
VDOT
Virginia Department of Transportation

VIRGINIA'S I-77 VARIABLE SPEED LIMIT SYSTEM FOR LOW VISIBILITY CONDITIONS

Christopher D. McDonald, PE, PTOE
Regional Operations Director, Southwest Region
Virginia Department of Transportation

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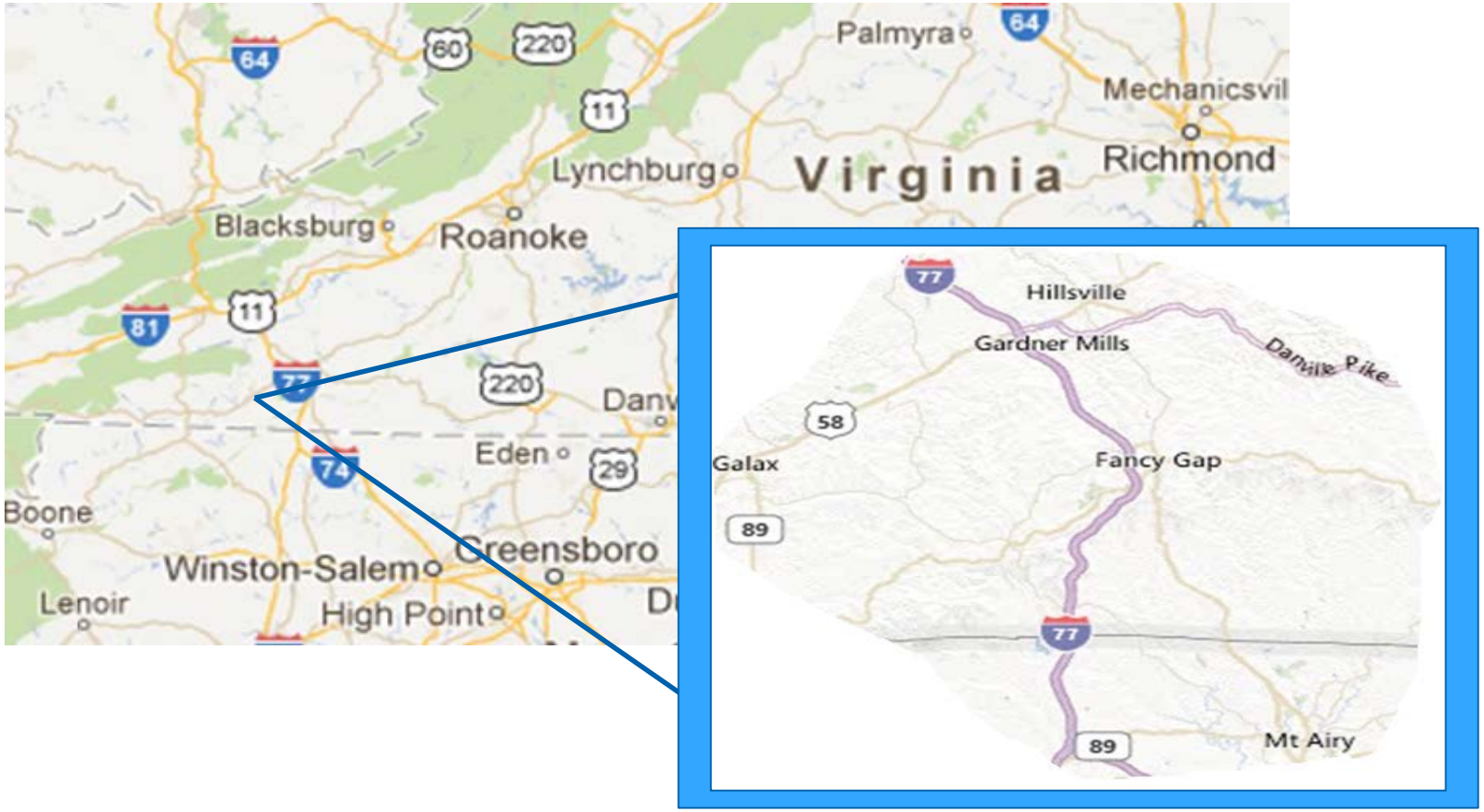
I-77 at Fancy Gap Mountain

- Transition from Blue Ridge/Appalachian Mountains to North Carolina Piedmont
- 1,000’ elevation drop over 11 horizontal curves – 4% grade
- Area subject to dense fog and severe cross winds – rapid changes
- Lack of power and communications infrastructure
- Traffic Volume 38,000 AADT – 25% trucks
- Speed Limit - 65 MPH



Problem Statement

Motorists transition from sunny skies…

To Thickening Fog…

MM 5.3, Visibility 197 ft

MM 4.3, Visibility 430 ft

MM 1.9, Visibility 2000 ft

Resulting in Rear-end Crashes

Visibility ???

I-77 at Fancy Gap Mountain
Significant Fog Related Incidents

Date of Crash	Vehicles	Fatalities	Injured	Direction
March 31, 2013	96	3	25	Southbound
Nov. 16, 2011	75	2	16	Southbound
Oct. 27, 2006	30	0	10	Southbound
Sept. 25, 2005	50	0	25	Both
Jan. 21, 2005	20	0	5	Both
May 21, 2001	40-50	0	12	Southbound
Jan. 18, 2000	60	2	N/A	Southbound
Oct. 5, 1998	46	0	10	Northbound
Feb. 14, 1997	65	0	11	Southbound

16 years, 9 crashes, 482+ vehicles, 7 fatalities, 114+ injuries

March 31, 2013 Incident Summary

96	• Total Vehicles Involved
17	• Separate Crashes
15	• Vehicles on Escape Ramp
3	• Fatalities
10 hrs/ 42 min	• Incident Duration
167 feet	• Shortest Visibility
>60 MPH	• Speeds

Previous Safety Improvements

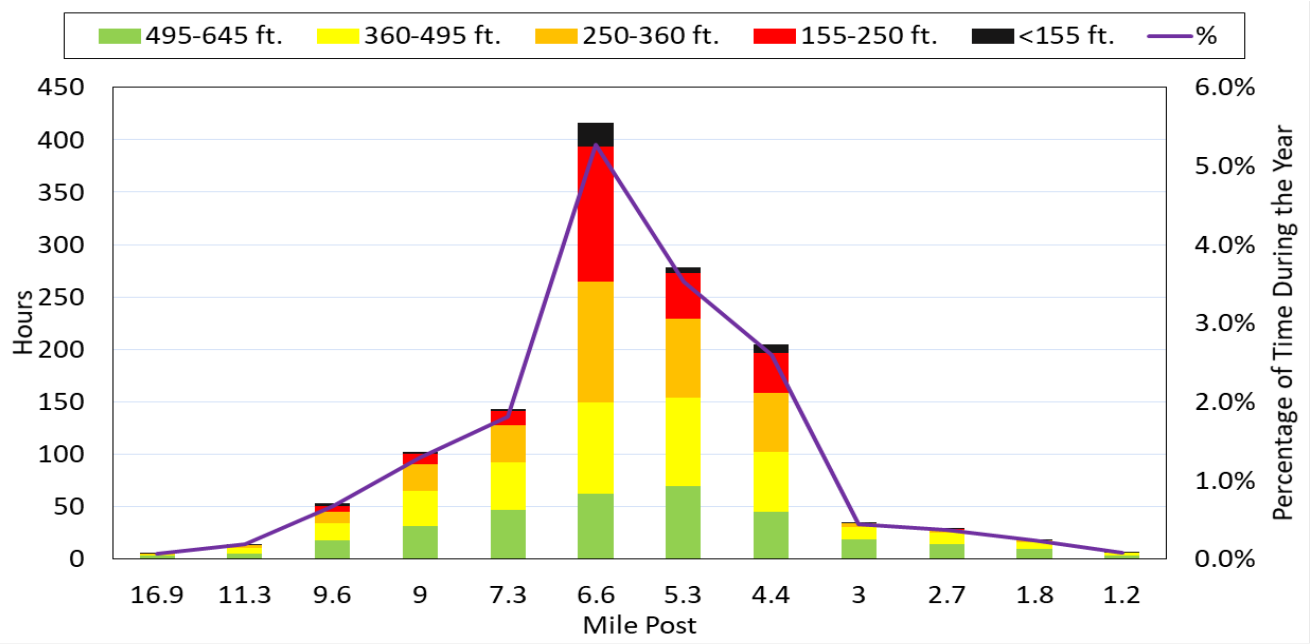
- Increased Frequency of Skip Lines
- Diagonal striping on shoulders
- Increased frequency of roadway delineators

Resulted in minimal safety benefit:

- Improvements addressed Run off the Road Crashes
- Did not address Rear End Crashes

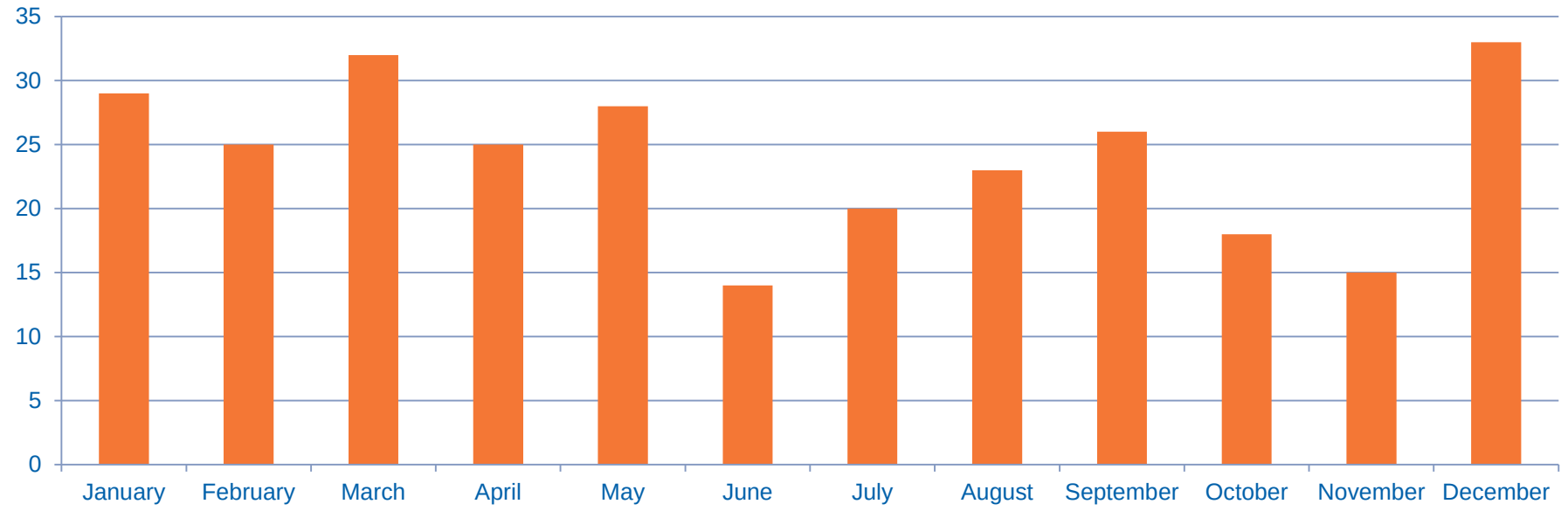
Fog Characteristics

- Fog occurs 425+ hours /year (5%)
- Most likely from MM 4 to MM 7
- Unpredictable – any month, day, or hour



Monthly Climatology

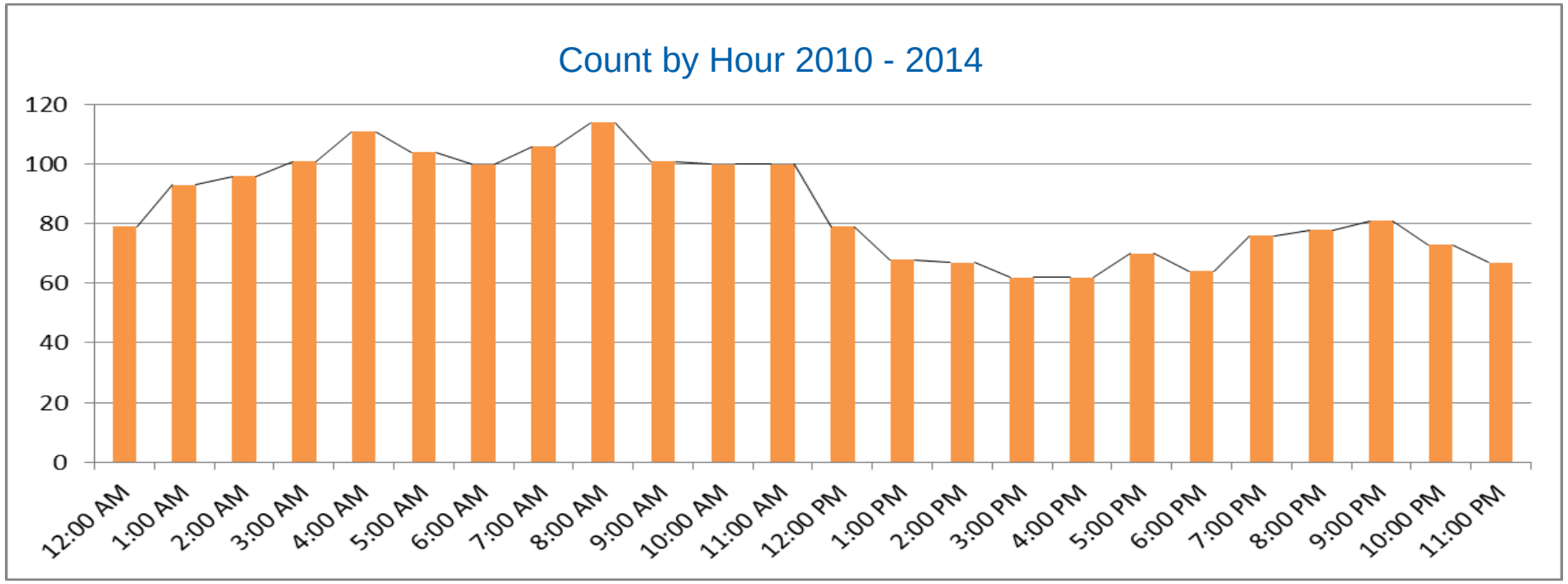
Days with less than 300 feet of visibility 2010-2014



➡ Limited visibility can occur during any month

Hourly Climatology

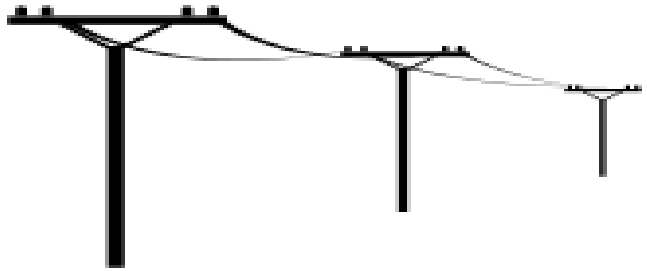
Hours when visibility falls below 300 feet in that hour.
(only one count per day per hour)



➡ Limited visibility can occur any hour of the day

Concept Development and Key Challenges

- **Problem approach – concept of operations**
  - Virginia Code
  - Speed recommendations, changes, approach
  - Scenario based modules – fog, snow, wind
  - Algorithm development
- **Lack of power and communications infrastructure**
  - Data collection
  - System monitoring and control
- **Spreadsheet tool**
  - Field device polling/data acquisition
  - Speed recommendations
  - Sign operation



How the system works?

Fog on the road

Weather Station

Strategically placed weather detection stations determines sight distance

Traffic Operations Center

When sight distance falls below visibility threshold

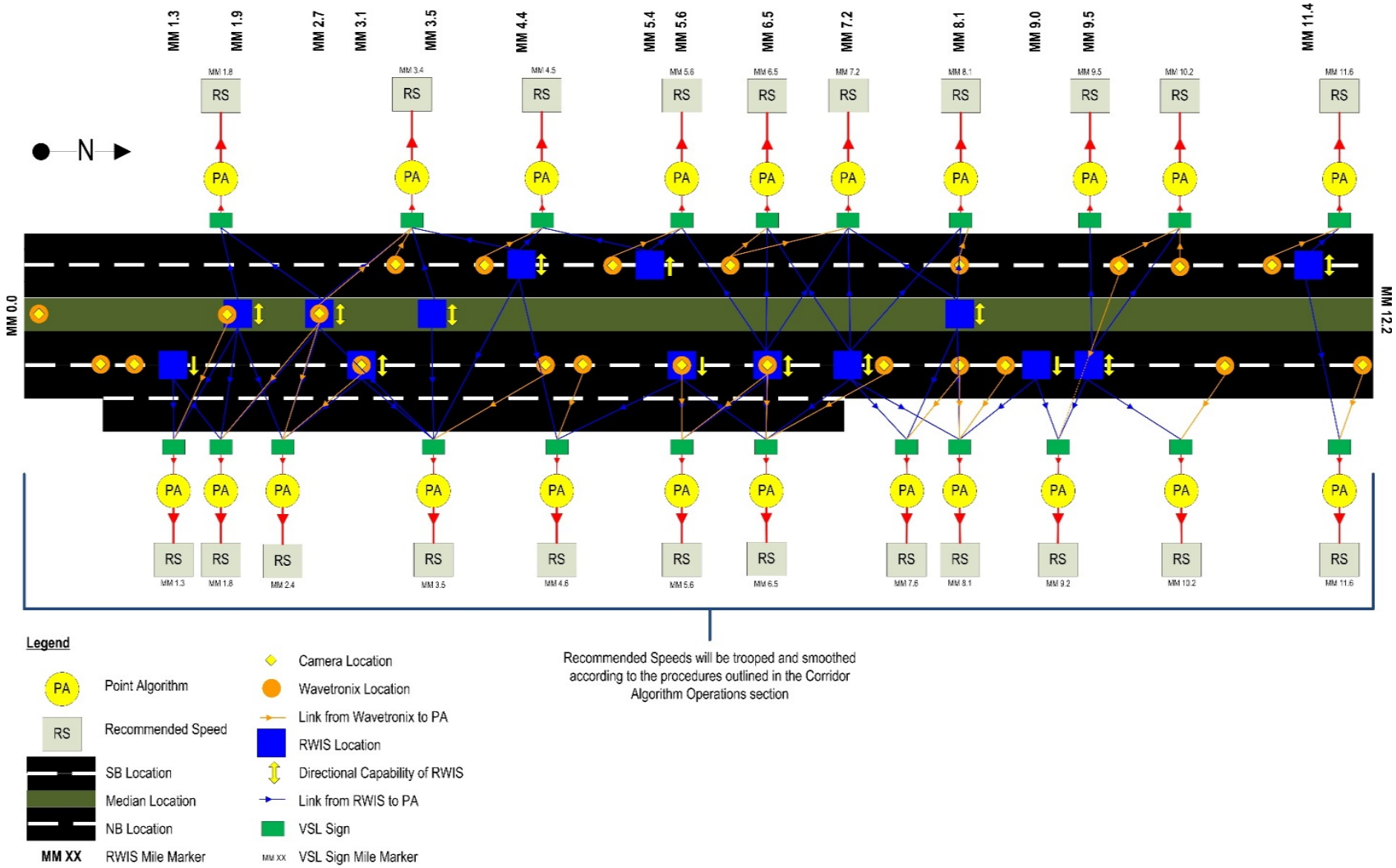
Speed limit reduced

Drivers slow down

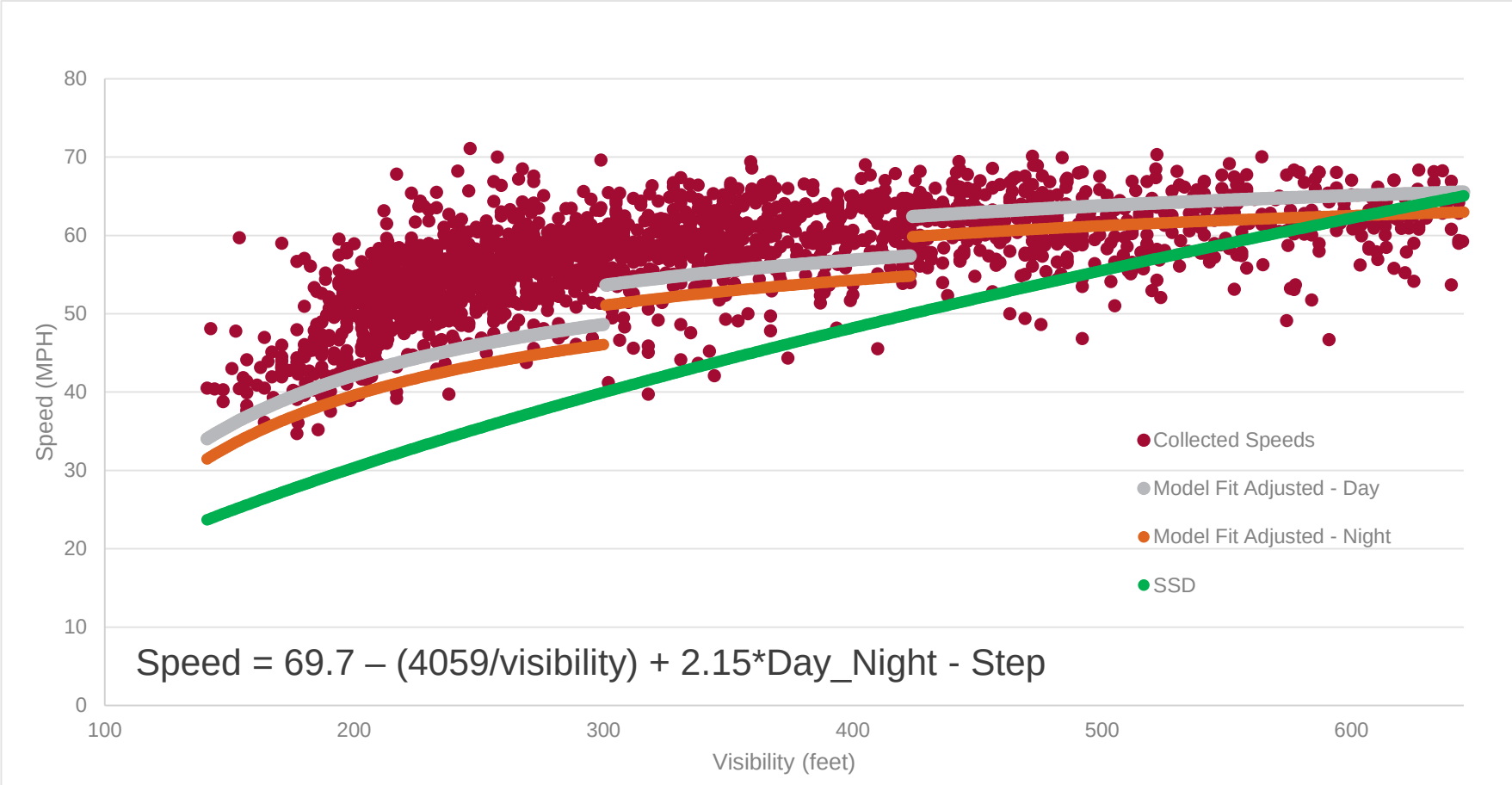
Signs

A total of 69 signs of various types (static, VMS, etc.) are in place in support of the variable speed limit system.

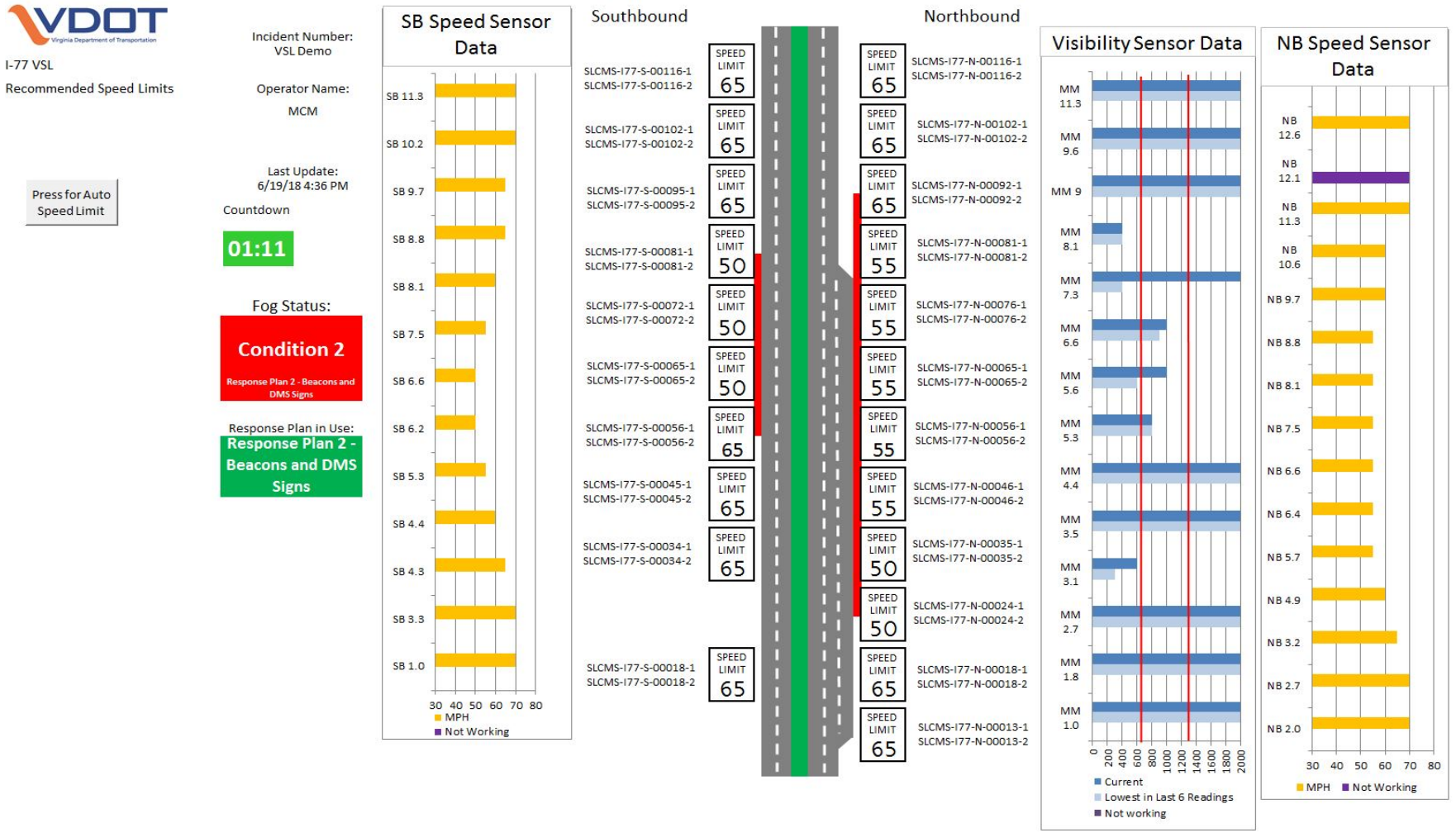
Corridor Device Map



Adjusted Step Model

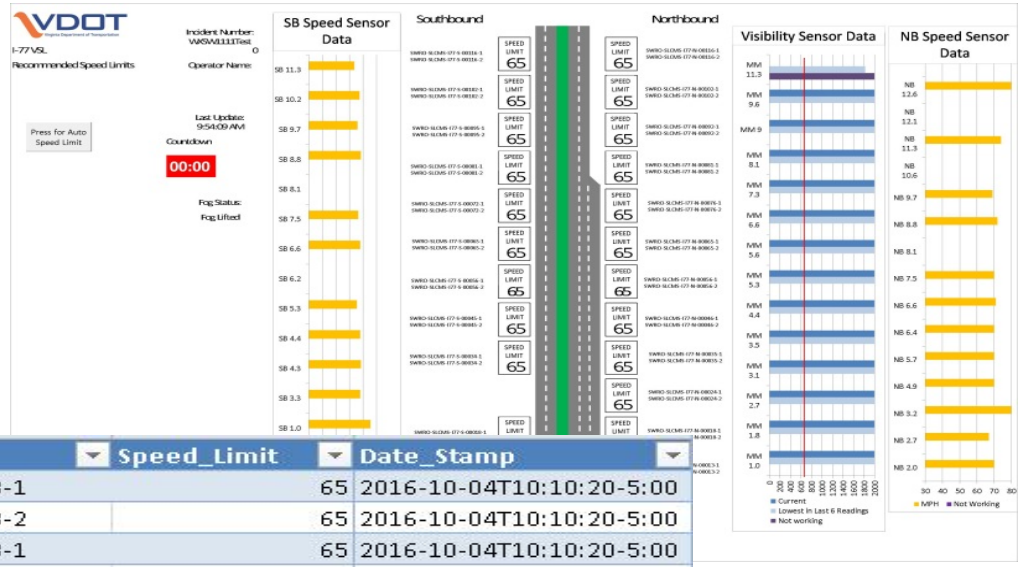


I-77 VSL Visibility Module



System Outputs

- Output for State Police – Situational awareness, enforcement documentation
- Output to Vanguard – DMS Software – sign control
- Output to ‘Datasummary’ file – VA Code documentation



Incident Number: friday2datasummary

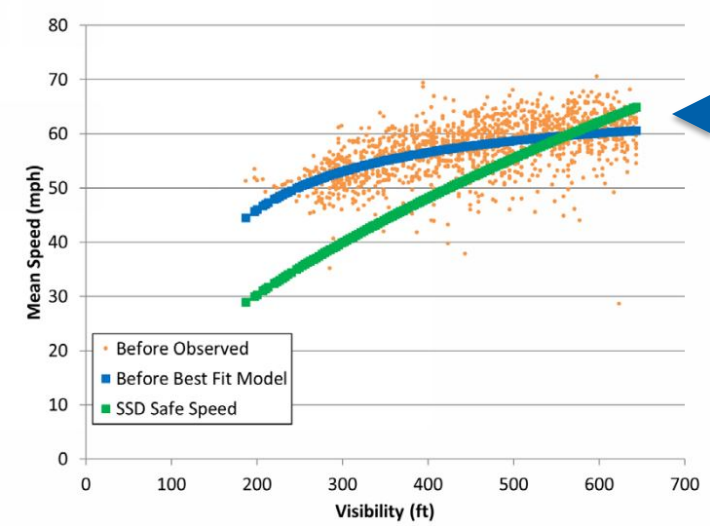
Current Visibility

RWIS Station at Mile Post	1.3	1.9	2.7	3.1	3.5	4.4	5.4	5.6	6.5	7.2	8.1
Time	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
9/16/2016 10:59	2000	2000	2000	2000	2000	2000	2000	549	155	2000	2000
9/16/2016 10:54	2000	2000	2000	2000	2000	2000	2000	274	160	2000	2000
9/16/2016 10:48	2000	2000	2000	2000	2000	2000	2000	318	188	2000	2000
9/16/2016 10:41	2000	2000	2000	2000	2000	2000	2000	484	202	2000	2000
9/16/2016 10:36	2000	2000	2000	2000	2000	2000	2000	464	184	2000	1442
9/16/2016 10:30	2000	2000	2000	2000	2000	2000	2000	736	277	1990	553
9/16/2016 10:24	2000	2000	2000	2000	2000	2000	2000	502	126	1410	338
9/16/2016 10:18	2000	2000	2000	2000	2000	2000	2000	613	99	1406	336
9/16/2016 10:13	2000	2000	2000	2000	2000	2000	1808	727	97	1124	299
9/16/2016 10:07	2000	2000	2000	2000	2000	2000	1388	331	107	1032	329
9/16/2016 10:01	2000	2000	2000	2000	2000	2000	1314	209	96	1060	483
9/16/2016 9:55	2000	2000	2000	2000	2000	2000	1107	382	77	1117	491
9/16/2016 9:50	2000	2000	2000	2000	2000	2000	1247	632	99	1150	527
9/16/2016 9:44	2000	2000	2000	2000	2000	2000	945	515	129	874	538
9/16/2016 9:38	2000	2000	2000	2000	2000	2000	1011	327	128	865	510
9/16/2016 9:30	2000	2000	2000	2000	2000	2000	888	310	87	1085	387
9/16/2016 9:25	2000	2000	2000	2000	2000	2000	495	138	75	535	283
9/16/2016 9:19	2000	2000	2000	2000	2000	1948	425	128	73	359	205

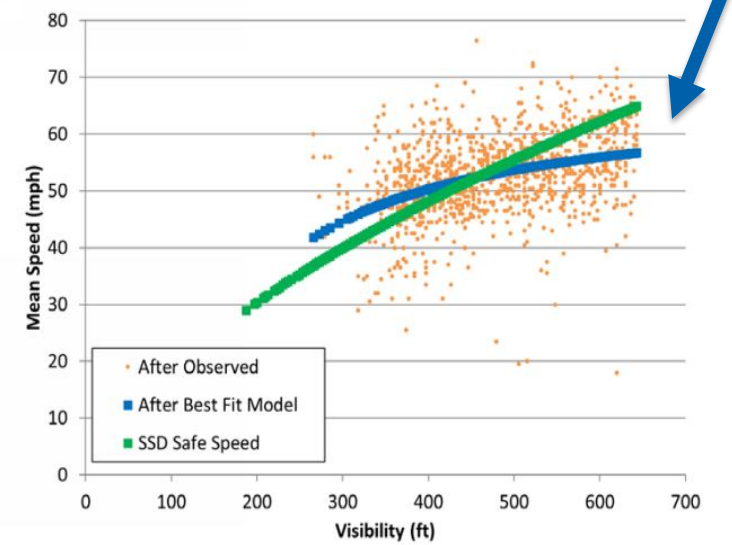
Sign_ID	Speed_Limit	Date_Stamp
SWRO-SLCMS-I77-N-00013-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00013-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00018-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00018-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-S-00018-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-S-00018-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00024-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00024-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-S-00034-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-S-00034-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00035-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00035-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-S-00045-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-S-00045-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00046-1	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00046-2	65	2016-10-04T10:10:20-5:00
SWRO-SLCMS-I77-N-00056-1	65	2016-10-04T10:10:20-5:00

Results

Before Project



After Project



- Mean speeds are reduced

Before - After Comparison of Mean Speed at MP 4.4 SB							
Visiblity Bin (ft)	SSD Safe Speed	Before			After		
		No.of Intervals (10-min intervals)	Mean Speed (mph)	Standard Deviation (mph)	No.of Intervals (5-min intervals)	Mean Speed (mph)	Standard Deviation (mph)
>645	65	69307	67.07	7.31	5158	64.34	5.41
495-645	55-65	513	59.88	8.45	526	55.12	6.33
360-494.9	45-55	524	56.63	9.03	561	51.83	5.4
250-359.9	35-45	297	52.43	8.83	73	50.49	5.04
155-249.9	25-35	22	49.75	7.96	0	-	
<155	<25	0	-	-	0	-	

Posted vs Observed Speed Differentials

Difference Between Mean Observed Speed and Posted Speed Limit SB										
Location (Milepost)			Posted Speed							
VSL	RWIS Station	Downstream Speed Sensor	65	60	55	50	45	40	35	30
11.6	11.3	11.3	0	4.8	2	9	12.4	-	-	-
10.2	9.7	9.7	2.6	2.5	8.5	9.4	-	-	-	-
9.5	8.8	8.8	3	4.7	4.2	7.9	4.5	-	-	-
8.1	7.5	7.5	0.7	2.4	5.7	6.4	11.3	10.3	-	12.1
7.2	6.6	6.6	4.1	7.2	7.6	12.2	13.6	17.5	22.3	22.9
5.6	5.3	5.3	1	5.5	4.8	10.2	10.8	15.3	17.2	21.3
4.5	4.4	4.4	0.1	2.7	3.5	5.6	4.9	8.1	6.4	-
4.5	4.3	4.3	0.5	3.3	3.5	5.1	3.8	5.8	5.3	-
3.4	3.3	3.3	2.9	4.8	3.5	7.1	5.6	9.6	-	-
1.8	1	1	3.4	4.7	-	-	-	-	-	-

Crash Data

Preliminary Results:
Rear end crashes reduced
Overall number of crashes reduced
Reduction in crash severity

	2010-2015		Oct 2016-Aug 2017	
	Total	Per Year	Total	Per Year
Low Visibility Crashes	62	10.3	2	2.2
Rear End Crashes	39	6.5	2	2.2
Fixed Object Off Road	3	0.5	0	0
Other	20	3.3	0	0

Summary of Results

- Speed reductions lag until drivers enter fog
- Speeds still above posted speed limit but closer to safe stopping speeds
- Continuing analysis on compliance and crash experience

Chris McDonald
cmcdonald@VDOT.Virginia.gov
1596 Deborah Lane
Salem, Virginia 24153
540-375-0114