Evaluation of the Sequential Dynamic Curve Warning System

Final Report
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HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

Source: ISU/TTI

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Federal Highway Administration

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16. Abstract

Implementing safety countermeasures on rural horizontal curves to address speeding can improve the safety performance for those locations. State safety and traffic engineers are faced with making decisions on what type of technology to use and which sites to use the technology on in a fiscally constrained environment. The research conducted for this project evaluated a Sequential Dynamic Curve Warning System (SDCWS) that could be an additional tool for these engineers to use either separately or in combination with other countermeasures to address horizontal curve locations with a history of safety concerns. TAPCO provided the SDCWS evaluated in this project and provided installation and maintenance support to the DOTs.

A summary of the full report is available as a separate document (report no. FHWA-15-CAI-012-A).

This project was undertaken in 2011 by the Federal Highway Administration's Highways for LIFE Technology Partnerships Program, a discretionary program of SAFETEA-LU (Public Law 109-59). The purpose of the program is to evaluate, document, and disseminate the performance results of promising innovative highway safety technologies that are commercially available through a partnership with general industry and state and local highway agencies.

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SI* (MODERN METRIC) CONVERSION

FACTORS APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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LIST OF ABBREVIATIONS AND ACRONYMS

AADT	Annual average daily traffic
Caltrans	California Department of Transportation
CC	Center of curve
DOT	Department of Transportation
DSFS	Dynamic speed feedback sign
FARS	Fatality Analysis Reporting System
GES	General Estimates System
HSIS	Highway Safety Information System
LIDAR	Light detection and ranging
MUTCD	Manual on Uniform Traffic Control Devices
PC	Point of curvature
SD	Standard deviation
SDCWS	Sequential Dynamic Curve Warning System
TE	True effect
vpd	Vehicles per day

SUMMARY OF FULL REPORT

Background

While horizontal curves make up a small percentage of total road miles, one-quarter of all highway fatalities occur on them. The average crash rate for horizontal curves is about three times that of other highways segments. The majority of curve-related crashes is attributed to speeding and driver error and involves lane departures.

More than 25 percent of fatal crashes are associated with a horizontal curve, and the vast majority of these crashes involve a roadway departure. About three-quarters of curve-related fatal crashes involve a single vehicle leaving the roadway and striking trees, utility poles, rocks, or other fixed objects, or overturning. The majority of these crashes are speed related.

Problem Description

Implementing safety countermeasures on rural horizontal curves to address speeding can improve the safety performance for those locations. State safety and traffic engineers are faced with making decisions on the types of technology to use and which sites to use the technology on in a fiscally constrained environment.

A number of low-cost countermeasures are traditionally used to help keep drivers on the road and in their lane; however, the impacts of applying these countermeasures can be limited. This led to the need for additional research and testing on more dynamic devices to assist safety and traffic engineers in managing speed and safety across their diverse roadway networks.

Research Overview and Objective

The research conducted for this project evaluated a Sequential Dynamic Curve Warning System (SDCWS) that could be an additional tool for engineers to use either separately or in combination with other countermeasures to address horizontal curve locations with a history of safety concerns. The objective of this project was to test and evaluate the effectiveness of the SDCWS in reducing vehicle speed, as well as its potential to reduce the frequency and severity of speed-related crashes on rural horizontal curves. The evaluation included rural curves in five States (Iowa, Missouri, Texas, Washington, and Wisconsin). Figure EX.1 shows a map of the test sites.

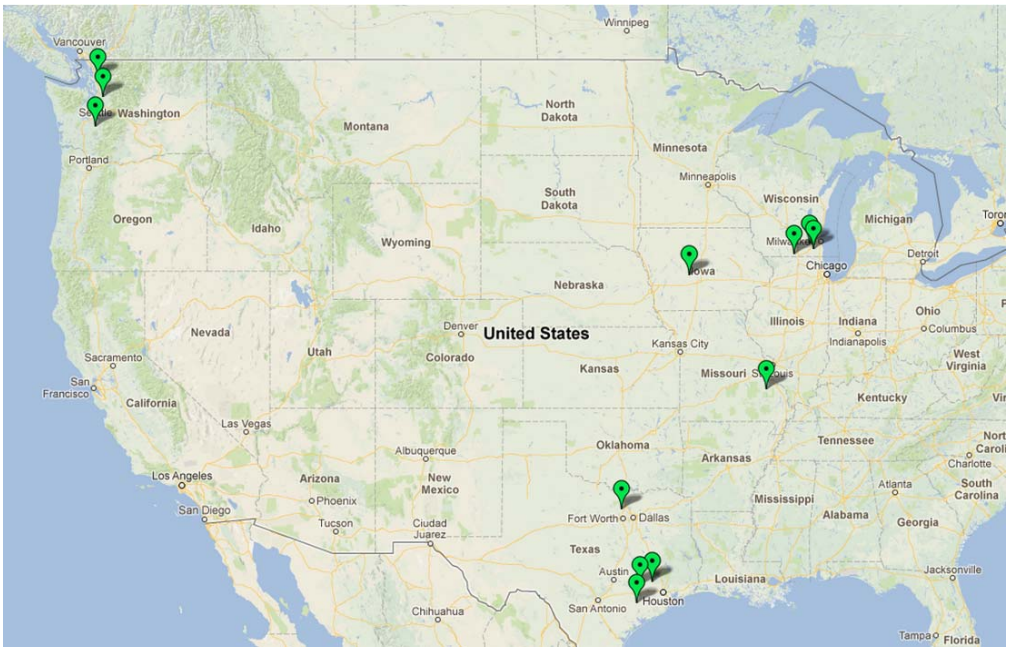

Figure EX.1. Map. Final test site locations. (Source: Google Maps)

While several dynamic curve sign systems have been tested in the past, this system is unique in terms of including guidance not just before or at the curve, but also throughout the curve with the blinking chevrons. The SDCWS is meant to replace existing static advance warning and chevron signage.

Research Description/Methodology

Site selection criteria were developed and the research team worked with each of the five participant States to develop a list of candidate locations. After reviewing the information from each State, the team developed a finalized list of potential sites and spatially located each site using Google Earth or the aerial images provided by the agency. The suitability of each curve location was evaluated. Locations that had major developments, railroads, or major points of access, including intersections other than low-volume intersections, were eliminated. Based on additional information received from each State about the remaining sites, the sites were ranked in terms of number of crashes. A threshold of at least 5 crashes over a 5-year period was used to define a high-crash location.

The research team conducted site visits to all candidate locations. Field observations identified roadway characteristics including curve layout, operational conditions, presence of speed and advisory signs, and relevant roadway conditions. In addition, a speed study was conducted using a radar gun and data were analyzed to verify whether a speeding problem exists. A field report was prepared which included all of the field information collected for each site visited.

Following the site visits, the research team selected the final test curve locations for installation of the SDCWS. Once the test sites were established, the research team provided the chevron quantity and sign curve warning sign details to the manufacturer (TAPCO). All installations were completed by the TAPCO with support from the respective State DOT. The manufacturer calibrated the sign and radar operational settings specific to each location.

The research team collected speed data using pneumatic road tubes for the 12 treatment sites. No sped data was collected for the 24 control sites. Speed data were collected before and one month after system installation, as well as 12 months, 18 months, and 24 months post installation. A simple crash analysis was conducted in addition to the speed analysis to determine the safety benefits.

Technology Description

TAPCO's SDCWS utilizes Day-Viz™ LED enhanced solar powered signs, and BlinkerBeam™ wireless controllers along with ultra-low power radar to detect and flash a series of chevron signs along with the advance warning sign in a horizontal curve. This system both warns and guides drivers through the upcoming horizontal curve. See Figure EX.2 for the system installation for the Iowa site.

Advance Warning sign


Chevron Installation


Chevron with LED and Solar Panel


Chevron in Operation

Figure EX.2. Photos. Installation of the TAPCO's SDCWS. (Source: ISU/TTI)

Using the length and speed of the curve, the user can set each of the W1-8 chevron signs to flash in a specific sequence or time interval in the direction of travel. Each curve design will have different sign placement and geometry for consideration when determining the appropriate flash sequence.

The radar can detect approaching vehicles up to 300 ft in advance of the curve sign. The threshold is commonly set to flash for vehicles approaching at or just below the advisory speed of the curve. When this speed threshold is exceeded, the radar will trigger the flash of the advance warning sign and sequential chevron signs using TAPCO's 900-Mhz BlinkerBeam™

wireless network. This wireless network is constantly communicating with each sign and providing a synchronization pulse throughout the network. This synchronization pulse is what each sign controller will use to keep the proper flash time and sequence. Figure EX.3 shows an example of the activation sequence.

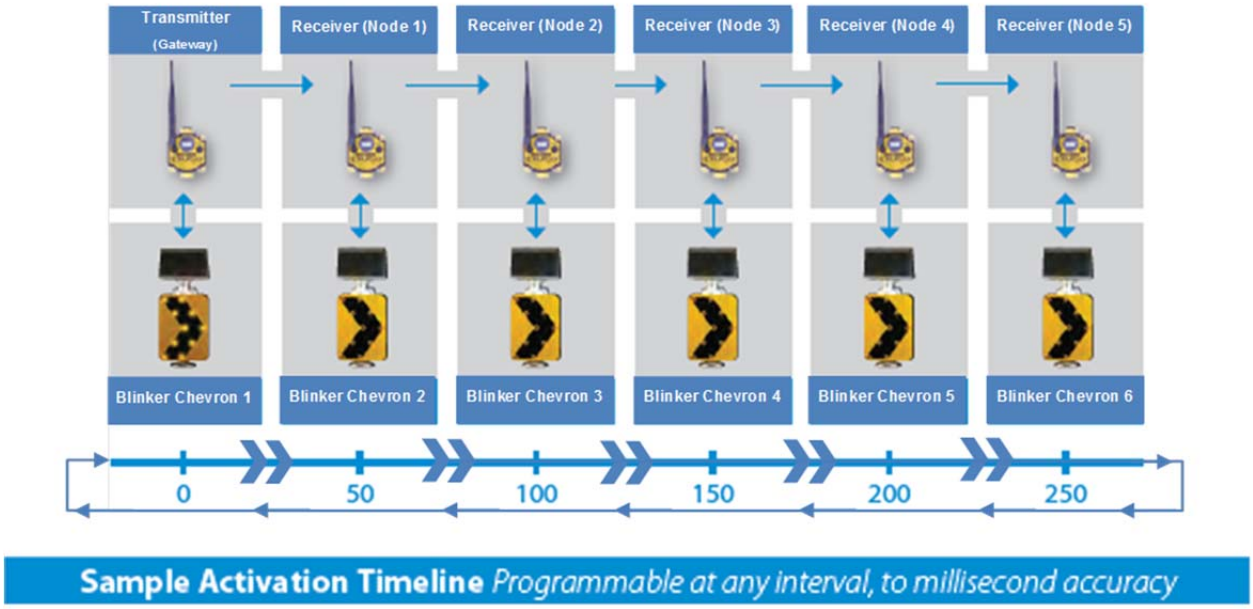

Figure EX.3. Photo. Example SDCWS activation sequence. (Source: TAPCO)

Data Collection Protocol and Quality Assurance

Road tubes were placed to collect speed and volume data at three locations per curve test site. The data was only collected in one direction of travel for each curve. The goal was to measure driver speed selection in advance, at the beginning of the curve, and within the curve. These three locations were described as follows:

- Upstream – Road tubes were placed approximately 500 ft before the advance curve warning sign (just in advance of being detected by the radar within the advance curve warning sign area).
- Point of Curvature (PC) – These tubes were placed at the point of curvature or beginning point of the horizontal curve.
- Center of Curve (CC) – Tubes placed within the center of the horizontal curve.

Speed patterns can vary as a result of weather and time of year; therefore, the purpose of the upstream data collection was to measure any changes in speed that may have occurred independent of the sign installation. The upstream data collection locations were placed outside of the SDCWS radar detection area so that they would not be affected by the sign and would not adjust driver behavior. The upstream locations also allowed vehicles to be tracked through the point of curvature and center of curve to determine individual vehicle speed reductions.

Speed and volume data were collected for at least 24 consecutive hours during the week (Monday through Friday) for the before, one month, 12 months, and 18 months after installation. For the final data collection period (24 months after installation) at least 48 consecutive hours of data were collected in order to analyze the day and night effects of the signs. During data collection, the equipment was spot checked to determine whether any problems had occurred. Data were also checked in the field during data collection to spot problems early, and the full data sets were checked when data collection was complete.

Data Reduction and Vehicle-Tracking

The data were reduced after each site collection period and a number of speed metrics were calculated for the direction of travel toward the SDCWS. They include average speed, standard deviation of speed, 50th percentile speed, 85th percentile speed, and percent of all vehicles traveling 5, 10, 15, or 20 mph over the posted speed limit and curve advisory speed. In addition to calculating these statistics for all vehicles collected, the dataset was further reduced by "tracking vehicles" through the curve.

Although data were collected and analyzed for all vehicles within the curve, vehicle tracking was used to remove vehicles with speeds impacted by turning movements or other vehicles. This allowed the analysis to hone in on the effect of SDCWS. Each vehicle that was recorded by the counter at all three data collection locations was designated a "tracked vehicle," removing vehicles that did not go through the entire curve from the "tracked vehicle" analysis. For example, a curve with a side street by the curve would have vehicles slowing down to make the turn or speeding up after turning off the side road. In both situations the lower speeds were influenced by the turning movement and not by the SDCWS. Tracking vehicles singles out only the vehicles that are influenced by the SDCWS through the curve.

Vehicles that were not in free flow, and thereby had their speed influenced by a vehicle in front or behind them were also removed from the analysis using the time between counters, the headway between vehicles, and the classification of the vehicles. The criteria for a free flowing vehicle used were having greater than a five second headway and/or three second tailway. If the upstream, point of curvature, or center of curve were not in free flow then the entire vehicles' data were removed.

The same speed metrics mentioned above for all vehicles were also calculated for tracked vehicles. In addition to these speed metrics for each tracked vehicle, a speed reduction metric can be calculated from the upstream to point of curvature, upstream to center of curve, and point of curvature to center of curve. The benefit to this metric is that it identifies where speed reductions are occurring. It also takes into account the speed reductions upstream where the other metrics used the upstream location as a control point. The average and 85th percentile speed reduction between all of the data collection locations were then calculated for each site.

Key Findings

The SDCWS was shown to be effective at reducing speed during all data collection periods from 1 month to 24 months after installation.

Table EX.1 shows the average change in speed at the point of curvature across all sites by data collection period. The statistics in parenthesis show the results of only tracked vehicles through

the curve, and are considered to be more representative of the driver response to the system without influence of other factors.

The change in mean speed was consistent between all data collection periods with reductions between 1.7 mph at 1 month after data collection, to 1.3 mph during the 12 and 18 month after data collection periods. The 85th percentile speed also showed reductions with a decrease of 1.7 mph during the 1 month after data collection period.

Also shown in Table EX.1, the fraction of vehicles exceeding the posted or advisory speed limit showed reductions during all data collection periods. The sites on average had a decrease of 11 percent in the fraction of vehicles exceeding the curve advisory speed by 5 mph or more. The fraction of vehicles exceeding the advisory speed by 10 mph or more decreased by an average of 22 percent and by 30 percent for the fraction of vehicles exceeding by 15 mph or more. An average decrease of 32 percent was shown in the fraction of vehicles exceeding the advisory speed by 20 mph or more.

Table EX.1. Average change across all sites at the point of curvature (PC).

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.7 (-1.8)	-1.3 (-1.3)	-1.3 (-1.6)	-1.5 (-1.4)
Change in 85th percentile speed(mph)		-1.7 (-1.9)	-1.4 (-1.3)	-1.3 (-1.7)	-1.4 (-1.4)
Change in fraction of vehicles exceeding advisory speed by	5 mph	-13.5% (-11.0%)	-9.1% (-6.1%)	-11.2% (-8.7%)	-10.7% (-6.7%)
	10 mph	-27.7% (-24.5%)	-18.1% (-12.9%)	-22.6% (-18.5%)	-20.9% (-15.7%)
	15 mph	-29.1% (-23.4%)	-32.6% (-23.8%)	-31.9% (-28.6%)	-27.7% (-21.7%)
	20 mph	-39.6% (-48.0%)	-30.7% (-43.9%)	-26.3% (-26.4%)	-32.3% (-38.7%)
Change in fraction of vehicles exceeding posted speed by	5 mph	-23.8% (-15.2%)	-31.1% (-18.8%)	-30.3% (-23.8%)	-23.6% (-16.8%)
	10 mph	-10.5% -1.6%	-3.2% (-9.2%)	-15.0% (-14.0%)	-15.2% (-10.9%)
	15 mph	0.0% (-8.3%)	0.0% (-6.7%)	-3.8% (0.0%)	0.0% (-7.4%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

Table EX.2 further shows the downward trend of vehicles exceeding the advisory speed and speed limit by showing the percentage of vehicles exceeding both at each time period. The highest changes occurred in the percentage of vehicles exceeding the advisory speed by 10 mph

with 54.3% of vehicles exceeding before installation and less than 46.7% of vehicles exceeding during all after periods.

Table EX.2. Percentage of vehicles exceeding at point of curvature (PC) by time period.

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.7 (-1.8)	-1.3 (-1.3)	-1.3 (-1.6)	-1.5 (-1.4)
Change in 85th percentile speed(mph)		-1.7 (-1.9)	-1.4 (-1.3)	-1.3 (-1.7)	-1.4 (-1.4)
		Time Period			
		Before	1 Month	12 Month	18 Month	24 Month
Percentage of vehicles exceeding advisory speed	5 mph	76.5% (80.7%)	69.8% (74.6%)	71.5% (80.8%)	68.3% (70.8%)	70.3% (75.9%)
	10 mph	54.3% (58.9%)	43.8% (47.8%)	46.7% (55.6%)	44.2% (48.3%)	45.7% (50.6%)
	15 mph	26.2% (29.8%)	18.6% (20.6%)	20.3% (25.3%)	20.4% (23.7%)	20.1% (23.3%)
	20 mph	10.0% (12.1%)	6.5% (7.3%)	6.8% (8.9%)	8.3% (9.5%)	6.5% (7.9%)
Percentage of vehicles exceeding posted speed	5 mph	4.9% (5.8%)	3.0% (3.7%)	3.6% (4.9%)	2.7% (3.1%)	2.6% (3.8%)
	10 mph	0.6% (0.8%)	0.3% (0.5%)	0.4% (0.5%)	0.3% (0.4%)	0.2% (0.3%)
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

Figure EX.4 and Figure EX.5 show the percentage of vehicles with a difference in speed (speed limit or advisory speed) during all time periods at the point of curvature. Looking at all of the sites, the leftward shift of the lines from the before speeds, specifically those exceeding the speed limit, shows there is a reduction in the percentage of vehicles that are exceeding the speed limit or advisory speed. In Figure EX.4., the lines for all after periods have shifted to the left and show that percentages of vehicles exceeding the speed limit were influenced – more vehicles traveled at or slightly below the speed limit after the system was installed. Furthermore in Figure EX.5, all of the after periods have shifted to the left from the before period showing the trend of slower speeds compared to the advisory speed at the point of curvature.

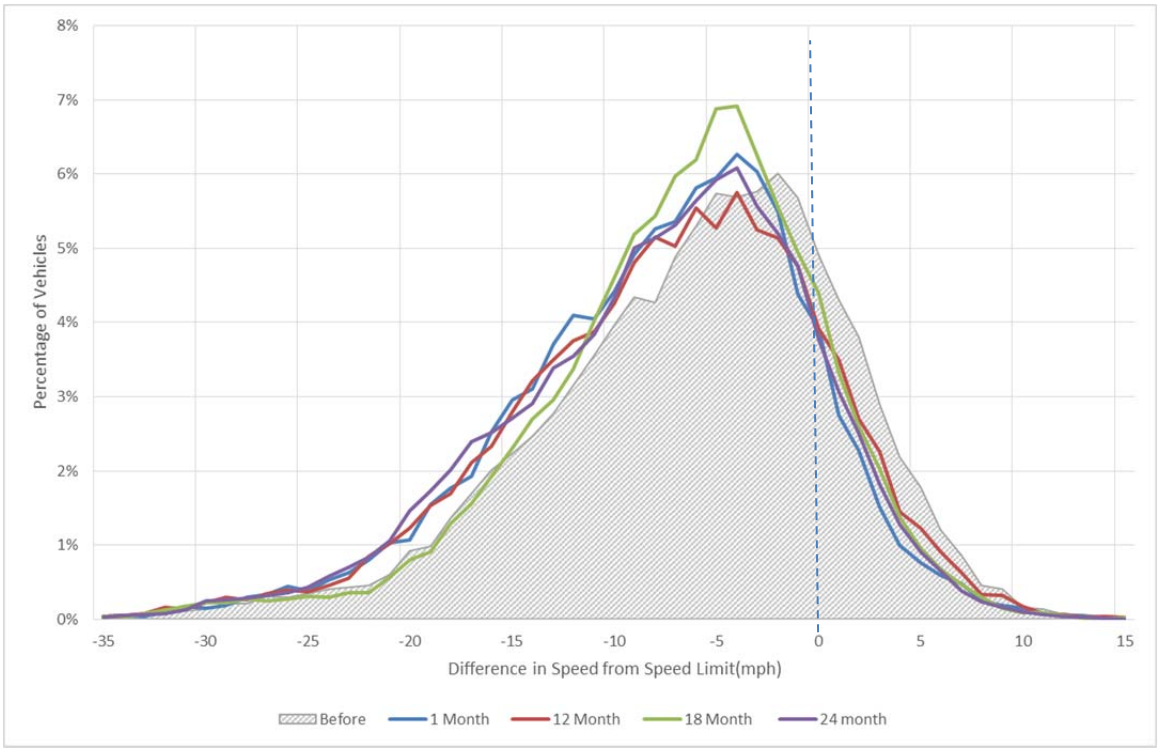

Figure EX.4. Percentage of vehicles with difference in speed from speed limit at point of curvature (PC).

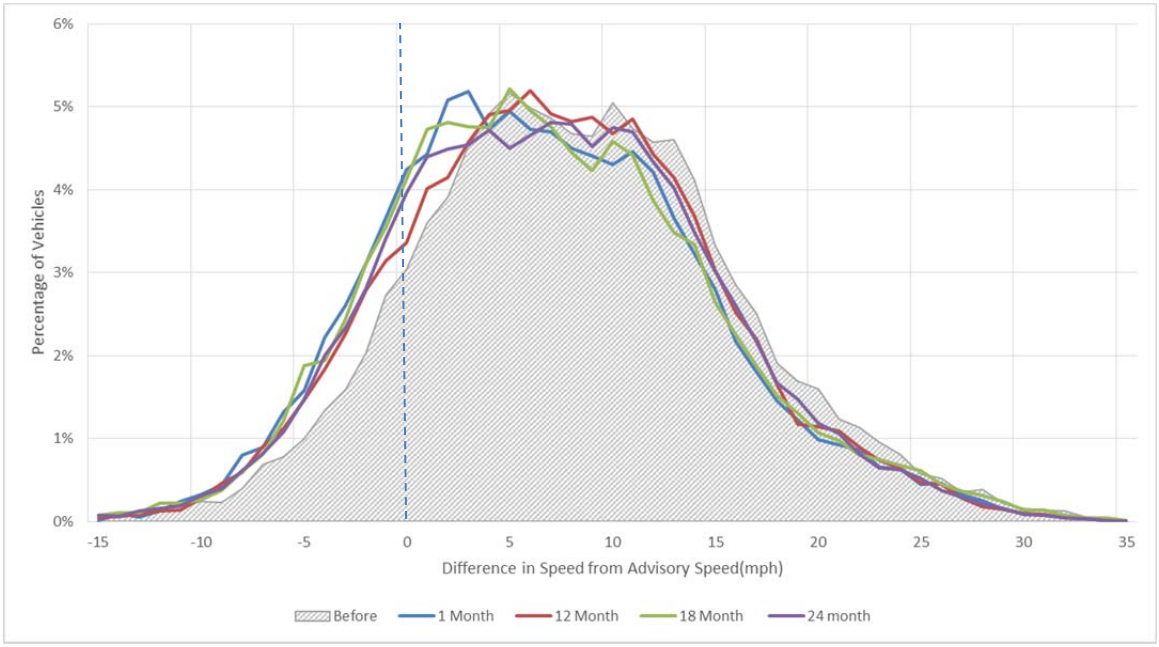

Figure EX.5. Percentage of vehicles with difference in speed from advisory speed at point of curvature (PC).

Table EX.3 shows the average change in speed at the center of curve across all sites by data collection period. The changes in mean speed were consistently lower across all time periods after installation.

The fraction of vehicles exceeding the posted or advisory speed also showed the effectiveness of the system in reducing speeds through decreases in vehicles exceeding speed/advisory limits. A 15 percent decrease in the fraction of vehicles exceeding the advisory speed by 5 mph or more was shown across all sites. For vehicles exceeding the advisory speed by 10 mph or more, the fraction of vehicles ranged from a decrease of 23.2 percent to 26.8 percent. The fraction of vehicles exceeding the advisory speed by 15 mph or more and 20 mph or more were 16 percent and 26 percent, respectively. The percentage of vehicles exceeding the advisory speed/speed limit at each time period at the center of curve is shown in Table EX.4. As shown, the percentage of vehicles exceeding were reduced and trended downward for all after periods.

Table EX.3. Average change across all sites at the center of curve (CC).

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.2 (-1.3)	-1.1 (-1.1)	-1.4 (-1.2)	-1.2 (-1.3)
Change in 85th percentile speed(mph)		-1.3 (-1.8)	-1.1 (-1.3)	-1.4 (-1.6)	-1.1 (-1.2)
Change in fraction of vehicles exceeding advisory speed by	5 mph	-12.7% (-10.2%)	-14.9% (-11.0%)	-19.9% (-17.8%)	-14.6% (-11.0%)
	10 mph	-25.3% (-22.9%)	-25.7% (-21.1%)	-23.2% (-29.8%)	-26.8% -45.6%
	15 mph	-19.9% (-22.2%)	-11.0% (-21.4%)	-18.9% (-34.0%)	-14.7% (-29.2%)
	20 mph	-29.3% (-22.7%)	-20.3% (-3.7%)	-18.8% (-18.9%)	-37.0% (-35.4%)
Change in fraction of vehicles exceeding posted speed by	5 mph	-6.4% (-3.1%)	-9.4% (-5.0%)	-16.2% (-10.5%)	-9.2% (-7.6%)
	10 mph	-0.5% (-2.6%)	6.0% -3.1%	3.5% -2.6%	0.0% (-3.5%)
	15 mph	0.0% (-0.2%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-4.1%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

Table EX.4. Percentage of vehicles exceeding at center of curve (CC) by time period.

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.2 (-1.3)	-1.1 (-1.1)	-1.4 (-1.2)	-1.2 (-1.3)
Change in 85th percentile speed(mph)		-1.3 (-1.8)	-1.1 (-1.3)	-1.4 (-1.6)	-1.1 (-1.2)
		Time Period			
		Before	1 Month	12 Month	18 Month	24 Month
Percentage of vehicles exceeding advisory speed	5 mph	68.0% (71.8%)	59.9% (63.8%)	60.8% (68.7%)	57.8% (61.5%)	59.3% (64.2%)
	10 mph	34.0% (38.3%)	26.1% (29.0%)	27.8% (33.5%)	28.1% (31.3%)	25.9% (29.3%)
	15 mph	9.9% (12.3%)	6.7% (7.4%)	7.8% (9.8%)	8.4% (9.8%)	7.4% (8.6%)
	20 mph	2.0% (2.5%)	1.0% (1.3%)	1.3% (1.9%)	1.8% (2.3%)	1.2% (1.5%)
Percentage of vehicles exceeding posted speed	5 mph	2.8% (3.3%)	2.3% (3.1%)	2.7% (3.5%)	2.3% (2.9%)	1.8% (2.7%)
	10 mph	0.2% (0.3%)	0.3% (0.3%)	0.3% (0.5%)	0.3% (0.4%)	0.2% (0.2%)
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

Figure EX.6 and Figure EX.7 show the percentage of vehicles with a difference in speed from the speed limit or advisory speed during all time periods at the center of curve. Both graphs show a reduction in the percentage of vehicles exceeding the speed limit or advisory speed during all after periods. Although not as defined as data from the point of curvature, the lines for all after periods have shifted, showing a reduction in speeds at the center of curve.

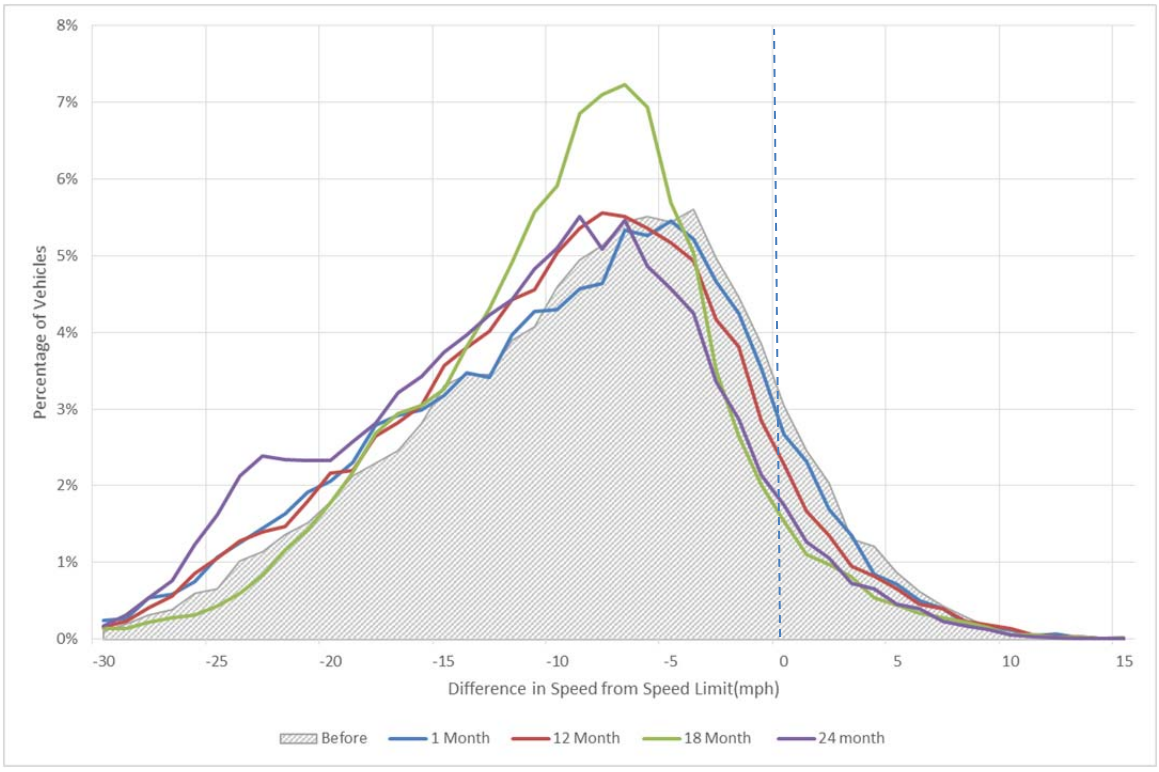

Figure EX.6. Percentage of vehicles with difference in speed from speed limit at center of curve (CC).

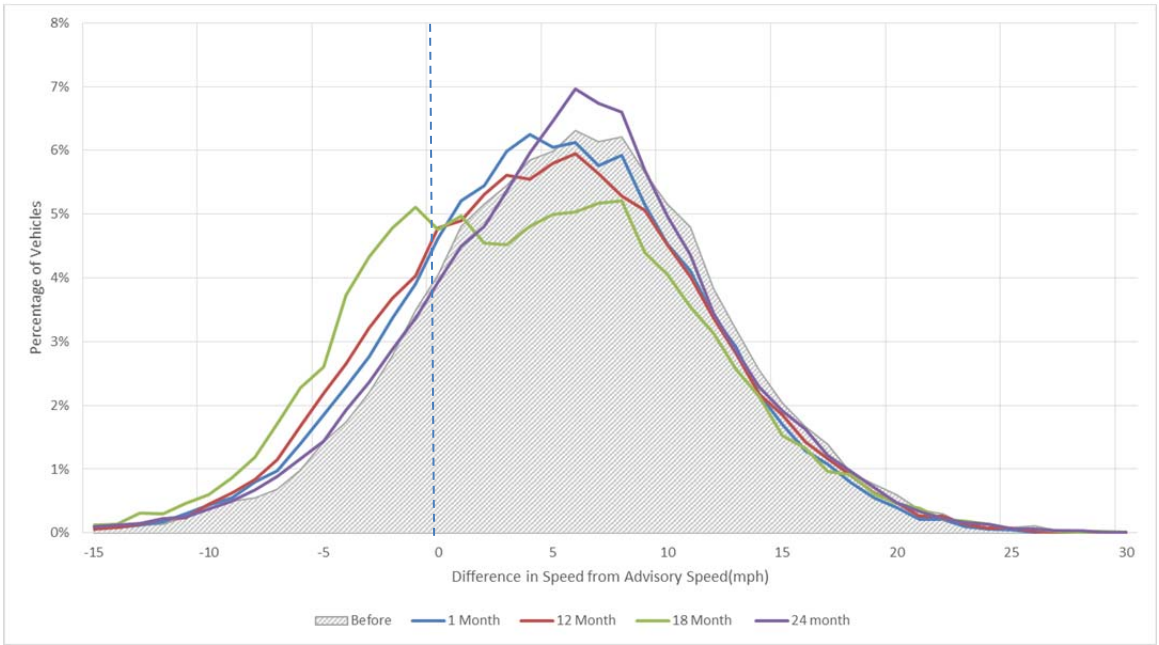

Figure EX7. Percentage of vehicles with difference in speed from advisory speed at center of curve (CC).

At both the point of curvature and center of curve, the tracked vehicle statistics were slightly higher or similar to the speed statistics for all vehicles. The tracked vehicle removed influences of trailing and following vehicles and showed that the vehicles only influenced by the SDCWS had a larger reduction in speed.

While speed was shown to be reduced, most agencies have a desire to lower the high-end speeds, which can substantially increase the safety of the curve. The results at both the point of curvature and center of curve suggest that the signs had an impact on high-end speeds during all data collection periods. Reductions were found in all vehicles exceeding the advisory speed but the largest decreases occurred in the vehicles exceeding by 20 mph or more. Higher decreases were found at the point of curvature suggesting that vehicles were reducing their speed prior to entering the curve and selecting an appropriate speed to negotiate the curve.

The speed results also indicate that the SDCWS was effective at reducing speed consistently between 1 and 24 months after installation. This suggests the signs may have a long-term impact on the speeds through the curve. With very little change in the mean and 85th percentile speed over time, the human factors impact of having a new or different sign had little effect.

Crash Analysis

The simple crash analysis, which was conducted to help determine the safety benefits, evaluated data 5 years before the SDCWS installation and 2 years after installation. The test sites where the SDCWS signs were installed and the selected control sites were evaluated.

Three of the sites had no crashes documented 2 years after the installation of the SDCWS (IA 141, TX FM 407, and TX FM 530). Reduction in the number of crashes per year was between 17 and 91 percent at seven other sites, while two sites had slight increases of 7 and 11 percent.

Although only a simple analysis of crashes was conducted (there were only two years of after data), the results showed improvement in safety by reducing crashes. A simple analysis cannot account for regression to the mean and other factors which will also affect crashes. Consequently, the results should be used to suggest that the treatment is effective but should be applied cautiously.

Conclusions

Overall, the SDCWS treatment appeared to be effective in reducing speed and crashes. The speed analysis showed small but consistent reductions in mean and 85 percentile speeds. The analysis also showed the reduction in the percent of vehicles exceeding the speed limit or advisory speed limit by 5, 10, 15, or 20 mph, particularly in the higher ranges. This shows the positive impact of the SDCWS in improving curve navigation and safety.

Agencies considering implementing the SDCWS should consider the following factors before installing the devices:

1. Location: Solar power is necessary for proper operation of the SDCWS. Locations should be investigated to ensure a proper view of the southern sky is feasible.
2. Maintenance: During the two year study, very few maintenance issues were encountered. However, it is recommended that agencies pay attention to the operation of the devices to make sure they are functioning.

3. Vandalism: Although devices with solar panels can be the subject of vandalism, the SDCWS solar panel doesn't attract much attention because of the relatively small size of the solar panel. No vandalism was reported during the two-year study.
4. Threshold settings: Due to the limited number of installations, one threshold setting – recommended by the manufacturer – was used. For operational use, agencies might want to experiment with speed threshold and blinking pattern settings to maximize the effectiveness of the devices.

The results from this research add to the body of knowledge and provide safety engineers with another tool to address curve-related crashes.

INTRODUCTION

Horizontal curves make up a small percentage of total road miles, yet account for one-quarter of all highway fatalities. The majority of curve-related crashes is attributed to speeding and driver error and involves lane departures. There are a number of low-cost countermeasures traditionally used to help keep vehicles on the road and in their lane; however, the impacts of their application can be limited, which leads to the need for additional research and testing on more dynamic devices to assist traffic engineers in managing speed and safety across their diverse roadway network.

Project Scope

More than 25 percent of fatal crashes are associated with a horizontal curve, and the vast majority of these crashes involve a roadway departure. The average crash rate for horizontal curves is about three times that of other highways segments. About three-quarters of curve-related fatal crashes involve a single vehicle leaving the roadway and striking trees, utility poles, rocks, or other fixed objects, or overturning. The majority of these crashes are speed related.

Implementing safety countermeasures on rural horizontal curves to address speeding can improve the safety performance for those locations. State safety and traffic engineers are faced with making decisions on what type of technology to use and which sites to use the technology on in a fiscally constrained environment. The research conducted for this project evaluated a Sequential Dynamic Curve Warning System (SDCWS) that could be an additional tool for these engineers to use either separately or in combination with other countermeasures to address horizontal curve locations with a history of safety concerns.

Project Objectives

The objective of this project is to test and evaluate the effectiveness of SDCWS in reducing vehicle speed as well as the frequency and severity of speed-related crashes on horizontal curves on rural roadways. With 12 treatment sites and 24 control sites having been identified in Missouri, Texas, Washington, and Wisconsin, speed data was collected before and one month after the installation, as well as at 12 months, 18 months and 24 months post installation.

Report Overview

The information in this report includes a summary of the literature on speed-activated display practices, site selection methodology, a list of treatment sites, the type and amount of data collected, data collection procedures and equipment, and analysis. The report analysis includes a summary of baseline data including roadway, traffic, and crash data as well as data analysis and results post installation data collection effort.

Literature Review

This section discusses the relationship between roadway geometry, vehicle speeds, and crashes on horizontal curves and reviews the effectiveness of various applications of Dynamic Speed Feedback Sign (DSFS) systems installed to date. This research effort will test the effectiveness of the SDCWS and its impact on safety. Even though several dynamic curve sign systems have been tested in the past, this system is unique in terms of including guidance not just before or at the curve, but also throughout the curve with the blinking chevrons. The results from this research will add to the body of knowledge and provide safety engineers with another tool to address curve crashes.

Relationship between Curve Crash Rate and Geometry

Curves have about three times the crash rate of tangent sections.[1] Preston and Schoenecker reported that 25 to 50 percent of the severe road departure crashes in Minnesota occurred on curves, even though curves account for only 10 percent of the total system mileage.[2] Shankar et al. evaluated divided State highways without median barriers in Washington State and found a relationship between the number of horizontal curves per kilometer and median crossover crashes.[3] Farmer and Lund evaluated single-vehicle fatal and injury rollover crashes using Fatality Analysis Reporting System (FARS) data and data from Florida, Pennsylvania, and Texas.[4] Using logistic regression, they found that the odds of having a rollover on a curved section were 1.42 to 2.15 times the odds of having a rollover on a straight section.

The majority of crashes on curves involve lane departures. A total of 76 percent of curve-related fatal crashes are single vehicles leaving the roadway and striking a fixed object or overturning. Another 11 percent of curve-related crashes are head-on collisions.[5]

The frequency and severity of curve-related crashes have been correlated to a number of geometric factors, including radius, degree of curve, length of curve, type of curve transition, lane and shoulder widths, preceding tangent length, and required speed reduction.

Luediger et al. found that crash rates increase as the degree of curve increases, even when traffic warning devices are used to warn drivers of the curve.[6] Miaou and Lum found that truck crash involvement increases as horizontal curvature increases, depending on the length of curve.[7] Council found that the presence of spirals on horizontal curves reduced crash probability on level terrain but did not find the same effect for hilly or mountainous terrain.[8] Vogt and Bared evaluated two-lane rural road segments in Minnesota and Washington State using Highway Safety Information System (HSIS) data and found a positive correlation between injury crashes and degree of horizontal curve.[9]

Zegeer et al. evaluated curves on two-lane roads in Washington State using a linear regression model.[10] The researchers found that the degree of curve was positively correlated with crashes, while total surface width and presence of spirals were negatively correlated. They also evaluated 10,900 horizontal curves on two-lane roads in Washington State using a weighted linear regression model and found that crash likelihood increases as the degree and length of curve increases.[10] Mohamedshah et al., however, found a negative correlation between crashes and degree of curve for two-lane roadways.[11]

Preston and Schoenecker examined severe roadway departure crashes and found that 90 percent of fatal crashes and 75 percent of injury crashes occurred on curves with a radius of less than

1,500 ft.[2] Milton and Mannering evaluated 2,725 miles of highway in Washington State using a negative binomial model and reported that an increase in radius was associated with decreases in crash frequency.[12] They also found that a shorter tangent length between horizontal curves was associated with decreases in crash frequency. They speculated that drivers may be traveling at lower speeds and are therefore more likely to be paying attention when tangent lengths between curves are short.

In contrast, Deng et al. evaluated head-on crashes on 729 segments of two-lane roads in Connecticut using an ordered probit model.[13] They included geometric characteristics in the analysis but did not find that the presence of horizontal or vertical curves was significant.

Taylor et al. evaluated the relationship between speed and crashes on rural single-carriageway roads in England.[14] The authors collected data from 174 road sections with 60 mph speed limits with a wide range of conditions. Data collected included injury crash data, traffic volume, speed data, and roadway geometry. Speed and flow were measured at each site for 1 or 2 days, and various speed metrics were calculated, including mean speed, 85th percentile speed, and standard deviation of speed. The authors found that crashes were more highly correlated with mean speed than any other speed metric. They also found that crash frequency increased with mean speed. In general, a 10 percent increase in mean speed resulted in a 26 percent increase in the frequency of injury crashes.

More recently, Khan et al. analyzed curves in Wisconsin to determine the relationship between safety, horizontal curve signs, and geometry.[15] Compared to previous research, a larger data set with greater detail was used to develop a model showing the relationship of the horizontal curves. The data showed that crashes increased with an increase in annual average daily traffic (AADT), posted speed, and curve length; they also increased with a decrease in curve radius. In addition, an analysis of traffic control signs indicated that sites with curve signs (W1-2) had fewer crashes than sites with turn signs (W1-1). Sharper curves, however, showed no significant correlation to sign type in reducing crashes because of other, more substantial influencing factors.

Relationship between Curve Crash Rate and Speed of Curve Negotiation

Although curve-related crashes are correlated to geometric factors, driver factors such as speed selection also contribute to curve-crash frequency and outcome. Driver factors include driver workload, driver expectancy, and speed selection.

Speeding, defined by FHWA as "exceeding the posted speed limit or driving too fast for conditions," is generally problematic. Council et al. evaluated FARS, General Estimates System (GES), and HSIS data to assess the impact of speeding on fatal crashes.[16] Using 2005 FARS data, they found that 29.5 percent of fatal crashes were speed-related. They conducted several different types of analyses and found the single-vehicle run-off-road crashes are more likely to be speed-related than are multi-vehicle crashes. Crashes on curves were more likely to be speed-related as compared to tangent sections and nighttime crashes. Additionally, FARS data indicated that 54 percent of speed-related rollover/overturn, jackknife, or fixed object crashes were on curves.[16]

FHWA estimates that approximately 56 percent of run-off-road fatal crashes on curves are speed-related.[6] The vehicle speed reduction from the tangent section required for traversing a curve has an impact on the frequency and severity of crashes in curves. Abrupt changes in

operating speed resulting from changes in horizontal alignment are suggested to be a major cause of crashes on rural two-lane roadways.[6]

Anderson and Krammes developed a model comparing mean speed reduction and mean crash rate for 1,126 horizontal curves on rural two-lane roadways.[17] They reported that the relationship between mean crash rate and required speed reduction to negotiate the curve is roughly linear. This finding is also supported by Fink and Krammes, who indicated that curves requiring no speed reduction did not have significantly different mean crash rates than their preceding roadway tangent.[18]

Driver errors on horizontal curves are often due to the inappropriate selection of speed and the inability to maintain lane position. Drivers' speed selection at curves depends on both explicit attentional cues and implicit perceptual cues.[19] A driver's speed prior to entering a curve has a significant effect on his or her ability to negotiate the curve successfully.[2] Inappropriate speed selection and lane positioning can be a result of a driver failing to notice an upcoming curve or misperceiving the roadway curvature.

Driver workload plays an important role in driver speed maintenance. Distracting tasks such as radio-tuning or cell phone conversations can draw a driver's attention away from speed monitoring, detection of headway changes, lane keeping, and detection of potential hazards.[19] Other factors include sight distance issues, fatigue, or complexity of the driving situation.[19,20]

Preston and Shoenecker evaluated vehicle paths through a curve on a two-lane rural roadway as part of an evaluation of a dynamic curve message sign.[2] The roadway had a posted speed limit of 55 mph and AADT of 3,250 vehicles per day (vpd). The researchers collected data over a 4-day period and randomly selected and evaluated 589 vehicles. A total of 340 of the vehicles (58 percent) were traveling over 55 mph, and the rest were traveling at or below the speed limit. The authors evaluated whether each vehicle successfully negotiated the curve. Vehicles that crossed a left or right lane line on one or more occasions were defined as "not successfully navigating the curve."

A logistic regression model was developed to determine the relationship between initial speed and the probability of a vehicle unsuccessfully navigating the curve. The researchers found that there was a 20 percent better chance for vehicles that were traveling at or below the speed limit to successfully navigate the curve than for vehicles that were traveling over the speed limit, with the difference being statistically significant at 99 percent. They found that 45 percent of vehicles traveling at or above 65 mph were unable to negotiate the curve compared to 30 percent for vehicles that were traveling under 65 mph, with the difference being statistically significant at the 90 percent confidence interval.

Hassan and Easa found that driver misperception of curvature was greatest when vertical curvature was combined with horizontal curvature.[21] This was particularly a problem when a crest vertical curve was superimposed on a severe horizontal curve, or when a sag vertical curve was combined with a horizontal curve, causing the horizontal curve to appear less severe and resulting in drivers underestimating the curve.

Charlton conducted a simulator study and evaluated driver speed adjustments on several types of curves with several types of signing.[20] Charlton found that, in general, drivers approached and entered curves at higher speeds when engaged in cell phone tasks than when in non-distraction scenarios.

Effectiveness of DSFS Systems

DSFS systems have been used in only a few cases to reduce speeds and warn drivers of upcoming curves. They have been used more extensively for a number of other related applications. A summary of information about the application of DSFS on curves and in related situations is provided below.

Bertini et al. studied the effectiveness of a DSFS system on Interstate 5 near Myrtle Creek, Oregon.[22] The system consisted of two displays that provided different messages to drivers based on the speed detected, as shown in table 1.

Table 1. Advisory message for Interstate 5 dynamic speed-activated feedback sign system.

Sign Panel	Sign Messages		
	Detected Vehicle Speeds Less than 50 mph	Detected Vehicle Speeds 50–70 mph	Detected Vehicle Speeds over 70 mph
1	CAUTION	SLOW DOWN	SLOW DOWN
2	SHARP CURVES AHEAD	YOUR SPEED IS XX MPH	YOUR SPEED IS OVER 70 MPH

The curve has an advisory speed of 45 mph with an AADT of 16,750 vpd. Before the DSFS system was in place, there was what the authors termed "dual overhead horizontal alignment/advisory speed combination sign assemblies with 4 flashing beacons." The DSFS system was put in place alongside one of the existing signs in both the northbound and southbound directions. Each system consisted of the actual dynamic message sign, a radar unit, a controller unit, and computer software. Figures 1 and 2 show the system.

The researchers collected speed data using a laser gun. Results indicated that, after installation of the DSFS system, passenger vehicle speeds were reduced by 2.6 mph and commercial truck speeds were reduced by 1.9 mph, with the results being statistically significant at the 95 percent confidence level. The distribution of speeds shifted to the left after installation of the signs, and the differences were found to be statistically significant based on a 95 percent confidence level using the chi-square test.

Results of a driver survey indicated that 95 percent of drivers surveyed noticed the DSFS system, and 76 percent said they slowed down due to the system.

Source: Oregon Department of Transportation. See Bertini et al. 2006.

Figure 1. Photo. Northbound Interstate 5 DSFS systems in Oregon.[22]

Source: Oregon Department of Transportation. See Bertini et al. 2006

Figure 2. Photo. Southbound Interstate 5 DSFS systems in Oregon.[22]

Another type of DSFS system, a vehicle-activated curve warning sign, was tested on curves in the United Kingdom.[23] Three curve warning signs were placed on two-lane roads in Norfolk, Wiltshire, and West Sussex. The signs, shown in figure 3, were placed 165 to 330 feet before the apex of a curve.

Figure 3. Photo. DSFS system in Norfolk.[(23)]

The signs were blank when the driver was under a specified speed threshold and displayed the curve sign when a driver exceeded the threshold. The speed threshold was set at the 50th percentile speed for the sign location because the researchers wanted to target the upper half of driver speeds. Once activated, the bend warning display was shown for 4 seconds. Based on previous research, the researchers had calculated this time as being sufficient for drivers to register and understand the message.

Speed data were collected for a minimum of 7 days before the signs were installed, and again 1 month and 1 year after installation. Data were collected at the 1-year period to determine if habituation occurs—in other words, whether drivers become immune to treatments and stop responding. Data were collected using pneumatic tubes at two sites and a radar gun at the third. Mean speeds were reduced by 2.1 mph at West Sussex, 3.0 mph at Wiltshire, and 6.9 mph at Norfolk.

Crash data were available for two sites, and the researchers found that crashes decreased 54 percent at the Norfolk bend site and 100 percent at the Wiltshire bend site. A public survey found that drivers approved of the signs.

The City of Bellevue Washington installed and evaluated 31 DSFS systems, including two used as curve advisory warnings (see figure 4). Both were on urban arterials with 35 mph speed limits and 25 mph advisory speeds. Speeds were collected before and between 18 months and 2 years after installation of the signs. One sign showed a 3.3 mph reduction in 85th percentile speed and the other showed a 3.5 mph reduction.

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Figure 4. Photo. DSFS system in Bellevue, Washington.[24]

Preston and Shoenecker also evaluated the safety effect of a DSFS system on County Highway 54 in Minnesota, which is a two-lane rural roadway with a speed limit of 55 mph and an AADT of 3,250 vpd.[2] The curve has an advisory speed of 40 mph. The DSFS system had a changeable message sign and radar unit. A field test was conducted over a 4-day period with a unit that consisted of a closed circuit TV camera, a VCR, and a personal computer. A portable trailer housed the entire system.

The sign displayed the following:

- From 6 a.m. to 10 a.m., 11 a.m. to 2 p.m., and 4 to 7 p.m.: CURVE AHEAD.
- No message during other times of the day unless activated.

During all times of the day, when the radar unit detected a vehicle traveling 53 or more mph, the camera would activate and record the vehicle for 18 seconds. Using a random number generator and depending on the time of day, the computer would either continue displaying the CURVE AHEAD message, display the CURVE AHEAD – REDUCE SPEED message, or display no message.

The team randomly selected 589 of the vehicles captured during data collection and evaluated whether each vehicle successfully negotiated the curve. Successful negotiation was defined as a vehicle remaining within the lane lines as it traversed the curve. Vehicles that crossed a left or right lane line on one or more occasions were defined as "not successfully navigating the curve."

The team found that approximately 35 percent of the drivers who received the message were unable to successfully negotiate the curve. Vehicles that received the CURVE AHEAD sign were more likely to negotiate the curve successfully, but the difference was not statistically significant. Only 26 percent of vehicles that received the CURVE AHEAD – REDUCE SPEED sign were unable to negotiate the curve successfully, and the difference was statistically significant at the 90 percent level of confidence.

Mattox et al. looked at the effectiveness of a DSFS system on secondary highways in South Carolina.[25] This system consisted of a radar device and a 4-ft by 4-ft yellow sign with 6-inch lettering reading YOU ARE SPEEDING IF FLASHING. In addition, there were two 1-ft by 1-ft orange flags and a type B flashing beacon light. Teams collected data in a before-and-after study upstream of the sign, at the sign, and then downstream of the sign. Results showed a significant reduction in speed at the sign and downstream of the sign. Overall mean speed and 85th percentile speeds were reduced by approximately 3 mph.

A report by the California Department of Transportation (Caltrans) provided a summary of the effectiveness of safety treatments in one California district.[26] A changeable message sign was installed at five locations along Interstate 5 to reduce truck collisions. Caltrans reported that truck crashes decreased from 71 percent to 91 percent at four of the sites, while truck crashes increased by 140 percent at one site.

A study by the 3M Company evaluated driver speed feedback signs, which display the approaching drivers' speeds, in the United Kingdom. Signs were tested at various locations in Doncaster, including semi-rural roadways. The sites had speed limits of 40 mph, and reductions up to 7 mph in 85th percentile speeds were noted.[27]

Tribbett et al. evaluated dynamic curve warning systems for advance notification of alignment changes and speed advisories at five sites in the Sacramento River Canyon on Interstate 5.[28] The roadway has high traffic volumes (7,650 to 9,300 vpd), mountainous terrain, and a number of heavy vehicle crashes. The signs were a 10-ft by 7-ft full matrix LED panel that could be programmed to display a variety of messages. Messages used by the researchers included curve warning (shown in figure 5) and driver speed feedback.

©Patrick McGowen. See Tribbet et al.

Figure 5. Photo. Speed warning sign in the Sacramento River Canyon.[26]

The researchers collected speed data using stopwatches. Data were collected before installation of the signs and at several points after the signs were installed; the researchers did not indicate when these after periods were, however. Speed results at the point of curvature (PC) include the following:

- Site 1: statistically significant decreases in mean truck speeds from 2.4 to 5.4 mph and decreases in mean passenger car speeds from 3.0 to 4.5 mph.

- Site 2: no statistically significant changes in truck or passenger car speeds for any time periods.
- Site 3: statistically significant decreases in mean truck speeds from 1.9 to 3.7 mph and increases in passenger cars from 5.2 to 7.8 mph.
- Site 4: no statistically significant change in mean truck speed and a 1.4 mph decrease for passenger cars for one time period that was statistically significant.
- Site 5: a statistically significant change in mean truck speed of 4.5 for one time period and decrease in mean passenger car speeds from 2 to 3 mph.

The researchers also compared 5 years of crash data before installation of the signs and 6 months after. However, due to the very short after period, the results were determined to be unreliable.

The Texas Transportation Institute evaluated the use of a portable speed display trailer in work zones.[29] They found that passenger vehicle speeds were reduced by 7 to 9 mph at one site and 2 to 3 mph at another. Truck speeds were reduced 3 to 10 mph at both sites.

Hallmark et al. also analyzed the installation of DSFS on curves throughout the country to determine the safety benefits.[30] Seven States participated, installing curve warning signs as well as speed feedback signs, which can be seen in figure 6. For the analysis, the mean speed, 85th percentile speed, and the percentage of vehicles going over the speed limit were compared.

Figure 6. Photo. Comparison of curve warning sign (left) and speed feedback sign (right).[30]

The average for all of the sites showed a 1.8 mph reduction in mean speed at 1 month, a 2.6 mph reduction in mean speed at 1 year, and a 2.0 mph reduction in speed at 2 years; all of these reductions occurred at the PC. The 85th percentile speed at the PC was reduced by 2.2 mph at both the 1-month and 2-year data collection period and was reduced by 2.9 mph at the 1-year data collection period. Similar decreases were seen in the percentage of vehicles going over the speed limit. The mean speed and 85th percentile speed were also lower at the center of curve, with the largest speed reductions occurring at the 1-month data collection period.

Between the two types of signs, larger decreases were seen with the speed feedback signs than with the curve warning signs. The signs were proven to be effective over time as well. A crash analysis was also performed for the direction of travel for the DSFS and for both directions combined. The analysis showed that, compared to control sites, crashes were reduced 2 to 4 times more for both directions and in the direction of travel by 1.7 to 6.0 times per quarter. Crash modification factors developed using a full Bayes model were .85 for both directions and .97 for the direction of the DSFS.

Sun et al. researched the effectiveness of sequential warning lights as a method to better define the beginning and taper into nighttime work zones.[31] The sequential lights were evaluated in Missouri along Interstate 70 with a right lane closure. Vehicle speeds at the closure were compared in addition to speeds at the point where the vehicle merged and at the lateral position in the taper. Decreases were seen in the mean speed of 2.2 mph and by 1 mph in the 85th percentile speeds, both of which were statistically significant. The lateral position of vehicles in the closed lane increased from 6.2 percent without sequential lights to 7.8 percent with sequential lights. The sequential lights had a negative effect, which could be due to drivers being more aggressive because the taper is illuminated better. The location where vehicles merged was split into eight zones with zone 8 being the zone closest to the taper. With the sequential lights, the total vehicles merging in zones 5 through 7 decreased while the vehicles merging in zones 1 through 4 increased. The exception that occurred was an increase in vehicles merging in zone 8, which further supports the aggressive driver assumption given the lateral position of the driver. Overall, vehicles were merging 20 ft. earlier with the sequential lights.

Santiago-Chaparro et al. evaluated the spatial effectiveness of speed feedback signs at a single location along State Highway 164 in Wisconsin.[32] Vehicles were tracked while approaching and receding from the speed feedback signs, and the speeds were monitored to determine when vehicles were slowing down and whether the speed reductions were sustained. The research found that vehicles were reducing their speed the most between 1,200 and 1,400 ft. upstream of the speed feedback sign. Speeds began to increase again between 300 to 500 ft. downstream of the speed feedback sign, and some vehicles increased speed before even passing the speed feedback sign. The results of the study showed that the speed feedback signs are not adequate for speed reductions at a corridor level but only at the location where the desired speed reduction should occur.

Tracking Vehicles for Data Reduction

Tracking involves monitoring individual vehicles as they traverse multiple data collection points. Limited research has been completed in this area; the literature search revealed only one study that used tracking to reduce data down to only affected vehicles.[33] In this study, tracking was used to determine how much vehicles were slowing down when approaching the sign. This aligns very well with curves, as the speeds of vehicles can be tracked while approaching and through the curve. Vehicles were tracked so that only free-flow passenger vehicles would be analyzed, eliminating vehicles that were influenced by a turning movement. To track the vehicles, the vehicle speed, vehicle length, and time headway were compared at each data collection location.

The standard method was used by determining the mean speed, 85th percentile speed, and

percentage of vehicles exceeding the posted speed first in their analysis, but it was not used in determining the effectiveness. Instead, a true effect (TE) was calculated by tracking vehicles and then determining the speed reduction for each vehicle before and after implementation. TE was calculated as shown in figure 7.

$$\text{True Effect} = \Delta V_{1\text{-}2,\ during} - \Delta V_{1\text{-}2,\ before}$$

Figure 7. Equation. True effect.

The tracked data were used to determine the statistics $\Delta V_{1\text{-}2,\ during}$, which is the mean speed reduction between sensors 1 and 2 during the study and $\Delta V_{1\text{-}2,\ before}$, which is the mean speed reduction between sensors 1 and 2 before implementation. Cruzado and Donnell briefly discussed that, depending on the upstream data collection, the data may be over- or underestimated by using only the mean speed reduction at the treatment location.[34] TE better reflects any changes in speeds while approaching the curve.

Another form of tracking was performed by McFadden and Elefteriadou, who determined whether calculating the difference of 85th percentile speeds between two points was significantly different than calculating the 85th percentile of speed reduction between the two points.[33] The 85th percentile of the speed reduction requires that individual vehicles be tracked to determine the speed reduction between the two points. This was achieved using light detection and a light detection and ranging (LIDAR) gun. With the tracked data, the 85th percentile speed reduction was significantly different than the change in 85th percentile speed. The change in the 85th percentile speed underestimated the speed reduction of the vehicles traversing the curve. Hirsh (1987) accounted for this with the differences of the distributions of the two locations.[35]

Misaghi and Hassan expanded on this research in Canada, but instead of using LIDAR guns they used counters.[36] The counters were tracked successfully if three criteria were met at both locations: number of axles, wheel base, and the expected time gap between the two locations. Tolerances were used in the tracking because of variance with the counter clock and inconsistencies with the data collected. Once complete, the speed reduction could be calculated between the points and the 85th percentile speed.

SELECTION OF TEST SITES FOR SDCWS

The intent of this project was to evaluate the SDCWS in five participant States (Iowa, Missouri, Texas, Washington, and Wisconsin). The research team developed site selection criteria for each and worked with each State to develop a list of candidate locations. The site selection criteria included the following:

- Two-lane rural paved roads.
- Posted speed limit of 50 mph or above.
- Existing chevrons.
- No unusual conditions within the curve (e.g., railroad crossing or major access).
- High crash location (10 or more crashes in the last 5 years, not including animal collisions); speed-related crashes preferred.
- No major rehabilitation/changes in alignment/operations in the last 3 years.
- No major rehabilitation/changes in alignment/operations planned for the next 2 years.

Specific information requested for each candidate site included:

- Curve location (Google map, latitude/longitude, etc.).
- Crash data including the location, direction, type, date, causation, etc.
- Posted speed limit (mph).
- Advisory curve speed, if present (mph).
- AADT.
- Truck traffic data, if available.
- Presence of passing lanes.

After reviewing the information from each State, the team developed a finalized list of potential sites and then conducted site visits. Final test sites were then selected in each State. The general methodology used to select sites in each State is described in the following sections.

Initial Review

A request for initial data was made to each State. The States were asked to provide data on multiple high-crash curve sites on rural two-lane roadways. It was left up to the discretion of each agency to determine what they thought were high-crash locations. Rural was defined as being at least 1 mile outside an incorporated area. Each curve was required to meet the following criteria:

- No rehabilitation or reconstruction activities that change the geometry of the roadway scheduled during the 2-year assessment.
- No geometric or cross-section changes made for 3 years prior to the study.
- Posted speed limit on tangent section 50 mph or greater.

Each State was also asked to provide the following information about the potential sites:

- Crash frequency.
- Traffic volume (AADT and percent trucks).

- Geometry (lane width, shoulder width, and type).
- Speed limit (posted or advisory) in mph.

The research team spatially located each site using Google Earth or the aerial images provided by the agency. The suitability of each curve location was evaluated, and locations that had major developments, railroads, or major points of access, including intersections other than low-volume intersections, were eliminated. Following this, additional information about the remaining sites was requested from each State, including:

- Presence of posted speed advisory on curve.
- Information about crashes (speed-related, severity, etc.).
- Expert opinion about safety and speed problems.
- Existence of unusual traffic or other conditions.

Based on the information received, the sites were ranked in terms of number of crashes with a threshold of at least 5 crashes over a 5-year period being used to define a high-crash location.

Figure 8 shows the 10 candidate curve locations identified by the Washington State Department of Transportation (DOT) for which the team conducted site visits. A similar site visit map of candidate test locations was developed for each State. In this map, the green locations were the sites that were selected after the site visits.

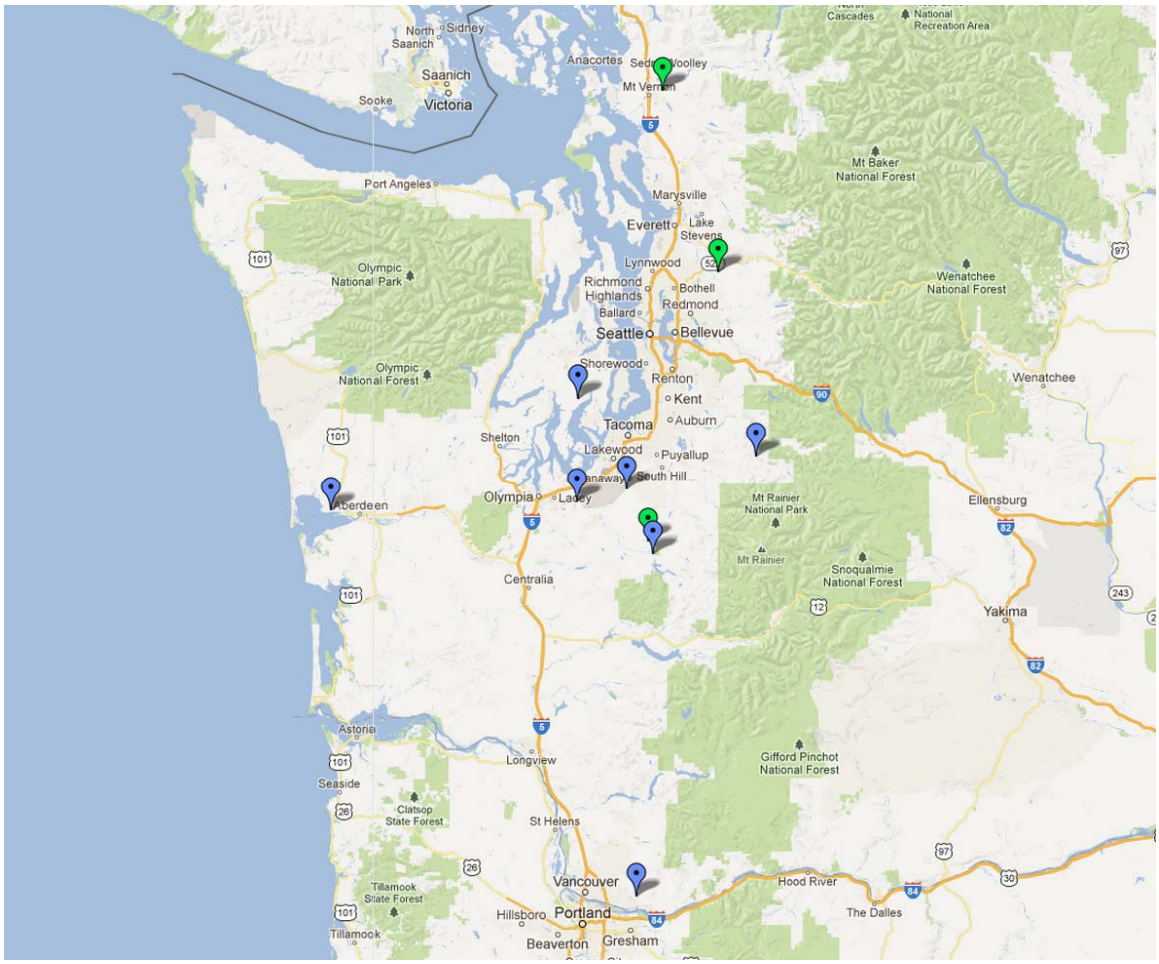


Figure 8. Map. Washington State DOT candidate sites. (Source: Google Maps)

Site Visits

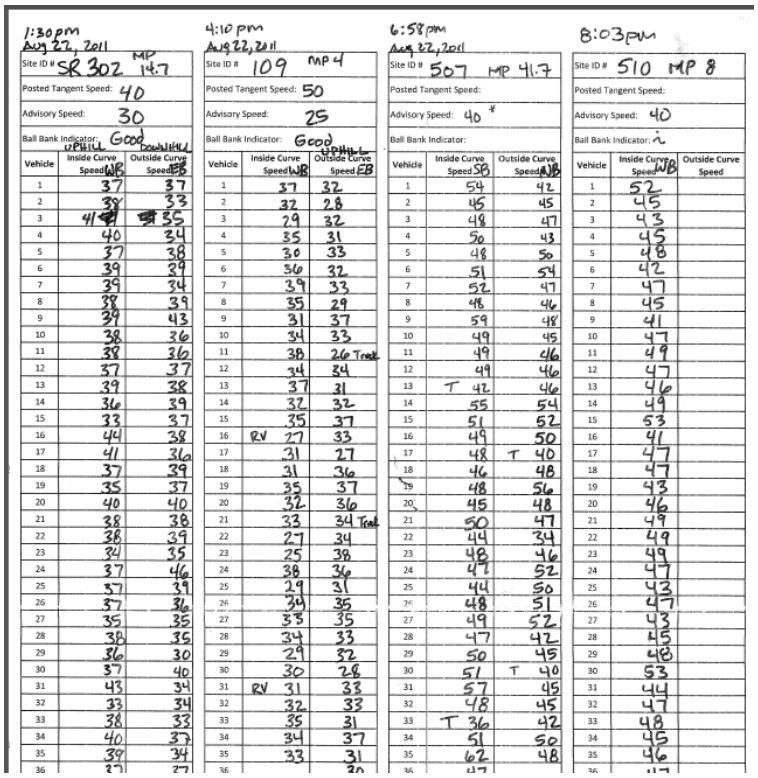
The research team conducted site visits to all candidate locations. These field observations identified roadway characteristics including curve layout, operational conditions, presence of speed and advisory signs, and relevant roadway conditions (see the example photo in figure 9).

In addition, a speed study was conducted using a radar gun to verify whether a speeding problem exists. (An example of the site visit data collection form is shown in figure 10.) At least 25 speed observations were collected for both directions of traffic unless physically prohibited due to site conditions or topography. Mean speed, by direction, was calculated for each location. When sample size was sufficient, 85th percentile speeds were calculated. A speeding problem was identified if at least one of the following conditions existed:

- Mean speed exceeded the advisory speed limit by 5 mph or more, or, if an advisory speed was not posted, exceeded the posted speed limit by 5 mph or more.
- 85th percentile speed exceeded the advisory speed limit by 5 mph or more, or exceeded the posted speed limit by 5 mph or more, if an advisory speed was not present.

A field report was prepared which included all of the field information collected for each site visited; see the example shown in figure 11.

Figure 9. Photo. Candidate curve site in Washington State. (Source: ISU/TTI)



1:30pm
Aug 22, 2011
Site ID # SR 302 MP 14.7
Posted Tangent Speed: 40
Advisory Speed: 30
Ball Bank Indicator: Good

Vehicle	Inside Curve Speed WB	Outside Curve Speed EB
1	37	37
2	38	33
3	41	35
4	40	34
5	37	38
6	39	39
7	39	34
8	38	39
9	39	43
10	38	36
11	38	36
12	37	37
13	39	38
14	36	39
15	33	37
16	44	38
17	41	36
18	37	39
19	35	37
20	40	40
21	38	38
22	38	39
23	34	35
24	37	46
25	37	39
26	37	36
27	35	35
28	38	35
29	36	30
30	37	40
31	43	34
32	33	34
33	38	33
34	40	37
35	39	34

4:10 pm
Aug 22, 2011
Site ID # 109 MP 4
Posted Tangent Speed: 50
Advisory Speed: 25
Ball Bank Indicator: Good

Vehicle	Inside Curve Speed WB	Outside Curve Speed EB
1	37	32
2	32	28
3	29	32
4	35	31
5	30	33
6	36	32
7	39	33
8	35	29
9	31	37
10	34	33
11	38	26 Truck
12	34	34
13	37	31
14	32	32
15	35	37
16	RV 27	33
17	31	27
18	31	36
19	35	37
20	32	36
21	33	34 Truck
22	27	34
23	25	38
24	38	36
25	29	31
26	34	35
27	33	35
28	34	33
29	29	32
30	30	28
31	RV 31	33
32	32	33
33	35	31
34	34	37
35	33	31

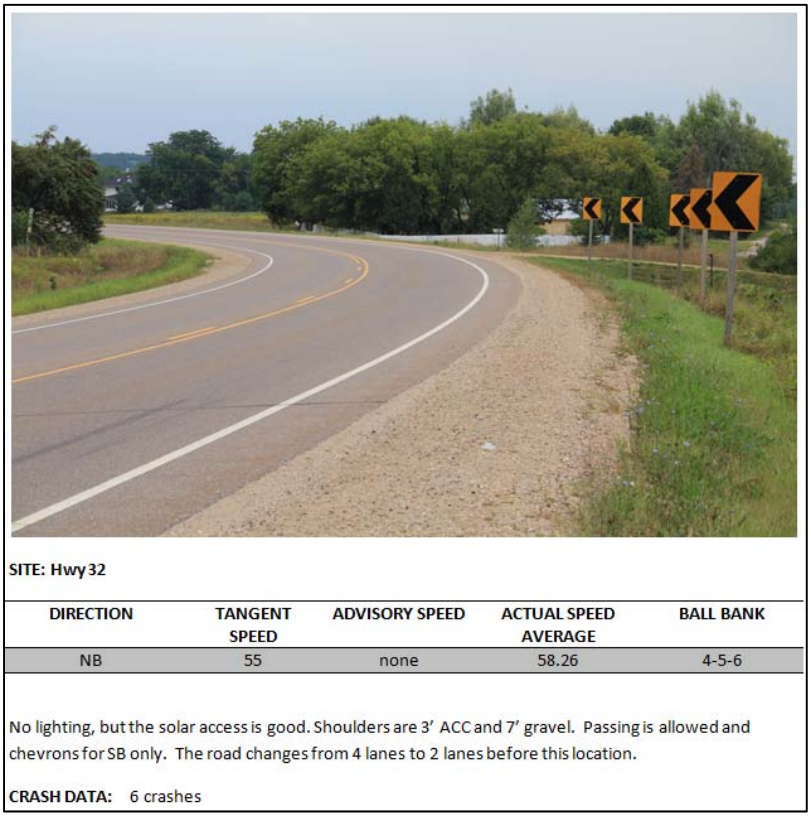
6:58pm
Aug 22, 2011
Site ID # 507 MP 41.7
Posted Tangent Speed:
Advisory Speed: 40 *
Ball Bank Indicator:

Vehicle	Inside Curve Speed SB	Outside Curve Speed NB
1	54	42
2	45	45
3	48	47
4	50	43
5	48	50
6	51	54
7	52	47
8	48	46
9	59	48
10	49	45
11	49	46
12	49	46
13	T 42	46
14	55	54
15	51	52
16	49	50
17	48	T 40
18	46	48
19	48	56
20	45	48
21	50	47
22	44	34
23	48	46
24	47	52
25	44	50
26	48	51
27	49	52
28	47	42
29	50	45
30	51	T 40
31	57	45
32	48	45
33	T 36	42
34	51	50
35	62	48

8:03pm
Site ID # 510 MP 8
Posted Tangent Speed:
Advisory Speed: 40
Ball Bank Indicator:

Vehicle	Inside Curve Speed WB	Outside Curve Speed
1	52	
2	45	
3	43	
4	45	
5	48	
6	42	
7	47	
8	45	
9	41	
10	47	
11	49	
12	47	
13	46	
14	49	
15	53	
16	41	
17	47	
18	47	
19	43	
20	46	
21	49	
22	49	
23	49	
24	47	
25	43	
26	47	
27	43	
28	45	
29	48	
30	53	
31	44	
32	47	
33	48	
34	45	
35	46	

Figure 10. Chart. Example site visit speed data collection form.



SITE: Hwy 32

DIRECTION	TANGENT SPEED	ADVISORY SPEED	ACTUAL SPEED AVERAGE	BALL BANK
NB	55	none	58.26	4-5-6

No lighting, but the solar access is good. Shoulders are 3' ACC and 7' gravel. Passing is allowed and chevrons for SB only. The road changes from 4 lanes to 2 lanes before this location.

CRASH DATA: 6 crashes

Figure 11. Photo. Example field report from initial visit. (Source: ISU/TTI)

Selection of Final Sites

Following the site visits, the research team selected the final test curve locations for installation of the SDCWS, as shown in table 2 and figure 12.

Table 2. Final test sites by State.

State	Number of Test Sites
Iowa	1
Missouri	1
Texas	4
Washington	3
Wisconsin	3

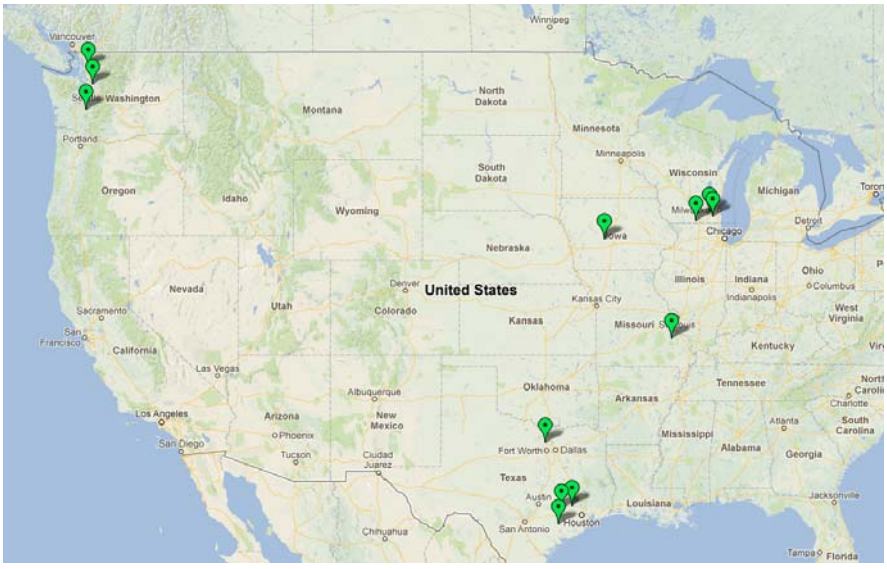


Figure 12. Map. Final test site locations. (Source: Google Maps)

Selection of Study Direction

Since only one SDCWS was installed per curve location, it was necessary to determine in which direction of travel the system would be installed (e.g., eastbound versus westbound). If one direction had a higher percentage of speed-related and/or single-vehicle run-off-road crashes than the other direction, the SDCWS was placed for this direction. It should be noted that direction information was not available for all crashes. If no predominant crash direction was noted, the SDCWS was assigned to whichever direction of travel had the highest speeds based on the initial speed study.

Final Site Information by State

Table 3 provides a summary of curve site characteristics for each final test site location. Appendix A includes a summary of the baseline data for each test location.

Table 3. Curve characteristics.

Site ID	State	Route	Study Direction	Number of Crashes	Number of Years	Crashes/Year	ADT	Roadway Geometry					Posted Speed of Tangent Sections	Curve Advisory Speed	Number of Chevrons	Chevron Size (in)	Access Points In/Near Curve?
								# Lanes	Lane Width (ft.)	Road Surface	Shoulder Width (ft.)	Shoulder Surface					
IA 144	Iowa	Hwy 144	EB	8	5	1.6	1,435	2	12	Asphalt	4	Gravel	55	45	7	30x36	Yes
MO 221	Missouri	Hwy 221	NB	31	5	6.2	1,000	2	11	Asphalt	4	Asphalt	55	40	6	18x24	No
WI 20	Wisconsin	Hwy 20	WB	7	3	2.3	3,583	2	12	Asphalt	2	Mix	55	30	9	18x24	Yes
WI 67	Wisconsin	Hwy 67	SB	9	3	3.0	3,494	2	12	Asphalt	3	Mix	55	25	5	18x24	No
WI 213	Wisconsin	Hwy 213	SB	7	3	2.3	2,369	2	12	Asphalt	3	Asphalt	55	50	5	18x24	Yes
SR 7	Washington	SR 7	SB	19	5	3.8	1,408	2	11	Asphalt	3	Asphalt	50	20	3	24x30	Yes
SR 9	Washington	SR 9	SB	6	5	1.2	5,800	2	10	Asphalt	2	Asphalt	50	40	3	18x24	Yes
SR 203	Washington	SR 203	SB	5	5	1.0	11,000	2	11	Asphalt	5	Asphalt	55	40	6	18x24	No
DAL 407	Texas	FM 407	EB	10	7	1.4	5,000	2	11	Treated Surface	1	Treated Surface	55	40	5	18x24	Yes
HOU 1488	Texas	FM 1488 (FM 362)	NB	8	7	1.1	4,400	2	11	Treated Surface	4	Treated Surface	55	40	13	18x24	No
YOA 109	Texas	FM 109	NB	16	7	2.3	2,500	2	11	Treated Surface	2	Treated Surface	60	35	6	18x24	Yes
YOA 530B	Texas	FM 530	WB	9	7	1.3	560	2	11	Asphalt	2	Asphalt	60	35	6	18x24	Yes

INSTALLATION

Once the test sites were established, the research team provided the chevron quantity and sign curve warning sign details to the manufacturer. All installations were completed by the SDCWS manufacturer with support from each State DOT. Table 4 provides a summary of installation dates by location. The manufacturer calibrated the sign and radar operational settings specific to each location. Figure 13 shows several photos from a typical installation.

Table 4. Installation dates.

State	Installation Date
Iowa	September 2012
Missouri	June 2012
Texas	July 2012
Washington	August 2012
Wisconsin	June 2012

Advance Warning sign

Chevron Installation

Chevron with LED and Solar Panel

Chevron in Operation

Figure 13. Photos. Installation of the SDCWS. (Source: ISU/TTI)

Technology Description

TAPCO's SDCWS utilizes Day-Viz™ LED enhanced solar powered signs and BlinkerBeam™ wireless controllers along with ultra-low power radar to detect and flash a series of chevron signs along with the advance warning sign in a horizontal curve. This system both warns and guides drivers through any upcoming horizontal curves.

The SDCWS is meant to replace existing W1-8 and advance warning signage or be used in the design of a new curve as a low-cost warning system. Chapter 2C of the Manual on Uniform Traffic Control Devices (MUTCD) and engineering judgment should be applied when determining appropriate sign layouts and locations.

Using the length and speed of the curve, the user can set each of the W1-8 chevron signs to flash in a specific sequence or time interval. Each curve design will have different sign placement and geometry for consideration when determining the appropriate flash sequence.

Typically, each sign will flash at least once per second according to MUTCD guidelines, with a flash "ON" time of 100 milliseconds. When the quantity of chevrons exceeds nine, chevrons are commonly divided into two separate sequentially flashing systems in which the first and fifth sign will start flashing at the same time, followed by the second and sixth, and so on. This gives the effect of the system guiding or pulling the driver through the curve and highlights the geometry while still meeting the MUTCD guidelines.

The speed of the sequence and flash duration are determined based on the quantity of signs and speed of the curve. For example, when the speed of the curve is 45 mph and the curve distance from the start of the advance warning sign to the last chevron is 1,000 ft., the flash duration can be set to 15 seconds (1,000 ft. ÷ 66 ft/sec = 15 seconds). This time will vary based on existing sign locations, driver speed, and other factors noticed during installation.

The radar can detect up to 300 ft in advance of the curve sign and will commonly be set to flash at or just below the advisory speed of the curve. Once this speed threshold is exceeded, the radar will trigger the flash of the advance warning sign and sequential chevron signs using TAPCO's 900-Mhz BlinkerBeam™ wireless network. This wireless network is constantly communicating with each sign and providing a synchronization pulse throughout the network. This synchronization pulse is what each sign controller will use to keep the proper flash time and sequence.

During setup, the user can program when the sign LEDs should turn on (called "Beacon Start") and the duration they should stay on (called "Beacon Stop"). The Beacon Stop will become the duty cycle, which is typically no less than 100 milliseconds. This allows many options for configuring the flash sequence and speed of the flash for each horizontal curve. An example of the system in its entirety can be seen in figure 14.

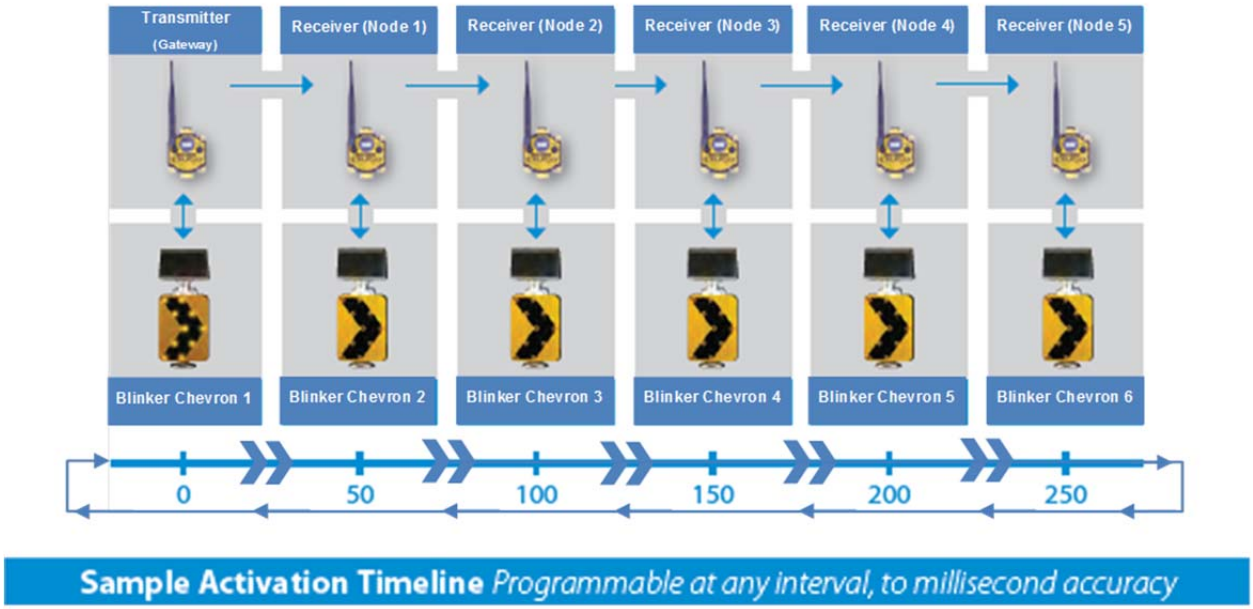


Figure 14. Photo. Example SDCWS activation sequence. (Source: TAPCO)

METHODOLOGY FOR SPEED DATA COLLECTION

The collection of traffic speed and volume data was integral to this project because these data provide the before-and-after contrast necessary to assess the effectiveness of the SDCWS.

Equipment

Pneumatic road tubes and counters were used to collect speed and volume data. The advantage of the road tubes is that they are reasonably accurate, can collect individual vehicle speeds (allowing for spot-checking of the data), are low-cost, and are nondestructive to the existing roadway surface. The counters used were Trax I automatic traffic recorders manufactured by JAMAR Technologies, Inc. The units can collect individual vehicle speeds, headways, vehicle class, and volume.

For each data collection period, the counters were set up to record time, vehicle speed, and vehicle class for individual vehicles. Other metrics such as volume, headway, average speed, etc., can be calculated from these data. Since the clocks on the counters can drift, the clocks were checked and reset each time they were used.

Data Collection Periods

Speed and volume data were collected at each test location using the pneumatic road tubes. Data collected about 1 month before installation are referred to as "before" data. Data collected about 1 month after installation are referred to as "1 month after" data. In all States, data were collected again at about 12 months, 18 months and 24 months after installation (referred to as "12 month", "18 months" and "24 months" data).

Data Collection Protocol and Quality Assurance

Speed and volume data were collected at three locations per test site. The goal was to understand driver speed selection in advance, at the beginning of the curve, and within the curve. These three locations are described below and shown in figure 15:

- Upstream – Road tubes were placed approximately 500 ft before the advanced curve warning sign (just in advance of being detected by the radar within the advance curve warning sign).
- PC – These tubes were placed at the point of curvature or beginning point of the curve.
- CC – Tubes placed within the center of the curve.

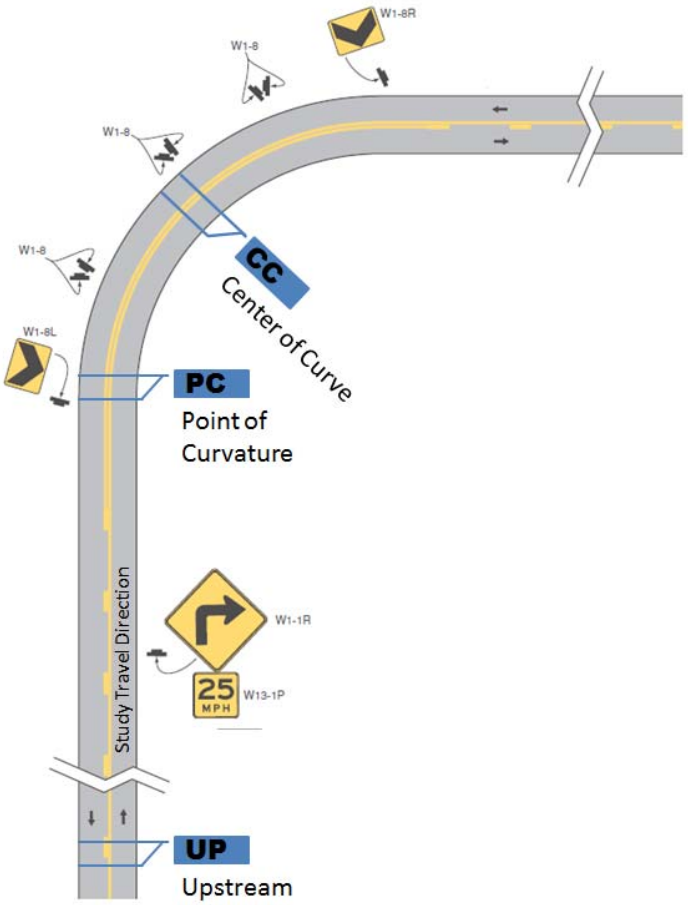


Figure 15. Diagram. Typical traffic counter placement.

Speed patterns can vary as a results of weather, time of year and so forth, so the purpose of the upstream data collection locations were to measure any changes in speed that may have occurred independent of the sign installation. The upstream data collection locations were placed outside of the radars detection area so that they would not be affected by the sign and would not adjust driver behavior. The upstream location also allowed vehicles to be tracked through the point of curvature and center of curve to determine individual vehicle speed reductions.

In most cases, data were collected for at least 1 day (24 hours) during the week (Monday through Friday). For the 24 month data collection period at least 2 days (48 hours) of data were collected in order to analyze the day and night effects of the signs. During data collection, the equipment was spot checked to determine whether any problems had occurred. Common problems included the pneumatic tubes getting pulled up from the pavement, the tubes being damaged in some way, or the counters malfunctioning. Any of the problems were addressed in the field and noted in the data.

Data were checked in the field during data collection to spot problems early, and the full data sets were checked when data collection was complete. Data were checked for the following situations that, based on the team's experience, indicate problems with the counters:

- Large number of low speeds (≤5 mph).

- Large number of high speeds (90 mph and higher) (this usually indicates a problem with road tube layout).
- Large number of vehicles with vehicle classification = 14 (class = 14 are vehicles that the counter cannot identify).

Data Reduction

When the data collection period for a site was complete, the data were downloaded and checked. The data were usually collected for more than 24 h and then "trimmed" to exactly 24 h. This allowed for the time the researchers were placing and picking up the counters to be removed and not impacting the data.

After trimming the data file, data were sorted by direction (i.e., SDCWS direction and non-SDCWS direction). An actual day count was calculated for each data collection period by dividing the total number of vehicles in both directions by the number of 24-h periods in the dataset.

Vehicles classified as 14 are vehicles that the counter could not classify. Class 14 vehicles were included in the count for the actual day count because vehicles were actually present and recorded but removed from the data set for the speed metric calculations. Frequently, a speed of 0 is associated with the Class 14 vehicle.

A number of speed metrics were then calculated for the direction of travel toward the SDCWS. They include average speed, standard deviation of speed, 50^{th} percentile speed, 85^{th} percentile speed, and percent of vehicles traveling 5, 10, 15, or 20 mph over the posted and advisory speed limit.

Data Reduction-Tracking

Tracking vehicles allows for only vehicles impacted by the SDCWS to be analyzed. To be tracked, the vehicle needed to be recorded by the counter at all three data collection locations. This process removed vehicles that did not go through the entire curve and would not have not been impacted by the SDCWS. For example, a curve with a side street by the curve would have vehicles slowing down to make the turn or speeding up after turning off the side road. In both situations the lower speeds were influenced by the turning movement and not by the SDCWS. Tracking vehicles singles out only the vehicles that are influenced by the SDCWS through the curve.

After removing the class 14 vehicles at all three data collection locations, three criteria were used to accurately track the vehicles between the data collection locations: the time between counters, the headway between vehicles and the classification of the vehicles. All three criteria were analyzed simultaneously and if one measurement was not within an acceptable range than the data would be removed from the tracking. The criteria applied between vehicles from the upstream to point of curvature data collection location and the point of curvature to center of curve data collection locations.

The time between the counters measured the time it took for a vehicle to be counted at one counter location until it was counted at the next counter location. The time stamps of the first

counter were subtracted from the time stamps of the next counter to get the actual time taken to drive from one counter to the next. An estimated time between the counters were calculated using the distance between the counters and the average of the speed at both counters. If the actual time between the counters and the estimated time between the counters were within five seconds then the first criteria was met. If the criteria were not met the vehicles were removed from the tracking dataset.

The second criteria used the headway between the vehicles. The time stamps of the current vehicle were subtracted from the vehicle before to determine the headway at both data collection locations. If the headways at both data collection locations were within five seconds then the second criteria was met. Again if the vehicles did not meet the criteria then the vehicles were removed for the dataset.

The final criteria used the FHWA vehicle classification to confirm the same vehicle class at both data collection locations. The pneumatic tube counter is able to determine the vehicle classification based on the number of axles and the distance between the axles. When the vehicle classifications were not the same, the classifications were analyzed further to determine if the vehicle classes were similar. If the vehicle class were the same or similar then the vehicles met the final criteria and were successfully tracked

Once the vehicles were tracked, vehicles were then removed based on their headway and tailway. This removed the vehicles that were not in free flow and had their speed influenced by a vehicle in front or behind them. The criteria for a free flowing vehicle used were having greater than a five second headway and/or three second tailway. If the upstream, point of curvature, or center of curve were not in free flow then the entire vehicles data were removed.

The same speed metrics for all vehicles were then calculated for tracked vehicles. In addition to these speed metrics for each tracked vehicle, a speed reduction metric can be calculated from the upstream to point of curvature, upstream to center of curvature and point of curvature to center of curve. The benefit to this metric is that it identifies where speed reductions are occurring. It also takes into account the speed reductions upstream where the other metrics used the upstream location as a control point. The average and 85^{th} percentile speed reduction between all of the data collection locations were then calculated for each site.

SPEED ANALYSIS

This chapter describes the speed metrics used to assess the effectiveness of the SDCWS. Speed results across sites are also summarized. Since data were collected at three locations per curve, results for individual sites are reported in appendix B. In addition, nighttime versus daytime speeds were compared for the 24 month after data collection period for all sites in appendix C.

Speed Metrics

The change in speed metrics from the before period were compared to each after period. A negative result indicates that speeds were reduced from the before period to the after period. A positive value indicates that speed increased from the before period to the after period. Mean and 85th percentile speeds are shown using a trend line. This is shown for graphical purposes only and should not be interpreted to indicate that speeds can be interpolated between data collection periods.

The change in mean and 85th percentile speed from the before period speed to specific after period speed are shown in miles per hour (mph). The percentage change in the percentage of vehicles exceeding the posted and advisory speed is also presented. This change in percentage was calculated by taking the difference in percentage of vehicles exceeding the speed from before to after then dividing by the percentage of vehicles exceeding in the before period. Determining this percentage allowed for better comparison between sites compared to calculating the difference in percentage of vehicle exceeding the speed limit/advisory speed. A number of speed metrics were calculated for the direction of travel towards the signs. They include average speed, standard deviation (SD) of speed, 50th percentile speed, 85th percentile speed, and percentage of vehicles traveling 5, 10, 15, or 20 mph over the posted and advisory speed limit. For simplicity in setting up the pneumatic road tubes, the traffic counters were set up to record both directions of traffic on the two-way roadway. Results were reduced by lane and are only presented for traffic traveling in the direction of the SDCWS.

Average or mean speed is the average of all spot speeds at the location in question. For the tracking mean speed, this only includes vehicles that were tracked through all three data collection locations and were not influenced by vehicles leading or following. Standard deviation indicates the amount of variability for a given speed. It can be used to show how speeds are dispersed around the mean. Higher standard deviations indicate greater variability in the data.

The 50^{th} percentile speed is the speed at which 50 percent of the vehicles are traveling or below. The 85^{th} percentile speed is the speed at which 85 percent of the vehicles are traveling or below. The percentage of vehicles traveling at or above the posted speed limit and/or advisory speed by a certain threshold amount was also calculated. This metric provides a measure of the number of vehicles traveling at high speeds. In many cases, agencies are more concerned with reducing the number of drivers traveling at excessive speeds than with simply reducing average speeds.

The mean, standard deviation, 85^{th} percentile, and percent of vehicles traveling at or above 5, 10, 15, and 20mph over the posted and advisory speed limit were calculated at each location for each data collection period. The same speed metrics were calculated again once the tracking was completed at each location for each data collection period. Mean speeds were compared at the 95-percent confidence level using a *t*-test (assuming unequal variances). Appendix D shows the

normal distribution for all data collected. The percent of vehicles traveling at 5, 10, 15, and 20 mph above the posted and advisory speed limit (before periods) were compared with those of after periods. A z-test was used to detect differences between two population's proportions at the 95-percent confidence level.[37]

With the tracking results, a speed reduction statistic was calculated from the upstream to point of curvature, the upstream to center of curve, and the point of curvature to center of curve. This is calculated for each tracked vehicle by taking the speed at the first counter then subtracting the speed at the second counter. Using all speed reductions calculated, the mean and 85th percentile were calculated similar to the mean speed before.

The change in speed reduction from the before period was compared to each after period. But different from the other speed metrics, a positive result indicates that speeds were reduced from the before period to the after period. This is because the higher the speed reduction, the more the vehicle is slowing down through the curve. A negative value indicates that speed increased from the before period to the after period. This will be noted with each table for reference. The mean speed reduction was compared at the 95-percent confidence level using a *t*-test (assuming unequal variances).

Summary of speed analysis

Data were collected at 12 sites for five time periods (before, 1 month after, 12 months after, 18 months after, and 24 months after). Data were also collected at three different locations at each site as described in the methodology. This resulted in a significant amount of information. Consequently, results for individual sites by time period and location are provided in appendix B. Results across sites were summarized and are presented in the following section.

Results of Speed Analysis at Point of Curvature

Summarized results of the data collected at the point of curvature are shown in Table 5 through Table 8. The changes in mean and 85th percentile speed from the before to designated after periods are shown. All changes are shown in mph with a negative sign showing a reduction in speed or percentage. The percent change in the fraction of vehicles exceeding the posted and advisory speed by 5, 10, 15 and 20 mph or more is also presented.

Data were collected for all vehicles and tracked vehicles as described in the Speed Metrics section of this chapter. Both results were shown in the table with the tracked results shown in parenthesis.

The tables also provide the posted speed limit on the route and advisory speed limit for the curve.

Two sites in Texas had issues during the before data collection at the PC. At FM 407 in Texas, a puncture in the tube occurred after 18 hours resulting in only 18 hours of data being represented. At FM 530, 48 hours of data were collected but a high amount of unknown data occurred towards the end of the data collection resulting in slightly less than 48 hours of data collected.

Table 5 shows the changes in the speed metrics at the PC for data collected 1 month after the installation of the SDCWS. Decreases were shown at all curves in the mean speed ranging from -2.8 mph on SR7 in Washington to -0.7 mph on Hwy 213 in Wisconsin. The tracked vehicles showed reductions in the mean speed as well with a maximum reduction of -3.0 mph at SR 7 in

Washington and a minimum reduction of -0.8 mph at SR 9 in Washington. Changes in 85th percentile speed after installation ranged from 0 mph at Hwy 213 in Wisconsin to -3 mph at FM 530 and FM 1488 in Texas. The tracked vehicles 85th percentile speed showed reductions at all curves with the largest reduction at FM 530 of -4 mph.

Table 5. Summary of results at point of curvature (PC) after 1 month.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-1.5 (-1.4)	-1.5 (-1.5)	-0.8 (-1.2)	-1.7 (-1.8)	-2.0 (-2.0)	-2.4 (-2.5)	-2.8 (-3.0)	-1.4 (-0.8)	-2.0 (-2.0)	-1.8 (-2.3)	-1.6 (-2.0)	-0.7 (-1.2)
Change in 85th percentile speed(mph)		-1 (-1)	-1 (-1)	-1 (-2)	-2 (-2)	-3 (-4)	-3 (-2)	-2 (-3)	-1 (-1)	-2 (-2)	-2 (-3)	-2 (-1)	0 (-1)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-19.8% (-14.6%)	-6.4% (-5.0%)	-2.2%[B] (-3.7%)	-7.0% (-8.4%)	-20.2% (-22.2%)	-8.2% (-7.1%)	-7.3% (-6.4%)	-31.7% (-13.0%)	-45.8% (-35.4%)	-8.5% (-3.4%)	0.0% (0.0%)	-8.9% (-12.6%)
	10 mph	-32.9% (-33.4%)	-17.5% (-13.2%)	-8.9% (-8%)	-20.9% (-20.1%)	-47.0% (-45.7%)	-26.9% (-24.5%)	-29.8% (-31.3%)	-39.2% (-19.9%[B])	-62.0% (-52.7%)	-19.7% (-18.3%)	-2.6% (-1.7%)	-25.3% (-24.9%)
	15 mph	0.0% (-18.1%[B])	-31.9% (-29.9%)	-24.9% (-30.9%)	-39.8% (-39.5%)	-55.0% (-63.6%)	-55.7% (-50.0%)	-51.1% (-52.4%)	-5.8%[B] (0.0%)	-37.0% (0.0%)	-39.4% (-43.1%)	-8.6% (-8.5%)	0.0% (-19.1%[B])
	20 mph	0.0% (0.0%)	-51.6% (-51.4%)	-41.7% (-40.9%)	-48.5% (-40.3%)	-100% (-100%)	-74.3% (-73.0%)	-77.3% (-78.0%)	0.0% (0.0%)	0.0% (0.0%)	-61.4% (-69.0%)	-20.5% (-23.6%)	0.0% (-100%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	0.0% (-18.1%[B])	-51.6% (-51.4%)	0.0% (0.0%)	-48.5% 0.0%	0.0% (0.0%)	-74.3% (-71.4%)	0.0% (0.0%)	-5.8%[B] (0.0%)	-62.0% (-52.7%)	0.0% (0.0%)	0.0% (0.0%)	-25.3% (-24.9%)
	10 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-89.1% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-37.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-19.1%[B])
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-100%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

[B]Not statistically significant at 95-percent level of significance

Table 6 provides changes in the speed metrics at the PC for data collected during the 12 month after period. All sites were collected but vehicles were not tracked at SR 9 due to the PC having to be recollected after the first 24 hours due to a puncture in the tube. Decreases were shown in mean speed at all curves except FM 109 in Texas and Hwy 213 in Wisconsin. The site at FM 530 in Texas showed a decrease in mean speed but was not statistically significant at a 95 percent level of significance. The curves with significant reductions in mean speeds ranged from -0.7 to -2.2 mph. Tracked vehicles mean speeds were reduced at all sites except FM 109 in Texas and Hwy 213 in Wisconsin. The sites with reductions in tracked vehicles mean speeds were reduced between -2.5 mph at Hwy 144 in Iowa to -0.7 mph at SR 203 in Washington.

The 12 month after data collection showed decreases in 85th percentile speeds ranging from a decrease of -3 mph to no change. The 85th percentile speed of tracked vehicles had no change at SR 203 in Washington and Hwy 213 in Wisconsin but decreases were shown at the other ten sites. The most significant decrease in 85th percentile speed for tracked vehicles occurred at Hwy 20 in Wisconsin of -3 mph.

Table 7 shows the changes in speed metrics at the PC during the 18 month after data collection. Decreases in mean speeds ranged from -0.4 to -3.1 mph. Three sites did not have statistically significant reductions in the mean speeds. The 85th percentile speeds for all vehicles did not change at SR 9 in Washington and Hwy 67 in Wisconsin. All other sites had reductions between -1 and -3 mph in the 85th percentile speeds.

The tracked vehicles had mean speed reductions between -0.6 and -5.6 mph with the largest change at SR 203 in Washington. Only FM 530 in Texas, SR 9 in Washington and Hwy 67 in Wisconsin did not have a statistically significant change in the mean speed at a 95 percent level of significance. Decreases in 85th percentile speeds were between -1 and -6 mph for tracked vehicles. Three sites had no change in 85th percentile speeds. No data was collected at SR 7 in Washington due to the SDCWS not functioning.

Table 8 provides results for the PC at 24 months after installation of the SDCWS. Changes in mean speed ranged from -0.7 to -3.1 mph. Only FM 109 did not have a statistically significant change in mean speed. The tracked vehicles mean speeds changed between -0.4 and -2.8 mph with two sites not having statistically significant changes in mean speeds.

Decreases were found in the 85th percentile except at Hwy 144 in Iowa and FM 109 in Texas which had no changes. The other sites had reductions in 85th percentile speed between -1 and -3 mph. Tracked vehicles had 85th percentile speed decreases up to -3 mph and no changes at Hwy 144 in Iowa, FM 1488 in Texas and SR 9 in Washington.

Table 6. Summary of results at point of curvature (PC) after 12 months.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-2.2 (-2.5)	-1.0 (-1.0)	0.0 (-0.3[B])	-1.8 (-2.2)	-1.1[B] (-1.6)	-2.2 (-1.6)	-1.7 (-1.4)	-1.5 (NC)	-0.7 (-0.7)	-2.2 (-2.4)	-1.3 (-1.4)	0.2[B] (0.0)
Change in 85th percentile speed(mph)		-2 (-2)	-1 (-1)	0 (-1)	-2 (-2)	-3 (-2)	-2 (-1)	-1 (-1)	-1 (NC)	-1 (0)	-2 (-3)	-2 (-2)	0 (0)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-29.9% (-31.2%)	-3.3% (-3.3%)	0.0% (0.0%)	-5.6% (-7.6%)	-2.9%[B] (-3.4%[B])	-8.0% (-3.3%)	-2.1% (-2.2%)	-30.0% (NC)	-17.6% (-14.5%)	-10.0% (-5.1%)	0.0% (0.0%)	0.0% (-2.2%[B])
	10 mph	-50.8% (-50.5%)	-13.2% (-10.6%)	0.0% (0.0%)	-19.4% (-22.6%)	-14.5% (-17.8%)	-24.5% (-15.5%)	-15.2% (-12.7%)	-35.4% (NC)	-16.8% (-2.6%[B])	-20.8% (-17.5%)	-1.0%[B] (-1.7%)	-5.9%[B] (-2.8%[B])
	15 mph	-66.1% (-76.0%)	-20.5% (-17.6%)	0.0% (-7.6%[B])	-44.2% (-47.9%)	-23.6% (-22.7%)	-40.6% (-31.8%)	-38.1% (-26.9%)	-73.1% (NC)	0.0% (0.0%)	-41.2% (-41.0%)	-4.9% (-3.7%)	38.4%[B] (-10.5%[B])
	20 mph	0.0% (-100%)	-20.3%[B] (-21.8%[B])	-22.0%[B] (-20.1%[B])	-68.3% (-70.1%)	-54.9% (-51.6%)	-60.2% (-51.9%)	-57.6% (-48.2%)	0.0% (NC)	0.0% (0.0%)	-69.8% (-68.4%)	-15.1% (-14.2%)	0.0% (-80.0%[B])
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	-66.1% (-76.0%)	-20.3%[B] (-21.8%[B])	0.0% (0.0%)	-68.3% (-70.1%)	0.0% (0.0%)	-60.2% (-51.9%)	0.0% (0.0%)	-73.1% (NC)	-16.8% (-2.6%[B])	0.0% (0.0%)	-62.9% (0.0%)	-5.9%[B] (-2.8%[B])
	10 mph	0.0% (-100%)	0.0% (0.0%)	0.0% (0.0%)	-76.6% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	38.4%[B] (-10.5%[B])
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-80.0%[B])
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics
[B]Not statistically significant at 95-percent level of significance
NC-Not Collected

Table 7. Summary of results at point of curvature (PC) after 18 months.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-3.1 (-2.8)	-1.2 (-1.4)	-0.4[B] (-0.6)	-2.1 (-2.0)	-0.9[B] (-1.3[B])	-1.2 (-0.9)	NC NC	-0.4 (-0.3[B])	-1.9 (-5.6)	-1.4 (-1.2)	-0.1[B] (-0.4[B])	-1.6 (-1.3)
Change in 85th percentile speed(mph)		-3 (-3)	-1.0 (-1)	-1 (-1)	-2 (-2)	-2 (-2)	-1 (0)	NC NC	0 (0)	-2 (-6)	-1 (-2)	0 (0)	-1 (-2)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-35.2% (-33.6%)	-2.4% (-2.4%)	-1.4%[B] (-0.8%[B])	-6.0% (-5.6%)	-1.5%[B] (-3.1%[B])	-4.8% (-3.8%)	NC NC	-5.8%[B] (-0.6%[B])	-40.0% (-27.0%)	-7.5% (-2.7%)	0.0% (0.0%)	-18.7% (-16.1%)
	10 mph	-53.8% (-53.5%)	-14.4% (-13.1%)	-5.5% (-4.2%[B])	-24.6% (-22.1%)	-10.9% (-13.2%)	-13.5% (-9.9%)	NC NC	-13.8%[B] (0.0%)	-57.3% (-41.8%)	-10.8% (-6.5%)	0.0% (0.0%)	-43.9% (-39.1%)
	15 mph	-71.5% (-76.0%)	-29.1% (-28.5%)	-11.6% (-20.4%)	-45.4% (-44.1%)	-23.9% (-23.0%)	-21.5% (-12.3%)	NC NC	-25.0%[B] (0.0%)	-71.2% (-58.8%)	-25.0% (-18.7%)	-1.3%[B] (0.0%)	-25.0%[B] (-32.3%[B])
	20 mph	0.0% (-64.2%[B])	-38.1% (-33.5%)	-17.8%[B] (-17.6%[B])	-62.0% (-55.6%)	-39.0% (-41.1%)	-32.4% (-16.1%[B])	NC NC	0.0% (0.0%)	0.0% (0.0%)	-54.0% (-54.1%)	-4.2%[B] (-8.3%)	-41.9%[B] (0.0%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	-71.5% (-76.0%)	-38.1% (-33.5%)	0.0% (0.0%)	-62.0% (-55.6%)	0.0% (0.0%)	-32.4% (-16.1%[B])	NC NC	-25.0%[B] (0.0%)	-57.3% (-41.8%)	0.0% (0.0%)	-4.3%[B] (0.0%)	-42.9% (-39.1%)
	10 mph	0.0% (-64.2%[B])	0.0% (0.0%)	0.0% (0.0%)	-68.8% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	NC NC	0.0% (0.0%)	-71.2% (-58.8%)	0.0% (0.0%)	0.0% (0.0%)	-25.0%[B] (-32.3%[B])
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	NC NC	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-41.9%[B] (0.0%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	NC NC	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics
[B]Not statistically significant at 95-percent level of significance
NC-Not Collected

Table 8. Summary of results at point of curvature (PC) after 24 months.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-0.9 (-1.1)	-1.4 (-1.9)	-0.1[B] (-0.3[B])	-2.2 (-2.2)	-3.1 (-2.8)	-0.7 (-0.4)	-1.2 (-0.9)	-0.7 (-0.3[B])	-1.9 (-1.2)	-2.0 (-2.3)	-1.1 (-1.3)	-2.1 (-2.0)
Change in 85th percentile speed(mph)		0 (0)	-1 (-2)	0 (-1)	-2 (-2)	-3 (-3)	-1 (0)	-1 (-1)	-1 (0)	-2 (-1)	-2 (-3)	-2 (-2)	-2 (-2)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-14.1% (-14.9%)	-3.5% (-3.8%)	-0.8%[B] (-1.0%[B])	-7.8% (-7.1%)	-10.9% (-6.2%[B])	-2.0% (0.0%)	-0.8%[B] (-0.9%[B])	-15.4% (0.0%)	-38.8% (-19.0%)	-8.8% (-5.0%)	0.0% (0.0%)	-25.6% (-22.7%)
	10 mph	-16.0% (-20.7%)	-15.8% (-18.6%)	-2.4%[B] (0.0%)	-27.4% (-26.0%)	-31.0% (-27.4%)	-8.1% (-2.7%[B])	-7.7% (-5.6%)	-20.0% (0.0%)	-50.3% (-26.8%)	-23.4% (-17.7%)	0.0% (-0.7%)	-48.8% (-42.6%)
	15 mph	14.4% (3.8%[B])	-30.6% (-40.8%)	-4.1%[B] (-6.1%[B])	-48.6% (-43.7%)	-43.9% (-39.1%)	-16.7% (-14.3%)	-29.7% (-16.3%)	-19.2%[B] (0.0%)	-45.2% (0.0%)	-40.2% (-36.8%)	-3.1% (-3.7%)	-65.8% (-62.8%)
	20 mph	0.0% (-11.3%)	-47.2% (-59.3%)	-23.1% (-17.7%[B])	-66.7% (-61.1%)	-71.7% (-76.1%)	-33.5% (-16.1%[B])	-60.1% (-48.8%)	0.0% (0.0%)	0.0% (0.0%)	-70.8% (-70.4%)	-14.3% (-14.6%)	0.0% (-89.2%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	14.4% (3.8%[B])	-47.2% (-59.3%)	0.0% (0.0%)	-66.7% (-61.1%)	0.0% (0.0%)	-33.5% (-16.1%[B])	0.0% (0.0%)	-19.2%[B] (0.0%)	-50.3% (-26.8%)	0.0% (0.0%)	-31.4%[B] (0.0%)	-48.8% (-42.6%)
	10 mph	0.0% (-11.3%)	0.0% (-56.9%[2])	0.0% (0.0%)	-71.9% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-45.2% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-65.8% (-62.8%)
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-89.2%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

[B]Not statistically significant at 95-percent level of significance

Changes in mean and 85th percentile speeds were plotted to show the distribution of change across all sites and time periods. Figure 16 and Figure 17 shows the changes in mean speed for all vehicles and tracked vehicles. The changes are shown for the 1, 12, 18 and 24 month after periods with the number of sites which experienced a change within the designated ranges compared to the before period. All time periods had results for 12 sites except the 18 month after which had results for only 11 sites collected.

A majority of the sites showed decreases in mean speed for both tracked and all vehicles during all data collection periods. For all vehicles, the changes in mean speeds between -1 and -4 mph occurred at 7-10 sites during all data collection periods. The remaining sites (2-4 sites) showed little change in mean speed between -1 and 1 mph. Tracked vehicles showed similar results where 8-11 sites had a decrease in mean speed between -1 and -4 mph while 1-4 sites had little change in the mean speed. The 18 month after tracked vehicles also had one site which had a mean speed change between -4 and -7 mph. No sites showed increases in mean speeds during any after data collection period.

Overall the changes in mean speed between -1 and -4 mph for all vehicles and tracked vehicles showed decreases in the number of sites over time. During the 1 month after data collection 10 sites experienced a mean reduction between -1 and -4 mph but this decreased to 8 sites at the 24 month after period. Tracked vehicles had similar results going from 11 sites during the 1 month after period to 8 sites at the 24 month after period for changes in mean speed between -1 and -4 mph. The signs effectiveness may decreases over time with less sites showing effectiveness by reducing the mean speed at the PC.

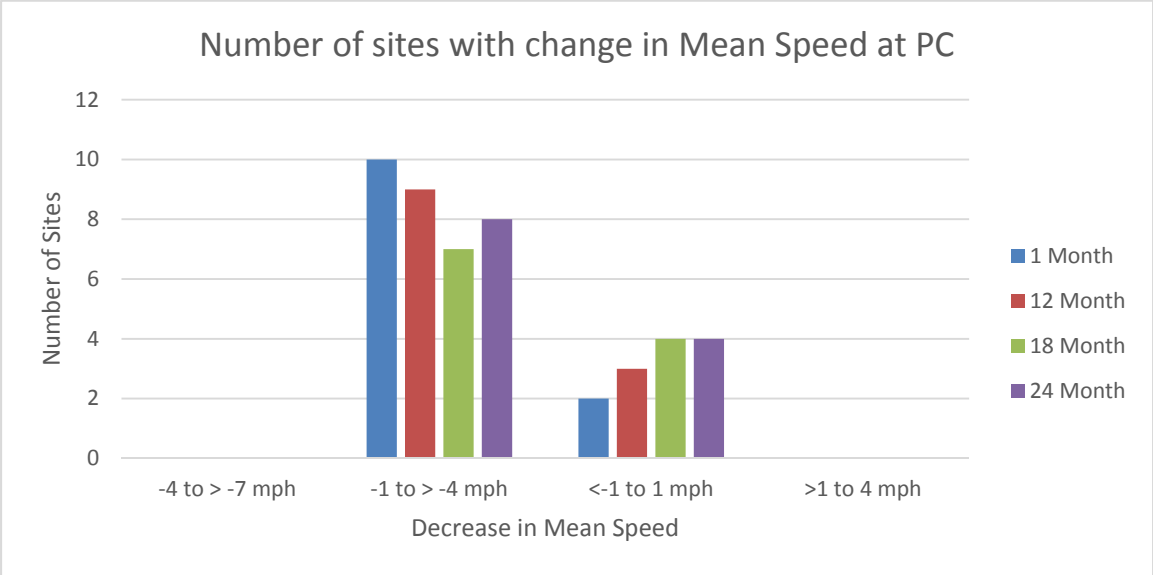


Figure 16. Graph. Number of sites with a change in mean speed for all vehicles of a certain magnitude at the point of curvature (PC).

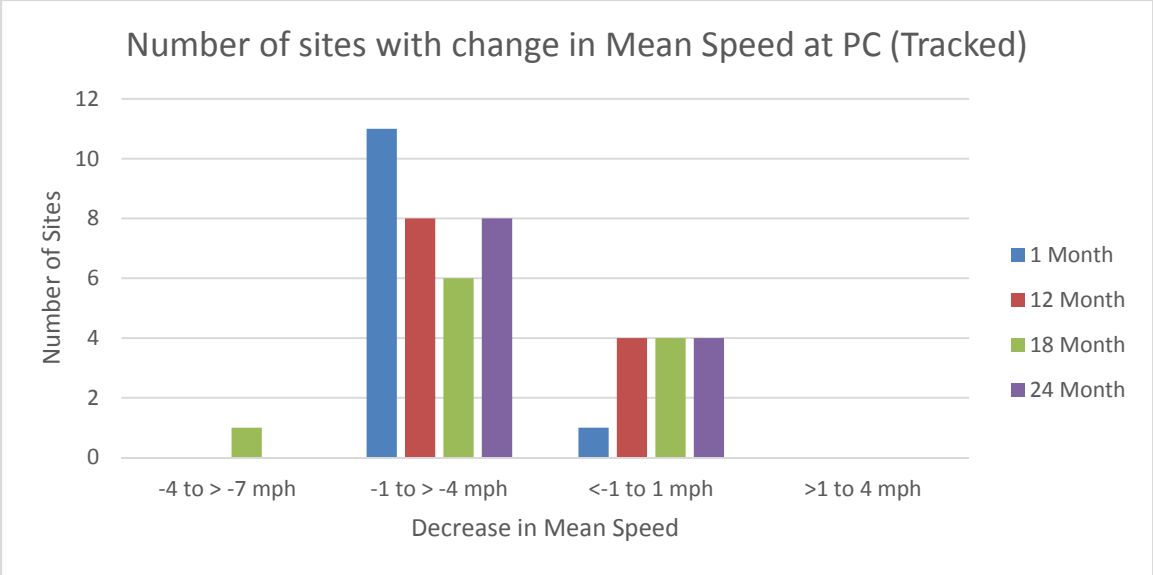


Figure 17. Graph. Number of sites with a change in mean speed for tracked vehicles of a certain magnitude at the point of curvature (PC).

Figure 18 and Figure 19 show the changes in 85th percentile speed for all vehicles and tracked vehicles. All data collection periods had results for 12 sites except the 18 month after which had results for only 11 sites.

The data from all vehicles showed consistent results with 11-9 sites having a change in 85th percentile speed between -1 and -4 mph. The remaining sites (1-2 sites) showed little change in the 85th percentile speed and no sites had an increase in 85th percentile speed.

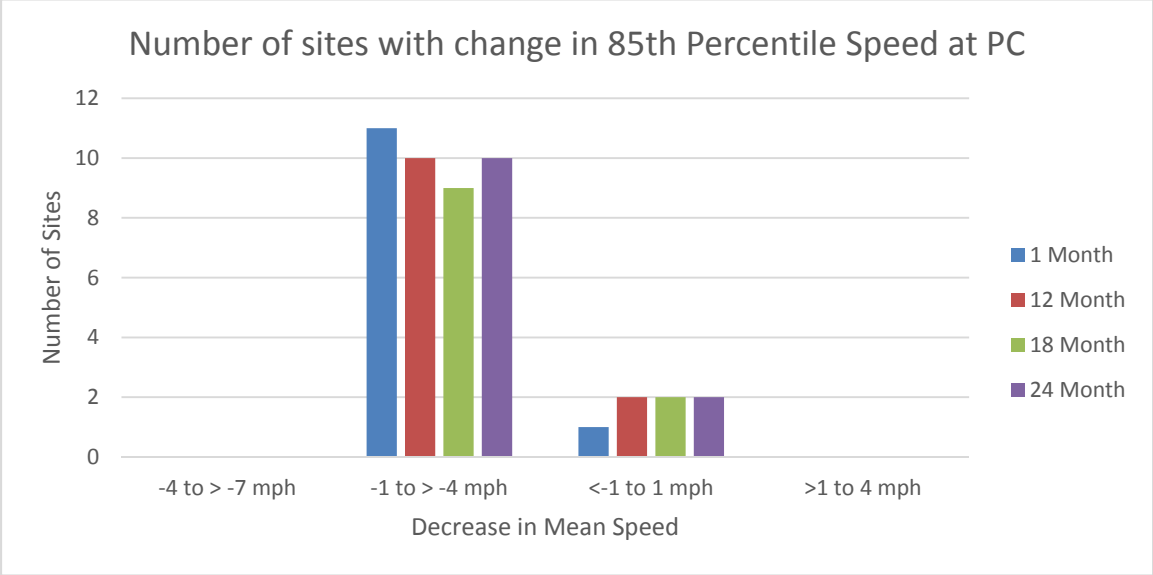


Figure 18. Graph. Number of sites with a change in 85th percentile speed for all vehicles of a certain magnitude at the point of curvature (PC).

Tracked vehicles in Figure 19 had slight decreases in the number of sites with reductions in 85th percentile speeds over time. The 1 month after period had all sites with a reduction in 85th percentile speed, 11 sites had reduction between -1 and -4 mph and 1 site had a reduction between -4 and -7 mph. The 12 month after period had 9 sites with reductions in 85th percentile between -1 and -4 mph with 3 sites having little change in the 85th percentile speed. The 18 month after period had 1 site experience a decrease between -4 and -7 mph, 7 sites had decreases between -1 and -4 mph and 3 sites with little change. Finally in the 24 month after period, 9 sites had decreases in 85th percentile speed between -1 and -4 mph while the remaining 3 sites had little change.

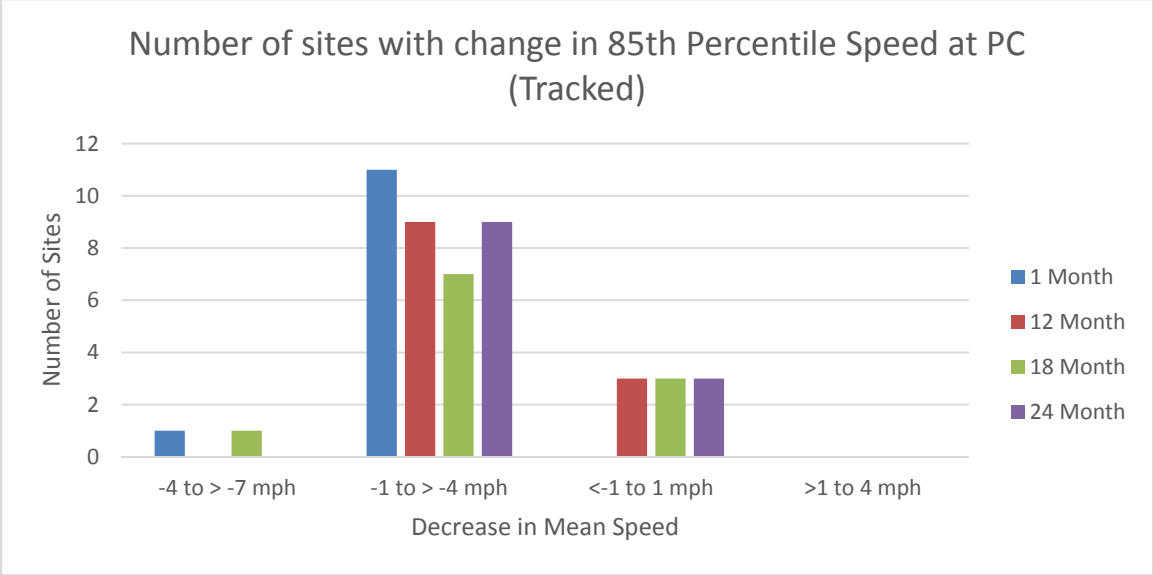


Figure 19. Graph. Number of sites with a change in 85th percentile speed for tracked vehicles of a certain magnitude at the point of curvature (PC).

Results of Speed Analysis at Center of Curve

Table 9 through Table 12 summarizes the overall results by curve collected at the center of curve. The changes in mean and 85th percentile speed from the before to designated after periods are shown with all results in mph. The percent change in the fraction of vehicle exceeding the advisory and speed limit are also shown in each table.

Data were collected for all vehicles and tracked vehicles as described in the Speed Metrics section of this chapter. Both results were shown in the table with tracked results in parenthesis.

Also in the table are the speed limits for each roadway and the associated advisory speed limit for the curve.

Table 9 shows the results at the 1 month after data collection. Changes in the mean speed were between 0.3 and -2.6 mph for all vehicles and between -0.1 and -2.9 mph for tracked vehicles. Nine sites had reductions in the 85th percentile speeds between -1 and -3 mph for all vehicles, while the other three had no change. For tracked vehicles, ten sites had reductions in 85th percentile speeds between -1 and -4 mph with the other two sites having no change.

Table 9. Summary of results at center of curve (CC) after 1 month.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-2.1 (-2.1)	0.3 (-0.1[B])	-1.6 (-1.8)	-1.4 (-1.7)	-2.6 (-2.9)	-0.1 (-0.1[B])	-1.4 (-1.4)	-0.9 (-0.4[B])	-0.1[B] (-0.1[B])	-1.8 (-1.9)	-1.8 (-2.4)	-1.0 (-1.2)
Change in 85th percentile speed(mph)		-2 (-3)	0 -1	-2 (-3)	-2 (-2)	-3 (-4)	0 (-1)	-1 (-1)	-1 (0)	0 (0)	-2 (-3)	-2 (-2)	-1 (-1)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-38.7% (-35.2%)	0.0% (-0.6%[B])	-5.9% (-4.2%)	-12.1% (-12.9%)	-20.2% (-22.2%)	-4.3% (-2.3%[B])	-18.4% (-20.3%)	-26.7% (-5.8%[B])	5.3%[B] (0.0%)	-18.4% (-17.3%)	-1.6% (-1.7%)	-11.1% (0.0%)
	10 mph	-54.3% (-50.7%)	10.3% (4.0%[B])	-28.6% (-29.7%)	-35.7% (-35.1%)	-47.0% (-45.7%)	2.1%[B] (-1.2%[B])	-42.9% (-50.5%)	-29.9% (0.0%)	0.0% (16.8%[B])	-45.4% (-46.9%)	-11.7% (-13.1%)	-20.1% (-22.4%)
	15 mph	0.0% (-13.9%[B])	17.6% (8.7%[B])	-51.7% (-54.5%)	-57.7% (-53.2%)	-55.0% (-63.6%)	0.0% (-16.9%[B])	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-69.2% (-77.5%)	-27.9% (-34.8%)	5.7%[B] (-30.7%[B])
	20 mph	0.0% (0.0%)	0.0% (17.4%[B])	-57.0% (-47.3%[B])	-56.8% (0.0%)	-100% (-100%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-89.9% (-85.1%)	-48.1% (-55.6%)	0.0% (-1.9%[B])
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	0.0% (-13.9%)	0.0% (17.4%[B])	0.0% (0.0%)	-56.8% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (16.8%[B])	0.0% (0.0%)	0.0% (0.0%)	-20.1% (-22.4%)
	10 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	5.7%[B] (-30.7%[B])
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-1.9%[B])
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

[B]Not statistically significant at 95-percent level of significance

Table 10 provides the changes in the speed metrics at the center of curve for data collected 12 month after the installation of the SDCWS. All sites were collected but vehicles were not tracked at SR 9 due to the PC having to be recollected after the first 24 hours. Statistically significant decreases were shown in the mean speed at ten of the sites between -0.6 and -2.8 mph for all vehicles. Two other curves had speeds increase by 0.2 and 0.6 mph. The 85th percentile speed for all vehicles decreased at all locations except on Hwy 221 in Missouri. The highest reduction in 85th percentile speed was -3 mph at FM 407 and FM 530 in Texas.

The tracked vehicles had similar results with reduction in the mean speed at the same nine sites between -0.6 and -3.0 mph. The two other sites showed statistically insignificant increases in speed of 0.2 and 0.5 mph at Hwy 221 in Missouri and Hwy 213 in Wisconsin. The tracked vehicles had eight sites with reductions in 85th percentile speeds up to -3.7 mph (FM 407 in Texas). Hwy 67 and Hwy 213 in Wisconsin had no changes in 85th percentile speeds and Hwy 221 in Missouri showed an increase of 1 mph.

Results for the 18 month after data collection at the center of curve are shown in Table 11. SR 7 had no data collected during this period due to the signs not functioning. Changes in mean speed ranged from 0.1 to -3.5 mph for all vehicles and from 0.4 to -3.8 mph for tracked vehicles. Hwy 221 in Missouri and Hwy 213 in Wisconsin did not have statistically significant changes in mean speed for both all and tracked vehicles. The largest change in mean speeds occurred at SR 203 in Washington with -3.5 mph for all vehicles and -3.8 mph for tracked vehicles.

The 85th percentile speeds were reduced between -1 and -4 mph for all vehicles and tracked vehicles. For all vehicles, no changes were found in the 85th percentile speed at Hwy 221 in Missouri and Hwy 213 in Wisconsin. The tracked vehicles had no changes at Hwy 67 and Hwy 213 in Wisconsin and showed an increase in 85th percentile speed of 1 mph at Hwy 221 in Missouri.

Table 12 showed the changes in speed metrics at the CC during the 24 month after data collection. All sites were collected but a puncture occurred at SR 203 which reduced the data collected to 18 hours. Decreases in mean speed for all vehicles ranged between -0.2 to -3.0 mph that were all statistically significant. The 85th percentile speeds for these vehicles decreased at eight sites by up to -3 mph. All three curves in Washington and FM 1488 in Texas showed no reduction in 85th percentile speed.

The tracked vehicles had mean speed reduction between -0.2 and -2.8 mph. The mean speed reduction at SR 9 was not statistically significant at a 95 percent level of significance. The largest mean speed reduction occurred at FM 407 in Texas. Decreases in 85th percentile speed were between -1 and -3 mph. Five sites had no change in 85th percentile speeds.

Table 10. Summary of results at center of curve (CC) after 12 months.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-1.2 (-1.7)	0.2 (0.2[B])	-0.6 (-0.9)	-2.5 (-3.0)	-2.8 (-2.8)	-1.2 (-1.0)	-0.7 (-0.6)	-1.7 (NC)	-1.3 (-1.5)	-0.9 (-0.9)	-0.8 (-1.0)	0.6[B] (0.5[B])
Change in 85th percentile speed(mph)		-1 (-2)	0 (1)	-1 (-1)	-3 (-3.7)	-3 (-3)	-1 (-2)	-1 (-1)	-1 (NC)	-1 (-1)	-1 (-1)	-1 (0)	1 (0)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-29.0% (-32.0%)	-0.8%[B] (-0.5%[B])	-1.7%[B] (-1.0%[B])	-21.1% (-24.0%)	-19.0% (-19.0%)	-8.5% (-6.0%)	-7.6% (-9.3%)	-41.4% (NC)	-38.9% (-31.3%)	-12.6% (-10.0%)	0.0% (-0.2%[B])	1.7%[B] (1.5%[B])
	10 mph	-36.4% (-40.3%)	5.8%[B] (1.3%[B])	-10.6% (-13.8%)	-49.8% (-55.0%)	-47.2% (-43.7%)	-24.8% (-18.7%)	-38.9% (-32.8%)	-45.5% (NC)	-51.1% (-41.5%)	-14.2% (-11.7%)	-3.0% (-4.3%)	7.0%[B] (6.8%[B])
	15 mph	0.0% (-51.9%[B])	23.4% (20.1%[B])	-17.7% (-26.7%)	-72.6% (-72.2%)	-69.2% (-73.1%)	-44.1% (-39.2%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	-14.9%[B] (-35.6%)	-12.9% (-15.2%)	72.0% (36.7%[B])
	20 mph	0.0% (0.0%)	0.0% (26.8%[B])	-58.2% (46.9%[B])	-68.5% (0.0%)	-89.4% (-100%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	0.0% (0.0%)	-27.1% (-18.5%)	0.0% (0.0%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	0.0% (-51.9%[B])	0.0% (26.8%[B])	0.0% (0.0%)	-68.5% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	-51.1% (-41.5%)	0.0% (0.0%)	0.0% (0.0%)	7.0%[B] (6.8%[B])
	10 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	72.0% (36.7%[B])
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (NC)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics
[B]Not statistically significant at 95-percent level of significance
NC-Not Collected

Table 11. Summary of results at center of curve (CC) after 18 months.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-3.0 (-3.1)	0.1[B] (-0.1[B])	-0.9 (-1.2)	-2.5 (-2.6)	-1.3 (-1.5)	-1.6 (-1.5)	NC NC	-0.9 (-0.9)	-3.5 (-3.8)	-1.3 (-1.2)	-0.1 (-0.6)	-0.3[B] (0.4[B])
Change in 85th percentile speed(mph)		-3 (-4)	0 (1)	-1 (-2)	-2 (-3)	-1 (-2)	-2 (-2)	NC NC	-1 (-1)	-4 (-4)	-1 (-1)	-1 (0)	0 (0)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-49.1% (-50.7%)	1.5%[B] (-0.7%[B])	-4.5% (-3.0%)	-21.8% (-20.3%)	-11.7% (-11.5%)	-11.2% (-8.2%)	NC NC	-27.3% (-17.4%)	-82.2% (-73.3%)	-12.0% (-10.9%)	1.6% (0.0%)	-2.5%[B] (0.0%)
	10 mph	-71.5% (-78.1%)	0.0% (-4.8%[B])	-15.0% (-17.0%)	51.3% (-51.6%)	-24.0% (-25.5%)	-34.1% (-30.2%)	NC NC	-34.2% (0.0%)	-92.1% (-95.3%)	-26.1% (-21.7%)	-1.5%[B] (-3.8%)	-8.2%[B] (0.0%)
	15 mph	0.0% (-51.9%[B])	15.6%[B] (-14.4%[B])	-22.8% (-33.5%)	-73.1% (-72.5%)	-40.0% (-48.7%)	-55.6% (-51.5%)	NC NC	0.0% (-58.1%[B])	0.0% (0.0%)	-62.4% (-61.3%)	-6.4% (-10.3%)	38.6%[B] (28.1%[B])
	20 mph	0.0% (0.0%)	0.0% (31.9%[B])	-36.1%[B] (-40.4%[B])	-77.4%[B] (0.0%)	-22.8%[B] (-52.1%[B])	-77.9% (-89.8%)	NC NC	0.0% (0.0%)	0.0% (0.0%)	-65.2% (-53.2%[B])	-2.9%[B] (-4.6%[B])	0.0% (0.0%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	0.0% (-51.9%[B])	0.0% (31.9%[B])	0.0% (0.0%)	-77.4%[B] (0.0%)	0.0% (0.0%)	0.0% (0.0%)	NC NC	0.0% (0.0%)	-92.1% (-95.3%)	0.0% (0.0%)	0.0% (0.0%)	-8.2%[B] (0.0%)
	10 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	NC NC	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	38.6%[B] (28.1%[B])
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	NC NC	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	NC NC	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

[B]Not statistically significant at 95-percent level of significance

NC-Not Collected

Table 12. Summary of results at center of curve (CC) after 24 months.

		State											
		IA	MO	TX				WA			WI		
Road		Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)		55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)		45	40	35	40	35	40	20	40	50	30	25	50
Change in mean speed (mph)		-1.5 (-2.0)	-0.4 (-1.0)	-1.0 (-1.2)	-2.6 (-2.8)	-3.0 (-2.7)	-1.0 (-1.0)	-0.6 (-0.5)	-0.6 (-0.2[B])	-1.3 (-0.9)	-1.5 (-1.6)	-0.2 (-0.4)	-0.9 (-0.9)
Change in 85th percentile speed(mph)		-1 (-2)	-1 (-1)	-1 (-2)	-3 (-3)	-3 (-3.3)	0 (0)	0 (0)	0 (0)	0 (0)	-2 (-2)	-1 (0)	-1 (-1)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-34.3% (-36.3%)	-2.2% (-4.6%)	-3.7% (-2.4%[B])	-24.6% (-23.4%)	-24.3% (-20.3%)	-7.5% (-4.6%)	-5.5% (-4.4%)	-15.2% (-2.7%[B])	-36.9% (-16.0%)	-5.3% (-3.5%)	1.2% (0.0%)	-17.0% (-13.8%)
	10 mph	-39.2% (-40.8%)	-9.6% (-22.8%)	-16.3% (-15.8%)	-52.6% (-52.6%)	-44.6% (-39.4%)	-19.4% (-20.5%)	-37.7% (-30.7%)	0.0% (8.2%[B])	-41.0% (0.0%)	-27.5% (-24.8%)	0.0% (-2.4%)	-34.0% (-22.9%)
	15 mph	100%[B] (0.0%)	-16.1% (-31.7%)	-33.1% (-38.2%)	-68.7% (-64.8%)	-57.4% (-69.0%)	-47.9% (-46.6%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-50.7% (-54.4%)	-2.6%[B] (-4.7%[B])	0.0% (-41.5%)
	20 mph	0.0% (0.0%)	-63.8% (-68.8%)	-50.2% (-50.0%)	-71.9% (0.0%)	-100% (-100%)	-65.1% (-62.2%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-77.9% (-84.5%)	-15.5% (-10.5%[B])	0.0% (-48.7%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	100%[B] (0.0%)	-63.8% (-68.8%)	0.0% (0.0%)	-71.9% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-41.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	-34.0% (-22.9%)
	10 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-41.5%)
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-48.7%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

[B]Not statistically significant at 95-percent level of significance

Figure 20 and Figure 21 show the distribution of mean speed results at the center of curve for all vehicles and tracked vehicles. All sites are included with the exception of SR 7 in the 18 month after data collection.

The results for tracked vehicles were identical to all vehicles showing the free flow vehicles were reducing mean speeds at the same magnitude as all vehicles. The changes in the mean speed were split between little change to reductions between -1 and -4 mph. At 1 month after, eight sites had decreases in mean speeds between -1 and -4 mph and four sites had little change in the mean speed. Half of the sites for the 12 month after period had reduction in mean speed while the other half had little change. The 18 month after had six sites with reduction in mean speed between -1 and -4 mph while the 24 month after period had seven sites. Both the 18 and 24 month after periods had five sites with little to no change in mean speed.

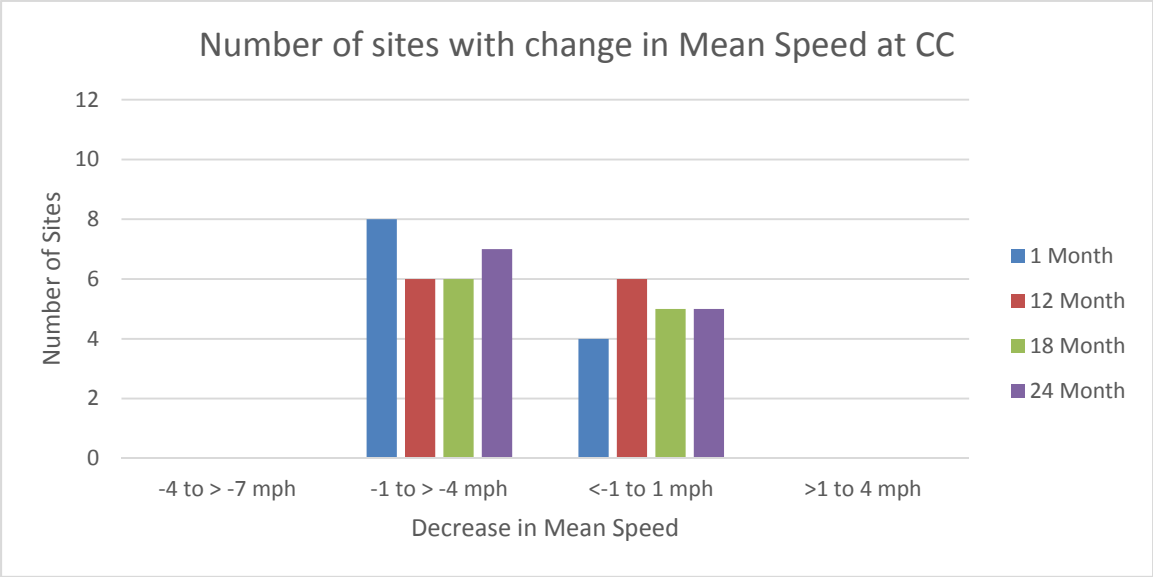


Figure 20. Graph. Number of sites with a change in mean speed for all vehicles of a certain magnitude at the center of curve (CC).

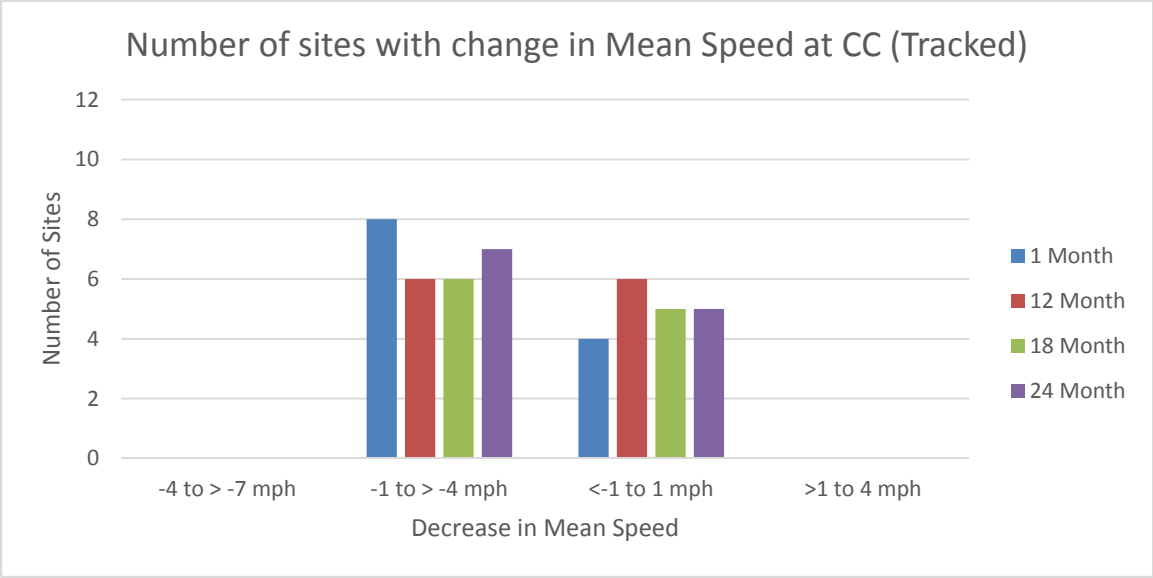


Figure 21. Graph. Number of sites with a change in mean speed for tracked vehicles of a certain magnitude at the center of curve (CC).

Figure 22 and Figure 23 shows the change in 85th percentile speeds at the CC at 1, 12, 18 and 24 month after periods for all and tracked vehicles. A majority of the sites had changes in 85th percentile speeds between -1 and -4 mph. The number of sites with reduction in mean speed between -1 and -4 mph for all vehicles was between 7 and 10 sites and for tracked vehicles was between 6 and 9 sites. All vehicles had one site decrease the 85th percentile speed between -4 and -7 mph during the 18 month after data collection. Tracked vehicles had one site during the 1 month after and 2 sites during the 18 month after with decreases in 85th percentile speed between -4 and -7 mph.

Some sites did not have any changes or increases in the 85th percentile speed. For all vehicles, the number of sites with no change in 85th percentile speeds were between 1 and 4 sites. There was also a site during the 12 month after data collection that had an increase in 85th percentile speed for all vehicles. The tracked vehicles showed similar results with 2-5 sites showing no change in 85th percentile speeds. During the 18 month after period there was an increase in 85th percentile speeds at one site for tracked vehicles.

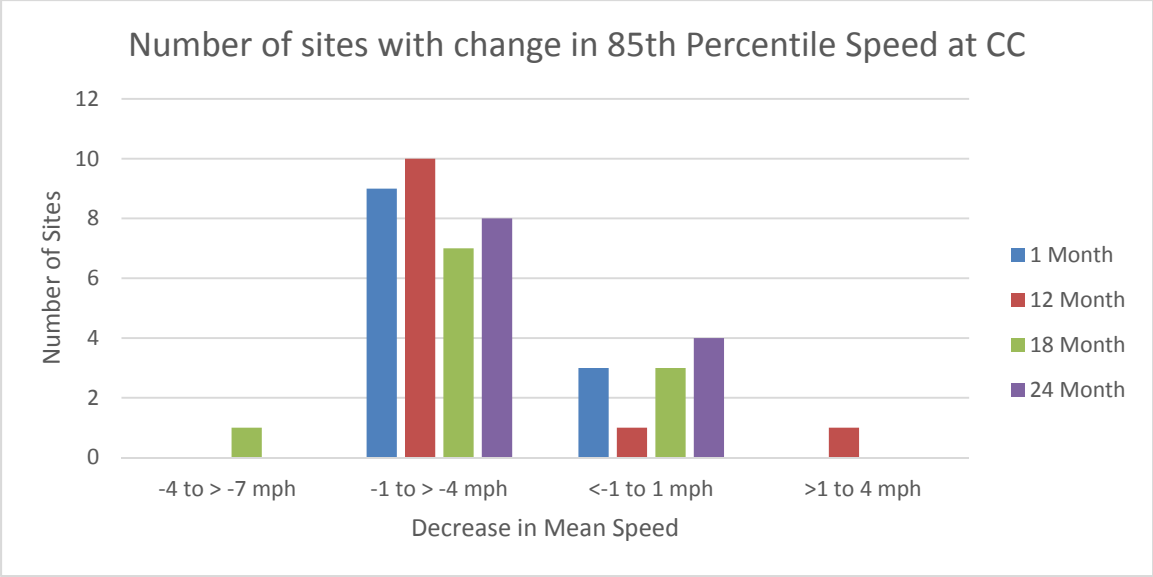


Figure 22. Graph. Number of sites with a change in 85th percentile speed for all vehicles of a certain magnitude at the center of curve (CC).

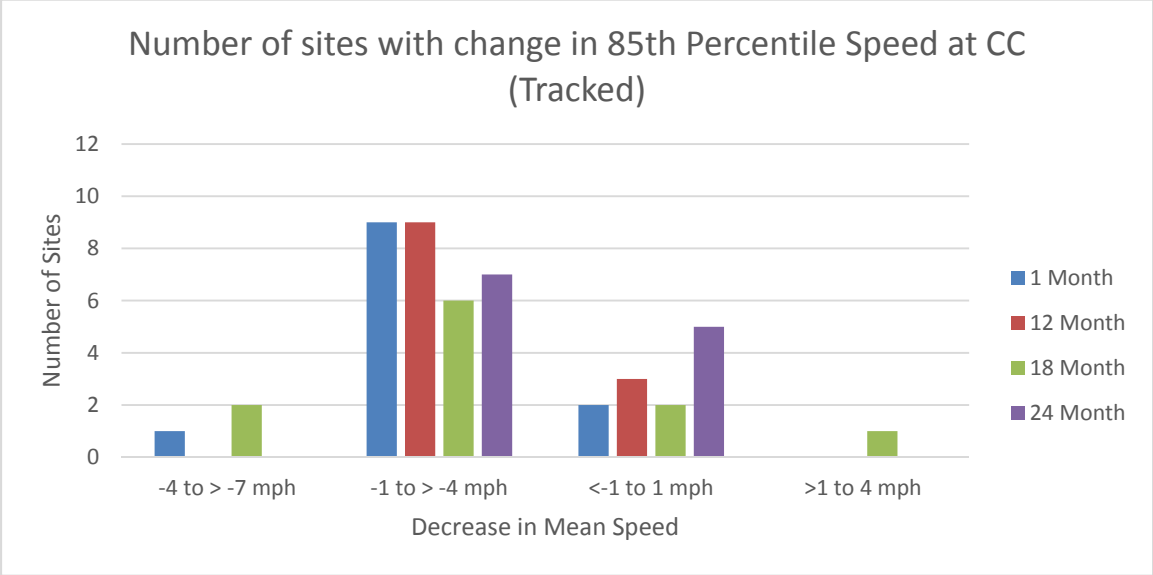


Figure 23. Graph. Number of sites with a change in 85th percentile speed for tracked vehicles of a certain magnitude at the center of curve (CC).

Results for Tracking Speed Reduction

Vehicles were tracked to determine which vehicles negotiated the curve at all three data collection locations. The vehicles were then reduced to only free flowing vehicles by removing vehicles following another vehicle by 5 seconds or leading another vehicle by 3 seconds. This reduced the tracked vehicle data set to only free flowing vehicles that negotiated the entire curve and would be influenced by the SDCWS.

After tracking vehicles, each individual vehicle's speed is known at all three data collection locations allowing for speed reductions to be calculated for each vehicle. This is found by taking

the difference in speed from one data collection location to the next. Different from other speed metrics, a positive change in mean speed reduction indicates the SDCWS was effective at reducing vehicle speeds. The reason for this is because vehicles are slowing down more with a higher speed reduction value than what was collected before the SDCWS. The other benefit of using a speed reduction statistic is that the speeds upstream are accounted for without having to reference the upstream speeds as a control for the roadway.

The largest change in mean speed reductions occurred between the upstream and point of curvature which shows that the SDCWS may have had more influence at reducing vehicles speeds prior to entering the curve. Table 13 displays the results of the speed reductions after tracking vehicles between the upstream and point of curvature for all data collection periods. The largest change in mean speed reduction occurred during the 1 month after period at SR 9 in Washington with speeds being reduced by 3.3 mph more than the before period.

During the 1 month after, speed reductions ranged from -3.2 to 3.3 mph. At 12 months after, speed reductions ranged between -3.0 and 3.7 mph. Speed reductions at 18 months after had a maximum reduction of 2.9 mph and a minimum of -2.8 mph. For all three of these periods, only two sites during each period did not have increases in speed reductions showing that a majority of the sites had vehicles slowing down due to the SDCWS before entering the curve. At 24 months after, speed reductions were between -2.4 and 2.3 mph. Three sites during this period had decreases in speed reduction with eight sites showing increases in speed reductions.

Consistently speed reductions increased compared to the before between the upstream and point of curvature. This showed that vehicles were reducing their speed more prior to entering the curve after installation of the SDCWS. Vehicles were able to identify the curve and select an appropriate speed to negotiate the curve. Only one site consistently had decreases in speed reduction from the upstream to PC but this site had increases in speed reduction between the PC and CC which will be discussed below.

Table 13. Tracking speed reduction summary from upstream to point of curvature (PC).

	State											
	IA	MO	TX				WA				WI	
Road	Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)	55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)	45	40	35	40	35	40	20	40	50	30	25	50
Mean Speed Reduction - 1 Mo (mph)	0.6	2.1	2.8	-3.2	-0.9[B]	2.1	1.1	3.3	2.4	3	1.1	1.9
Mean Speed Reduction - 12 Mo (mph)	0.9	1.8	1.6	-3	-0.1[B]	3.7	1.1	NC	0.2[B]	2.9	1.4	1.6
Mean Speed Reduction - 18 Mo (mph)	1.3	2.0	2.9	-2.8	1.1[B]	1	NC	1.9	-1.5	1.8	1.3	2.7
Mean Speed Reduction - 24 Mo (mph)	0.0	1.9	-2.0	-2.4	1.9	-0.4	1.6	2.3	1.4	1	1.9	2.2

[B]Not statistically significant at 95-percent level of significance
NC-Not Collected
Note: Positive change represents vehicles slowing down

Table 14 shows the results of the speed reduction for all time periods from the upstream to center of curve. Similar results to the speed reduction between the upstream and PC are shown. Vehicles were slowing down through the entire curve but not at the magnitude when they were entering the curve.

At 1 month after, four sites had statistically insignificant change in mean speed reduction at a 95 percent level of significance. The largest change in speed reduction occurred at FM 109 with a 3.5 mph increase in speed reduction. For 12 months, three sites had statistically insignificant changes but all other sites had increases in speed reduction between 0.6 and 3.1 mph. All site had increases in speed reduction for 18 months between 0.3 and 3.4 mph with only one not being statistically significant. The speed reductions at 24 months after ranged between -1.1 and 2.3 mph.

Table 14. Tracking speed reduction summary from upstream to center of curve (CC).

	State											
	IA	MO	TX				WA			WI		
Road	Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)	55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)	45	40	35	40	35	40	20	40	50	30	25	50
Mean Speed Reduction - 1 Mo (mph)	1.5	0.5	3.5	0.7	0.2[B]	-0.2[B]	-0.4[B]	2.8	0.6	2.6	1.5	1.9
Mean Speed Reduction - 12 Mo (mph)	0.2[B]	0.6	2.1	1.8	1.2[B]	3.1	0.3[B]	NC	1.0	1.3	1.0	1.1
Mean Speed Reduction - 18 Mo (mph)	1.7	0.8	3.4	1.8	1.3[B]	1.5	NC	2.4	0.3	1.6	1.5	0.9
Mean Speed Reduction - 24 Mo (mph)	1.0	1.0	-1.1	2.3	1.8	0.2[B]	1.2	2.1	1.4	0.4[B]	1.0	1.1

[B]Not statistically significant at 95-percent level of significance

NC-Not Collected

Note: Positive change represents vehicles slowing down

The speed reduction between the point of curvature and center of curve are shown in Table 15. Speed reductions in this table show how vehicles speeds changed while negotiating the curve. Little change in speed reduction occurred between the PC and CC.

At 1 month after, the changes in speed reduction varied between -2.3 and 3.8 mph. The 12 month after data had changes in speed reductions between -1.5 and 4.8 mph. Changes in speed reductions between -1.7 and 4.6 mph were found during the 18 month after data collection. Finally, the 24 moth after data collection had changes in speed reduction between -0.9 and 4.7 mph.

A majority of speed reductions between the PC and CC had little change or decreases in speed reduction. This may be due to the vehicles selecting a slower speed prior to entering the curve which was shown with the increases in speed reduction between the upstream and point of curvature. With a slower speed entering the curve, the driver may feel they can successfully negotiate the curve without the need to slow down more throughout the curve. Vehicles select an appropriate speed prior to entering the curve then maintain this speed through the curve compared to before where vehicles entered the curve at a higher speed then had to continuously reduce their speed through the curve.

While a majority of the sites were consistent, one site varied from the rest. At FM 407 in Texas, speed reductions decreases from the upstream to PC but then considerably increased between the PC and CC. At this site vehicles were not reducing their speed as much prior to entering the curve then had to reduce their speed while negotiating the curve. Vehicles may have either identified the curve from the SDCWS then decided they could maintain a higher speed through the curve or the sequential arrows through the curve may have caused the drivers to decrease speed through the curve.

Table 15. Tracking speed reduction summary from point of curvature (PC) to center of curve (CC).

	State											
	IA	MO	TX				WA			WI		
Road	Hwy 144	Hwy 221	FM 109	FM 407	FM 530	FM 1488	SR 7	SR 9	SR 203	Hwy 20	Hwy 67	Hwy 213
Posted Speed (mph)	55	55	60	55	60	55	50	55	55	55	55	55
Curve Advisory Speed (mph)	45	40	35	40	35	40	20	40	50	30	25	50
Mean Speed Reduction - 1 Mo (mph)	0.7	-1.7	0.7	3.8	1.1	-2.3	-1.5	-0.4	-1.8	-0.3[B]	0.4	0.1B
Mean Speed Reduction - 12 Mo (mph)	-0.8	-1.1	0.6	4.8	1.3	-0.6	-0.8	NC	0.8	-1.5	-0.4	-0.4
Mean Speed Reduction - 18 Mo (mph)	0.0	-1.3	0.5	4.6	0.2[B]	0.5	NC	0.6	1.9	0.0	0.3	-1.7
Mean Speed Reduction - 24 Mo (mph)	0.9	-0.9	0.9	4.7	0.0	0.6	-0.4	-0.1	-0.2	-0.7	-0.8	-1.0

[B]Not statistically significant at 95-percent level of significance
NC-Not Collected
Note: Positive change represents vehicles slowing down

Figure 24 through Figure 26 graphically show the results explained in Table 13 through Table 15. The majority of sites had mean speed reductions between 1 and 4 mph during all after periods between the upstream and PC. Through the entire curve, between the upstream and CC, most speed reductions were between 1 and 4 mph varying between six to nine sites. Between the PC and CC a majority of the sites showed little change in the mean speed reduction. Six to ten sites had little change in mean speed reductions with the remaining sites split equally between increases and decreases in mean speed reduction.

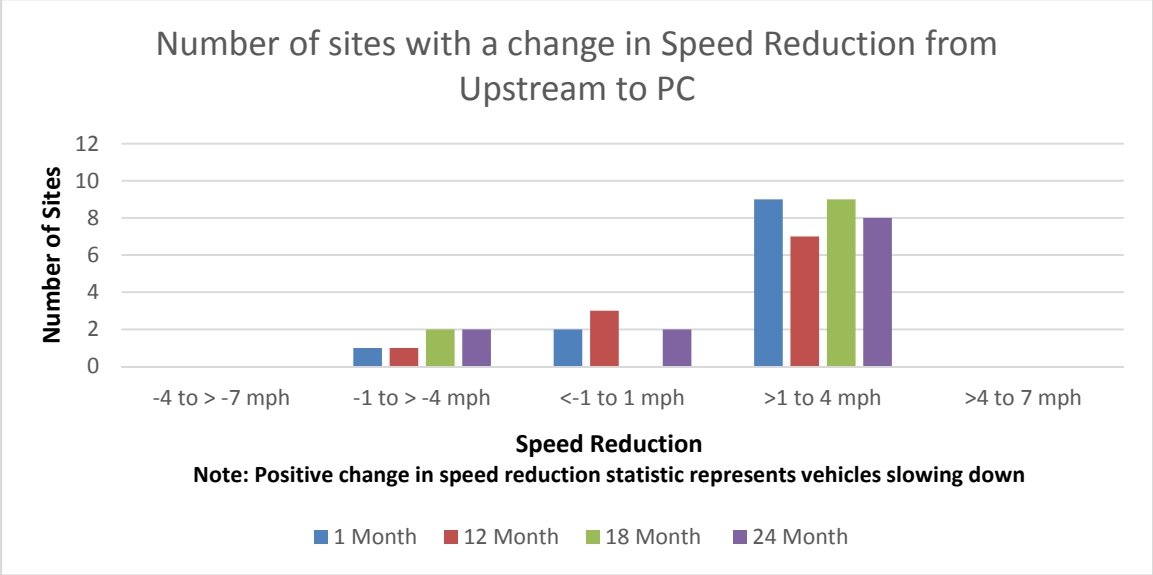


Figure 24. Graph. Number of sites with a change in speed reduction for tracked vehicles of a certain magnitude between the upstream and point of curvature (PC).

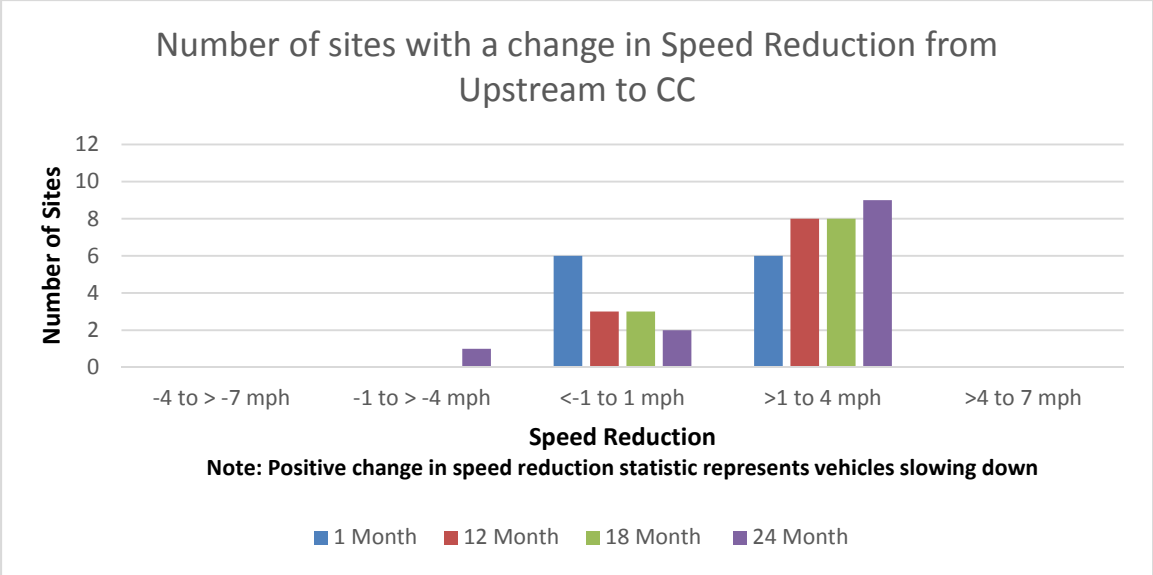


Figure 25. Graph. Number of sites with a change in speed reduction for tracked vehicles of a certain magnitude between the upstream and center of curve (CC).

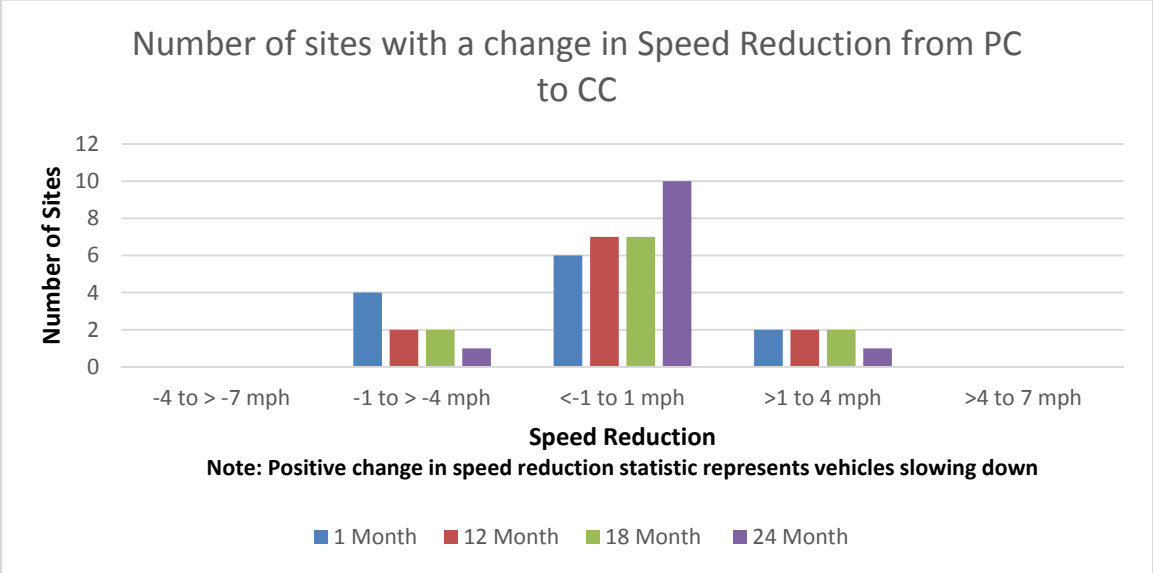


Figure 26. Graph. Number of sites with a change in speed reduction for tracked vehicles of a certain magnitude between the point of curvature (PC) and center of curve (CC).

CRASH ANALYSIS

A simple crash analysis was conducted in addition to the speed analysis to determine the safety benefits. Crash data were collected for 5 years before and 2 years after installation. Since all the treatments were installed in 2012, the before period was 2007 to 2011 and the after period was 2013 to 2014. Both test sites where the SDCWS signs were installed and the selected control sites were evaluated.

Crash data were obtained from the corresponding state or county agency. Crashes were selected by either their spatial location or after reviewing the crash report. Spatially, crashes 500 feet before the point of curvature, within the curve and 500 feet after the point of tangency were selected.

The crash rate per year was calculated using the equation below:

$$CR_{ij} = \frac{Crash_{ij}}{Qtr_{ij}}$$

Figure 27. Equation. Crash Rate.

Where:

CR_{ij} = crash rate per year for period j for location *i* or state *i*

$Crash_i$ = number of crashes for period *j*

Yr_{ij} = number of years for period *j* for location *i* or state *i*

With the crash rates a comparison can be made at each location as well as between the test and control sites. Since crash rates may be trending downwards due to other outside factors the comparison with the control sites can determine additional benefits in relation to the SDCWS.

Before and after data by site is shown in Table 16. All sites except 2 had decreases in crashes per year. Both of those sites had an increase of 0.2 crashes/year (WI 20 and HOU 1488). Five test sites had minor decreases in crashes 0.1 to 0.2 crashes per year (WI 213; SR 9; SR 203; YOA 109; YOA 530B). Three test sites had decreases from 1.5 to 1.8 crashes per year (IA 144; DAL 407; and WI 67) and 2 sites had decreases from 5.1 to 5.7 crashes per year (MO 221 and SR 7). Overall, crashes were reduced by 58%.

Table 16. Changes in Crashes for Test Sites.

State	Site	Crashes		crashes/year		change	percent change
		Before	After	Before	After		
Missouri	MO 221	36	3	7.2	1.5	-5.7	-79%
Iowa	IA 144	9	0	1.8	0.0	-1.8	-100%
Wisconsin	WI 20	14	6	2.8	3.0	0.2	7%
	WI 213	3	1	0.6	0.5	-0.1	-17%
	WI 67	15	3	3.0	1.5	-1.5	-50%
Washington	SR 7	28	1	5.6	0.5	-5.1	-91%
	SR 9	6	2	1.2	1.0	-0.2	-17%
	SR 203	6	2	1.2	1.0	-0.2	-17%
Texas	DAL 407	9	0	1.8	0.0	-1.8	-100%
	HOU 1488	9	4	1.8	2.0	0.2	11%
	YOA 109	6	2	1.2	1.0	-0.2	-17%
	YOA 530B	1	0	0.2	0.0	-0.2	-100%
All		142	24	28.4	12.0	-16.4	-58%

Table 17 provides crash data for control sites. Ten sites had increases in crashes which ranged from 0.6 to 2.4 crashes per year. One site had no change (BRY 3090). Twelve sites had decreases which ranged from 0.1 to 2.1 crashes per year. Overall a decrease of 1.0 crash per year was noted. This suggests that not all of the decrease was due to the treatment.

Figure 28 illustrates the change in crashes per year by state. In a few cases, only one treatment site was present in a state. As noted, the difference between treatment and control was the largest in Washington and Missouri. Both have an average change in crashes per year over 5 while crashes at control sites increased. Iowa and Wisconsin had moderate decreases in crashes per year at treatment sites with a minor increase in control crashes in Iowa and a minor decrease in Wisconsin. Crashes per year decreased in Texas but a larger decrease at control sites was noted.

Note: Tables 16 and 17 include a calculation of the change in crash rate (crashes per year) using five years of "before" data and 2 years of "after" data. Additionally, the study team performed an analysis of the potential for weather impacts on crashes. For three sites, including Wisconsin WI 71, Washington SR510, and Texas BRY 3090, no weather related crashes occurred. For Wisconsin WI 22, one crash in the "after" period had snow listed as the road condition. For Washington SR 507, one crash in the "before" period had ice listed as the road condition. For Iowa IA 125, two crashes in the "before" period and two crashes in the "after" period had snow listed as the road condition. The Missouri (Saline) site did not have data on road conditions to accompany the crash data.

Table 17. Change in Crashes for Control Sites

State	Site	Crashes		crashes/year		Change*	percent change
		Before	After	Before	After		
	Stoddard	1	0	0.2	0.0	-0.2	-100%
Missouri	Saline	1	4	0.2	2.0	1.8	900%
	IA 125	4	4	0.8	2.0	1.2	150%
Iowa	IA 4	8	1	1.6	0.5	-1.1	-69%
	WI 167	6	0	1.2	0.0	-1.2	-100%
	WI 71	1	2	0.2	1.0	0.8	400%
	WI 22	6	4	1.2	2.0	0.8	67%
Wisconsin	WI 51	10	0	2.0	0.0	-2.0	-100%
	WI 45	8	8	1.6	4.0	2.4	150%
	WI 32	9	1	1.8	0.5	-1.3	-72%
	SR 007	7	5	1.4	2.5	1.1	79%
	SR 109	16	4	3.2	2.0	-1.2	-38%
	SR 302	7	0	1.4	0.0	-1.4	-100%
Washington	SR 410	7	0	1.4	0.0	-1.4	-100%
	SR 507	6	6	1.2	3.0	1.8	150%
	SR 510	5	6	1.0	3.0	2.0	200%
	BEA 565	13	1	2.6	0.5	-2.1	-81%
	BRY 3090	1	1	0.2	0.5	0.3	150%
	HOU 362	10	1	2.0	0.5	-1.5	-75%
Texas	HOU 517B	2	2	0.4	1.0	0.6	150%
	PAR1567	4	0	0.8	0.0	-0.8	-100
	TYL 1249	0	3	0.0	1.5	1.5	NA
	YOA 331	3	0	0.6	0.0	-0.6	-100%
	YOA 530A	5	0	1.0	0.0	-1.0	-100%
Total		135	52	27.0	26.0	-1.0	-4%

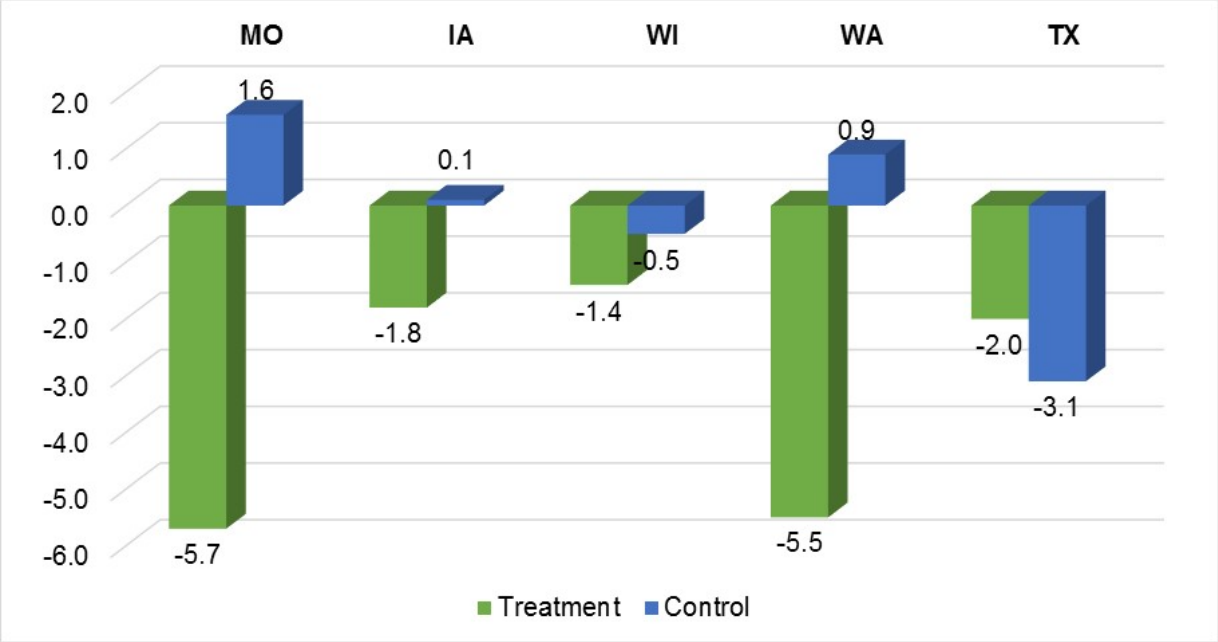


Figure 28. Chart. Change in Crashes per Year at Treatment and Control Site

Table 18 shows the distribution of crashes annually for all of the locations with SDCWS installed. The three locations with the highest number of crashes (Missouri Hwy 221, Wisconsin Hwy 67 and Washington SR 7) were evaluated to verify that crashes were not skewed between years. The crashes on Missouri Hwy 221 was the only site that had crashes skewed toward earlier years. 12 crashes occurred in 2007 but then remained consistent for the remaining before period. A decreasing trend in crashes is shown in Wisconsin on Hwy 67. Crashes were consistent in Washington on SR 7 with the exception of an increase to 8 crashes in 2011. Overall, with the exceptions of Missouri Hwy 221, the crash data was consistent annually during the before period.

Table 18. Distribution of crashes annually

	Iowa	Missouri	Texas				Washington			Wisconsin		
YEAR	IA 144	MO 221	DAL 147	HOU 1488	YOA 109	YOA 530B	WA 7	WA 9	WA 203	US 67	WI 20	WI 213
2007	2	12	0	0	1	0	5	0	2	4	2	1
2008	0	6	4	0	1	0	4	3	3	5	6	1
2009	2	4	1	3	1	1	5	0	1	2	2	0
2010	3	6	2	3	2	0	5	1	0	2	2	1
2011	2	7	2	3	1	0	8	2	0	1	2	0

Overall the treatment appeared to be effective in reducing crashes. However only a simple analysis was conducted since there were only two years of after data. A simple analysis cannot account for regression to the mean and other factors which will also affect crashes. Consequently, the above should be used to suggest that the treatment is effective but the results should be applied cautiously.

CONCLUSION

This chapter summarizes the findings from the speed and crash analysis assessing the effectiveness of the SDCWS. The SDCWS was shown to be effective at reducing speed during all data collection periods from 1 month to 24 months after installation.

Table 19 shows the average change in speed at the point of curvature across all sites by data collection period. The statistics in parenthesis show the results of only tracked vehicles through the curve. The change in mean speed was consistent between all data collection periods with reductions between 1.7 mph at 1 month after to 1.3 mph during the 12 and 18 month after data collection. The 85th percentile speed also showed reductions with a decrease of 1.7 mph during the 1 month after data collection period.

Table 20**Error! Not a valid bookmark self-reference.** also shows that the fraction of vehicles exceeding the posted or advisory speed limit experienced reductions during all data collection periods. The sites on average had a decrease of 11 percent in the fraction of vehicles exceeding the curve advisory speed by 5 mph or more. The fraction of vehicles exceeding the advisory speed by 10 mph or more decreased by an average of 22 percent and by 30 percent for the fraction of vehicles exceeding by 15 mph or more. An average decrease of 32 percent was shown in the fraction of vehicles exceeding the advisory speed by 20 mph or more. The results indicate the effectiveness of the SDCWS in reducing speeds and the ability to maintain that reduction over time (2 years after installation).

Table 19. Average change across all sites at the point of curvature (PC).

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.7 (-1.8)	-1.3 (-1.3)	-1.3 (-1.6)	-1.5 (-1.4)
Change in 85th percentile speed(mph)		-1.7 (-1.9)	-1.4 (-1.3)	-1.3 (-1.7)	-1.4 (-1.4)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-13.5% (-11.0%)	-9.1% (-6.1%)	-11.2% (-8.7%)	-10.7% (-6.7%)
	10 mph	-27.7% (-24.5%)	-18.1% (-12.9%)	-22.6% (-18.5%)	-20.9% (-15.7%)
	15 mph	-29.1% (-23.4%)	-32.6% (-23.8%)	-31.9% (-28.6%)	-27.7% (-21.7%)
	20 mph	-39.6% (-48.0%)	-30.7% (-43.9%)	-26.3% (-26.4%)	-32.3% (-38.7%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	-23.8% (-15.2%)	-31.1% (-18.8%)	-30.3% (-23.8%)	-23.6% (-16.8%)
	10 mph	-10.5% -1.6%	-3.2% (-9.2%)	-15.0% (-14.0%)	-15.2% (-10.9%)
	15 mph	0.0% (-8.3%)	0.0% (-6.7%)	-3.8% (0.0%)	0.0% (-7.4%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

Table 20. Percentage of vehicles exceeding at the point of curvature (PC) by time period.

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.7 (-1.8)	-1.3 (-1.3)	-1.3 (-1.6)	-1.5 (-1.4)
Change in 85th percentile speed(mph)		-1.7 (-1.9)	-1.4 (-1.3)	-1.3 (-1.7)	-1.4 (-1.4)
		Time Period			
		Before	1 Month	12 Month	18 Month	24 Month
Percentage of vehicles exceeding advisory speed	5 mph	76.5% (80.7%)	69.8% (74.6%)	71.5% (80.8%)	68.3% (70.8%)	70.3% (75.9%)
	10 mph	54.3% (58.9%)	43.8% (47.8%)	46.7% (55.6%)	44.2% (48.3%)	45.7% (50.6%)
	15 mph	26.2% (29.8%)	18.6% (20.6%)	20.3% (25.3%)	20.4% (23.7%)	20.1% (23.3%)
	20 mph	10.0% (12.1%)	6.5% (7.3%)	6.8% (8.9%)	8.3% (9.5%)	6.5% (7.9%)
Percentage of vehicles exceeding posted speed	5 mph	4.9% (5.8%)	3.0% (3.7%)	3.6% (4.9%)	2.7% (3.1%)	2.6% (3.8%)
	10 mph	0.6% (0.8%)	0.3% (0.5%)	0.4% (0.5%)	0.3% (0.4%)	0.2% (0.3%)
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

Figure 29 and Figure 30 show the percentage of vehicles with a difference in speed (speed limit or advisory speed) during all time periods at the point of curvature. Looking at all of the sites, the graphs show there is a reduction in the percentage of vehicles that are exceeding the speed limit or advisory speed. In Figure 29, the lines for all after periods have shifted to the left showing lower percentages of vehicles exceeding the speed limit and more vehicles traveling at or slightly below the speed limit. Furthermore in Figure 30, all of the after periods have shifted to the left from the before period showing the trend of slower speeds compared to the advisory speed at the point of curvature.

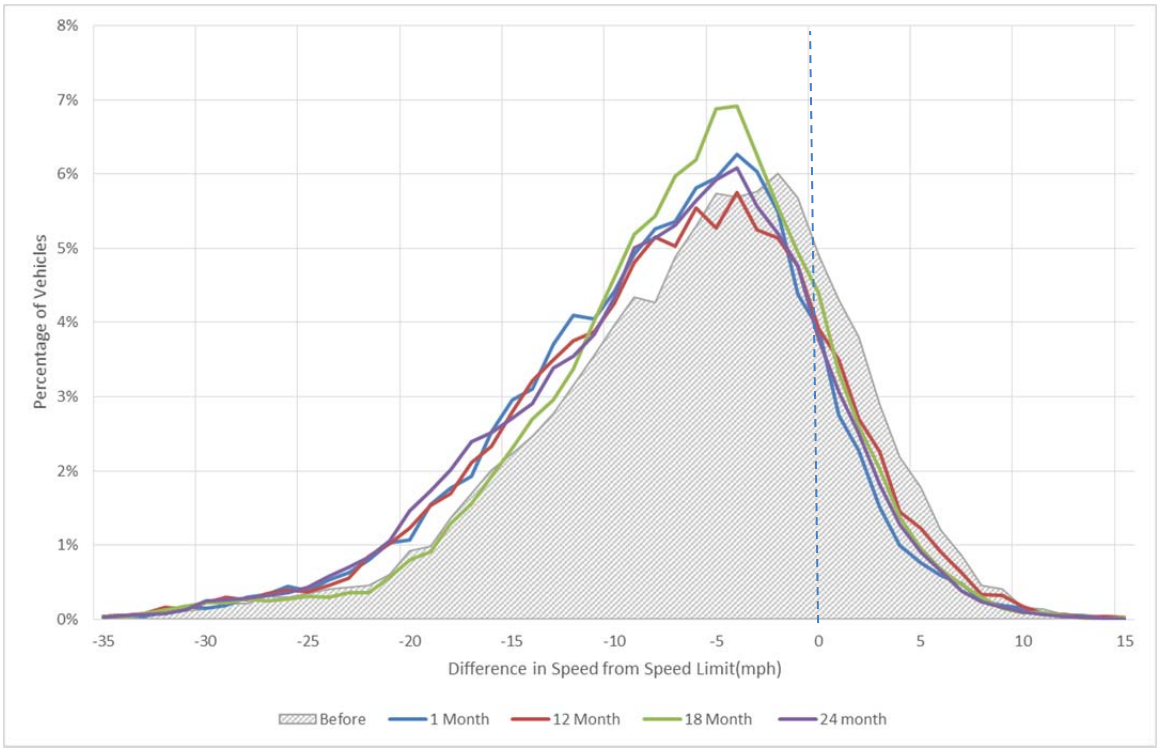


Figure 29. Graph. Percentage of vehicles with difference in speed from speed limit at point of curvature (PC).

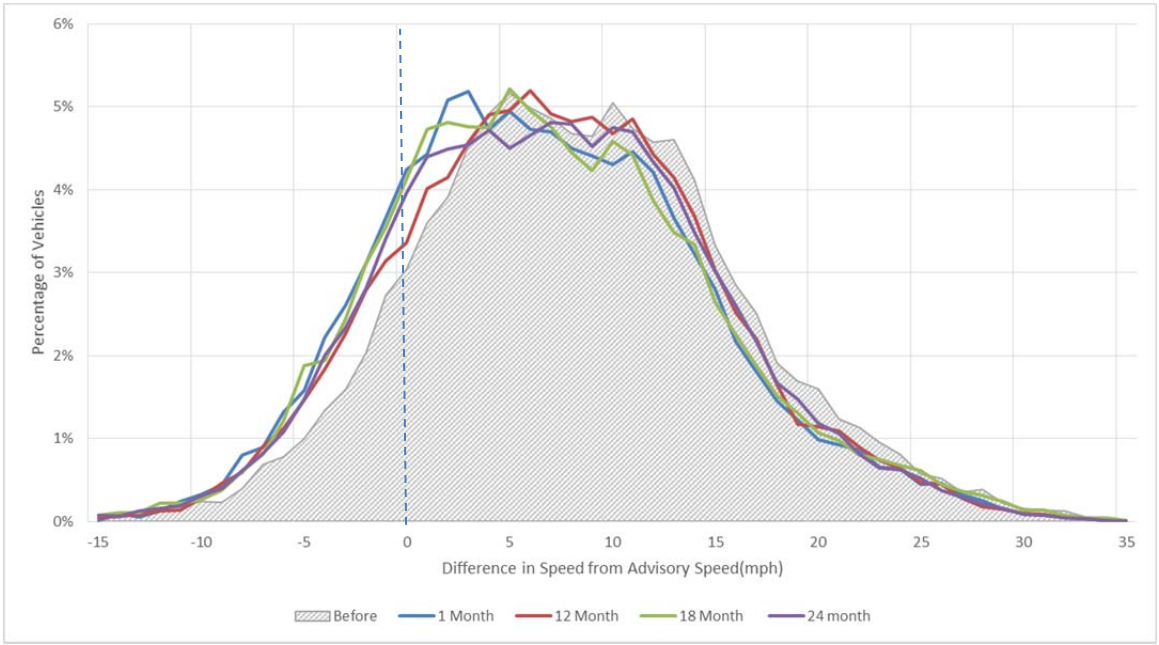


Figure 30. Graph. Percentage of vehicles with difference in speed from advisory speed at point of curvature (PC).

Table 21**Error! Not a valid bookmark self-reference.** shows the average change in speed at the center of curve across all sites by data collection period. The changes in mean speed were consistent across all time periods. The largest decrease in mean speed occurred during the 18 month after period of 1.4 mph and the smallest decreases occurred at the 12 month after period of 1.1 mph. The 85th percentile speed showed similar results with changes between 1.1 and 1.4 mph.

The fraction of vehicles exceeding the posted or advisory speed also showed decreases in speed. A 15 percent decrease in the fraction of vehicles exceeding the advisory speed by 5 mph or more was shown across all sites. For vehicles exceeding the advisory speed by 10 mph or more, the fraction of vehicles ranged from a decrease of 23.2 percent to 26.8 percent. The fraction of vehicles exceeding the advisory speed by 15 mph or more and 20 mph or more were 16 percent and 26 percent.

Table 21. Average change across all sites at the CC

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.2 (-1.3)	-1.1 (-1.1)	-1.4 (-1.2)	-1.2 (-1.3)
Change in 85th percentile speed(mph)		-1.3 (-1.8)	-1.1 (-1.3)	-1.4 (-1.6)	-1.1 (-1.2)
Percent change in fraction of vehicles exceeding advisory speed before vs. after SWDCS installed	5 mph	-12.7% (-10.2%)	-14.9% (-11.0%)	-19.9% (-17.8%)	-14.6% (-11.0%)
	10 mph	-25.3% (-22.9%)	-25.7% (-21.1%)	-23.2% (-29.8%)	-26.8% -45.6%
	15 mph	-19.9% (-22.2%)	-11.0% (-21.4%)	-18.9% (-34.0%)	-14.7% (-29.2%)
	20 mph	-29.3% (-22.7%)	-20.3% (-3.7%)	-18.8% (-18.9%)	-37.0% (-35.4%)
Percent change in fraction of vehicles exceeding posted speed before vs. after SWDCS installed	5 mph	-6.4% (-3.1%)	-9.4% (-5.0%)	-16.2% (-10.5%)	-9.2% (-7.6%)
	10 mph	-0.5% (-2.6%)	6.0% -3.1%	3.5% -2.6%	0.0% (-3.5%)
	15 mph	0.0% (-0.2%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (-4.1%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

Table 22. Percentage of vehicles exceeding at the center of curve (CC) by time period.

		Time Period			
		1 Month	12 Month	18 Month	24 Month
Change in mean speed (mph)		-1.2 (-1.3)	-1.1 (-1.1)	-1.4 (-1.2)	-1.2 (-1.3)
Change in 85th percentile speed(mph)		-1.3 (-1.8)	-1.1 (-1.3)	-1.4 (-1.6)	-1.1 (-1.2)
		Time Period			
		Before	1 Month	12 Month	18 Month	24 Month
Percentage of vehicles exceeding advisory speed	5 mph	68.0% (71.8%)	59.9% (63.8%)	60.8% (68.7%)	57.8% (61.5%)	59.3% (64.2%)
	10 mph	34.0% (38.3%)	26.1% (29.0%)	27.8% (33.5%)	28.1% (31.3%)	25.9% (29.3%)
	15 mph	9.9% (12.3%)	6.7% (7.4%)	7.8% (9.8%)	8.4% (9.8%)	7.4% (8.6%)
	20 mph	2.0% (2.5%)	1.0% (1.3%)	1.3% (1.9%)	1.8% (2.3%)	1.2% (1.5%)
Percentage of vehicles exceeding posted speed	5 mph	2.8% (3.3%)	2.3% (3.1%)	2.7% (3.5%)	2.3% (2.9%)	1.8% (2.7%)
	10 mph	0.2% (0.3%)	0.3% (0.3%)	0.3% (0.5%)	0.3% (0.4%)	0.2% (0.2%)
	15 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
	20 mph	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)

(X) – Tracked vehicles only statistics

Figure 31 and Figure 32 show the percentage of vehicles with a difference in speed from the speed limit or advisory speed during all time periods at the center of curve. Both graphs show a reduction in the percentage of vehicles exceeding the speed limit or advisory speed during all after periods. Although not as defined as data from the point of curvature, the lines for all after periods have shifted, showing a reduction in speeds at the center of curve.

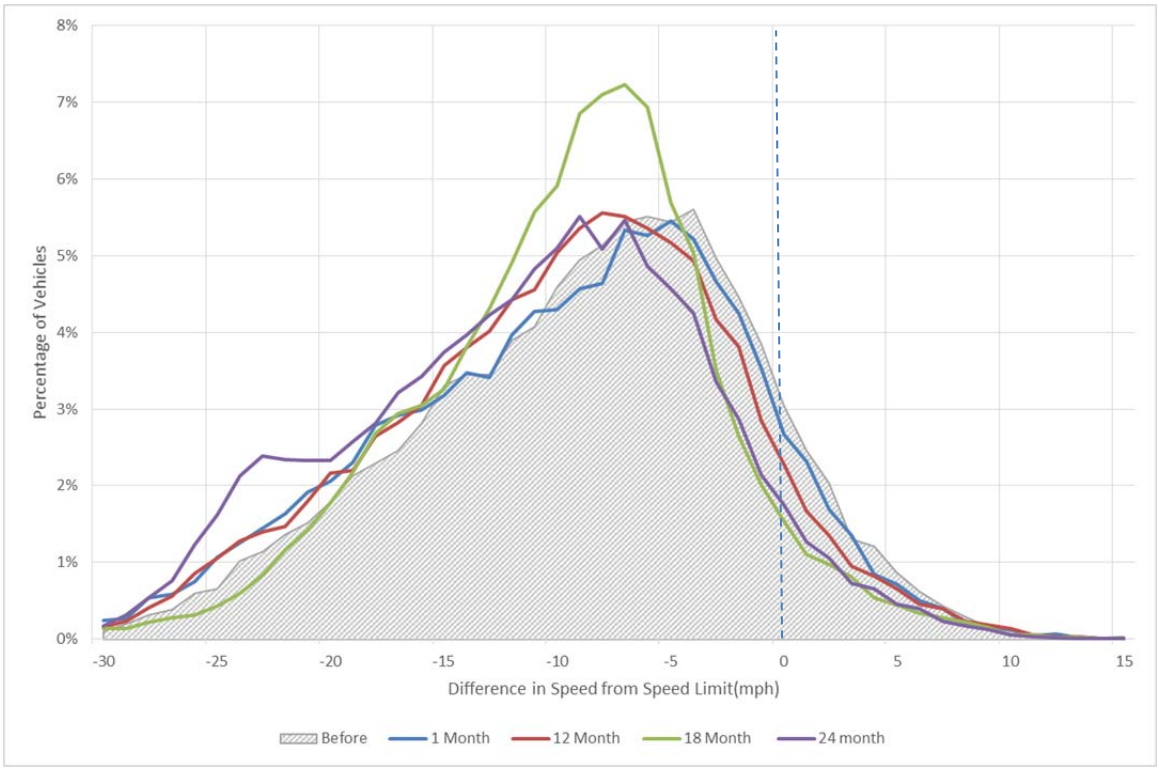


Figure 31. Graph. Percentage of vehicles with difference in speed from speed limit at center of curve (CC).

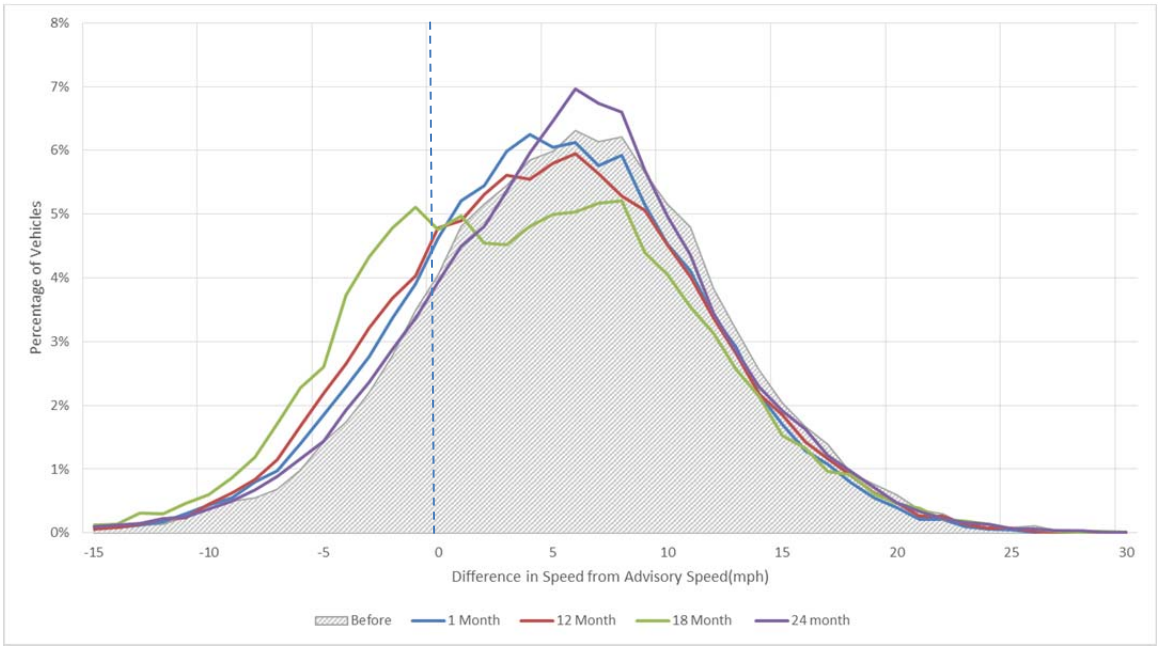


Figure 32. Graph. Percentage of vehicles with difference in speed from advisory speed at center of curve (CC).

At both the point of curvature and center of curve the tracked vehicle statistics were slightly higher or similar to the speed statistics for all vehicles. The tracked vehicle removed influences of trailing and following vehicles and showed that the vehicles only influenced by the SDCWS had larger reduction in speed. This is further evidence of the effectiveness of the SDCWS in reducing speeds and sustaining that reduction over time.

While speed were shown to be reduced, most agencies have a desire to lower the high-end speeds which can substantially increase the safety of the curve. The results at both the point of curvature and center of curve suggest that the signs had an impact on high-end speeds during all data collection periods. Reductions were found in all vehicles exceeding the advisory speed but the largest decreases occurred in the vehicles exceeding by 20 mph or more. Higher decreases were found at the point of curvature suggesting that vehicles were reducing their speed prior to entering the curve and selecting an appropriate speed to negotiate the curve.

The speed results also indicate that the SDCWS were effective at reducing speed consistently between 1 and 24 months after installation. This suggest the signs have a long-term impact on the speeds through the curve. With very little change in the mean and 85th percentile speed over time, the human factors impact of having a new or different sign had little effect.

A simple crash analysis was conducted to determine the safety benefits. The crash analysis evaluated data 5 years before the SDCWS installation and 2 years after installation. Test sites where the SDCWS signs were installed and the control sites were evaluated.

Three of the sites had no crashes documented 2 years after the installation of the SDCWS (IA 141, TX FM 407 and TX FM 530). Reduction in the number of crashes per year were between -17 and 91 percent at seven other sites, while two sites had slight increases of 7 and 11 percent.

Overall the treatment appeared to be effective in reducing crashes. However only a simple analysis was conducted since there were only two years of after data. A simple analysis cannot account for regression to the mean and other factors which will also affect crashes. Consequently, the results should be used to suggest that the treatment is effective but should be applied cautiously.

Finally, evaluating safety countermeasures provides a great resource to DOTs and local agencies to develop effective safety plans to improve safety statewide in the most cost effective way. To effectively conduct this research, the following aspects should be carefully managed:

1. Selection of test and control sites: sites should be selected to allow for isolating the impact of the countermeasure. In this case, sites that already had chevrons were selected to allow for the determination of the impact of the dynamic and sequential nature of the tested devices.
2. Coordination with agencies participating in the research: it is critical to have good communication and coordination among the research team and participating agencies. This allows for smooth installation, maintenance, data collection, and closeout.
3. Data collection: using objective and consistent methods to collect speed data across all test sites.

APPENDIX A. BASELINE DATA FOR EACH TEST SECTION

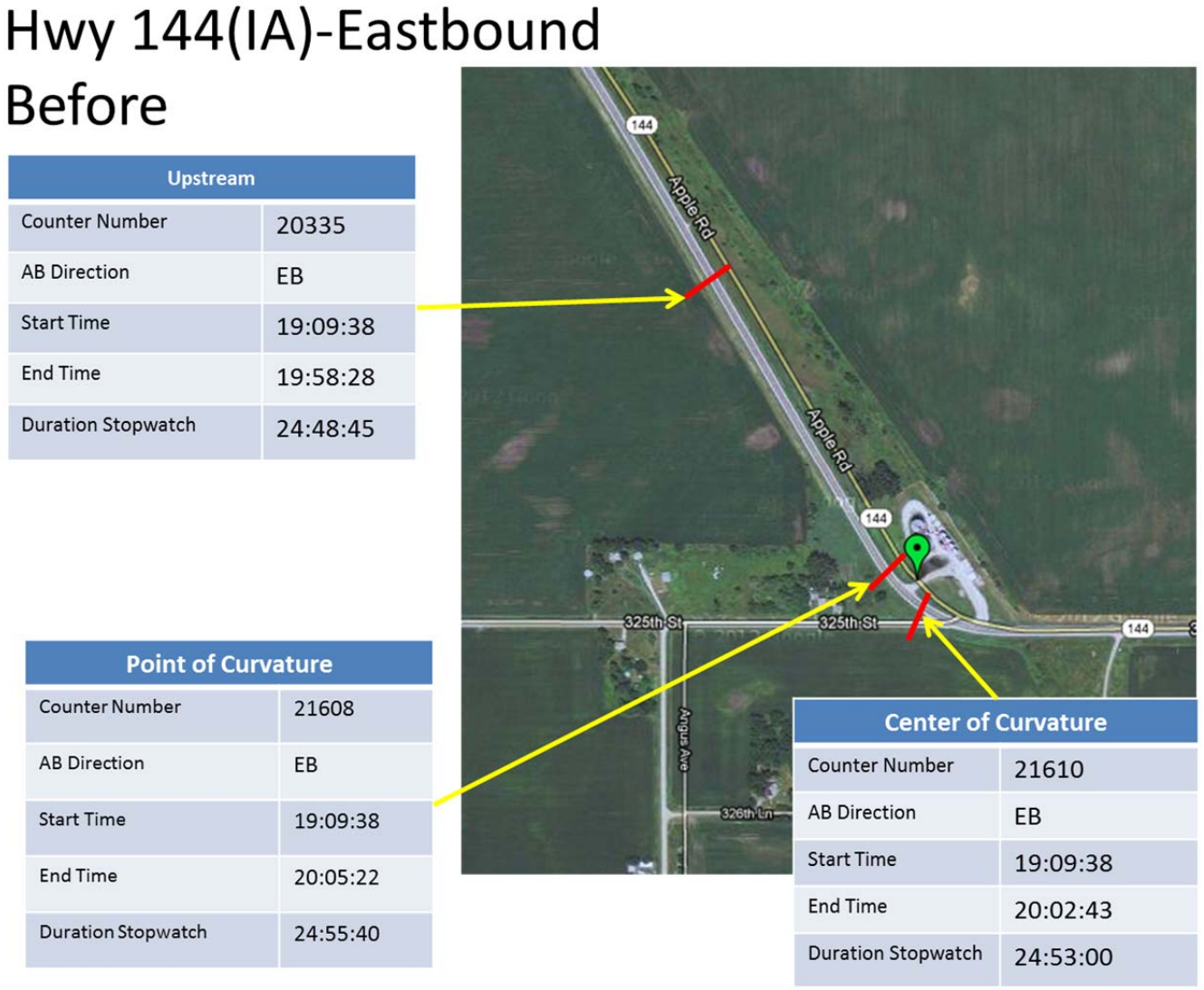


Figure 33. Map. Iowa Highway 144 data collection layout.

Figure 34. Map. Iowa Highway 144 site layout.

Iowa 144

	location (gps at center of curve)
2 Lanes, 12’ lanes	# lanes and width
Left	curve direction (left or right)
Gravel 4’	shoulder type and width
45	posted speed of curve in each direction
55	tangent speed in each direction
55	advisory speed in each direction
See below	grade (average of 3 readings and list if positive or negative)
See below	super elevation
See Layout	location and type of signing before and in the
Asphalt	pavement type and condition
None	presence and location of street lighting

	Begin S-N				Center W-E				End W-E			
Grade	EB	Center	WB	Average	EB	Center	WB	Average	EB	Center	WB	Average
	-.4	-.1	-.2	-.23	-0	-.9	-.4	-.43	-.6	-.5	-.8	-.63

	Begin W-E				Center S-N				End S-N			
Super Elevation	EB	Center	WB	Average	EB	Center	WB	Average	EB	Center	WB	Average
	-5.3	-3.7	-4.9	-4.63	-8.5	-7.1	-7.4	-7.67	-1.2	+1	-1.4	-.53

Figure 35. Chart. Iowa Highway 144 site information

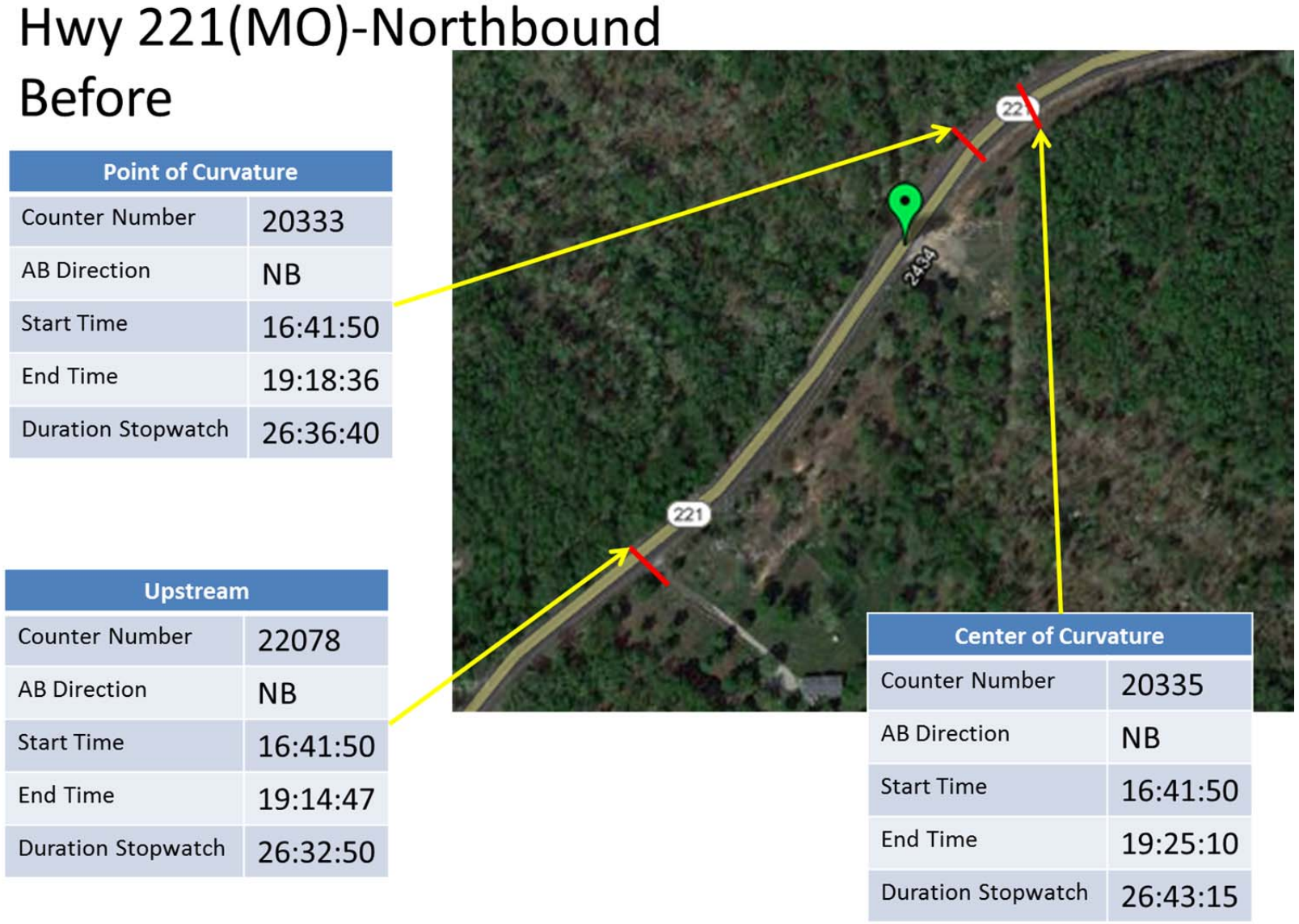


Figure 36. Map. Missouri Highway 221 data collection layout.

Hwy 221(MO)-Northbound

Figure 37. Map. Missouri Highway 221 site layout.

Missouri 221

N42°31.432’ W088°58.944’	location (gps at center of curve)
2 Lanes, 22’ Asphalt	# lanes and width
Right	curve direction (left or right)
4’Asphalt Right 4’ +3’ Asphalt Left sharp drop	shoulder type and width
55	posted speed of curve in each direction
55	tangent speed in each direction
40	advisory speed in each direction
See Below	grade (average of 3 readings and list if positive or negative)
See Below	super elevation
See Layout	location and type of signing before and in the
Asphalt, Good	pavement type and condition
None	presence and location of street lighting

Grade	Begin S-N				Center S-N				End W-E			
	NB	Center	SB	Average	NB	Center	SB	Average	NB	Center	SB	Average
	-3.6	-3.3	-2.9	-3.27	-4.5	-4.4	-4.7	-4.53	-8.8	-9.1	-9.8	-9.23

Super Elevation	Begin W-E				Center S-N				End S-N			
	NB	Center	SB	Average	NB	Center	SB	Average	NB	Center	SB	Average
	-4.2	-2.6	-1.2	-2.67	-8.6	-8.0	-6.0	-7.53	2.0	-0.7	-1.4	-.03

Figure 38. Chart. Missouri Highway 221 site information.

Washington SR9
Date: 7/17-7/18, 2012
Period: Before

PC	
Counter Number	20333
AB Direction	SB
Start Time	7:59
End Time	8:25

Upstream	
Counter Number	20334
AB Direction	SB
Start Time	7:22
End Time	8:25

Center of Curve	
Counter Number	21608
AB Direction	SB
Start Time	7:41
End Time	8:25

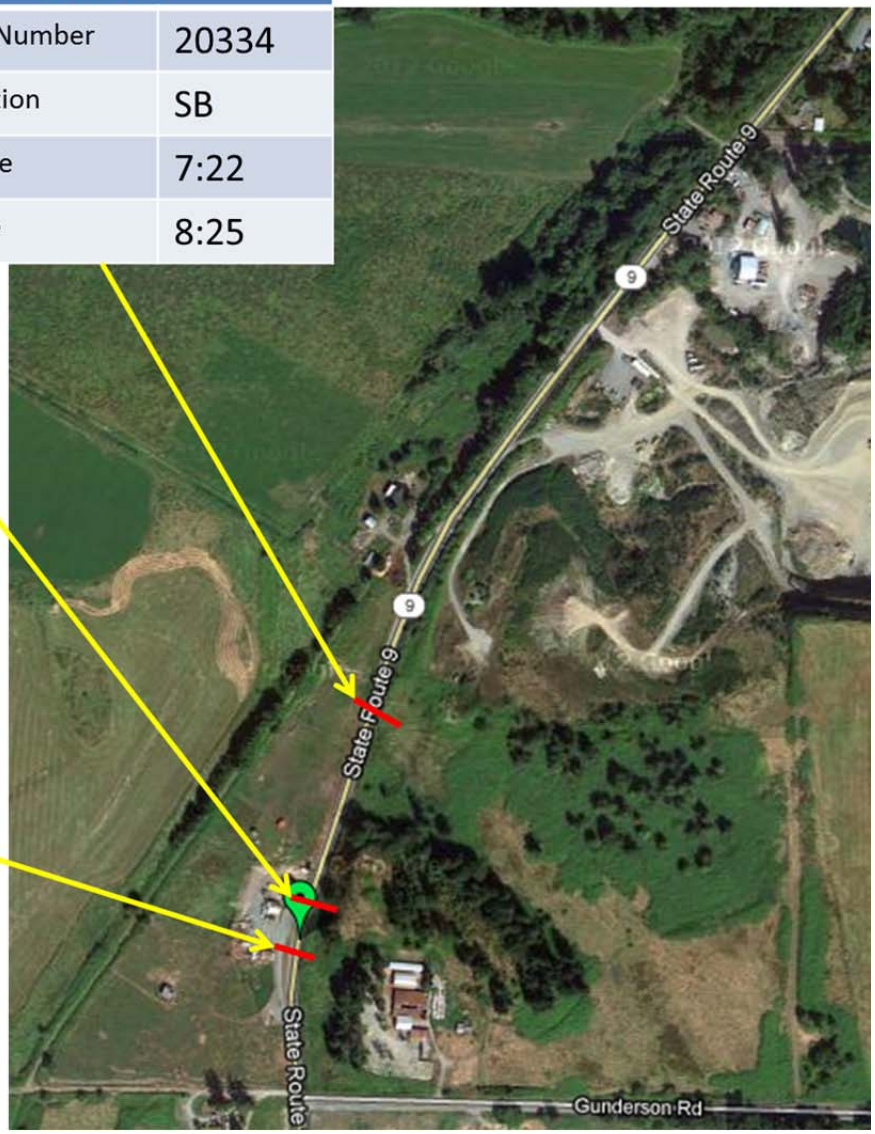


Figure 39. Map. Washington State Route 9 data collection layout.

Figure 40. Map. Washington State Route 9 site layout.

Washington SR9

	location (gps at center of curve)
2 Lanes, 10’ Each CL Rumble 12” Wide	# lanes and width
Left	curve direction (left or right)
2’ Asphalt Shoulder Both	shoulder type and width
50	posted speed of curve in each direction
50	tangent speed in each direction
40	advisory speed in each direction
See Below	grade (average of 3 readings and list if positive or negative)
See Below	super elevation
See Layout	location and type of signing before and in the
Asphalt	pavement type and condition
None	presence and location of street lighting

Grade	Begin W-E				Center W-E				End W-E			
	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	6.0	5.8	5.7	5.8	4.1	4.0	3.9	4.0	3.9	4.1	4.3	4.1

Super Elevation	Begin S-N				Center S-N				End S-N			
	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	2.3	1.8	0	1.4	1.8	0.5	2.1	1.5	0.2	1.9	1.0	1.0

Figure 41. Chart. Washington State Route 9 site information.

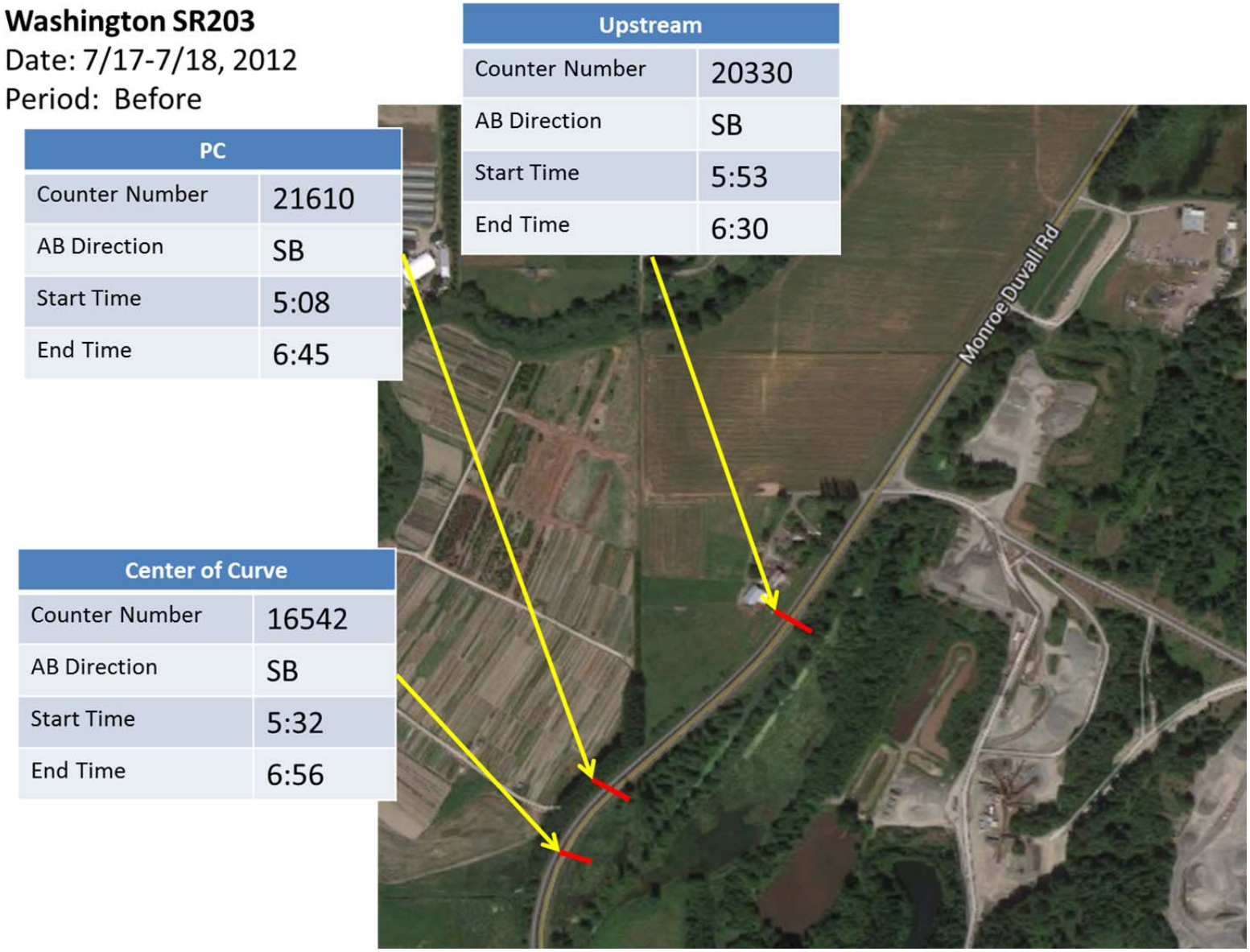


Figure 42. Map. Washington State Route 203 data collection layout.

Washington SR203

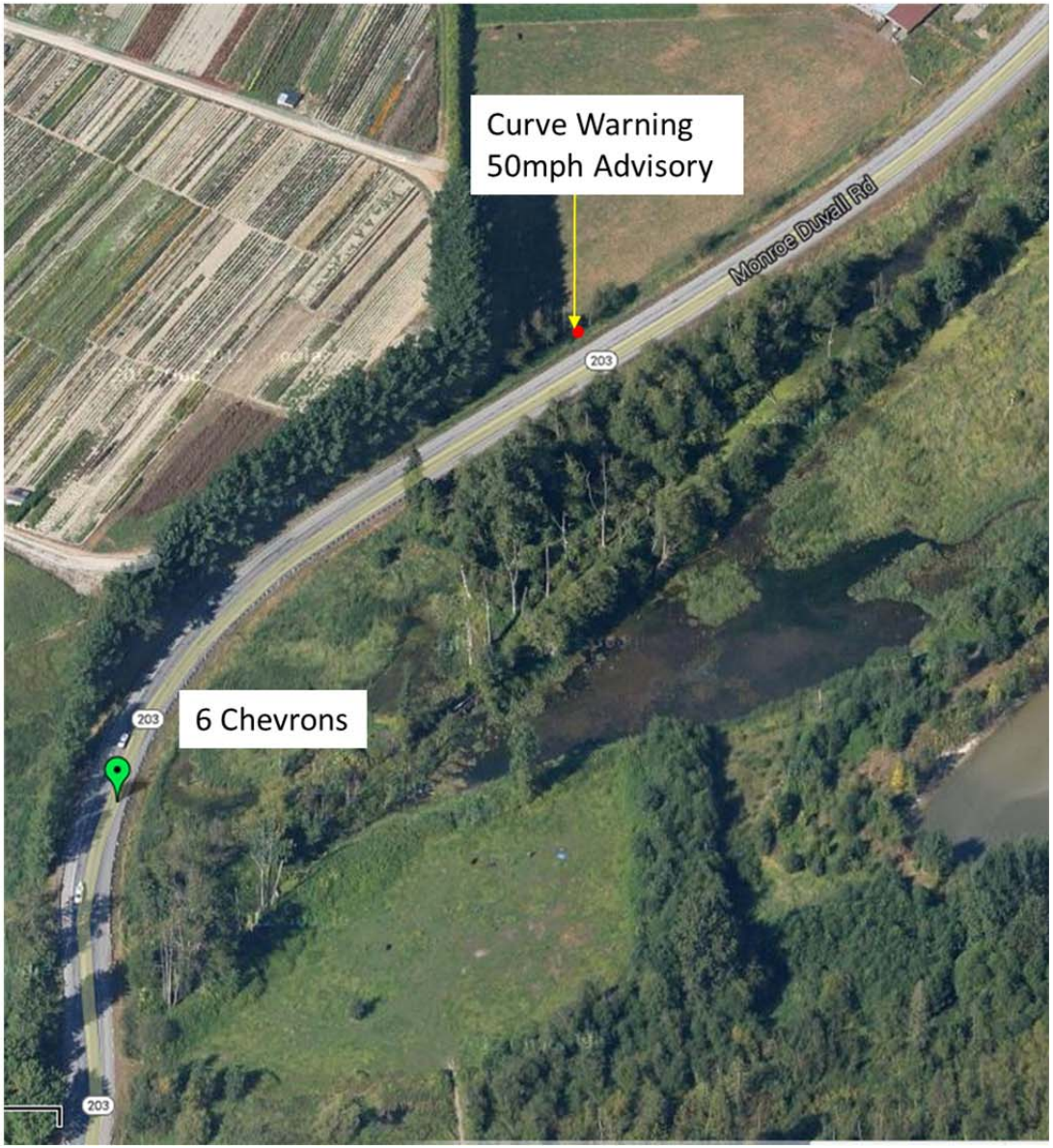


Figure 43. Map. Washington State Route 203 site layout.

Washington SR203

	location (gps at center of curve)
2 lanes with 12” CL Rumble, 11’ NB Lane;10.5’ SB Lane	# lanes and width
Left	curve direction (left or right)
NB-4.5’ Asphalt Shld SB-8’ Asphalt w/ 12” Rumble	shoulder type and width
55	posted speed of curve in each direction
55	tangent speed in each direction
50	advisory speed in each direction
See Below	grade (avg. of 3 readings and list if positive or negative)
See Below	super elevation
See Layout	location and type of signing before and in the
Asphalt	pavement type and condition
None	presence and location of street lighting

Grade	Begin W-E				Center W-E				End W-E			
	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	-4.9	-3.0	-3.0	-3.6	-1.9	-2.0	-2.0	-2.0	2.8	2.8	2.8	2.8

Super Elevation	Begin S-N				Center S-N				End S-N			
	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	4.8	4.1	4.3	4.4	3.8	4.8	4.2	4.3	1.2	1.4	2.5	1.7

Figure 44. Chart. Washington State Route 203 site information.

Figure 45. Map. Washington State Route 7 data collection layout.

Washington SR7

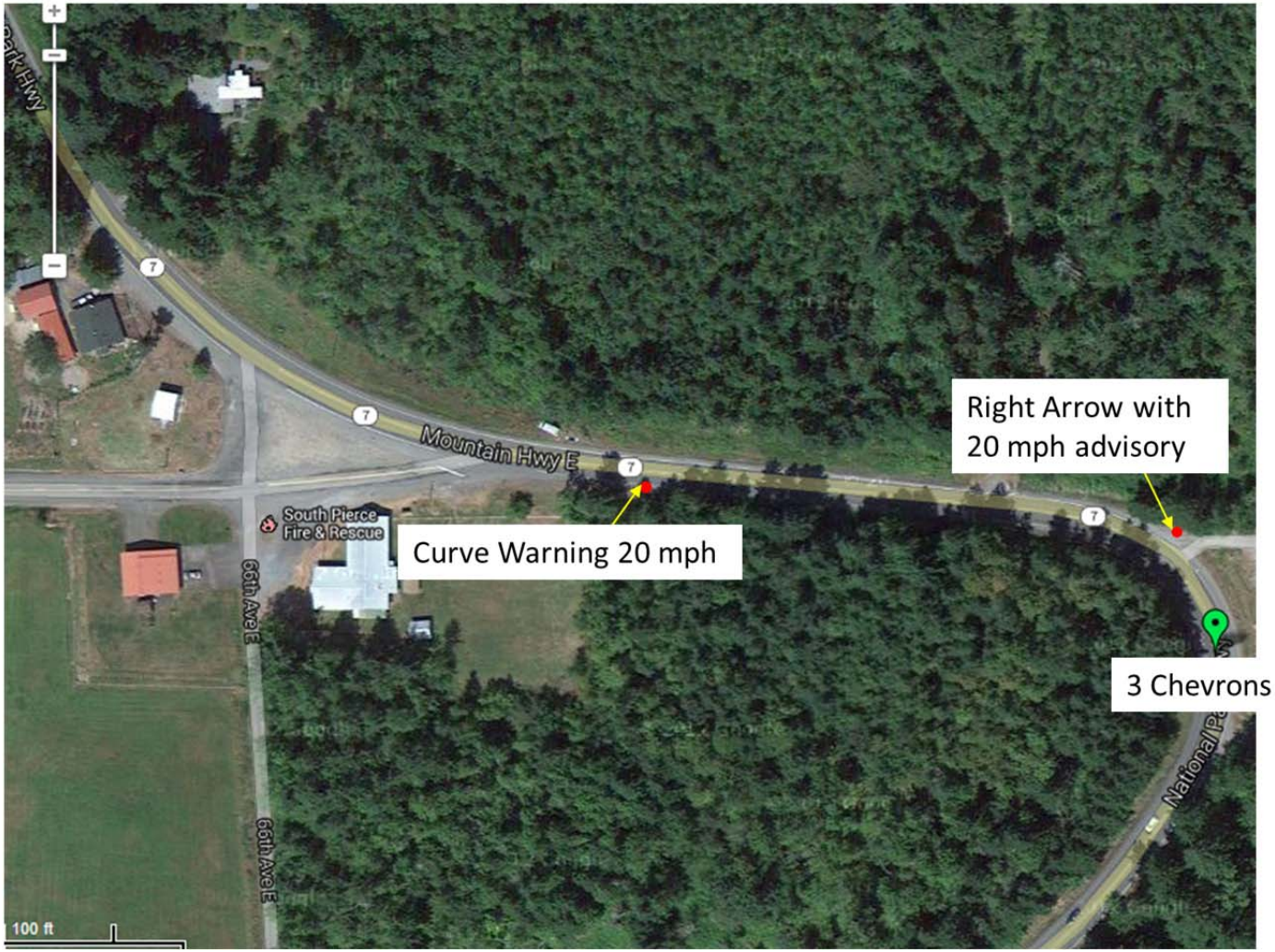


Figure 46. Map. Washington State Route 7 site layout.

Washington SR7

	location (gps at center of curve)
2 Lane with 12” Rumble NB 11’ Lane; SB 10’ Lane	# lanes and width
Right	curve direction (left or right)
Paved	shoulder type and width
50	posted speed of curve in each direction
50	tangent speed in each direction
20	advisory speed in each direction
See Below	grade (average of 3 readings and list if positive or negative)
See Below	super elevation
See Layout	location and type of signing before and in the
Asphalt, Good	pavement type and condition
None	presence and location of street lighting

	Begin S-N				Center S-N				End S-N			
Grade	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	1.1	1.5	1.5	1.4	-3.3	-3.3	-3.0	-3.2	-4.5	-4.3	-4.3	-4.4

	Begin W-E				Center W-E				End W-E			
Super Elevation	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	5.5	4.1	3.0	4.2	10.1	8.5	7.6	8.7	5.3	4.7	5.5	5.2

Figure 47. Chart. Washington State Route 7 site information.

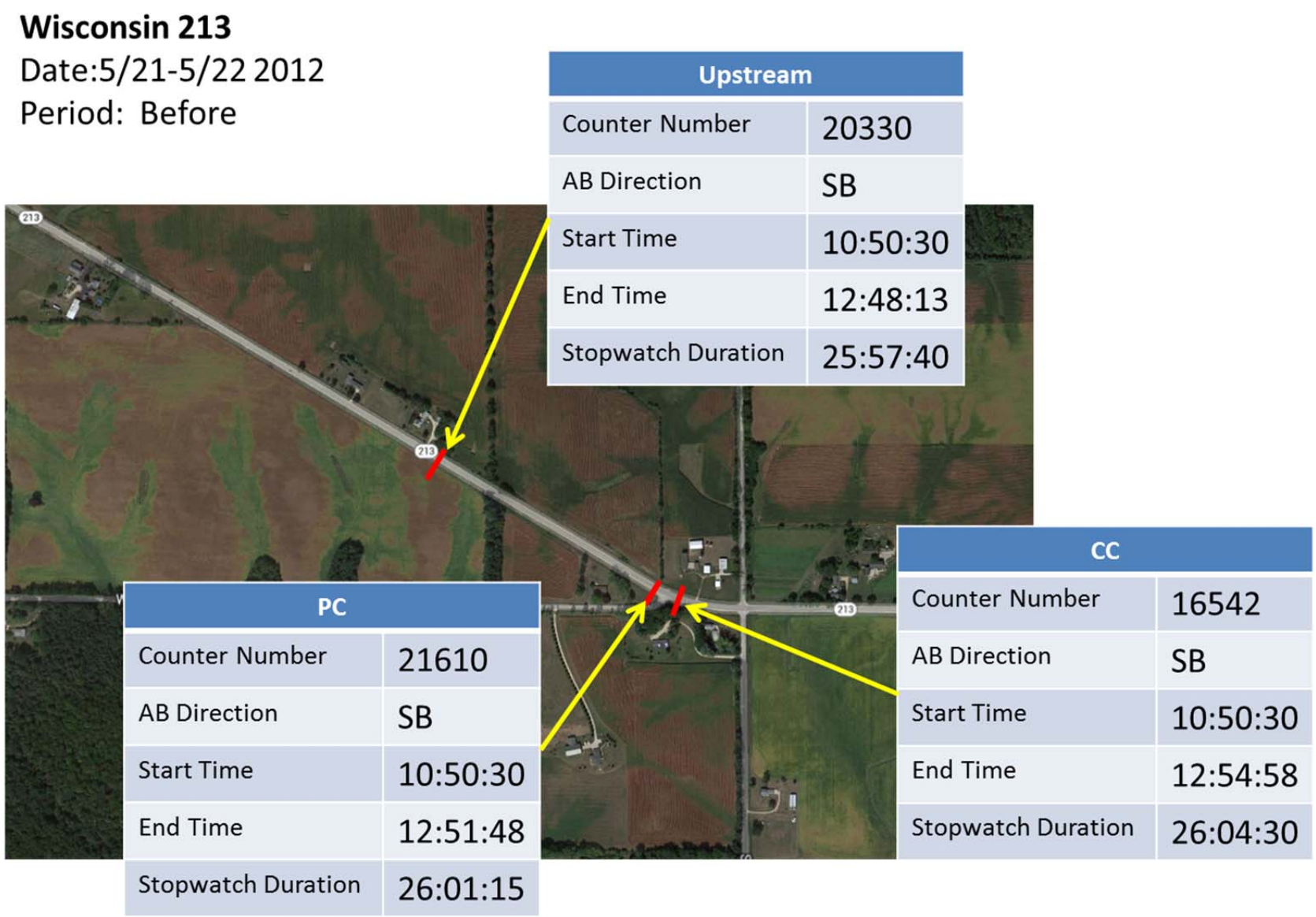


Figure 48. Map. Wisconsin Highway 213 data collection layout.

Wisconsin 213

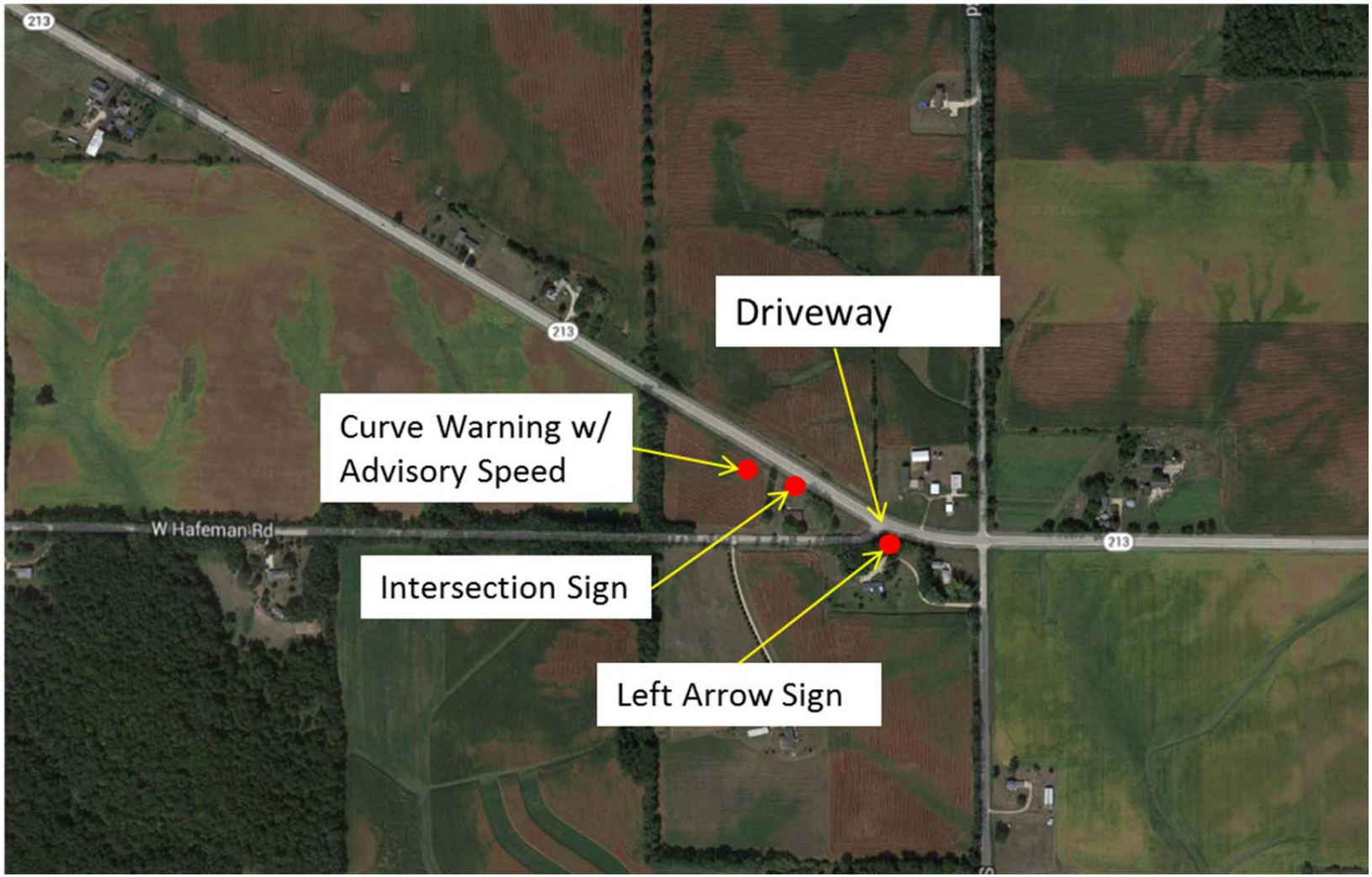


Figure 49. Map. Wisconsin Highway 213 site layout.

Wisconsin 213

N42°35.977’ W089°12.570’	location (gps at center of curve)
2 Lanes, 24’	# lanes and width
Left	curve direction (left or right)
3’Asphalt with varying gravel edge	shoulder type and width
55	posted speed of curve in each direction
55	tangent speed in each direction
50	advisory speed in each direction
Below	grade (average of 3 readings and list if positive or negative)
Below	super elevation
Previous Slide(5 Chevrons)	location and type of signing before and in the
Asphalt, Good	pavement type and condition
None	presence and location of street lighting

	Begin W-E				Center W-E				End W-E			
Grade	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	-4.9	-4.9	-4.8	-4.87	-5.6	-5.4	-5.7	-5.57	-3.8	-3.2	-3.1	-3.37

	Begin S-N				Center S-N				End S-N			
Super Elevation	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	-3.8	-3.5	-4.7	-4.00	-6.5	-7.1	-8.6	-7.40	-4.6	-4.8	-5.4	-4.93

Figure 50. Chart. Wisconsin Highway 213 site information.

Figure 51. Map. Wisconsin Highway 20 data collection layout.

Wisconsin 20

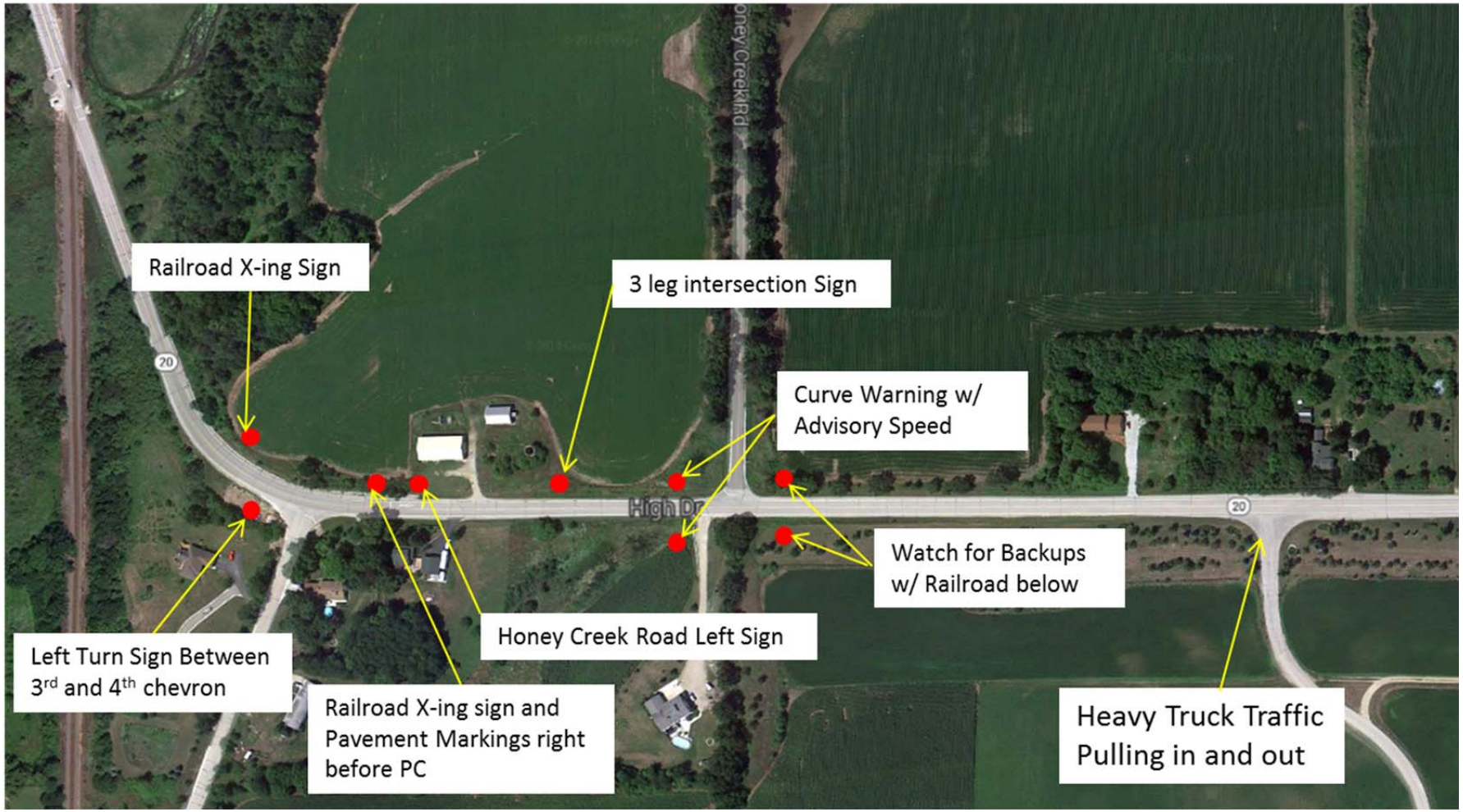


Figure 52. Map. Wisconsin Highway 20 site layout.

Wisconsin 20

N42°46.212' W088°18.078'	location (gps at center of curve)
2 Lanes, 25'	# lanes and width
Right	curve direction (left or right)
South(2'Asphalt, 6'gravel) North(14'Asphalt w/Drainage	shoulder type and width
55	posted speed of curve in each direction
55	tangent speed in each direction
30	advisory speed in each direction
See Below	grade (average of 3 readings and list if positive or negative)
See Below	super elevation
See Layout (9 Chevrons)	location and type of signing before and in the curve
Asphalt, Good	pavement type and condition
None	presence and location of street lighting

	Begin W-E				Center W-E				End S-N			
Grade	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	3	3	2.5	2.83	7.3	7	7.2	7.17	-5.9	-6.4	-6.5	-6.27

	Begin S-N				Center S-N				End W-E			
Super Elevation	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	-4	-5.3	-3	-4.10	-7.7	-8.3	-8.2	-8.07	-3.4	-5.6	-4	-4.33

Figure 53. Chart. Wisconsin Highway 20 site information.

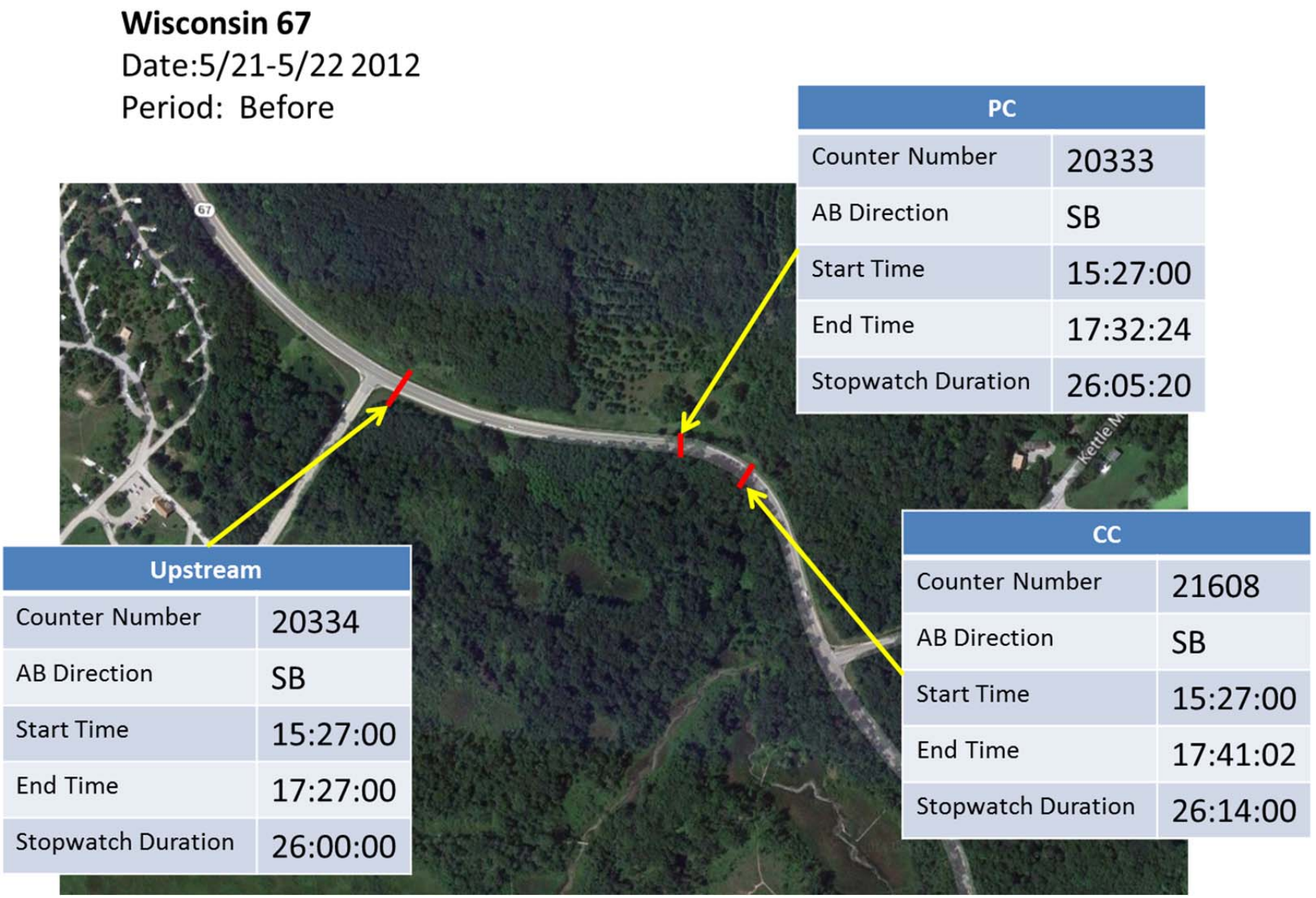


Figure 54. Map. Wisconsin Highway 67 data collection layout.

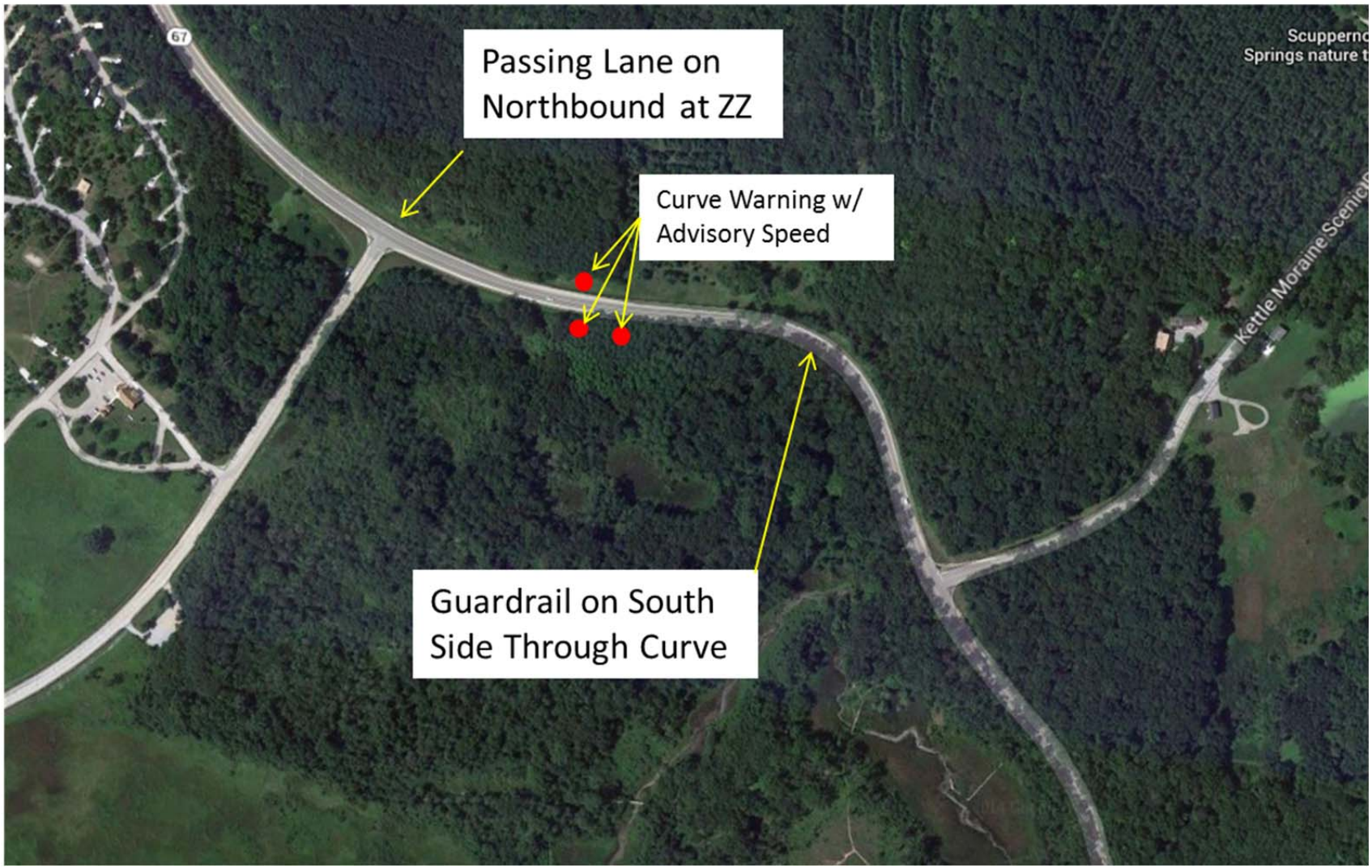


Figure 55. Map. Wisconsin Highway 67 site layout.

Wisconsin 67

N42°56.244’ W088°28.056’	location (gps at center of curve)
2 Lanes, 24’	# lanes and width
Right	curve direction (left or right)
South(3.5’asphalt w/4’ Gravel then guardrail through curve) North(1.5’ asphalt w/ 3’ gravel)	shoulder type and width
55	posted speed of curve in each direction
55	tangent speed in each direction
25	advisory speed in each direction
See Below	grade (average of 3 readings and list if positive or negative)
See Below	super elevation
See Layout(5 Chevrons)	location and type of signing before and in the curve
Asphalt, good	pavement type and condition
None	presence and location of street lighting

	Begin W-E				Center W-E				End S-N			
Grade	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	-1.6	-1.7	-1.9	-1.73	-0.1	-0.12	-0.2	-0.14	0.7	0.6	1	0.77

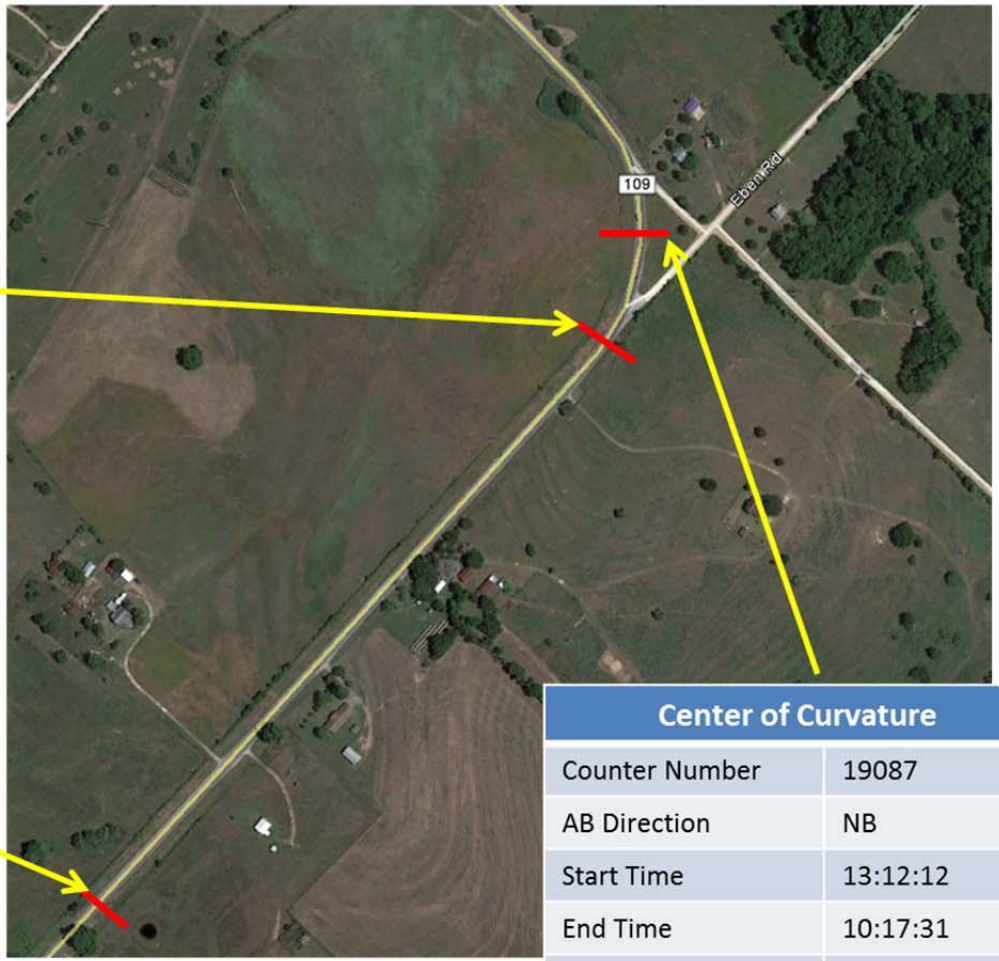
	Begin S-N				Center S-N				End W-E			
Super Elevation	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	2	1.1	-0.4	0.90	5.8	5.2	5.1	5.37	3.6	3.2	3.1	3.30

Figure 56. Chart. Wisconsin Highway 67 site information.

FM 109(TX)-Northbound Before

Point of Curvature	
Counter Number	19090
AB Direction	NB
Start Time	12:56:01
End Time	10:11:34
Duration	69:15:33

Upstream	
Counter Number	19083
AB Direction	NB
Start Time	12:10:20
End Time	09:49:44
Duration	69:39:24



Center of Curvature	
Counter Number	19087
AB Direction	NB
Start Time	13:12:12
End Time	10:17:31
Duration	69:05:19

Figure 57. Map. Texas FM 109 data collection layout

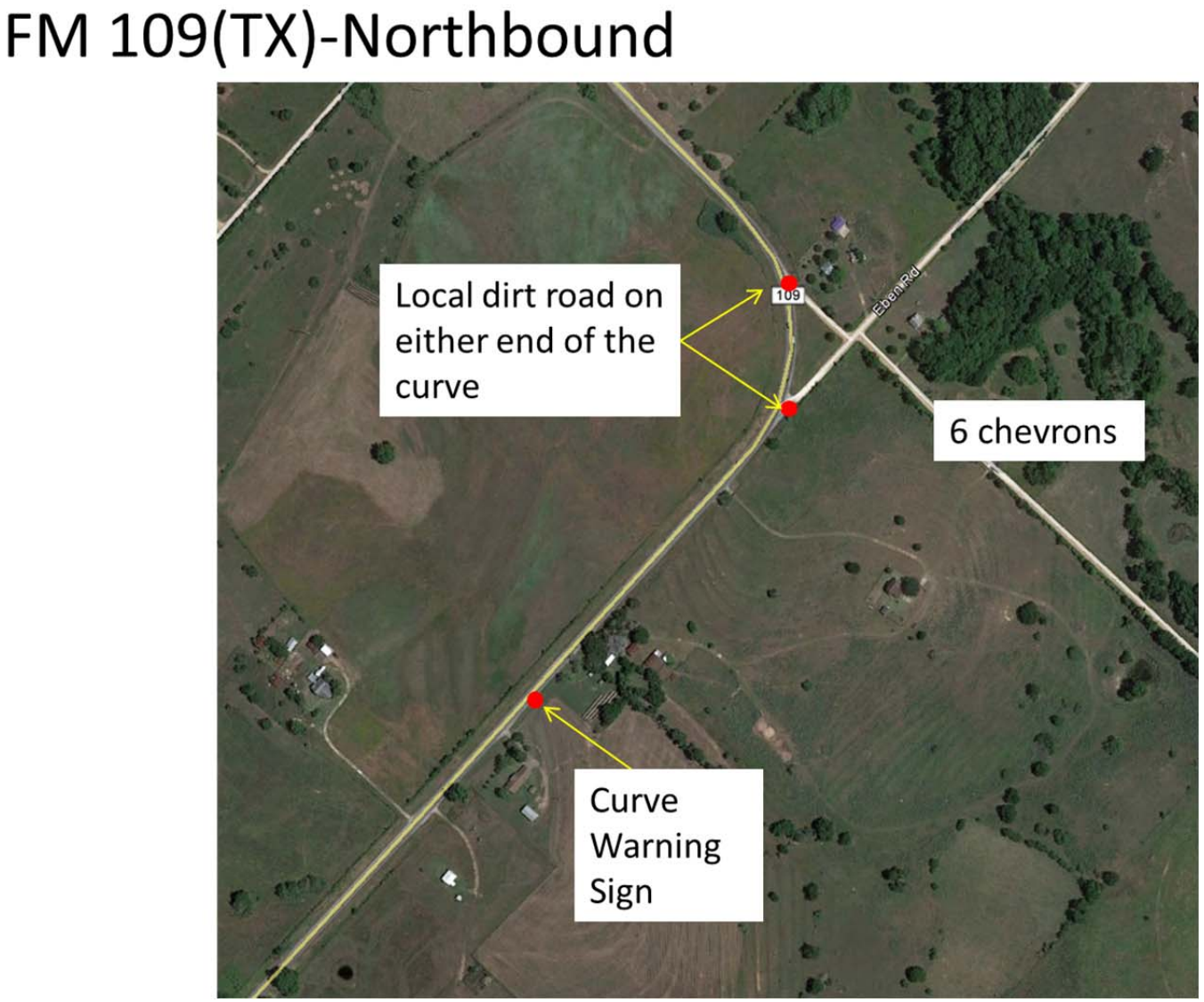


Figure 58. Map. Texas FM 109 site layout.

Texas FM 109

N30°00.792’ W96°29.094’	location (gps at center of curve)
2 Lanes, 11’ lanes	# lanes and width
Left	curve direction (left or right)
Chip seal 2’	shoulder type and width
60	posted speed of curve in each direction
60	tangent speed in each direction
35	advisory speed in each direction
See below	grade (average of 3 readings and list if positive or negative)
See below	super elevation
See Layout	location and type of signing before and in the curve
Chip seal, good	pavement type and condition
None	presence and location of street lighting

	Begin S-N				Center S-N				End S-N			
Grade	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	-1.6	-1.2	-0.9	-1.23	0.9	1.4	1.5	1.3	0.5	0.2	0.5	0.3

	Begin W-E				Center W-E				End W-E			
Super Elevation	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	3.8	2.8	1.8	2.8	4.4	3.4	2.9	3.57	1.7	1.3	1.2	1.4

Figure 59. Chart. Texas FM 109 site information.

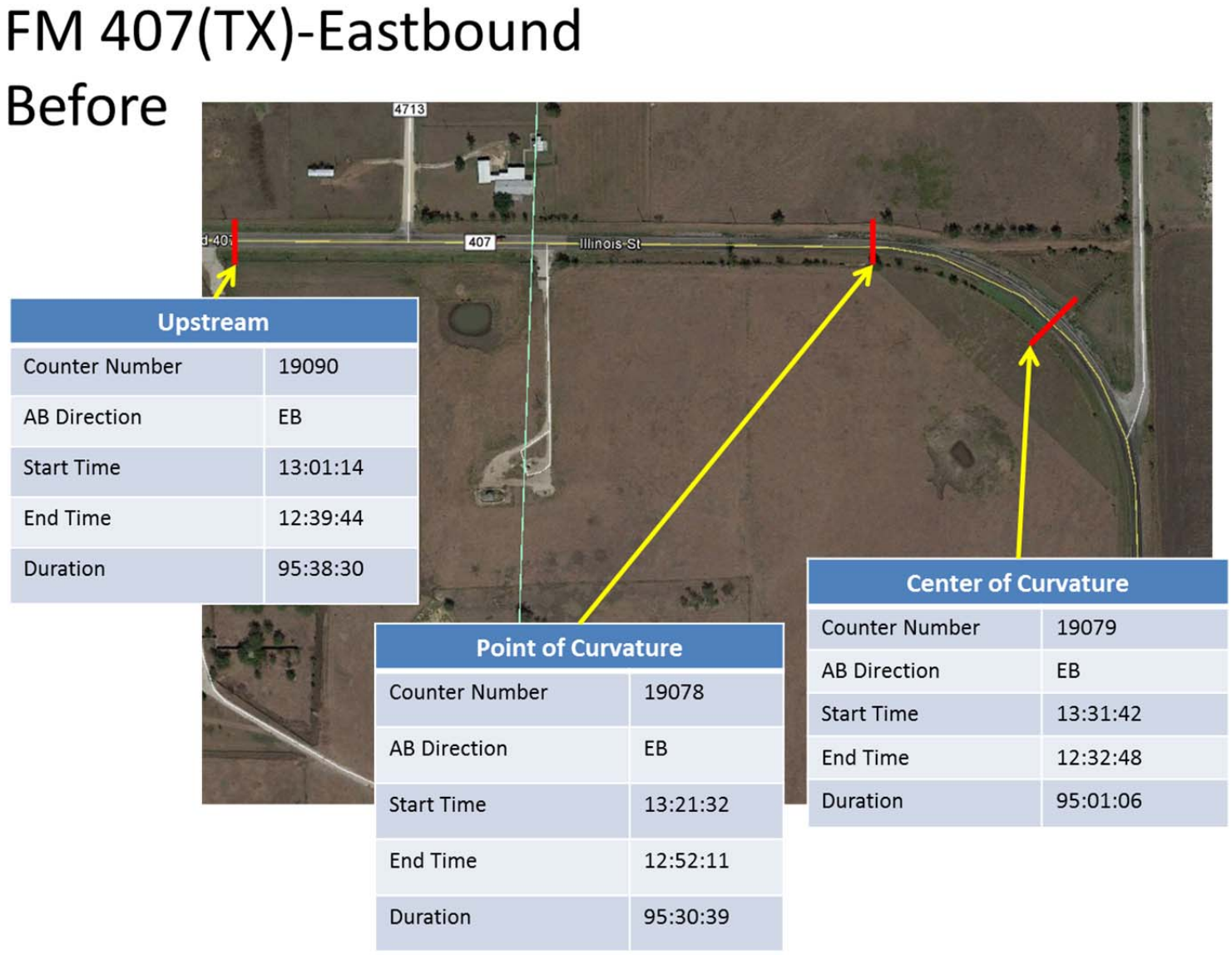


Figure 60. Map. Texas FM 407 data collection layout.

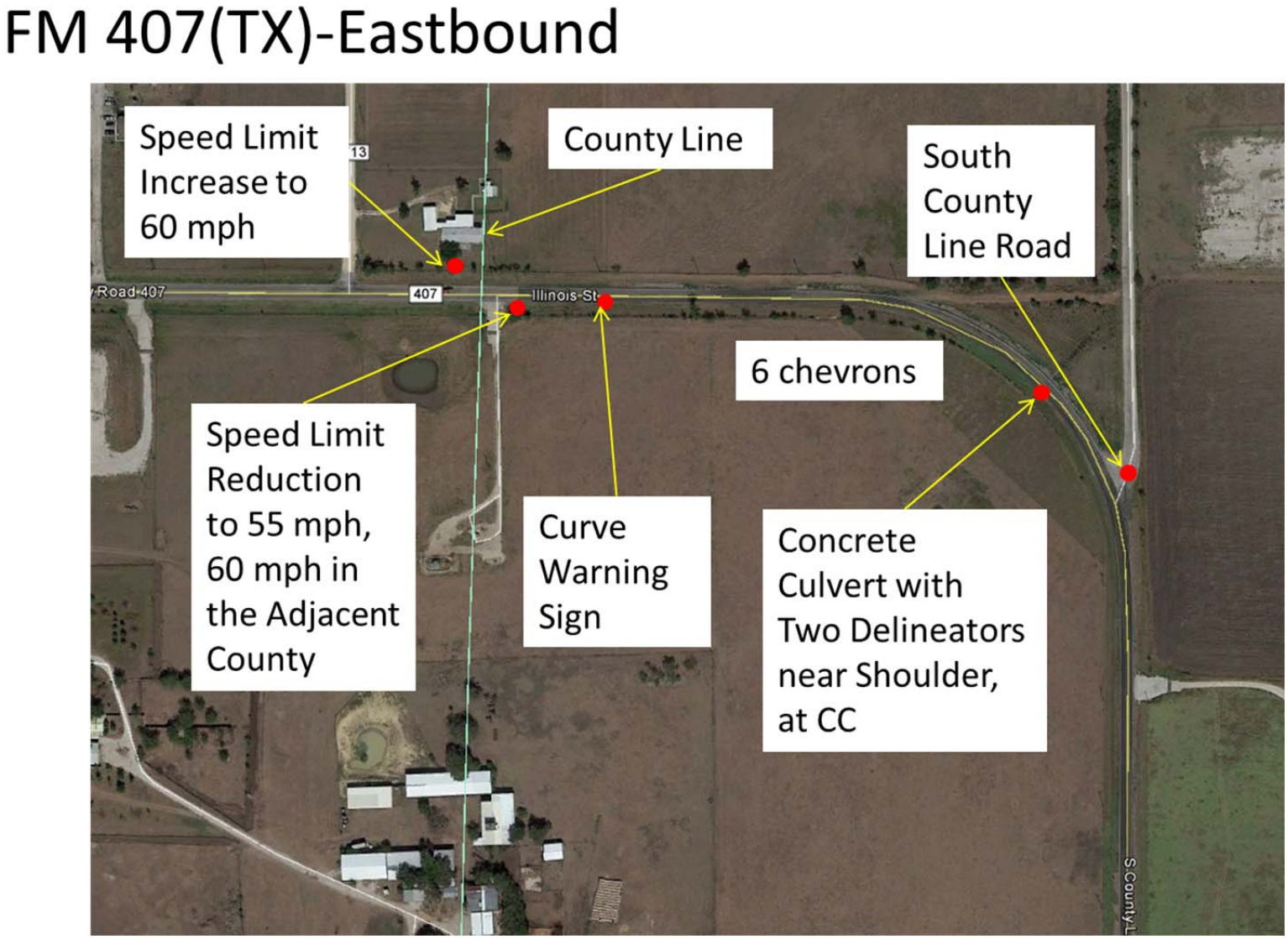


Figure 61. Map. Texas FM 407 site layout.

Texas FM 407

N33°05.869’ W97°23.495’	location (gps at center of curve)
2 Lanes, 11’ lanes	# lanes and width
Right	curve direction (left or right)
Seal coat 1’	shoulder type and width
55	posted speed of curve in each direction
55	tangent speed in each direction
40	advisory speed in each direction
See below	grade (average of 3 readings and list if positive or negative)
See below	super elevation
See Layout	location and type of signing before and in the curve
Seal coat	pavement type and condition
None	presence and location of street lighting

	Begin W-E				Center W-E				End S-N			
Grade	EB	Center	WB	Average	EB	Center	WB	Average	EB	Center	WB	Average
	-0.5	-0.5	-0.2	-0.4	0.1	0.1	0.0	0.07	0.1	0.0	0.1	0.07

	Begin S-N				Center S-N				End W-E			
Super Elevation	EB	Center	WB	Average	EB	Center	WB	Average	EB	Center	WB	Average
	2.5	0.8	-0.1	1.07	2.4	1.8	2.7	2.3	2.2	1.0	0.0	1.07

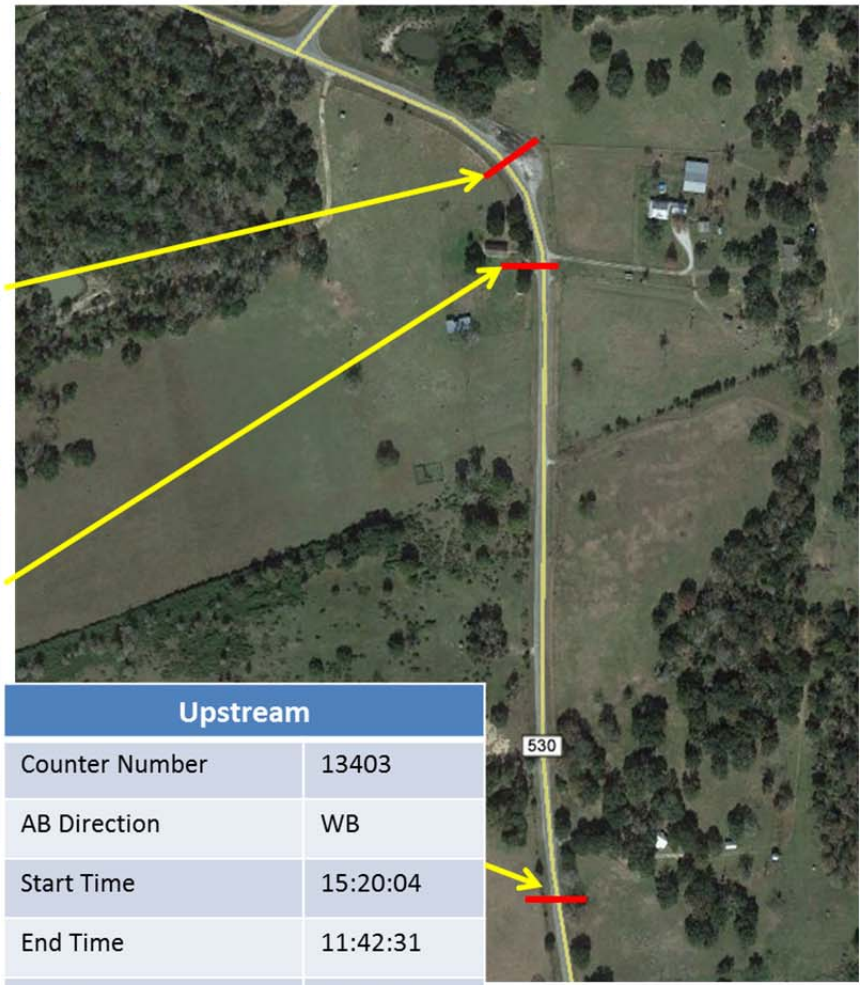
Figure 62. Chart. Texas FM 407 site information.

FM 530(TX)-Westbound

Before

Center of Curvature	
Counter Number	19078
AB Direction	WB
Start Time	16:21:37
End Time	12:15:41
Duration	67:54:04

Point of Curvature	
Counter Number	18337
AB Direction	WB
Start Time	16:07:09
End Time	11:56:37
Duration	67:49:28



Upstream	
Counter Number	13403
AB Direction	WB
Start Time	15:20:04
End Time	11:42:31
Duration	68:22:27

Figure 63. Map. Texas FM 530 data collection layout.

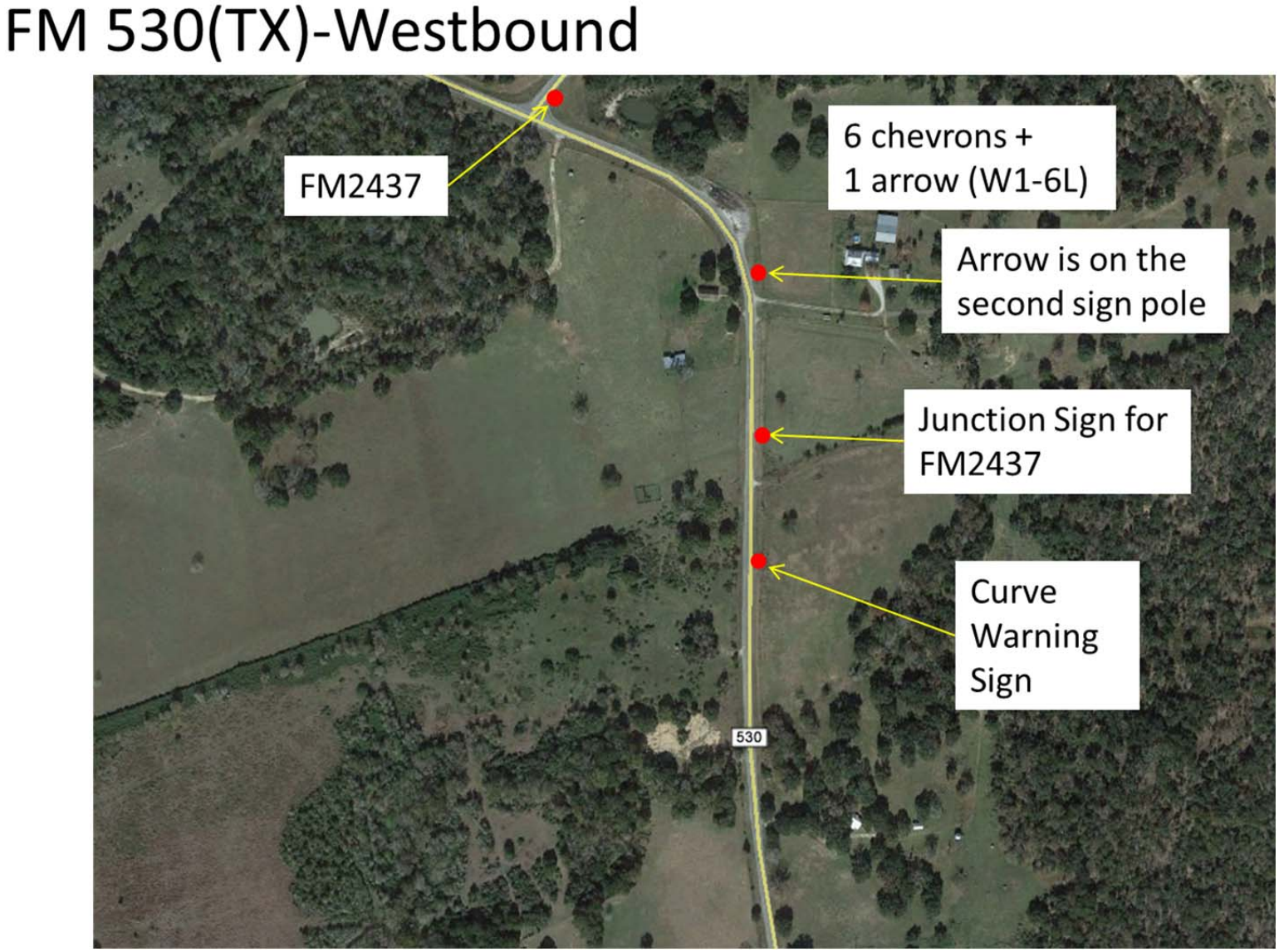


Figure 64. Map. Texas FM 530 site layout.

Texas FM 530

N29°19.093’ W96°41.865’	location (gps at center of curve)
2 Lanes, 11’ lanes	# lanes and width
Left	curve direction (left or right)
Asphalt 2’	shoulder type and width
60	posted speed of curve in each direction
60	tangent speed in each direction
35	advisory speed in each direction
See below	grade (average of 3 readings and list if positive or negative)
See below	super elevation
See Layout	location and type of signing before and in the curve
Asphalt, good	pavement type and condition
None	presence and location of street lighting

	Begin S-N				Center S-N				End W-E			
Grade	EB	Center	WB	Average	EB	Center	WB	Average	EB	Center	WB	Average
	0.4	0.6	0.9	0.63	-1.1	-1.0	-0.9	-0.73	0.5	0.5	0.3	0.43

	Begin W-E				Center W-E				End S-N			
Super Elevation	EB	Center	WB	Average	EB	Center	WB	Average	EB	Center	WB	Average
	2.5	-1.8	-0.3	0.13	5.7	5.3	4.5	5.17	2.7	1.0	-0.1	1.2

Figure 65. Chart. Texas FM 530 site information.

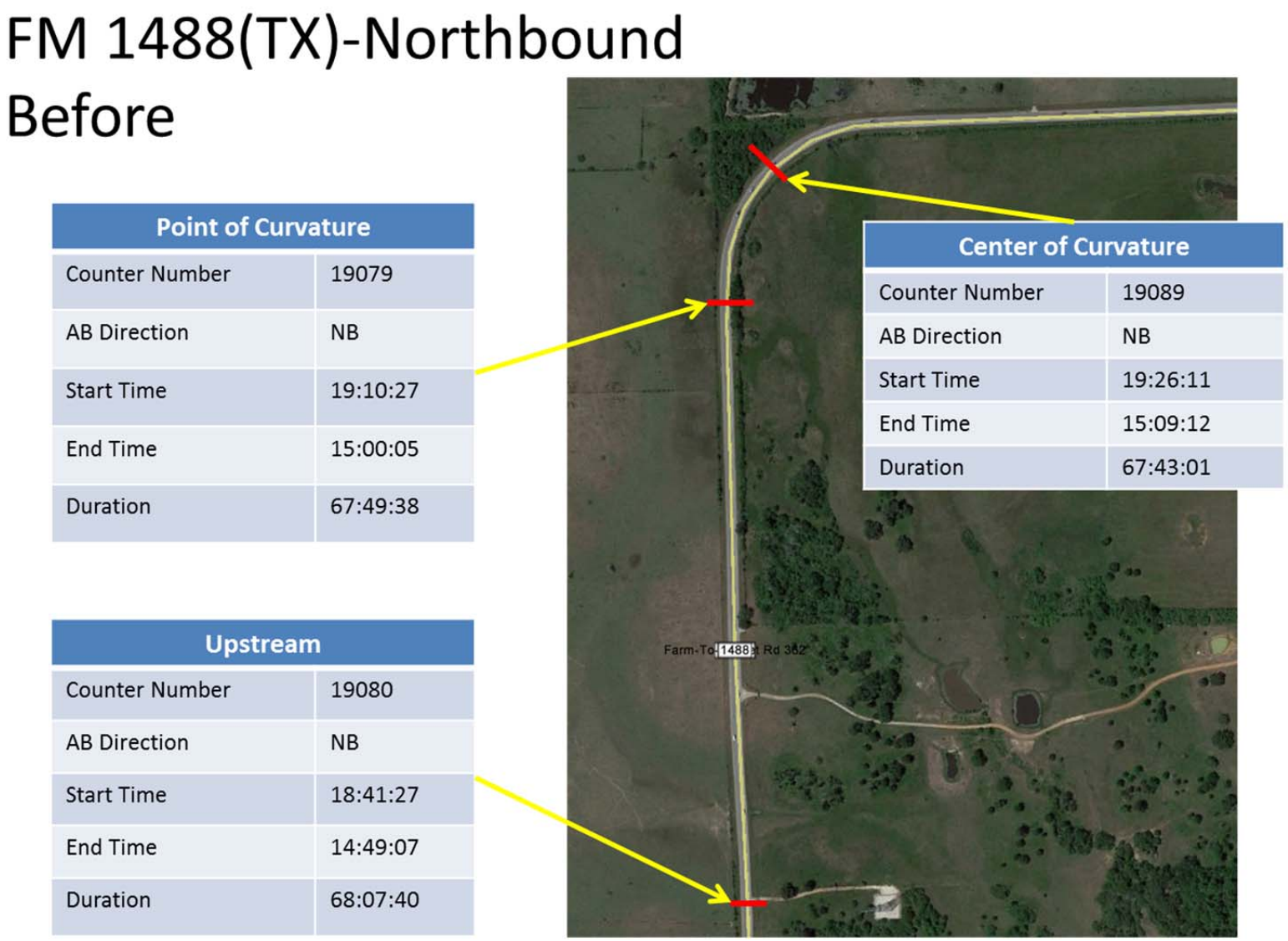


Figure 66. Map. Texas FM 1488 data collection layout.

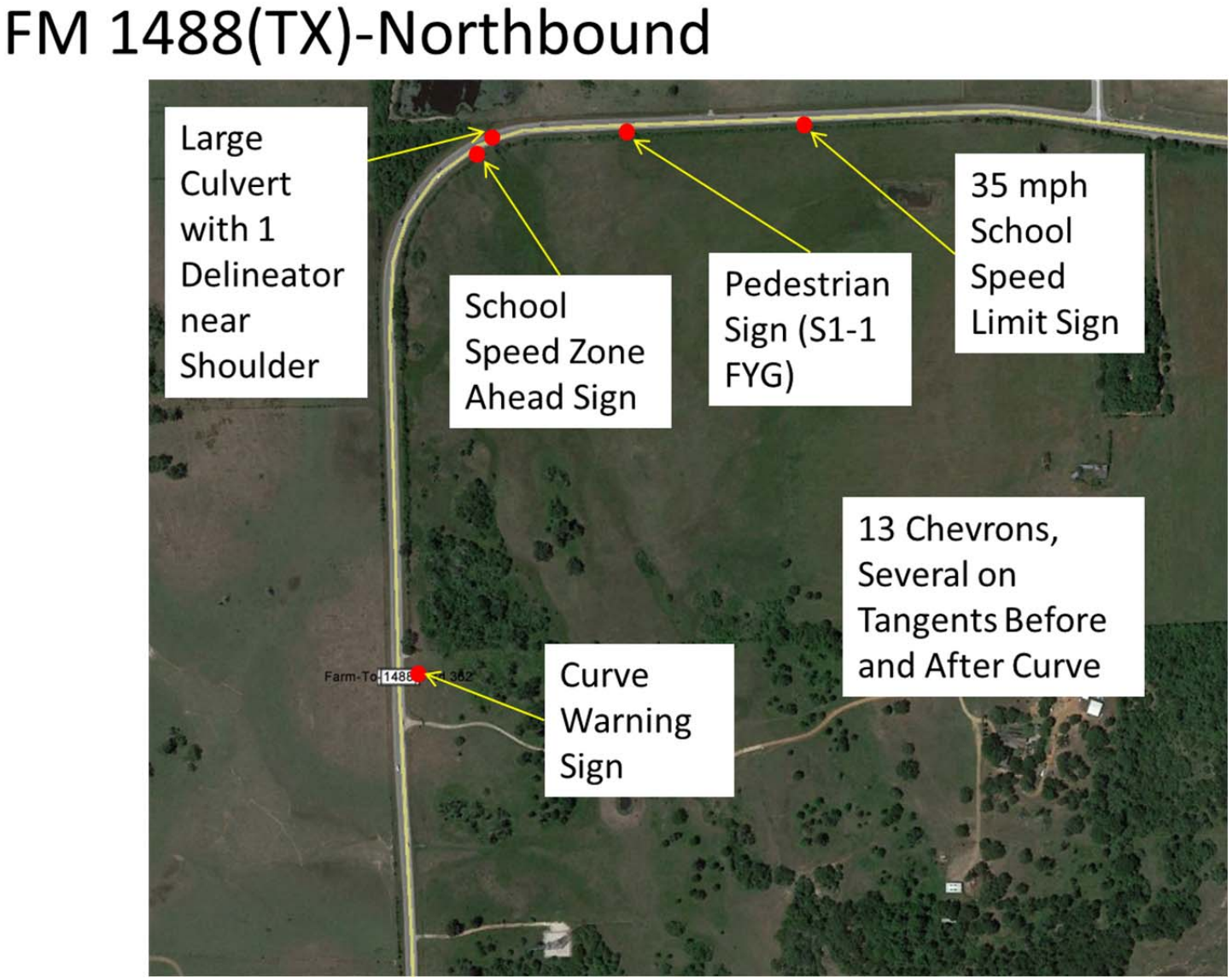


Figure 67. Map. Texas FM 1488 site layout.

Texas FM 1488

N30°09.863’ W95°56.373’	location (gps at center of curve)
2 Lanes, 11’ lanes	# lanes and width
Left	curve direction (left or right)
Asphalt 4’	shoulder type and width
55	posted speed of curve in each direction
55	tangent speed in each direction
40	advisory speed in each direction
See below	grade (average of 3 readings and list if positive or negative)
See below	super elevation
See Layout	location and type of signing before and in the curve
Asphalt, good	pavement type and condition
None	presence and location of street lighting

	Begin S-N				Center W-E				End W-E			
Grade	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	0.1	0.0	-0.1	0.0	0.1	0.2	0.3	0.2	0.0	0.1	0.1	0.07

	Begin W-E				Center S-N				End S-N			
Super Elevation	SB	Center	NB	Average	SB	Center	NB	Average	SB	Center	NB	Average
	1.2	-0.8	-2.8	-0.8	+6.9	+6.1	+8.4	7.13	-0.9	1.9	3.0	1.33

Figure 68. Chart. Texas FM 1488 site information.

APPENDIX B. SITE DATA TABLES AND FIGURES

In this appendix are the data tables and figures for each site. Each curve has multiple tables and figures representing the data collected during the before, 1 month after, 12 month after, 18 month after, and 24 month after periods. The first two tables are the speed metrics collected at the PC and CC using all of the data collected by the counters. The metrics compare the before data to after periods, with a negative change representing a reduction. The next two tables show the same speed metrics using the tracked vehicles. The fraction of vehicles exceeding the speed limit and advisory speed change shows a percentage change in the vehicles exceeding the speed limit/advisory speed between the before and after data collection periods.

The final table shows the speed reduction metrics using the tracking methodology. The metrics compare the before data to after periods, with a positive change representing a speed reduction. A positive change represents vehicles slowing down through the curve which is desired. The speed metrics are calculated for upstream to the point of curvature, upstream to the center of curve, and from the point of curvature to the center of the curve.

The figures are graphical representations of the data shown in the tables. One figure shows the vehicles mean and 85th percentile speeds at the data collection points, this is shown for graphical purposes only and should not be interpreted to indicate that speeds can be interpolated between data collection periods. The other figure displays the change in vehicles exceeding the speed limit at all three data collection points. The final figure shows the speed profile at each data collection period by plotting the mean speeds at each data collection location.

Iowa Highway 144

The SCDWS was installed at Iowa treatment site Hwy 144 in September 2012 for the EB direction. The site is about 5 miles north of Perry, IA. The speed limit for this road was 55 mph with an advisory speed of 45 mph on the curve.

Table 233 shows the results at the PC for all data collection periods. There was a significant decrease in all speed metrics for all after periods. There was also a statistically significant decrease in the mean speed upstream for all after periods which suggest that speeds overall may have decreased independent of the sign. The change in mean speed at the point of curvature was greater than the speed reduction upstream in all periods except for 24 months after with the speed reductions both were -0.9 mph. The mean speed decreased in all cases by up to 3.1 mph. The 85^{th} percentile decreased in all cases except the 24 month by up to 3 mph.

Moderate decreases were found in the percent of vehicles exceeding the advisory speed. Decreases of up to 21% occurred for vehicles exceeding the advisory speed by 5 mph or more and up to 13% for vehicles exceeding by 10 mph or more. Only slight changes were shown at 15 mph or more with a maximum decrease at 3%.

Table 244 presents the results for the CC. Similar speed decreases to the PC were shown at the CC. With the exception of the 12 month after period, all mean speed changes were lower than the mean speed changes upstream. The mean speed decreased by up to 3.0 mph. The 85^{th} percentile decreased in all cases except the 24 month after period by up to 3 mph.

Table 23. All Vehicle Results for Iowa - Hwy 144 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	1435	1408	-27	1334	-101	1401	-34	1340	-95
Vehicles Count in SDCWS Direction	717	708		656		697		1319	
Upstream Mean Speed (mph)	60.0	58.9	-1.1[A]	58.7	-1.3[A]	58.1	-1.9[A]	59.1	-0.9[A]
Mean Speed (mph)	50.7	49.2	-1.5	48.5	-2.2	47.6	-3.1	49.8	-0.9
Standard Deviation	5.2	5.8		5.1		5.8		5.8	
85th Percentile Speed (mph)	56	55	-1	54	-2	53	-3	56	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	61%	49%	-19.8%	43%	-29.9%	40%	-35.2%	52%	-14.1%
% of Vehicles 10+ Over Advisory	24%	16%	-32.9%	12%	-50.8%	11%	-53.8%	20%	-16.0%
% of Vehicles 15+ Over Advisory	4%	4%	0.0%	1%	-66.1%	1%	-71.5%	5.0%	14.4%
% of Vehicles 20+ Over Advisory	0%	1%	0.0%	0%	0.0%	0%	0.0%	0.0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	4%	4%	0.0%	1%	-66.1%	1%	-71.5%	5.0%	14.4%
% of Vehicles 10+ Over Limit	0%	1%	0.0%	0%	0.0%	0%	0.0%	0.0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0.0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0.0%	0.0%

[A]Upstream difference was statistically significant

Table 24. All Vehicle Results for Iowa - Hwy 144 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	1468	1428	-40	1370	-98	1423	-45	1355	-113
Vehicles Count in SDCWS Direction	718	713		656		703		1319	
Upstream Mean Speed (mph)	60.0	58.9	-1.1[A]	58.7	-1.3[A]	58.1	-1.9[A]	59.1	-0.9[A]
Mean Speed (mph)	48	45.9	-2.1	46.8	-1.2	45.0	-3.0	46.5	-1.5
Standard Deviation	6.2	6.3		5.6		6.1		5.9	
85th Percentile Speed (mph)	53	51	-2	52	-1	50	-3	52	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	42%	26%	-38.7%	30%	-29.0%	21%	-49.1%	27%	-34.3%
% of Vehicles 10+ Over Advisory	12%	5%	-54.3%	8%	-36.4%	3%	-71.5%	7%	-39.2%
% of Vehicles 15+ Over Advisory	1%	1%	0.0%	1%	0.0%	1%	0.0%	2%	100%[B]
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	1%	0.0%	1%	0.0%	1%	0.0%	2%	100%[B]
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

[C]8% of data had Class 14 readings that were removed

Table 255 shows the results found from the tracked vehicles at the PC. Slightly lower changes in mean speed were found but with all changes being greater than the changes in mean speed upstream. The mean speed changes ranged from -1.1 mph and -2.8mph. Similar results were found in the change in 85th percentile speed with the 24 month after showing no change and the other periods showing -1 to -2.9 mph changes. Moderate decreases occurred for the percent traveling 5 and 10 mph or more over the advisory speed limit.

Table 25. Tracked Vehicle Results for Iowa - Hwy 144 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	568	514		527		527		1075	
Upstream Mean Speed (mph)	60.3	59.7	-0.6[A]	58.8	-1.5[A]	58.9	-1.4[A]	59.3	-1.0[A]
Mean Speed (mph)	51.1	49.7	-1.4	48.6	-2.5	48.3	-2.8	50.0	-1.1
Standard Deviation	5.1	5.4		5.1		5.2		5.8	
85th Percentile Speed (mph)	56	55	-1	54	-2	53.1	-2.9	56	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	63%	54%	-14.6%	43%	-31.2%	42%	-33.6%	54%	-14.9%
% of Vehicles 10+ Over Advisory	26%	17%	-33.4%	13%	-50.5%	12%	-53.5%	20%	-20.7%
% of Vehicles 15+ Over Advisory	5%	4%	-18.1%[B]	1%	-76.0%	1%	-76.0%	5%	3.8%[B]
% of Vehicles 20+ Over Advisory	1%	1%	0.0%	0%	-100%	0%	-64.2%[B]	0%	-11.3%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	5%	4%	-18.1%[B]	1%	-76.0%	1%	-76.0%	5%	3.8%[B]
% of Vehicles 10+ Over Limit	1%	1%	0.0%	0%	-100%	0%	-64.2%[B]	0%	-11.3%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Speed decreased in all cases at the CC when tracking vehicles shown in Table 266. All changes in mean speed were significantly higher than changes in mean speed upstream. The changes in mean speed ranged from -1.7 to -3.0 mph. Decrease were also documented in the 85th percentile for all periods between -2 to -4 mph.

Table 26. Tracked Vehicle Results for Iowa - Hwy 144 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	568	514		527		527		1075	
Upstream Mean Speed (mph)	60.3	59.7	-0.6[A]	58.8	-1.5[A]	58.9	-1.4[A]	59.3	-1.0[A]
Mean Speed (mph)	48.6	46.5	-2.1	46.9	-1.7	45.5	-3.1	46.6	-2.0
Standard Deviation	5.5	5.6		5.5		5.4		5.8	
85th Percentile Speed (mph)	54	51	-3	52	-2	50	-4	52	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	44%	28%	-35.2%	30%	-32.0%	21%	-50.7%	28%	-36.3%
% of Vehicles 10+ Over Advisory	13%	6%	-50.7%	8%	-40.3%	3%	-78.1%	8%	-40.8%
% of Vehicles 15+ Over Advisory	2%	1%	-13.9%[B]	1%	-51.9%[B]	1%	-51.9%[B]	2%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	2%	1%	-13.9%	1%	-51.9%	1%	-51.9%	2%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance
[C]8% of data had Class 14 readings that were removed

The speed reductions calculated from tracking vehicles through the curve is found in Table 277. The highest change in speed reductions were found between the upstream and PC with the exception of the 24 month where there was no change. This showed more vehicles were slowing down while approaching the curve. In the 24 month period, a change in speed reduction was occurring but primarily between the PC and CC.

Table 27. Speed Reduction for Iowa - Hwy 144.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	9.3	9.9	0.6	10.2	0.9	10.6	1.3	9.3	0.0
Mean Speed Reduction Upstream to CC (mph)	11.7	13.2	1.5	11.9	0.2[B]	13.4	1.7	12.7	1.0
Mean Speed Reduction PC to CC (mph)	2.5	3.2	0.7	1.7	-0.8	2.8	0.0	3.4	0.9
85th Percentile Speed Reduction Upstream to PC (mph)	14	15	1	15	1	15	1	14	0
85th Percentile Speed Reduction Upstream to CC (mph)	17	19	2	17	0	18	1	18	1
85th Percentile Speed Reduction PC to CC (mph)	5	5	0	4	-1	5	0	6	1

[B]Not statistically significant at 95-percent level of significance
Note: Positive change represents vehicles slowing down

Iowa (Hwy 144)

Speed Limit: 55 mph
Curve Advisory Speed: 45 mph
Installed: September 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

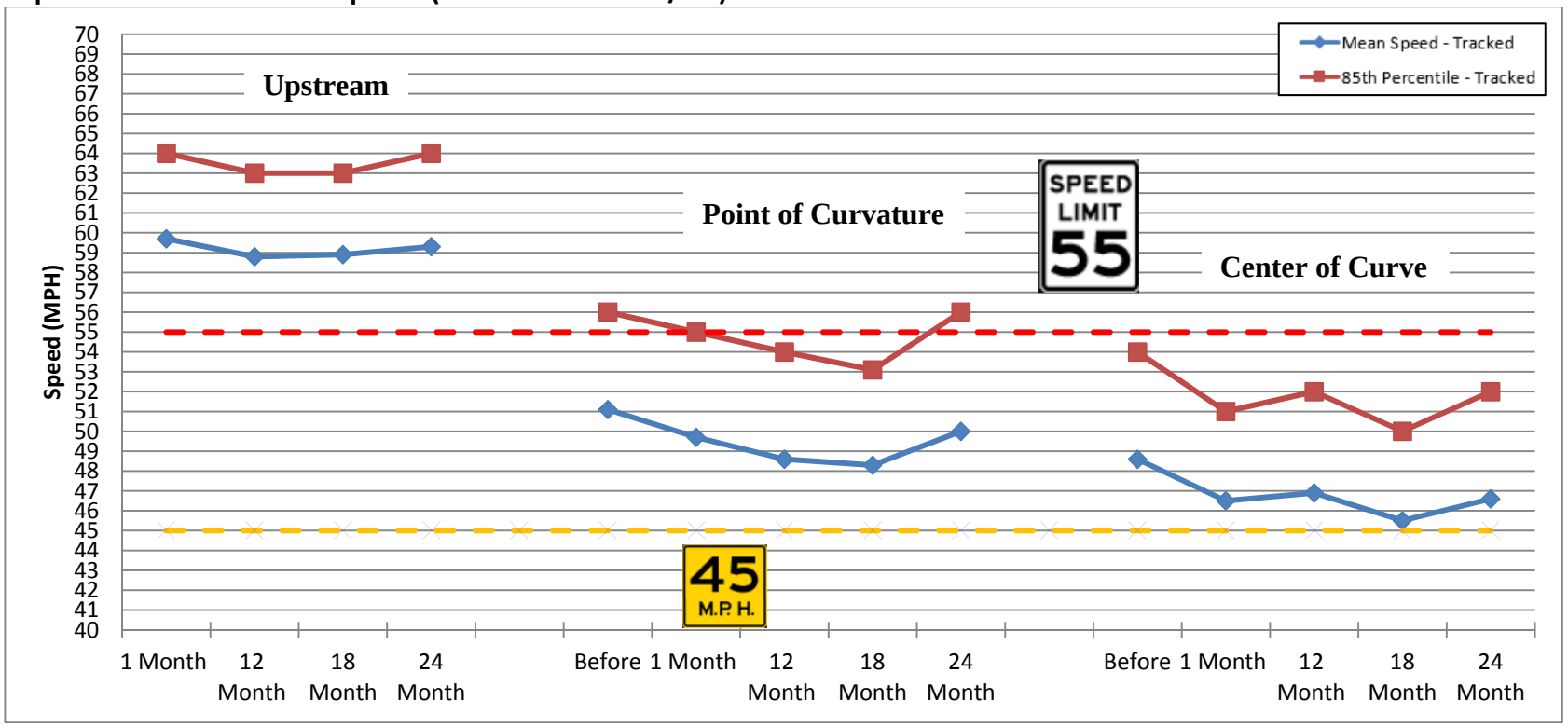


Figure 69. Graph. Impact on tracked vehicle speed - Iowa Hwy 144.

Iowa (Hwy 144)

Speed Profile All Vehicles

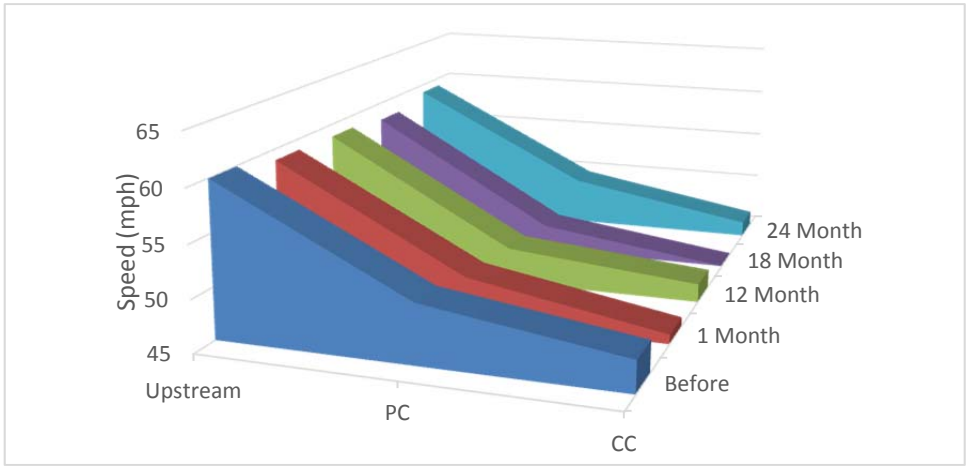


Figure 70. Graph. Speed profiles of all vehicles – Iowa Hwy 144.

Speed Profile Tracked Vehicles

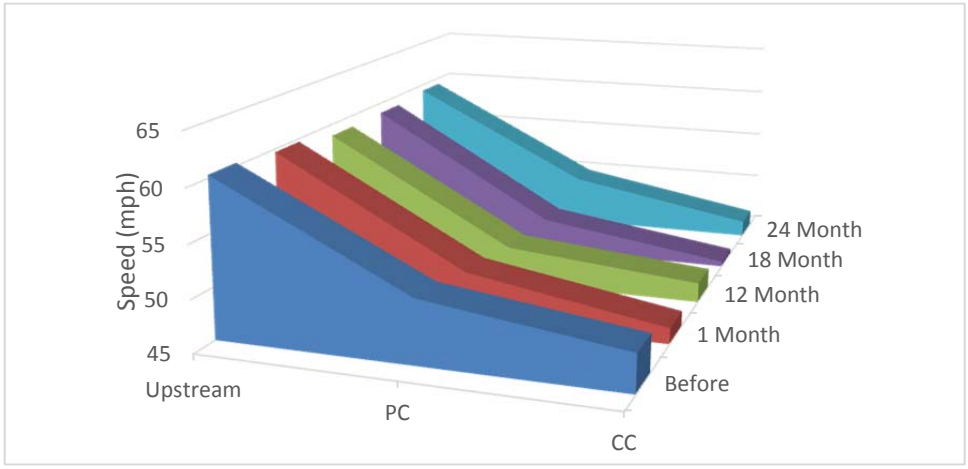


Figure 71. Graph. Speed profiles of tracked vehicles – Iowa Hwy 144.

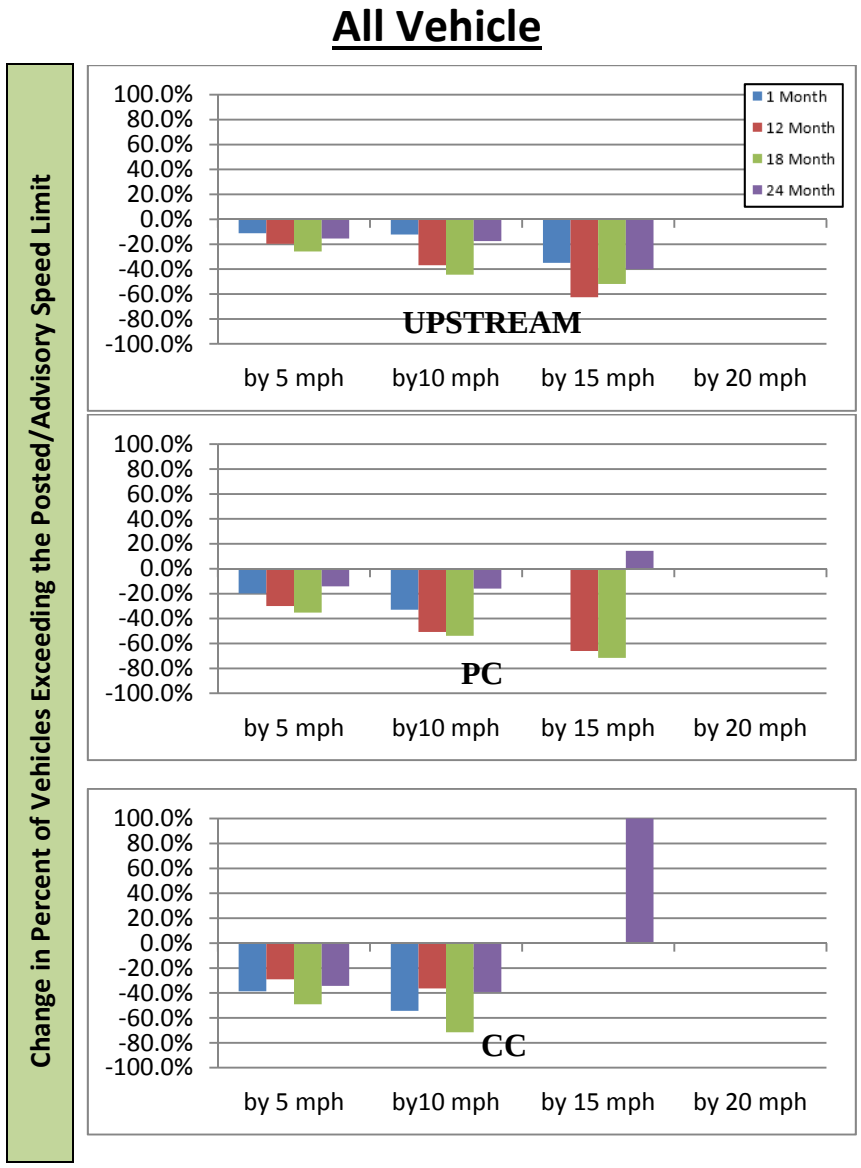


Figure 72. Graphs. Change in percentile (compared to before) of all vehicle speed - Iowa Hwy 144.

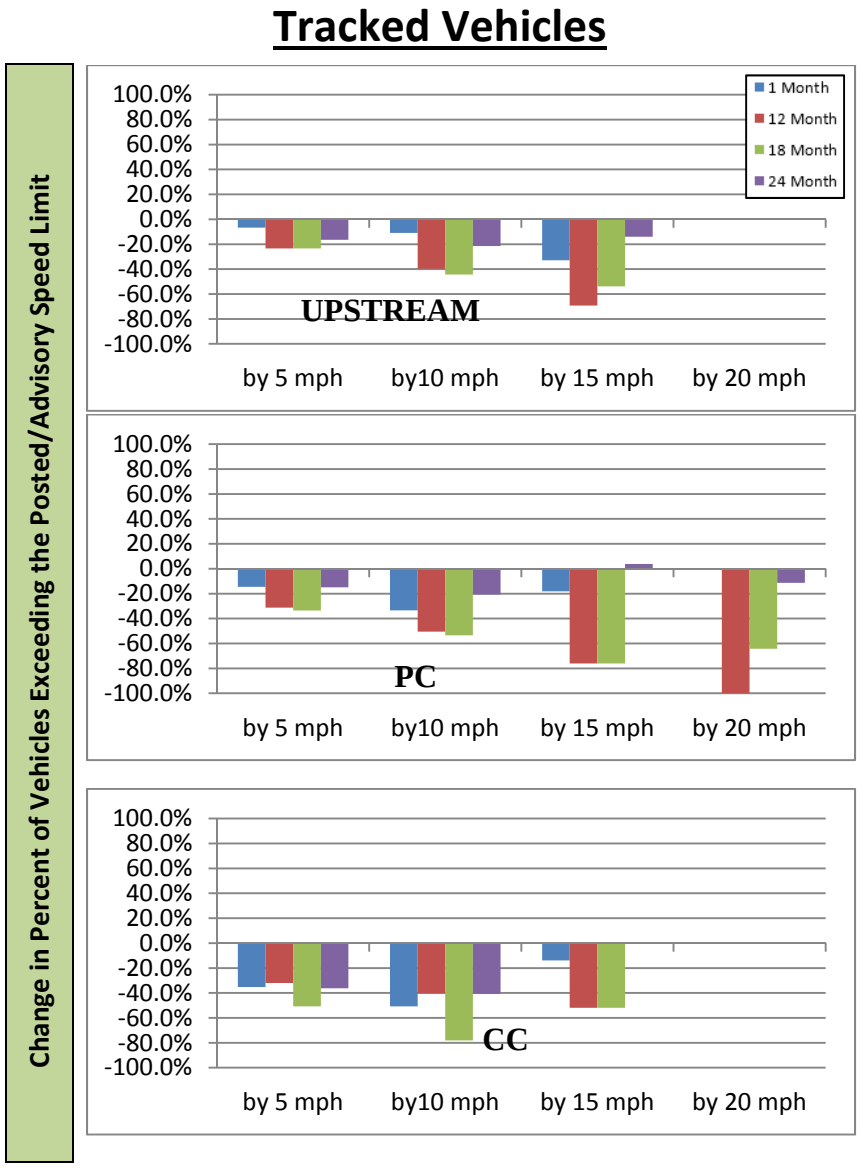


Figure 73. Graphs. Change in percentile (compared to before) of tracked vehicle speed – Iowa Hwy 144.

Missouri Highway 221

The SCDWS was installed on Hwy 221 in Missouri in June 2012. The system was installed in the NB direction of travel about 6 miles southwest of Farmington, MO. The speed limit for the road was 55 mph with a 40 mph advisory speed on the curve.

The upstream speeds in all after periods were 0.6 to 0.8 mph higher than the before data collection. With the increase in speed on the roadway, Table 28 shows decreasing speeds at the PC. The change in mean speed was between -1.0 to -1.5 mph, and the 85th percentile speeds all decreased by -1 mph.

There were also consistent decreases in the percent of vehicles exceeding the advisory speed. Decreases were seen by up to 6 percent for vehicles exceeding by 5 mph or more, up to 12 percent for 10 mph or more over, up to 8 percent for 15 mph over and up to 2 percent for 20 mph or more over.

Table 29 shows the results at the CC. Little change in speed occurred at the CC with mean speed changes between -0.4 to 0.3 mph. Only the 24 month after period had change in the 85th percentile with a decrease of -1 mph. Overall, the speed were similar for all data collection periods. Primarily changes in speed occurred at the PC which shows vehicles may be identifying the curve earlier and slowing down before entering the curve and maintaining a similar speed through the curve.

Table 28. All Vehicle Results for Missouri - Hwy 221 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	5277	5158	-119	5076	-201	4726	-551	4913	-364
Vehicles Count in SDCWS Direction	2566	2523		2484		2291		4759	
Upstream Mean Speed (mph)	52.2	52.8	0.6[A]	53	0.8[A]	53.0	0.8[A]	52.9	0.7[A]
Mean Speed (mph)	51.7	50.2	-1.5	50.7	-1.0	50.5	-1.2	50.3	-1.4
Standard Deviation	4.7	4.8		4.7		4.7		4.7	
85th Percentile Speed (mph)	56	55	-1	55	-1	55	-1	55	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	94%	88%	-6.4%	91%	-3.3%	92%	-2.4%	91%	-3.5%
% of Vehicles 10+ Over Advisory	70%	58%	-17.5%	61%	-13.2%	60%	-14.4%	59%	-15.8%
% of Vehicles 15+ Over Advisory	25%	17%	-31.9%	20%	-20.5%	18%	-29.1%	17%	-30.6%
% of Vehicles 20+ Over Advisory	4%	2%	-51.6%	3%	-20.3%[B]	3%	-38.1%	2%	-47.2%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	4%	2%	-51.6%	3%	-20.3%[B]	3%	-38.1%	2%	-47.2%
% of Vehicles 10+ Over Limit	1%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 29. All Vehicle Results for Missouri - Hwy 221 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	5274	5169	-105	5040	-234	4728	-546	4931	-343
Vehicles Count in SDCWS Direction	2559	2522		2460		2285		4731	
Upstream Mean Speed (mph)	52.2	52.8	0.6[A]	53.0	0.8[A]	53.0	0.8[A]	52.9	0.7[A]
Mean Speed (mph)	48.3	48.6	0.3	48.5	0.2	48.4	0.1[B]	47.9	-0.4
Standard Deviation	4.4	4.6		4.5		4.5		4.4	
85th Percentile Speed (mph)	53	53	0	53	0	53	0	52	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	82%	82%	0.0%	81%	-0.8%[B]	83%	1.5%[B]	80%	-2.2%
% of Vehicles 10+ Over Advisory	38%	42%	10.3%	40%	5.8%[B]	38%	0.0%	35%	-9.6%
% of Vehicles 15+ Over Advisory	7%	9%	17.6%	9%	23.4%	8%	15.6%[B]	6%	-16.1%
% of Vehicles 20+ Over Advisory	1%	1%	0.0%	1%	0.0%	1%	0.0%	0%	-63.8%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	1%	0.0%	1%	0.0%	1%	0.0%	0%	-63.8%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

The tracked data at the PC in Table 3030 and the CC in Table 3131 show similar results as the speed metrics from all vehicles. Upstream speeds were slightly higher or the same as before in all after periods. The PC saw consistent reductions in speeds in all after periods with mean speed changes between -1.0 to -1.9 mph. The CC had similar mean speeds as the before period and increases in the 85th percentile of 1 mph for the 1 month, 12 month and 18 month. In the 24 month, the mean speed decreased by -1 mph and also had the same decrease in 85th percentile speed.

Table 30. Tracked Vehicle Results for Missouri – Hwy 221 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	1161	1176		1178		1100		3002	
Upstream Mean Speed (mph)	53.1	53.7	0.6[A]	53.9	0.8[A]	53.8	0.7[A]	53.1	0.0
Mean Speed (mph)	52.5	51.0	-1.5	51.5	-1.0	51.1	-1.4	50.6	-1.9
Standard Deviation	4.9	4.9		4.8		4.8		4.7	
85th Percentile Speed (mph)	57	56	-1	56	-1	56	-1	55	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	95%	91%	-5.0%	92%	-3.3%	93%	-2.4%	92%	-3.8%
% of Vehicles 10+ Over Advisory	75%	65%	-13.2%	67%	-10.6%	65%	-13.1%	61%	-18.6%
% of Vehicles 15+ Over Advisory	32%	22%	-29.9%	26%	-17.6%	23%	-28.5%	19%	-40.8%
% of Vehicles 20+ Over Advisory	6%	3%	-51.4%	5%	-21.8%[B]	4%	-33.5%	3%	-59.3%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	6%	3%	-51.4%	5%	-21.8%[B]	4%	-33.5%	3%	-59.3%
% of Vehicles 10+ Over Limit	1%	1%	0.0%	1%	0.0%	1%	0.0%	0%	-56.9%[B]
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 31. Tracked Vehicle Results for Missouri – Hwy 221 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	1161	1176		1178		1100		3002	
Upstream Mean Speed (mph)	53.1	53.7	0.6[A]	53.9	0.8[A]	53.8	0.7[A]	53.1	0.0
Mean Speed (mph)	49.1	49.2	0.1[B]	49.3	0.2[B]	49.0	-0.1[B]	48.1	-1.0
Standard Deviation	4.6	4.7		4.7		4.6		4.4	
85th Percentile Speed (mph)	53	54	1	54	1	54	1	52	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	86%	85%	-0.6%[B]	85%	-0.5%[B]	85%	-0.7%[B]	82%	-4.6%
% of Vehicles 10+ Over Advisory	47%	49%	4.0%[B]	47%	1.3%[B]	44%	-4.8%[B]	36%	-22.8%
% of Vehicles 15+ Over Advisory	10%	11%	8.7%[B]	12%	20.1%[B]	12%	14.4%[B]	7%	-31.7%
% of Vehicles 20+ Over Advisory	1%	2%	17.4%[B]	2%	26.8%[B]	2%	31.9%[B]	0%	-68.8%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	2%	17.4%[B]	2%	26.8%[B]	2%	31.9%[B]	0%	-68.8%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

The speed reduction from tracked vehicles show similar findings as the reductions in mean speeds in Table 32. The change in mean speed reduction from the upstream to point of curvature were between 1.8 and 2.1 mph for all periods meaning vehicles were slowing down more while approaching the curve. The change in mean speed reduction from the point of curvature to the center of curve saw decreases between -0.9 to -1.7 mph. This shows that vehicles were not slowing down through the curve as much as in the before period. Both of these results show the potential effectiveness of the SCDWS with vehicles slowing down prior to entering the curve and selecting an appropriate speed to negotiate the curve without the need to further reduce their speed throughout the curve.

Table 32. Speed reduction for Missouri - Hwy 221.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	0.6	2.7	2.1	2.4	1.8	2.6	2.0	2.5	1.9
Mean Speed Reduction Upstream to CC (mph)	4.0	4.5	0.5	4.6	0.6	4.8	0.8	5	1.0
Mean Speed Reduction PC to CC (mph)	3.4	1.7	-1.7	2.3	-1.1	2.1	-1.3	2.5	-0.9
85th Percentile Speed Reduction Upstream to PC (mph)	3	6	3	5	2	6	3.0	5	2.0
85th Percentile Speed Reduction Upstream to CC (mph)	7	8	1	8	1	8	1.0	8	1.0
85th Percentile Speed Reduction PC to CC (mph)	5	4	-1	4	-1	4	-1.0	4	-1.0

Note: Positive change represents vehicles slowing down

Figure 744 through Figure 788 graphically show the consistent decrease in speed through all periods. In all figure the point of curvature shows the highest change in speed compared to the other data collection locations.

Missouri (Hwy 221)

Speed Limit: 55 mph
Curve Advisory Speed: 40 mph
Installed: July 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

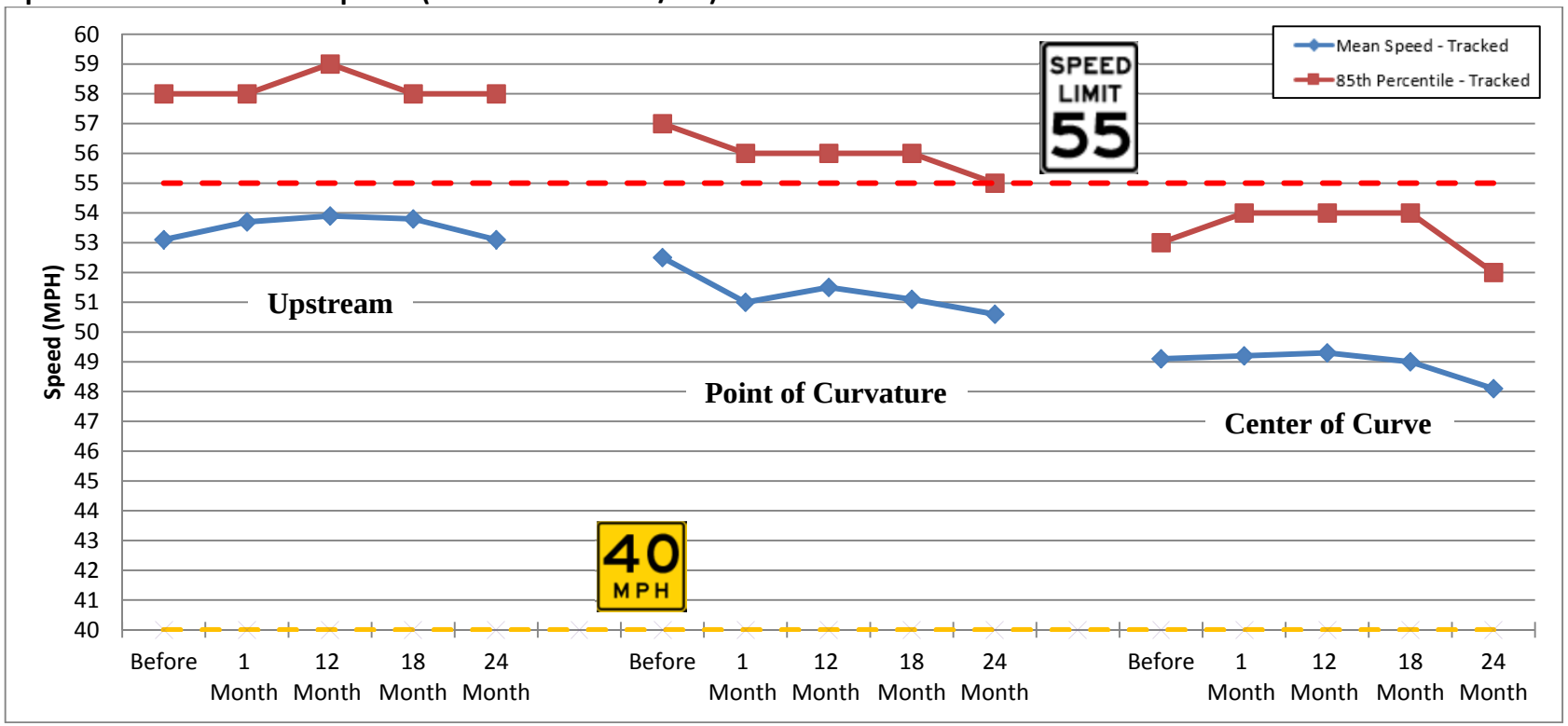


Figure 74. Graph. Impact on tracked vehicle speed - Missouri Hwy 221.

Missouri (Hwy 221)

Speed Profile All Vehicles

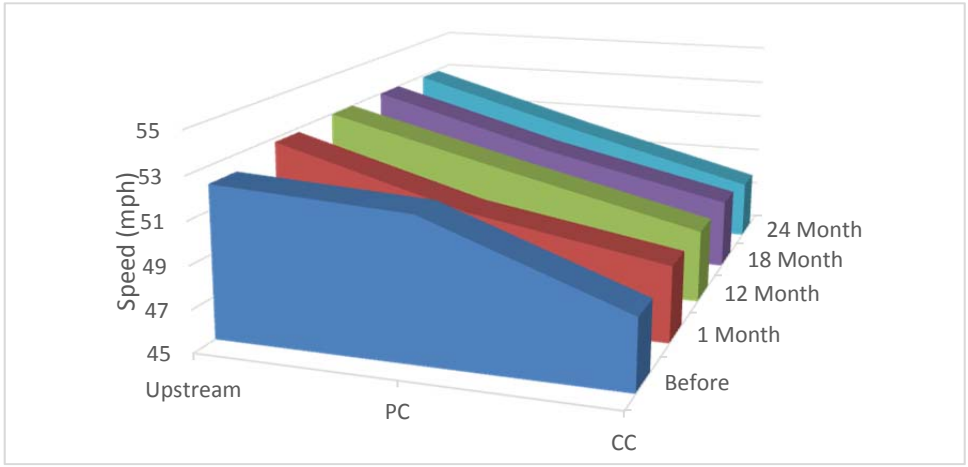


Figure 75. Graph. Speed profiles of all vehicles – Missouri Hwy 221.

Speed Profile Tracked Vehicles

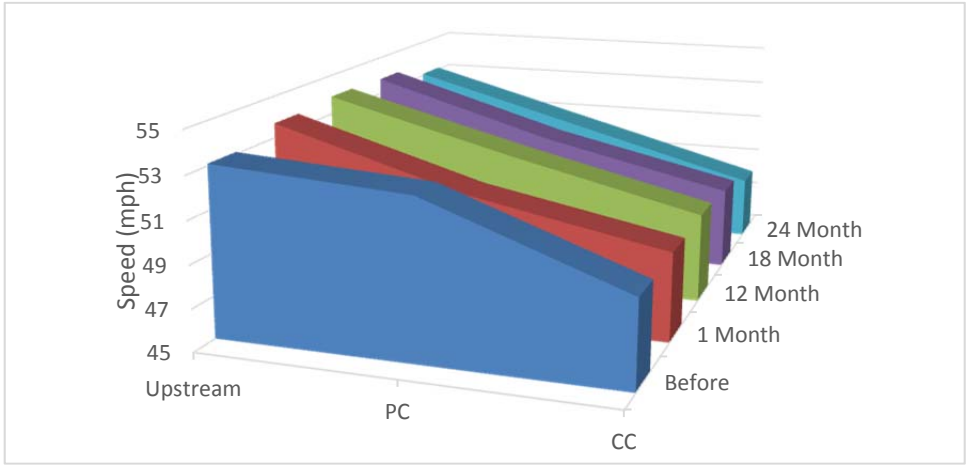


Figure 76. Graph Speed profiles of tracked vehicles – Missouri Hwy 221.

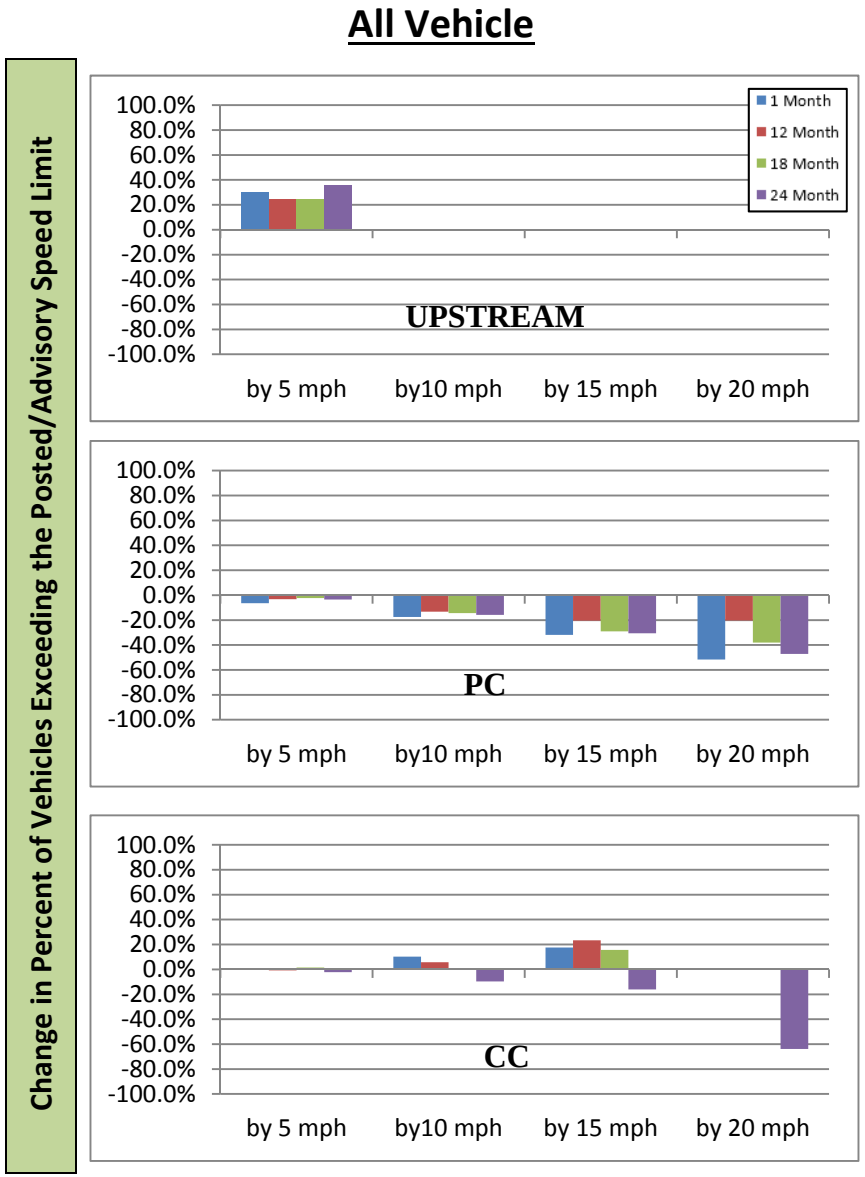


Figure 77. Graphs. Change in percentile (compared to before) of all vehicle speed - Missouri Hwy 221.

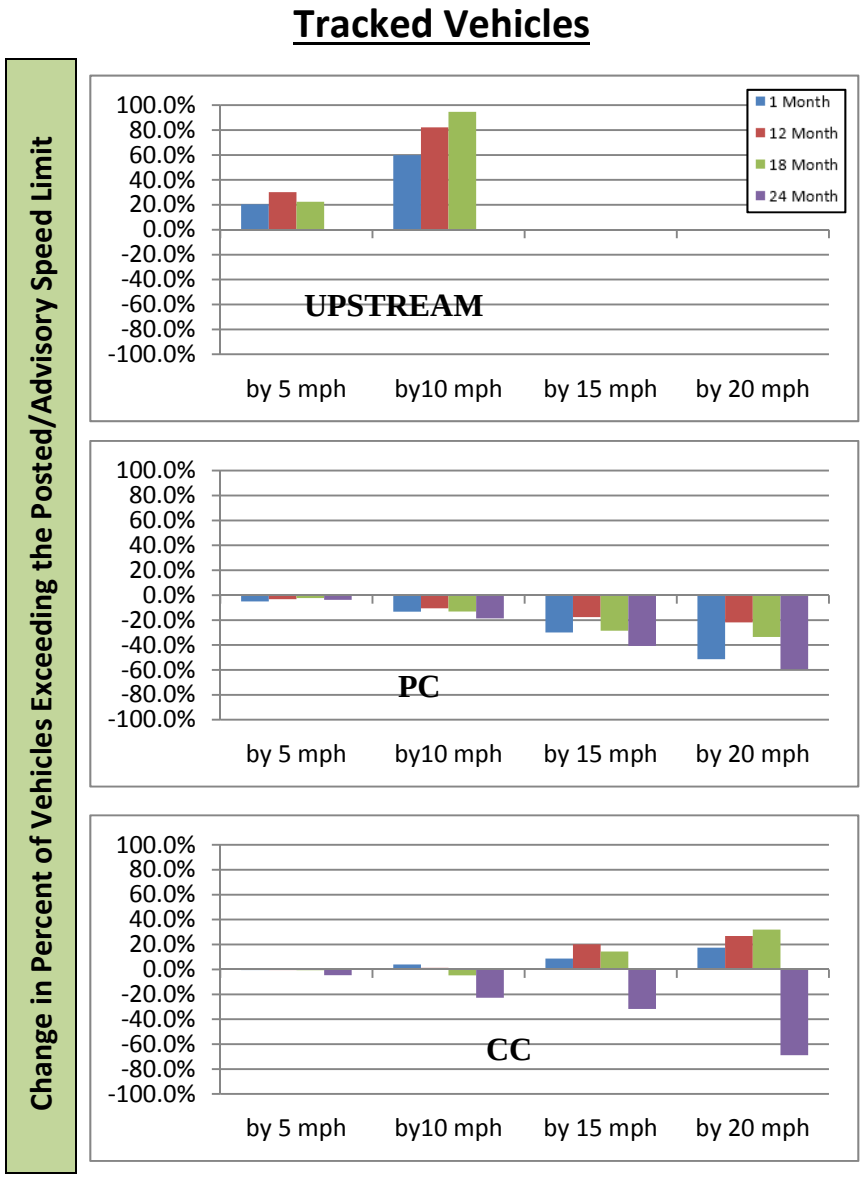


Figure 78. Graphs. Change in percentile (compared to before) of tracked vehicle speed - Missouri Hwy 221.

Washington SR 7

The SDCWS was installed for the SB direction on SR 7 in Washington. The site was around 30 mile south of Puyallup, WA and had a 50 mph speed limit with a 20 mph advisory speed. The installation of the sign occurred in August 2012.

Table 33 shows the results at the PC. No data was collected at this site during the 18 month after period due to weather and signs not functioning. Upstream speeds did not significantly change during the 12 month and 24 month data collection but during the 1 month data collection there was a decrease in the mean speed of -2.0 mph. The mean speed at the point of curvature decreased between -1.2 to -2.8 mph. The highest decrease in mean speed occurred during the 1 month after data collection and may partly be due to the decrease in speed overall upstream. The decrease in mean speed was larger at the PC showing the system was still effective at slowing vehicles before entering the curve. Decreases also occurred in the 85th percentile speed between -1 to -2 mph.

Consistent decreases in the percent of vehicles traveling 5, 10, 15, or 20 mph over the advisory speed of 20 mph occurred. Decreases were seen by up to 7 percent for vehicles exceeding by 5 mph or more, up to 24 percent for 10 mph or more over, up to 19 percent for 15 mph over and up to 7 percent for 20 mph or more over.

Table 33. Results for Washington - SR 7 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	1408	1413	5	1710	302	NC		3685	2277
Upstream Mean Speed (mph)	763	766		926		NC		3388	
Mean Speed (mph)	42.5	40.5	-2.0[A]	42.1	-0.4	NC		42.6	0.1
Standard Deviation	33.1	30.3	-2.8	31.4	-1.7	NC		31.9	-1.2
85th Percentile Speed (mph)	4.7	4.6		4.3		NC		4.3	
Vehicles Tracked	37	35	-2	36	-1	NC		36	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	96%	89%	-7.3%	94%	-2.1%	NC		95%	-0.8%[B]
% of Vehicles 10+ Over Advisory	80%	56%	-29.8%	68%	-15.2%	NC		74%	-7.7%
% of Vehicles 15+ Over Advisory	37%	18%	-51.1%	23%	-38.1%	NC		26%	-29.7%
% of Vehicles 20+ Over Advisory	9%	2%	-77.3%	4%	-57.6%	NC		3%	-60.1%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Modest speed changes were noted for the CC in Table 344. At one month after the change in mean speed upstream of -2.0 mph was greater than the change at the center of curve at -1.4 mph. The other time periods had only slight reductions in the mean speed of -0.6 and -0.7 mph. The 85th percentile speed decreased by 1 mph during all time periods. Decreases in percent of vehicles traveling 5 and 10 mph over the advisory speed were noted with up to a -42.9 percent change. The data collected during the 12 month after data collection had 25% of the vehicles identified as unknown and removed from the speed metrics.

Table 34. Results for Washington - SR 7 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	1420	1444	24	1965	545	NC		3771	2351
Vehicles Count in SDCWS Direction	750	770		867		NC		3289	
Upstream Mean Speed (mph)	42.5	40.5	-2.0[A]	42.1	-0.4	NC		42.6	0.1
Mean Speed (mph)	27.2	25.8	-1.4	26.5	-0.7	NC		26.6	-0.6
Standard Deviation	2.9	3.3		2.9		NC		2.8	
85th Percentile Speed (mph)	30	29	-1	29	-1	NC		29	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	84%	68%	-18.4%	78%	-7.6%	NC		79%	-5.5%
% of Vehicles 10+ Over Advisory	20%	11%	-42.9%	12%	-38.9%	NC		12%	-37.7%
% of Vehicles 15+ Over Advisory	1%	1%	0.0%	1%	0.0%	NC		1%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%

[A]Upstream difference was statistically significant
[C]25% of data was unknown and removed

The tracked vehicles at the PC in Table 355 showed slightly different results than the all vehicle metrics. The mean speed change at the 1 month after collection had a lower change of -1.8 mph with the change in mean speed at the PC being higher at -3.0 mph. The upstream mean speed also changed during the 24 month after data collection period with a statistically significant increase of 0.9 mph..

Table 35. Tracked Vehicle Results for Washington - SR 7 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	472	477		466		NC		1415	
Upstream Mean Speed (mph)	43.2	41.4	-1.8[A]	43.0	-0.2	NC		44.1	0.9[A]
Mean Speed (mph)	33.6	30.6	-3.0	32.2	-1.4	NC		32.7	-0.9
Standard Deviation	4.5	4.3		4.3		NC		4.1	
85th Percentile Speed (mph)	38	35	-3	37	-1	NC		37	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	98%	92%	-6.4%	96%	-2.2%	NC		97%	-0.9%[B]
% of Vehicles 10+ Over Advisory	85%	58%	-31.3%	74%	-12.7%	NC		80%	-5.6%
% of Vehicles 15+ Over Advisory	39%	18%	-52.4%	28%	-26.9%	NC		32%	-16.3%
% of Vehicles 20+ Over Advisory	10%	2%	-78.0%	5%	-48.2%	NC		5%	-48.8%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance

Table 366 shows the results of the tracked vehicles at the CC. Similar speed results were found with the tracked vehicles as with all vehicles. The change in mean speed upstream was greater than the change in mean speed at the PC during the 1 month after data collection. The 12 month and 24 month after periods showed only slight reductions in the mean speed of -0.6 and -0.5 mph respectively.

Table 36. Tracked Vehicle Results for Washington - SR 7 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	472	477		466		NC		1415	
Upstream Mean Speed (mph)	43.2	41.4	-1.8[A]	43	-0.2	NC		44.1	0.9[A]
Mean Speed (mph)	27.4	26.0	-1.4	26.8	-0.6	NC		26.9	-0.5
Standard Deviation	2.7	3.0		2.9		NC		2.7	
85th Percentile Speed (mph)	30	29	-1	29	-1	NC		30	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	87%	69%	-20.3%	79%	-9.3%	NC		83%	-4.4%
% of Vehicles 10+ Over Advisory	22%	11%	-50.5%	15%	-32.8%	NC		15%	-30.7%
% of Vehicles 15+ Over Advisory	0%	0%	0.0%	1%	0.0%	NC		1%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	NC		0%	0.0%

[A]Upstream difference was statistically significant

[C]25% of data in direction 1 was class 14 and removed.

Table 377 displays the speed reductions for SR 7 using the tracked vehicles. The speed reductions occurred primarily between the upstream and point of curvature with changes in speed of 1.1 to 1.6 mph. This showed that vehicles were slowing down before entering the curve. The change in speed reduction from the point of curvature to the center of curve decreased between -0.4 and -1.5 mph, showing that vehicles were not slowing down as much through the curve as before.

Table 37. Speed reduction for Washington - SR 7.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	9.7	10.8	1.1	10.8	1.1	NC		11.3	1.6
Mean Speed Reduction Upstream to CC (mph)	15.9	15.5	-0.4[B]	16.2	0.3[B]	NC		17.1	1.2
Mean Speed Reduction PC to CC (mph)	6.2	4.7	-1.5	5.4	-0.8	NC		5.8	-0.4
85th Percentile Speed Reduction Upstream to PC (mph)	15	16	1	16	1	NC		16	1.0
85th Percentile Speed Reduction Upstream to CC (mph)	21	21	0	21	0	NC		22	1.0
85th Percentile Speed Reduction PC to CC (mph)	9	7	-2	8	-1	NC		9	0.0

[B]Not statistically significant at 95-percent level of significance

Note: Positive change represents vehicles slowing down

Figure 799 shows the mean and 85th percentile speeds of tracked vehicles throughout the different time periods. Reductions in the mean and 85th percentile speed can primarily be seen at the point of curvature. The speed profiles in Figure 8080 and Figure 8181 show the means speeds at each of the data collection points for each time period for all vehicles and tracked

vehicles. Figure 8282 and Figure 8383 compare the percent change in vehicles traveling over the advisory speed.

Washington (SR 7)

Speed Limit: 50 mph
Curve Advisory Speed: 20 mph
Installed: August 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

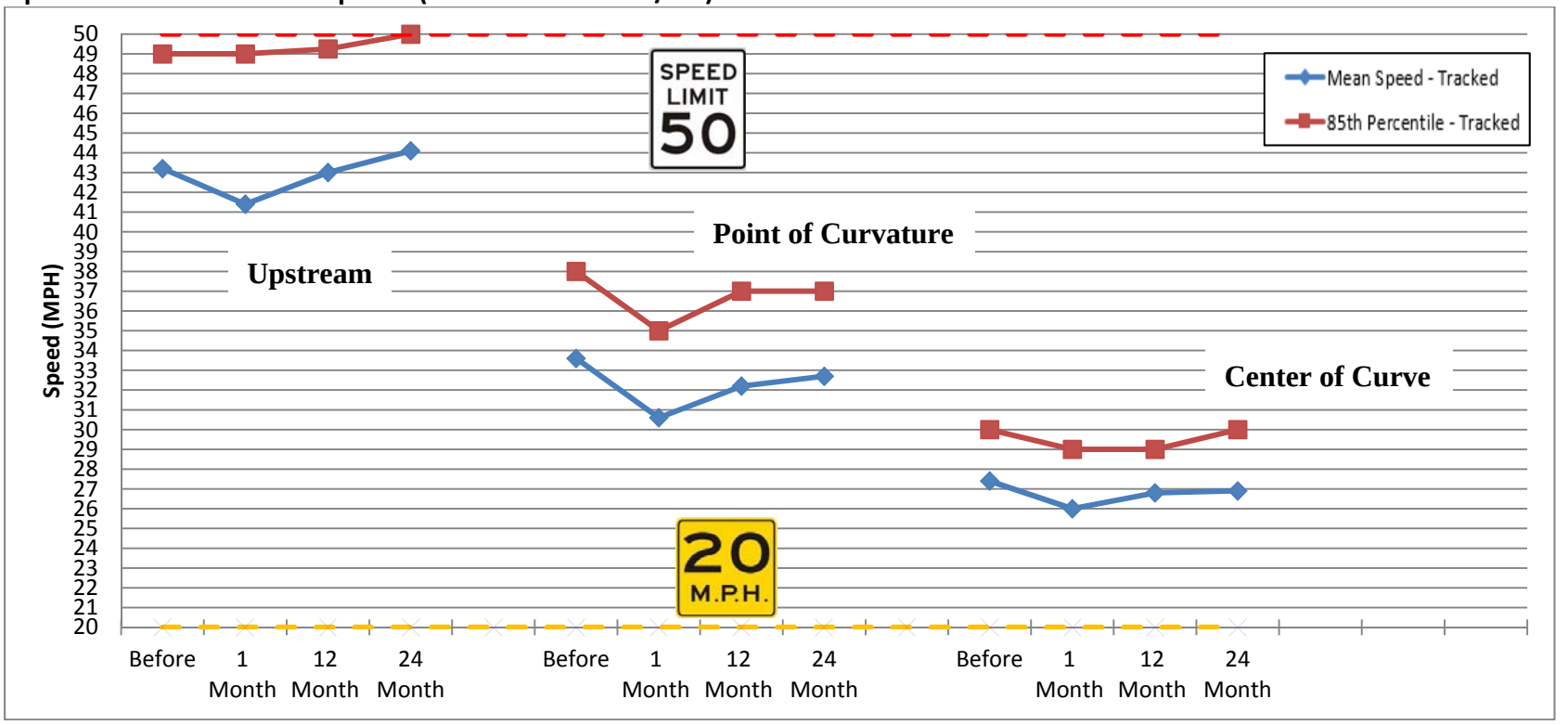


Figure 79. Graph. Impact on tracked vehicle speed - Washington SR 7.

Washington (SR 7)

Speed Profile
All Vehicles

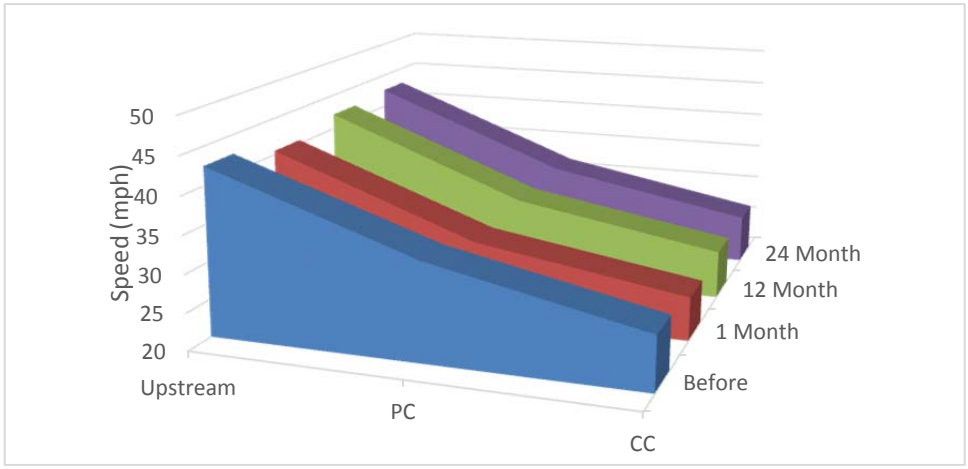


Figure 80. Graph . Speed profiles of all vehicles – Washington SR 7.

Speed Profile
Tracked Vehicles

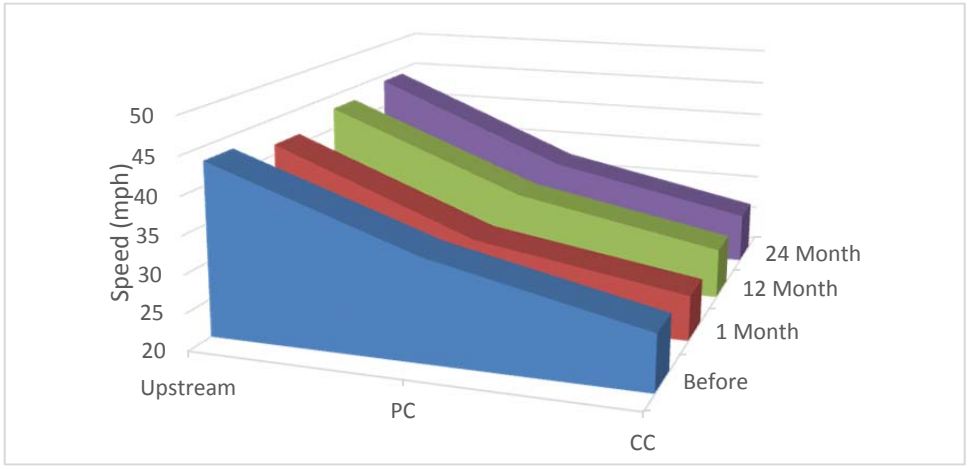


Figure 81. Graph . Speed profiles of tracked vehicles – Washington SR 7.

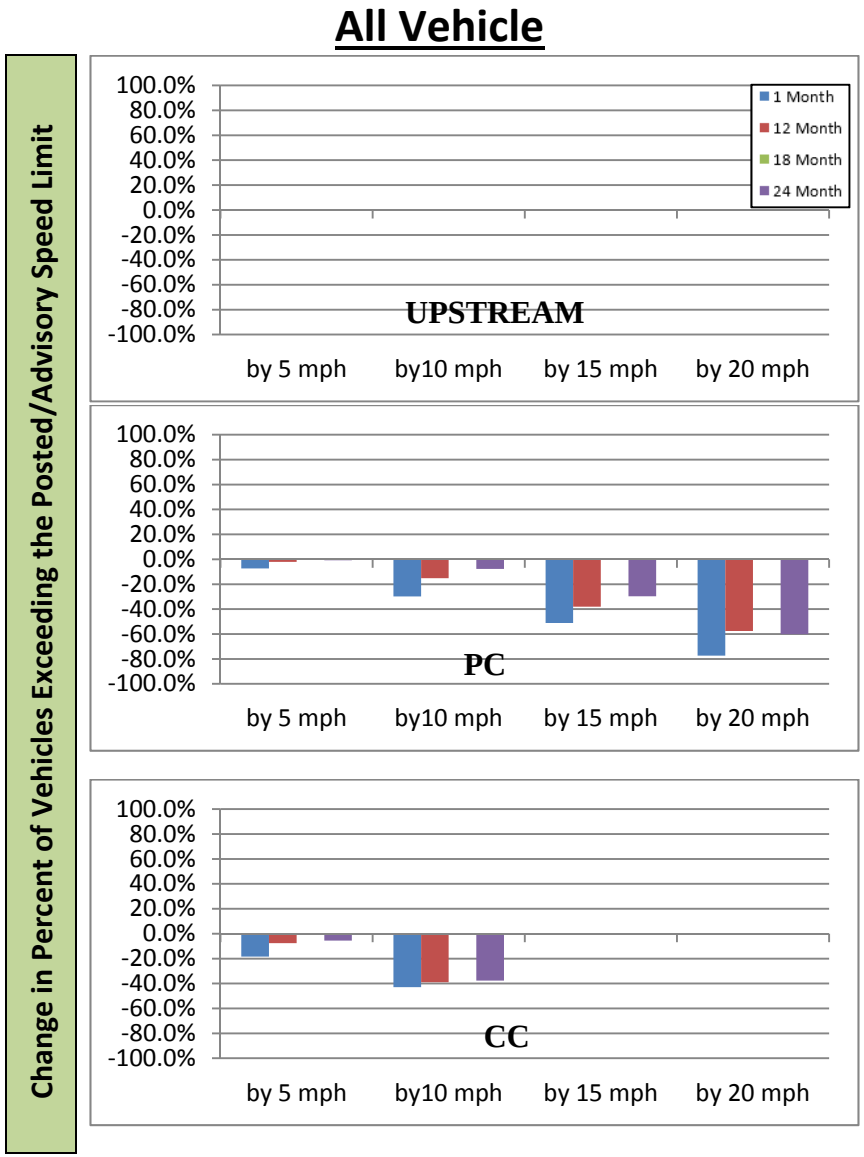


Figure 82. Graphs. Change in percentile (compared to before) of all vehicle speed - Washington SR 7.

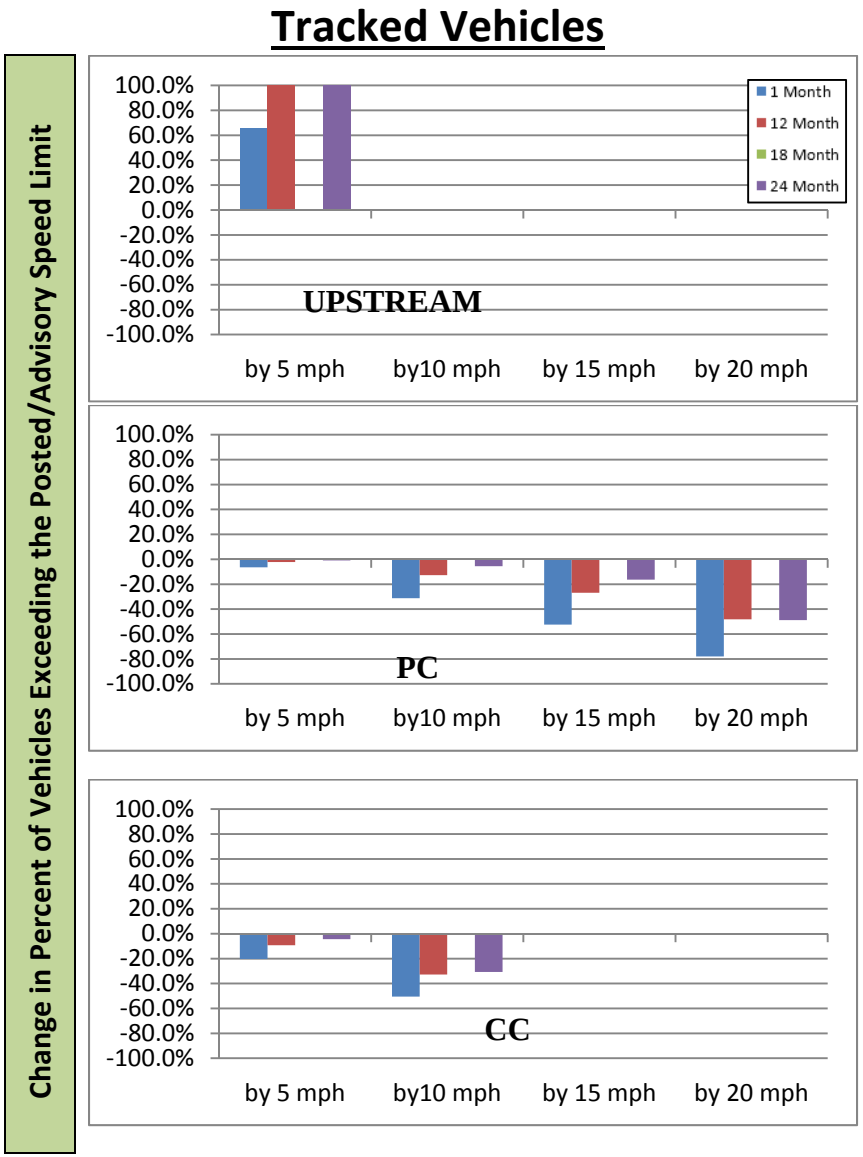


Figure 83. Graphs. Change in percentile (compared to before) of tracked vehicle speed - Washington SR 7.

Washington SR 9

SR 9 in Washington was selected for a SDCWS installed in August 2012. The site has a posted speed limit of 55 mph and an advisory speed of 40 mph, and is located about 5 miles east of Mt Vernon, Washington. The system was placed for the SB direction of traffic.

Significant increases in the mean speed occurred in all of the after periods between 0.7 to 1.9 mph. This shows that overall speeds were increasing on the roadway. Table 388 shows there were decreases in the mean speed between -0.4 and -1.5 mph. With the exception of the 18 month after period, the 85th percentile speed decreased by -1 mph. Slight reductions of up to 7% were shown in the percent of vehicles exceeding 5 mph or more.

Table 38. Results for Washington - SR 9 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	5533	6212	679	5889	356	5219	-314	6068	535
Vehicles Count in SDCWS Direction	2702	3062		2842		2569		5703	
Upstream Mean Speed (mph)	46.9	48.7	1.8[A]	47.6	0.7[A]	48.5	1.6[A]	48.8	1.9[A]
Mean Speed (mph)	41.0	39.6	-1.4	39.5	-1.5	40.6	-0.4	40.3	-0.7
Standard Deviation	5.0	5.0		5.2		4.9		5.0	
85th Percentile Speed (mph)	46	45	-1	45	-1	46	0	45	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	23%	16%	-31.7%	16%	-30.0%	22%	-5.8%[B]	20%	-15.4%
% of Vehicles 10+ Over Advisory	4%	2%	-39.2%	2%	-35.4%	3%	-13.8%[B]	3%	-20.0%
% of Vehicles 15+ Over Advisory	1%	0%	-5.8%[B]	0%	-73.1%	0%	-25.0%[B]	0%	-19.2%[B]
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	0%	-5.8%[B]	0%	-73.1%	0%	-25.0%[B]	0%	-19.2%[B]
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 399 shows the changes in speed metrics at the CC on SR 9. Mean speed decreased by up to -1.7 mph with the lowest being -0.6 mph. Decreases also occurred in the 85th percentile at all periods with the exception of the 24 month after period. Slight changes were shown in the percentage of vehicles traveling 5 mph or more over the advisory speed by up to 41.4%.

Table 39. Results for Washington - SR 9 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	5523	6227	704	6091	568	5230	-293	6072	549
Vehicles Count in SDCWS Direction	2688	3081		2931		2580		5714	
Upstream Mean Speed (mph)	46.9	48.7	1.8[A]	47.6	0.7[A]	48.5	1.6[A]	48.8	1.9[A]
Mean Speed (mph)	40.2	39.3	-0.9	38.5	-1.7	39.3	-0.9	39.6	-0.6
Standard Deviation	5.0	5.0		5.3		4.8		5.1	
85th Percentile Speed (mph)	45	44	-1	44	-1	44	-1	45	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	19%	14%	-26.7%	11%	-41.4%	14%	-27.3%	16%	-15.2%
% of Vehicles 10+ Over Advisory	3%	2%	-29.9%	2%	-45.5%	2%	-34.2%	3%	0.0%
% of Vehicles 15+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0.0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0.0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0.0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0.0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant
[C]11% of data was unknown and removed

Table 40 shows the results of the tracked vehicle speed metrics at the PC. The 12 month after data was not able to be tracked due to a tube being cut and being replaced. The upstream mean speeds showed significant increases from 1.6 to 2.5 mph. This affected the mean speed at the PC which did not have a statistically significant change in mean speed for the 18 or 24 month after period. At 1 month after the mean speed decreased by -0.8 mph. Many of the changes in percent of vehicles over the advisory speed were not statistically significant.

Similar results were found for the tracked vehicles at the CC in Table 4141. Statistically insignificant changes in mean speed are shown at the 1 month and 24 month after periods. A change in mean speed of -0.9 mph during the 18 month after period was statistically significant at a 95-percent level of significance. Many changes in the percent vehicles over the advisory speed were not statistically significant.

Table 40. Tracked Vehicle Results for Washington – SR 9 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	1607	1140		NC		1164		2459	
Upstream Mean Speed (mph)	47.7	50.2	2.5[A]	NC		49.3	1.6[A]	49.8	2.1[A]
Mean Speed (mph)	42.0	41.2	-0.8	NC		41.7	-0.3[B]	41.7	-0.3[B]
Standard Deviation	4.8	4.9		NC		4.9		4.9	
85th Percentile Speed (mph)	47	46	-1	NC		47	0	47	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	28%	25%	-13.0%	NC		29%	0.6%[B]	28%	0.0%
% of Vehicles 10+ Over Advisory	5%	4%	-19.9%[B]	NC		5%	0.0%	5%	0.0%
% of Vehicles 15+ Over Advisory	1%	1%	0.0%	NC		1%	0.0%	1%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	NC		0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	1%	0.0%	NC		1%	0.0%	1%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	NC		0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	NC		0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	NC		0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance
[C]PC data was not tracked

Table 41. Tracked Vehicle Results for Washington – SR 9 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	1607	1140		NC		1164		2459	
Upstream Mean Speed (mph)	47.7	50.2	2.5[A]	NC		49.3	1.6[A]	49.8	2.1[A]
Mean Speed (mph)	41.2	40.8	-0.4[B]	NC		40.3	-0.9	41.0	-0.2[B]
Standard Deviation	4.9	5.0		NC		4.9		5.1	
85th Percentile Speed (mph)	46	46	0	NC		45	-1	46	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	23%	22%	-5.8%[B]	NC		19%	-17.4%	24%	2.7%[B]
% of Vehicles 10+ Over Advisory	4%	4%	0.0%	NC		4%	0.0%	5%	8.2%[B]
% of Vehicles 15+ Over Advisory	1%	1%	0.0%	NC		0%	-58.1%[B]	1%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	NC		0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	1%	0.0%	NC		0.0%	0.0%	1%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	NC		0.0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	NC		0.0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	NC		0.0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance
[C]PC data was not tracked

A benefit to calculating the speed reduction metric is that the upstream speeds are taken into account when displaying the results as shown in Table 42. Speed reduction from upstream to the PC increased from 1.9 to 3.3 mph, showing vehicles were slowing down while approaching the curve taking into account for the higher upstream speeds. The mean speed reduction between the point of curvature and the center of curve were between -0.4 and 0.6 mph. Vehicles did not need to slow down as much through the curve.

Table 42. Speed reduction for Washington - SR 9.

	Before	1 Mo	1 Mo Change	12 Mo[C]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	5.7	9.0	3.3	NC		7.6	1.9	8.0	2.3
Mean Speed Reduction Upstream to CC (mph)	6.6	9.4	2.8	NC		9.0	2.4	8.7	2.1
Mean Speed Reduction PC to CC (mph)	0.8	0.4	-0.4	NC		1.4	0.6	0.7	-0.1
85th Percentile Speed Reduction Upstream to PC (mph)	9	12	3	NC		11	2.0	12	3.0
85th Percentile Speed Reduction Upstream to CC (mph)	10	13	3	NC		12	2.0	13	3.0
85th Percentile Speed Reduction PC to CC (mph)	2	1	-1	NC		2	0.0	2	0.0

[C]PC data was not tracked

Note: Positive change represents vehicles slowing down

Figure 844 through Figure 888 graphically represent the data collected on SR 9 is Wisconsin. The speed profiles in Figure 855 and Figure 866 show the higher upstream speed and a steeper reduction in the mean speed when approaching the PC. Figure 877 and Figure 888 show the increase in the percent of vehicles exceeding the speed limit up stream while slight reductions can be seen at the PC and CC.

Washington (SR 9)

Speed Limit: 55 mph
Curve Advisory Speed: 40 mph
Installed: August 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

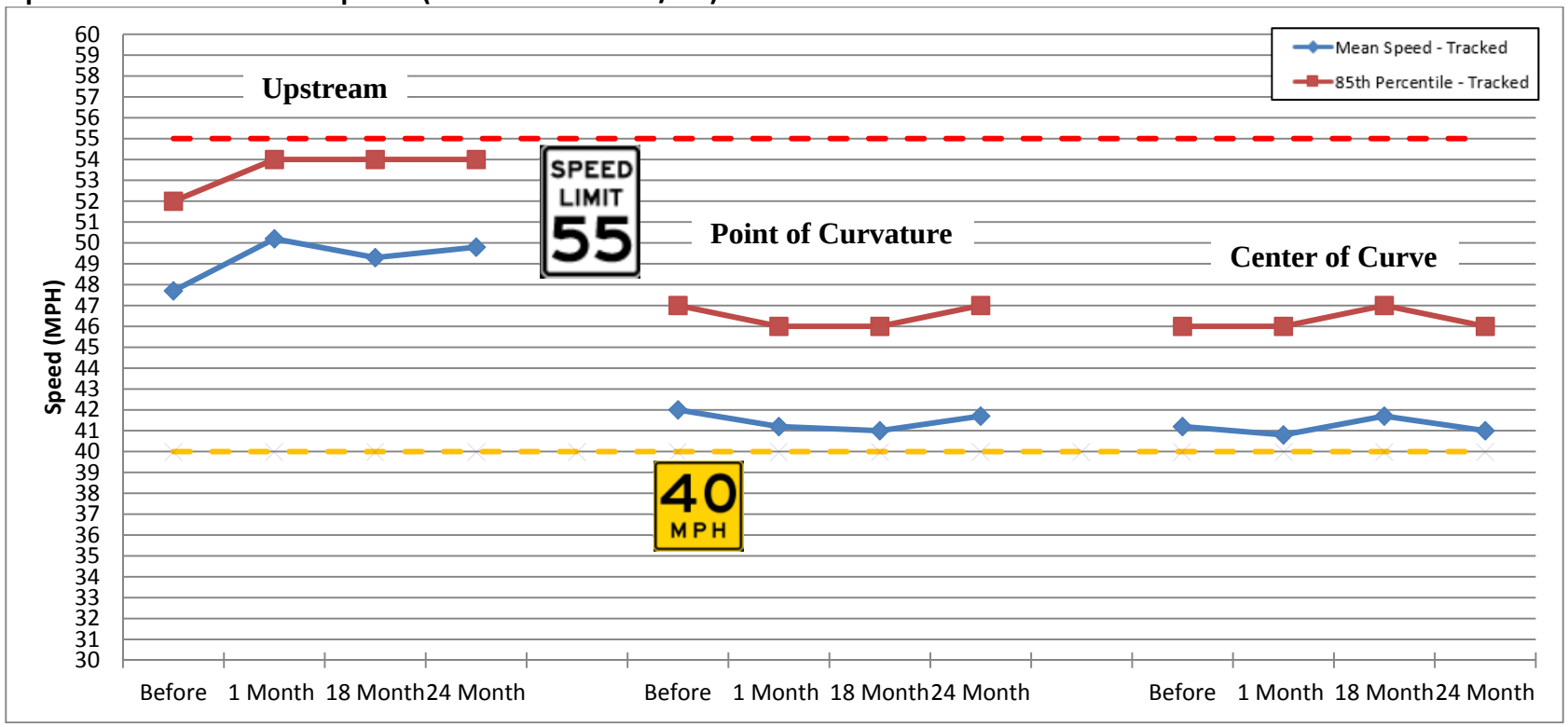


Figure 84. Graph. Impact on tracked vehicle speed - Washington SR 9.

Washington (SR 9)

Speed Profile
All Vehicles

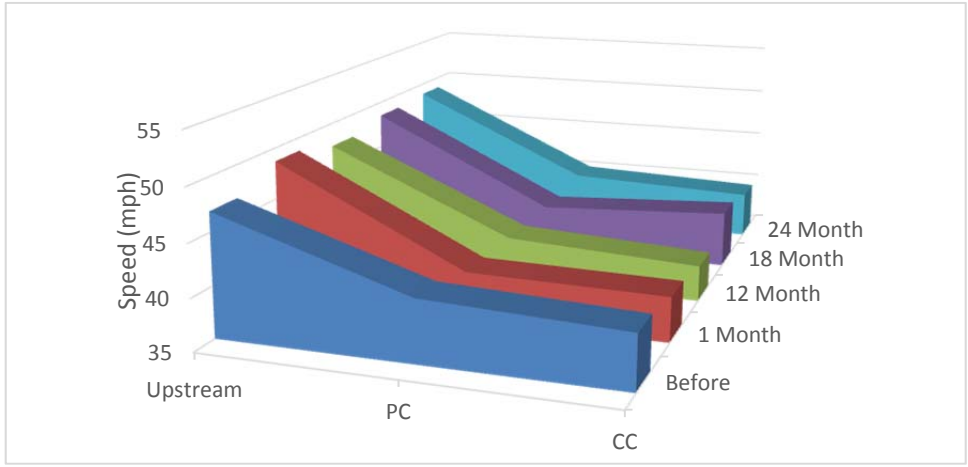


Figure 85. Graph. Speed profiles of all vehicles – Washington SR 9.

Speed Profile
Tracked Vehicles

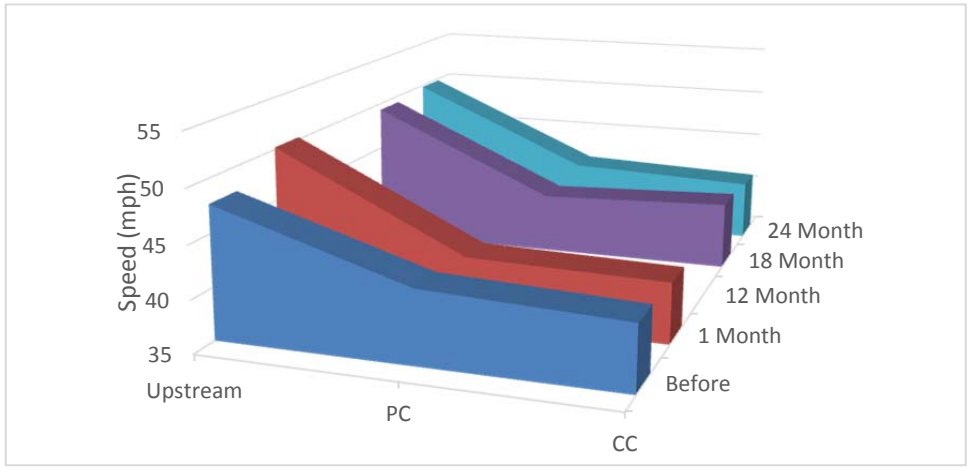


Figure 86. Graph. Speed profiles of tracked vehicles – Washington SR 9.

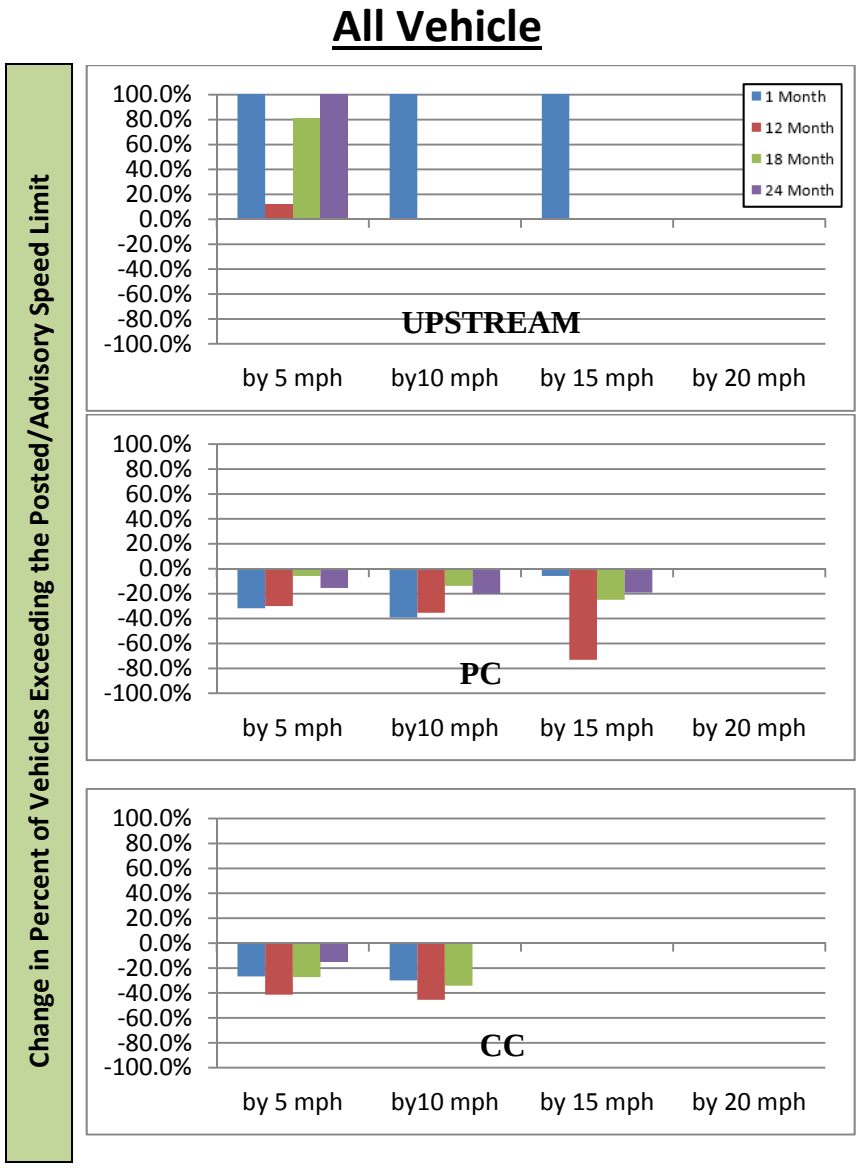


Figure 87. Change in percentile (compared to before) of all vehicle speed - Washington SR 9.

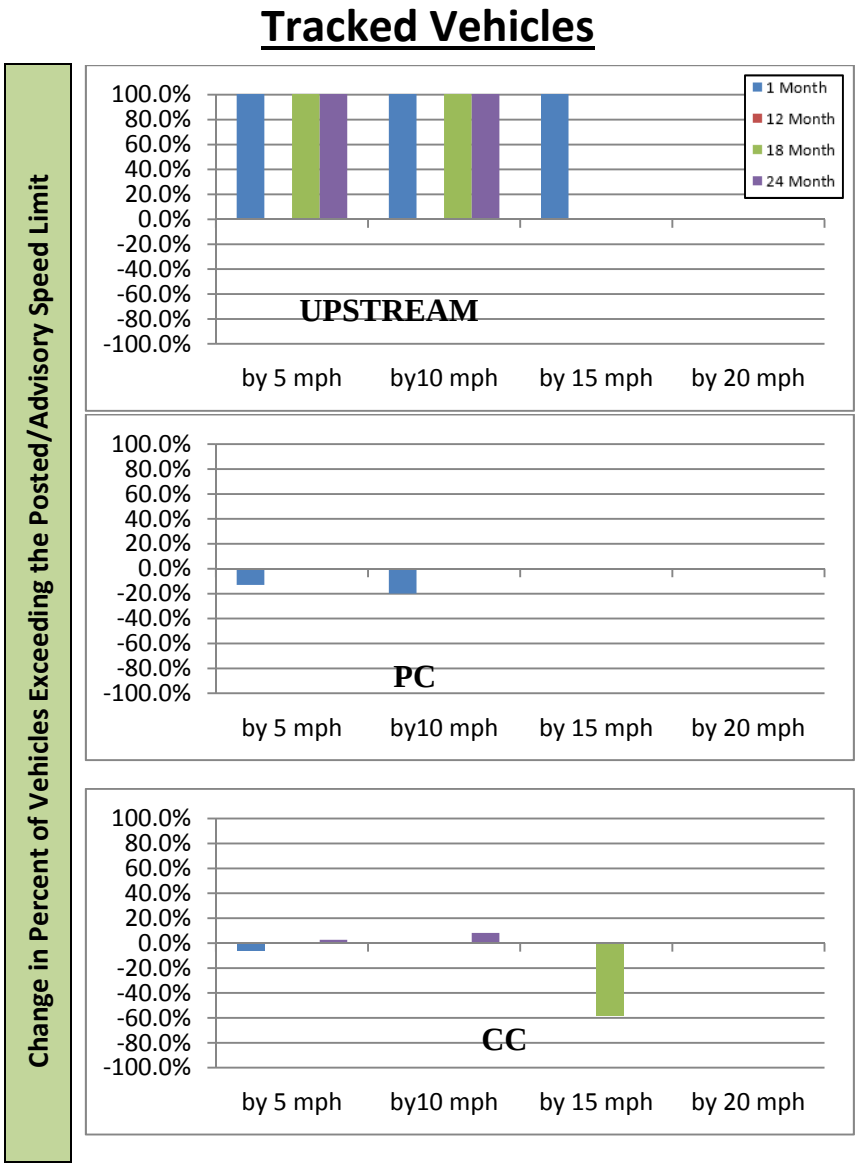


Figure 88. Change in percentile (compared to before) of tracked vehicle speed - Washington SR 9.

Washington SR 203

SR 203 in Washington was selected for SDCWS installed in August 2012. The site was located 3 miles south of Monroe, WA with a speed limit of 55 mph and an advisory speed of 40 mph. The sign was placed in the SB direction of traffic.

As shown in Table 433, the upstream mean speed significantly decreased for the 18 month after period. Minor decreases of -0.6 mph occurred in the 12 month and 24 month period while a slight increase in mean speed occurred in the 1 month after period.

The most significant decrease in mean speed at the PC occurred in the 1 month after period of -2.0 mph. During the 12 month after period, the decrease in mean speed was similar to the decrease in mean speed at the upstream location. The decrease in mean speed during the 18 month after period was less than the decrease in mean speed at the upstream location.

During the 1 month after period, the 85th percentile speed decreased by -2 mph. Significant reductions were observed for the percent change in vehicles exceeding the advisory speed by 5 and 10 mph. The percent of vehicles exceeding the advisory speed by 5 mph or more were reduced by 20 percent.

Table 43. Results for Washington - SR 203 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	10088	10761	673	10718	630	10825	737	11377	1289
Vehicles Count in SDCWS Direction	4901	5190		5097		5241		11451	
Upstream Mean Speed (mph)	53.8	54.2	0.4[A]	53.2	-0.6[A]	50.5	-3.3[A]	53.2	-0.6[A]
Mean Speed (mph)	53.5	51.5	-2.0	52.8	-0.7	51.6	-1.9	51.6	-1.9
Standard Deviation	5.0	4.5		4.7		4.7		5.0	
85th Percentile Speed (mph)	58	56	-2	57	-1	56	-2	56	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	43%	23%	-45.8%	36%	-17.6%	26%	-40.0%	27%	-38.8%
% of Vehicles 10+ Over Advisory	8%	3%	-62.0%	7%	-16.8%	3%	-57.3%	4%	-50.3%
% of Vehicles 15+ Over Advisory	1%	0%	-37.0%	1%	0.0%	0%	-71.2%	0%	-45.2%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	8%	3%	-62.0%	7%	-16.8%	3%	-57.3%	4%	-50.3%
% of Vehicles 10+ Over Limit	1%	0%	-37.0%	1%	0.0%	0%	-71.2%	0%	-45.2%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

Table 444 provides results for the CC. Little change in speed was noted through all time periods compared to the upstream speeds. At 1 month, the decrease in speed was not statistically significant at a 95-percent level of significance. The 12 and 24 month after periods both had a reduction in mean speed of -1.3 mph but this was only slightly higher than the decrease in mean speed of -0.6 mph upstream. The 24 month after period had a -3.5 mph reduction in the mean speed but this decrease was similar to the decrease in speeds that were shown at the upstream location.

Table 44. Results for Washington - SR 203 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo[C]	24 Mo Change
Actual Day Vehicle Count	10120	10756	636	10839	719	10845	725	8427	-1693
Vehicles Count in SDCWS Direction	4921	5148		5089		5266		4072	
Upstream Mean Speed (mph)	53.8	54.2	0.4[A]	53.2	-0.6[A]	50.5	-3.3[A]	53.2	-0.6[A]
Mean Speed (mph)	51.6	51.5	-0.1[B]	50.3	-1.3	48.1	-3.5	50.3	-1.3
Standard Deviation	4.6	4.6		4.4		4.0		4.7	
85th Percentile Speed (mph)	56	56	0	55	-1	52	-4	55	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	25%	24%	-5.3%[B]	15%	-38.9%	4%	-82.2%	16%	-36.9%
% of Vehicles 10+ Over Advisory	3%	3%	0.0%	2%	-51.1%	0%	-92.1%	2%	-41.0%
% of Vehicles 15+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	3%	3%	0.0%	2%	-51.1%	0%	-92.1%	2%	-41.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

[C]Only 18 hours of data collected from puncture in the tube

The impact of the SDCWS changed slightly when looking at only tracked vehicles at SR 203 in Table 455 at the PC. Similar changes were shown for the upstream data collection location for all periods except the 24 month after period where a slight increase in mean speed occurred. Significant reductions in the mean speed at the PC occurred during all data collection periods with the exception of the 12 month after period where the changes were similar to the upstream data. At 18 months, a -5.6 mph reduction in mean speed occurred which was significantly higher than the reduction upstream. Also during the 18 month after period, a reduction of -6 mph occurred for the 85th percentile speed.

The tracking data at the CC in Table 466 showed similar results as the all vehicle speed metrics. Little change in the mean speed occurred during the 1 month and 18 month after periods compared to upstream mean speeds. The 12 month after period had a significant reduction in mean speed of -1.5 mph with a -1 mph reduction in the 85th percentile speed. The number of vehicles exceeding 5 mph over the advisory speed changed by 31.3 percent during this time period. The 24 month after period had a reduction of -0.9 mph in the mean speed but no impact on the 85th percentile speed.

Table 45. Tracked Vehicle Results for Washington – SR 203 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	1493	1442		1215		1487		2993	
Upstream Mean Speed (mph)	55.3	55.7	0.4[A]	54.8	-0.5[A]	51.8	-3.5[A]	55.5	0.2
Mean Speed (mph)	54.6	52.6	-2.0	53.9	-0.7	49.0	-5.6	53.4	-1.2
Standard Deviation	4.4	4.5		4.9		4.1		4.8	
85th Percentile Speed (mph)	59	57	-2	59	0	53	-6	58	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	52%	33%	-35.4%	44%	-14.5%	9%	-27.0%	42%	-19.0%
% of Vehicles 10+ Over Advisory	13%	6%	-52.7%	12%	-2.6%[B]	0%	-41.8%	9%	-26.8%
% of Vehicles 15+ Over Advisory	1%	1%	0.0%	1%	0.0%	0%	-58.8%	1%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	13%	6%	-52.7%	12%	-2.6%[B]	0%	-41.8%	9%	-26.8%
% of Vehicles 10+ Over Limit	1%	1%	0.0%	1%	0.0%	0%	-58.8%	1%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 46. Tracked Vehicle Results for Washington – SR 203 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo[C]	24 Mo Change
Vehicles Tracked	1493	1442		1215		1487		938	
Upstream Mean Speed (mph)	55.3	55.7	0.4[A]	54.8	-0.5[A]	51.8	-3.5[A]	55.5	0.2
Mean Speed (mph)	52.8	52.7	-0.1[B]	51.3	-1.5	49.0	-3.8	51.9	-0.9
Standard Deviation	4.3	4.8		4.5		4.9		5.1	
85th Percentile Speed (mph)	57	57	0	56	-1	53	-4	57	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	34%	34%	0.0%	23%	-31.3%	9%	-73.3%	28%	-16.0%
% of Vehicles 10+ Over Advisory	6%	7%	16.8%[B]	3%	-41.5%	0%	-95.3%	6%	0.0%
% of Vehicles 15+ Over Advisory	0%	1%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	6%	7%	16.8%[B]	3%	-41.5%	0%	-95.3%	6%	0.0%
% of Vehicles 10+ Over Limit	0%	1%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

[C]Only 18 hours of data collected from puncture in the tube

The results of tracking vehicles speed reductions are show in Table 477. The mean speed reduction from the upstream location to the PC increased in the 1 month after period and 24 month after period which shows vehicles were slowing down before entering the curve. The speed reduction did not change for the 12 month after period and vehicles were not slowing down as much during the 18 month after period. During the 12 and 18 month time periods, vehicles were slowing down through the curve between the point of curvature and center of curve instead. Little change occurred for the 24 month period of vehicles speeds through the curve while at the 1 month after data collection vehicles were maintaining their speed through the curve. This shows that vehicles are selecting an appropriate speed to negotiate the curve prior to entering the curve and not having to significantly reduce their speed while in the curve.

Table 47. Speed reduction for Washington - SR 203.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	0.7	3.1	2.4	0.9	0.2[B]	-0.8	-1.5	2.1	1.4
Mean Speed Reduction Upstream to CC (mph)	2.5	3.1	0.6	3.5	1.0	2.8	0.3	3.9	1.4
Mean Speed Reduction PC to CC (mph)	1.8	0	-1.8	2.6	0.8	3.7	1.9	1.6	-0.2
85th Percentile Speed Reduction Upstream to PC (mph)	3	6	3	4	1	2	-1.0	5	2.0
85th Percentile Speed Reduction Upstream to CC (mph)	6	7	1	7	1	6	0.0	8	2.0
85th Percentile Speed Reduction PC to CC (mph)	3	2	-1	4	1	6	3.0	3	0.0

[B]Not statistically significant at 95-percent level of significance

Note: Positive change represents vehicles slowing down

Figure 899 visually represent the tracking vehicles mean and 85th percentile speed. The speeds at the PC and CC replicate changes shown upstream with the exception of the 1 month after period where decreases are shown in the speeds. This is also shown in Figure 9090 and Figure 9191 where similar speed profiles are represented with the exception of the 1 month after period.

Washington (SR 203)

Speed Limit: 55 mph
Curve Advisory Speed: 50 mph
Installed: August 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

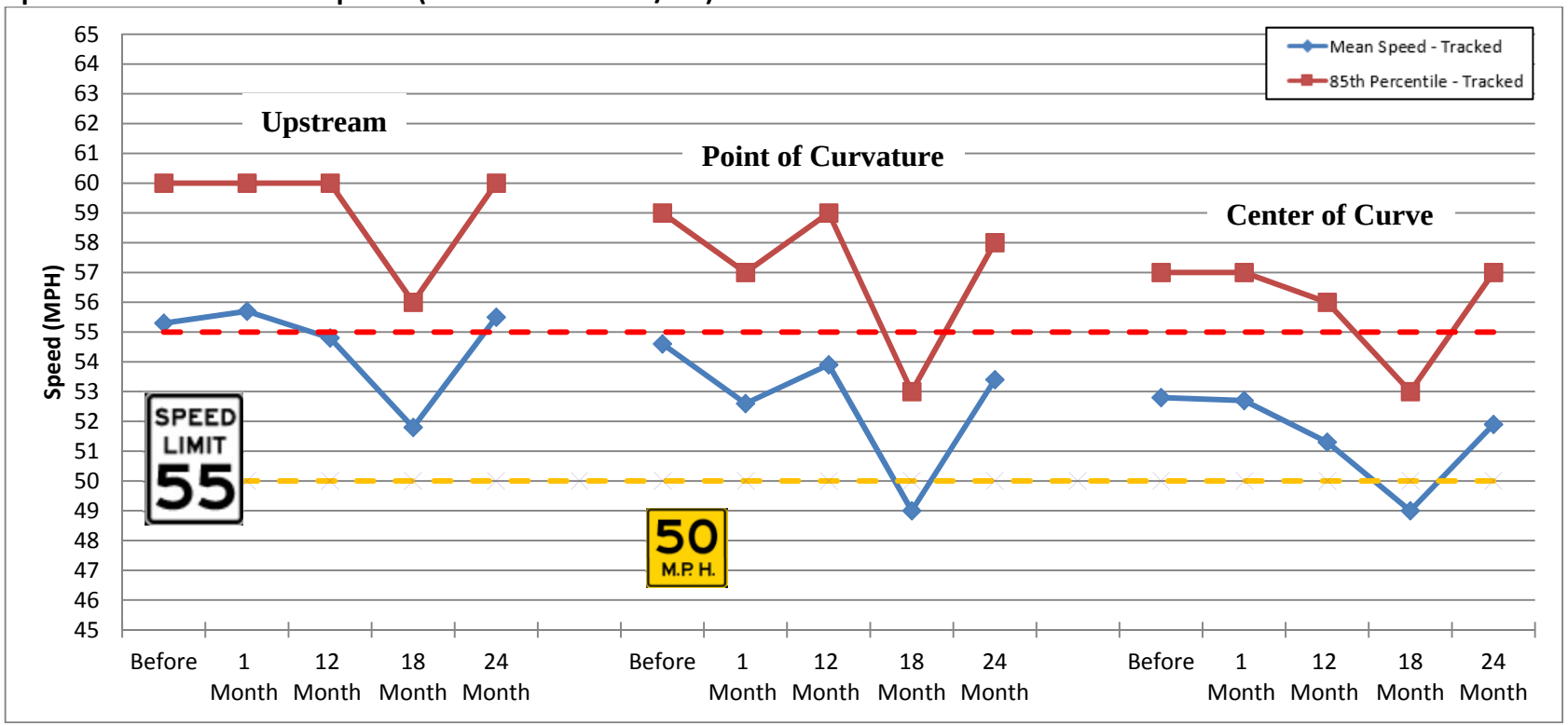


Figure 89. Graph. Impact on tracked vehicle speed - Washington SR 203.

Washington (SR 203)

Speed Profile All Vehicles

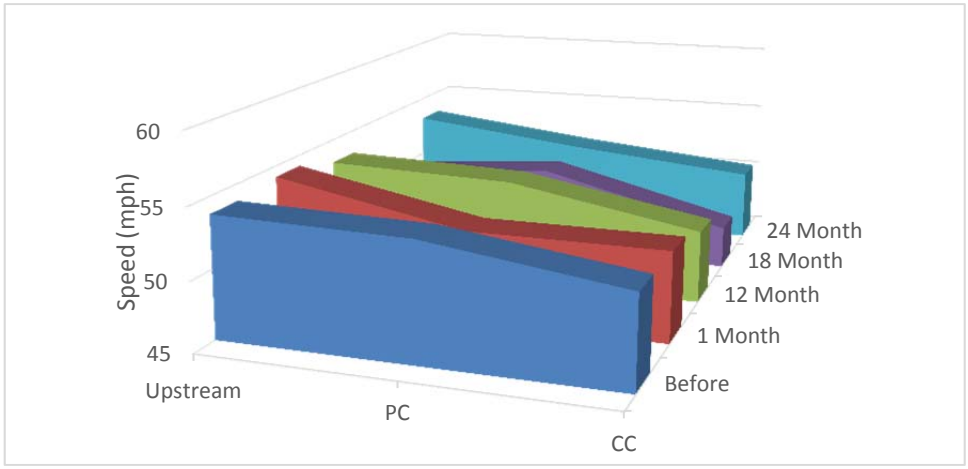


Figure 90. Graph . Speed profiles of all vehicles – Washington SR 203

Speed Profile Tracked Vehicles

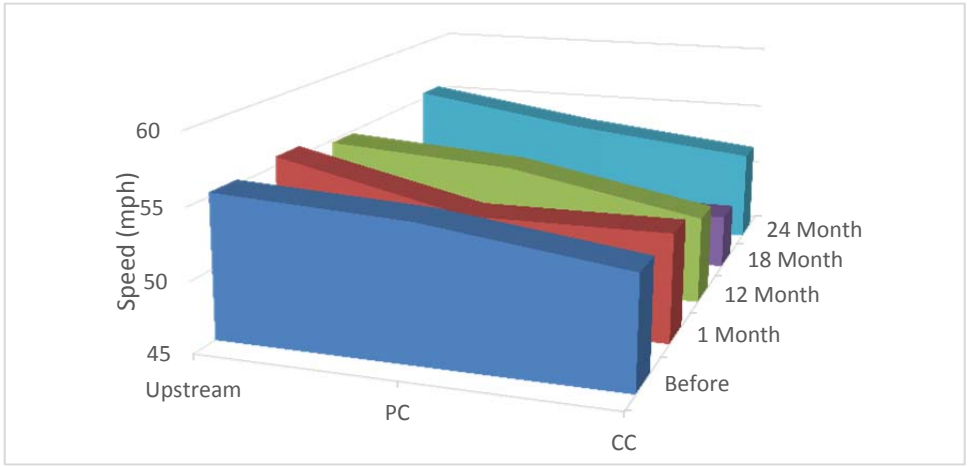


Figure 91. Graph. Speed profiles of tracked vehicles – Washington SR 203

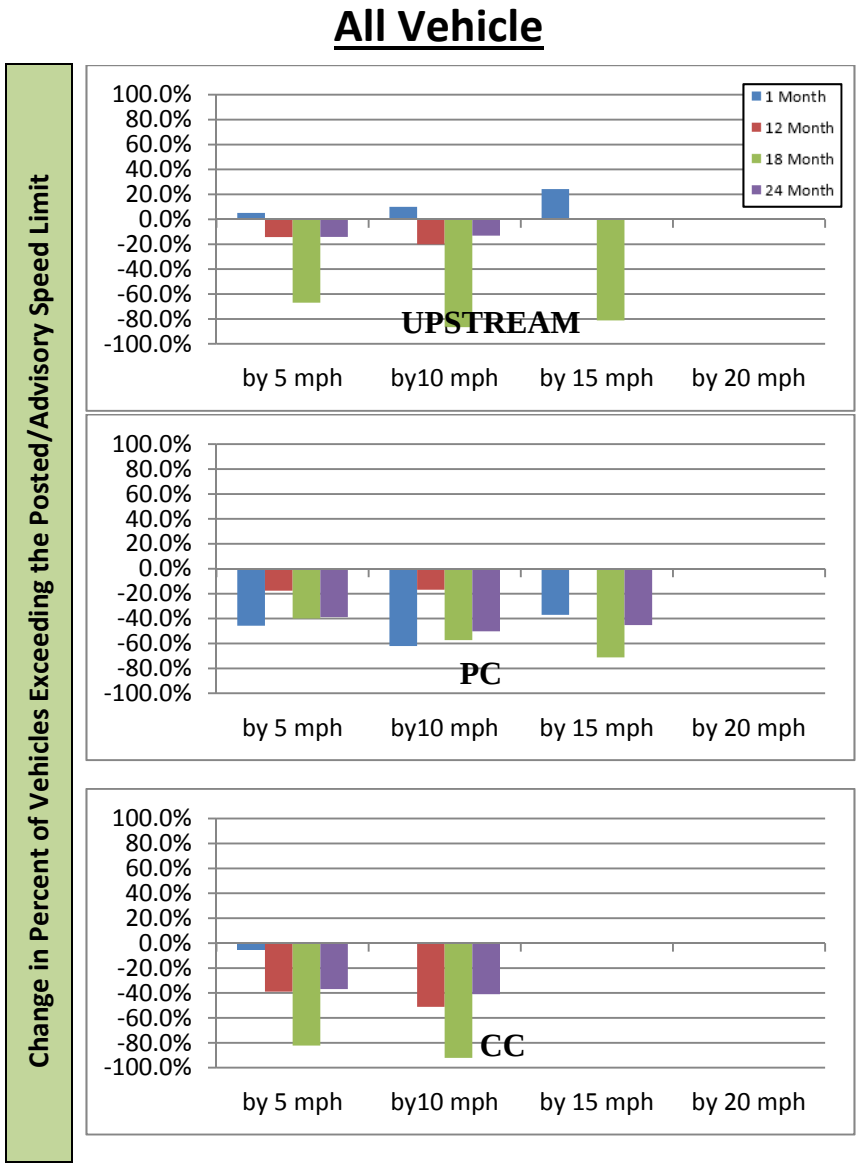


Figure 92. Graphs. Change in percentile (compared to before) of all vehicle speed - Washington SR 203.

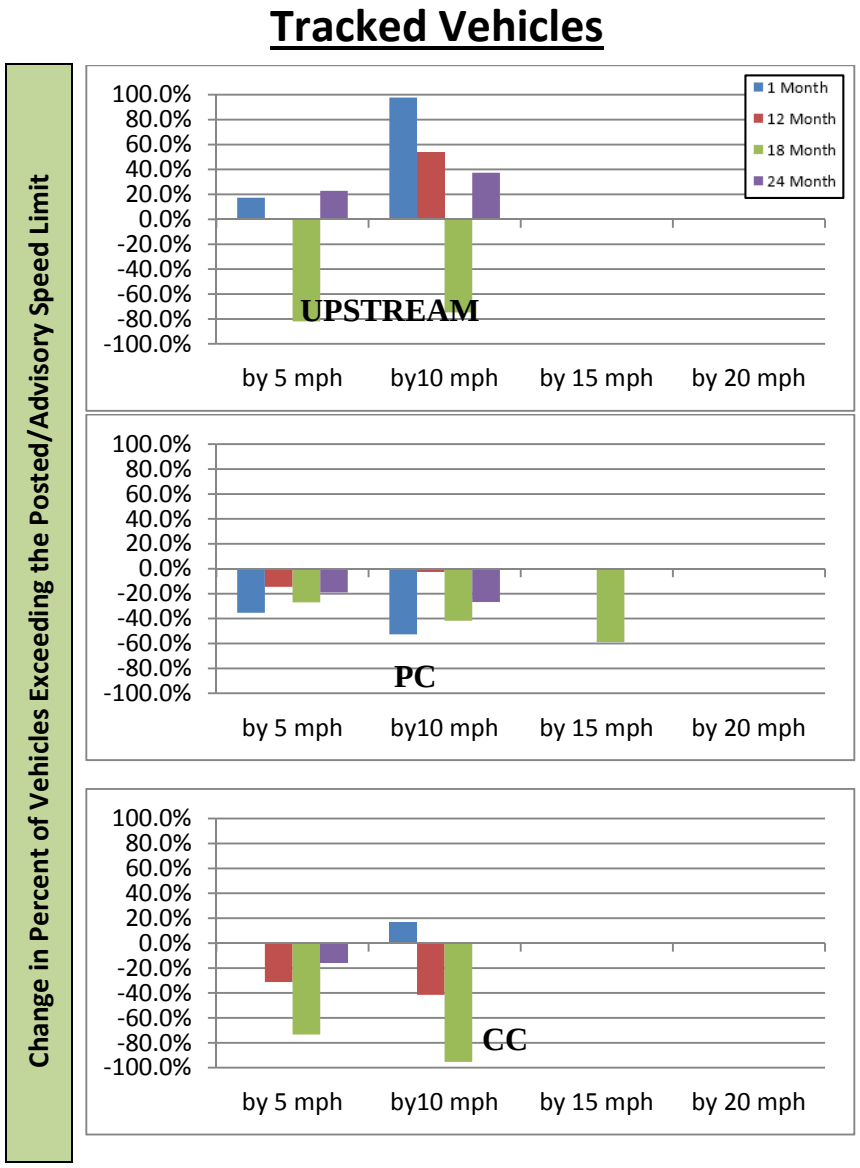


Figure 93. Graphs. Change in percentile (compared to before) of all vehicle speed - Washington SR 203.

Wisconsin Highway 20

The SDCWS was installed in June 2012 on Highway 20 in Wisconsin. The posted speed limit is 55 mph with a 30 mph advisory speed. The site is located about 6 miles east of East Troy, Wisconsin and installed for the WB direction of travel.

Table 488 shows the results at the PC data collection location. Increase in speeds were noted at the upstream location for all time periods except the 24 month after period were a significant decrease in mean speed occurred. Decreases in mean speeds between -1.4 and -2.2 mph occurred during all time periods with the 85th percentile speeds decreasing between -1 and -2 mph. The decrease in mean speed during the 24 month after period was similar to the decrease in mean speed upstream and may have reduced the effectiveness due to the SDCWS. Modest decreases occurred in the percent of vehicles exceeding the advisory speed by 5, 10, 15 and 20 mph. These decreases in percent of vehicles exceeding the advisory speed had changes in the percent between -7.5 and -70.8 percent.

Table 48. All Vehicle Results for Wisconsin - Hwy 20 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	3583	3250	-333	3371	-212	3028	-555	3438	-145
Vehicles Count in SDCWS Direction	1692	1556		1674		1482		3361	
Upstream Mean Speed (mph)	53.7	55.2	1.5[A]	55	1.3[A]	54.6	0.9[A]	51.5	-2.2[A]
Mean Speed (mph)	39.6	37.8	-1.8	37.4	-2.2	38.2	-1.4	37.6	-2.0
Standard Deviation	7.6	7.1		7.3		7.6		7.0	
85th Percentile Speed (mph)	47	45	-2	45	-2	46	-1	45	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	77%	70%	-8.5%	69%	-10.0%	71%	-7.5%	70%	-8.8%
% of Vehicles 10+ Over Advisory	58%	47%	-19.7%	46%	-20.8%	52%	-10.8%	45%	-23.4%
% of Vehicles 15+ Over Advisory	27%	16%	-39.4%	16%	-41.2%	20%	-25.0%	16%	-40.2%
% of Vehicles 20+ Over Advisory	7%	3%	-61.4%	2%	-69.8%	3%	-54.0%	2%	-70.8%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

The results at the CC are shown in Table 499. Decreases occurred for all speed metrics for all of the after periods. The decrease in the 24 month after period was lower than the decrease in mean speed upstream.

Decreases were the greatest in the 1 month after period, with a decrease of -1.8 mph in mean speed and -2 mph in 85th percentile speed. All percent of vehicles exceeding the advisory speed were decreased with the highest decreases occurring in the number of vehicles exceeding 10 mph or more. During the 1 month after period, a 15 percent reduction in the percent of vehicles exceeding 10 mph occurred which equated to a -45.4% change.

Table 49. All Vehicle Results for Wisconsin - Hwy 20 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	3128	2823	-305	2883	-245	2536	-592	2982	-146
Vehicles Count in SDCWS Direction	1456	1350		1425		1243		2888	
Upstream Mean Speed (mph)	53.7	55.2	1.5[A]	55	1.3[A]	54.6	0.9[A]	51.5	-2.2[A]
Mean Speed (mph)	37.4	35.6	-1.8	36.5	-0.9	36.1	-1.3	35.9	-1.5
Standard Deviation	4.8	4.6		5.1		5.0		4.6	
85th Percentile Speed (mph)	42	40	-2	41	-1	41	-1	40	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	77%	63%	-18.4%	68%	-12.6%	68%	-12.0%	64.0%	-5.3%
% of Vehicles 10+ Over Advisory	33%	18%	-45.4%	28%	-14.2%	24%	-26.1%	20.0%	-27.5%
% of Vehicles 15+ Over Advisory	6%	2%	-69.2%	5%	-14.9%[B]	2%	-62.4%	2.0%	-50.7%
% of Vehicles 20+ Over Advisory	1%	0%	-89.9%	1%	0.0%	0%	-65.2%	0.0%	-77.9%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

After tracking vehicles, the impact of the SDCWS on speeds were larger for free flowing vehicles. Table 5050 shows the results at the PC. Upstream speeds were higher during all time periods except the 24 month period which had a reduction in mean speed of -0.6 mph.

A significant decrease in mean and 85th percentile speed occurred during all time periods. Comparing all vehicles, the 24 month after period had a significant reduction in the mean speed with speeds decreases more than at the upstream location. The mean speed reductions were between -1.2 and -2.4 mph which the 85th percentile speed reductions between -2 and -3 mph.

Decreases in the percent of vehicles exceeding the advisory speed by 5, 10, 15, and 20 mph occurred. Significant reductions in the percent of vehicles exceeding the advisory speed by 20 mph or more occurred with changes in the percent between -54.1 and -70.4 percent.

Table 5151 shows the results of tracking vehicle speed metrics at the CC. These results replicated the speed metrics for all vehicles. Mean speeds decreased between -0.9 and -1.9 mph with the 85th percentile speeds between -1 and -3 mph. Significant decrease in percent of vehicles exceeding the advisory speed limit also occurred at each time period.

Table 50. Tracked Vehicle Results for Wisconsin – Hwy 20 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	743	740		775		688		1470	
Upstream Mean Speed (mph)	55.9	56.7	0.8[A]	56.4	0.5	56.5	0.6	55.3	-0.6
Mean Speed (mph)	43.3	41.0	-2.3	40.9	-2.4	42.1	-1.2	41.0	-2.3
Standard Deviation	5.3	4.7		5.1		5.0		5.0	
85th Percentile Speed (mph)	49	46	-3	46	-3	47	-2	46	-3
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	95%	92%	-3.4%	91%	-5.1%	93%	-2.7%	91%	-5.0%
% of Vehicles 10+ Over Advisory	77%	63%	-18.3%	64%	-17.5%	72%	-6.5%	64%	-17.7%
% of Vehicles 15+ Over Advisory	39%	22%	-43.1%	23%	-41.0%	32%	-18.7%	25%	-36.8%
% of Vehicles 20+ Over Advisory	13%	4%	-69.0%	4%	-68.4%	6%	-54.1%	4%	-70.4%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

Table 51. Tracked Vehicle Results for Wisconsin – Hwy 20 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	743	740		775		688		1470	
Upstream Mean Speed (mph)	55.9	56.7	0.8[A]	56.4	0.5	56.5	0.6	55.3	-0.6
Mean Speed (mph)	38.4	36.5	-1.9	37.5	-0.9	37.2	-1.2	36.8	-1.6
Standard Deviation	4.4	3.9		4.6		4.3		4.1	
85th Percentile Speed (mph)	43	40	-3	42	-1	42	-1	41	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	83%	69%	-17.3%	75%	-10.0%	74%	-10.9%	72%	-3.5%
% of Vehicles 10+ Over Advisory	38%	20%	-46.9%	33%	-11.7%	30%	-21.7%	25%	-24.8%
% of Vehicles 15+ Over Advisory	9%	2%	-77.5%	6%	-35.6%	3%	-61.3%	3%	-54.4%
% of Vehicles 20+ Over Advisory	1%	0%	-85.1%	1%	0.0%	0%	-53.2%[B]	0%	-84.5%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

The speed reductions after tracking vehicles are shown in Table 52. The speed reductions from the upstream to point of curvature show that vehicles are slowing down prior to entering the curve and with only slight changes in the speed reduction between the point of curvature and the center of curve shows vehicles are selecting a better speed to negotiate the curve. The speed reduction between the upstream and PC was the greatest at the 1 month after period with vehicles slowing down by 3.0 mph more before entering the curve. The change in speed reduction between the PC and CC were either not significant or decreased, meaning vehicles did not have to slow down as much through the curve.

Table 52. Speed reduction for Wisconsin - Hwy 20.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo[C]	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	12.6	15.6	3.0	15.5	2.9	14.4	1.8	13.6	1.0
Mean Speed Reduction Upstream to CC (mph)	17.6	20.2	2.6	18.9	1.3	19.2	1.6	18.0	0.4[B]
Mean Speed Reduction PC to CC (mph)	4.9	4.6	-0.3[B]	3.4	-1.5	4.9	0.0	4.2	-0.7
85th Percentile Speed Reduction Upstream to PC (mph)	18	20	2	20	2	19	1.0	19	1.0
85th Percentile Speed Reduction Upstream to CC (mph)	23	25	2	24	1	24	1.0	23.4	0.4
85th Percentile Speed Reduction PC to CC (mph)	8	8	0	6	-2	8	0.0	7	-1.0

[B]Not statistically significant at 95-percent level of significance

[C]Only 26 hours of data at upstream

Note: Positive change represents vehicles slowing down

Figure 94 shows the decreases found at the PC and CC for the tracked vehicles data. Speed at the upstream data collection had very little change where the PC and CC data collection locations had reductions in mean and 85th percentile speed.

Wisconsin (Hwy 20)

Speed Limit: 55 mph
Curve Advisory Speed: 30 mph
Installed: June 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

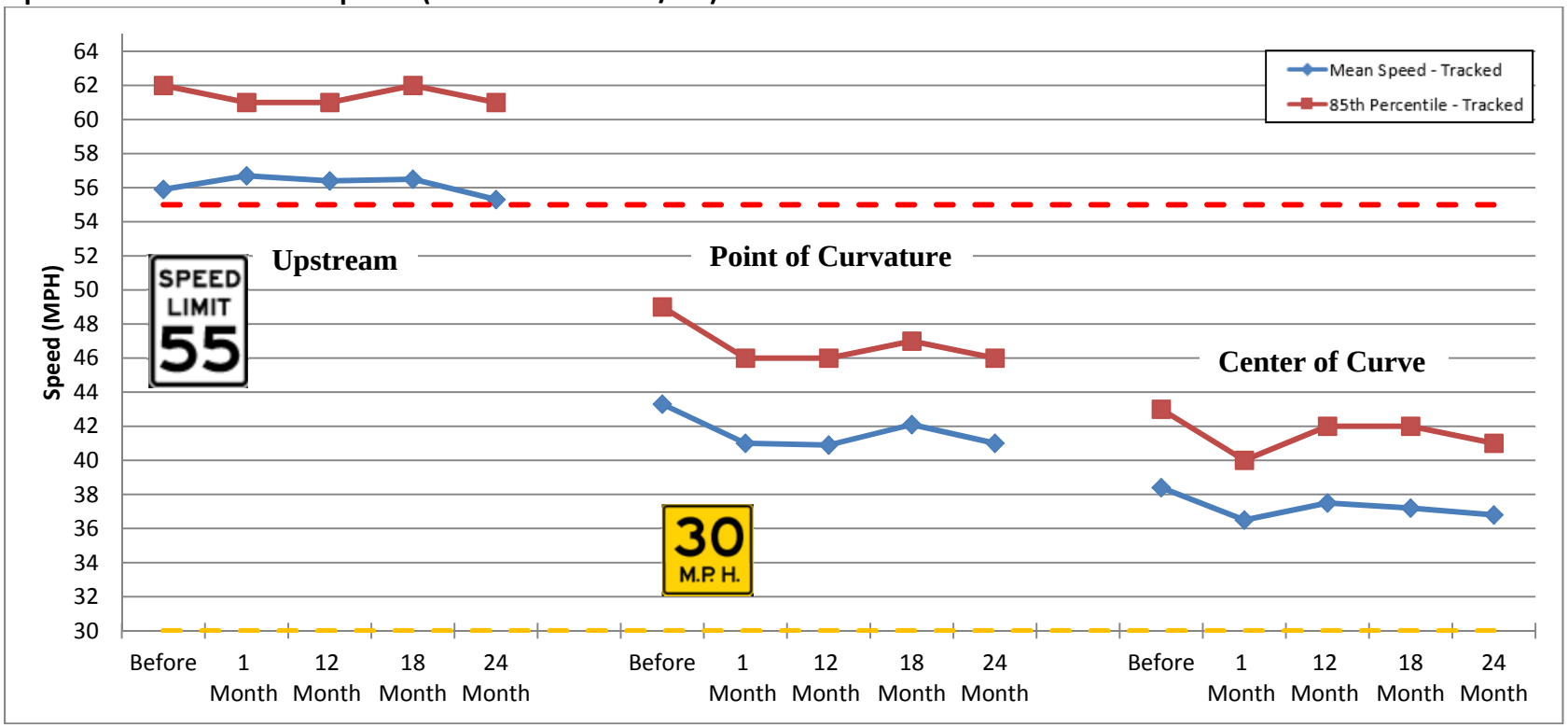


Figure 94. Graph. Impact on tracked vehicle speed - Wisconsin Hwy 20.

Wisconsin (Hwy 20)

Speed Profile All Vehicles

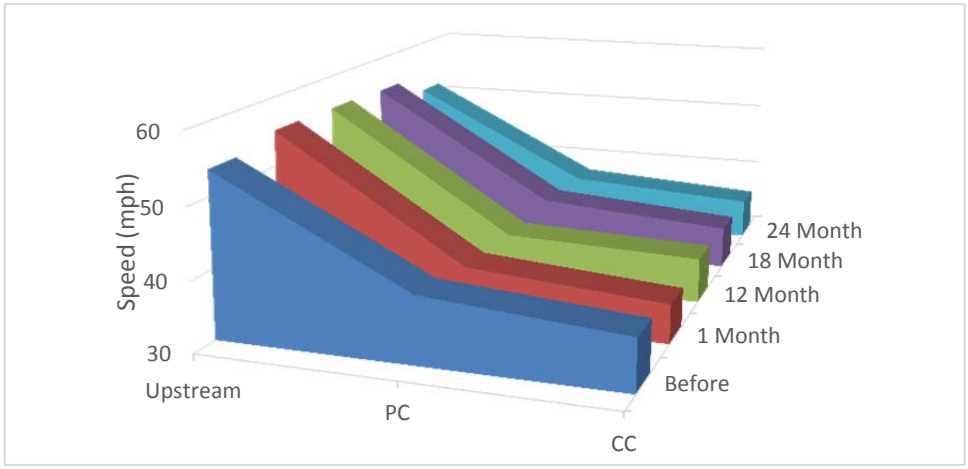


Figure 95. Graph. Speed profiles of all vehicles – Wisconsin Hwy 20.

Speed Profile Tracked Vehicles

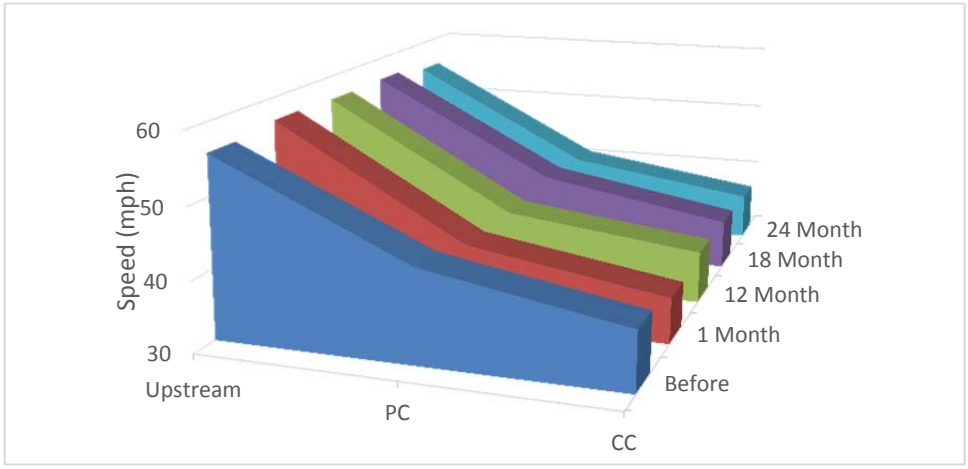


Figure 96. Graph. Speed profiles of tracked vehicles – Wisconsin Hwy 20.

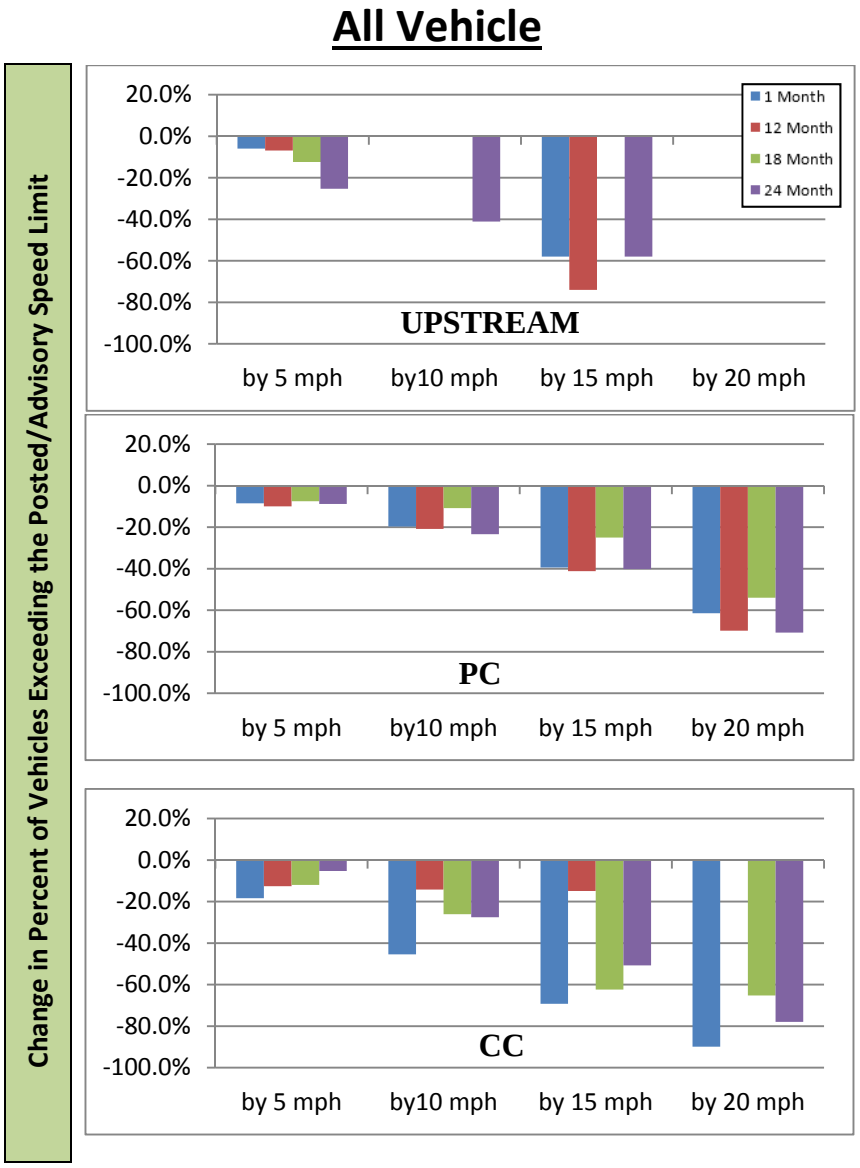


Figure 97. Graphs. Change in percentile (compared to before) of all vehicle speed - Wisconsin Hwy 20.

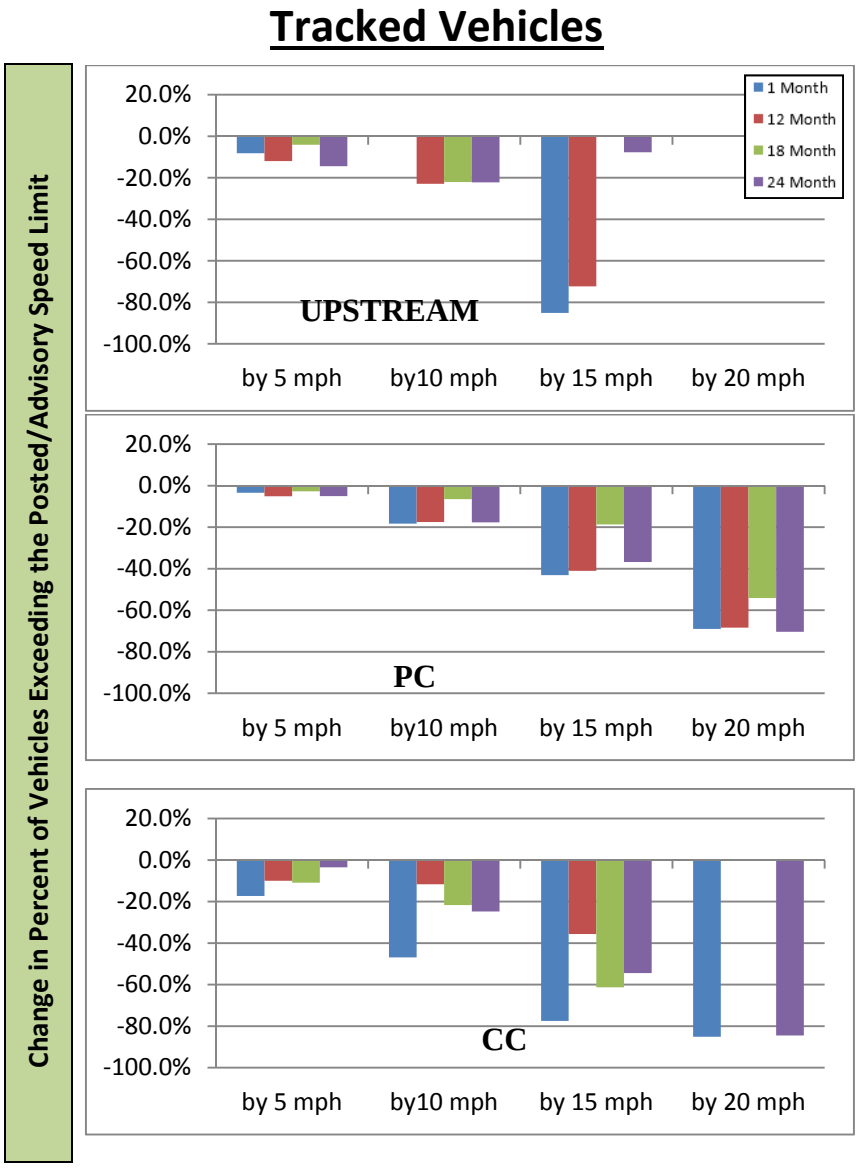


Figure 98. Graphs. Change in percentile (compared to before) of tracked vehicle speed - Wisconsin Hwy 20.

Wisconsin Highway 67

A SDCWS was installed on Highway 67 in Wisconsin in June 2012. The site is located 6 miles south of Dousman, WI. The speed limit for the road was 55 mph with a 25 mph advisory speed. The system was installed for the SB direction of traffic.

The upstream speeds on Highway 67 varied with changes in mean speed between -1.1 and 0.8 mph. The results for the PC are shown in Table 533. All changes in mean speed were greater than the speed changes shown upstream. At the 1 month and 12 month after periods, the change in mean speed at the PC was -0.5 mph showing speeds may have been influenced by the SDCWS. The 18 month after period did not have a statistically significant reduction in speed at a 95-percent level of significance but there was a statistically significant increase in the upstream mean speed of 0.8 mph which may suggest speeds were influenced. The 24 month after period also had a reduction in the mean speed of -1.1 mph. 85th percentile speeds were reduced by -2 mph for the 12 and 24 month after periods, -1 mph for the 1 month after period and no change for the 18 month after period. Little change occurred in the percent of vehicles exceeding the advisory speed. The largest change in percent of vehicles exceeding the advisory speed occurred for 20 mph or over with a change of -14.3 to -20.5 percent. The SDCWS did have an impact on the vehicles traveling significantly over the advisory speed entering the curve.

Table 53. All Vehicle Results for Wisconsin - Hwy 67 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	3494	4018	524	3842	348	3362	-132	3964	470
Vehicles Count in SDCWS Direction	1726	1992		1912		1651		3927	
Upstream Mean Speed (mph)	50.0	48.9	-1.1[A]	49.2	-0.8	50.8	0.8[A]	49.6	-0.4
Mean Speed (mph)	46.1	44.5	-1.6	44.8	-1.3	46.0	-0.1[B]	45.0	-1.1
Standard Deviation	5.9	6.0		5.6		5.9		5.5	
85th Percentile Speed (mph)	52	51	-1	50	-2	52	0	50	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	99%	99%	0.0%	99%	0.0%	99%	0.0%	99%	0.0%
% of Vehicles 10+ Over Advisory	97%	94%	-2.6%	96%	-1.0%[B]	97%	0.0%	97%	0.0%
% of Vehicles 15+ Over Advisory	87%	80%	-8.6%	83%	-4.9%	86%	-1.3%[B]	85%	-3.1%
% of Vehicles 20+ Over Advisory	65%	51%	-20.5%	55%	-15.1%	62%	-4.2%[B]	55%	-14.3%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	1%	0.0%	0%	-62.9%	1%	4.3%[B]	0%	-31.4%[B]
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 54 shows the results at the CC. Changes in speed at the CC were similar to the PC. Changes in mean speed at the 1 month and 24 month periods were reduced and higher than the reductions in mean speed upstream. The mean speed reduction at 18 month was not statistically significant but had an increase of 0.8 mph upstream. At 12 month, the mean speed reduction was equal to the mean speed reduction upstream.

Table 54. All Vehicle Results for Wisconsin - Hwy 67 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	3496	4004	508	3821	325	3352	-144	3964	468
Vehicles Count in SDCWS Direction	1713	1979		1899		1651		3926.0	
Upstream Mean Speed (mph)	50.0	48.9	-1.1[A]	49.2	-0.8	50.8	0.8[A]	49.6	-0.4
Mean Speed (mph)	39.7	37.9	-1.8	38.9	-0.8	39.6	-0.1	39.5	-0.2
Standard Deviation	5.0	5.0		4.7		5.0		4.8	
85th Percentile Speed (mph)	45	43	-2	44	-1	44.5	-0.5	44	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	97%	95%	-1.6%	97%	0.0%	98%	1.6%	98%	1.2%
% of Vehicles 10+ Over Advisory	86%	76%	-11.7%	84%	-3.0%	85%	-1.5%[B]	86%	0.0%
% of Vehicles 15+ Over Advisory	53%	38%	-27.9%	46%	-12.9%	50%	-6.4%	52%	-2.6%[B]
% of Vehicles 20+ Over Advisory	15%	8%	-48.1%	11%	-27.1%	15%	-2.9%[B]	13%	-15.5%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 555 shows the results at the PC after tracking vehicles through the curve. The upstream speeds decreases in the 1 month after period, did not change in the 12 month after period and increases in the 18 and 24 month after periods. Significant mean speed reduction occurred between -1.3 and -2.0 mph at all time periods except the 18 month after period which did not have a statistically significant change in speed. There was also a reduction in the 85th percentile speed of -2 mph. Little change occurred in the percent of vehicles going 5, 10, and 15 mph over the advisory speed limit. The percent of vehicles exceeding the advisory speed limit of 20 mph or more was reduced by up to 18%. The SCDWS is effective at reducing the number of vehicles significantly exceeding the advisory speed limit.

Little reductions in speeds metrics occurred at the CC after tracking vehicles, as shown in Table 566. Mean speed were reduced between -0.4 and -2.4 mph. The 85th percentile speed was only reduced in the 1 month after period by -2 mph. With the exception of the 1 month after period, only small changes in the percent of vehicles exceeding the advisory speed occurred. During the 1 month after period, the largest change in percent of vehicles exceeding the advisory speed was -23.6 percent at 20 mph or more.

Table 55. Tracked Vehicle Results for Wisconsin – Hwy 67 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	905	1008		912		910		1848	
Upstream Mean Speed (mph)	51.1	50.2	-0.9	51.1	0.0	52.0	0.9	51.7	0.6
Mean Speed (mph)	47.4	45.4	-2.0	46.0	-1.4	47.0	-0.4[B]	46.1	-1.3
Standard Deviation	5.3	5.7		5.4		5.4		5.3	
85th Percentile Speed (mph)	53	51	-2	51	-2	53	0	51	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	99%	99%	0.0%	99%	0.0%	99%	0.0%	99%	0.0%
% of Vehicles 10+ Over Advisory	99%	97%	-1.7%	97%	-1.7%	99%	0.0%	98%	-0.7%
% of Vehicles 15+ Over Advisory	92%	84%	-8.5%	89%	-3.7%	92%	0.0%	89%	-3.7%
% of Vehicles 20+ Over Advisory	74%	56%	-23.6%	63%	-14.2%	67%	-8.3%	63%	-14.6%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	1%	0.0%	0%	0.0%	0%	0.0%	1%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

Table 56. Tracked Vehicle Results for Wisconsin – Hwy 67 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	905	1008		912		910		1848.0	
Upstream Mean Speed (mph)	51.1	50.2	-0.9	51.1	0.0	52.0	0.9	51.7	0.6
Mean Speed (mph)	40.7	38.3	-2.4	39.7	-1.0	40.1	-0.6	40.3	-0.4
Standard Deviation	4.7	4.7		4.7		4.9		4.6	
85th Percentile Speed (mph)	45	43	-2	45	0	45	0	45	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	99%	97%	-1.7%	98%	-0.2%[B]	99%	0.0%	99%	0.0%
% of Vehicles 10+ Over Advisory	92%	80%	-13.1%	88%	-4.3%	88%	-3.8%	90%	-2.4%
% of Vehicles 15+ Over Advisory	61%	40%	-34.8%	52%	-15.2%	55%	-10.3%	58%	-4.7%[B]
% of Vehicles 20+ Over Advisory	19%	9%	-55.6%	16%	-18.5%	18%	-4.6%[B]	17%	-10.5%[B]
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

The speed reductions after tracking vehicles are shown in Table 577. Speeds were reduced during almost all time periods between all data collection locations. Significant speed reductions between 1.1 and 1.9 mph occurred between the upstream and point of curvature. This showed vehicles were slowing down prior to entering the curve. Speed reductions between the point of curvature and the center of curve varied between -0.8 to 0.4 mph showing that speed reductions were similar to the before data collection period. This data showed that vehicles in free flow were being influenced by the SDCWS.

Table 57. Speed Reduction for Wisconsin - Hwy 67.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	3.7	4.8	1.1	5.1	1.4	5	1.3	5.6	1.9
Mean Speed Reduction Upstream to CC (mph)	10.4	11.9	1.5	11.4	1.0	11.9	1.5	11.4	1.0
Mean Speed Reduction PC to CC (mph)	6.6	7	0.4	6.2	-0.4	6.9	0.3	5.8	-0.8
85th Percentile Speed Reduction Upstream to PC (mph)	11	13	2	12	1	12	1	11	0.0
85th Percentile Speed Reduction Upstream to CC (mph)	18	21	3	19	1	19	1	18	0.0
85th Percentile Speed Reduction PC to CC (mph)	9	10	1	9	0	10	1	8	-1.0

Note: Positive change represents vehicles slowing down

Figure 999 thru Figure 103103 graphically display the data collected on Highway 67. All figures show that only slight changes in the speed metrics occurred at this site when looking at all vehicles data.

Wisconsin (Hwy 67)

Speed Limit: 55mph
Curve Advisory Speed: 25 mph
Installed: June 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

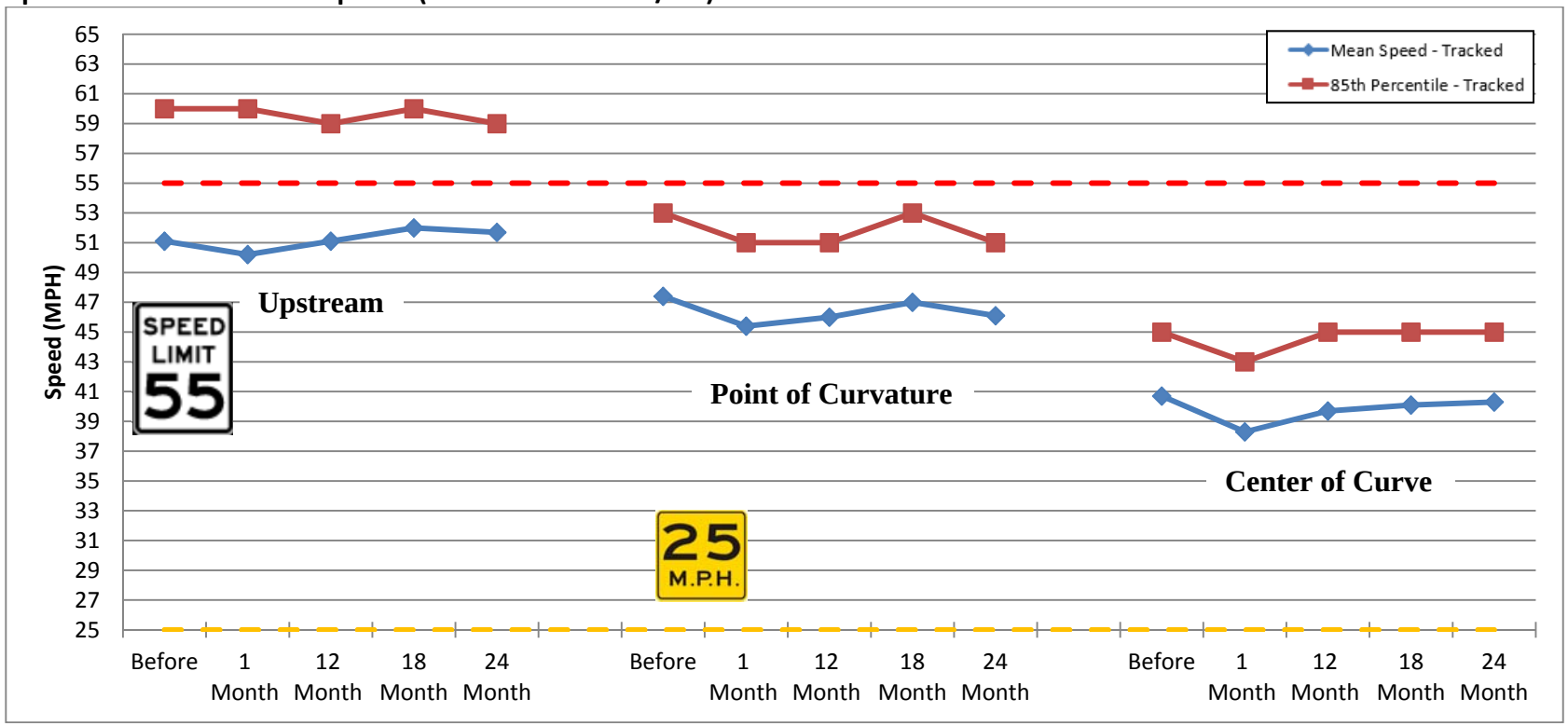


Figure 99. Graph. Impact on tracked vehicle speed - Wisconsin Hwy 67.

Wisconsin (Hwy 67)

Speed Profile All Vehicles

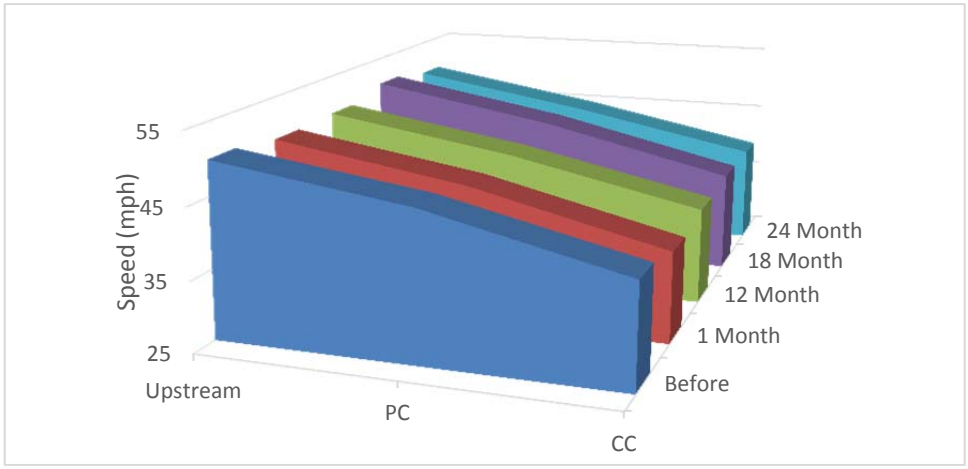


Figure 100. Graph. Speed profiles of all vehicles – Wisconsin Hwy 67.

Speed Profile Tracked Vehicles

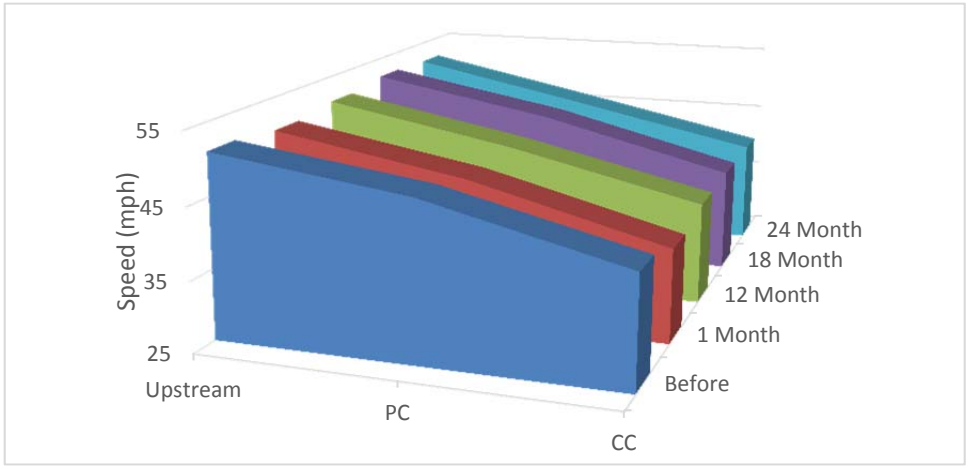


Figure 101. Graph. Speed profiles of tracked vehicles – Wisconsin Hwy 67.

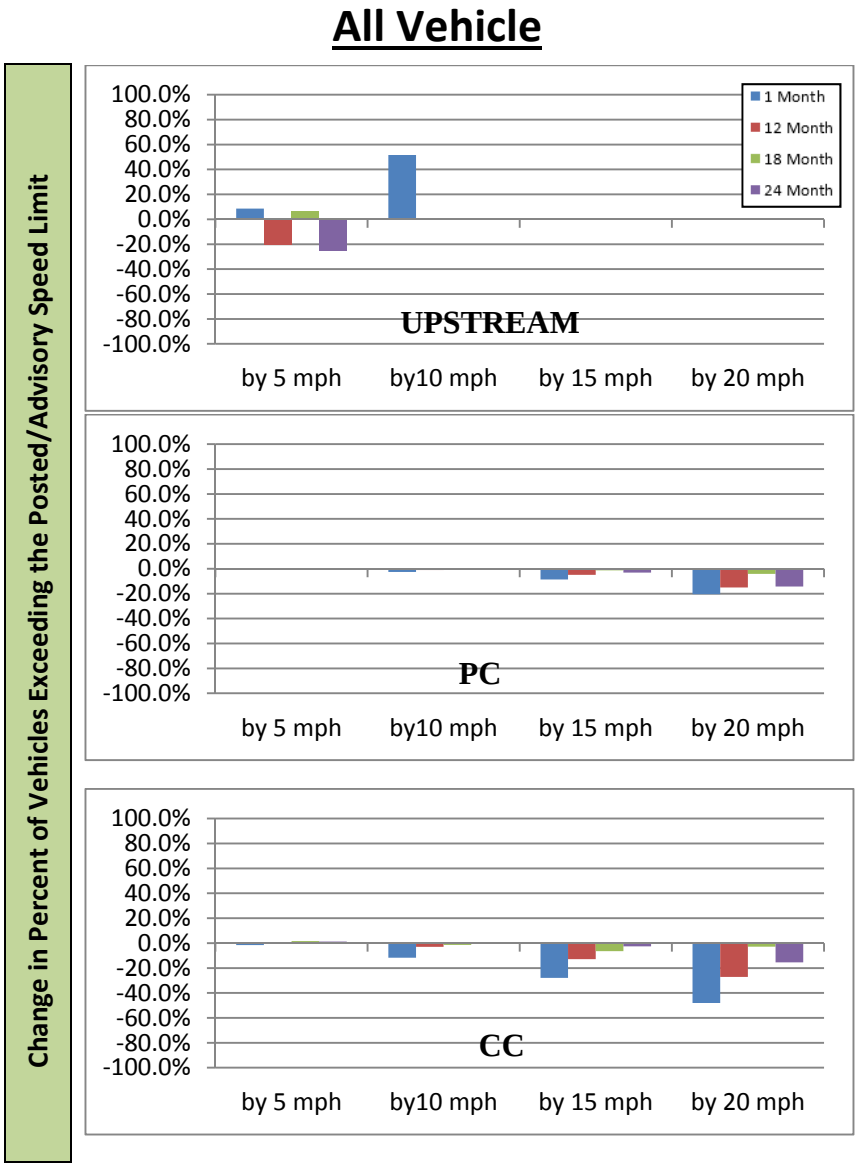


Figure 102. Graphs. Change in percentile (compared to before) of all vehicle speed - Wisconsin Hwy 67.

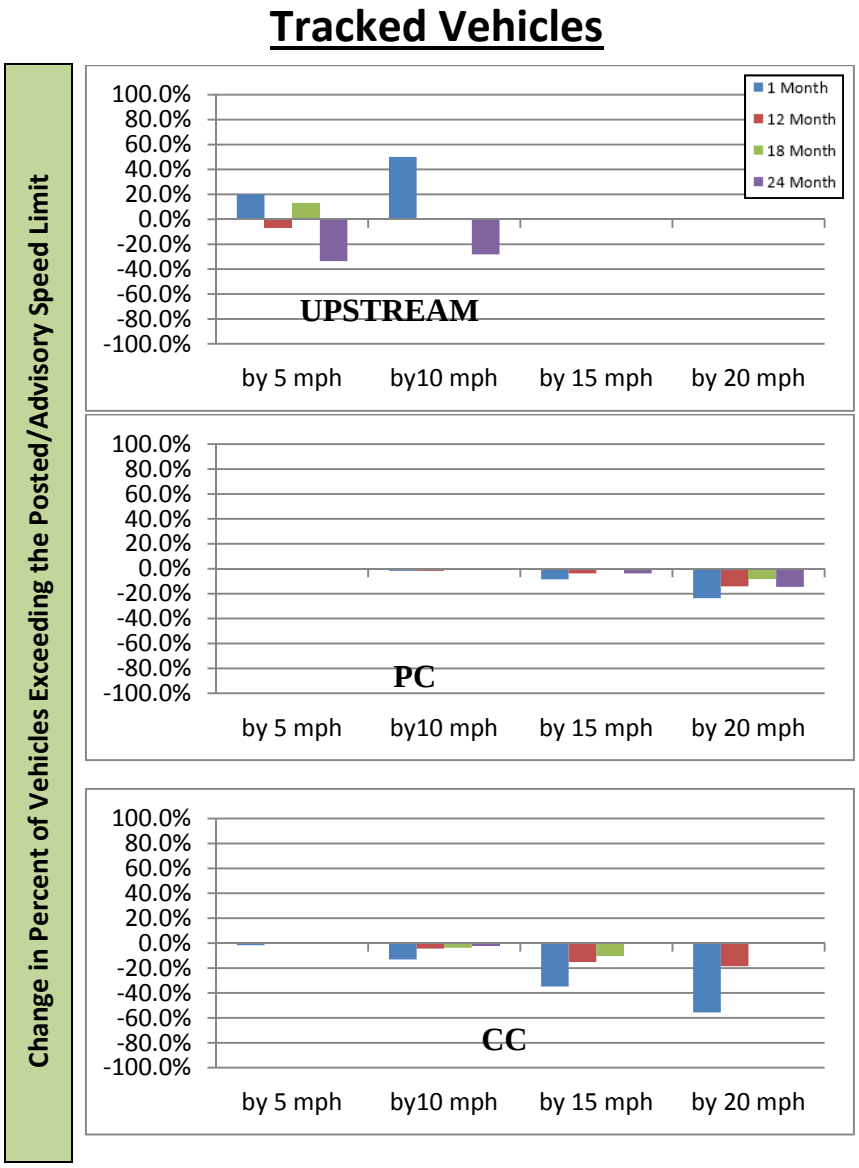


Figure 103. Graphs. Change in percentile (compared to before) of tracked vehicle speed - Wisconsin Hwy 67.

Wisconsin Highway 213

The site on Highway 213 in Wisconsin had a posted speed limit of 55 mph and an advisory speed of 50 mph. The signs were installed in June 2012 in the SB direction of travel. This site was located 3 miles east of Orfordville, WI.

Upstream speeds at this location significantly increased between 1.0 and 1.7 mph. Only the 24 month after period had little change in the upstream mean speed.

Reductions in the speed metrics at the PC varied which may be impacted by the upstream speed. The results at the PC are shown in Table 588. Large reductions in the mean speed occurred during the 18 and 24 month after periods of -1.6 and -2.1 mph respectively. A slight reduction in mean speed occurred at the 1 month after period of -0.7 mph. The mean speed during the 12 month after period increased by 0.2 mph but was not statistically significant at a 95-percent level of significant. This increase in the mean speed was significantly lower than the increase in mean speed upstream of 1.7 mph. Reductions in the 85th percentile speed only occurred during the 18 and 24 month after periods of -1 and -2 mph. Reductions in the percent of vehicles exceeding the advisory speed by 5 and 10 mph or more were found during the 18 and 24 month after periods. Changes in percent of vehicles were between -18.7 and -25.6 percent for 5 mph or more and between -43.9 and -48.8 percent for 10 mph or more.

Table 58. All Vehicle Results for Wisconsin - Hwy 213 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	2369	2249	-120	2445	76	2305	-64	2299	-70
Vehicles Count in SDCWS Direction	1156	1119		1214		1146		2290	
Upstream Mean Speed (mph)	58.8	59.8	1.0[A]	60.5	1.7[A]	60.1	1.3[A]	58.9	0.1
Mean Speed (mph)	55.3	54.6	-0.7	55.5	0.2[B]	53.7	-1.6	53.2	-2.1
Standard Deviation	7.0	6.6		6.2		6.8		6.6	
85th Percentile Speed (mph)	61	61	0	61	0	60	-1	59	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	63%	57%	-8.9%	63%	0.0%	51%	-18.7%	47%	-25.6%
% of Vehicles 10+ Over Advisory	28%	21%	-25.3%	27%	-5.9%[B]	16%	-43.9%	14%	-48.8%
% of Vehicles 15+ Over Advisory	3%	3%	0.0%	4%	38.4%[B]	2%	-25.0%[B]	1%	-65.8%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	1%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	28%	21%	-25.3%	27%	-5.9%[B]	16%	-42.9%	14%	-48.8%
% of Vehicles 10+ Over Limit	3%	3%	0.0%	4%	38.4%[B]	2%	-25.0%[B]	1%	-65.8%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	1%	41.9%[B]	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Reductions in the speed metrics occurred during the 1 month after and 24 month periods at the CC. The results at the CC are shown in Table 599. The changes in mean speed were not statistically significant for the 12 and 18 month after periods. The changes in mean speed were lower than the increase in mean speed that occurred upstream for the same periods. The reductions in mean speed were between -0.9 and -1.0 mph during the 1 and 24 month after periods with both also having a -1 mph change in the 85th percentile speed. Very little changed in the percent of vehicles exceeding the advisory speed at the CC.

Table 59. All Vehicle Results for Wisconsin - Hwy 213 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	2552	2428	-124	2596	44	2504	-48	2447	-105
Vehicles Count in SDCWS Direction	1220	1193		1278		1203		2416	
Upstream Mean Speed (mph)	58.8	59.8	1.0[A]	60.5	1.7[A]	60.1	1.3[A]	58.9	0.1
Mean Speed (mph)	53.2	52.2	-1.0	53.8	0.6[B]	52.9	-0.3[B]	52.3	-0.9
Standard Deviation	9.7	9.8		9.4		10.2		9.2	
85th Percentile Speed (mph)	61	60	-1	62	1	61	0	60	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	59%	52%	-11.1%	60%	1.7%[B]	58%	-2.5%[B]	50%	-17.0%
% of Vehicles 10+ Over Advisory	25%	20%	-20.1%	27%	7.0%[B]	23%	-8.2%[B]	18%	-34.0%
% of Vehicles 15+ Over Advisory	2%	3%	5.7%[B]	4%	72.0%	3%	38.6%[B]	2%	0.0%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	1%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	25%	20%	-20.1%	27%	7.0%[B]	23%	-8.2%[B]	18%	-34.0%
% of Vehicles 10+ Over Limit	2%	3%	5.7%[B]	4%	72.0%	3%	38.6%[B]	2%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	1%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance

Results for the tracked vehicles at the PC in Table 6060 were similar to the speed metrics for all vehicles. Increases in the mean speed occurred during all time periods except for the 24 month after period which had little change. The mean speed reductions were significantly reduced up to -2.0 mph. Only the 12 month after period did not have a statistically significant reduction in mean speed. The increase in upstream mean speed may have factored in speed at the PC.

For the three periods that had reductions in speed at the PC, the 85th percentile speeds were reduced between -1 and -2 mph. Changes in the percent of vehicles exceeding the advisory speed occurred in only the 5 and 10 mph or more ranges. The changes in percent of vehicles ranged between -12.6 and -42.6 percent.

Table 6161 shows the results of the tracked vehicles at the CC. Mean speeds were only reduced in the 1 month and 24 month after period of -1.2 and -0.9 mph respectively. Both of these time periods also had a reduction in 85th percentile speed of -1 mph. The 12 month and 18 month after periods had slight increases in the mean speed that were not statistically significant at a 95-percent level of significance. These slight increases were significantly lower than the increases in mean speed upstream.

Table 60. Tracked Vehicle Results for Wisconsin - Hwy 213 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	773	785		775		694		1473	
Upstream Mean Speed (mph)	59.4	60.1	0.7[A]	60.9	1.5[A]	60.7	1.3[A]	59.6	0.2
Mean Speed (mph)	56.2	55.0	-1.2	56.2	0.0	54.9	-1.3	54.2	-2.0
Standard Deviation	5.9	5.8		5.6		5.5		5.5	
85th Percentile Speed (mph)	62	61	-1	62	0	60	-2	60	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	67%	59%	-12.6%	66%	-2.2%[B]	56%	-16.1%	51%	-22.7%
% of Vehicles 10+ Over Advisory	31%	23%	-24.9%	30%	-2.8%[B]	19%	-39.1%	17%	-42.6%
% of Vehicles 15+ Over Advisory	4%	3%	-19.1%[B]	4%	-10.5%[B]	2%	-32.3%[B]	1%	-62.8%
% of Vehicles 20+ Over Advisory	1%	0%	-100%	0%	-80.0%[B]	1%	0.0%	0%	-89.2%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	31%	23%	-24.9%	30%	-2.8%[B]	19%	-39.1%	17%	-42.6%
% of Vehicles 10+ Over Limit	4%	3%	-19.1%[B]	4%	-10.5%[B]	2%	-32.3%[B]	1%	-62.8%
% of Vehicles 15+ Over Limit	1%	0%	-100%	0%	-80.0%[B]	1%	0.0%	0%	-89.2%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 61. Tracked Vehicle Results for Wisconsin - Hwy 213 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	773	785		775		694		1473	
Upstream Mean Speed (mph)	59.4	60.1	0.7[A]	60.9	1.5[A]	60.7	1.3[A]	59.6	0.2
Mean Speed (mph)	55.5	54.3	-1.2	56.0	0.5[B]	55.9	0.4[B]	54.6	-0.9
Standard Deviation	7.1	7.1		6.7		6.5		6.6	
85th Percentile Speed (mph)	62	61	-1	62	0	62	0	61	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	66%	57%	-12.9%	67%	1.5%[B]	66%	0.0%	57%	-13.8%
% of Vehicles 10+ Over Advisory	29%	23%	-22.4%	31%	6.8%[B]	29%	0.0%	23%	-22.9%
% of Vehicles 15+ Over Advisory	3%	2%	-30.7%[B]	5%	36.7%[B]	4%	28.1%[B]	2%	-41.5%
% of Vehicles 20+ Over Advisory	0%	0%	0.0%	0%	0.0%	1%	0.0%	0%	-48.7%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	29%	23%	-22.4%	31%	6.8%[B]	29%	0.0%	23%	-22.9%
% of Vehicles 10+ Over Limit	3%	2%	-30.7%[B]	5%	36.7%[B]	4%	28.1%[B]	2%	-41.5%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	1%	0.0%	0%	-48.7%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

After tracking the vehicles, the speed reductions for free flowing vehicles are shown in Table 62. Speed reductions were increases between the upstream and point of curvature between 1.6 and 2.7 mph with the largest increase in the 18 month period. Vehicles were slowing down more prior to entering the curve after the SDCWS was installed. The speed reductions from the point of curvature to the center of curve decreased after the SDCWS installation. This showed that vehicles were selecting an appropriate speed prior to entering the curve and did not need to further reduce their speed while negotiating the curve.

Table 62. Speed reduction for Wisconsin - Hwy 213.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	3.2	5.1	1.9	4.8	1.6	5.9	2.7	5.4	2.2
Mean Speed Reduction Upstream to CC (mph)	3.9	5.8	1.9	5	1.1	4.8	0.9	5.0	1.1
Mean Speed Reduction PC to CC (mph)	0.6	0.7	0.1[B]	0.2	-0.4	-1.1	-1.7	-0.4	-1.0
85th Percentile Speed Reduction Upstream to PC (mph)	8	10	2	10	2	10	2.0	10.2	2.2
85th Percentile Speed Reduction Upstream to CC (mph)	9	11	2	10	1	10	1.0	10.0	1.0
85th Percentile Speed Reduction PC to CC (mph)	2	2	0	1	-1	0	-2.0	0.0	-2.0

[B]Not statistically significant at 95-percent level of significance

Note: Positive change represents vehicles slowing down

Figure 1044 shows the impact the SDCWS had on the tracked vehicle speeds through the curve. Reductions in both mean and 85th percentile speed are shown at the PC while little change occurred at the center of curve with the exception of the 1 and 24 month after periods.

Figure 1055 and Figure 1066 show the mean speed profiles of all and tracked vehicles. The speed profiles at the 18 and 24 month periods are significantly different than the before speed profile. The change in percentile in Figure 1077 and Figure 1088 show the decreases in the percent of vehicles exceeding the advisory speed at both the PC and CC.

Wisconsin (Hwy 213)

Speed Limit: 55 mph
Curve Advisory Speed: 50 mph
Installed: June 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU)

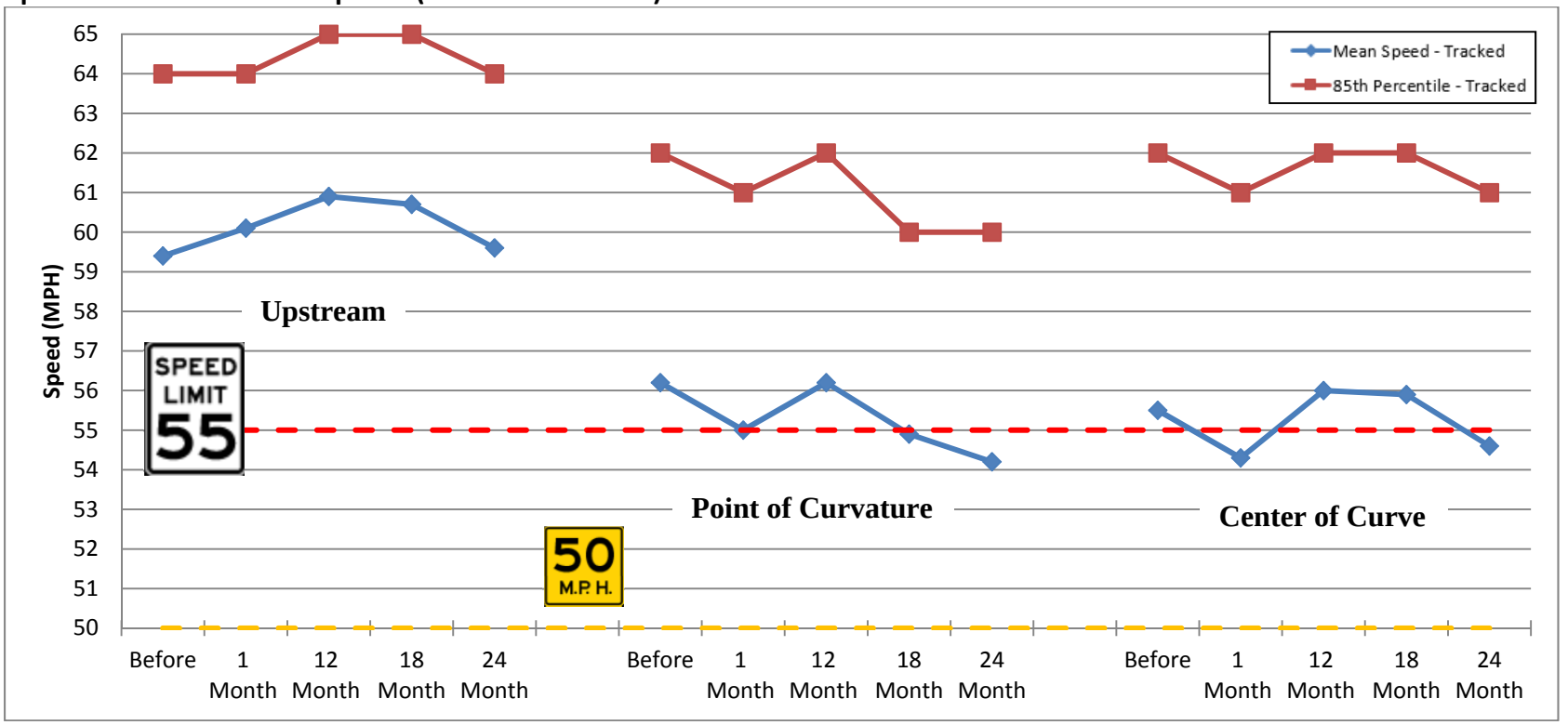


Figure 104. Graph. Impact on tracked vehicle speed - Wisconsin Hwy 213.

Wisconsin (Hwy 213)

Speed Profile All Vehicles

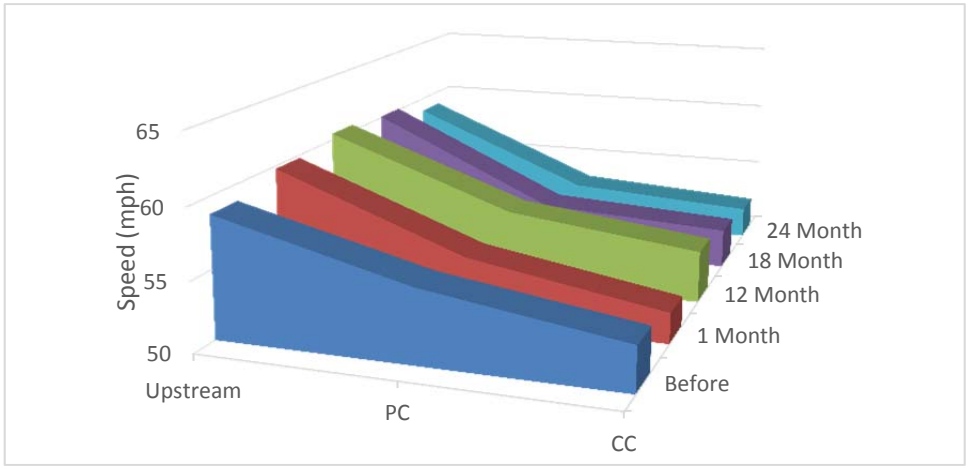


Figure 105. Graph. Speed profiles of all vehicles – Wisconsin Hwy 213.

Speed Profile Tracked Vehicles

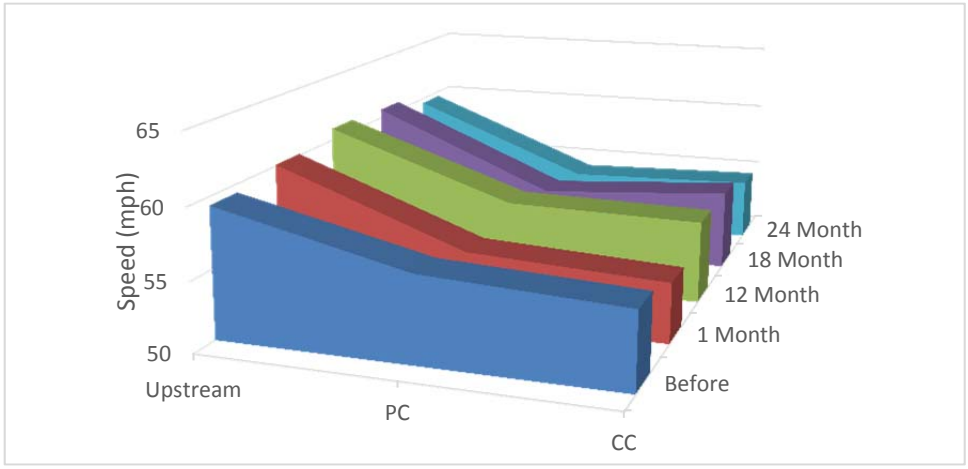


Figure 106. Graph. Speed profiles of tracked vehicles – Wisconsin Hwy 213.

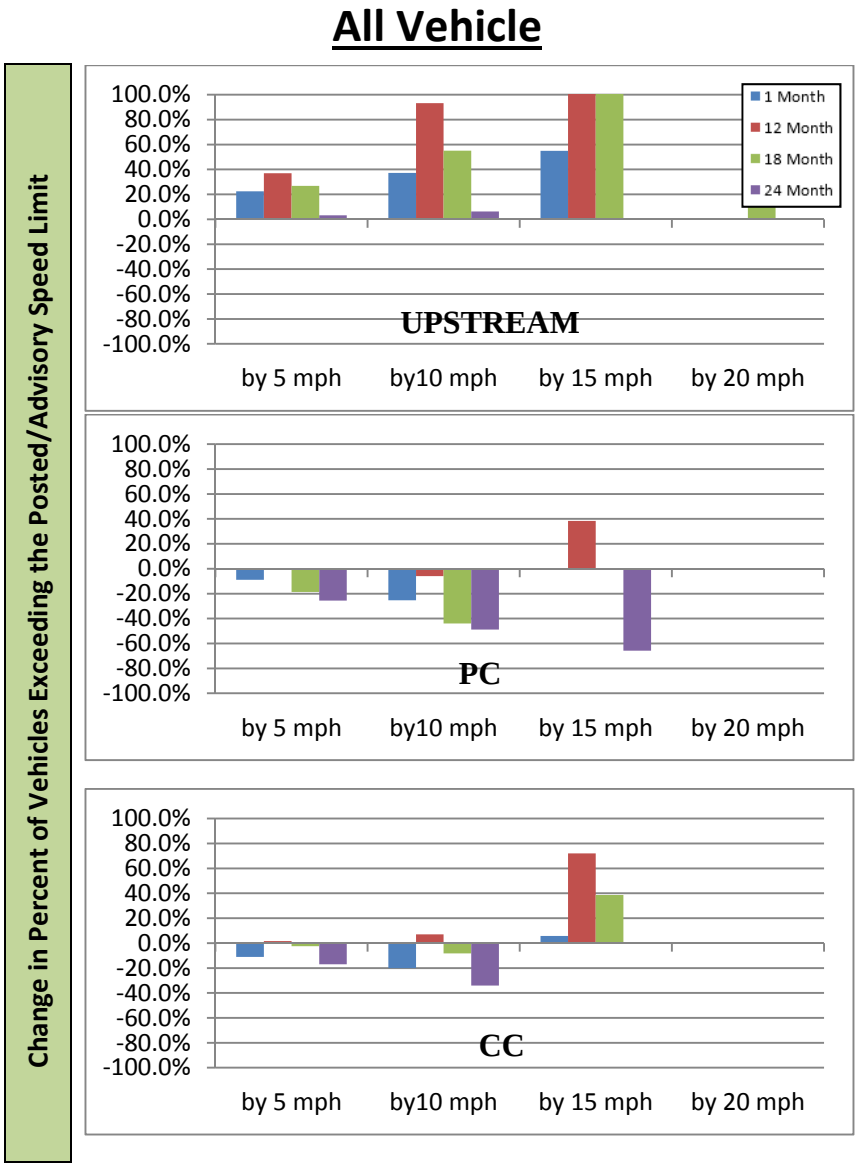


Figure 107. Graphs. Change in percentile (compared to before) of all vehicle speed - Wisconsin Hwy 213.

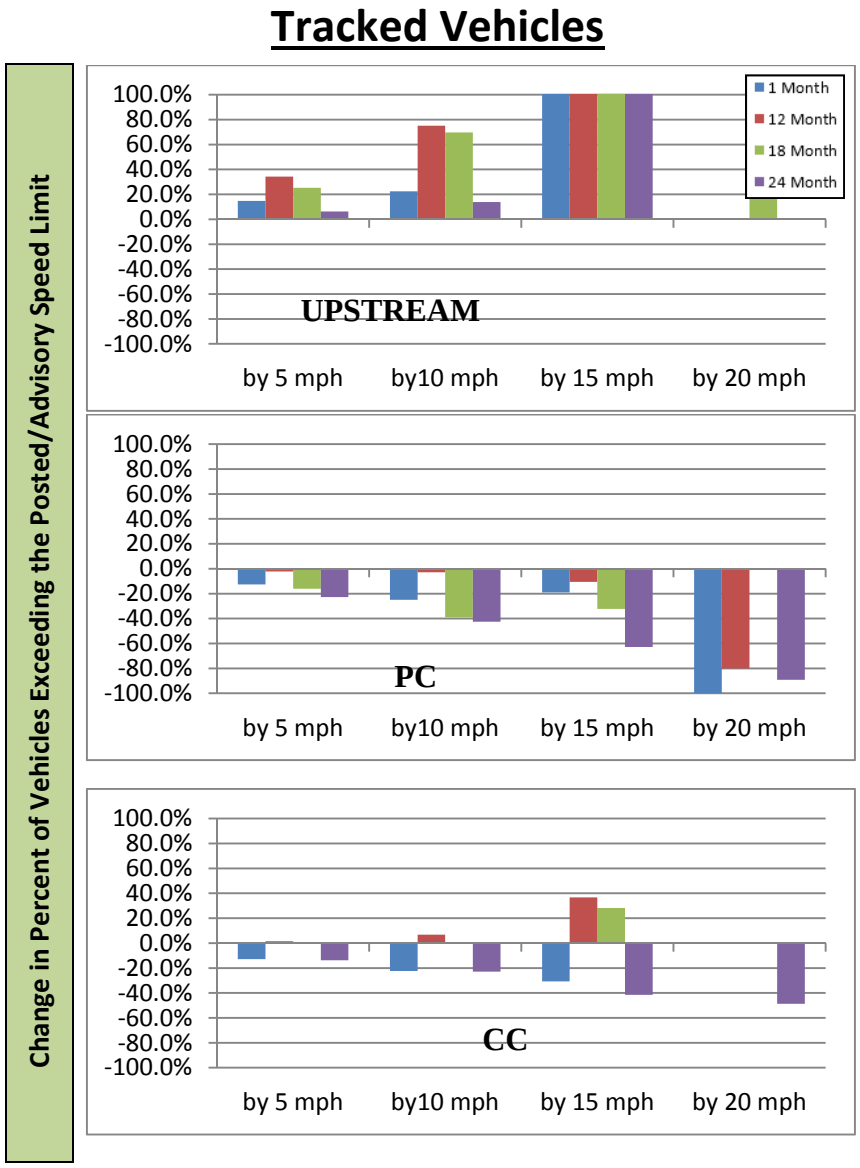


Figure 108. Graphs. Change in percentile (compared to before) of tracked vehicle speed - Wisconsin Hwy 213.

Texas FM 109

The SDCWS was installed in July of 2012 on FM 109 in Texas. The site is located 3 miles north of Industry, Texas with a posted speed limit of 60 mph and advisory speed of 35 mph. The system was installed for the NB direction of traffic.

The upstream mean speeds at FM 109 increased during the 1, 12, and 18 month after periods between 1.3 and 2.4 mph. During the 24 month after period, the mean speed reduced by -2.1 mph. The PC data is shown in Table 633. The only statistically significant reduction in mean speed was during the 1 month after period of -0.8 mph. Little change occurred during the 12 and 18 month after period but this may have been due to the increased mean speeds upstream. The change in mean speed was significantly lower at the PC then upstream showing that the SDCWS may have still impacted vehicle speeds. At 24 months after there was no change at the PC while the upstream had a statistically significant reduction in mean speed. Little to no change occurred in the percentage of vehicles exceeding the advisory speed limit.

Table 63. All Vehicle Results for Texas - FM 109 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	2193	2011	-182	2211	18	2082	-111	2154	-39
Vehicles Count in SDCWS Direction	1027	953		1079		1024		2132	
Upstream Mean Speed (mph)	58.3	59.6	1.3[A]	60.0	1.7[A]	60.7	2.4[A]	56.2	-2.1[A]
Mean Speed (mph)	46.7	45.9	-0.8	46.7	0.0	46.3	-0.4[B]	46.6	-0.1[B]
Standard Deviation	5.7	5.4		5.3		5.5		5.3	
85th Percentile Speed (mph)	52	51	-1	52	0	51	-1	52	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	92%	90%	-2.2%[B]	92%	0.0%	91%	-1.4%[B]	91%	-0.8%[B]
% of Vehicles 10+ Over Advisory	69%	63%	-8.9%	69%	0.0%	65%	-5.5%	67%	-2.4%[B]
% of Vehicles 15+ Over Advisory	30%	23%	-24.9%	30%	0.0%	27%	-11.6%	29%	-4.1%[B]
% of Vehicles 20+ Over Advisory	7%	4%	-41.7%	5%	-22.0%[B]	6%	-17.8%[B]	5%	-23.1%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Even with the increased speeds upstream, significant reductions were found at the CC in Table 644. During the 1, 12 and 18 month after periods the mean speeds were reduced between -0.6 and -1.6 mph as well as a reduction in the 85th percentile speed between -1 and -2 mph. The 24 month after period had a statistically significant reduction in mean speed of -1.0 mph but this was far less than the reduction in mean speed upstream of -2.1 mph. Due to this decreases in speed upstream the effectiveness of the SDCWS may have been reduced. Small reductions in the percentage of vehicles exceeding the advisory speed by 5, 10, and 15 mph or more were found. The greatest reductions occurred during the 1 month after period with a change in percentage of vehicles going over the advisory speed by 10 mph of -28.6 percent.

Table 64. All Vehicle Results for Texas - FM 109 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	2141	1970	-171	2174	33	2032	-109	2104	-37
Vehicles Count in SDCWS Direction	1006	937		1060		1006		2098	
Upstream Mean Speed (mph)	58.3	59.6	1.3[A]	60.0	1.7[A]	60.7	2.4[A]	56.2	-2.1[A]
Mean Speed (mph)	45.4	43.8	-1.6	44.8	-0.6	44.5	-0.9	44.4	-1.0
Standard Deviation	5.1	4.7		4.6		4.7		4.7	
85th Percentile Speed (mph)	50	48	-2	49	-1	49	-1	49	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	90%	85%	-5.9%	89%	-1.7%[B]	86%	-4.5%	87%	-3.7%
% of Vehicles 10+ Over Advisory	60%	44%	-28.6%	55%	-10.6%	52%	-15.0%	51%	-16.3%
% of Vehicles 15+ Over Advisory	18%	9%	-51.7%	15%	-17.7%	14%	-22.8%	12%	-33.1%
% of Vehicles 20+ Over Advisory	2%	1%	-57.0%	1%	-58.2%	2%	-36.1%[B]	1%	-50.2%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Speed metrics were reduced at the PC after tracking vehicles in Table 655 compared to the all vehicle speed metrics. Upstream speeds were still higher compared to the before data collection between 1.3 and 2.2 mph. Only the 24 month after period had a reduction in mean speed upstream. The major change from all vehicles was that the 18 month after data collection had a statistically significant mean speed change of -0.6 mph. The 85th percentile speed reduced by -2 mph during the 1 month after period and by -1 mph during all other after periods. Slight reductions occurred in the percent of vehicles exceeding the advisory speed. The largest reductions occurred in the 1 month after period in vehicles exceeding the advisory speed of 15 mph or more. At this data collection, the difference in percent of vehicles exceeding the advisory speed was 11 percent or a change in percent of vehicles of -30.9 percent.

Slightly higher reductions in speed metrics occurred after tracking vehicles at the CC in Table 666. The change in mean speed for the 1 month through 18 month after period were between -0.9 and -1.8 mph. During the 24 month after period, a -1.2 mph change in mean speed occurred but the change in upstream mean speed of -2.3 mph may have attributed to the reduction at the CC. The 85th percentile speed changed for the tracked vehicles up to -3 mph during the 1 month after period. The percentage of vehicles exceeding the advisory speed decreases for vehicles 5, 10 and 15 mph or more. The percentage of vehicles exceeding the advisory speed by 20 mph or more were not statistically significant. The 1 month after period showed a 20 percent difference in the percentage of vehicles 10 mph or more over the advisory speed.

Table 65. Tracked Vehicle Results for Texas - FM 109 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	655	586		727		645		1381	
Upstream Mean Speed (mph)	59.4	61.0	1.6[A]	60.7	1.3[A]	61.6	2.2[A]	57.1	-2.3[A]
Mean Speed (mph)	47.6	46.4	-1.2	47.3	-0.3[B]	47.0	-0.6	47.3	-0.3[B]
Standard Deviation	5.1	4.9		4.9		4.9		5.1	
85th Percentile Speed (mph)	53	51	-2	52	-1	52	-1	52	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	95%	91%	-3.7%	95%	0.0%	94%	-0.8%[B]	94%	-1.0%[B]
% of Vehicles 10+ Over Advisory	73%	67%	-8.0%	73%	0.0%	70%	-4.2%B	73%	0.0%
% of Vehicles 15+ Over Advisory	36%	25%	-30.9%	33%	-7.6%[B]	29%	-20.4%	34%	-6.1%[B]
% of Vehicles 20+ Over Advisory	8%	5%	-40.9%	6%	-20.1%[B]	7%	-17.6%[B]	7%	-17.7%[B]
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 66. Tracked Vehicle Results for Texas - FM 109 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	655	586		727		645		1381	
Upstream Mean Speed (mph)	59.4	61.0	1.6[A]	60.7	1.3[A]	61.6	2.2[A]	57.1	-2.3[A]
Mean Speed (mph)	46.1	44.3	-1.8	45.2	-0.9	44.9	-1.2	44.9	-1.2
Standard Deviation	4.9	4.3		4.5		4.5		4.6	
85th Percentile Speed (mph)	51	48	-3	50	-1	49	-2	49	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	92%	88%	-4.2%	91%	-1.0%[B]	89%	-3.0%	89%	-2.4%[B]
% of Vehicles 10+ Over Advisory	67%	47%	-29.7%	58%	-13.8%	55%	-17.0%	56%	-15.8%
% of Vehicles 15+ Over Advisory	22%	10%	-54.5%	16%	-26.7%	15%	-33.5%	14%	-38.2%
% of Vehicles 20+ Over Advisory	3%	1%	-47.3%[B]	1%	-46.9%[B]	2%	-40.4%[B]	1%	-50.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

The speed reductions for tracked vehicles in Table 677 shows if vehicles are reducing their speed while negotiating the curve. Increases in speed reduction occurred at all time periods except the 24 month after period. During this time the vehicles were not slowing down as much while approaching the curve which is due to the lower speeds while vehicles were approaching the curve. Higher speed reductions were then found while negotiating the curve between the PC and CC during the 24 month after period.

The 1, 12 and 18 month after periods showed mean speed reductions between 1.6 and 2.9 mph from the upstream to point of curvature. Vehicles were slowing down prior to the curve due to the SDCWS. Slightly higher mean speed reductions also occurred through the curve between the point of curvature and center of curve. These speed reductions show that the SDCWS was also effective throughout the curve by slowing driver down further.

Table 67. Speed Reduction for Texas – FM 109

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	11.8	14.6	2.8	13.4	1.6	14.7	2.9	9.8	-2.0
Mean Speed Reduction Upstream to CC (mph)	13.3	16.8	3.5	15.4	2.1	16.7	3.4	12.2	-1.1
Mean Speed Reduction PC to CC (mph)	1.5	2.2	0.7	2.1	0.6	2	0.5	2.4	0.9
85th Percentile Speed Reduction Upstream to PC (mph)	17	20	3	19	2	19	2	14	-3
85th Percentile Speed Reduction Upstream to CC (mph)	18	22	4	21	3	21	3	17	-1
85th Percentile Speed Reduction PC to CC (mph)	4	4.3	0.3	4	0	4	0	5	1

Note: Positive change represents vehicles slowing down

Figure 1099 shows the tracked vehicle speeds for all time periods at data collection locations on FM 109. The graphical representation of the data shows the higher speeds at the upstream location then a sharp drop during the 24 month after period. Meanwhile, speeds at the PC and CC reduced consistently after the before data collection.

Figure 11212 and Figure 11313 shows the changes in percent of vehicles exceeding the posted/advisory speed at the upstream, PC and CC. Reductions in vehicles exceeding the advisory speed limit are visually shown at both the PC and CC for all vehicles and similar results for the tracked vehicles.

Texas (FM 109)

Speed Limit: 60 mph
Curve Advisory Speed: 35 mph
Installed: July 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

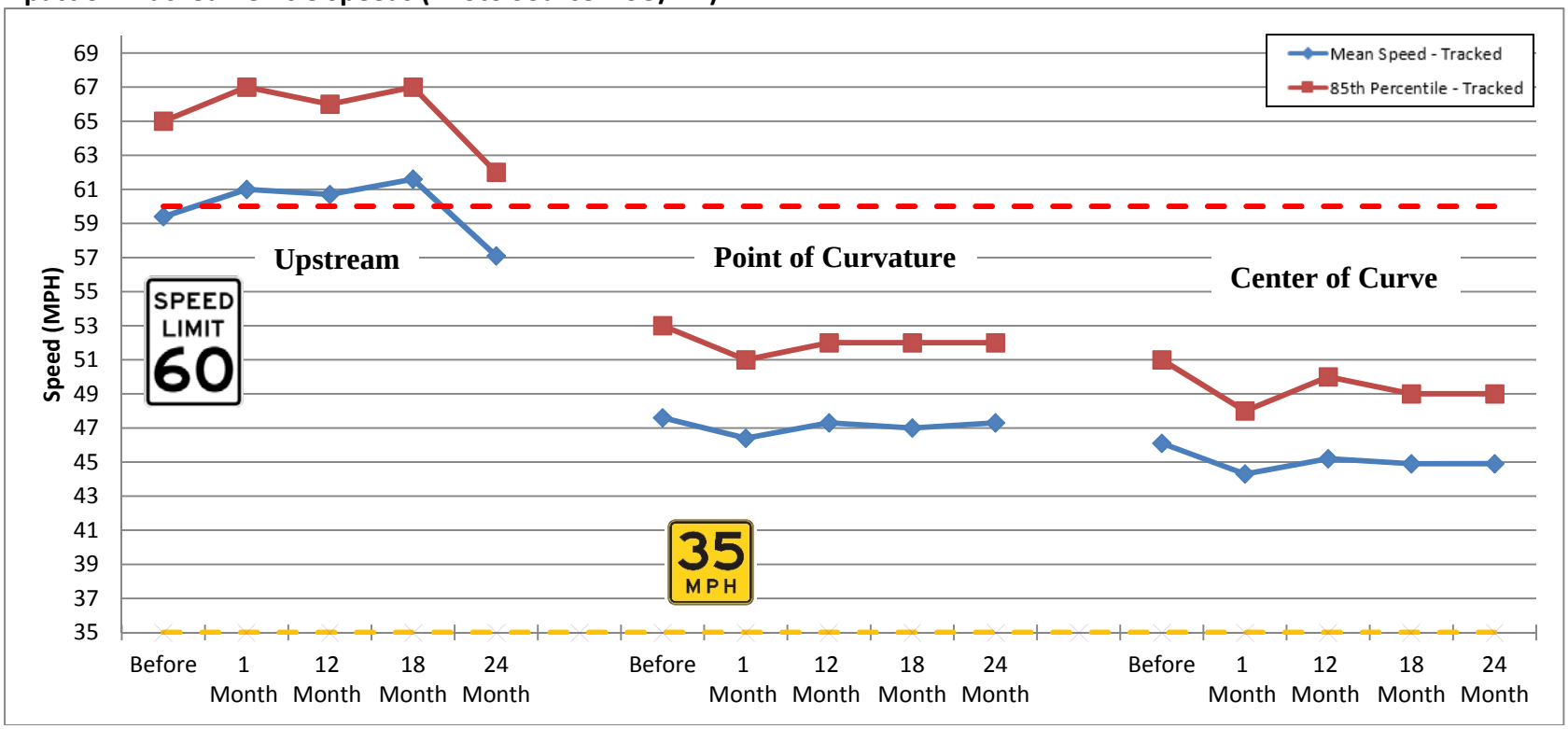


Figure 109. Graph. Impact on tracked vehicle speed - Texas FM 109.

Texas (FM 109)

Speed Profile All Vehicles

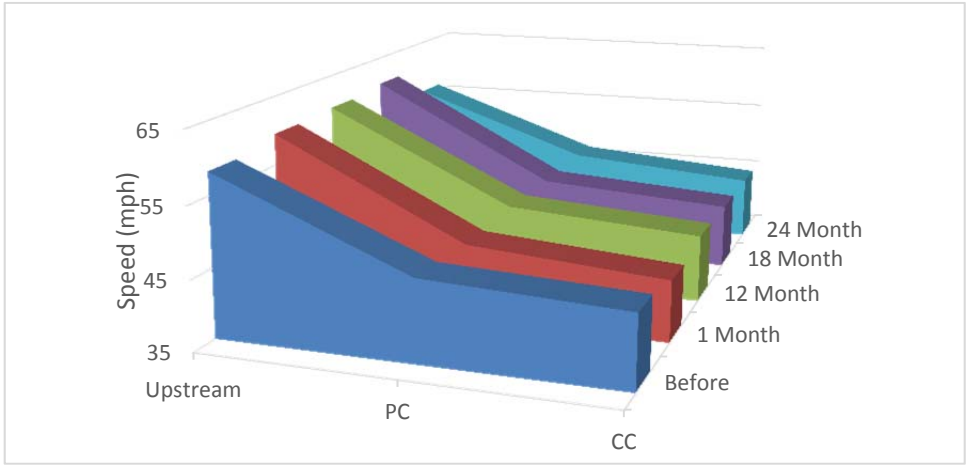


Figure 110. Graph. Speed profiles of all vehicles – Texas FM 109.

Speed Profile Tracked Vehicles

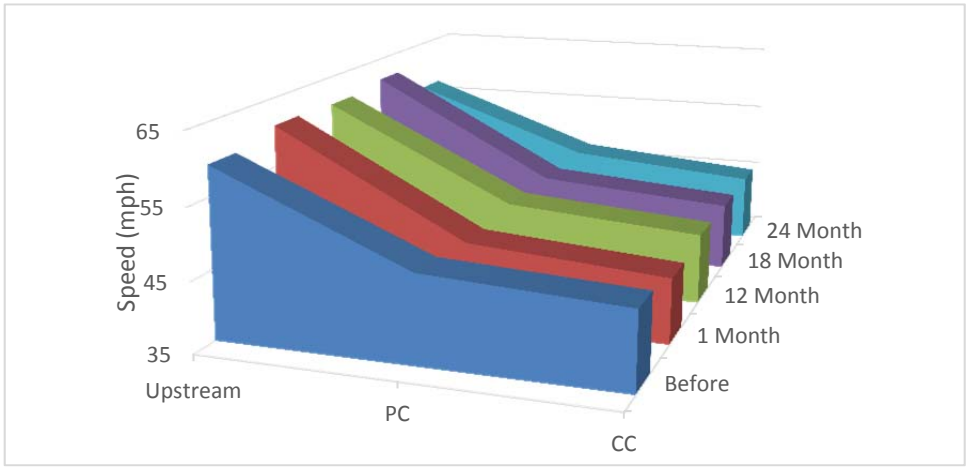


Figure 111. Graph. Speed profiles of tracked vehicles – Texas FM 109.

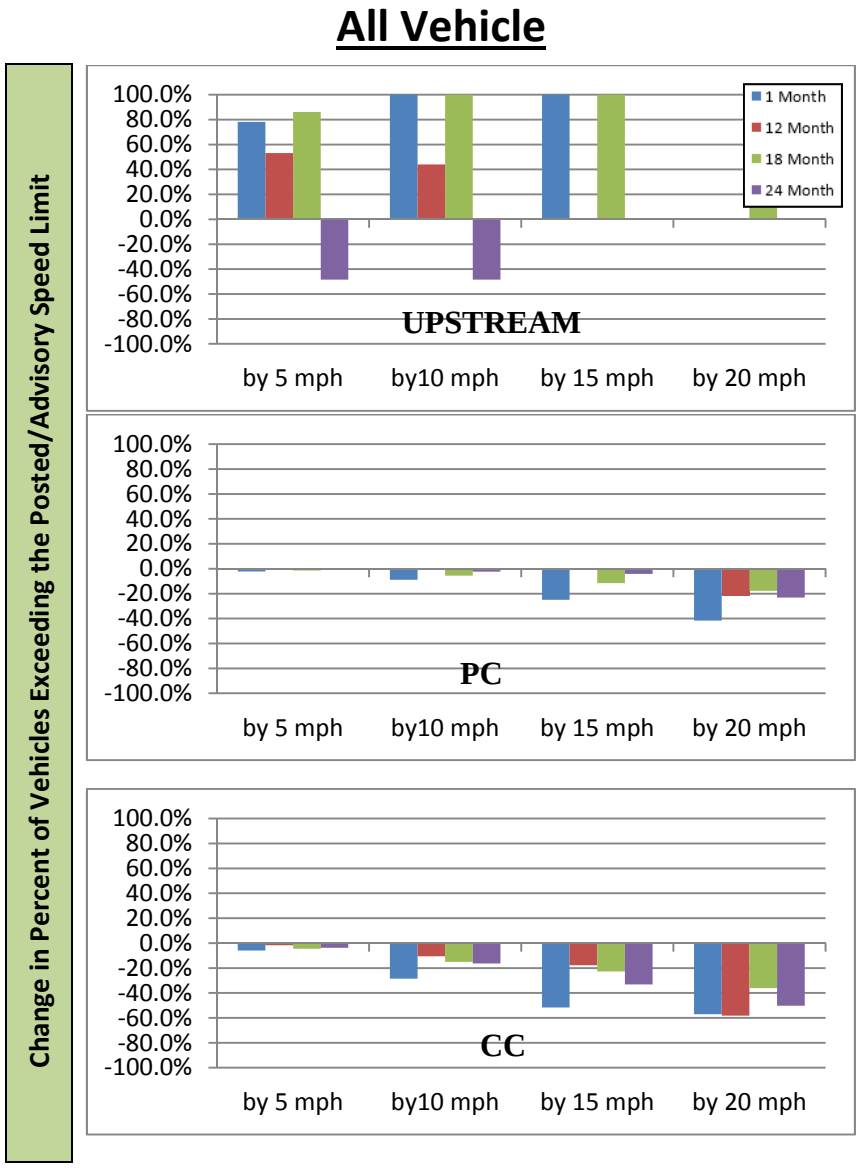


Figure 112. Graphs. Change in (compared to before) percentile of all vehicle speed - Texas FM 109.

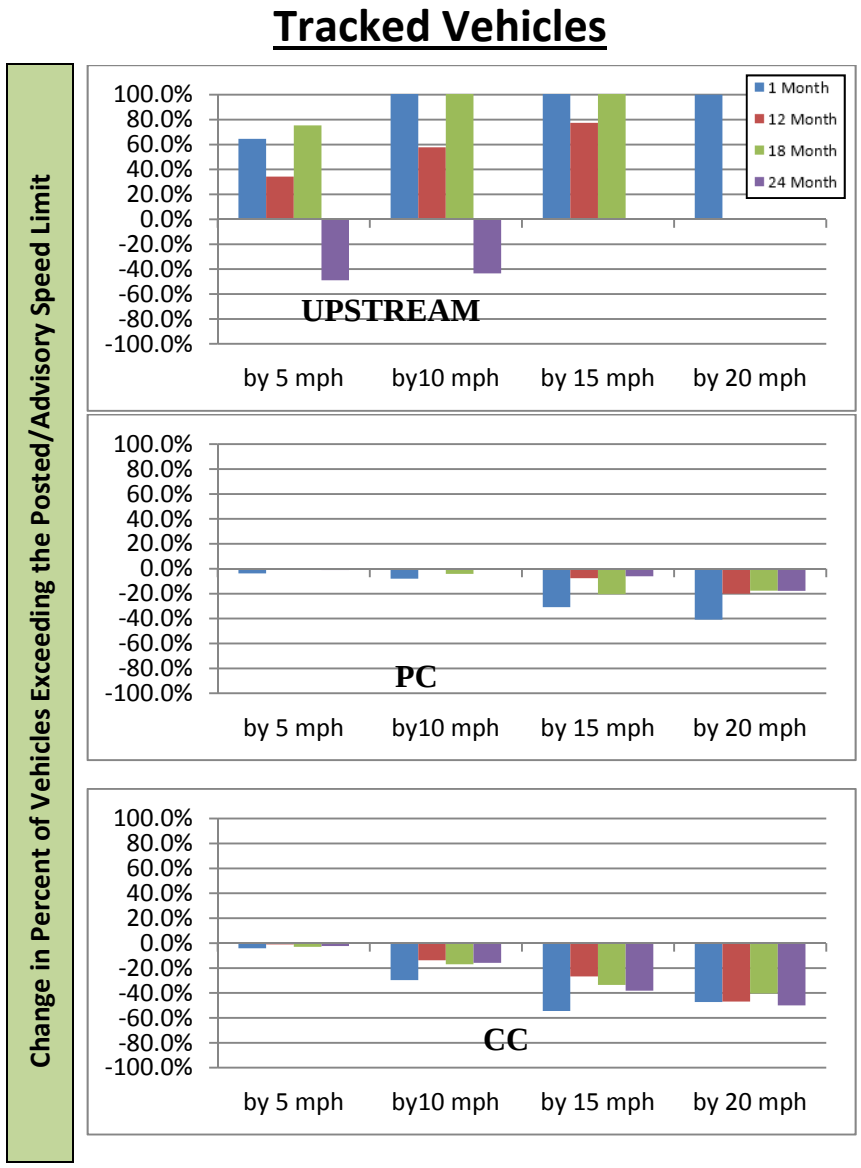


Figure 113. Graphs. Change in (compared to before) percentile of tracked vehicle speed - Texas FM 109.

Texas FM 407

The site on FM 407 in Texas had a posted speed limit of 55 mph and an advisory speed of 40 mph. The location of the upstream data collection was in a 60 mph area. The speed reduced to 55 mph approximately 150 feet prior to the curve warning sign. The signs were installed in July 2012 in the EB direction of travel. This site was located 6 miles west of Justin, Texas.

Table 688 shows the results at the PC for all vehicles. The upstream speeds showed reductions in mean speed between -0.6 and -1.2 mph. The mean speed changes at the PC were greater than the mean speed changes upstream showing that the SDCWS was effective at slowing vehicles before entering the curve. The largest reduction in mean speed at the PC occurred in the 24 month after period with a change of -2.2 mph. All time periods also had a reduction of -2 mph in the 85th percentile speed. Reductions are shown in the percent of vehicles exceeding the advisory speed by 5, 10, 15 and 20 mph or more. The largest change in percentage in vehicles exceeding the advisory speed occurred in the 20 mph or more vehicles with changes up to -68.3 percent. The largest difference in percent was in the vehicles of 10 mph or more with 67 percent of vehicles driving 10 mph or more before installation and down to 48.6 percent during the 24 month after period.

Table 68. All Vehicle Results for Texas - FM 407 at point of curvature (PC).

	Before[C]	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	2587	2771	184	2694	107	3019	432	3362	775
Vehicles Count in SDCWS Direction	1245	1425		1304		1510		3398	
Upstream Mean Speed (mph)	61.3	60.1	-1.2[A]	60.4	-0.9[A]	60.3	-1.0[A]	60.7	-0.6
Mean Speed (mph)	51.4	49.7	-1.7	49.6	-1.8	49.3	-2.1	49.2	-2.2
Standard Deviation	5.8	5.3		5.3		5.5		5.3	
85th Percentile Speed (mph)	57	55	-2	55	-2	55	-2	55	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	89%	83%	-7.0%	84%	-5.6%	84%	-6.0%	82%	-7.8%
% of Vehicles 10+ Over Advisory	67%	53%	-20.9%	54%	-19.4%	51%	-24.6%	49%	-27.4%
% of Vehicles 15+ Over Advisory	29%	18%	-39.8%	16%	-44.2%	16%	-45.4%	15%	-48.6%
% of Vehicles 20+ Over Advisory	6%	3%	-48.5%	2%	-68.3%	2%	-62.0%	2%	-66.7%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	6%	3%	-48.5%	2%	-68.3%	2%	-62.0%	2%	-66.7%
% of Vehicles 10+ Over Limit	1%	0%	-89.1%	0%	-76.6%	0%	-68.8%	0%	-71.9%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[C]Only 18 hours of data collected from puncture in the tube

The results at the CC are shown in Table 699. Significant reductions were found in the speed metrics at the CC. The mean speed reductions were all greater than the reductions in mean speed shown upstream. Significant reductions occurred during the 12, 18 and 24 month after periods with -2.5 mph changes.

The 85th percentile speeds were reduced by up to -3 mph at the CC. The reductions in the percentage of vehicles exceeding the advisory speed by 5, 10, 15, and 20 mph were all significant. The changes in percentage of vehicles going 10, 15, and 20 mph over the advisory speed were all greater than -35.7 percent with a majority greater than a 50 percent change.

Table 69. All Vehicle Results for Texas - FM 407 at center of curve (CC).

	Before[C]	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	2773	2781	8	2692	-81	3024	251	3364	591
Vehicles Count in SDCWS Direction	1299	1424		1305		1505		3377	
Upstream Mean Speed (mph)	61.3	60.1	-1.2[A]	60.4	-0.9[A]	60.3	-1.0[A]	60.7	-0.6
Mean Speed (mph)	47.7	46.3	-1.4	45.2	-2.5	45.2	-2.5	45.1	-2.6
Standard Deviation	6.7	5.5		5.6		5.8		5.6	
85th Percentile Speed (mph)	53	51	-2	50	-3	51	-2	50	-3
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	77%	67%	-12.1%	60%	-21.1%	60%	-21.8%	58%	-24.6%
% of Vehicles 10+ Over Advisory	41%	26%	-35.7%	21%	-49.8%	20%	51.3%	19%	-52.6%
% of Vehicles 15+ Over Advisory	11%	4%	-57.7%	3%	-72.6%	3%	-73.1%	3%	-68.7%
% of Vehicles 20+ Over Advisory	2%	1%	-56.8%	0%	-68.5%	0%	-77.4%	0%	-71.9%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	2%	1%	-56.8%	0%	-68.5%	0%	-77.4%	0%	-71.9%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[C]Only 16 hours of data collected from puncture in the tube

The results after tracking vehicles are shown for the PC in Table 7070 and for the CC in Table 7171. The upstream speeds showed reductions in the mean speeds between -0.6 and -1.2 mph. The mean speeds at the PC and CC had greater changes than upstream showing the SDCWS was effective as slowing vehicles down in free flow. Changes in mean speed between -1.8 and -2.2 mph occurred at the PC with a reduction in 85th percentile speed of -2 mph. Slightly higher changes in mean speed are also shown at the CC. The maximum reduction in mean speed at the CC occurred during the 12 month after period with -3.0 mph. The 85th percentile speeds reduced between -2 and -4 mph.

Significant reductions were also shown in the percentage of vehicles exceeding the advisory speed at the PC and CC. At the CC, over a 50 percent change in percent of vehicles exceeding the advisory speed by 10 and 15 mph except during the 1 month after period. Consistent decreases at the PC also resulted in the percentage of vehicles traveling over the advisory speed, with up to -8.4 percent for the 5 mph over, up to -26.0 percent for 10 mph or more over, up to -47.9 percent for the 15 mph over, and up to -70.1 percent for 20 mph over.

Table 70. Tracked Vehicle Results for Texas –FM 407 at point of curvature (PC).

	Before[C]	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	772	931		926		938		1942	
Upstream Mean Speed (mph)	62.0	61.0	-1.0[A]	60.8	-1.2[A]	61.2	-0.8[A]	61.4	-0.6[A]
Mean Speed (mph)	51.9	50.1	-1.8	49.7	-2.2	49.9	-2.0	49.7	-2.2
Standard Deviation	5.2	5.4		5.2		5.2		5.1	
85th Percentile Speed (mph)	57	55	-2	55	-2	55	-2	55	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	92%	84%	-8.4%	85%	-7.6%	87%	-5.6%	85%	-7.1%
% of Vehicles 10+ Over Advisory	71%	57%	-20.1%	55%	-22.6%	55%	-22.1%	52%	-26.0%
% of Vehicles 15+ Over Advisory	31%	19%	-39.5%	16%	-47.9%	17%	-44.1%	18%	-43.7%
% of Vehicles 20+ Over Advisory	6%	4%	-40.3%	2%	-70.1%	3%	-55.6%	3%	-61.1%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	6%	4%	-40.3%	2%	-70.1%	3%	-55.6%	3%	-61.1%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[C]Only 18 hours of data collected from puncture in the tube

Table 71. Tracked Vehicle Results for Texas –FM 407 at center of curve (CC).

	Before[C]	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	836	931		926		938		1942	
Upstream Mean Speed (mph)	62.0	61.0	-1.0[A]	60.8	-1.2[A]	61.2	-0.8[A]	61.4	-0.6[A]
Mean Speed (mph)	48.4	46.7	-1.7	45.4	-3.0	45.8	-2.6	45.6	-2.8
Standard Deviation	5.6	5.4		5.4		5.3		5.4	
85th Percentile Speed (mph)	54	52	-2	50.3	-4	51	-3	51	-3
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	80%	70%	-12.9%	61%	-24.0%	64%	-20.3%	61%	-23.4%
% of Vehicles 10+ Over Advisory	45%	29%	-35.1%	20%	-55.0%	22%	-51.6%	21%	-52.6%
% of Vehicles 15+ Over Advisory	11%	5%	-53.2%	3%	-72.2%	3%	-72.5%	4%	-64.8%
% of Vehicles 20+ Over Advisory	1%	1%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	1%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[C]Only 16 hours of data collected from puncture in the tube

The results of speed reductions after tracking vehicles are shown in Table 722. Unlike the other sites, the mean speed reduction from upstream to the PC was negative showing vehicles were not slowing down as much prior to entering the curve. Modest changes were shown in the speed reduction from the upstream to center of curve showing vehicles were slowing down from the SDCWS but this was occurring through the curve. The highest changes in speed reduction occurred within the curve between the point of curvature and center of curves. Vehicles were slowing down between 3.8 and 4.8 mph more after the installation. At this curve, vehicles were not slowing down as much before entering the curve but significantly reduced their speed while traversing the curve. Overall speed reductions were greater from the upstream to center of curve showing the signs were effective.

Table 72. Speed Reduction for Texas – FM 407.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	14.1	10.9	-3.2	11.1	-3	11.3	-2.8	11.7	-2.4
Mean Speed Reduction Upstream to CC (mph)	13.6	14.3	0.7	15.4	1.8	15.4	1.8	15.9	2.3
Mean Speed Reduction PC to CC (mph)	-0.5	3.3	3.8	4.3	4.8	4.1	4.6	4.2	4.7
85th Percentile Speed Reduction Upstream to PC (mph)	17	16	-1	16	-1	16	-1	17	0
85th Percentile Speed Reduction Upstream to CC (mph)	19	20	1	20	1	21	2	21	2
85th Percentile Speed Reduction PC to CC (mph)	6	6	0	7	1	7	1	7	1

Note: Positive change represents vehicles slowing down

Figure 1144 through Figure 1188graphically represent the data collected on FM 407. The tracked vehicle mean and 85th percentile speeds are shown in Figure 1144. The reductions in speed are shown at the point of curvature and center of curve.

Figure 1177 and Figure 1188 show the change in percent of vehicles exceeding the advisory speed. The change in percentage are significantly higher at the point of curvature and center of curve compared to the reductions at the upstream location.

Texas (FM 407)

Speed Limit: 55 mph
Curve Advisory Speed: 40 mph
Installed: July 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

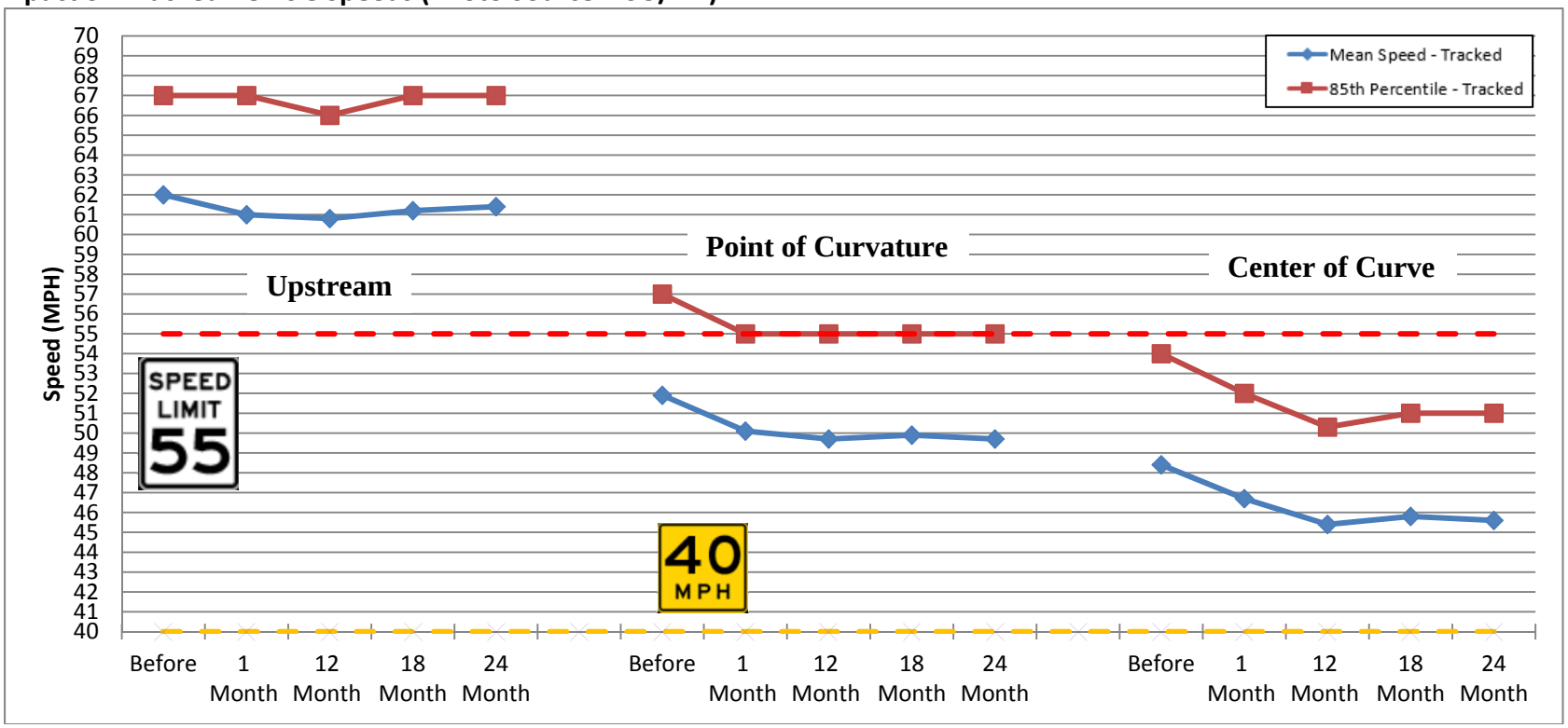


Figure 114. Graph. Impact on tracked vehicle speed - Texas FM 407.

Texas (Hwy 407)

Speed Profile
All Vehicles

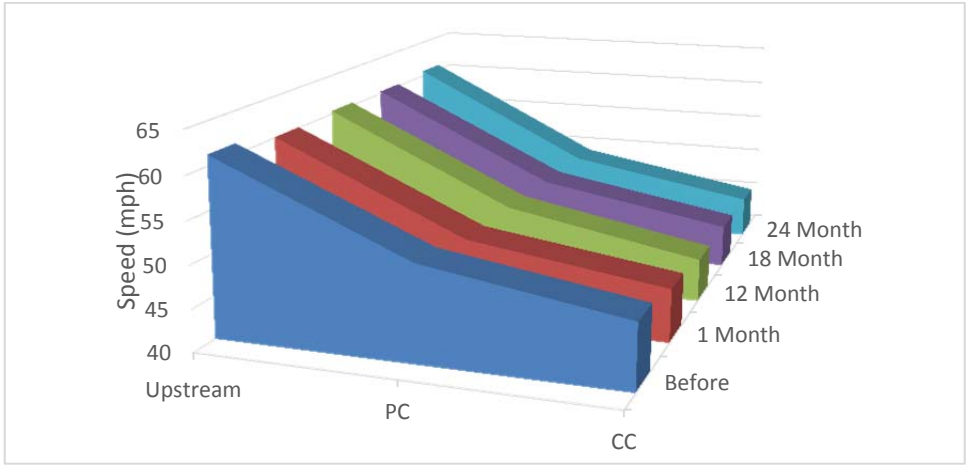


Figure 115. Graph. Speed profiles of all vehicles – Texas FM 407.

Speed Profile
Tracked Vehicles

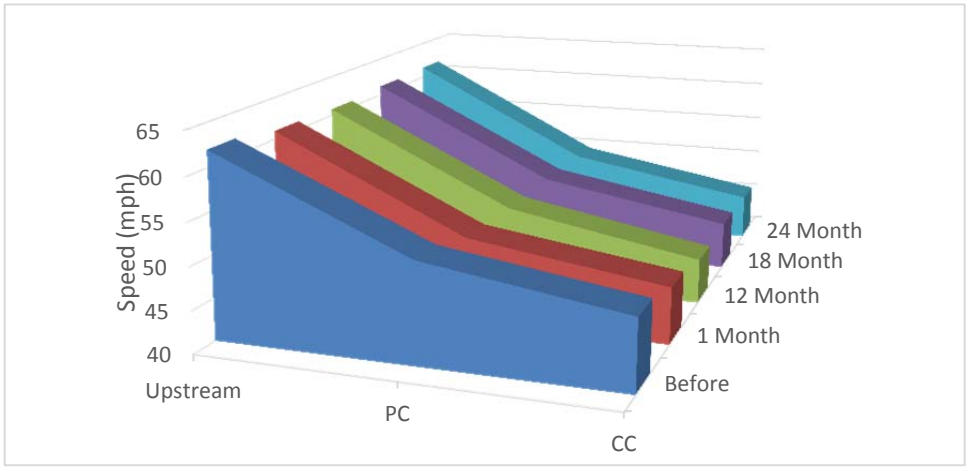


Figure 116. Graph. Speed profiles of all vehicles – Texas FM 407.

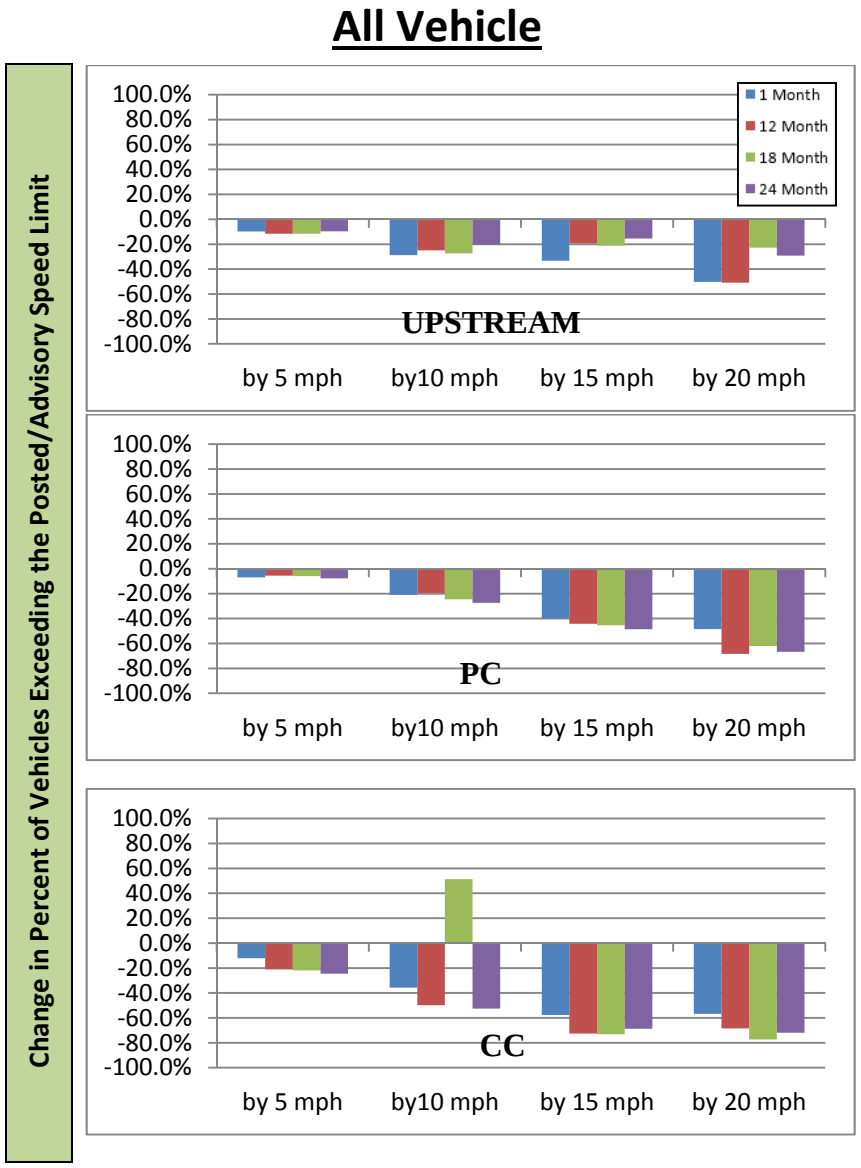


Figure 117. Graphs. Change in percentile (compared to before) of all vehicle speed - Texas FM 407.

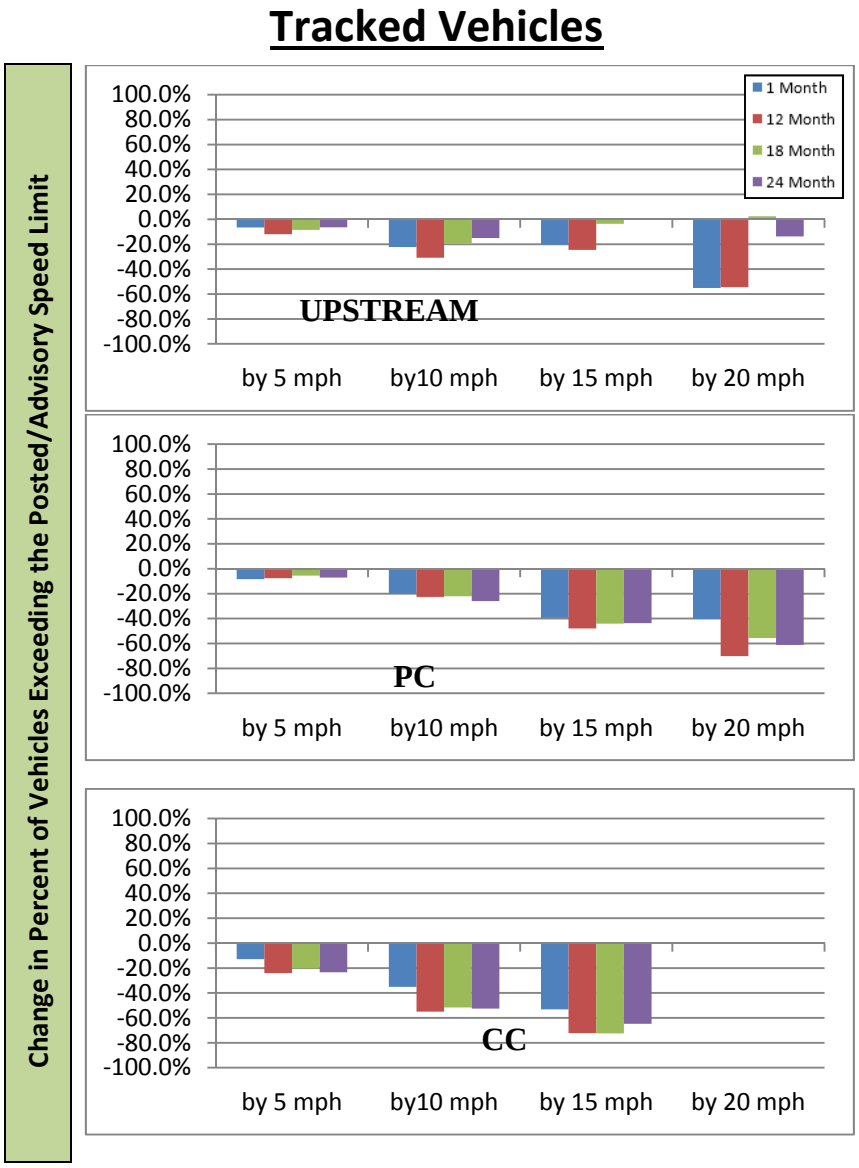


Figure 118. Graphs. Change in percentile (compared to before) of all vehicle speed - Texas FM 407.

Texas FM 530

FM 530 in Texas has a posted speed limit of 60 mph with an advisory speed limit of 35 mph. The SDCWS was installed for the WB direction of traffic in July 2012. The site is located 18 miles southeast of Hallettsville, Texas.

Little speed change occurred at the PC on FM 530 shown in Table 73. Statistically significant decreases in the upstream speed occurred during the 1 month, 12 month and 24 month periods. The decreases in speed at the PC were not statistically significant at a 95 percent level of significance for the 1 month, 12 month and 18 month after period. With the mean speed changes at the PC being smaller than the changes upstream, the effectiveness of the SDCWS may have been reduced due to the overall lower speeds on the roadway. Only the 24 month after period had a significant mean speed reduction of -3.1 mph which was higher than the change in mean speed upstream. During this time, the 85th percentile speeds changed by -3 mph and decreases were shown in the percentage of vehicles exceeding the advisory speed.

Table 73. All Vehicle Results for Texas - FM 530 at point of curvature (PC).

	Before[C]	1 Mo	1 Mo Change	12 Mo[D]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	303	418	115	497	194	397	94	501	198
Vehicles Count in SDCWS Direction	140	394		499		409		559	
Upstream Mean Speed (mph)	62.6	60.2	-2.4[A]	61.2	-1.4[A]	62.5	-0.1	60.9	-1.7[A]
Mean Speed (mph)	47.3	46.3	-1.0[B]	46.2	-1.1[B]	46.4	-0.9[B]	44.2	-3.1
Standard Deviation	8.6	6.5		6.7		6.5		7.6	
85th Percentile Speed (mph)	55	53	-2	52	-3	53	-2	52	-3
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	87%	88%	1.1%[B]	85%	-2.9%[B]	86%	-1.5%[B]	78%	-10.9%
% of Vehicles 10+ Over Advisory	76%	62%	-17.5%	65%	-14.5%	67%	-10.9%	52%	-31.0%
% of Vehicles 15+ Over Advisory	41%	31%	-24.0%	32%	-23.6%	32%	-23.9%	23%	-43.9%
% of Vehicles 20+ Over Advisory	16%	10%	-38.2%	7%	-54.9%	10%	-39.0%	5%	-71.7%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

[C]Before count had many unknown counts leading to less counts for 24 hour period

[D]There were 38% Class 14 but only in direction 2 which was not part of analysis

The results at the CC in Table 744 were slightly better than at the PC. All changes in mean speed were statistically significant at a 95 percent level of significance. During the 1 month after period, changes in mean speed at the PC and upstream were similar suggesting that speeds at the PC may have been influenced by the overall decrease in speeds on the roadway.

The 12, 18 and 24 month after periods had significant reductions in mean speeds between -1.3 and -3.0 mph, while the 85th percentile speeds were between -1 and -3 mph. This shows the SDCWS is effective at slowing vehicles through the curve.

Table 74. All Vehicle Results for Texas - FM 530 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	471	430	-41	501	30	408	-63	498	27
Vehicles Count in SDCWS Direction	477	402		508		411		560	
Upstream Mean Speed (mph)	62.6	60.2	-2.4[A]	61.2	-1.4[A]	62.5	-0.1	60.9	-1.7[A]
Mean Speed (mph)	43.6	41.0	-2.6	40.8	-2.8	42.3	-1.3	40.6	-3.0
Standard Deviation	6	5.5		5.8		5.4		6.1	
85th Percentile Speed (mph)	49	46	-3	46	-3	48	-1	46	-3
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	81%	64%	-20.2%	65%	-19.0%	71%	-11.7%	61%	-24.3%
% of Vehicles 10+ Over Advisory	47%	25%	-47.0%	25%	-47.2%	36%	-24.0%	26%	-44.6%
% of Vehicles 15+ Over Advisory	12%	5%	-55.0%	4%	-69.2%	7%	-40.0%	5%	-57.4%
% of Vehicles 20+ Over Advisory	2%	0%	-100%	0%	-89.4%	1%	-22.8%[B]	0%	-100%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 755 shows the results after tracking vehicles at the PC. The upstream speeds were lower during all after periods by up to -2.7 mph. With the exception of the 24 month after period, mean speed changes at the PC were lower than upstream or not statistically significant. This suggests that the effectiveness of the SDCWS may have been reduced due to overall slower speeds. During the 24 month after period, a mean speed reduction of -2.8 and 85th percentile speed reduction of -3 mph was documented. The percentage of vehicles exceeding the speed limit by 10, 15, and 20 mph were reduced with the largest decrease at 20 mph or more with -76.1 percent.

Similar results to all vehicles were found after tracking vehicles at the CC in Table 766. Vehicle speeds decreased from the SDCWS during the 12, 18 and 24 month after periods. The 1 month after period had little change in mean speed compared to the upstream. The 85th percentile speeds during the effective time periods were between -2 and -3 mph.

Table 75. Tracked Vehicle Results for Texas – FM 530 at point of curvature (PC).

	Before[C]	1 Mo	1 Mo Change	12 Mo[D]	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	107	327		398		336		403	
Upstream Mean Speed (mph)	63.1	60.4	-2.7[A]	61.4	-1.7	62.9	-0.2	62.2	-0.9
Mean Speed (mph)	48.3	46.5	-1.8	46.7	-1.6	47.0	-1.3[B]	45.5	-2.8
Standard Deviation	7.6	6.6		6.5		6.2		6.5	
85th Percentile Speed (mph)	55	53	-2	53	-2	53	-2	52	-3
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	90%	88%	-1.5%[B]	87%	-3.4%[B]	87%	-3.1%[B]	84%	-6.2%[B]
% of Vehicles 10+ Over Advisory	81%	63%	-22.5%	67%	-17.8%	71%	-13.2%	59%	-27.4%
% of Vehicles 15+ Over Advisory	45%	32%	-28.4%	35%	-22.7%	35%	-23.0%	27%	-39.1%
% of Vehicles 20+ Over Advisory	19%	11%	-39.5%	9%	-51.6%	11%	-41.1%	4%	-76.1%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	1%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance
[C]Before count had many unknown counts leading to less counts for 24 hour period
[D]There were 38% Class 14 but only in direction 2 which was not part of analysis

Table 76. Tracked Vehicle Results for Texas – FM 530 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	107	327		398		336		403	
Upstream Mean Speed (mph)	63.1	60.4	-2.7[A]	61.4	-1.7	62.9	-0.2	62.2	-0.9
Mean Speed (mph)	44.3	41.4	-2.9	41.5	-2.8	42.8	-1.5	41.6	-2.7
Standard Deviation	6.1	5.2		5.2		5.2		5.3	
85th Percentile Speed (mph)	50	46	-4	47	-3	48	-2	46.7	-3
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	84%	65%	-22.2%	68%	-19.0%	74%	-11.5%	67%	-20.3%
% of Vehicles 10+ Over Advisory	50%	27%	-45.7%	28%	-43.7%	37%	-25.5%	30%	-39.4%
% of Vehicles 15+ Over Advisory	17%	6%	-63.6%	5%	-73.1%	9%	-48.7%	5%	-69.0%
% of Vehicles 20+ Over Advisory	4%	0%	-100%	0%	-100%	2%	-52.1%[B]	0%	-100%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance

Changes in the speed reductions after tracking vehicles are shown in Table 777. The 18 month after period had no statistically significant difference in speed reductions between any of the data collection points. The 1 and 12 month after periods also did not have statistically significant reductions from the upstream to PC or CC but had a statistically significant change between the PC and CC. During the 24 month after period the SDCWS were effective in increasing the speed reduction while approaching the curve. Vehicles were slowing down 1.9 mph more between the upstream and PC.

Table 77. Speed Reduction for Texas – FM 530.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	14.8	13.9	-0.9[B]	14.7	-0.1[B]	15.9	1.1[B]	16.7	1.9
Mean Speed Reduction Upstream to CC (mph)	18.8	19.0	0.2[B]	20	1.2[B]	20.1	1.3[B]	20.6	1.8
Mean Speed Reduction PC to CC (mph)	4.0	5.1	1.1	5.3	1.3	4.2	0.2[B]	4	0.0
85th Percentile Speed Reduction Upstream to PC (mph)	21	19	-2	20.5	-0.5	21.8	1	22.7	2
85th Percentile Speed Reduction Upstream to CC (mph)	25	25	0	25.5	0.5	26	1	26.7	2
85th Percentile Speed Reduction PC to CC (mph)	8	8	0.1	8	0	8	0	7	-1

[B]Not statistically significant at 95-percent level of significance

Note: Positive change represents vehicles slowing down

Figure 1199 through Figure 12323 graphically show the data collected on FM 530. Little change can be seen in the data other than the reductions see at the CC. Other changes were either statistically insignificant or mirrored the changes in speed upstream.

Texas (FM 530)

Speed Limit: 60 mph
Curve Advisory Speed: 35 mph
Installed: July 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

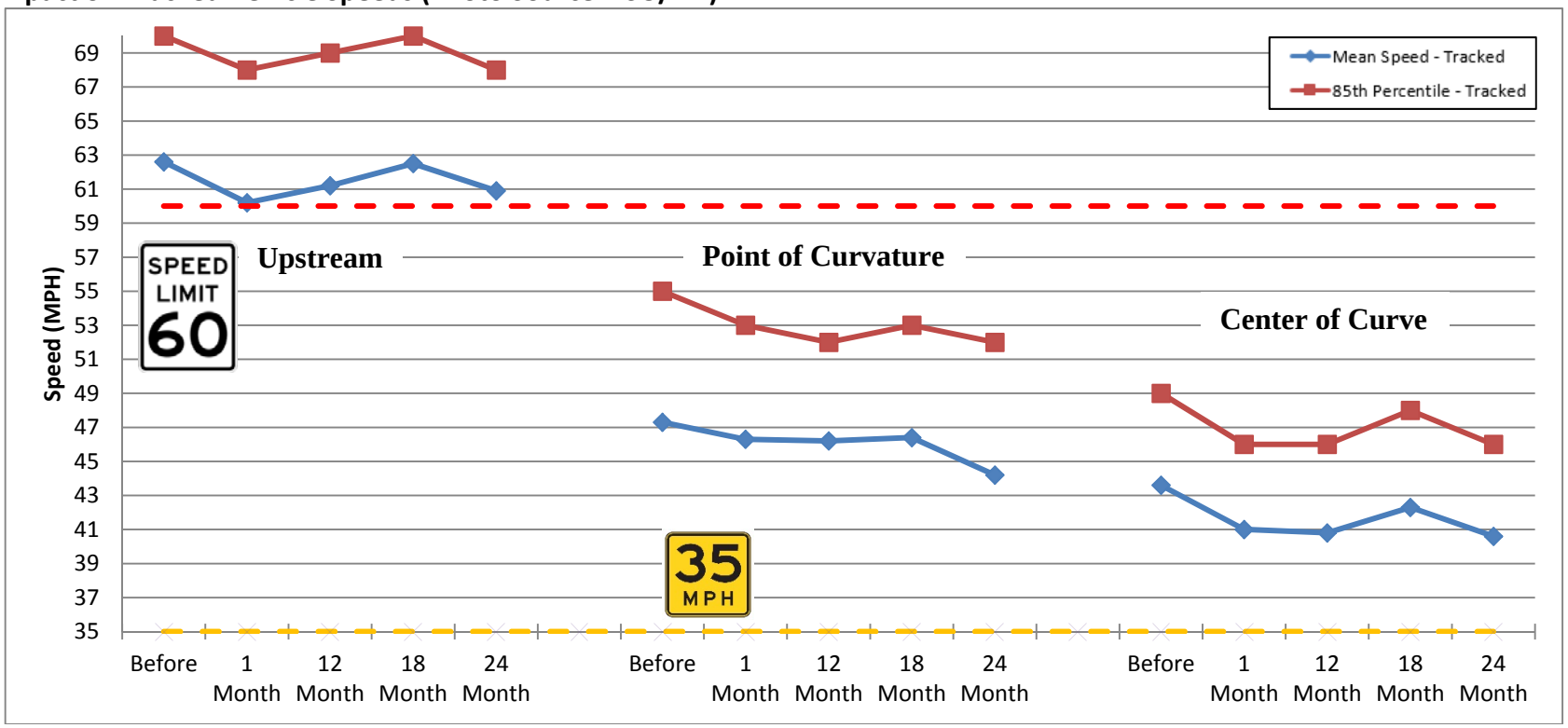


Figure 119. Graph. Impact on tracked vehicle speed - Texas FM 530.

Texas (FM 530)

Speed Profile
All Vehicles

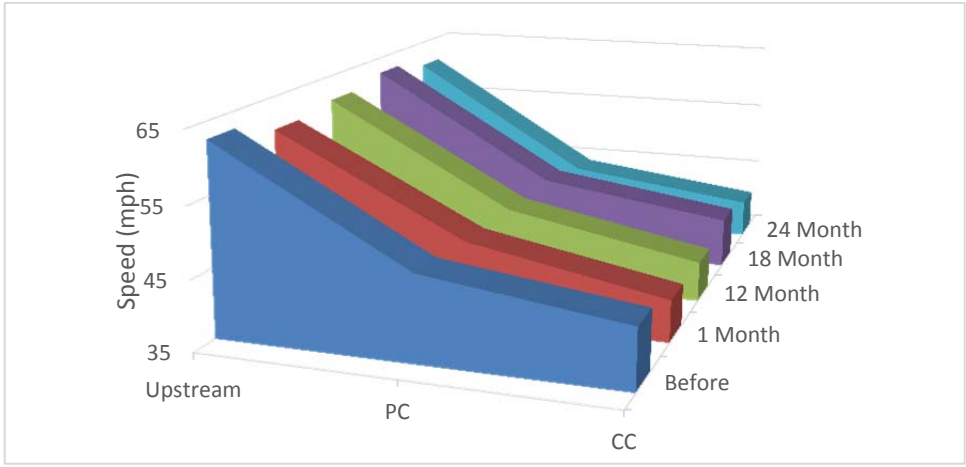


Figure 120. Graph. Speed profiles of tracked vehicles – Texas FM 530.

Speed Profile
Tracked Vehicles

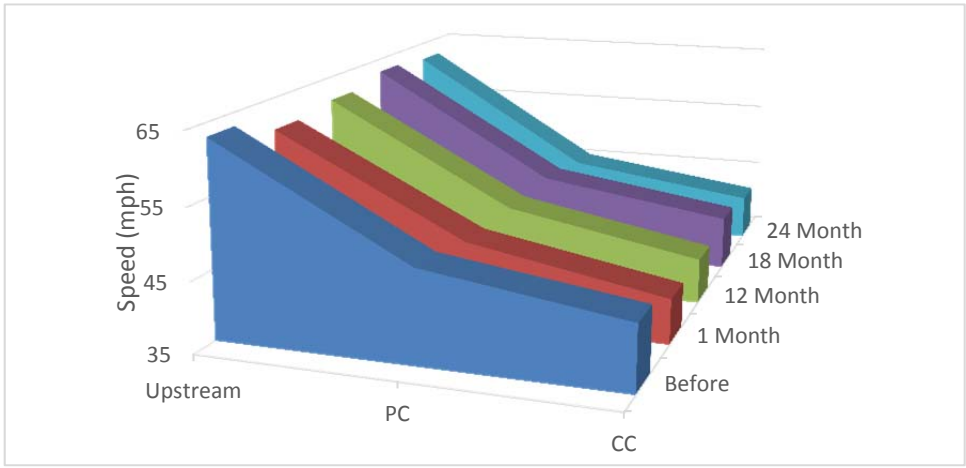


Figure 121. Graph. Speed profiles of tracked vehicles – Texas FM 530.

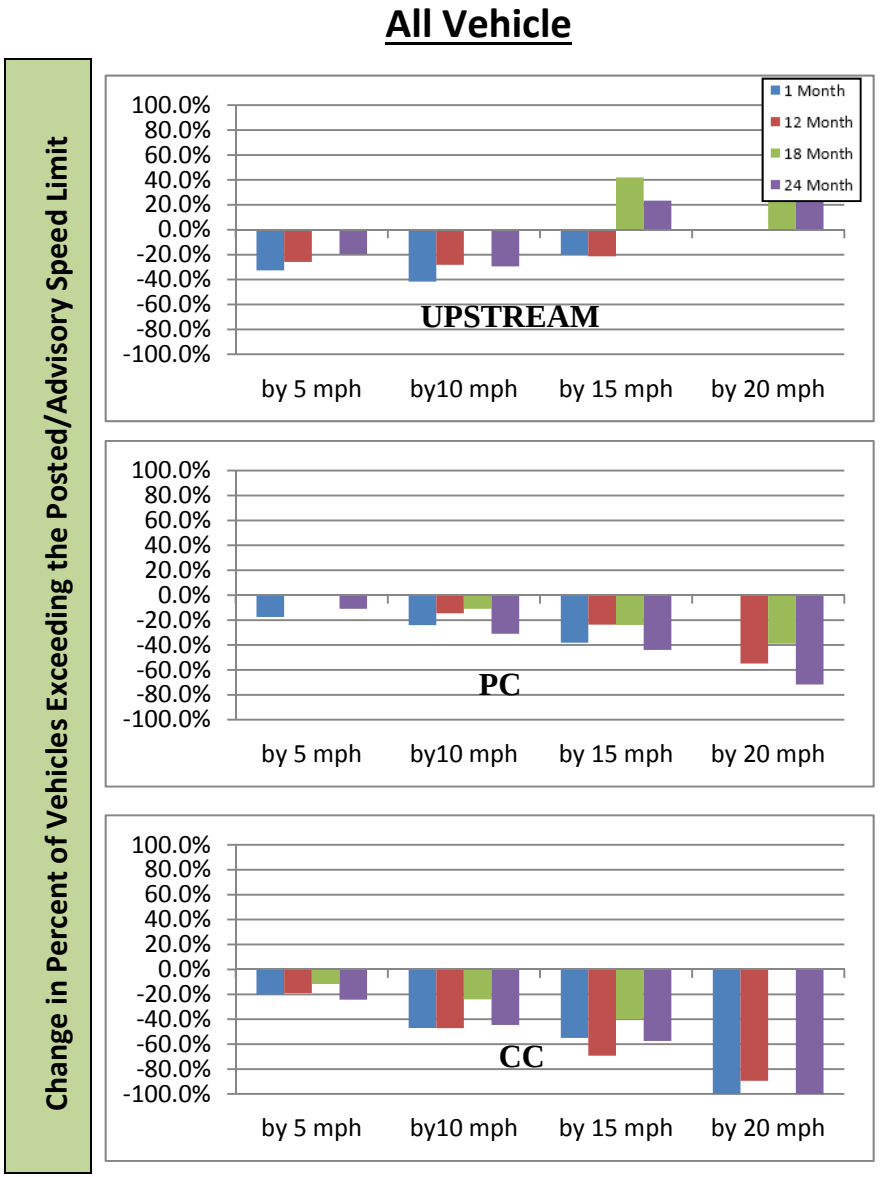


Figure 122. Graphs. Change in percentile (compared to before) of all vehicle speed - Texas FM 530.

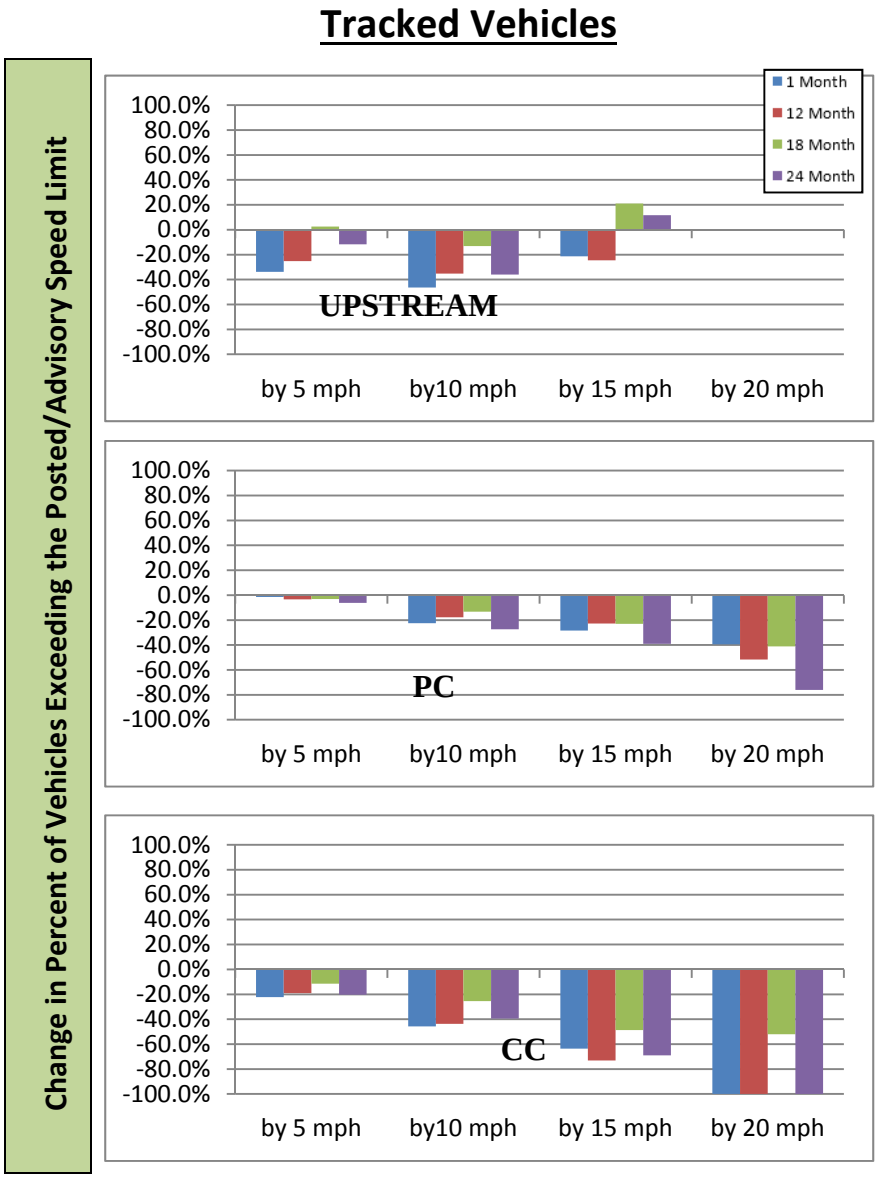


Figure 123. Graphs. Change in percentile (compared to before) of all vehicle speed - Texas FM 530.

Texas FM 1488

A SDCWS was installed on FM 1488 in Texas in July 2012. The site is located 11 miles northeast of Hempstead, Texas with a posted speed limit of 55 mph and advisory speed of 40 mph. The system was installed in the NB direction of travel.

Reduction in speed metrics at the PC gradually reduced after the installation of the SDCWS (Table 78). The mean speed was reduced by -2.4 mph with the 85th percentile speed reduced by -3 mph during the 1 month after period. Gradual decreases occurred until the 24 month where the mean speed was reduced by -0.7 mph and the 85th percentile speed by -1 mph. At the 24 month after period, upstream speeds were lower than the before period which may have reduced the effectiveness of the SDCWS. During the 1 month after period, decreases were found at all percentage of vehicles exceeding the advisory speed.

Table 78. All Vehicles Results for Texas - FM 1488 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	3536	3745	209	4069	533	4045	509	4067	531
Vehicles Count in SDCWS Direction	1741	1825		2128		2137		4053	
Upstream Mean Speed (mph)	59.2	58.9	-0.3[A]	60.7	1.5[A]	58.9	-0.3[A]	58.1	-1.1[A]
Mean Speed (mph)	51.9	49.5	-2.4	49.7	-2.2	50.7	-1.2	51.2	-0.7
Standard Deviation	5.0	4.8		5.3		5.4		5.0	
85th Percentile Speed (mph)	57	54	-3	55	-2	56	-1	56	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	94%	86%	-8.2%	86%	-8.0%	89%	-4.8%	92%	-2.0%
% of Vehicles 10+ Over Advisory	70%	51%	-26.9%	53%	-24.5%	61%	-13.5%	64%	-8.1%
% of Vehicles 15+ Over Advisory	29%	13%	-55.7%	17%	-40.6%	22%	-21.5%	24%	-16.7%
% of Vehicles 20+ Over Advisory	6%	2%	-74.3%	3%	-60.2%	4%	-32.4%	4%	-33.5%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	6%	2%	-74.3%	3%	-60.2%	4%	-32.4%	4%	-33.5%
% of Vehicles 10+ Over Limit	1%	0%	0.0%	0%	0.0%	1%	0.0%	1%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

Table 799 showed the results at the CC. Speed changes upstream and at the PC were similar during the 1 and 24 month after period showing that the SDCWS did not impact speeds at the CC. Speeds were impacted at the 12 and 18 month after periods with mean speed changes of -1.2 and -1.6 mph. The 85th percentile speeds were also reduced during these times by -1 and -2 mph. A decrease of up to 24.5 percent resulted for vehicles traveling 10 mph or more over the advisory speed and a decrease up to -55.6 percent for vehicles traveling 15 mph or more over the advisory speed.

Table 79. All Vehicles Results for Texas - FM 1488 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Actual Day Vehicle Count	3526	3718	192	4053	527	4294	768	4078	552
Vehicles Count in SDCWS Direction	1741	1824		2119		2133		4046	
Upstream Mean Speed (mph)	59.2	58.9	-0.3[A]	60.7	1.5[A]	58.9	-0.3[A]	58.1	-1.1[A]
Mean Speed (mph)	48.5	48.4	-0.1	47.3	-1.2	46.9	-1.6	47.5	-1.0
Standard Deviation	4.5	4.9		4.7		4.5		4.3	
85th Percentile Speed (mph)	53	53	0	52	-1	51	-2	52	-1
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	83%	79%	-4.3%	76%	-8.5%	73%	-11.2%	76%	-7.5%
% of Vehicles 10+ Over Advisory	40%	41%	2.1%[B]	30%	-24.8%	26%	-34.1%	32%	-19.4%
% of Vehicles 15+ Over Advisory	8%	8%	0.0%	5%	-44.1%	4%	-55.6%	4%	-47.9%
% of Vehicles 20+ Over Advisory	1%	1%	0.0%	1%	0.0%	0%	-77.9%	0%	-65.1%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	1%	0.0%	1%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

The gradual reduction in effectiveness at the PC were also shown when tracking vehicles in Table 8080. Mean speed changes of -2.5 during the 1 month after period were reduced to -0.4 mph during the 24 month after period. The 85th percentile speeds showed similar results until from -2 mph at 1 month and no change during the 18 month after period.

Similar results for the CC are shown for tracked vehicles in Table 81. The changes in speed at the upstream and PC were similar during the 1 month and 24 month after periods which suggests speeds may have been influenced by slower speeds on the roadway overall. The 12 and 18 month after periods had significant changes in mean speed of -1.0 and -1.5 mph with 85th percentile speed reduction of -2 mph. Slight changes were shown in the percentage of vehicles exceeding the advisory speed by 5, 10, and 15 mph during these times.

Table 80. Tracked Vehicle Results for Texas – FM 1488 at point of curvature (PC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	919	950		842		966		1868	
Upstream Mean Speed (mph)	60.0	59.6	-0.4	62.1	2.1[A]	60.1	0.1	59.2	-0.8[A]
Mean Speed (mph)	52.3	49.8	-2.5	50.7	-1.6	51.4	-0.9	51.9	-0.4
Standard Deviation	5.1	5.0		5.1		5.5		5.0	
85th Percentile Speed (mph)	57	55	-2	56	-1	57	0	57	0
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	94%	87%	-7.1%	91%	-3.3%	90%	-3.8%	94%	0.0%
% of Vehicles 10+ Over Advisory	71%	54%	-24.5%	60%	-15.5%	64%	-9.9%	69%	-2.7%[B]
% of Vehicles 15+ Over Advisory	32%	16%	-50.0%	22%	-31.8%	28%	-12.3%	28%	-14.3%
% of Vehicles 20+ Over Advisory	7%	2%	-73.0%	4%	-51.9%	6%	-16.1%[B]	6%	-16.1%[B]
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	7%	2%	-71.4%	4%	-51.9%	6%	-16.1%[B]	6%	-16.1%[B]
% of Vehicles 10+ Over Limit	1%	0%	0.0%	0%	0.0%	1%	0.0%	1%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

Table 81. Tracked Vehicle Results for Texas – FM 1488 at center of curve (CC).

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Vehicles Tracked	919	950		842		966		1868	
Upstream Mean Speed (mph)	60.0	59.6	-0.4	62.1	2.1[A]	60.1	0.1	59.2	-0.8[A]
Mean Speed (mph)	49.0	48.9	-0.1[B]	48.0	-1.0	47.5	-1.5	48.0	-1.0
Standard Deviation	4.9	4.7		4.6		4.4		4.3	
85th Percentile Speed (mph)	54	53	-1	52	-2	52	-2	52	-2
percentage of vehicles exceeding advisory speed									
% of Vehicles 5+ Over Advisory	84%	82%	-2.3%[B]	79%	-6.0%	77%	-8.2%	80%	-4.6%
% of Vehicles 10+ Over Advisory	46%	45%	-1.2%[B]	37%	-18.7%	32%	-30.2%	36%	-20.5%
% of Vehicles 15+ Over Advisory	12%	10%	-16.9%[B]	7%	-39.2%	6%	-51.5%	6%	-46.6%
% of Vehicles 20+ Over Advisory	1%	2%	0.0%	1%	0.0%	0%	-89.8%	0%	-62.2%
percentage of vehicles exceeding speed limit									
% of Vehicles 5+ Over Limit	1%	2%	0.0%	1%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
% of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%

[A]Upstream difference was statistically significant

[B]Not statistically significant at 95-percent level of significance

The speed reductions after tracking vehicles display similar findings that the SDCWS may have lost some effectiveness over time at FM 1488 in Table 82. The 1 month after period had a significant increase in speed reduction between the upstream and PC showing vehicles were slowing down prior to entering the curve. The vehicles did not slow down through the curve as much which is shown in the speed reduction from the PC to CC being lower. The 12 month after period had similar results as the 1 month after. The SDCWS were still effective at 18 months after but were only changing vehicles speed reductions by 1.0 mph between the upstream and PC. Vehicles showed similar speed reductions from the PC to CC as the before data collection. During the 24 month after data collection, vehicles speed reductions were similar to the before data collection showing the SDCWS were no longer effective.

Table 82. Speed Reduction for Texas – FM 1488.

	Before	1 Mo	1 Mo Change	12 Mo	12 Mo Change	18 Mo	18 Mo Change	24 Mo	24 Mo Change
Mean Speed Reduction Upstream to PC (mph)	7.7	9.8	2.1	11.4	3.7	8.7	1.0	7.3	-0.4
Mean Speed Reduction Upstream to CC (mph)	11.0	10.8	-0.2[B]	14.1	3.1	12.5	1.5	11.2	0.2[B]
Mean Speed Reduction PC to CC (mph)	3.3	1.0	-2.3	2.7	-0.6	3.8	0.5	3.9	0.6
85th Percentile Speed Reduction Upstream to PC (mph)	12	14	2	16	4	13	1	12	0
85th Percentile Speed Reduction Upstream to CC (mph)	15	15	0	19	4	17	2	16	1
85th Percentile Speed Reduction PC to CC (mph)	6	3	-3	5	-1	6	0	7	1

[B]Not statistically significant at 95-percent level of significance

Note: Positive change represents vehicles slowing down

Figure 1244 shows the mean and 85th percentile speeds after tracking vehicles. At both the PC and CC, vehicles speeds initially are decreased but then gradually increase to near before period speeds. The speed profiles in Figure 1255 and Figure 1266 show similar findings with a significant change during the 1 month and 12 month after periods. During the 18 month after and 24 month after periods the speed profiles showed similar changes as the before period.

Texas (FM 1488)

Speed Limit: 55 mph
Curve Advisory Speed: 40 mph
Installed: July 2012

Impact on Tracked Vehicle Speeds (Photo Source: ISU/TTI)

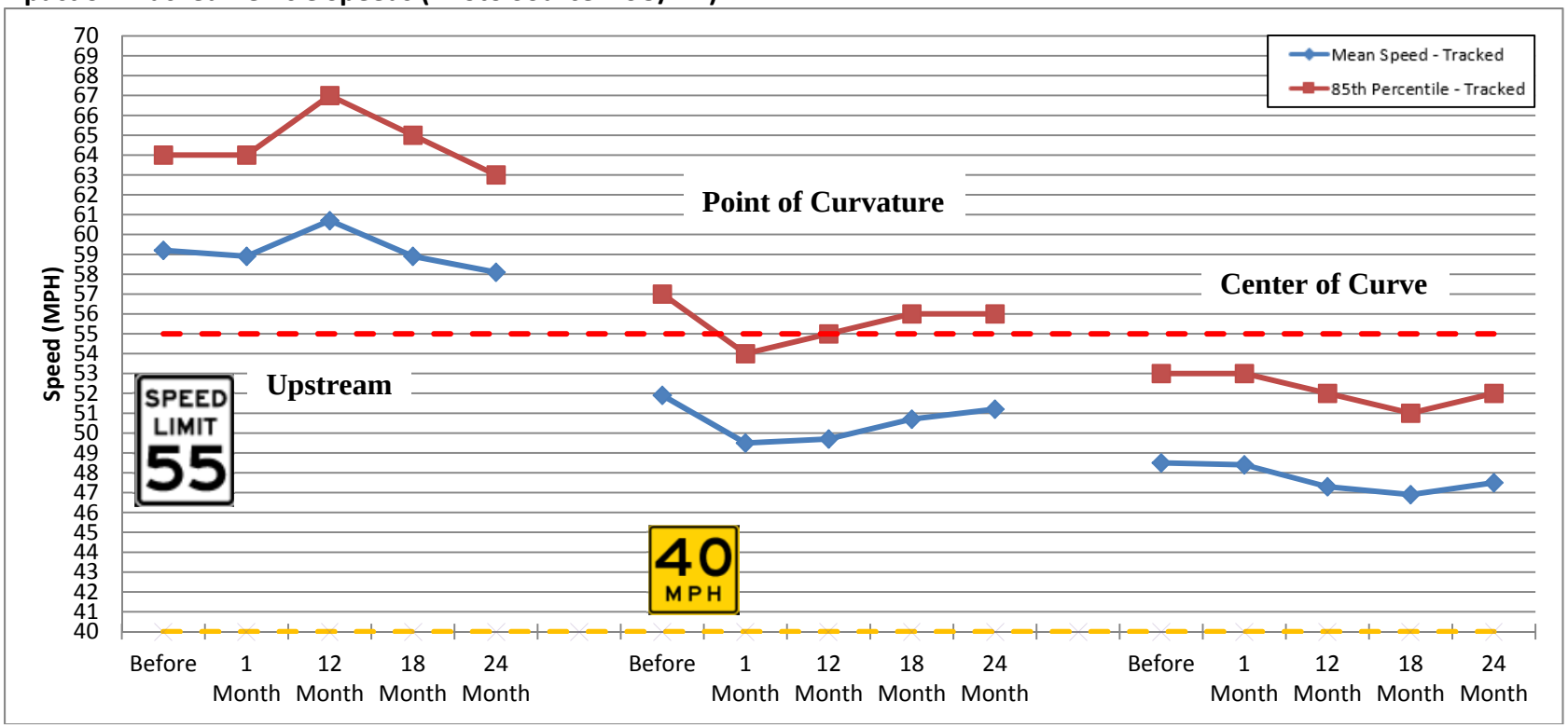


Figure 124. Graph. Impact on tracked vehicle speed - Texas FM 14488.

Texas (FM 1488)

Speed Profile All Vehicles

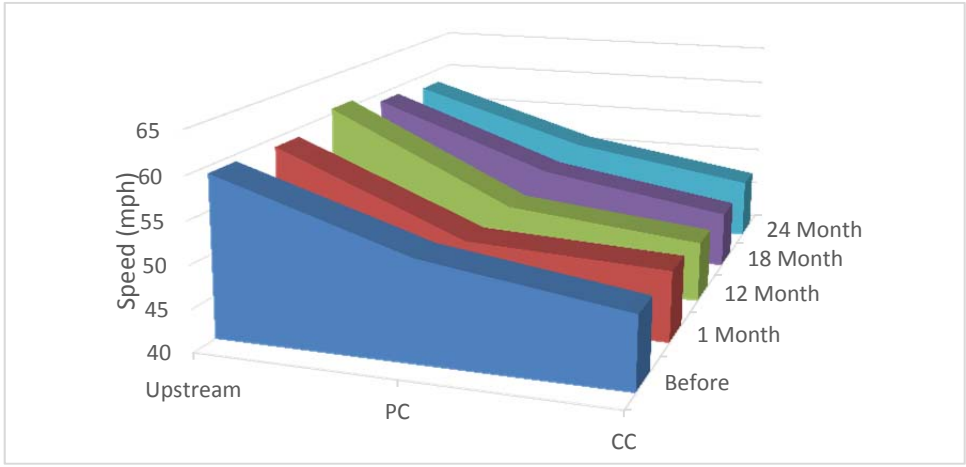


Figure 125. Speed Reduction for all vehicles - Texas FM 1488

Speed Profile Tracked Vehicles

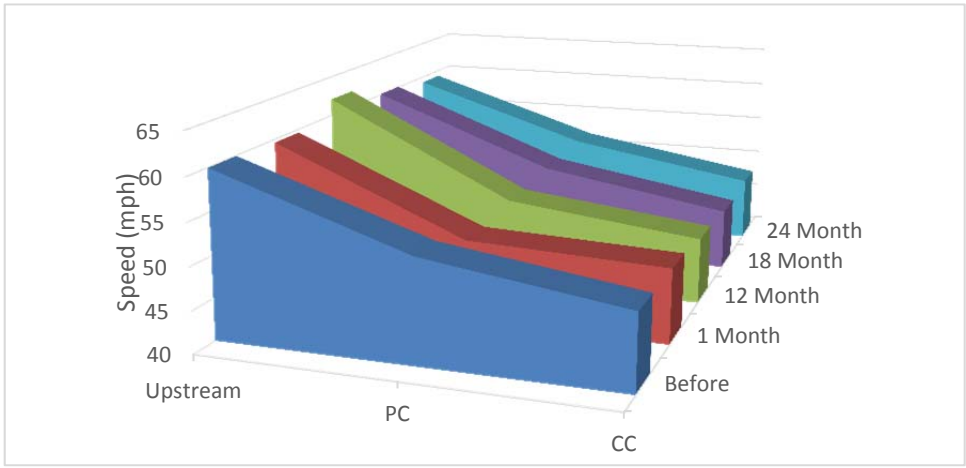


Figure 126. Speed Reduction for tracked vehicles – Texas FM 1488.

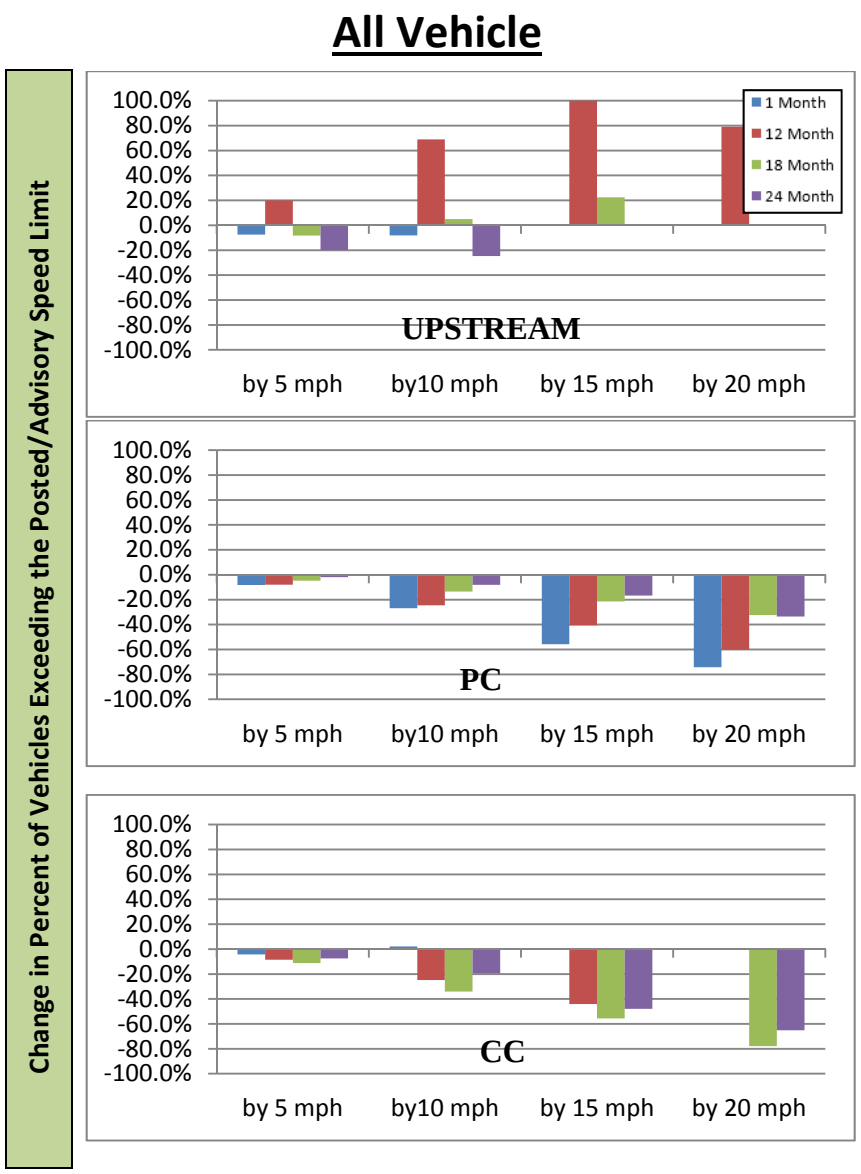


Figure 127. Graphs. Change in percentile (compared to before) of all vehicle speed - Texas FM 1488.

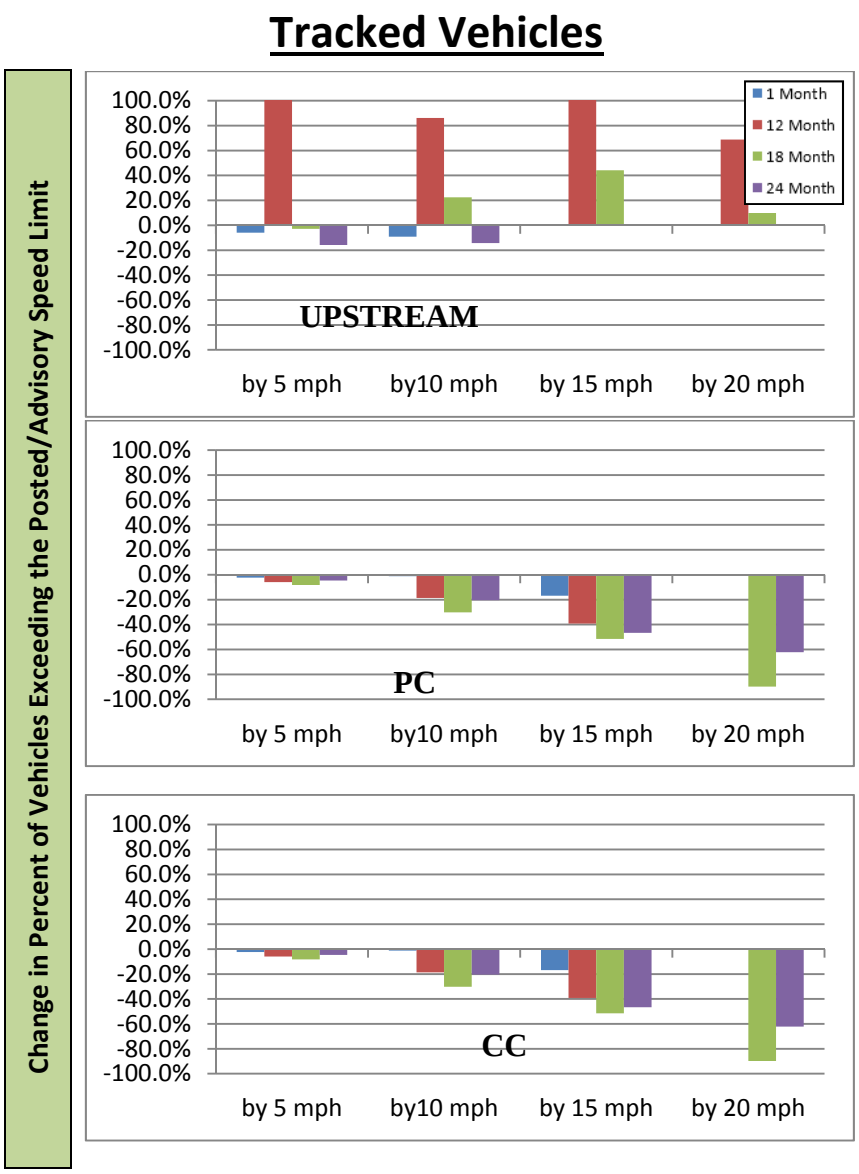


Figure 128. Graphs. Change in percentile (compared to before) of tracked vehicle speed - Texas FM 1488.

APPENDIX C. COMPARISON OF DAYTIME AND NIGHTTIME SPEEDS

Changes in speed were compared for daytime versus nighttime for all sites during the 24 month after period. Data was collected for 48 hours during this time period compared to 24 hours collected during all other data collection periods.

Data were disaggregated by daytime and nighttime during the 48 hours of data collection. Daytime was defined as sunrise until 30 minutes before sunset as determined by reported sunrise and sunset time for the dates when data were collected. Nighttime was considered as sunset until 30 minutes before sunrise. Data 30 minutes before sunrise and sunset were discarded. Data were compared at both the point of curvature and center of curve.

The same speed metrics used in the speed analysis were used for comparison of daytime versus nighttime. Change was calculated by subtracting the daytime speed from the nighttime speeds. This comparison was done to determine whether speeds were similar for daytime versus nighttime.

Mean speeds were compared at the 95-percent confidence level using a *t*-test (assuming unequal variances). Because fewer vehicles were collected during the nighttime period, tracked vehicles were not used in this comparison. Vehicles are removed if they are not tracked which reduces the number of vehicles analyzed. Because of the lower volumes during the nighttime period, an inadequate number of vehicles were reliably tracked.

Table 833 shows speeds for vehicles during the daytime compared with speeds for the nighttime for Iowa Hwy 144 at the point of curvature and center of curve. Nighttime speeds were lower at all data collection locations. Speeds were 2.3 mph lower at the upstream and point of curvature and -1.9 mph lower at the center of curve. Overall the speeds were lower during the nighttime period which can also be seen in the speed profiles in Figure 1299. The 85th percentile speeds were also 2.0 mph lower at the point of curvature and center of curve.

The speeds for vehicles during the daytime compared with the speed for the nighttime for Missouri Hwy 221 are shown in Table 844. All three data collection locations had 0.6 mph higher speeds during the nighttime period. A 1 mph increase in the 85th percentile speed at night is shown at both the point of curvature and center of curve. The speed profile in Figure 13030 is identical in both the daytime and nighttime.

Table 855 shows the comparison of nighttime speed to daytime speeds for Washington SR 7. Speeds upstream were slightly higher by 0.2 mph during the nighttime. Mean speeds at the point of curvature were -1.6 mph lower during the nighttime period and the 85th percentile speeds were unchanged.

At the center of the curve, statistically insignificant changes were shown in the mean speed and no change in the 85th percentile speeds. The largest change in percentage of vehicles going over the advisory speed occurred at the point of curvature for vehicles going 10 mph or more over. There was an 8 percent reduction or 24.5 percent change in the percentage.

Table 83. Day vs Night comparison for all vehicles – Iowa Hwy 144.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	1016	237		1016	236	
Upstream Mean Speed	59.6	57.3	-2.3[A]	59.6	57.3	-2.3[A]
Mean Speed	50.3	48.0	-2.3	46.9	45.0	-1.9
Standard Deviation	5.7	5.8		5.8	6.0	
85th Percentile Speed	56	54	-2.0	52	50	-2.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	56%	38%	-33.3%	30%	18%	-40.9%
Percentage of Vehicles 10+ Over Limit	22%	14%	-37.4%	8%	5%	-37.1%
Percentage of Vehicles 15+ Over Limit	5%	3%	-51.5%	2%	1%	-58.9%[B]
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	5%	3%	-51.5%	2%	1%	-58.9%[B]
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance

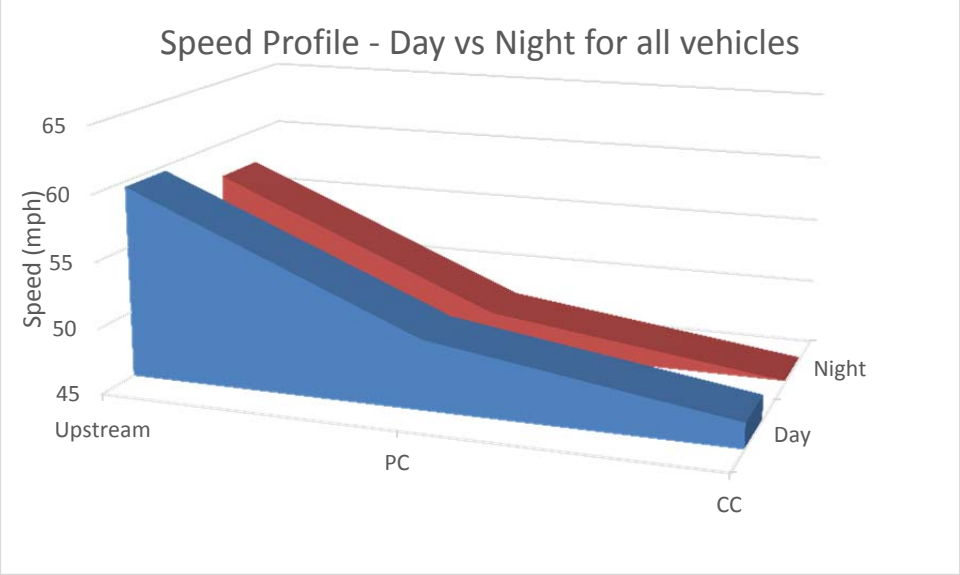


Figure 129. Graph. Day vs Night speed profile comparison for all vehicles – Iowa Hwy 144.

Table 84. Day vs Night comparison for all vehicles – Missouri Hwy 221.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	3738	784		3707	788	
Upstream Mean Speed	52.8	53.4	0.6[A]	52.8	53.4	0.6[A]
Mean Speed	50.22	50.9	0.6	47.78	48.4	0.6
Standard Deviation	4.59	5.08		4.4	4.61	
85th Percentile Speed	55	56	1.0	52	53	1.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	91%	91%	0.0%	80%	83%	4.1%
Percentage of Vehicles 10+ Over Limit	58%	63%	7.6%	34%	39%	16.3%
Percentage of Vehicles 15+ Over Limit	16%	22%	39.9%	6%	9%	65.3%
Percentage of Vehicles 20+ Over Limit	2%	5%	163.8%	0%	0%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	2%	5%	163.8%	0%	0%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[A]Upstream difference was statistically significant

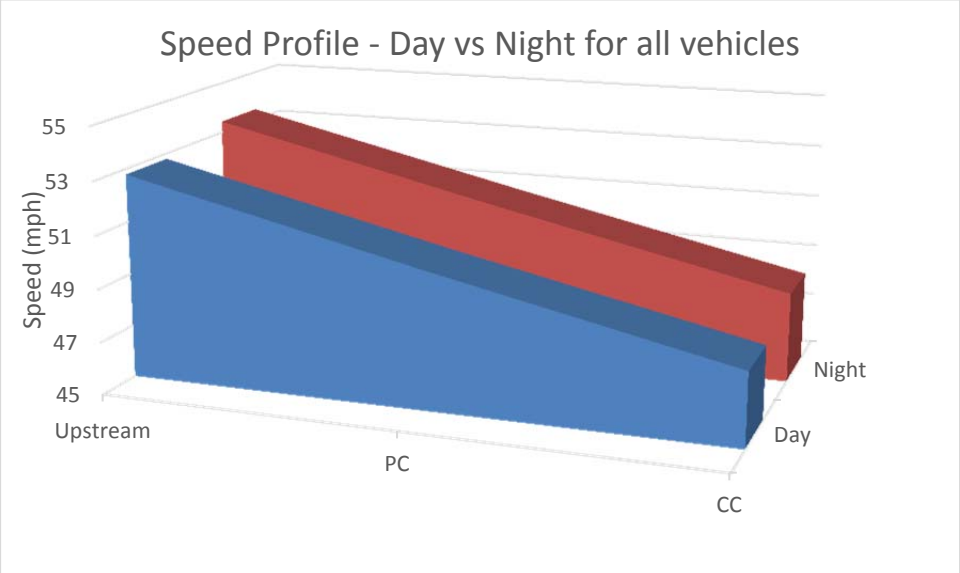


Figure 130. Graph. Day vs Night speed profile comparison for all vehicles – Missouri Hwy 221.

Table 85. Day vs Night comparison for all vehicles – Washington SR 7.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	3176	153		3176	153	
Upstream Mean Speed	42.6	42.7	0.2	42.6	42.7	0.2
Mean Speed	32.0	30.4	-1.6	26.6	26.3	-0.3[B]
Standard Deviation	4.3	4.9		2.8	3.1	
85th Percentile Speed	36	36	0.0	29	29	0.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	96%	90%	-6.5%	80%	72%	-9.9%
Percentage of Vehicles 10+ Over Limit	75%	57%	-24.5%	12%	14%	17.6%[B]
Percentage of Vehicles 15+ Over Limit	26%	21%	-20.2%[B]	1%	1%	0.0%
Percentage of Vehicles 20+ Over Limit	3%	1%	-62.0%	0%	0%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

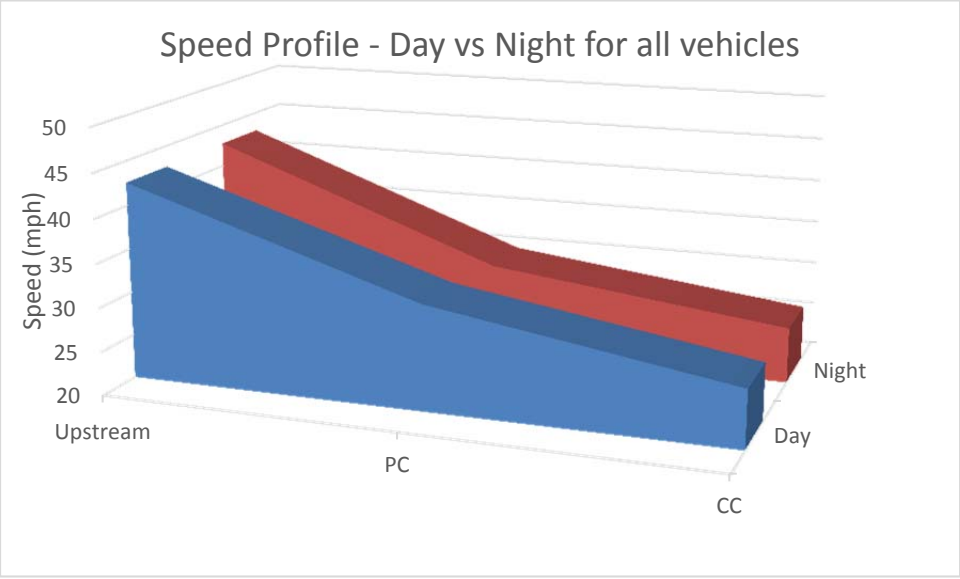


Figure 131. Graph. Day vs Night speed profile comparison for all vehicles – Washington SR 7.

Table 866 provides changes in speeds for the daytime period compared with changes for the nighttime period for Washington SR 9. The changes in mean speed were not statistically significant and a 95 percent level of significance for all three data collection locations. The 85th percentile speed increased by 2 mph at the point of curvature and 1 mph at the center of curve during the nighttime period.

Table 877 shows changes for Washington SR 203 for the daytime period compared with changes for the nighttime period. Mean speeds were similar at the upstream location during the nighttime and daytime period. At the point of curvature, mean speeds were slightly lower by -0.6 mph during the nighttime period and a reduction in the 85th percentile speed of -1 mph. At the center of the curve, mean speeds increased by 1.3 mph and the 85th percentile speed increased by 1 mph during the nighttime period.

The speed profile for Washington 203 is shown in Figure 13333. The speed profile during the daytime show a consistent decrease in speed through the curve. During the nighttime, speeds are lower at the point of curvature but then increase at the center of curve. Vehicles may be slowing down prior to entering the curve due to the SDCWS.

The daytime period speeds compared to the nighttime period speeds for Wisconsin Hwy 20 are shown in Table 888. Upstream speeds were significant higher at this location by 6.0 mph during the nighttime period. At the point of curvature, there was no statistically significant change in mean speed while the center of curve had an increase in mean speed of 2.3 mph during the nighttime. The 85th percentile speed increased by 1 mph at the point of curvature and 3 mph at the center of curve during the nighttime period.

With overall speeds upstream increasing at Wisconsin Hwy 20, the SDCWS may still be effective during the nighttime period with significantly lower increases shown at the point of curvature and center of curve. The speed profile in Figure 1344 shows similar speeds through the PC and CC but a significantly larger reduction in speed between the upstream and PC during the nighttime.

Table 899 provides changes in speed for the daytime period compared with the nighttime period for Wisconsin Hwy 67. Statistically insignificant reductions in mean speed are shown at the upstream data collection location of -0.5 mph. The center of curve also had statistically insignificant changes in the mean speed and an increase in 85th percentile speeds of 1 mph. At the point of curvature, mean speeds were reduced by -1.2 mph but had no change in 85th percentile speeds. The percentage of vehicles exceeding the advisory speed decreased at the point of curvature for vehicles going 10 mph, 15 mph, and 20 mph over. The largest decrease occurred in the percentage of vehicles going 20 mph over the advisory speed with a -16.0 percent change.

The changes in speed between the daytime and nighttime period for Wisconsin Hwy 213 are shown in Table 9090. The changes in mean speed upstream were statistically insignificant. At the point of curvature, mean speeds were reduced by -1.6 mph during the nighttime period. Mean speeds were also reduced at the center of curve by -1.4 mph during the nighttime. Both the point of curvature and center of curve had a -1 mph decrease in 85th percentile speed. Little change occurred in the percentage of vehicles exceeding the advisory and speed limit at both data collection locations.

Figure 1366 shows the speed profiles for Wisconsin Hwy 213 during the daytime and nighttime. Lower speeds are shown during the nighttime at the data collection locations through the curve.

Table 86. Day vs Night comparison for all vehicles – Washington SR 9.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	5209	374		5221	373	
Upstream Mean Speed	48.7	49.1	0.4	48.7	49.1	0.4
Mean Speed	40.3	40.7	0.4[B]	39.6	40.0	0.4[B]
Standard Deviation	5.0	5.8		5.0	6.0	
85th Percentile Speed	45	47	2.0	45	46	1.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	19%	24%	23.5%	16%	21%	37.6%
Percentage of Vehicles 10+ Over Limit	0%	2%	0.0%	0%	2%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	0%	2%	0.0%	0%	2%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

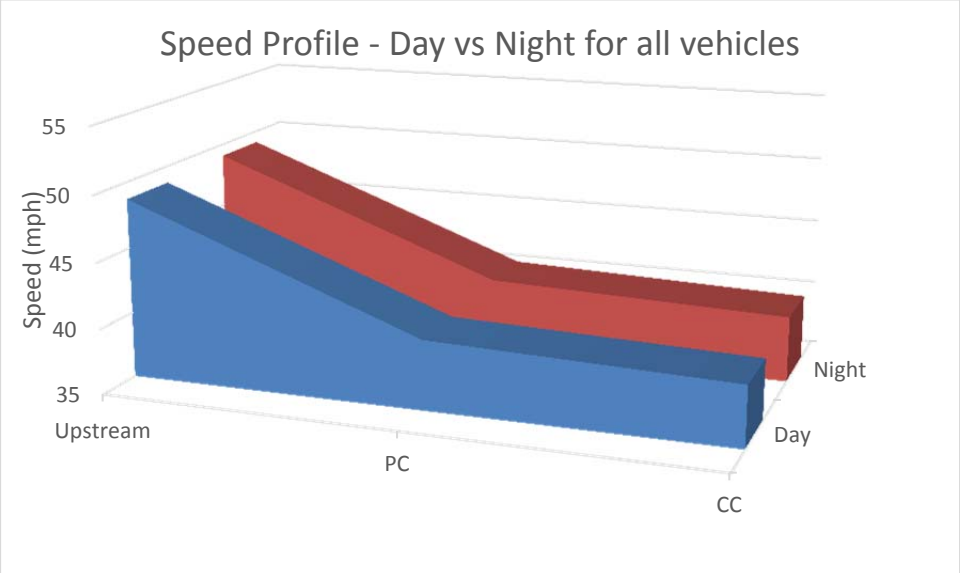


Figure 132. Graph. Day vs Night speed profile comparison for all vehicles – Washington SR 9.

Table 87. Day vs Night comparison for all vehicles – Washington SR 203.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	6215	4154		1655	1995	
Upstream Mean Speed	53.4	53.5	0.1	53.4	53.5	0.1
Mean Speed	52.1	51.5	-0.6	49.9	51.2	1.3
Standard Deviation	4.9	4.8		4.6	4.7	
85th Percentile Speed	57	56	-1.0	54	55	1.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	30%	25%	-17.7%	13%	21%	54.7%
Percentage of Vehicles 10+ Over Limit	4%	4%	0.0%	1%	3%	230.8%
Percentage of Vehicles 15+ Over Limit	0%	1%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	4%	4%	0.0%	1%	3%	230.8%
Percentage of Vehicles 10+ Over Limit	0%	1%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

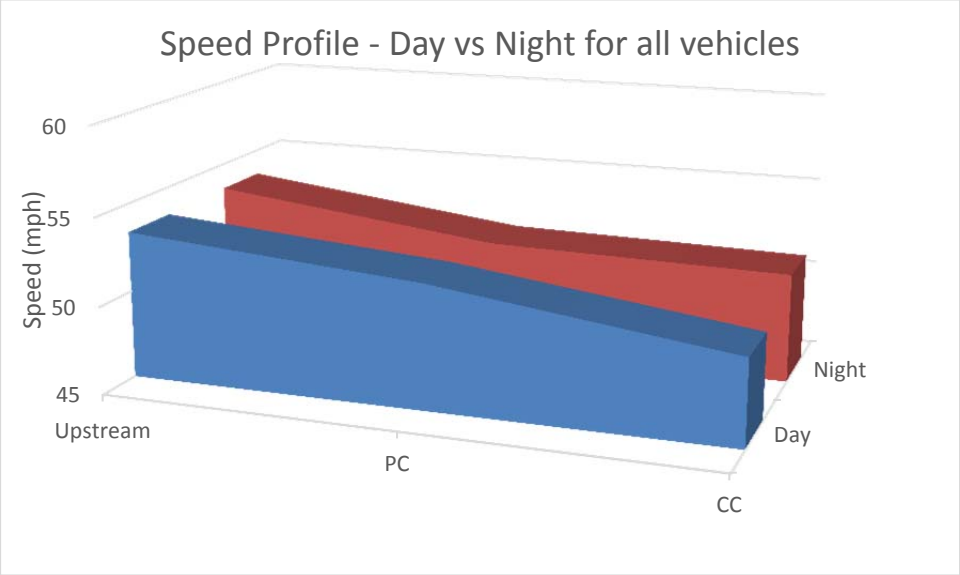


Figure 133. Graph. Day vs Night speed profile comparison for all vehicles – Washington SR 203.

Table 88. Day vs Night comparison for all vehicles – Wisconsin Hwy 20.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	3078	219		2667	169	
Upstream Mean Speed	51.2	57.2	6.0[A]	51.2	57.2	6.0[A]
Mean Speed	37.6	38.1	0.5[B]	35.7	38.0	2.3
Standard Deviation	6.9	8.3		4.5	5.3	
85th Percentile Speed	45	46	1.0	40	43	3.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	70%	68%	-2.7%[B]	63%	80%	27.6%
Percentage of Vehicles 10+ Over Limit	44%	53%	21.9%	19%	40%	113.8%
Percentage of Vehicles 15+ Over Limit	16%	23%	50.0%	2%	7%	200%
Percentage of Vehicles 20+ Over Limit	2%	6%	216.0%	0%	1%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[A]Upstream difference was statistically significant
[B]Not statistically significant at 95-percent level of significance

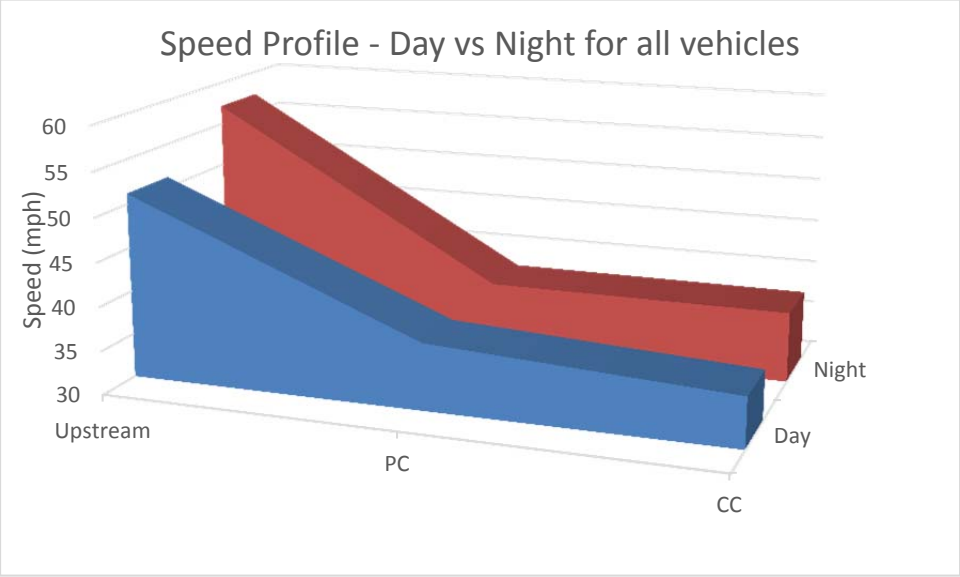


Figure 134. Graph. Day vs Night speed profile comparison for all vehicles – Wisconsin Hwy 20.

Table 89. Day vs Night comparison for all vehicles – Wisconsin Hwy 67.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	3538	285		3537	286	
Upstream Mean Speed	49.6	49.1	-0.5	49.6	49.1	-0.5
Mean Speed	45.1	43.9	-1.2	39.6	39.3	-0.3[B]
Standard Deviation	5.4	6.2		4.7	5.6	
85th Percentile Speed	50	50	0.0	44	45	1.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	99%	99%	0.0%	98%	97%	-0.6%[B]
Percentage of Vehicles 10+ Over Limit	97%	93%	-4.0%	87%	82%	-5.5%
Percentage of Vehicles 15+ Over Limit	86%	74%	-12.8%	52%	48%	-8.4%[B]
Percentage of Vehicles 20+ Over Limit	56%	47%	-16.0%	13%	15%	18.8%[B]
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	0%	1%	0.0%	0%	1%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

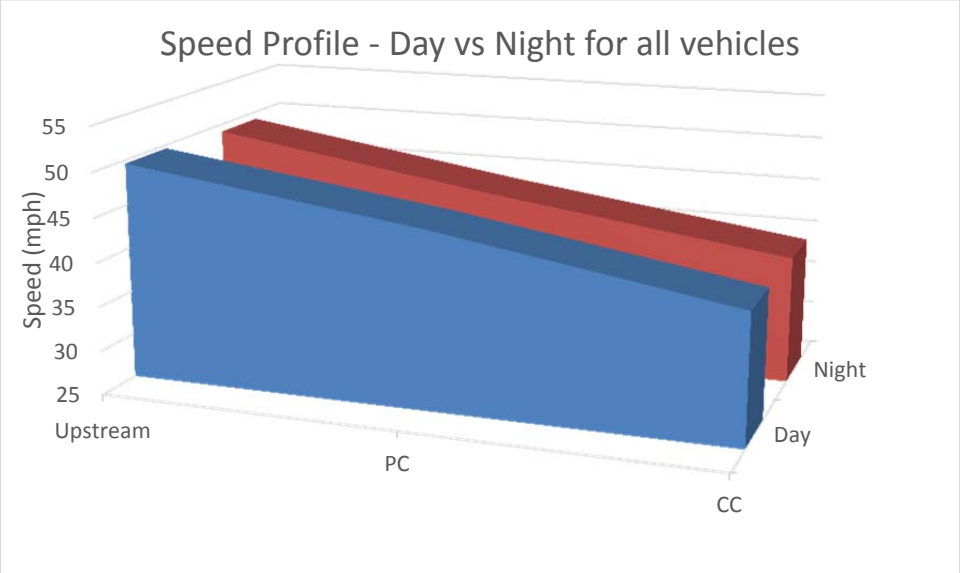


Figure 135. Graph. Day vs Night speed profile comparison for all vehicles – Wisconsin Hwy 67.

Table 90. Day vs Night comparison for all vehicles – Wisconsin Hwy 213.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	2066	167		2170	182	
Upstream Mean Speed	58.9	58.7	-0.2	58.9	58.7	-0.2
Mean Speed	53.4	51.8	-1.6	52.4	51.0	-1.4
Standard Deviation	6.6	6.5		9.1	9.1	
85th Percentile Speed	59	58	-1.0	60	59	-1.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	99%	100%	1.2%	96%	95%	-0.6%[B]
Percentage of Vehicles 10+ Over Limit	98%	98%	0.0%	92%	92%	0.0%
Percentage of Vehicles 15+ Over Limit	97%	97%	0.0%	89%	89%	0.0%
Percentage of Vehicles 20+ Over Limit	92%	87%	-5.2%	85%	83%	-2.9%[B]
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	14%	11%	-23.2%[B]	18%	13%	-30.4%
Percentage of Vehicles 10+ Over Limit	1%	2%	42.9%[B]	2%	3%	70.8%[B]
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

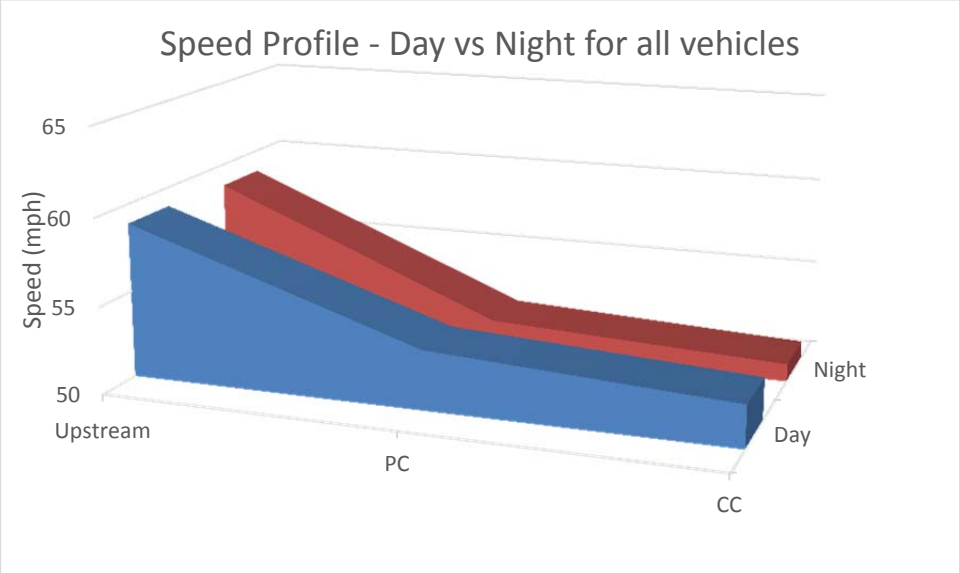


Figure 136. Graph. Day vs Night speed profile comparison for all vehicles – Wisconsin Hwy 213.

Table 9191 shows the difference between the daytime and nighttime speeds for Texas FM 109. Overall speeds were lower during the nighttime period with a -1.8 mph change in mean speed at the upstream data collection location. Mean speeds at the point of curvature were reduced by -1.4 mph and -0.9 mph at the center of curve during the nighttime period. The 85th percentile speeds reduced by -1.0 mph at the point of curvature and had no change at the center of curve. The effectiveness of the SDCWS may be reduced at this site due to the overall speeds dropping at the upstream location.

Table 922 provides change in speed for the daytime period compared with the nighttime period for Texas FM 407. Statistically insignificant increases in mean speed are shown at the upstream location. At the point of curvature, increases in mean and 85th percentile speeds during the nighttime period are shown of 0.9 mph and 1 mph. Similar results were found at the center of curve with a mean speed increase of 1.7 mph and 85th percentile speed increase of 1 mph during the nighttime. The speed profile in Figure 1386 shows the higher speeds through the curve.

The comparison of speeds for the daytime and nighttime for Texas FM 530 are shown in Table 933. This site had the lowest volume of cars with only 35 vehicles being recorded during the night over 48 hours. With such low volume of vehicles, all changes in mean speed were statistically insignificant.

Table 944 shows the changes in speed for the daytime period compared to the changes for the nighttime period for Texas FM 1488. No changes in the mean speed occurred at the upstream location. The mean speed at the point of curvature decreased by -1.2 mph while the mean speed at the center of curve decreased by -0.7 mph. The 85th percentile speed decreased by -1 mph at both the point of curvature and center of curve. A significant change in percentage of vehicles exceeding the advisory speed occurred at 10mph or more. The change in percent at the point of curvature was 9 percent while the change at the center of curve was 8 percent.

In summary, nighttime speeds were slightly lower at the point of curvature for six of the twelve sites with changes in mean speeds between -1.2 and -2.3 mph. The remaining six sites showed little change of less than 1 mph at the point of curvature.

Results were lower at the center of curve. Reductions in mean speed greater than 1 mph were shown at only two of the twelve sites for the nighttime period. Half of the sites had little to no change in mean speeds while three sites had increases greater than 1 mph in the mean speeds.

Table 91. Day vs Night comparison for all vehicles – Texas FM 109.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	1852	181		1823	179	
Upstream Mean Speed	56.4	54.6	-1.8[A]	56.4	54.6	-1.8[A]
Mean Speed	46.8	45.4	-1.4	44.5	43.6	-0.9
Standard Deviation	5.2	6.1		4.6	5.7	
85th Percentile Speed	52	51	-1.0	49	49	0.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	92%	85%	-7.7%	88%	79%	-10.5%
Percentage of Vehicles 10+ Over Limit	69%	57%	-17.3%	52%	47%	-9.2%[B]
Percentage of Vehicles 15+ Over Limit	30%	25%	-14.8%[B]	12%	11%	-14.4%[B]
Percentage of Vehicles 20+ Over Limit	6%	6%	0.0%	1%	2%	38.8%[B]
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

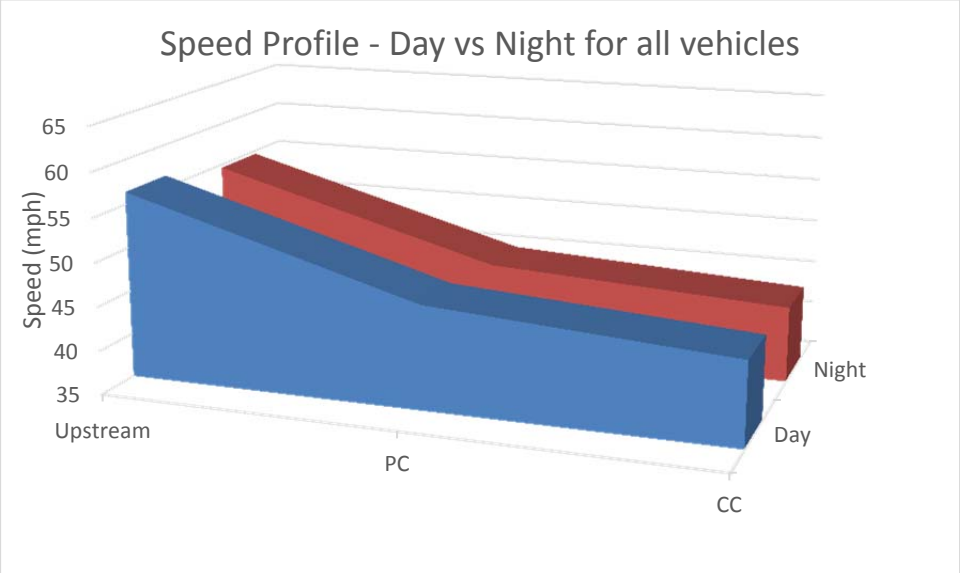


Figure 137. Graph. Day vs Night speed profile comparison for all vehicles – Texas FM 109.

Table 92. Day vs Night comparison for all vehicles – Texas FM 407.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	1769	1323		1761	1311	
Upstream Mean Speed	60.7	61.0	0.3	60.7	61.0	0.3
Mean Speed	48.9	49.8	0.9	44.4	46.1	1.7
Standard Deviation	5.2	5.4		5.6	5.6	
85th Percentile Speed	54	55	1.0	50	51	1.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	81%	84%	3.4%	52%	66%	26.1%
Percentage of Vehicles 10+ Over Limit	45%	55%	20.2%	16%	26%	65.9%
Percentage of Vehicles 15+ Over Limit	13%	19%	42.3%	2%	5%	103.0%
Percentage of Vehicles 20+ Over Limit	1%	3%	105.4%	0%	0%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	1%	3%	105.4%	0%	0%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

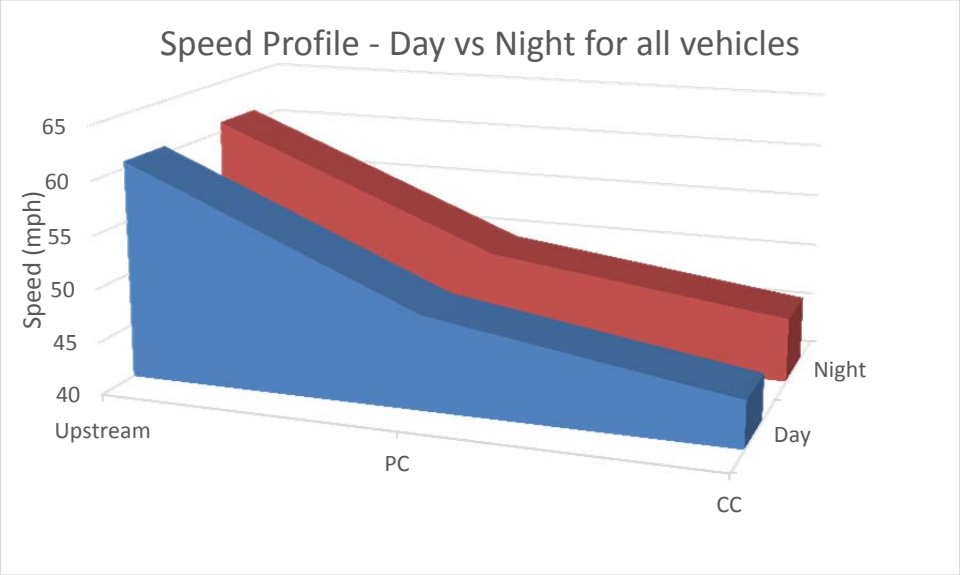


Figure 138. Graph. Day vs Night speed profile comparison for all vehicles – Texas FM 407.

Table 93. Day vs Night comparison for all vehicles – Texas FM 530.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	507	35		508	35	
Upstream Mean Speed	60.9	60.4	-0.5	60.9	60.4	-0.5
Mean Speed	44.3	42.6	-1.7[B]	40.7	38.9	-1.8[B]
Standard Deviation	44.3	42.6		6.2	5.1	
85th Percentile Speed	52	48	-4	46	44	-2
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	78%	69%	-12%B	61%	46%	-25.6%
Percentage of Vehicles 10+ Over Limit	52%	37%	-29.2%	28%	9%	-69.1%
Percentage of Vehicles 15+ Over Limit	25%	9%	-65.2%	5%	3%	-44.1%[B]
Percentage of Vehicles 20+ Over Limit	5%	0%	-100%	0%	0%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 10+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

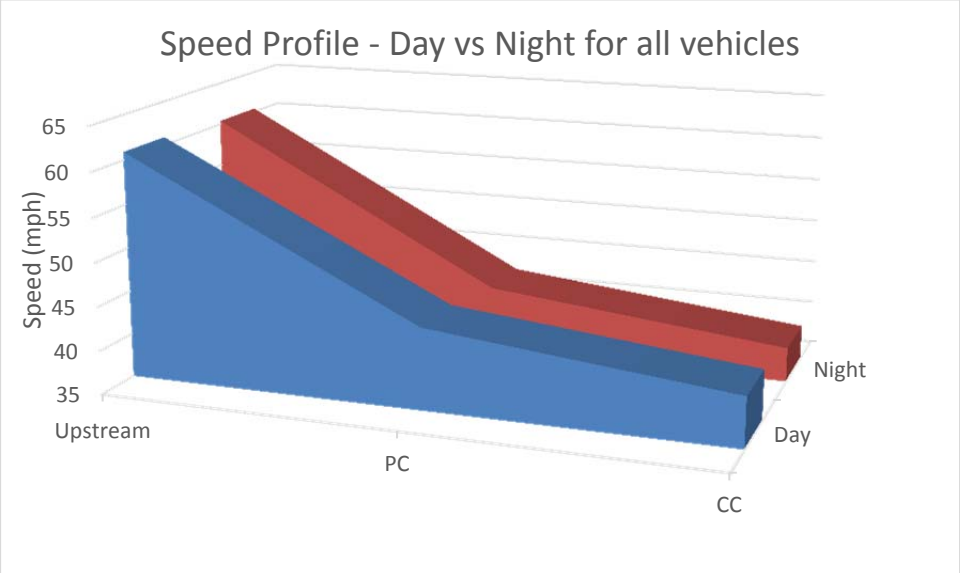


Figure 139. Graph. Day vs Night speed profile comparison for all vehicles – Texas FM 530.

Table 94. Day vs Night comparison for all vehicles – Texas FM 1488.

	Point of Curvature			Center of Curve		
	Day	Night	Change	Day	Night	Change
Number of Vehicles	2955	836		2939	841	
Upstream Mean Speed	58.1	58.1	0.0	58.1	58.1	0.0
Mean Speed	51.4	50.2	-1.2	47.6	46.9	-0.7
Standard Deviation	5.0	5.2		4.3	4.6	
85th Percentile Speed	56	55	-1.0	52	51	-1.0
percentage of vehicles exceeding advisory speed						
Percentage of Vehicles 5+ Over Limit	93%	89%	-3.9%	78%	71%	-8.8%
Percentage of Vehicles 10+ Over Limit	67%	56%	-16.2%	34%	27%	-20.2%
Percentage of Vehicles 15+ Over Limit	26%	18%	-28.8%	5%	4%	-9.4%[B]
Percentage of Vehicles 20+ Over Limit	4%	4%	0.0%	0%	1%	0.0%
percentage of vehicles exceeding speed limit						
Percentage of Vehicles 5+ Over Limit	4%	4%	0.0%	0%	1%	0.0%
Percentage of Vehicles 10+ Over Limit	1%	1%	0.0%	0%	0%	0.0%
Percentage of Vehicles 15+ Over Limit	0%	0%	0.0%	0%	0%	0.0%
Percentage of Vehicles 20+ Over Limit	0%	0%	0.0%	0%	0%	0.0%

[B]Not statistically significant at 95-percent level of significance

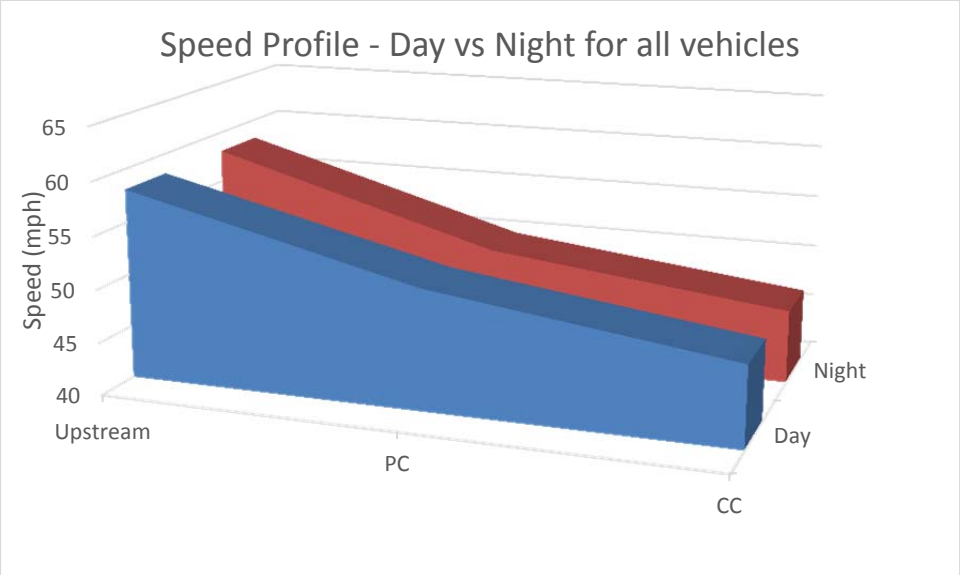


Figure 140. Graph Day vs Night speed profile comparison for all vehicles – Texas FM 1488.

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