AN EVALUATION OF SPEED CONTROL TECHNIQUES IN WORK ZONES (WORK ZONES 2)

FINAL REPORT

EXECUTIVE SUMMARY

PREPARED FOR
MICHIGAN DEPARTMENT OF TRANSPORTATION

PREPARED BY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
MICHIGAN STATE UNIVERSITY

Richard W. Lyles
and
Virginia Sisiopiku

30 July 99

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16. Abstract

This study was conc peed control strategies in freeway work zones. These d trailers (which displayed the speed limit and the moto alysis was compromised at two sites where Michigan S l, results at a third site indicated that police presenc closures but less so within the lane closure area. Spee mise in reducing speeds compared to police presence.

17. Key Words

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DISCLAIMER

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EXECUTIVE SUMMARY

Introduction and Problem Statement

The objective of this project was to study the effectiveness of specific speed control techniques in work zones on selected limited-access highways in Michigan during the 1998 construction season. It was a follow-up to a study done for the Michigan Department of Transportation (MDOT) during the 1997 season where motorist speeds in work zones on the same type of highway were observed and analyzed. The current study was to be directed to the evaluation of several speed control strategies in work zones—for example, the use of changeable message signs (CMS) such as "speed limit 50 mph when workers present" and the use of police presence in the work area.

The general results of the 1997 study were that while different speed limits seemed to have some effect in lowering average speeds, all average speeds were considerably higher than the posted limits. Moreover, the speeds at which motorists travel through work zone seemed to be related to characteristics of the zone such as the number of open lanes, whether workers were present, and the type of separation between the work activity and the motorists traveling through the zone. To that end, the effectiveness of posted limits and the effects of these other characteristics were intertwined. In this context, the objective of the study done during the 1998 construction season was to determine the effects of alternative types of signs and enforcement in controlling motorist speeds in work zones.

It should be noted that all data collection was originally proposed to be done by the Michigan State University (MSU) research team at sites jointly identified by MSU and MDOT. As the project was executed, an evaluation of the effects of extra Michigan State Police (MSP) enforcement at two selected work zone sites in southeastern Michigan was added to the project. While the purpose of the extra enforcement was very similar to that for the project *per se* (i.e., to control/lower motorist speeds in work zones), experiment design and data collection were done by MDOT with the only the subsequent analysis and interpretation done by MSU.

Data Collection Procedures

The data collection procedure was quite similar to the 1997 project. MSU's data collection was done using a videotape surveillance system which requiref the use of a bridge over the data collection location and a marked "trap" on the roadway just upstream of the bridge. Vehicles passing through the site (and under the bridge) were videotaped in 1-2 hour sessions. The videotapes were then processed using Autoscope, a computer-based reduction system to get data appropriate for the analysis. The MDOT-collected data consisted of standard speed and volume data from standard MDOT automatic counters.

Site Selection and Identification of Speed Control Techniques to be Tested

The general characteristics of a "good" site included: a freeway site not prone to significant congestion; fairly long duration of the work zone activities; reasonably consistent activities in the zone; cooperation of MDOT field staff, the prime contractor, traffic control device sub-contractors, and local and state police; appropriate data collection opportunities; and reasonable proximity to East Lansing. Site selection was difficult for a number of reasons which included the fact that considerable 1998 construction work was done at night, quickly changing major site characteristics, and site shortcoming related to data collection. One useful site was identified: I-69 southwest of Flint. There were also two "MSP extra enforcement" sites identified in southeastern Michigan where MDOT was responsible for data collection.

I-69 Southwest of Flint (near Swartz Creek)

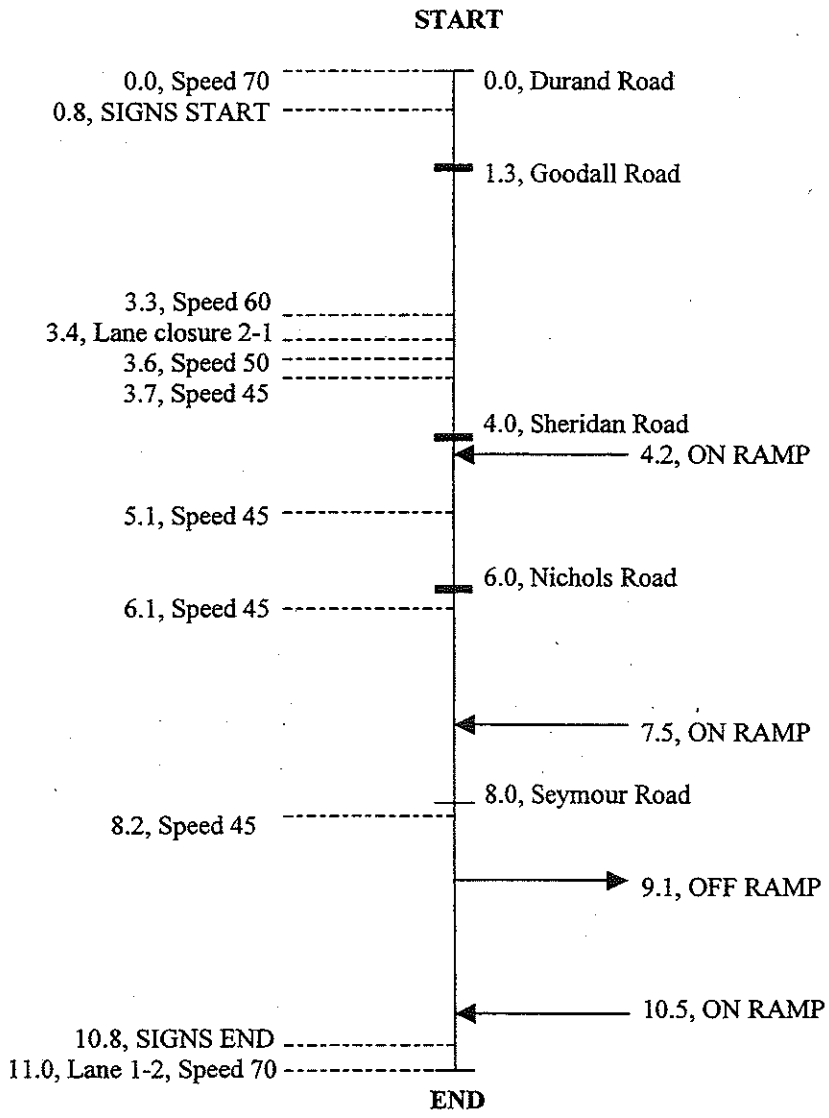
The work at this site consisted of resurfacing and shoulder work along with some work on several interchanges and required the closure of one of two normal lanes. The actual extent of the site was from near Durand Road east to about three miles beyond Seymour Road. All of the data collection occurred on the eastbound side of the freeway and specific data collection points were the overpasses at Goodall, Sheridan, and Nichols Roads. The initial lane closure occurred east of Goodall Road. In all instances, data were collected at all three locations. The schematic of the site is shown in Figure 1.

The selection of speed control alternatives was done with cooperation and guidance from MDOT. The following alternatives were tested:

- stationary MSP presence at two different locations separately (a single patrol car was clearly visible near the beginning of the zone [near Goodall] **or** within the zone [near Sheridan]);
- a drone radar installation (i.e., a radar unit was placed in one location although there was no police presence and no other vehicle was obvious to motorists);
- a speed trailer which displayed the messaged "speed limit XX" and "your speed is YY" at one of two different locations (near the beginning of the zone [near Goodall] **or** within the zone [near Sheridan]);
- a CMS which displayed the message "workers ahead, obey speed limit" and was located near the beginning of the zone; and
- a CMS which displayed "workers ahead, speed limit 45 mph" and was located within the zone.

Data were also collected with no extra signs or police present (i.e., only standard work zone signs were deployed) and after the work activity was over and all signs had been removed. The speed trailer and the changeable message sign were provided by Work Safe Supply Co. Work Safe also provided installation and maintenance of the signs at no cost to the project.

I-69 EB@SWARTZ CREEK



Approx. Scale: 1 inch = 2 mile

Figure 1. Schematic of I-69 site

While the basic boundaries of the site and the data collection locations remained the same throughout the project, there were some day-to-day changes in the work zone configuration which affected the data that were collected. For example, during data collection for some "treatments," the 2→1 lane closure was nearer to Goodall than Sheridan while for other treatments (days), the closure was moved closer to Sheridan and the work zone speed limit was changed.

MSP/MDOT Cooperative Enforcement Project

During the summer of 1998, MDOT and MSP were involved in a project where MDOT funded extra enforcement by MSP in selected work zones. Two specific sites were targeted: work zones on I-94 in Detroit and I-275 in and near Canton Township. Originally, MSU had no role in this cooperative effort. All negotiations/agreements with respect to where and when additional enforcement would be undertaken, record-keeping, and the like were carried out between MDOT and MSP personnel. All of the data collection at these two sites was also done by MDOT. After the fact, it was agreed that MSU would analyze the data that were obtained by MDOT to assess the effectiveness of the extra MSP enforcement. The only "treatment" that was tested at these sites was police presence versus no police presence.

The **I-275 site** was a zone where the construction work was done primarily at night. The overall site boundaries with respect to the data collection and enforcement were approximately Hannan and 5-Mile Roads. Data were collected using automatic counters at several sites within this area. However, only a limited amount of the data was useful since a match was desired between site conditions with and without police presence, the number of lanes that were open, and so forth. Little information was available regarding the exact locations of police during data collection or their actual mode of operation (e.g., fixed location, roving) although it was known when they were at the site.

At the **I-94 site**, the coordination between MDOT and MSP was somewhat more problematic. MDOT collected data at Central Avenue and further east at Junction Avenue (the locations are about a mile apart) while the MSP presence was between Warren and Mt. Elliott. Warren is ~½ mile further east of Junction and Mt. Elliott is five miles (east) beyond that. Thus, the police were possibly adjacent to, but not "in," the area where data were collected. Many of the drivers/vehicles in the data set probably did not see the police in the area.

Discussion

The data collection on the I-69 site was much more controlled than that at either of the Detroit-area sites. At the I-69 site, the speed control strategies were well-defined with respect to where devices or police were placed and the time periods when they were present. At the Detroit-area sites, while it is relatively clear when the police were present, it is not at all clear how they were operating. Moreover, on the I-94 site, police were not necessarily even in close proximity to the data collection locations—e.g., if they were at the far eastern end of their patrol area, they were as far away as five-six miles. Thus, the data collected at the Detroit-area sites can, at best, provide only the most general sense of the effectiveness of the police presence.

Basic Approach to Measuring Speed Control Effectiveness

At **the I-69 site**, speed data were collected during AM and PM off-peak periods (9:00-11:00 AM and 1:00-3:00 PM, respectively) at each of three locations: the first position was at the beginning of the zone just before the lane closure (and a mile after the first signs had indicated the presence of the zone ahead)—Goodall Road (see Figure 1); the second position was 2.7 miles into the zone—Sheridan Road; and the third position 2.0 miles further into the zone—Nichols Road. Thus, comparisons of speeds can occur at any given position (e.g., compare average speeds at Sheridan Road for all conditions) or they can be compared longitudinally (a speed profile using the three positions can be constructed for a given condition and then compared to a profile for some other condition). The latter can be used, for example, to show whether police presence at the first location has a "lasting" effect into the zone.

At **the Detroit-area sites**, the experimental design was imprecise in the sense that there was no control exercised over the MSP with respect to where they would be and what their operating regime would be. By and large, they were simply "there" (in the general vicinity) or not.

Results

Results for I-69

The results for I-69 are summarized in Table 1 and Figure 2 and 3. The table is a summary of average speeds and speed differences observed at each of three data collection locations during both the AM and PM time periods. The values of average speeds at Goodall represents an "entry" speed into the active part of the construction zone (but before the lane drop) although motorists would have already encountered numerous constructions zone signs and could see the lane closure ahead. The Sheridan and Nichols sites were "within" the lane closure area. The results in the first line of the table are for the normal conditions when no work zone was present (these speeds were taken after the construction was completed). It can be seen that the average speedd at Goodall (69.0 mph in the PM and 71.9 mph in the AM) are reasonably close to the normally-posted limit of 70 mph. The average speed changes from one data collection location to another (e.g., Goodall to Sheridan) are shown in the "speed differences" columns.

Figures 2 and 3 show a graphical representation of the speed profiles under different conditions for the AM and PM data collection periods, respectively.

The first thing that is apparent are the differences between AM and PM speeds. For example, the AM-PM differences at Goodall for no construction, standard work zone treatment, and police presence at Goodall are 2.9, 0.2, and 4.6 mph, respectively. This sort of difference attests to the general variance in motorist speeds that was observed and, presumably, attributable to either differences in motorist groups (e.g., fundamental differences between motorists driving during the AM and PM periods), variations in the construction zone itself (e.g., changes in work activities or intensity), or both.

Table 1. Comparison of AM and PM average speeds at I-69 site

		average speeds						speed differences						
		Goodall		Sheridan		Nichols		Goodall to Sheridan		Goodall to Nichols		Sheridan to Nichols		
test condition	deployment location	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	comments
no construction	none	69.0	71.9	72.2	73.4	72.5	70.0	3.2	1.5	3.5	-1.9	0.3	-3.4	Sheridan and Nichols speed limit = 70
standard WZ	standard	65.5	65.7	43.0	44.6	47.0	43.3	-22.5	-21.1	-18.5	-22.4	4.0	-1.3	Sheridan and Nichols speed limit = 35
police present	Goodall	56.6	61.2	41.4	42.6	42.9	42.5	-15.2	-18.6	-13.7	-18.7	1.5	-0.1	Sheridan and Nichols speed limit = 35
police present	Sheridan	71.2	66.5	44.5	41.2	46.0	49.0	-26.7	-25.3	-25.2	-17.5	1.5	7.8	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-on[1]	60.2	64.3	43.5	44.6	48.9	49.5	-16.7	-19.7	-11.3	-14.8	5.4	4.9	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-off[1]	53.1	63.2	43.8	42.3	46.8	49.3	-9.3	-20.9	-6.3	-13.9	3.0	7.0	Sheridan and Nichols speed limit = 35
speed trailer showing motorist speed	in advance of closure[2]	69.0	68.9	44.9	47.4	46.8	48.0	-24.1	-21.5	-22.2	-20.9	1.9	0.6	Sheridan and Nichols speed limit = 45
speed trailer showing motorist speed	Sheridan	73.3	70.0	48.2	51.1	52.7	51.3	-25.1	-18.9	-20.6	-18.9	4.5	0.0	Sheridan and Nichols speed limit = 50
CMS: workers ahead, obey speed limits	in advance of closure[2]	70.0	68.9	53.1	49.4	63.3	50.0	-16.9	-19.5	-6.7	-18.9	10.2	0.6	Sheridan and Nichols speed limit = 45
CMS: workers ahead, speed limit 45 mph	Sheridan	76.8	71.0	53.8	52.8	55.5	54.3	-23.0	-18.2	-21.3	-16.7	1.7	1.5	Sheridan and Nichols speed limit = 45

Notes:
1. Data were taken with radar on and off under the exact same conditions (sequentially)
2. The initial lane closure was changed somewhat (moved closer to Sheridan) and sign was placed in the same position relative to the lane closure; data collection positions did not vary

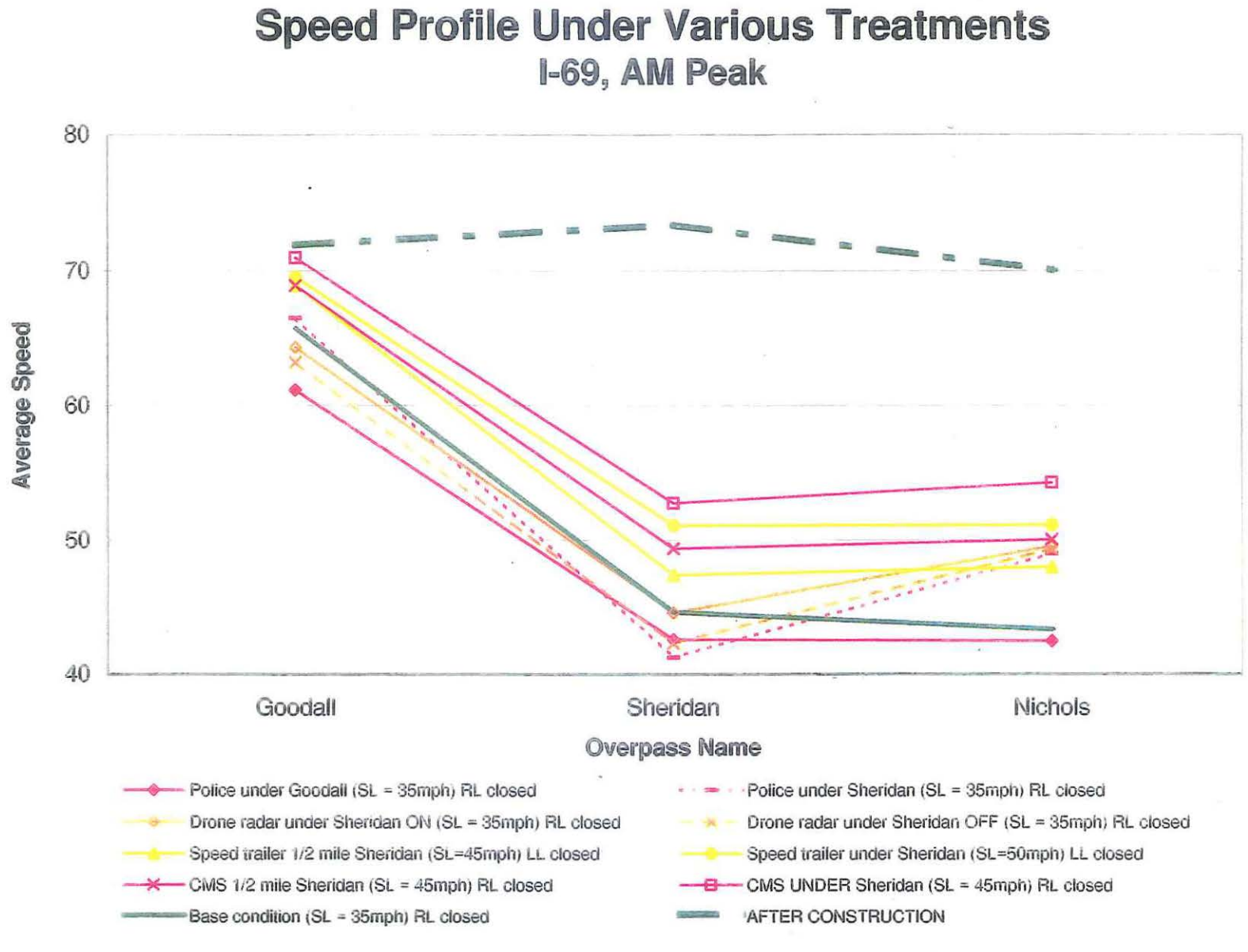


Figure 2. Speed profile under various treatments—I-69, AM

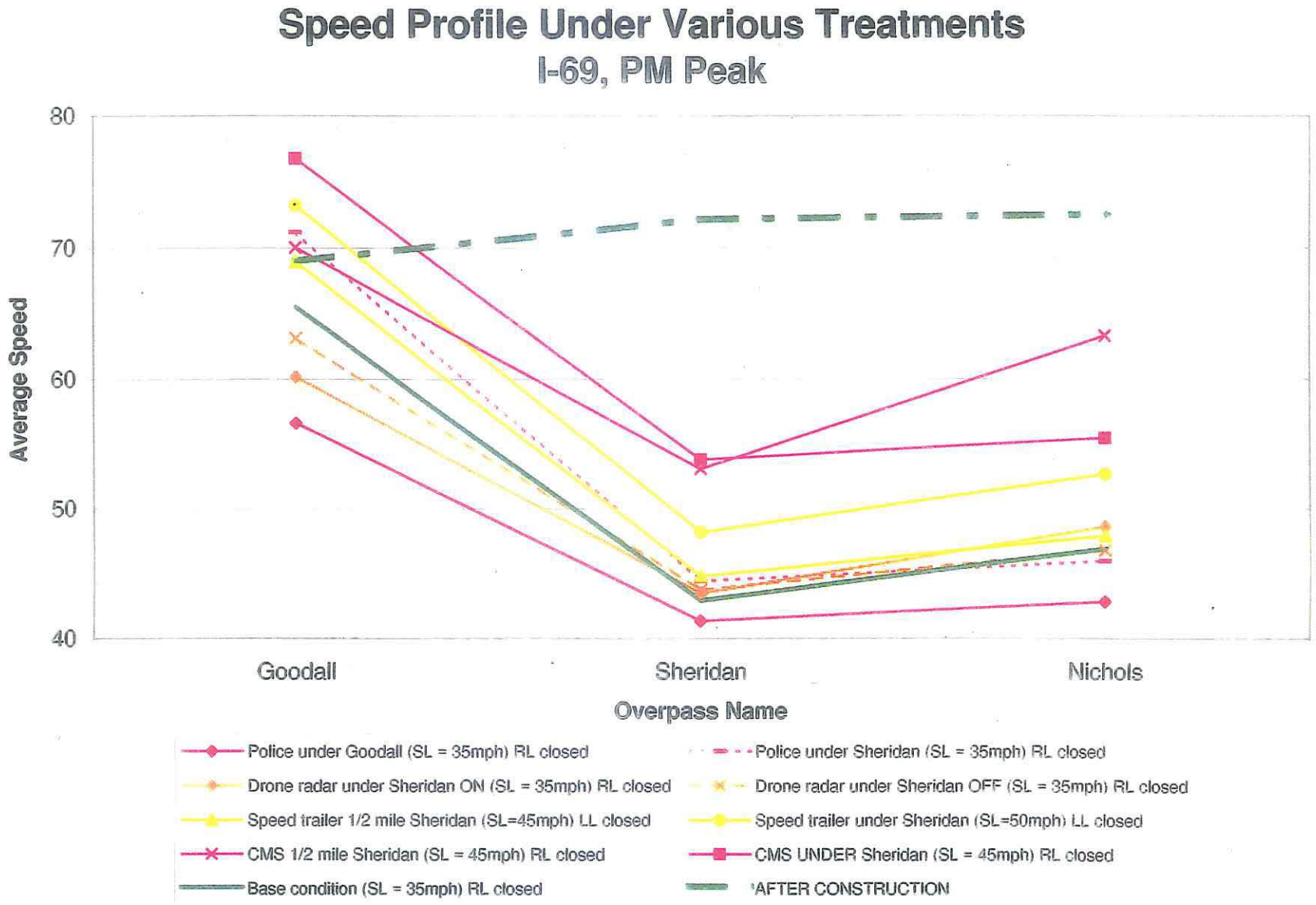


Figure 3. Speed profile under various treatments—I-69, PM

Given that there were changes in the work zone configuration and speed limit (noted in Table 1) and that there appears to be a fairly large variance in the responses of motorists to different treatments, it is argued that the most important conclusions to take from this analysis are the general trends that can be noted. So, based on the collective results shown in the figures and tables, the following summary comments are offered:

- The presence of police appears to have had an immediate effect on motorist speeds (speeds at Goodall). This was seen during both AM and PM periods when police were positioned in advance of the actual lane closure. However, when police were present in the area where the lane was already closed, the speed decrease was not as apparent (speeds at Sheridan and Nichols). In the latter instance, while observed average speeds were approximately the same as when only standard work zone signing was present, the relative decrease from the first data collection location was greater. Thus, there was reasonably good evidence that free-flowing speeds in advance of the lane closure (Goodall) were decreased by police presence (in advance of the closure). Subsequent effects (Sheridan and Nichols) were not as clear although there was some evidence that police presence within the closure area resulted in a greater relative decrease in average speed than may not have otherwise occurred. Evidence of a "carryover effect" of police presence to the last data collection location was mixed—in one instance, speeds actually increased further away from the police.

- The conclusions regarding the effects of other speed control devices are somewhat problematic. In general, there was not consistent evidence that they made much difference in motorist speeds. The speeds observed at the three locations were higher when the other devices were present when compared to those when only the standard construction zone signing was present. At the same time, effects were clouded by the fact that the speed limit had been changed (higher) when these devices were present. A comparison of speeds with the CMS and speed trailer present at two different locations did show some evidence that there might be some initial speed reduction attributable to the presence of either device, although the magnitude is less than that achieved by the police presence.

- Once in the lane closure area, the effects of the different strategies are not as clear. While the police presence still results in lower speeds, they are not necessarily appreciably lower and the incremental difference is within what appears to be the day-to-day and location-to-location variations that are observed when no construction is present and when only the standard work zone signing is present. For the most part, variation in average speeds between the last two locations is not great, the most significant exception being when the police were present at Sheridan—in this instance, there was an appreciable **increase** in average speed between the two sites, a counter-intuitive result.

Results for MSP/MDOT Cooperative Enforcement Project

For these sites there was considerably less control and information regarding the police presence during data collection. At the I-275 site, there were, according to MSP, four patrol cars operating in both stationary and mobile modes. It is not clear precisely where or in what mode

the patrols were operating during data collection periods or if there was significant variation in their operational mode during the time they were on site, but they were there. Motorists whose speeds were recorded were fairly likely to have encountered an MSP patrol car either while they were in the congestion in advance of the lane drops OR actually in the active work zone area (i.e., where the lanes were actually closed). This defines "police presence" for this site.

For the I-94 site, the MSP enforcement was somewhat "disconnected" from the construction zone activities where data were being collected. Data were collected at Central and Junction Avenues while police activities were focused in an area further east (between Mt. Elliott and Warren)—the police presence could have been as much as five-six miles away. Moreover, many motorists who went through the data collection area may have gotten on I-94 **after** the area where the MSP had been deployed. Thus, while it was known that MSP was in the I-275 construction zones when some data were collected, there is no information to indicate whether police were near the locations on I-94 or the fraction of motorists who had encountered the police presence. Similarly, their mode of operation (on I-94) is unknown.

Typical results from the I-275 and I-94 sites are shown in Figures 4 and 5, respectively. In Figure 4, a speed versus time profile is shown for site NB 10L on I-94. The location is well within the lane closure area and two of three lanes were closed during the data collection period. In this instance, there appears to be congestion earlier in the data collection period when the average speed varies from about 50 mph all the way down to 20 mph. After 10:00 PM, the average speed increases steadily to about 50 mph shortly after midnight. This gradually increasing trend holds through the "no police presence" period and peaks at 62 mph at 4:00 AM.

In Figure 5, several days of data with and without police presence under similar roadway conditions (as far as could be ascertained) are shown for the westbound Central data collection location. On all days, workers were present on the site and two lanes were open to traffic with a posted speed limit of 45 mph. For these four days of data, traffic did not appear to be subjected to major disruptions in flow (at the data collection site). Average speeds are seen to vary between the mid-50s and mid-60s mph. Speeds are seen to be at their lowest for the several hours around midnight and highest during the AM rush period. Most apparent, however, is the lack of any consistent difference between data when police were present upstream and when they were not. In some time periods, the "no presence" speeds are a little higher than "presence" speeds (around the AM rush and mid-morning), while in others there is no clear trend (from around midnight to the AM rush), and yet in others, the "presence" speeds are higher (from about noon until 7:00 PM). The clearest indication of one condition being superlative to the other is in the latter period, and those results are counterintuitive. Overall, the average speeds are within a mph or so of each other.

I-94 data were also examined to insure that, if there had been a police "presence" effect, the data collection approach would have been adequate to detect it. To this end, data were isolated when different lanes were open and when workers were present or not. While not shown here, speed versus time graphs for "worker presence" versus "no-worker presence" showed some clear differences. With respect to measuring the effect of police presence, this finding gives confidence in the conclusion that no effect of police presence was detected.

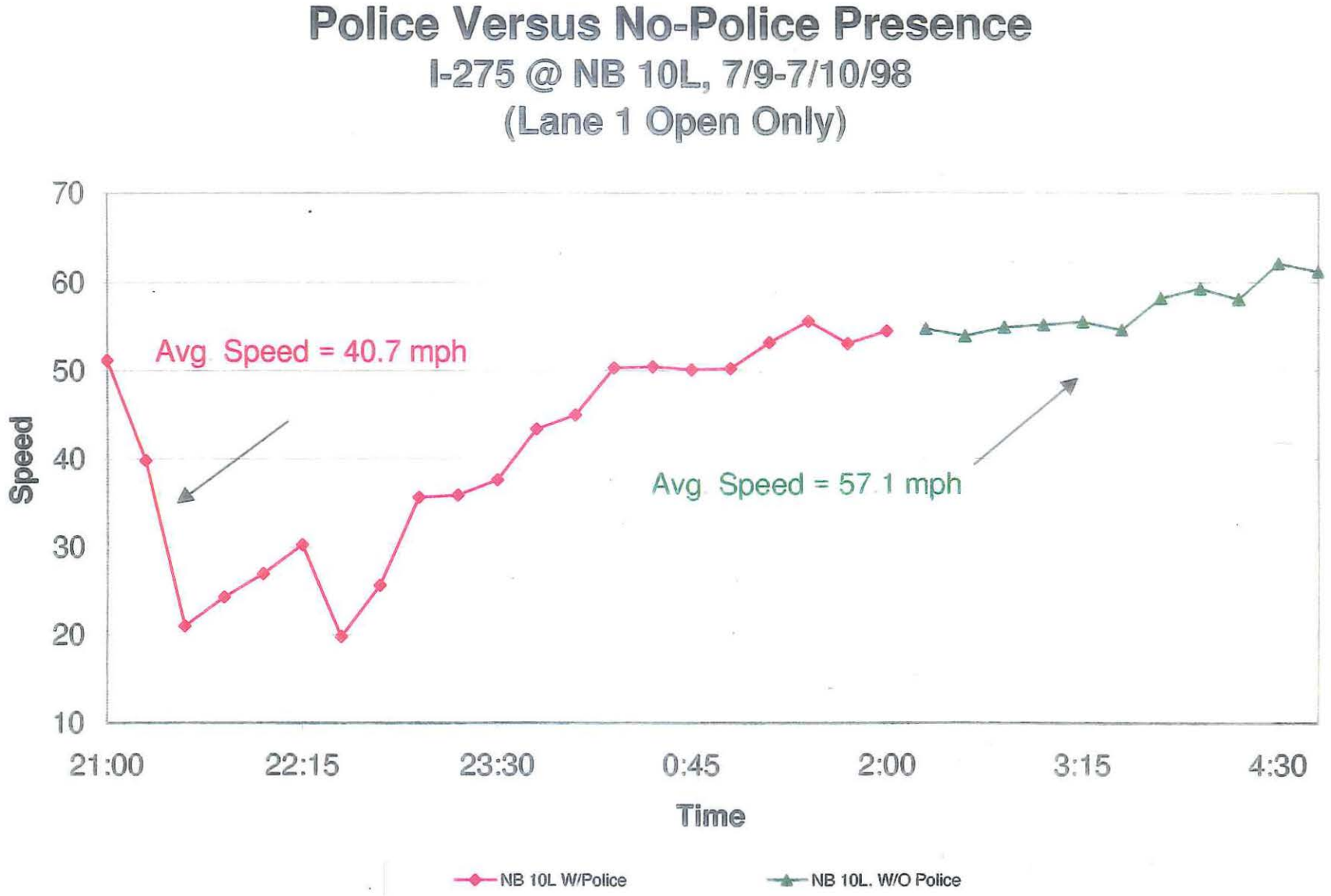


Figure 4. Police vs. no-police—I-275 NB 10L

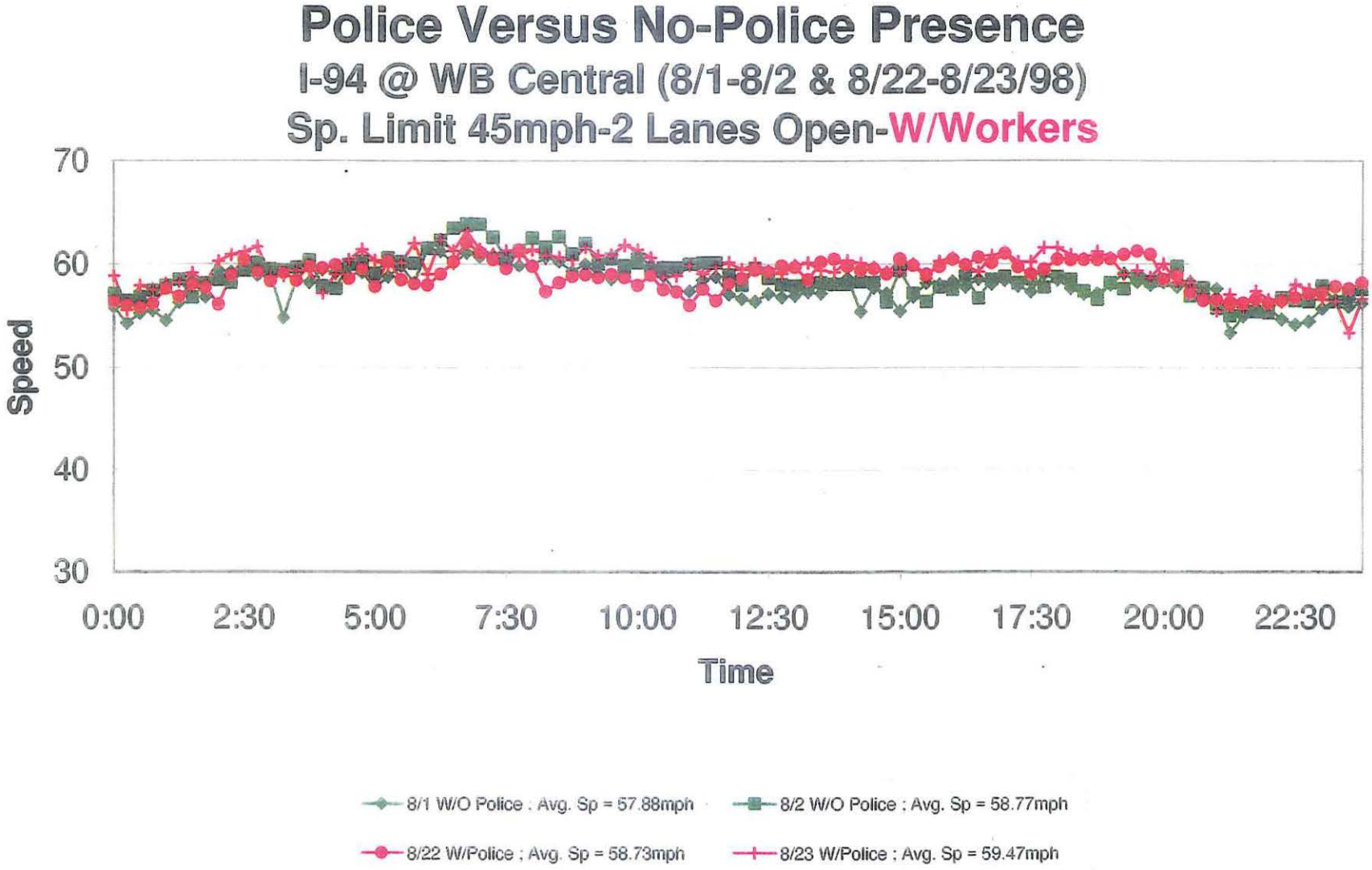


Figure 5. Police vs. no-police—I-94 WB Central

Summary, Conclusions, and Discussion

There were two basic parts to this project: a relatively detailed examination of the effectiveness of different speed control strategies in work zones that was carried out at a site on I-69 southwest of Flint (including use of police in the zone); and an examination of the effects of special extra enforcement in work zones by MSP in two work zones on I-94 and I-275 in southeastern Michigan. The results are summarized below.

For the I-69 site...

- The presence of a stationary police car (with radar on) appears to have had an immediate positive effect on motorist speeds (they decreased). This was especially clear when police were positioned in advance of the actual lane closure. However, when police were present in the area where the lane was already closed, the speed decrease was not as apparent.

- Evidence of a "carryover effect" of police presence downstream from their location to the last of three sequential data collection locations was mixed—in one instance, speeds actually increased further away from the police.

- In general, there was not much consistent evidence that other extra devices (i.e., CMS and speed trailers) made much difference in motorist speeds. However, results were somewhat compromised by the fact that the speed limit was increased when these devices were present. A comparison of speeds with the CMS and speed trailer present at two different locations in the marked zone (in advance of the lane closure versus "in" the closure area) did show some evidence that there might be some initial speed reduction attributable to the presence of either device—the magnitude appeared to be less than that achieved by the police presence.

- Once in the lane closure area, the effects of the different strategies are not as clear. While the police presence still results in lower speeds, they are not necessarily appreciably lower and the incremental difference is within what appears to be the day-to-day and location-to-location variation that is observed when no construction is present and when only the standard work zone signing is present.

- The effects of other factors in the lane closure area that affect speeds are very difficult to separate from the effects of the speed control strategies. Day-to-day variation in work zone activities which would affect motorists' speeds were virtually impossible to control.

For the I-94 and I-275 sites...

- There was some minimal evidence at the I-275 site that police presence in advance of and/or in the zone (the operating mode for the police was mixed) might have had some effect in decreasing motorist speeds within the lane closure areas. The effects were not large and could not be separated from background variation in speed by time of day—i.e., at other similar sites, the speeds with no police present appeared to increase as a (presumed) function of

roadway conditions, thus speeds may have increased slightly even if the police had been present.

- There was no evidence at the I-94 site that the police presence had any effect on motorist speeds in the work zone (at the data collection site). It is possible that there were effects that were not measurable due to the location of the police relative to the data collection location.

The results of this project are equivocal for several reasons. First, the I-69 site was less consistent than had been expected (e.g., work zone speed limits were unexpectedly changed in the data collection area). In addition, motorist speeds through the site were somewhat lower than had been expected *a priori*. Normal traffic on I-69 is perceived to "move well" and it was expected that there would be real need to decrease motorists' speeds through the project area. In many instances, however, the speeds, while in excess of posted limits, did not seem excessively high. The point being that motorists had already "selected" what they considered to be a reasonably safe speed and did not need to slow down further.

The results at the MDOT-identified extra enforcement sites (I-275 and I-94) were compromised because of the relative lack of a coherent experiment design which would have included more specific monitoring of site activities (including the location of police patrol cars) and better coordination of data collection with work and police activities. That notwithstanding, the I-275 site was significantly different than the I-69 site as there was congestion in advance of the work zone which negated the need for the initial reduction of average motorist speeds. But, even when congestion cleared, no measurements of motorist speeds in advance of the lane closure area were taken. Comparison of such results with those from I-69 would have been useful, but were impossible to make. The I-94 results were the most compromised of all as the relationship between the data collection sites and the location of the MSP efforts was quite unclear.

Notwithstanding the site-related problems, there are still conclusions that can be drawn from this effort. Based on the I-69 results, there was a clear reduction in motorists' speeds when police are placed in advance of the lane closure for a construction zone (e.g., 4-9 mph). Other devices, such as CMS with speed-related messages and speed trailers, also seemed to have some effect on reducing motorists' speeds in similar locations. The direct comparison of police to CMS/speed trailer effects was not possible because of changes in site conditions. Based on the results at the I-69 and I-275 sites, the effects of police and other techniques on reducing speeds within the lane closure areas are completely clear. While there was some evidence that police presence reduced speeds in this situation, the effect does not appear to be great. Moreover, it is not clear whether that effect would be greater if the motorists' speeds were higher to start with—if motorists were going well over the posted speed limit in the lane closure area, it seems reasonable to assume that speed reductions similar to those identified above could be achieved in that situation as well.

In summary, it would appear that police presence can be effective in reducing speeds at spot locations, such as in advance of construction lane drops in uncongested conditions. However, the downstream effects are not as great or as certain. Other devices appear to have some effect as well, although not as much as the police presence.

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16. Abstract

This study was concerned with the evaluation of the effectiveness of various speed control strategies in freeway work zones. These strategies included police presence in the work zone, speed trailers (which displayed the speed limit and the motorist's speed), and changeable message signs. While data analysis was compromised at two sites where Michigan State Police were deployed and results were less than expected, results at a third site indicated that police presence was effective in reducing speeds in advance of initial lane closures but less so within the lane closure area. Speed trailers and changeable message signs showed limited promise in reducing speeds compared to police presence.

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DISCLAIMER

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FINAL REPORT

INTRODUCTION

The objective of this project was to study the effectiveness of specific speed control techniques in work zones on selected limited-access highways in Michigan during the 1998 construction season. It was a follow-up to a study done for the Michigan Department of Transportation (MDOT) during the 1997 season where motorist speeds in work zones on the same type of highway were observed and analyzed. The first study was limited to studying sites where conventional speed limit signs were deployed—i.e., comparing speeds when no formal work zone was present (typically 70 mph) to those observed when there were work zones and limits of 60, 50, and 45 mph present with the posted limit depended on the type and duration of the work being undertaken. The current study was to be directed to the evaluation of several speed control strategies in work zones—for example, the use of changeable message signs (CMS) such as "speed limit 50 mph when workers present" and the use of police presence in the work area.

The general results of the 1997 study were that while different speed limits seemed to have some effect in lowering average speeds (i.e., average speeds were lower with lower speed limits), all average speeds were considerably higher than the posted limits (whatever they were). Moreover, the speeds at which motorists travel through work zone seemed to be related to characteristics of the zone such as the number of open lanes, whether workers were present, and the type of separation between the work activity and the motorists traveling through the zone. To that end, the effectiveness of posted limits and the effects of these other characteristics were intertwined.

In this context, the objective of the study done during the 1998 construction season was to determine the effects of alternative types of signs and enforcement in controlling motorist speeds in work zones.

It should be noted that, at the outset, all data collection was originally proposed to be done by the Michigan State University (MSU) research team at sites jointly identified by MSU and MDOT. As the project was executed, evaluations of the effects of extra Michigan State Police (MSP) enforcement at two selected work zone sites in southeastern Michigan were added to the project. While the purpose of the extra enforcement was very similar to that for the project *per se* (i.e., what are the effects of police presence on motorist speeds in work zones), experiment design and data collection were done by MDOT with the subsequent analysis and interpretation being undertaken by MSU.

GENERAL DISCUSSION OF DATA COLLECTION PROCEDURES

The data collection procedure was quite similar to that used during the 1997 project and is discussed only briefly here (for more detail see the ***1997 Work Zone Speed Study*** Lyles, Sisiopiku, and others). The basic procedure was to collect data at sites before, during, and after

the work zone was in place. Data were collected using a videotape surveillance system which requires the use of a bridge over the data collection location and a marked "trap" on the roadway just upstream of the bridge. Vehicles passing through the site (and under the bridge) were videotaped in 1-2 hour sessions. The videotapes were then processed using Autoscope, a computer-based reduction system that provides summary data on the observed vehicles (e.g., numbers of vehicles by class and total, vehicle speeds) on a lane-by-lane basis over a user-specified aggregation period (e.g., 5 minutes). The data are presented in a worksheet-type format in a file that can be manipulated using a number of different programs (e.g., Excel, SPSS).

SITE SELECTION AND IDENTIFICATION OF SPEED CONTROL TECHNIQUES TO BE TESTED

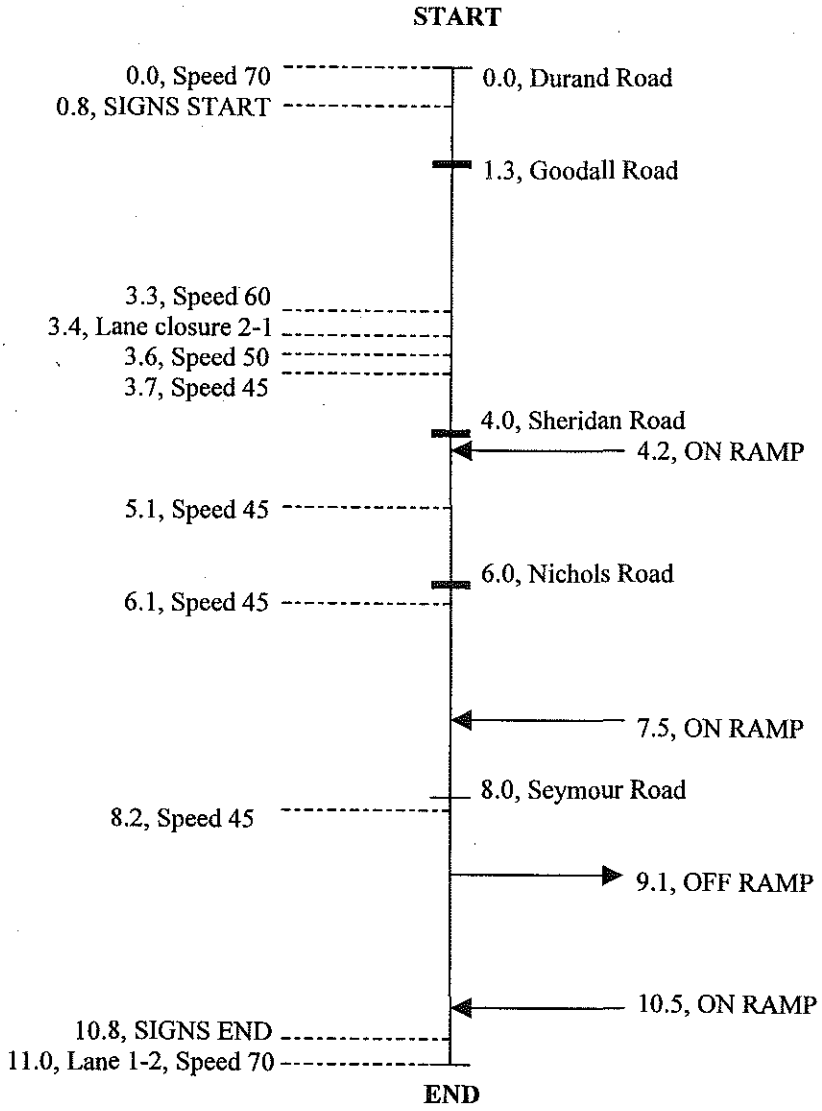
The general characteristics of a "good" site included: a freeway site not prone to significant congestion (i.e., so that traffic would be reasonably free-flowing); fairly long duration of the work zone activities; reasonably consistent (or at least predictable) activities in the zone; cooperation of MDOT field staff, the prime contractor, traffic control device sub-contractors, and local and state police; appropriate data collection opportunities (e.g., overpasses that could be used for data collection); and reasonable proximity to East Lansing. Site selection was difficult for a number of reasons which included the fact that considerable 1998 construction work was done at night, quickly changing major site characteristics (that rendered day-to-day comparisons of speed control strategies meaningless), and data collection difficulties. One useful site was identified: I-69 southwest of Flint. There were also two "MSP extra enforcement" sites identified in southeastern Michigan where MDOT was responsible for data collection.

I-69 SOUTHWEST OF FLINT (near Swartz Creek)

The I-69 site met most of the criteria noted above: this section of road is not prone to heavy congestion and is perceived to be a fairly high-speed location with freely moving traffic under normal circumstances; the work zone was several miles long and in place for several months; several data collection locations were identified that were easily accessible and safe for the data collection team; work was reasonably consistent although the level of activity did vary somewhat near the data collection locations; and cooperation with MDOT, the contractors, and MSP was good. The work consisted of resurfacing and shoulder work along with some work on several interchanges. The actual extent of the site was from near Durand Road east to about three miles beyond Seymour Road. All of the data collection occurred on the eastbound side of the freeway and specific data collection points were at the overpasses at Goodall, Sheridan, and Nichols Roads. The initial lane closure occurred east of Goodall Road. In all instances, data were collected at all three locations. Normally, this is a two-lane section but was narrowed to one during the time when construction was undertaken. The schematic of the site is shown in Figure 1.

The selection of speed control alternatives was done with cooperation and guidance from MDOT. The following techniques were tested:

I-69 EB@SWARTZ CREEK



Approx. Scale: 1 inch = 2 mile

Figure 1. Schematic of I-69 site

- stationary MSP presence at two different locations separately (a single patrol car was clearly visible near the beginning of the zone [near Goodall] **or** within the zone [near Sheridan]);

- a drone radar installation (i.e., a radar unit was placed in one location although there was no police presence and no other vehicle was obvious to motorists);

- a speed trailer which displayed the messaged "speed limit XX" and "your speed is YY" at one of two different locations (near the beginning of the zone [near Goodall] **or** within the zone [near Sheridan]);

- a CMS which displayed the message "workers ahead, obey speed limit" and was located near the beginning of the zone; and

- a CMS which displayed "workers ahead, speed limit 45 mph" and was located within the zone.

Data were also collected with no extra signs or police present (i.e., only standard work zone signs were deployed) and after the work activity was over and all signs had been removed. The speed trailer and the changeable message sign were provided by Work Safe Supply Co. Work Safe also provided installation and maintenance of the signs at no cost to the project.

It should also be noted that there were some day-to-day changes in the work zone configuration which affected the data that were collected. For example, during data collection for some "treatments," the 2→1 lane closure was nearer to Goodall than Sheridan while for other treatments (days), the closure was moved closer to Sheridan and the work zone speed limit was changed. Other changes included which lane was closed—sometimes it was the "slow" lane while in other instances it was the "passing" lane. At other times, there was a slight jog in the lane (although there was no change in usable lane width) near the Sheridan Road overpass. In still other instances, there was somewhat more construction activity in the vicinity of one of the data collection locations (e.g., on the ramps at Sheridan Road) which sometimes included trucks turning through the median. The latter would typically slow one or two through vehicles.

MSP/MDOT COOPERATIVE ENFORCEMENT PROJECT

As a separate effort during the summer of 1998, MDOT and MSP were involved in a project where MDOT funded extra enforcement by MSP in selected work zones. Two specific sites were targeted: work zones on I-94 and I-275 in the Detroit area. Originally, MSU had no role in this cooperative effort. All negotiations/agreements with respect to where and when additional enforcement would be undertaken, record-keeping, and the like were carried out between MDOT field personnel and MSP post personnel. All of the data collection at these two sites was also done by MDOT. After the fact, it was agreed that MSU (as a part of the current project) would analyze the data that were obtained by MDOT to assess the effectiveness of the extra MSP enforcement—i.e., what was the effect of the extra police presence on motorists' speeds in the construction zones.

I-275 IN/NEAR CANTON TOWNSHIP

The I-275 site was a zone where the construction work was done primarily at night. The overall site boundaries with respect to the data collection and enforcement were approximately Hannan Road and 5-Mile Road. Data were collected using automatic counters at several sites: between Hannan and Ecorse Roads, between Ecorse Road and Michigan Avenue, between Michigan Avenue and Cherry Hill Road, between Ford and Joy Roads, between Joy and Ann Arbor Roads, between Ann Arbor Road and I-96, and between I-96 and 5-Mile Road. Only some of these sites were useful since a match was desired between site conditions with and without police presence, the number of lanes that were open, and so forth.

The only speed enforcement strategy to be tested at this site was presence versus no-presence of MSP. The following are the details (from MSP) regarding the nature of the additional enforcement that was provided in this work zone:

- patrol cars were used in both roaming (assumed to be in and around the work zone) and stationary (although the position was not clear) modes;
- hours worked were from 6:00 PM until 2:00 AM; and
- the majority of tickets written during the 6:00-10:00 PM period were for median crossing violations (traffic was stop-and-go with about a 2-mile long backup) although after this period, they were primarily for speeding.

The police (according to the operating regime given above) were in the vicinity of Michigan and Ford Roads on northbound I-275 for three days when data were collected.

I-94 IN DETROIT

The coordination between MDOT and MSP was somewhat more problematic at the I-94 site. MDOT collected data at Central Avenue and further east at Junction Avenue (the locations are about a mile apart) while the MSP presence was between Warren and Mt. Elliott. Warren is ~½ mile further east of Junction and Mt. Elliott is five miles (east) beyond that. Thus, the police were possibly adjacent to, but not "in," the area where data were collected.

The following are the details of the MSP additional enforcement (from MSP):

- it is difficult to assess how much time was spent in stationary versus mobile patrol (troopers use a combination of tactics) although there was some indication that it was probably a "majority" in a roaming mode; and
- laser and pace-clocking were used to determine speeds of suspected violators.

The best matches possible were made between the data collected when police were expected to have been present in the Warren-Mt. Elliott part of the construction zone and the data collected when they were not.

DISCUSSION

The data collection on the I-69 site was much more controlled than that at either of the Detroit-area sites. At the I-69 site, the speed control strategies were well-defined with respect to where devices or police were placed and the time periods when they were present. At the Detroit-area sites, while it is relatively clear when the police were present, it is not at all clear how they were operating. Moreover, on the I-94 site, police were not necessarily even in the vicinity of the data collection locations—e.g., if they were at the far eastern end of their patrol area, they were as far away as five-six miles. Thus, the data collected at the Detroit-area sites can, at best, provide only the most general sense of the effectiveness of the police presence.

BASIC APPROACH TO MEASURING SPEED CONTROL EFFECTIVENESS

Given that the basic objective of the project was to determine the effectiveness of different speed control strategies, the approach was to measure motorist speeds "with" and "without" treatment. If all else is equal at the site, any difference in motorists' speeds will be a result of their reaction to the speed control strategy that they encounter.

At **the I-69 site**, speed data were collected during AM and PM off-peak periods (9:00-11:00 AM and 1:00-3:00 PM, respectively) at each of three locations: the first position was at the beginning of the zone just before the lane closure (and a mile after the first signs had indicated the presence of the zone ahead)—Goodall Road (see Figure 1); the second position was 2.7 miles into the zone—Sheridan Road; and the third position 2.0 miles further into the zone—Nichols Road. Thus, comparisons of speeds can occur at any given position (e.g., compare average speeds at Sheridan Road for all conditions) or they can be compared longitudinally (a speed profile using the three positions can be constructed for a given condition and then compared to a profile for some other condition). The latter can be used, for example, to show whether police presence at the first location has a "lasting" effect into the zone.

At **the Detroit-area sites**, the experimental design was imprecise in the sense that there was no control exercised over the MSP with respect to where they would be and what their operating regime would be. By and large, they were simply "there" or not. "There" being indicative that they were in the general vicinity. For these two sites, the evaluation procedure is very basic:

- measure motorist speeds **without** MSP presence at "specified" locations;
- measure motorist speeds **with** MSP presence at the same locations; and
- compare the two.

This assumes, of course, that all other conditions are similar (with and without police presence). In interpreting these results, it will have to be recalled that "presence" was not always well-defined.

ANALYSIS AND RESULTS

The analysis and results are presented on a site-by-site basis since the sites were quite different with respect to layout and control of the data collection activities.

I-69 RESULTS

As noted, there are two basic types of comparisons: a comparison of the average speeds under all test conditions at a given location; a comparison of the speed profiles through the zone under all test conditions.

AM RESULTS

Table 1 is a summary of AM average speeds under all conditions that were tested. The values of average speeds at Goodall represents an "entry" speed into the active part of the construction zone although motorists would have already encountered numerous constructions zone signs and could see the lane closure ahead. The exceptions to the latter are the last four conditions (rows) when the lane closure had been moved closer to Sheridan Road. The results in the first line of the table are for the normal conditions when no work zone was present (these speeds were taken after the construction was completed). It can be seen that the average speed (71.9 mph) is slightly above the posted limit of 70 mph.

The lowest speed at Goodall (61.2 mph) was recorded when the MSP patrol car was at that location (with radar operating). Otherwise, the speeds range from ~63 to 66 mph when the lane closure is close to Goodall—lower than when no work zone is present. The last several rows of results in the table show somewhat higher speeds at the Goodall location when the actual lane closure had been moved closer to Sheridan (away from the Goodall location) and the speed limits through the zone had been increased to either 45 or 50 mph. None of these results is particularly unexpected. Overall, the police presence near Goodall had a positive impact on slowing down motorists as they approached the lane closure.

The average speeds at Sheridan and Nichols show a significant decline from the "entry" speeds at Goodall. A positive speed difference indicates a speed increase from one data collection location to the next while a negative number indicates a speed decrease. Interestingly, under the "no construction" condition there is a 1-3 mph variation from place to place (this could be considered operational or normal background variation). By, comparison when the zone is marked in any way, the initial speed changes (Goodall to Sheridan) range from 18.9 to 25.3 mph. The maximum speed change occurs when the police are encountered at Sheridan (the Goodall to Sheridan reduction is 25.3 mph). If that value is eliminated, the range of speed changes is from 18.2 to 21.5 mph—a much more restricted range. The standard work zone signing resulted in a speed

Table 1. Comparison of average speeds at I-69 site (AM results)

test condition	deployment location	average speeds			speed differences			comments
		Goodall	Sheridan	Nichols	Goodall to Sheridan	Goodall to Nichols	Sheridan to Nichols	
no construction	none	71.9	73.4	70.0	1.5	-1.9	-3.4	Sheridan and Nichols speed limit = 70
standard WZ	standard	65.7	44.6	43.3	-21.1	-22.4	-1.3	Sheridan and Nichols speed limit = 35
police present	Goodall	61.2	42.6	42.5	-18.6	-18.7	-0.1	Sheridan and Nichols speed limit = 35
police present	Sheridan	66.5	41.2	49.0	-25.3	-17.5	7.8	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-on[1]	64.3	44.6	49.5	-19.7	-14.8	4.9	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-off[1]	63.2	42.3	49.3	-20.9	-13.9	7.0	Sheridan and Nichols speed limit = 35
speed trailer showing motorist speed	in advance of closure[2]	68.9	47.4	48.0	-21.5	-20.9	0.6	Sheridan and Nichols speed limit = 45
speed trailer showing motorist speed	Sheridan	70.0	51.1	51.1	-18.9	-18.9	0.0	Sheridan and Nichols speed limit = 50
CMS: workers ahead, obey speed limits	in advance of closure[2]	68.9	49.4	50.0	-19.5	-18.9	0.6	Sheridan and Nichols speed limit = 45
CMS: workers ahead, speed limit 45 mph	Sheridan	71.0	52.8	54.3	-18.2	-16.7	1.5	Sheridan and Nichols speed limit = 45

Notes:
1. Data were taken with radar on and off under the exact same conditions (sequentially)
2. The initial lane closure was changed somewhat (moved closer to Sheridan) and sign was placed in the same position relative to the lane closure; data collection positions did not vary

reduction that is near the top end of this range, although not all that different from the other sign conditions.

The Sheridan-to-Nichols speed changes are generally fairly small with a 3.4 mph change observed when no construction was present. (Both of these sites are well within the lane closure area.) The exceptions are when the police were present at the Sheridan Road bridge and for the "drone radar" conditions (both "on" and "off"). When the police were present in the vicinity of Goodall, motorist speeds were lower at Goodall, dropped further at Sheridan, and stayed low at Nichols. So, while overall speeds were lower far into the zone (at least as far as Nichols), the overall decrease was achieved at the beginning of the zone—the absolute decrease after Goodall was consistent with other decreases. On the other hand, when the police were located further into the zone at Sheridan, the speeds at Goodall were higher (not unexpectedly) and decreased most dramatically at Sheridan. However, in this situation the speeds increased after the location was passed—i.e., motorist speeds at Nichols were higher than at Sheridan. The only other significant speed increases between Sheridan and Nichols occurred for the drone radar deployment. The reaction to the drone radar is not easily explained—it may simply be a function of sample size.

These results are also illustrated in Figure 2 where speed profiles through the three data collection locations are shown. The differences between the "no work zone condition" (the top line in the figure) and all treatment conditions are abundantly clear. Likewise, the similarities among all treatment conditions are also evident. For purposes of further clarification, Figure 3 shows a direct comparison between no work zones, the base (standard) work zone treatment, and police presence at Goodall and Sheridan. With the exception of the speed increase that occurs at Nichols when police were present at Sheridan, police presence results in lower speeds in the zone. Other similar graphical comparisons (i.e., no work zones, standard work zone treatment, one type of special treatment) are shown in Appendix A. These comparisons show that the standard treatment results in lower speeds at all three locations. It should be noted, however, that for these other treatments, the speed limit in the work zone had been raised. Thus, the comparison of the speed differences (from Table 1) may be more appropriate. Examination of those differences reveals that the CMS and speed trailer did not result in any more speed decrease than the standard signing.

As indicated above, the comparison of the speed trailer and CMS effects is complicated by the change in work zone speed limit (it was increased in the lane closure area zone from 35 to 45 or 50 mph). However, there is some limited evidence that when these devices were deployed in advance of the closure versus near Sheridan that there was possibly some attributable speed decrease—e.g., when the speed trailer was near Goodall the observed average speed was 70 versus 68.9 mph when the trailer was further downstream at Sheridan. Likewise, when the CMS was nearer Goodall, the average speed was 71 versus 68.9 mph when it was at Sheridan.

PM Results

Table 2 shows the results from the PM data collection periods. The speeds when no construction was present are comparable to those observed during the AM periods although the PM average speeds are slightly lower at Goodall and Sheridan but higher at Nichols. The lowest average

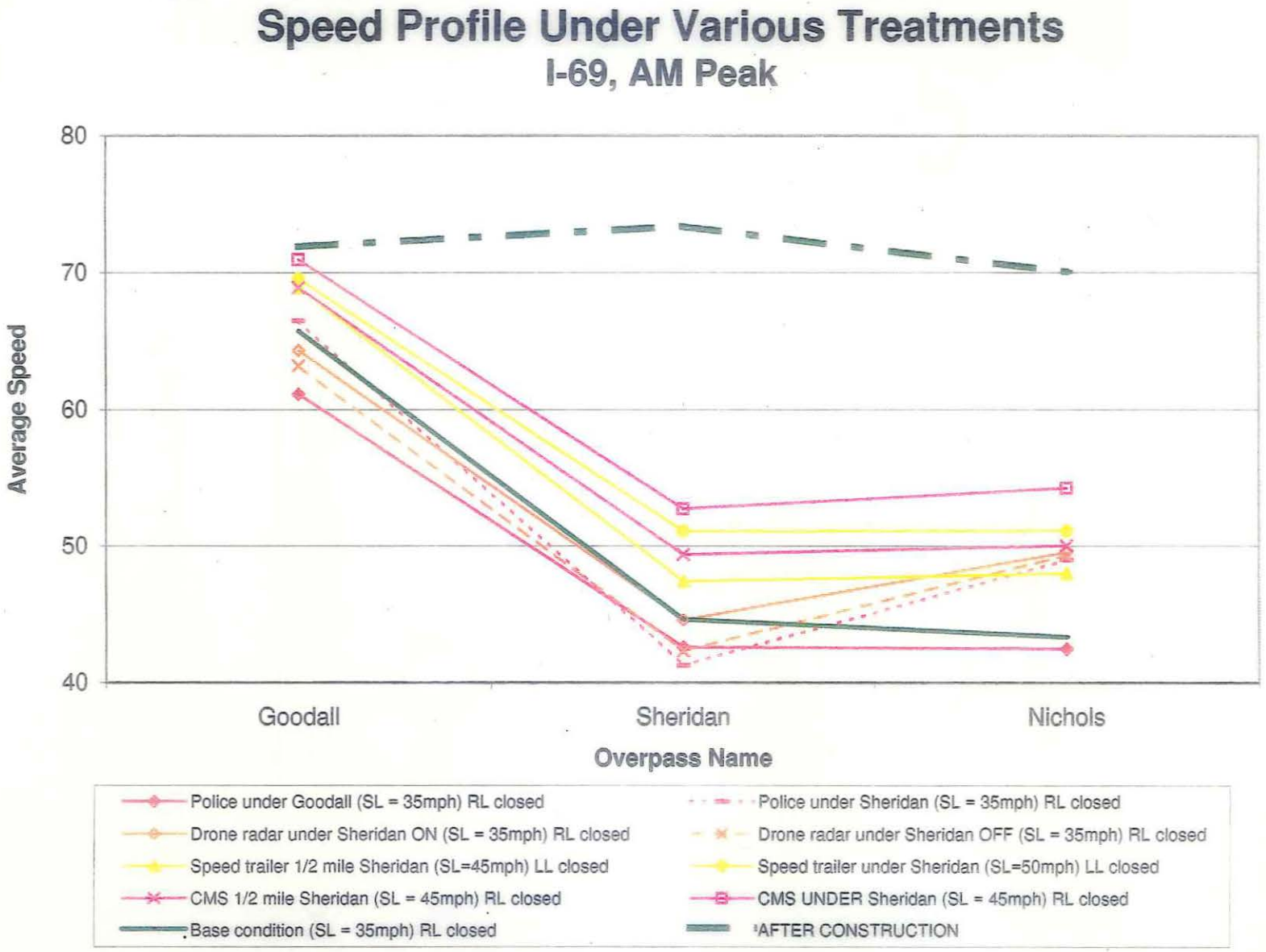


Figure 2. Speed profile under various treatments—I-69, AM

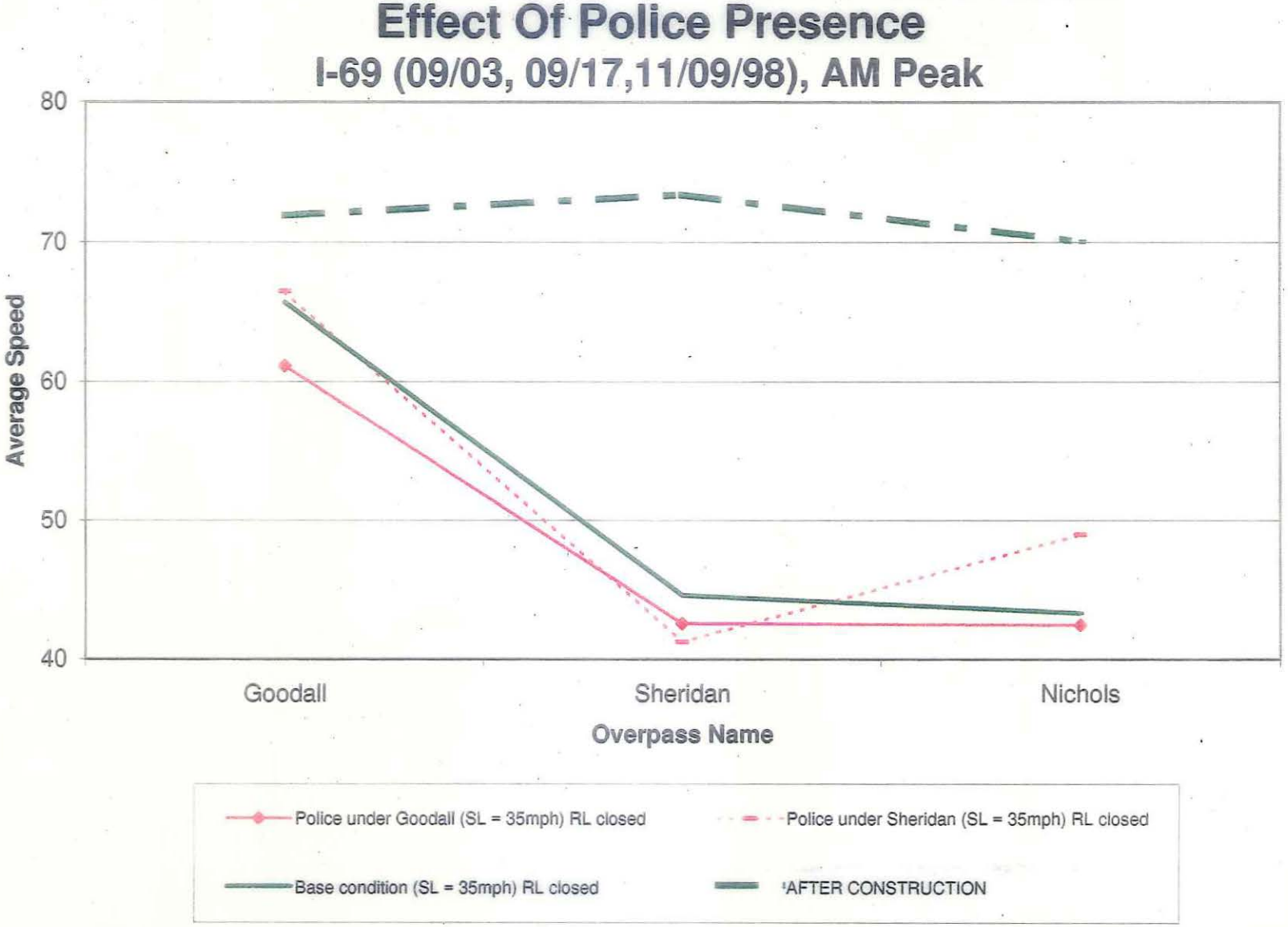


Figure 3. Effect of police presence—I-69, AM

Table 2. Comparison of average speeds at I-69 site (PM results)

test condition	deployment location	average speeds			speed differences			comments
		Goodall	Sheridan	Nichols	Goodall to Sheridan	Goodall to Nichols	Sheridan to Nichols	
no construction	none	69.0	72.2	72.5	3.2	3.5	0.3	Sheridan and Nichols speed limit = 70
standard WZ	standard	65.5	43.0	47.0	-22.5	-18.5	4.0	Sheridan and Nichols speed limit = 35
police present	Goodall	56.6	41.4	42.9	-15.2	-13.7	1.5	Sheridan and Nichols speed limit = 35
police present	Sheridan	71.2	44.5	46.0	-26.7	-25.2	1.5	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-on[1]	60.2	43.5	48.9	-16.7	-11.3	5.4	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-off[1]	53.1	43.8	46.8	-9.3	-6.3	3.0	Sheridan and Nichols speed limit = 35
speed trailer showing motorist speed	in advance of closure[2]	69.0	44.9	46.8	-24.1	-22.2	1.9	Sheridan and Nichols speed limit = 45
speed trailer showing motorist speed	Sheridan	73.3	48.2	52.7	-25.1	-20.6	4.5	Sheridan and Nichols speed limit = 50
CMS: workers ahead, obey speed limits	in advance of closure[2]	70.0	53.1	63.3	-16.9	-6.7	10.2	Sheridan and Nichols speed limit = 45
CMS: workers ahead, speed limit 45 mph	Sheridan	76.8	53.8	55.5	-23.0	-21.3	1.7	Sheridan and Nichols speed limit = 45

Notes:
1. Data were taken with radar on and off under the exact same conditions (sequentially)
2. The initial lane closure was changed somewhat (moved closer to Sheridan) and sign was placed in the same position relative to the lane closure; data collection positions did not vary

speed through the site occurred when the MSP patrol car was present at Goodall, which is consistent with the AM results.

Again, the police presence at Goodall appears to cause a speed decrease in advance of that site with speeds remaining relatively low through both Sheridan and Nichols. On the other hand, when MSP was at the Sheridan site, the Goodall speed was high with a significant drop in speed between Goodall and Sheridan. The increase in speed after Sheridan was not nearly as apparent as it was in the AM results. While the speed at Sheridan (with police presence there) was not the lowest of all treatments, it was among the lowest. The two lowest average speeds at Nichols came when police were present. However, the Sheridan-to-Nichols changes for all treatments (during the PM) were, unexpectedly, increases and some were fairly large. There appeared to be more variance in the PM observations in general than had been noted for the AM time period.

Figure 4 is an illustration of the PM results for all treatments. The figure also shows speeds when there was no work zone and when only the standard treatment was present. As before, figures in Appendix A show the isolation of various types of treatments versus standard work zone signing and the no-treatment condition. Results are similar to those observed for the AM period.

The comparisons for the speed trailer and CMS show more dramatic effects in the PM period. Comparing the speeds at Goodall when the speed trailer is present near Goodall versus near Sheridan, a 4.3 mph difference is noted (69 versus 73.3 mph). Likewise, for the CMS presence, average speeds of 70 and 76.8 mph are noted.

SUMMARY AND DISCUSSION OF I-69 RESULTS

Results presented earlier are summarized in Table 3 which shows side-by-side comparisons of AM and PM results at all three data collection locations and the average speed changes through the area (Goodall to Sheridan, Goodall to Nichols, and Sheridan to Nichols). The first thing that is apparent are the differences between AM and PM speeds. While this had been noted earlier, it is made clearer in this table. For example, the AM-PM differences at Goodall for no construction, standard work zone treatment, and police presence at Goodall are 2.9, 0.2, and 4.6 mph, respectively. This sort of difference attests to the general variance in motorist speeds that was observed and, presumably, attributable to either differences in motorist groups (e.g., fundamental differences between motorists driving during the AM and PM periods), variations in the construction zone itself (as noted earlier—e.g., a different speed limit in the work zone), or both.

Given that there were changes in the work zone configuration and that there appears to be a fairly large variance in the responses of motorists to different treatments, it is argued that the most important conclusions to take from this analysis are the general trends that can be noted. So, based on the collective results shown in the figures and tables (both here and in the appendix), the following summary comments are offered:

- The presence of police appears to have had an immediate effect on motorist speeds. This was seen during both AM and PM periods when police were positioned in advance of the actual lane closure. However, when police were present in the area where the lane was already

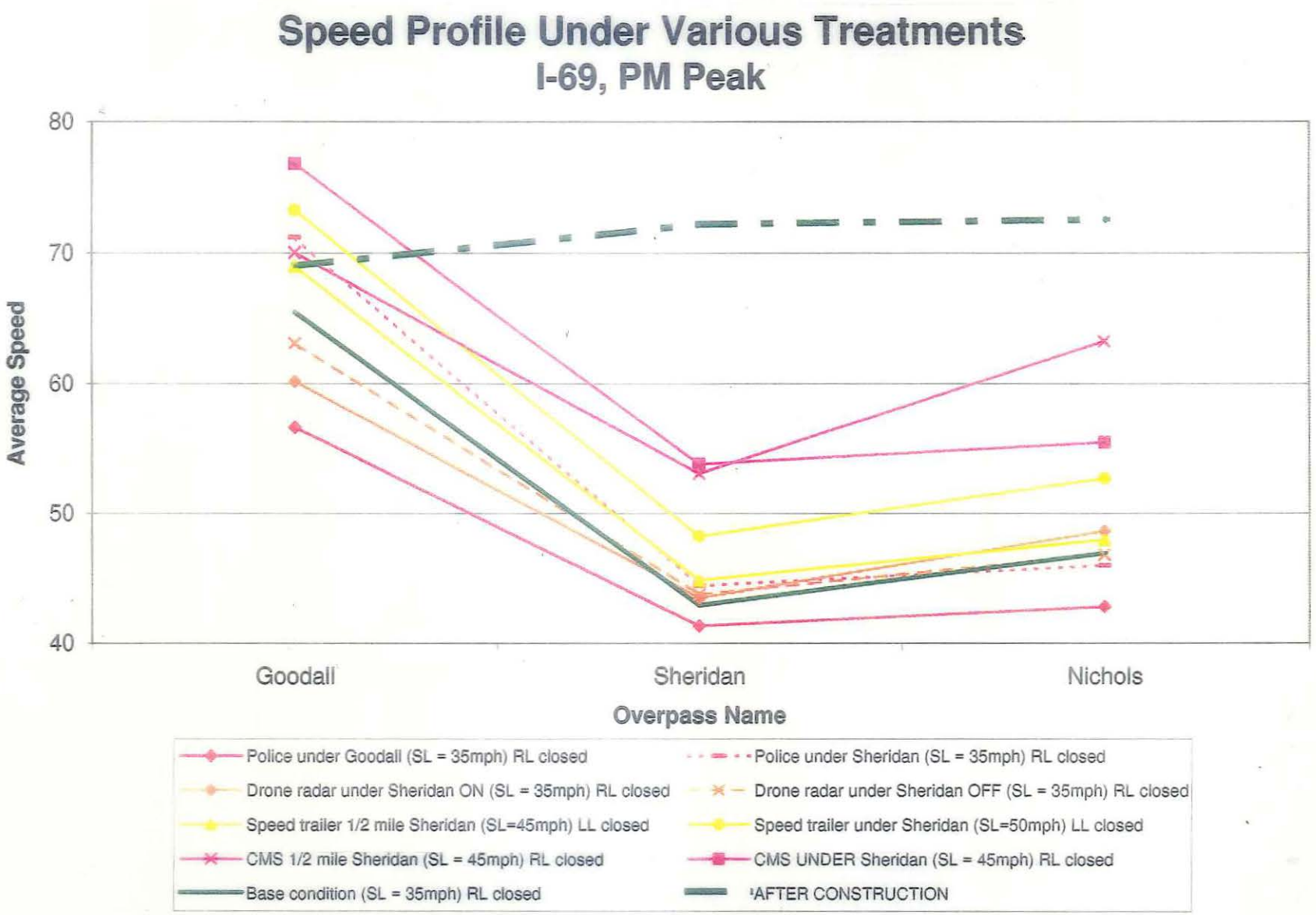


Figure 4. Speed profile under various treatments—I-69, PM

Table 3. Comparison of AM and PM average speeds at I-69 site

		average speeds						speed differences						
		Goodall		Sheridan		Nichols		Goodall to Sheridan		Goodall to Nichols		Sheridan to Nichols		
test condition	deployment location	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	comments
no construction	none	69.0	71.9	72.2	73.4	72.5	70.0	3.2	1.5	3.5	1.9	0.3	-3.4	Sheridan and Nichols speed limit = 70
standard WZ	standard	65.5	65.7	43.0	44.6	47.0	43.3	-22.5	-21.1	-18.5	-22.4	4.0	-1.3	Sheridan and Nichols speed limit = 35
police present	Goodall	56.6	61.2	41.4	42.6	42.9	42.5	-15.2	-18.6	-13.7	-18.7	1.5	-0.1	Sheridan and Nichols speed limit = 35
police present	Sheridan	71.2	66.5	44.5	41.2	46.0	49.0	-26.7	-25.3	-25.2	-17.5	1.5	7.8	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-on[1]	60.2	64.3	43.5	44.6	48.9	49.5	-16.7	-19.7	-11.3	-14.8	5.4	4.9	Sheridan and Nichols speed limit = 35
drone radar	Sheridan-off[1]	53.1	63.2	43.8	42.3	46.8	49.3	-9.3	-20.9	-6.3	-13.9	3.0	7.0	Sheridan and Nichols speed limit = 35
speed trailer showing motorist speed	in advance of closure[2]	69.0	68.9	44.9	47.4	46.8	48.0	-24.1	-21.5	-22.2	-20.9	1.9	0.6	Sheridan and Nichols speed limit = 45
speed trailer showing motorist speed	Sheridan	73.3	70.0	48.2	51.1	52.7	51.1	-25.1	-18.9	-20.6	-18.9	4.5	0.0	Sheridan and Nichols speed limit = 50
CMS: workers ahead, obey speed limits	in advance of closure[2]	70.0	68.9	53.1	49.4	63.3	50.0	-16.9	-19.5	-6.7	-18.9	10.2	0.6	Sheridan and Nichols speed limit = 45
CMS: workers ahead, speed limit 45 mph	Sheridan	76.8	71.0	53.8	52.8	55.5	54.3	-23.0	-18.2	-21.3	-16.7	1.7	1.5	Sheridan and Nichols speed limit = 45

Notes:
1. Data were taken with radar on and off under the exact same conditions (sequentially)
2. The initial lane closure was changed somewhat (moved closer to Sheridan) and sign was placed in the same position relative to the lane closure; data collection positions did not vary

closed, the speed decrease was not as apparent. In the latter instance, while observed average speeds were approximately the same as when only standard work zone signing was present, the relative decrease from the first data collection location was greater. Thus, there was reasonably good evidence that free-flowing speeds in advance of the lane closure were decreased by police presence (in advance of the closure). Subsequent effects were not as clear although there was some evidence that police presence within the closure area resulted in a greater relative decrease in average speed than may not have otherwise occurred. Evidence of a "carryover effect" of police presence to the last data collection location was mixed—in one instance, speeds actually increased further away from the police.

- The conclusions regarding the effects of other speed control devices are somewhat problematic. In general, there was not consistent evidence that they made much difference in motorist speeds. The speeds observed at the three locations were higher when the other devices were present when compared to those when only the standard construction zone signing was present. At the same time, effects were clouded by the fact that the speed limit had been changed (higher) when these devices were present. A comparison of speeds with the CMS and speed trailer present at two different locations did show some evidence that there might be some initial speed reduction attributable to the presence of either device, although the magnitude is less than that achieved by the police presence.

- Once in the lane closure area, the effects of the different strategies are not as clear. While the police presence still results in lower speeds, they are not necessarily appreciably lower and the incremental difference is within what appears to be the day-to-day and location-to-location variations that are observed when no construction is present and when only the standard work zone signing is present. For the most part, variation in average speeds between the last two locations is not great, the most significant exception being when the police were present at Sheridan—in this instance, there was an appreciable **increase** in average speed between the two sites, a counter-intuitive result.

I-275 RESULTS

At the I-275 site there was less control of police presence than had been the case at the I-69 site. While the MSP patrol car had been in one of two specified, fixed positions for the duration of the data collection periods at I-69, at the I-275 site there were, according to MSP, four patrol cars operating in both stationary and mobile modes. It is not clear precisely where or in what mode the patrols were operating during data collection periods or if there was significant variation in their operational mode during the time they were on site. Notwithstanding these problems, as far as can be ascertained from the information received from MSP, the patrol cars were in the vicinity of the beginning of the lane closures when they were present and perhaps elsewhere. The lane closure went from 3→2→1 with two sequential tapers. According to anecdotal MDOT reports and information from MSP, some of the police activity was concerned with enforcing illegal turns through the median in advance of the lane drops. That sort of activity was especially the case prior to 10:00 PM.

According to information from MDOT on where the lane drops were located on different days and where the data collection stations were located, the data collection locations appeared to be well within the construction area (i.e., where only one lane was open). Thus, it would appear that motorists whose speeds were monitored were fairly likely to have encountered an MSP patrol car either while they were in the congestion in advance of the lane drops OR actually in the active work zone area (i.e., where the lanes were actually closed). This defines "police presence" for this site.

Given the above, Figures 5-7 show comparisons of average motorists' speeds with and without "police presence" (defined as above) on three different days in July 1998. These are the only comparisons that appear to be possible with the data that were collected and the police schedule. The comparisons were complicated because the "zone" that was closed each evening was generally different—e.g., construction activities moved further toward I-96 each day. Each figure shows the average speed over time from early evening (e.g., 8:00 PM) until early morning the next day (e.g., 5:00 AM). In each instance, during the early part of the evening and until 2:00 AM, police had "presence" on the site. At approximately 2:00 AM, MSP left the site ("no presence"). The construction zone was opened back up shortly after the data collection period was over. So, the "presence" versus "no presence" comparison should be very consistent for the zone although there would be some variation in the "motorist group" using the roadway.

Figure 5 (8-9 July) shows the average speed profile over time at data collection site NB 8L (MDOT's designation for the site). Two of three lanes were closed from the vicinity of Ford Road to near Joy Road with the data collection site much closer to Joy. The average speed is fairly consistent throughout the period when police were present with an overall average of 51 mph. In the four hours after MSP left the site, the overall average increased to 59 mph. For the first hour or so after MSP departed, the average speed was actually somewhat lower (50 mph) than when they were present but then increased steadily until it reached 70 mph about 5:00 AM.

The same sort of profile is illustrated in Figure 6 (9-10 July). The site is NB 10L and the location is, again, well within the lane closure area.. Two of three lanes were closed during the data collection period. In this instance, there appears to be congestion earlier in the data collection period when the average speed varies from about 50 mph all the way down to 20 mph. After 10:00 PM, the average speed increases steadily to about 50 mph shortly after midnight. This gradually increasing trend holds through the "no presence" period and peaks at 62 mph at 4:00 AM.

Finally, Figure 7 is slightly different in that it shows the average speed for two open lanes (versus only one in Figures 5 and 6). Once again, there is some variation in the average speed early in the data collection period although a minimum is not reached until about midnight. From then on there is a fairly steady increase in the speed until 1:45 AM (58 mph) when it decreases. During the "no presence" period, speeds increase gradually (albeit with some variation) from 50 to almost 60 mph.

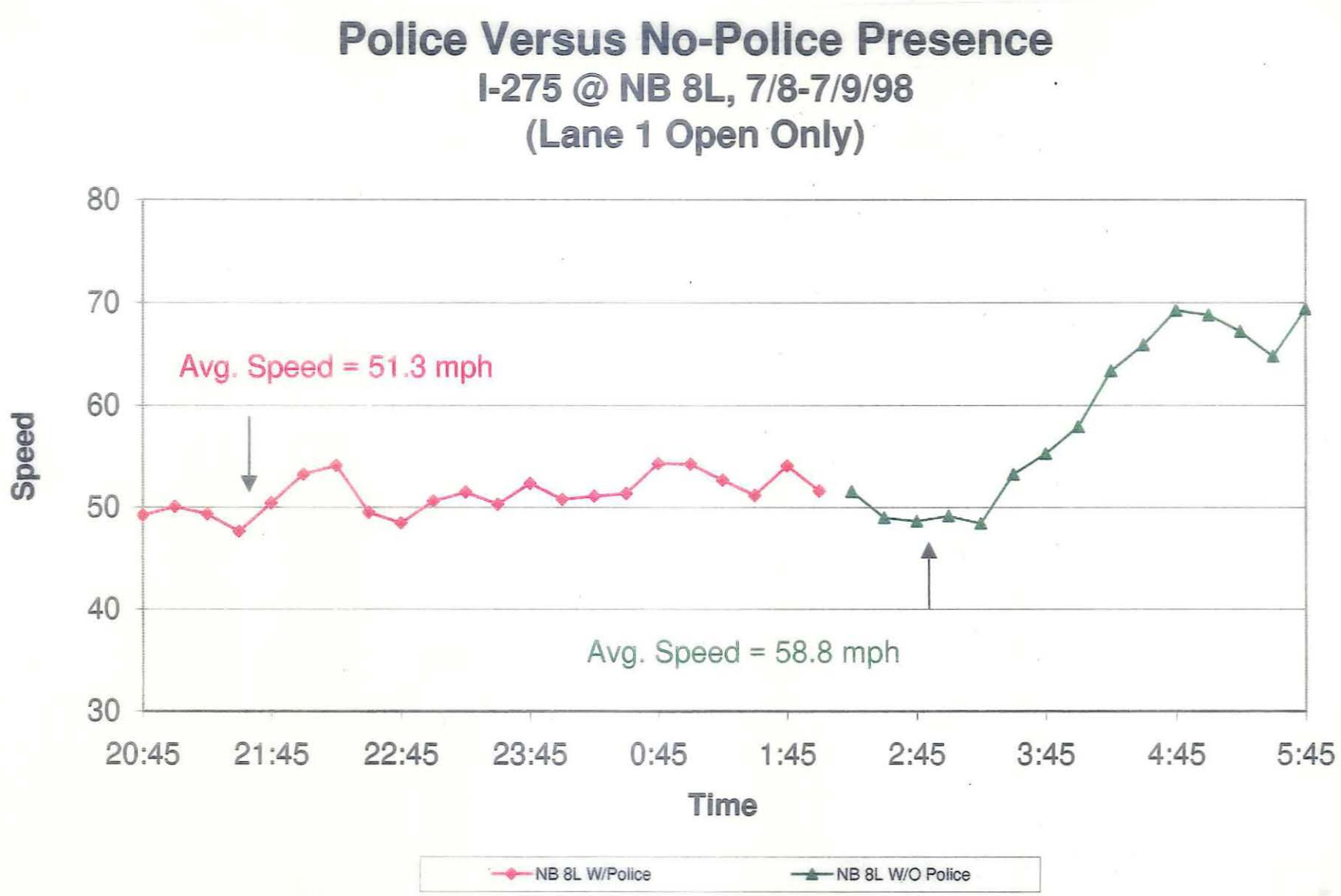


Figure 5. Police vs. no-police—I-275 NB 8L

Figure 6. Police vs. no-police—I-275 NB 10L

Figure 7. Police vs. no-police—I-275 NB 11L

While it is clear from each of these three figures that the average speed when there is "presence" is lower than when there is not, in each instance it could also be argued that the trend in increasing average speed began while MSP was still at the site or that the speed increases may be simply correlated with decreasing volumes of traffic in the zone. So, there is probably some increase that is due to the police leaving and some that is simply an extension of the late evening/very early morning trend. It is not clear whether the mode in which police operated varied at all during the data collection periods. To gain some insight to how speeds vary over time when police are not present at all, Figure 8 shows the average speed versus time plot for several other data collection locations (with only one lane open)—however, none of these had any police presence. It can be observed that, while several of the sites exhibit considerable variation earlier in the evening (probably due to congestion), there are typical trends toward gradually increasing speeds after midnight with speeds increasing almost as much as 30 mph in one case (NB 2L) from 40 to near 70 mph although the averages hold fairly steady at a couple of the sites. A consistent background trend in speed versus time in these construction zones is hard to pinpoint and there appear to be some site-specific responses to the work activity.

Similar to Figure 8, Figure 9 shows speed versus time plots for the same data collection locations with two lanes open and no police presence for the very early morning period. In this instance the average speeds are seen to gradually increase from the low 60s at 3:00 AM to the mid-60s/low 70s be 6:00 AM after which time there is a general decrease, probably due to the onset of the morning rush hour.

Thus, while there appears to be some positive effect due to the police presence, it is difficult to separate it from effects due to variations in volume and other factors.

I-94 RESULTS

The MSP enforcement are was somewhat "disconnected" from the construction zone activities on I-94 where data were being collected. Data were collected at Central and Junction Avenues while police activities were focused in an area further east (between Mt. Elliott and Warren). While it was known that MSP was in the I-275 construction zones when some data were collected, there is no information to indicate whether police were near the locations on I-94. Similarly, their mode of operation is unknown.

For the data that were collected at Central and Junction, the following should be noted:

- Eastbound traffic at Central and Junction would not have encountered any extra police enforcement (the MSP enforcement area was east of the data collection site).

- Some westbound traffic at Central and Junction would probably have encountered extra police enforcement ***if*** they had been westbound on I-94 between Mt. Elliott and Warren.

- Some westbound traffic at Central and Junction would probably not have encountered the police effort. For example, I-96 traffic which exited to westbound I-94 would have a low

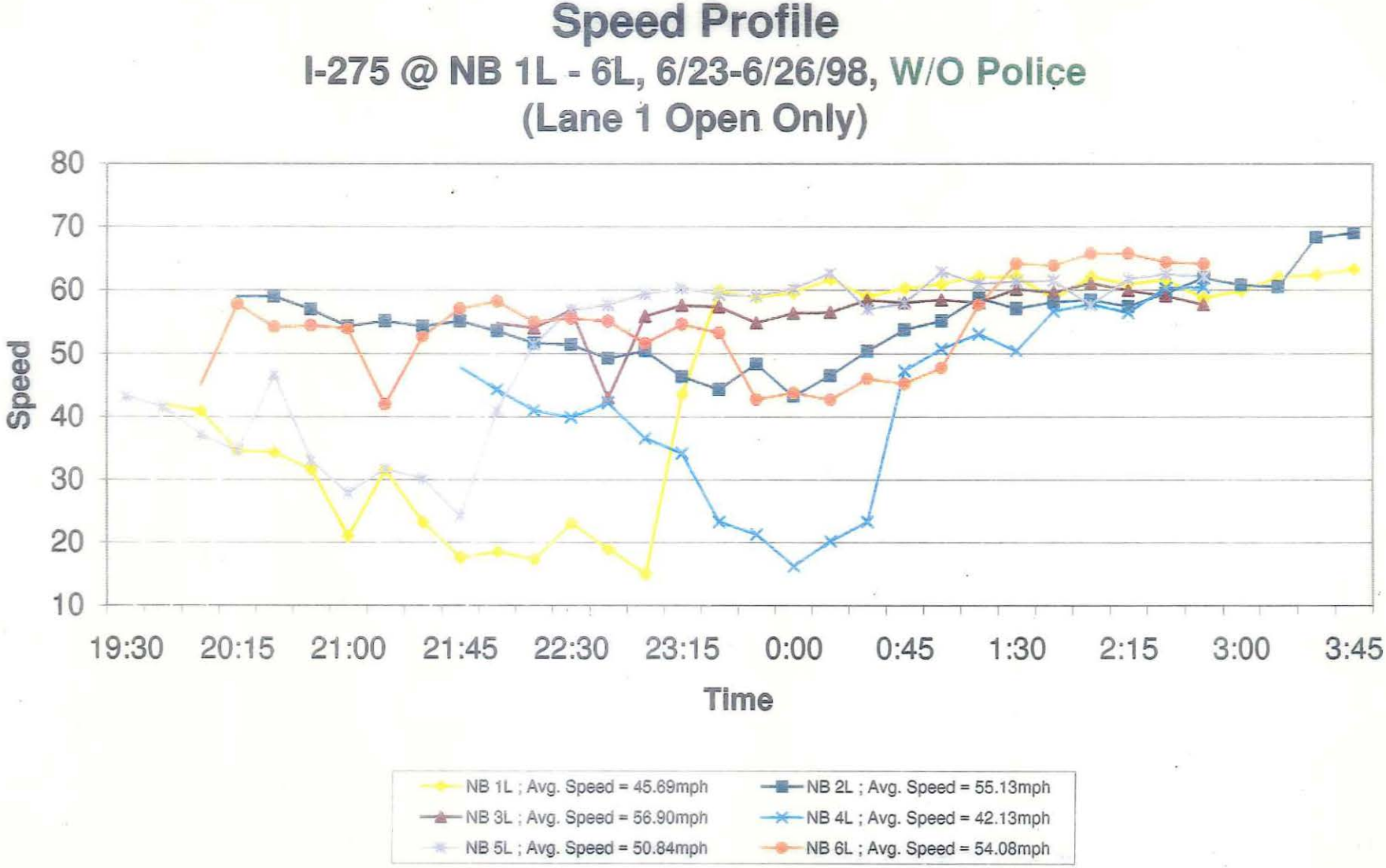


Figure 8. Speed profile—I-275 NB 1L-6L, w/out police, one lane open

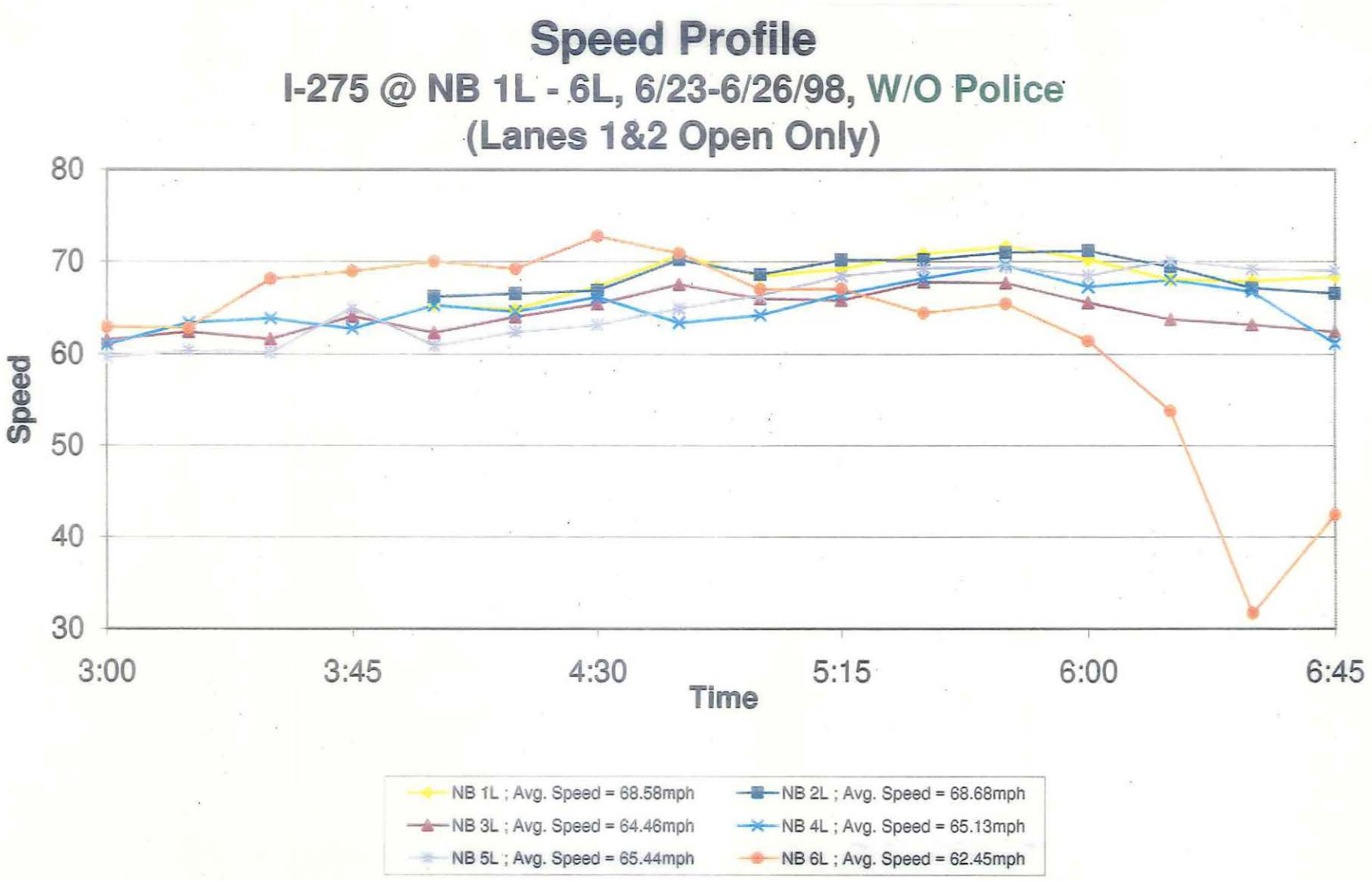


Figure 9. Speed profile—I-275 NB 1L-6L, w/out police, two lanes open

likelihood of encountering police; likewise US-10 traffic which exited to I-94 westbound would have traveled through about half of the extra enforcement area.

- The extent of the police presence (e.g., what hours in a given day were the police actually present) was not clear.

In summary, only westbound traffic might have encountered some extra enforcement. Based on the above, it was not expected that much evidence would be found regarding the effects of police presence.

Figures 10 and 11 are characteristic of the results and show several days of data with and without police presence under similar roadway conditions (as far as could be ascertained) at the westbound Central data collection location. On all days, workers were present on the site and two lanes were open to traffic with a posted speed limit of 45 mph. Figure 10 shows four days of data when traffic did not appear to be subjected to major disruptions in flow (at the data collection site) while for Figure 11, four additional days of data are "added in." It can be seen that there is more variation in speed when these additional days are also considered.

In Figure 10, average speeds are seen to vary between the mid-50s and mid-60s mph. Speeds are seen to be at their lowest for the several hours around midnight and highest during the AM rush period. Most apparent, however, is the lack of any consistent difference between data when police were present upstream and when they were not. In some time periods, the "no presence" speeds are a little higher than "presence" speeds (around the AM rush and mid-morning), while in others there is no clear trend (from around midnight to the AM rush), and yet in others, the "presence" speeds are higher (from about noon until 7:00 PM). The clearest indication of one condition being superlative to the other is in the latter period, and those results are counterintuitive. Overall, the average speeds are within a mph or so of each other. Figure 11 serves only to confirm that on days when there is apparently some congestion (probably due to construction activities) there is no real discernible difference between "presence" and "no presence" conditions.

For comparison, average speeds at eastbound Central (motorists would not have encountered any extra MSP enforcement) are shown for several days (no workers present, three lanes open, 55 mph speed limit) in Figure 12. In general, it is seen that speeds are actually somewhat lower than were observed in Figure 10 and generally more consistent throughout the day. While different days are noted as having police presence or not, the "presence" would have been further east and these motorists would not really have encountered it—it is marked only for comparison. In any event, there is no discernible difference between the two conditions.

Data were also examined to insure that, if there had been a police "presence" effect, the data collection approach would have been adequate to detect it. To this end, data were isolated when different lanes were open and when workers were present or not. Graphs showing these results are provided in Appendix B. The materials in the appendix amply illustrate that such differences can be discerned—the speed versus time graphs for "worker presence" versus "no-worker

Figure 10. Police vs. no-police—I-94 WB Central

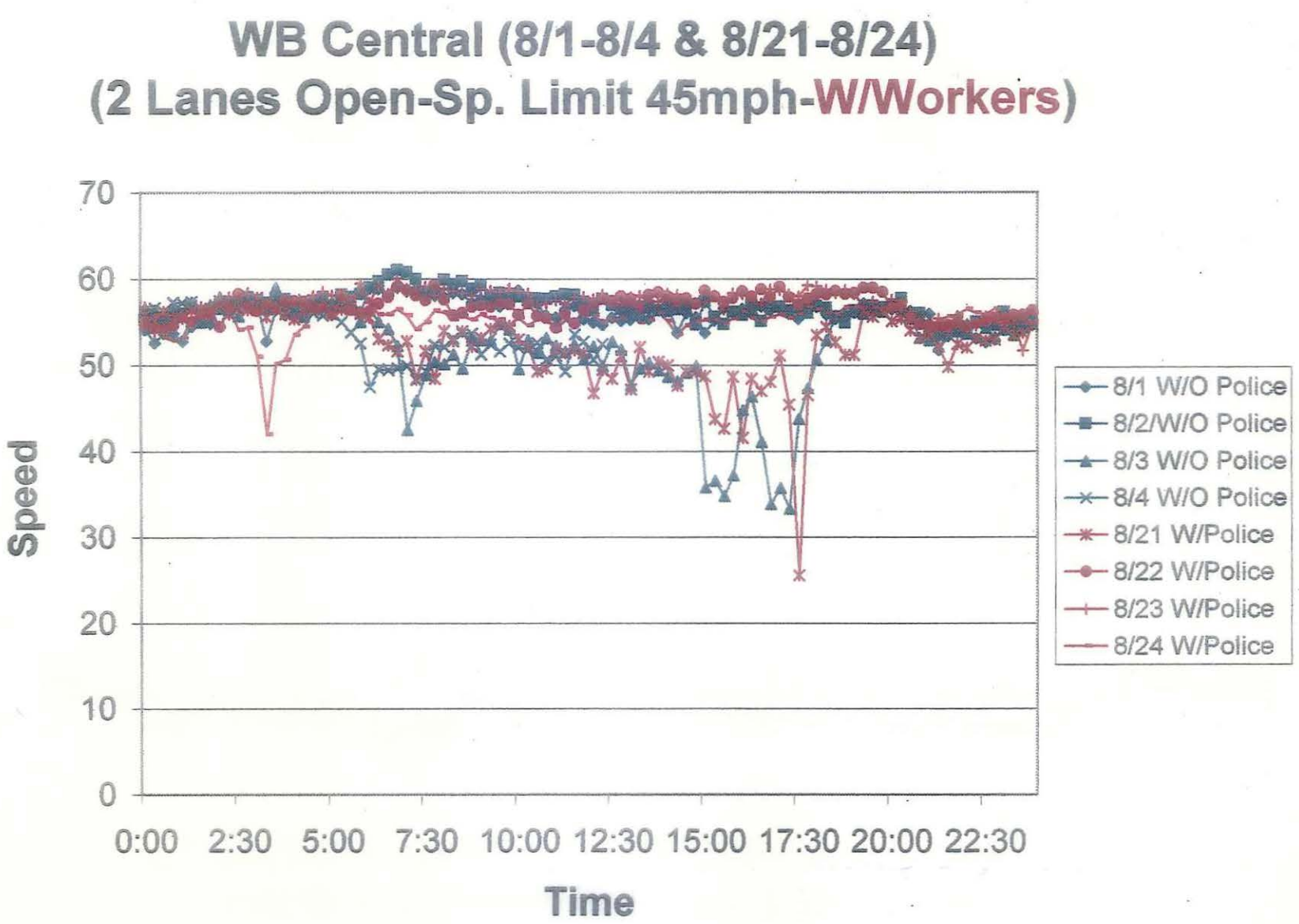


Figure 11. Police vs. no-police w/additional data—I-94 WB Central

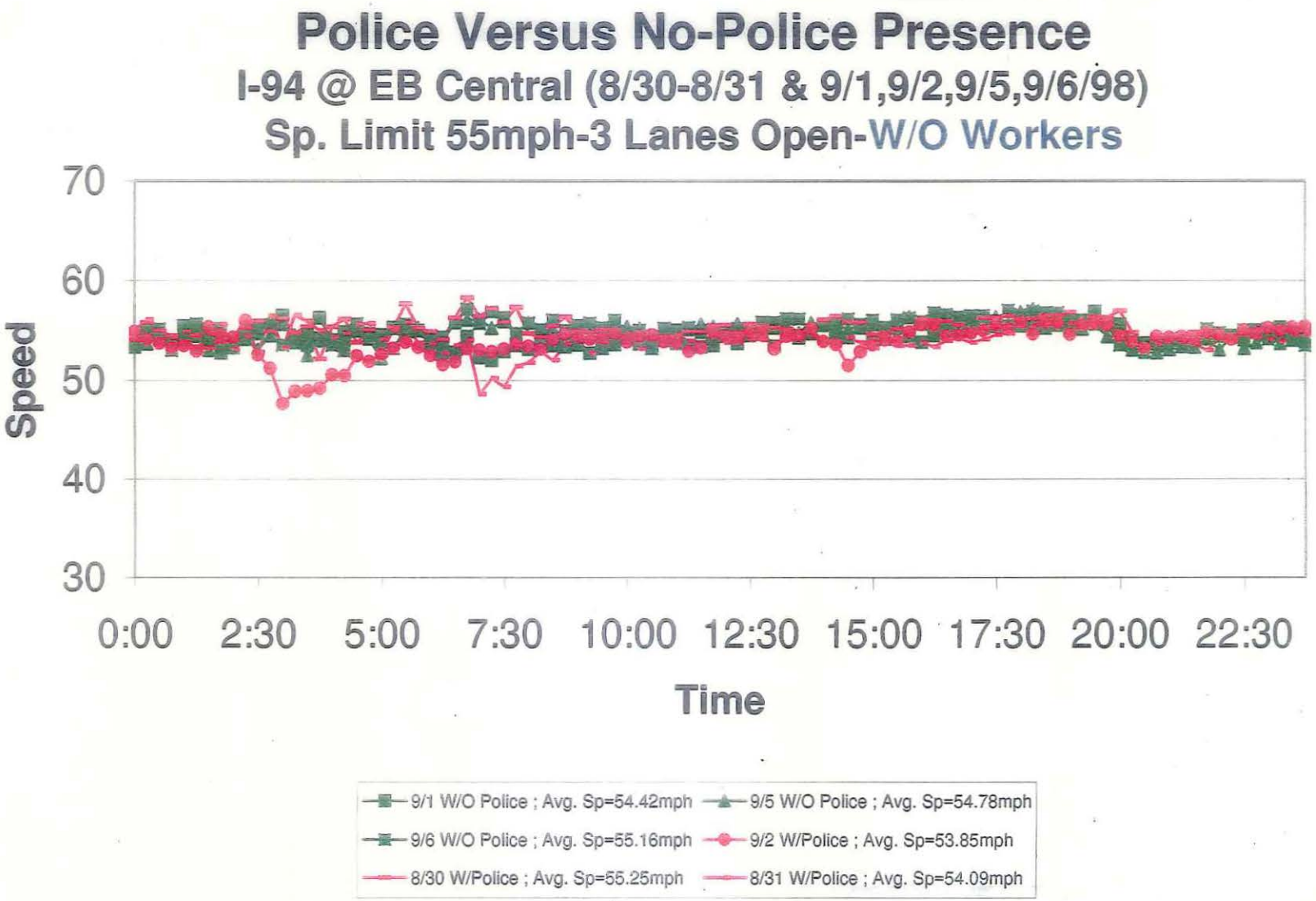


Figure 12. Police vs. no-police—I-94 EB Central

presence" show some clear differences. With respect to measuring the effect of police presence, this finding gives confidence in the conclusion that no effect of police presence was detected.

The conclusions to be drawn from the I-94 are sparse. MSP enforcement does not seem to have been well coordinated with the MDOT data collection activities and, in addition, details of the enforcement are limited. Moreover, there were at least two major freeway-to-freeway interchanges where motorists could have gotten on westbound I-94 to the east of the data collection site and not encountered any enforcement (it may have been present, but farther east). Examination of the "results" shows no effect due to the extra enforcement—however, it should be noted that this may well be a result of where enforcement was done and where the data were collected. That is, there may have been some effect but the distance between where enforcement was encountered and the data collection site was such that the effect of police presence would have "worn off." These caveats notwithstanding, no effects of the police presence were detected.

SUMMARY, CONCLUSIONS, AND DISCUSSION

There were two basic parts to this project: a relatively detailed examination of the effectiveness of different speed control strategies in work zones that was carried out at a site on I-69 southwest of Flint (including use of police in the zone); and an examination of the effects of special "extra" enforcement in work zones by MSP in two work zones on I-94 and I-275 in southeastern Michigan. The results are summarized below.

For the I-69 site...

- The presence of a stationary police car (with radar on) appears to have had an immediate positive effect on motorist speeds (they decreased). This was especially clear when police were positioned in advance of the actual lane closure. However, when police were present in the area where the lane was already closed, the speed decrease was not as apparent.

- Evidence of a "carryover effect" of police presence downstream from their location to the last of three sequential data collection locations was mixed—in one instance, speeds actually increased further away from the police.

- In general, there was not much consistent evidence that other extra devices (i.e., CMS and speed trailers) made much difference in motorist speeds. However, results were somewhat compromised by the fact that the speed limit was increased when these devices were present. A comparison of speeds with the CMS and speed trailer present at two different locations in the marked zone (in advance of the lane closure versus "in" the closure area) did show some evidence that there might be some initial speed reduction attributable to the presence of either device—the magnitude appeared to be less than that achieved by the police presence.

- Once in the lane closure area, the effects of the different strategies are not as clear. While the police presence still results in lower speeds, they are not necessarily appreciably lower and the incremental difference is within what appears to be the day-to-day and location-to-location

variation that is observed when no construction is present and when only the standard work zone signing is present.

- The effects of other factors in the lane closure area that affect speeds are very difficult to separate from the effects of the speed control strategies. Day-to-day variation in work zone activities which would affect motorists' speeds were virtually impossible to control.

For the I-94 and I-275 sites...

- There was some minimal evidence at the I-275 site that police presence in advance of and/or in the zone (the operating mode for the police was mixed) might have had some effect in decreasing motorist speeds within the lane closure areas. The effects were not large and could not be separated from background variation in speed by time of day—i.e., at other similar sites, the speeds with no police present appeared to increase as a (presumed) function of roadway conditions, thus speeds may have increased slightly even if the police had been present.

- There was no evidence at the I-94 site that the police presence had any effect on motorist speeds in the work zone (at the data collection site). It is possible that there were effects that were not measurable due to the location of the police relative to the data collection location.

The results of this project are somewhat equivocal for several reasons. First, the I-69 site was less consistent in terms of work activities and work zone treatments than had been expected (e.g., work zone speed limits were unexpectedly changed in the data collection area). In addition, motorist speeds through the site were somewhat lower than had been expected *a priori*. Normal traffic on I-69 is perceived to "move well" and it was expected that there would be real need to decrease motorists' speeds through the project area. In many instances, however, the speeds, while in excess of posted limits, did not seem excessively high. The point being that motorists had already "selected" what they considered to be a reasonably safe speed and did not need to slow down further.

The results at the MDOT-identified extra enforcement sites (I-275 and I-94) were compromised because of the relative lack of a coherent experiment design which would have included more specific monitoring of site activities (including the location of police patrol cars) and better coordination of data collection with work and police activities. That notwithstanding, the I-275 site (at least) was significantly different than the I-69 site insofar as for much of the time, there was congestion in advance of the work zone which negated the need for the initial reduction of average motorist speeds. But, even when congestion cleared, no measurements of motorist speeds in advance of the lane closure area were taken. Comparison of such results with those from I-69 would have been useful, but were impossible to make. The I-94 results were the most compromised of all as the relationship between the data collection sites and the location of the MSP efforts was quite unclear.

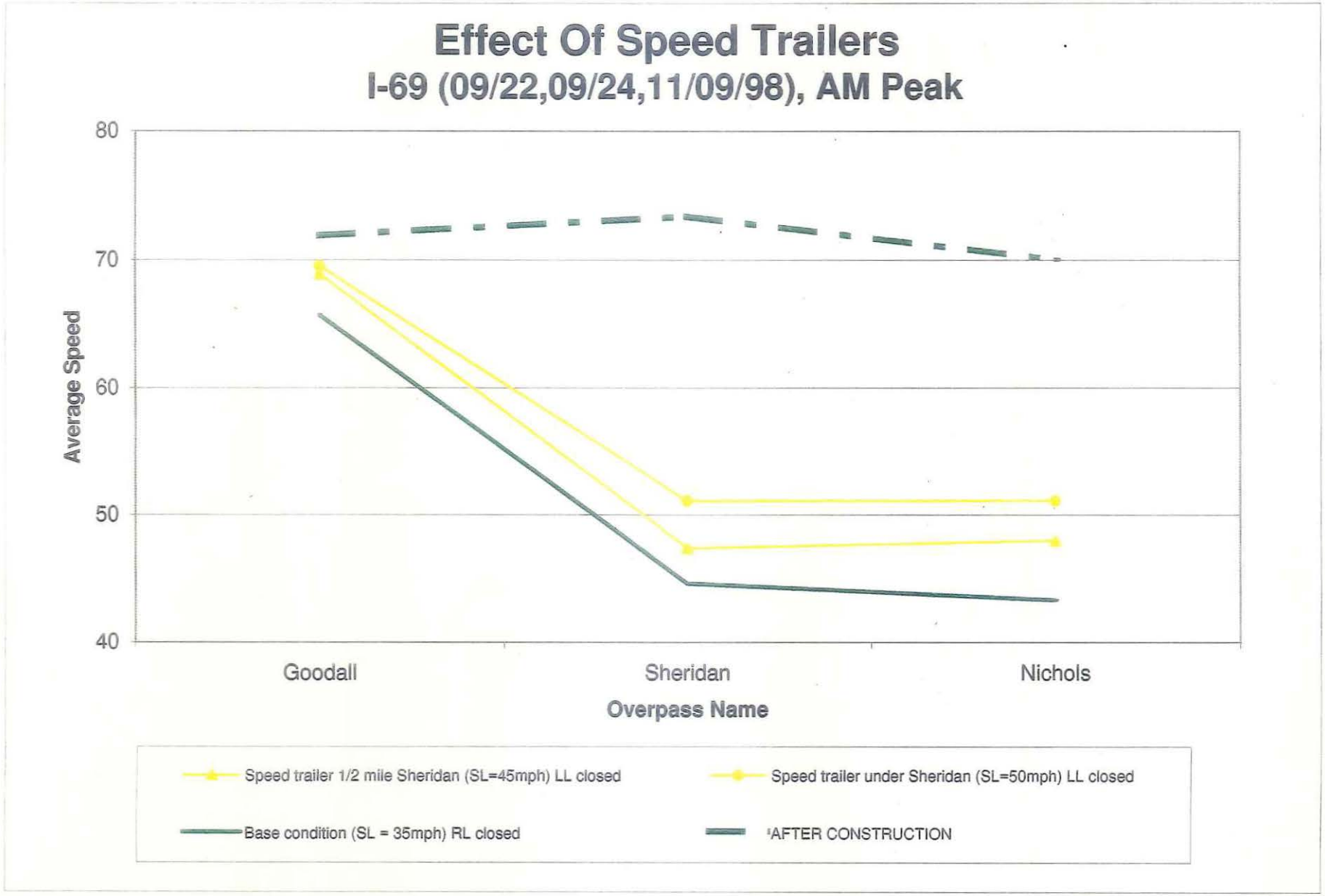
Notwithstanding the site-related problems, there are still conclusions that can be drawn from this effort. Based on the I-69 results, there was a clear reduction in motorists' speeds when police are

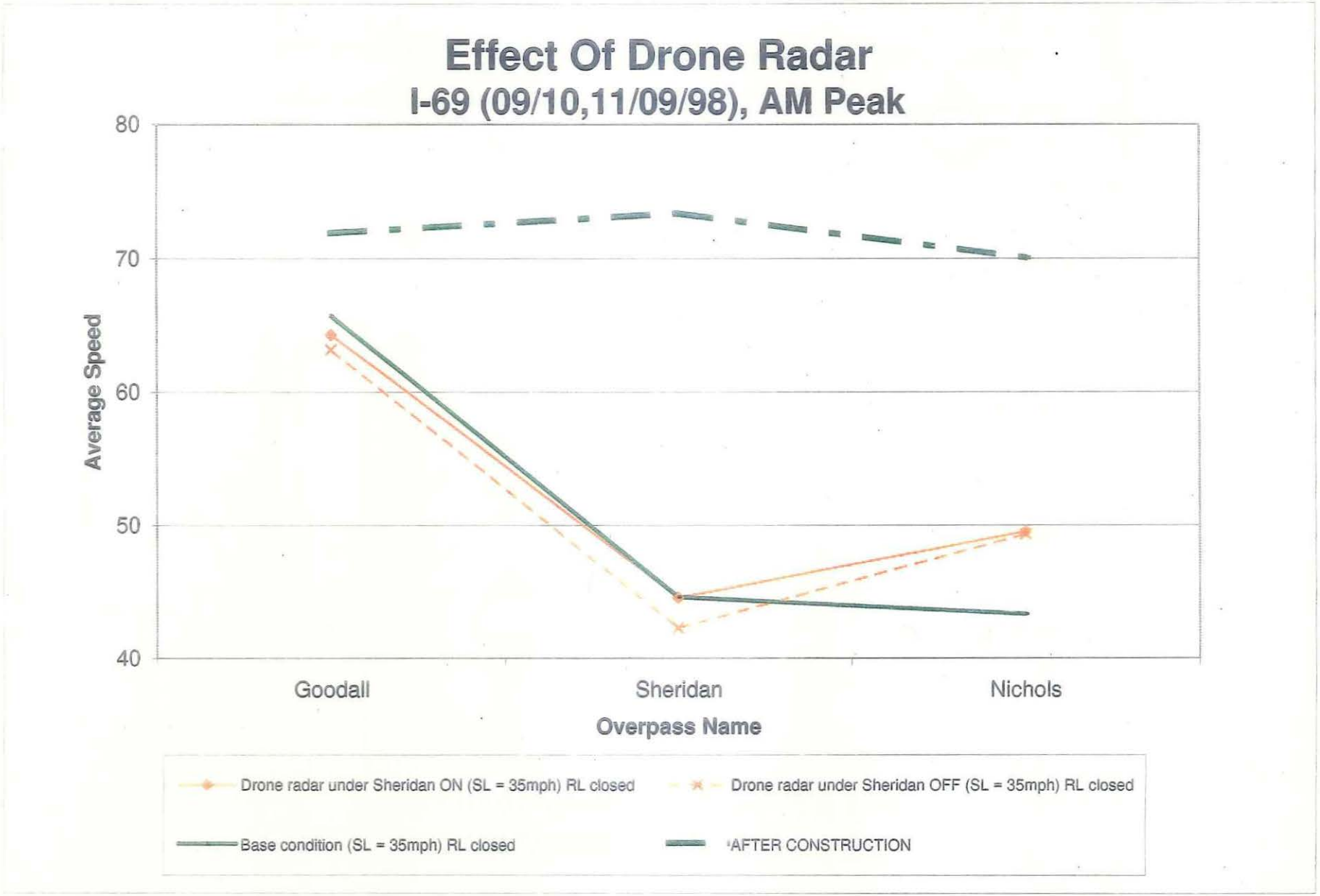
placed in advance of the lane closure for a construction zone (e.g., 4-9 mph). Other devices, such as CMS with speed-related messages and speed trailers, also seemed to have some effect on reducing motorists' speeds in similar locations. Unfortunately, the direct comparison of police to CMS/speed trailer effects was not possible because of changes in site conditions. Based on the results at the I-69 and I-275 sites, the effects of police and other techniques on reducing speeds within the lane closure areas are not as clear. While there was some evidence that police presence reduced speeds in this situation, the effect does not appear to be great. It is not clear, however, whether that effect would be greater if the motorists' speeds were higher to start with—if motorists were going well over the posted speed limit in the lane closure area, it seems reasonable to assume that speed reductions similar to those identified above could be achieved in that situation as well.

In summary, it would appear that police presence can be effective in reducing speeds at spot locations, such as in advance of construction lane drops in uncongested conditions. However, the downstream effects are not as great or as certain. Other devices appear to have some effect as well, although not as much as the police presence.

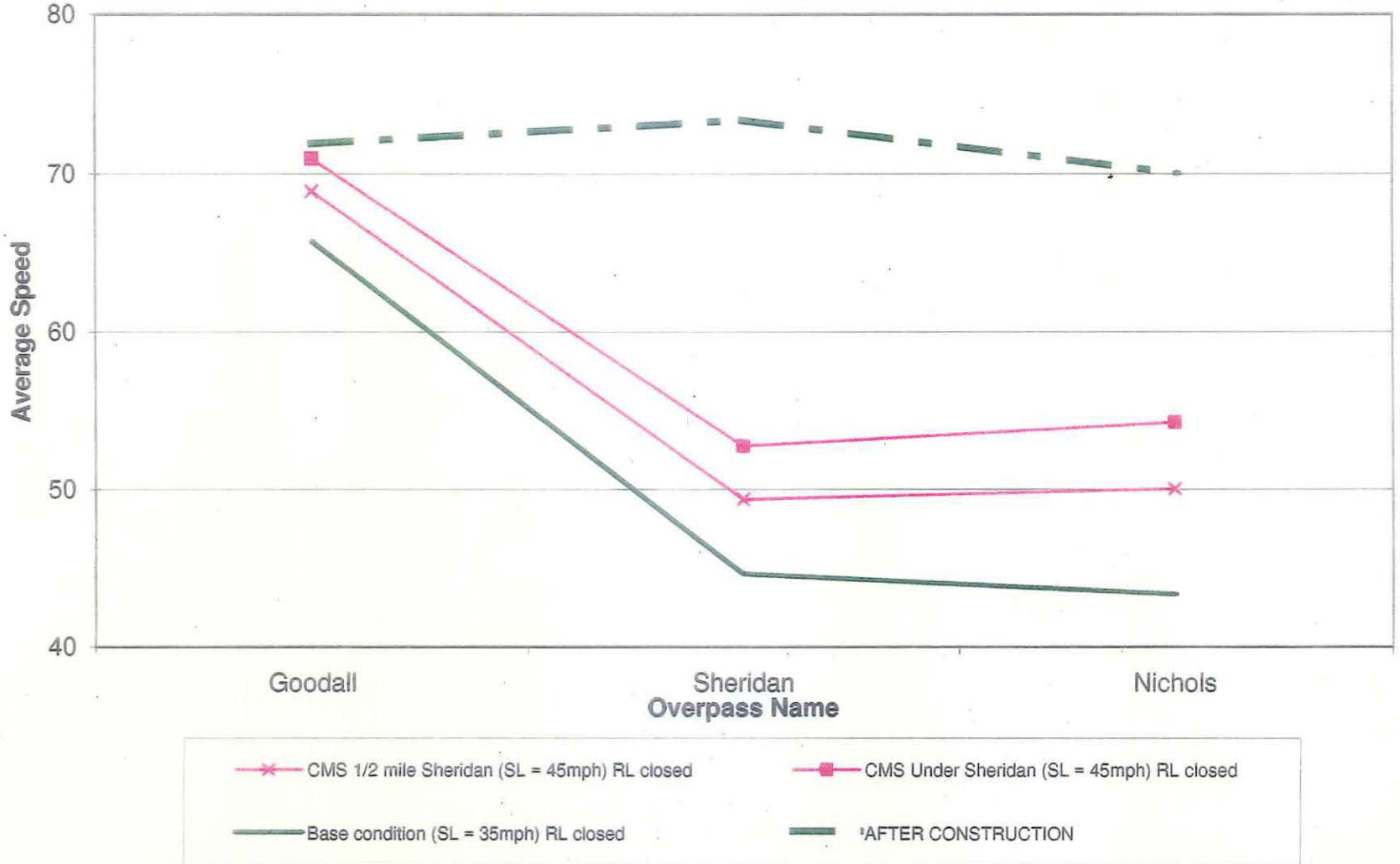
APPENDIX A

Additional Results for I-69


Effect Of Speed Trailers
I-69 (09/22,09/24,11/09/98), AM Peak
80
70
60
50
40
Average Speed
Goodall
Sheridan
Nichols
Overpass Name
Speed trailer 1/2 mile Sheridan (SL=45mph) LL closed
Speed trailer under Sheridan (SL=50mph) LL closed
Base condition (SL = 35mph) RL closed
AFTER CONSTRUCTION

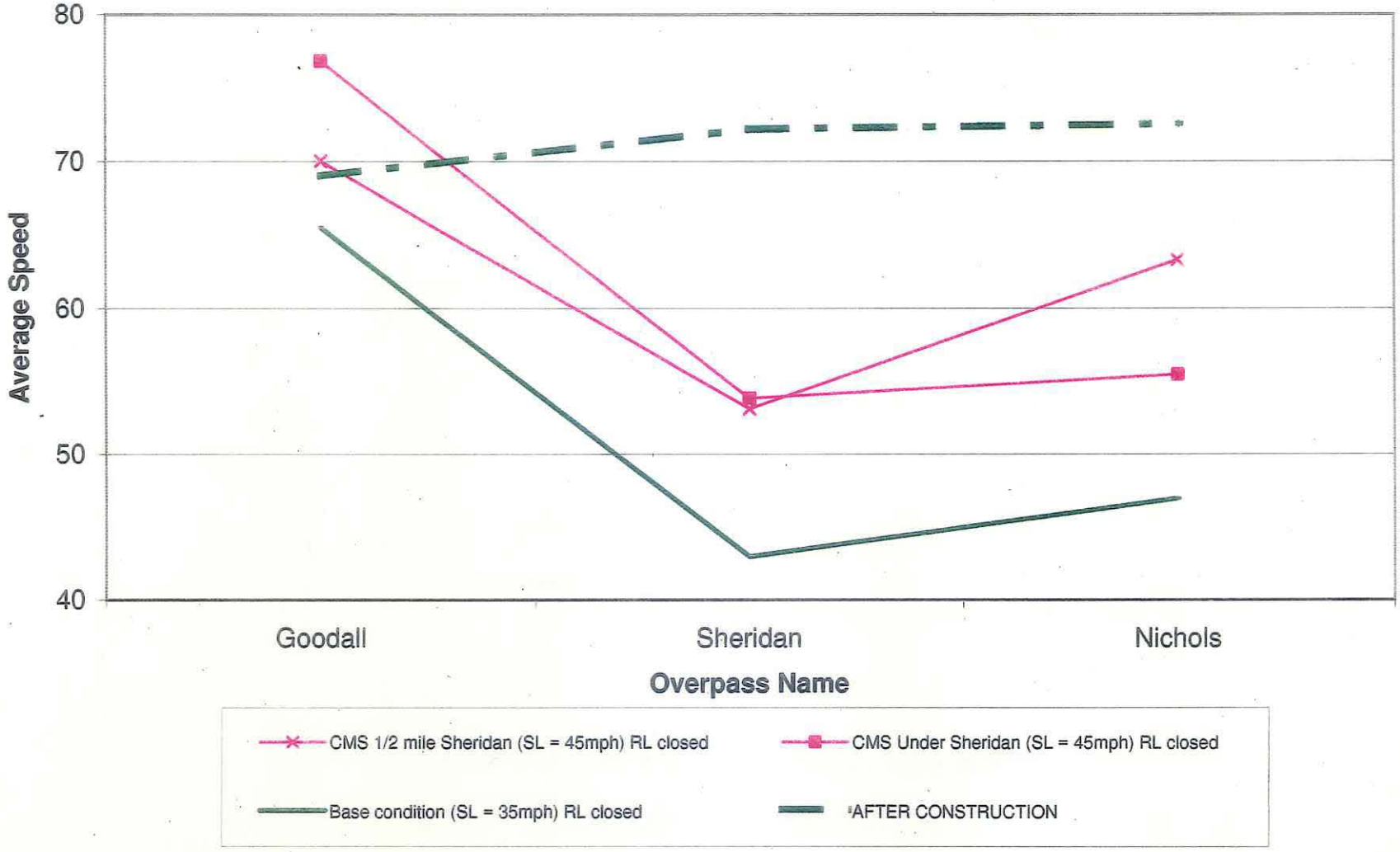

Effect Of Drone Radar
I-69 (09/10,11/09/98), AM Peak
80
70
60
50
40
Average Speed
Goodall
Sheridan
Nichols
Overpass Name
Drone radar under Sheridan ON (SL = 35mph) RL closed
Drone radar under Sheridan OFF (SL = 35mph) RL closed
Base condition (SL = 35mph) RL closed
AFTER CONSTRUCTION

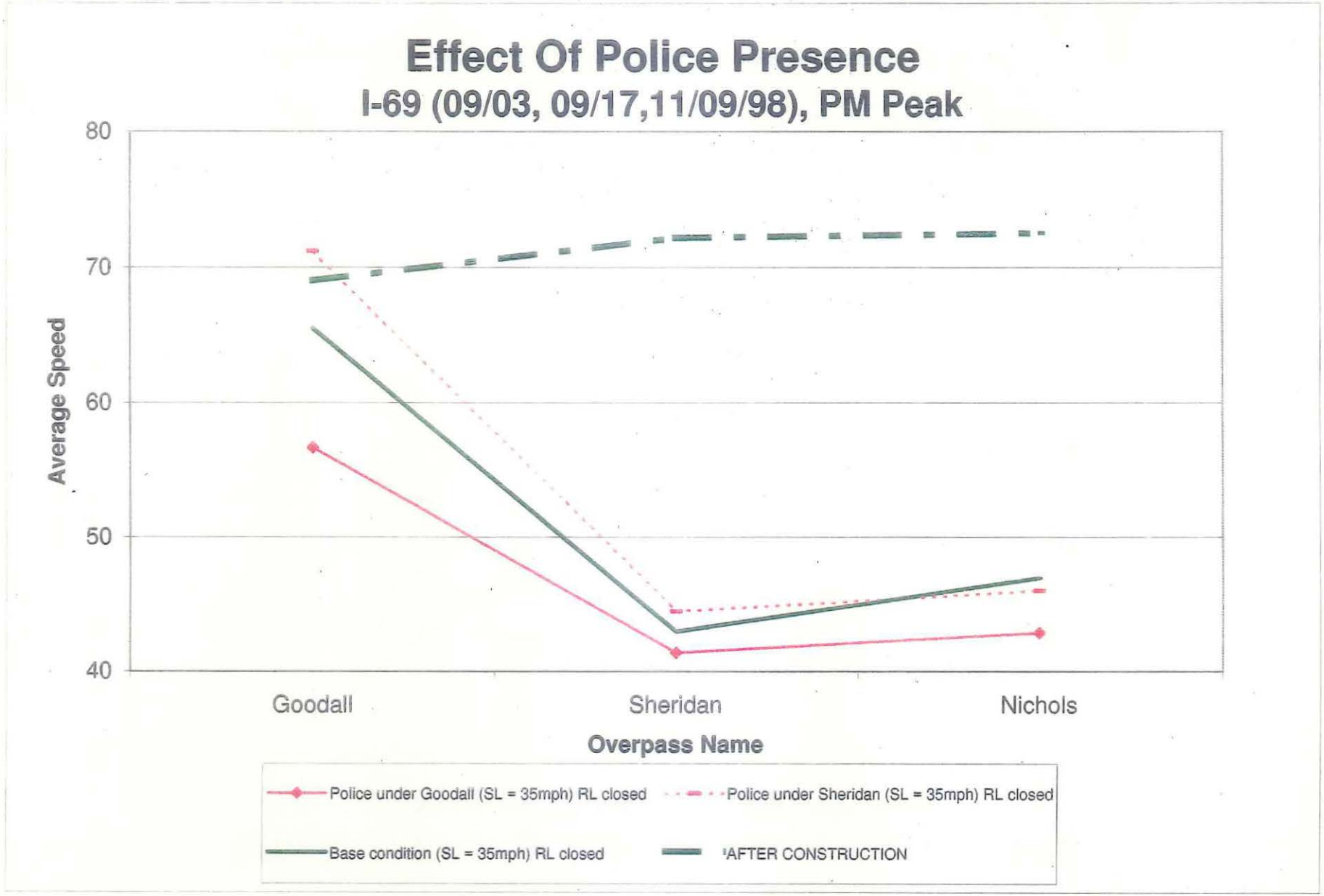
Effect Of Changeable Message Signs (CMS)
I-69 (10/01,10/06,11/09/98), AM Peak



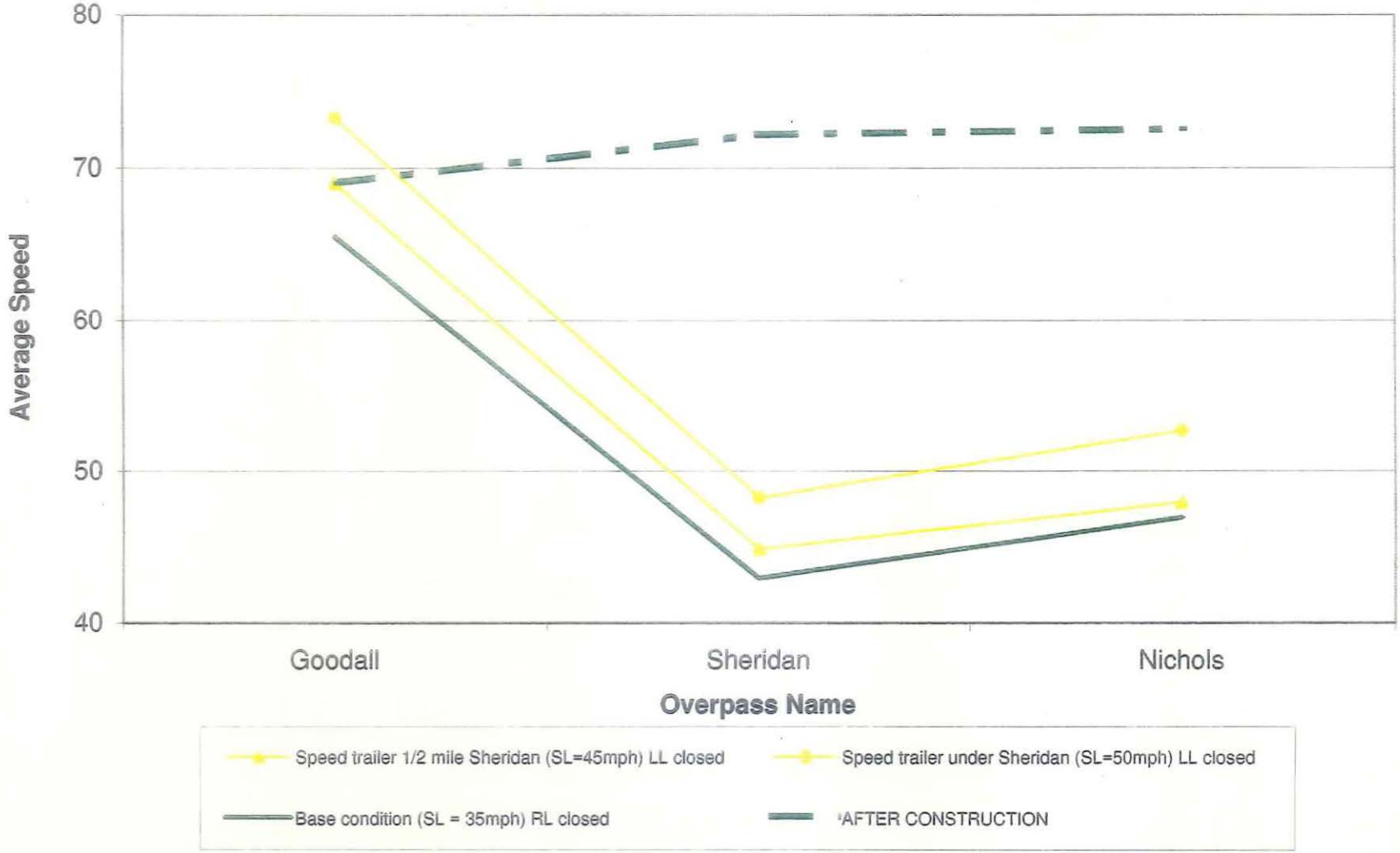
Effect Of Changeable Message Signs (CMS)

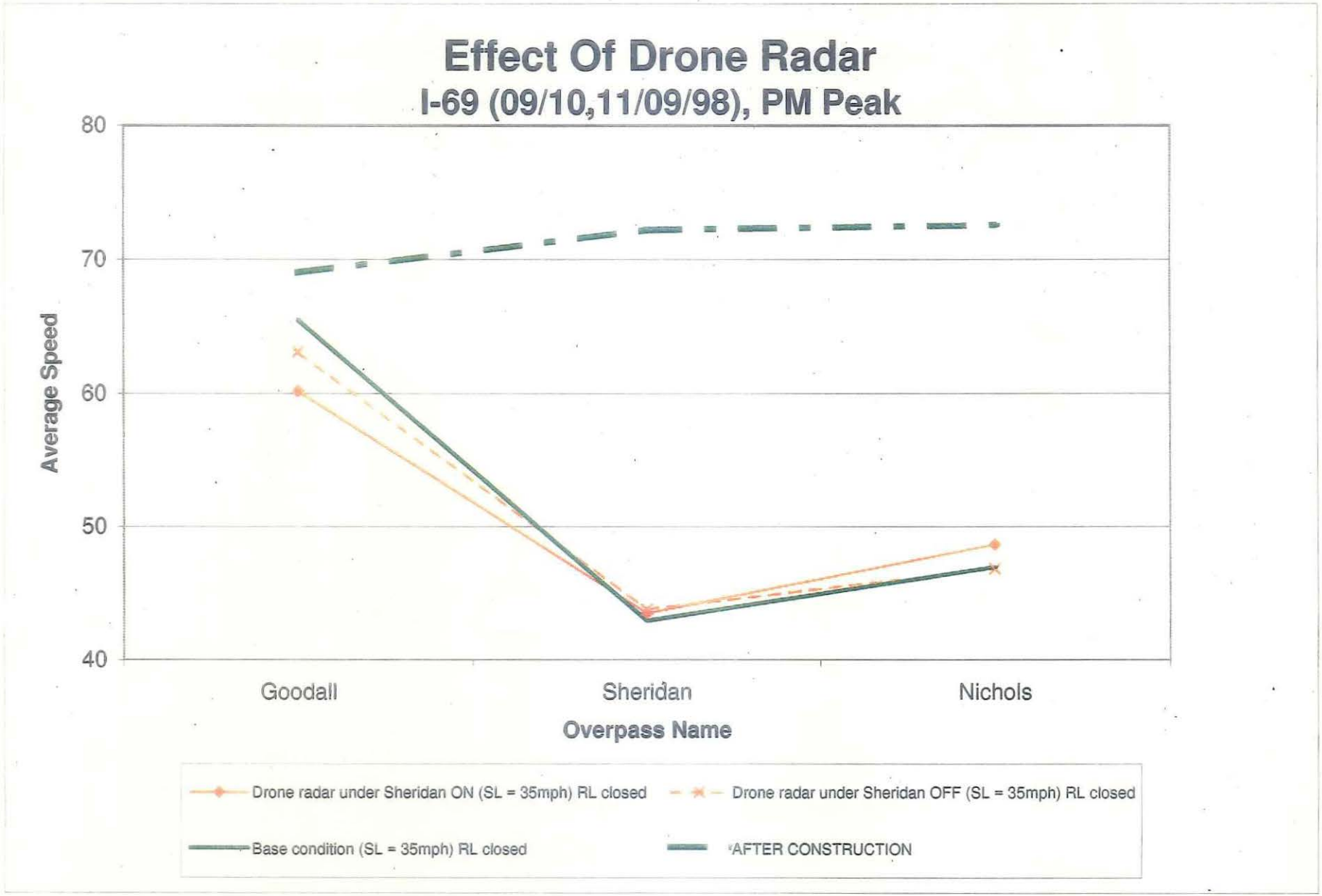
I-69 (10/01,10/06,11/09/98), PM Peak




Effect Of Police Presence
I-69 (09/03, 09/17,11/09/98), PM Peak
80
70
60
50
40
Average Speed
Goodall
Sheridan
Nichols
Overpass Name
Police under Goodall (SL = 35mph) RL closed
Police under Sheridan (SL = 35mph) RL closed
Base condition (SL = 35mph) RL closed
AFTER CONSTRUCTION

Effect Of Speed Trailers
I-69 (09/22,09/24,11/09/98), PM Peak




Effect Of Drone Radar
I-69 (09/10,11/09/98), PM Peak
80
70
60
50
40
Average Speed
Goodall
Sheridan
Nichols
Overpass Name
Drone radar under Sheridan ON (SL = 35mph) RL closed
Drone radar under Sheridan OFF (SL = 35mph) RL closed
Base condition (SL = 35mph) RL closed
AFTER CONSTRUCTION

APPENDIX B

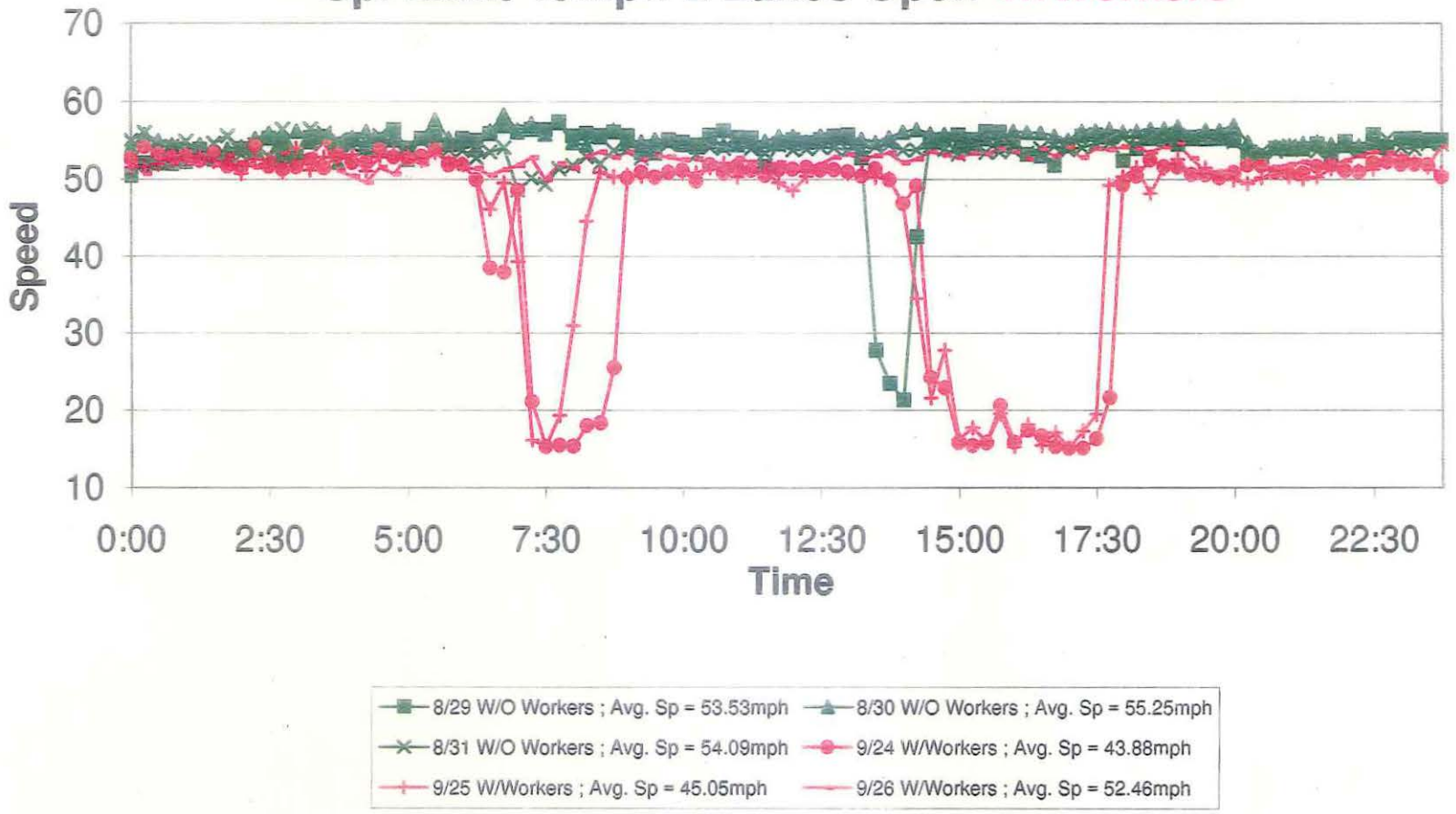
Additional Results for I-94

Workers Versus No-Workers Presence

EB Central (8/29-8/31 & 9/24-9/26 - W/O Police)

Sp. Limit 55mph-3 Lanes Open-W/O Workers

Sp. Limit 45mph-2 Lanes Open-W/Workers

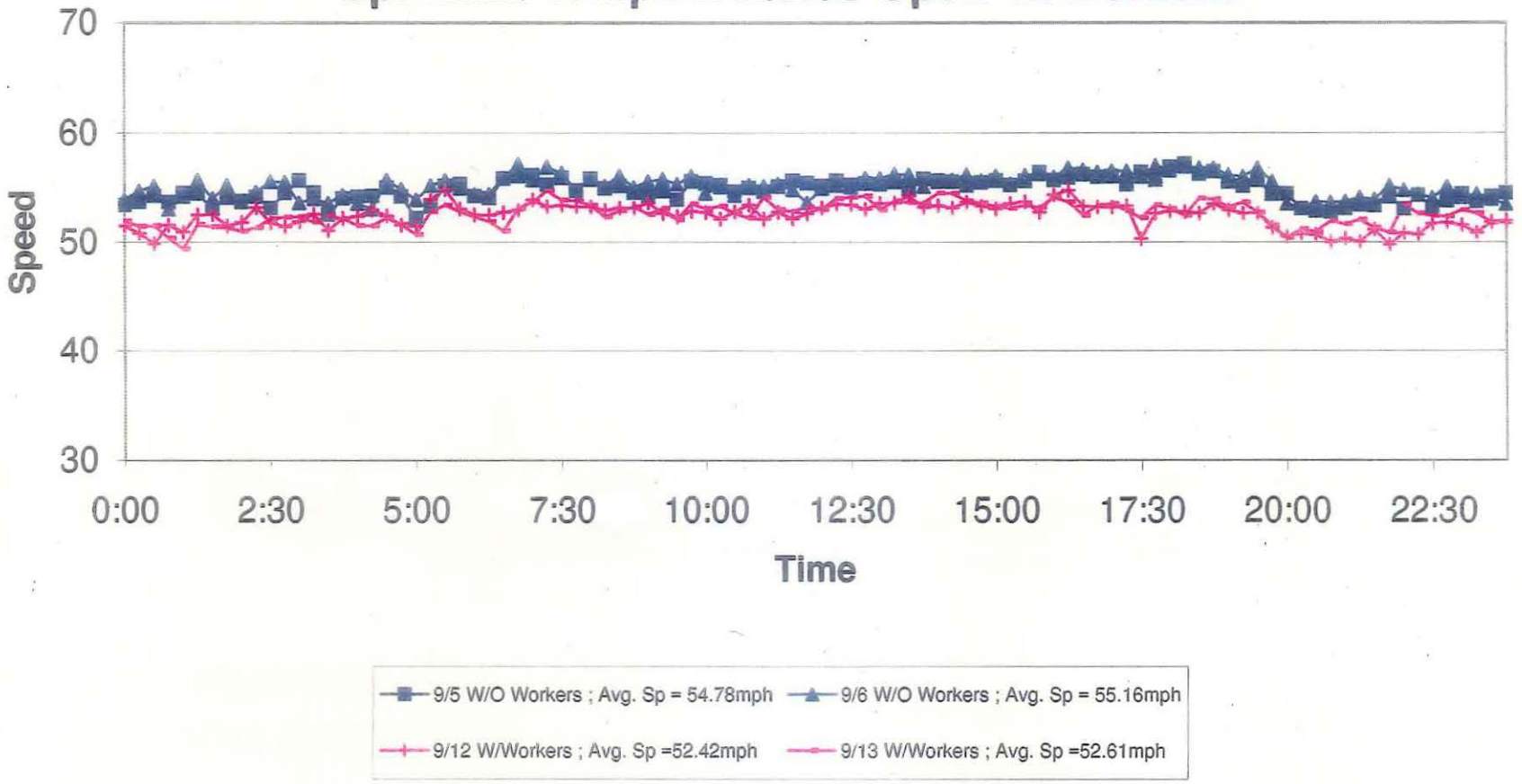


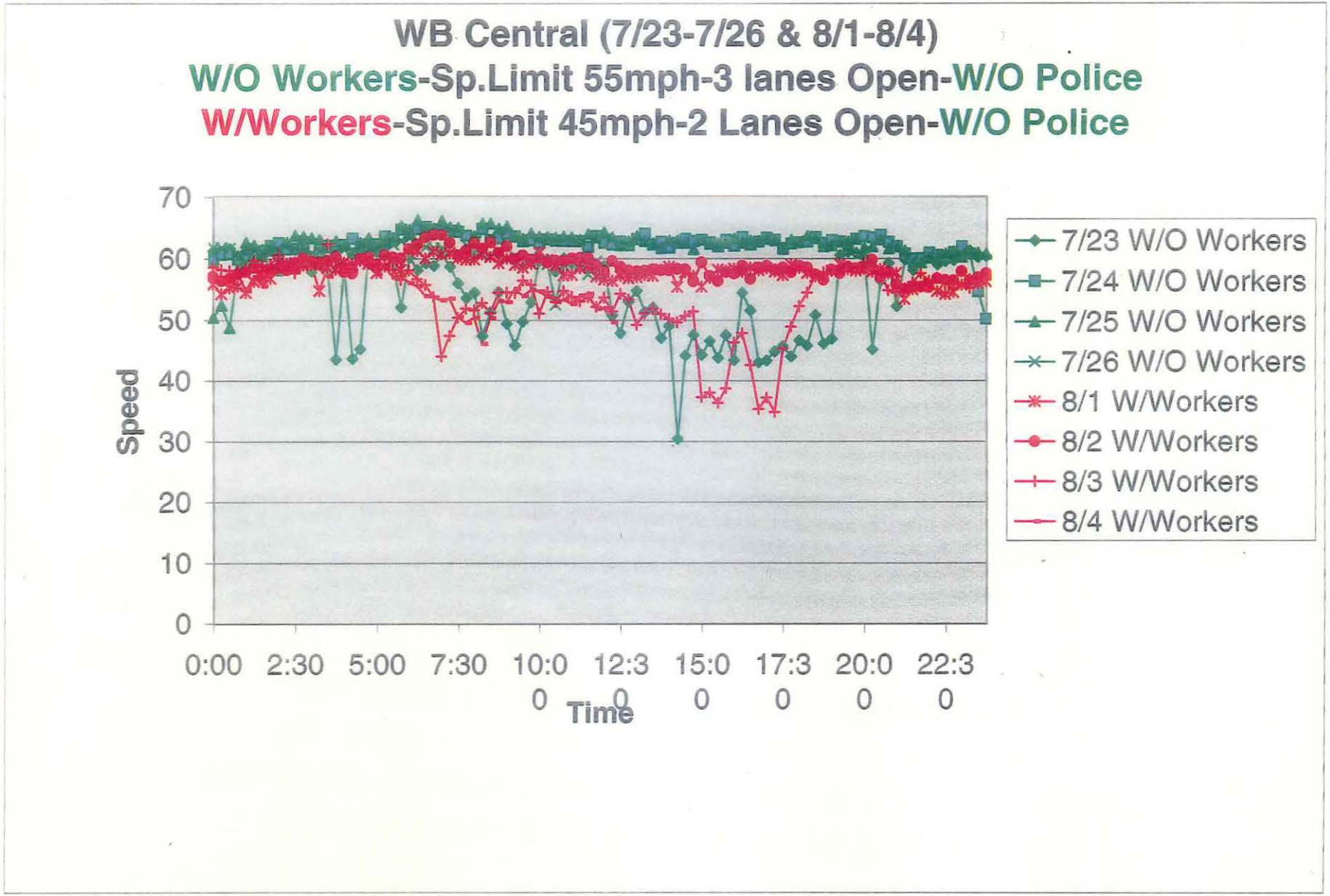
Workers Versus No-Workers Presence

I-94 @ EB Central (9/5-9/6 & 9/12-9/13/98 - W/O Police)

Sp. Limit 55mph-3 Lanes Open-W/O Workers

Sp. Limit 45mph-2 Lanes Open-W/Workers




WB Central (7/23-7/26 & 8/1-8/4)
W/O Workers-Sp.Limit 55mph-3 lanes Open-W/O Police
W/Workers-Sp.Limit 45mph-2 Lanes Open-W/O Police
Speed
70
60
50
40
30
20
10
0
0:00
2:30
5:00
7:30
10:00
12:30
15:00
17:30
20:00
22:30
Time
7/23 W/O Workers
7/24 W/O Workers
7/25 W/O Workers
7/26 W/O Workers
8/1 W/Workers
8/2 W/Workers
8/3 W/Workers
8/4 W/Workers