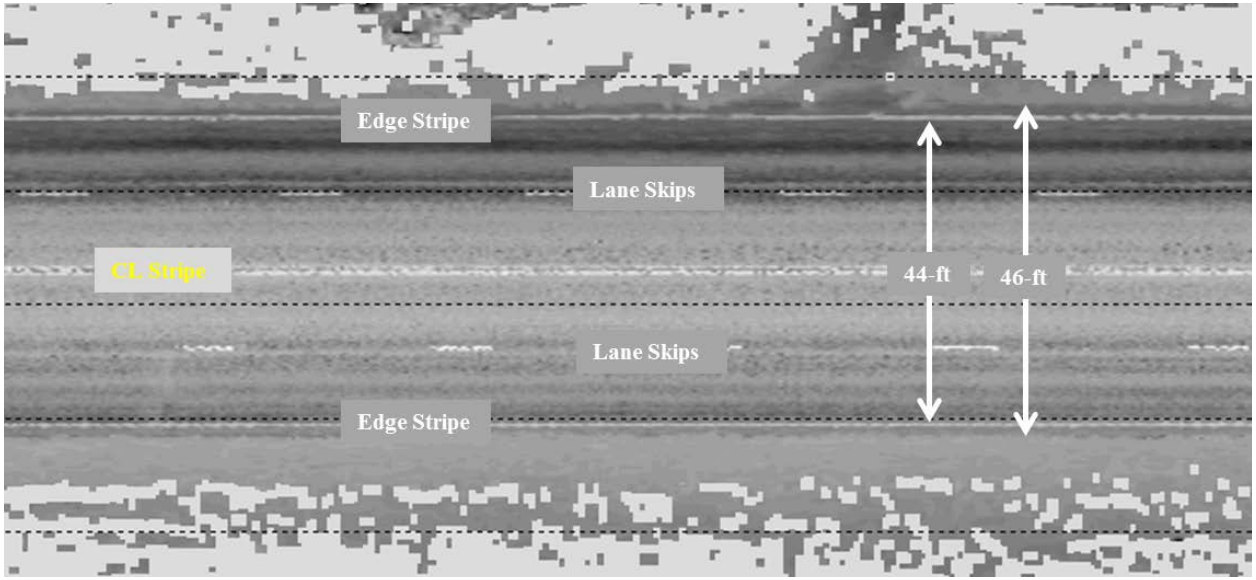
- Potential “gyp-sink” issues
- Built-in low water crossings with high deflections
- Use mobile LiDAR data to design new roadway profile and corresponding ditch profiles
  - Increase ditch depth without violating front slope steepness requirements

FM 652 – Project Level Analysis



US 77 – Project Level Analysis

- Develop rut maps for potential maintenance work
- Evaluate outside lane rutting with ditch depths



Texas A&M Transportation Institute

US 77 – Project Level Analysis

The table contains rut fill locations along US 77

The table on the following slide provides roadside ditch grading information

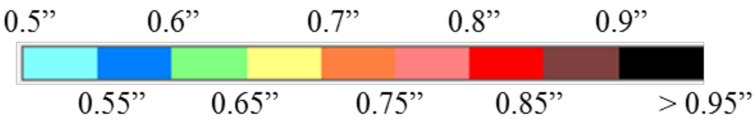
The final slide associated with US 77 provides an example of a rut map

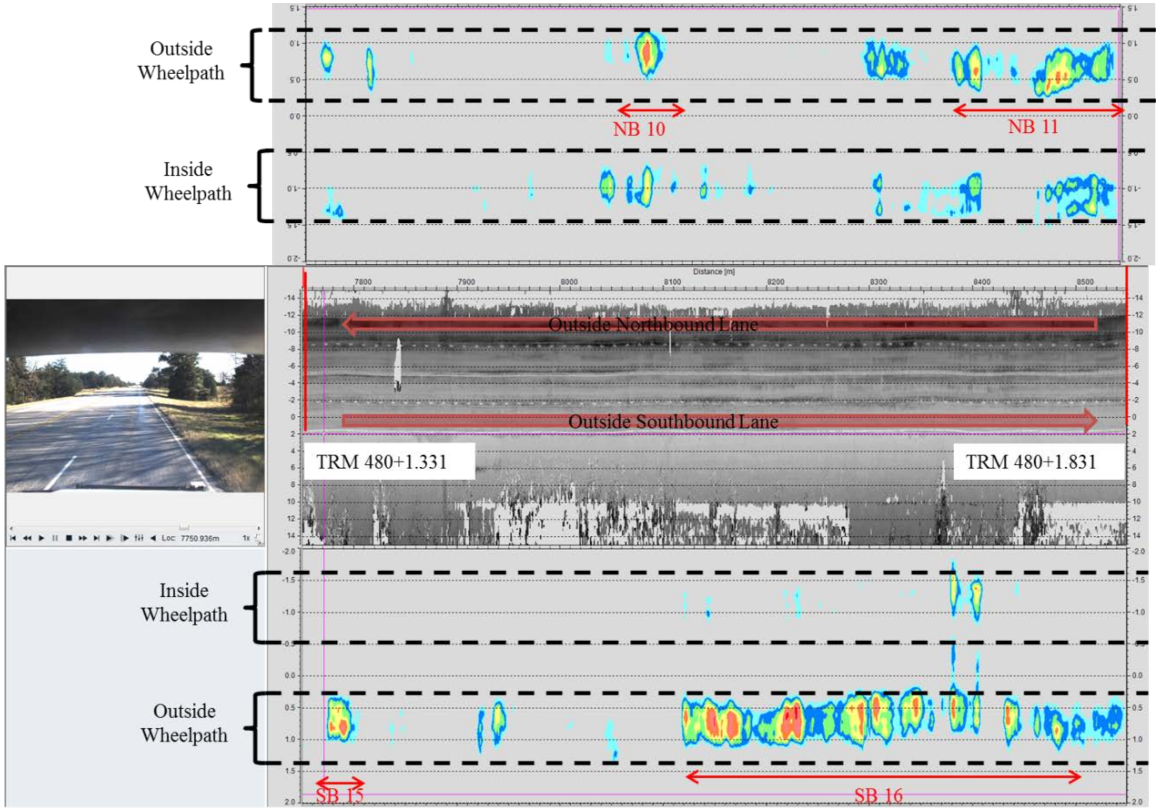
Section No.	Location No.	Begin Disp.	End Disp.	Lane	Wheel Path	Length (ft)
1	SB1	200	475	Outside SB	Outside	275
	SB2	875	980	Outside SB	Both	105
	SB3	2135	2575	Outside SB	Inside	440
	NB1	370	1750	Outside NB	Both	1380
	NB2	2270	2675	Outside NB	Inside	405
2	SB4	2625	2805	Outside SB	Both	180
3	SB 5	6235	6490	Outside SB	Outside	255
	NB 3	6530	6700	Outside NB	Outside	170
4	NB 4	8630	9510	Outside NB	Outside	880
	SB 6	8670	9030	Outside SB	Outside	360
	SB 7	9700	10360	Outside SB	Outside	660
5	SB 8	10825	11125	Outside SB	Outside	300
	SB 9	11680	11820	Outside SB	Both	140
	SB 10	12330	12535	Outside SB	Outside	205
	NB 5	11075	11200	Outside NB	Both	125
	NB 6	11655	11955	Outside NB	Inside	300
	NB 7	12300	12395	Outside NB	Outside	95
6	SB 11	13130	13420	Outside SB	Outside	290
	SB 12	13775	13850	Outside SB	Outside	75
	NB 8	13130	13740	Outside NB	Outside	610
	NB 9	14060	14185	Outside NB	Outside	125
7	SB 13	16175	16295	Outside SB	Outside	120
	SB 14	17550	18235	Outside SB	Both	685
8	SB 15	18375	18495	Outside SB	Outside	120
	SB 16	19505	24145	Outside SB	Outside	4640
	NB 10	19235	19465	Outside NB	Outside	230
	NB 11	20075	21005	Outside NB	Outside	930
9	NB 12	21200	22000	Outside NB	Both	800
	NB 13	22505	23050	Outside NB	Inside	545
	SB 17	21440	21685	Outside SB	Inside	245
10	SB 18	24450	27115	Outside SB	Both	2665
	NB 14	26035	27000	Outside NB	Outside	965

US 77 – Project Level Analysis

Grading Location	Roadside	Section	Downstream Point Description	Begin Work Dist. (ft)	End Work Dist (ft)	Flow Direction	Length of Ditch Cleaning
1	Southbound	2	Front slope only area where water exits ROW	2925 (just south of driveway)	3700 (ROW transitions to front slope only)	South at approx. 1.85% fall	775
2	Southbound	3	Deep Cross Culvert	5850 (just south of driveway)	6850 (at cross culvert)	South at approx. 2.85% fall	1000
3	Southbound	5	Cross Culvert	11050	12135	South at approx. 1.80% fall	1085
4	Southbound	8	Large Cross Culvert	18680 (just south of small cross culvert	20335 (at large cross culvert)	South at approx. 1.3% fall	1655
5	Southbound	9	Shallow Cross Culvert	21140 (rutter area on ROW)	22215 (at small cross culvert)	South at approx. 0.5% fall	75
6	Southbound	10	Cross Culvert	23940 (at cross culvert)	24520	North at approx. 1.50% fall	580
7	Southbound	10	Cross Culvert	24520	25100 (at cross culvert)	South at approx. 2.10% fall	580
8	Southbound	10	Low spot approaching bridge	25100	26060	South at approx. 1.30% fall	960

US 77 – Project Level Analysis

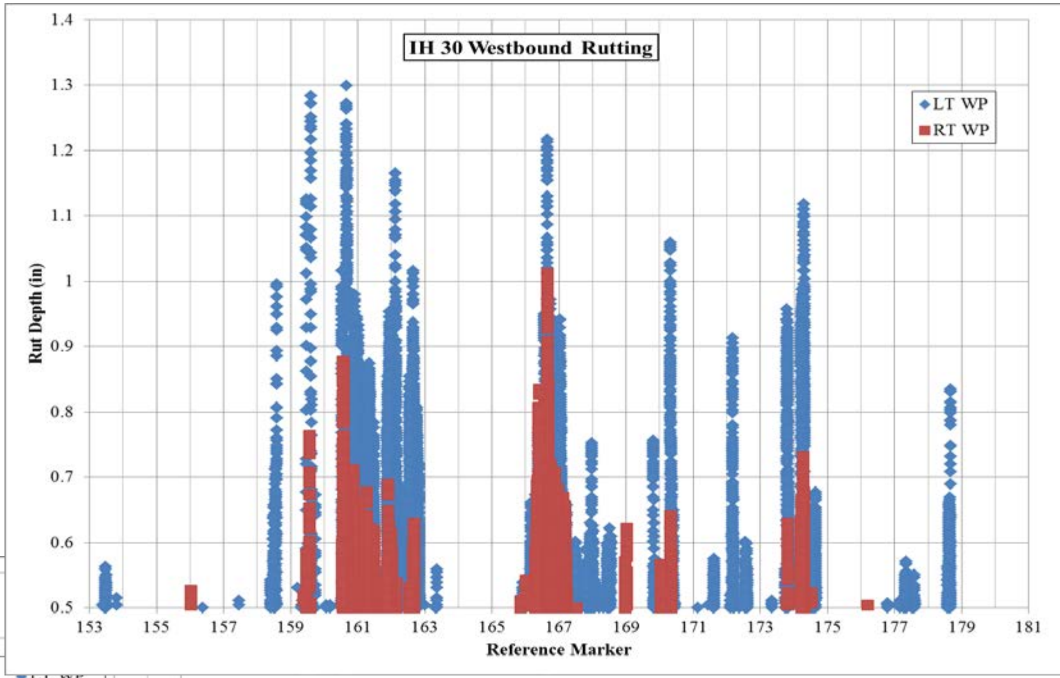


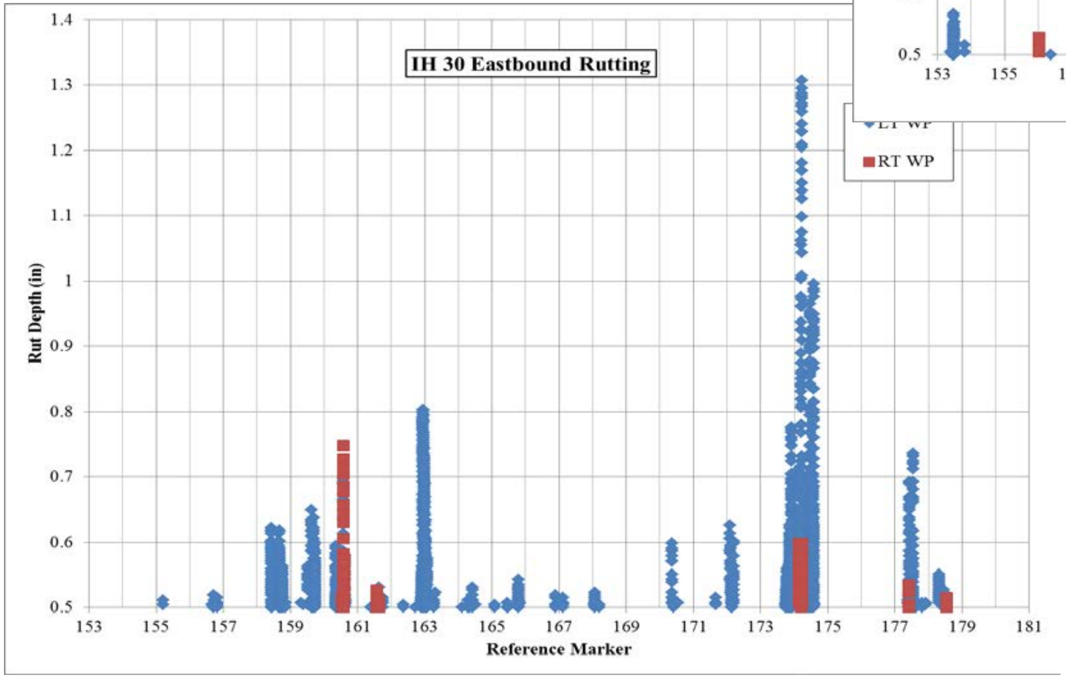


IH 30 – Project Level Analysis

- 

IH 30 – Project Level Analysis





Summary, Recommendations, and Conclusions

- A single laser mobile LiDAR system is capable of creating a network level rating for two lane facilities
  - This rating should apply only to the data collection direction
- 1-ft x 1-ft gridded data effectively and accurately creates a paved surface rating
  - No interpolation is required between points
- 3-ft x 3-ft gridded data effectively and accurately creates a roadside surface rating
  - Typically no interpolation is required until beyond the clear zone

Summary, Recommendations, and Conclusions

- The network level rating captures the following paved surface elements
  - Width
    - Developed from establishing the interface between the paved surface and roadside
    - Deductions based on design criteria
  - Cross slope
    - Accuracy of the LiDAR leads to a stepwise deduction curve based on design standards and climate
  - Hydroplaning potential
    - Created by processing LiDAR data into a gridded format and using a Monte Carlo simulation

Summary, Recommendations, and Conclusions

- The network level rating captures the following roadside elements
  - Front slope steepness
    - Deductions are based design criteria with safety emphasized over drainage
  - Ditch depth
  - Ditch flowline slope
    - Only too flat receives a deduction
- Roadside vegetation presents a target surface for the laser
  - Collect data shortly after mowing cycles or after the first hard freeze when the grass is dormant

Summary, Recommendations, and Conclusions

- Urban and metro sections should be treated similar to project level analyses.
  - These sections present different paved surface elements
  - These sections have little to no roadside impact
  - Basic elements such as lane width and lane cross slope are easily attainable
  - Wide widths, particularly in metro sections can create holes in the data

Summary, Recommendations, and Conclusions

- Mobile LiDAR is a highly effective tool at the project level with manual processing and analysis
  - Rut mapping from data collected at highway speeds
  - Curb height
  - Driveway openings
  - Rut depth and ditch depth comparisons
  - Drainage basin determination for urban hydraulic considerations
- Mobile LiDAR can be used at the project level for detailed preliminary designs
  - Can be used to help create and guide detailed designs

Thank you!

Questions?