SUMMARY REPORT
"BEFORE AND AFTER" DATA RESULTS

STOP LINE LED LIGHTS
EXPERIMENTAL TRAFFIC CONTROL DEVICE APPLICATION

Southwest Intersection
Anaheim, California

June 2002

SUBMITTED TO:

CALIFORNIA TRAFFIC CONTROL DEVICES COMMITTEE

SUBMITTED BY:

CITY OF ANAHEIM

SUMMARY REPORT
"BEFORE AND AFTER" DATA RESULTS

STOP LINE LED LIGHTS
EXPERIMENTAL TRAFFIC CONTROL DEVICE APPLICATION

Southwest Intersection
Anaheim, California

June 2002

Submitted to:

CALIFORNIA TRAFFIC CONTROL DEVICES COMMITTEE

Submitted by:

CITY OF ANAHEIM

Prepared by:

KAKU ASSOCIATES, INC.
1453 Third Street, Suite 400
Santa Monica, California 90401
(310) 458-9916

Ref: 855.06

I. INTRODUCTION

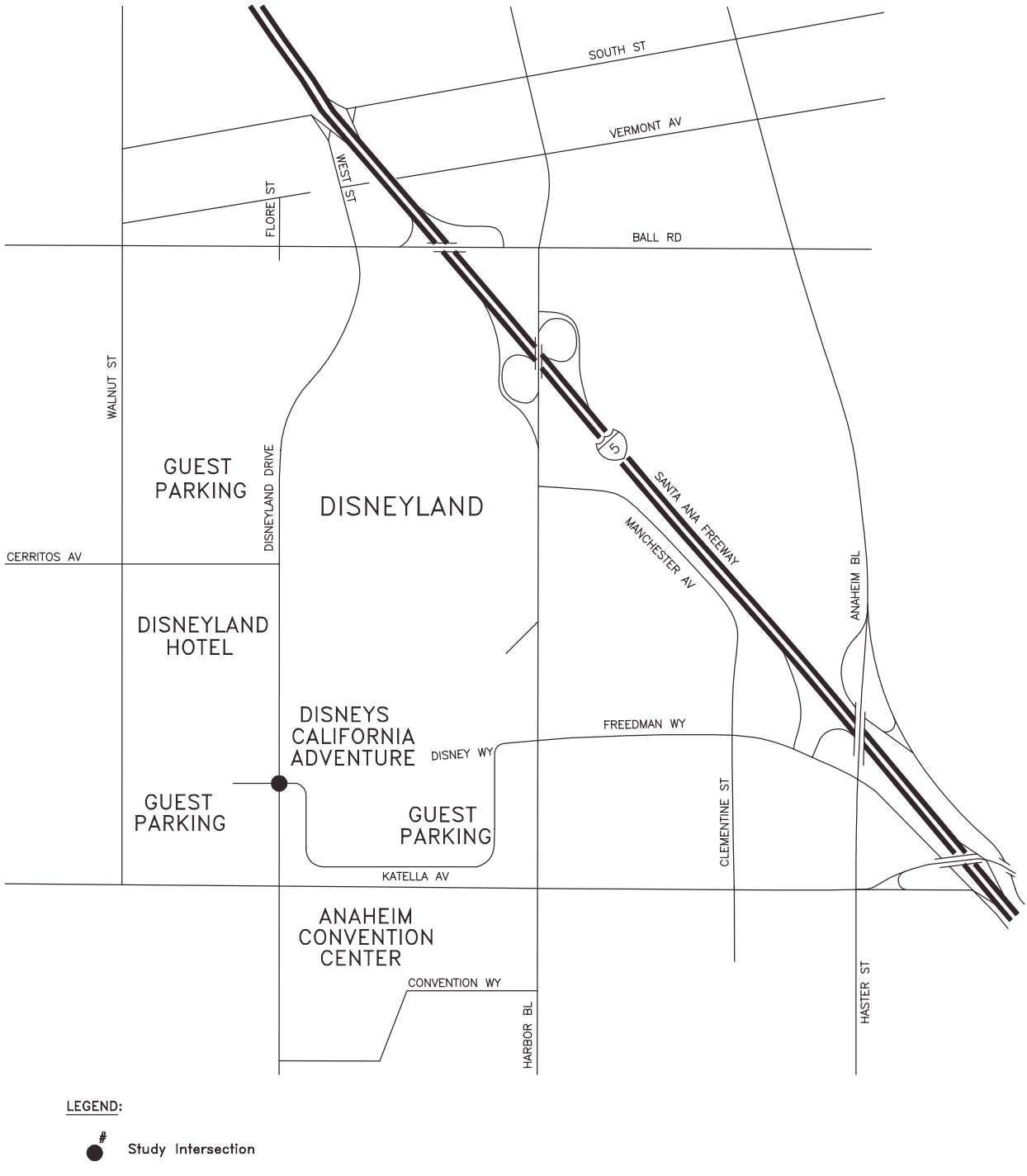
BACKGROUND

The City of Anaheim requested permission from the California Traffic Control Devices Committee to test the experimental use of In-road LED lights across the stop line of an intersection.

The study intersection, known as the Southwest Intersection, is located in the midst of the Disneyland Resort along Disneyland Drive north of Katella Avenue. The intersection is of particular concern from a safety standpoint since north/south motorists seemed to be having difficulty focusing on the presence of the traffic signal. Violations of the stop line were common and there was an abnormally high instance of north/south red light violations. Figures 1 and 2 show the location of the study intersection.

As shown on Figure 1, the intersection serves Disneyland Drive, a four-lane divided north-south arterial street connecting Interstate 5 on the north to Disneyland Resort Theme Parks, parking for the theme parks, Resort hotels and the Anaheim Convention Center on the south. When the application to the California Traffic Control Devices Committee was made, the Disney's California Adventure theme park was under construction, and the construction activity immediately adjacent to the intersection was likely a contributing factor to the driver inattentiveness.

The east and west legs of the intersection served Disneyland Resort theme park guest parking. Guests were transported from the parking areas to the Disneyland theme park entrance via trams crossing the intersection in the east-west direction. In addition, guest automobiles checked into the Resort off Harbor Boulevard and then were directed westbound across Disneyland Drive as soon as the Harbor parking lot filled. Thus, the east-west traffic at this intersection was made up of guest vehicles traveling to/from parking spaces and trams full of guests moving between the Disneyland theme park entrance and the parking lot.



KAKU ASSOCIATES

FIGURE 1
LOCATION OF STUDY INTERSECTION

The primary goal of the installation was the reduction/elimination of north-south red light violations, thus improving the safety of the intersection.

On November 19, 1999 the California Traffic Control Devices Committee approved the use of LED lights across the north/south stop lines on an experimental basis.

INSTALLATION

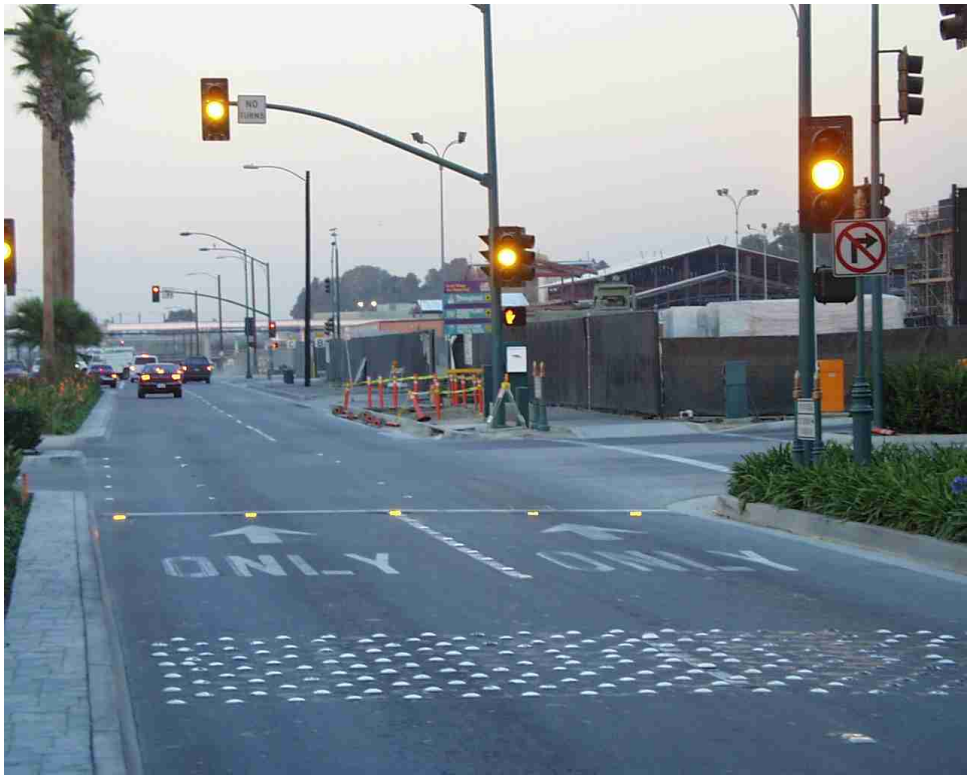
The LED light installation was accomplished during the week of December 13, 1999 through a cooperative effort of the City of Anaheim and LightGuard Systems.

The installation included five LED units across the stop lines facing both northbound and southbound traffic. The units were placed toward the median, toward the right curb, along the centerline separating the two lanes of travel and toward the center of each lane. In this way, the tires of most vehicles would pass through the row of LED units without driving over one.

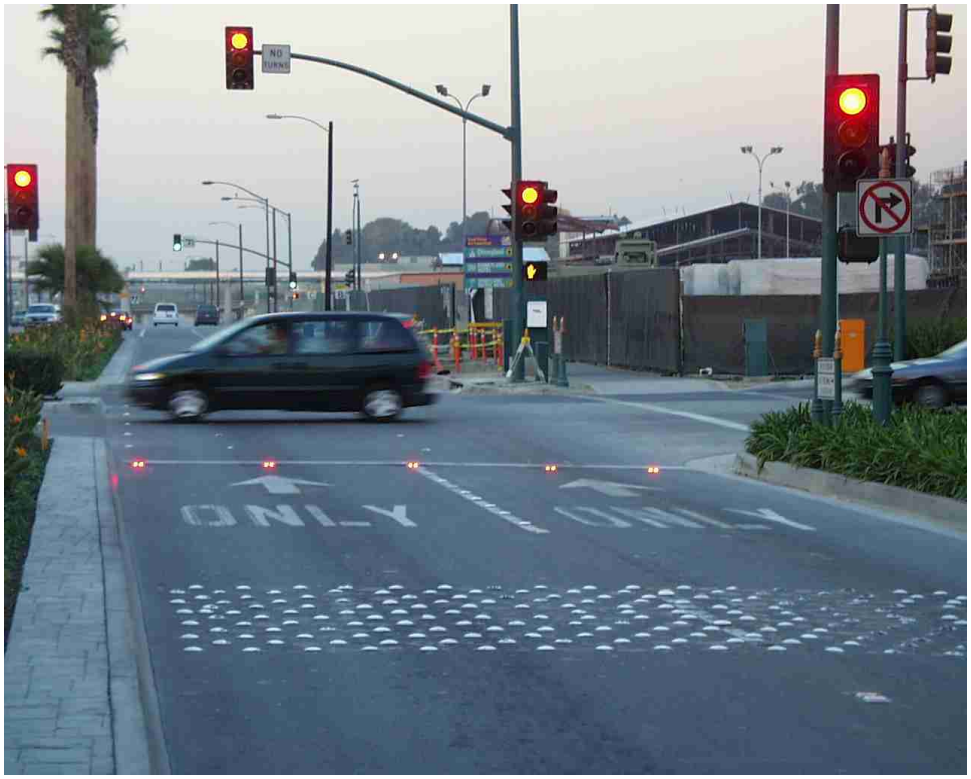
OPERATION

The LED lights are dark when the traffic signal phase is green for north/south traffic. The lights flash yellow when the traffic signal turns amber for north/south traffic, and the LED lights turn and remain a solid red indication during the north/south red phase.

Figure 3 shows photos of the completed installation.



Flashing Yellow LED During Clearance Phase



Solid Red LED During Red Phase

FIGURE 3
Completed Installation
Northbound Disneyland Drive at the Southwest Intersection

II. STUDY METHODOLOGY

BEFORE AND AFTER TESTS

The City of Anaheim committed to evaluate the installation of the LED lights by measuring the "before and after" occurrences of four evaluation factors:

a. Number of vehicles running the red light
b. Number of vehicles violating the stop line
c. Number of properly stopped vehicles "creeping" over the stop line during the red phase, and
d. Number of traffic accidents.

Data collection entailed measuring the stopping point of the first vehicle in the queue in each of the four lanes of travel on Disneyland Drive. Southbound traffic was videotaped while northbound traffic data was collected manually. Marks were painted on the median curb in order to assist in identifying the specific stopping point of each lead vehicle. No data was recorded if the light turned green in time for the queue to move through without coming to a complete stop.

The "before" tests were conducted over a period of seven different days. Both weekdays and Saturdays were tested beginning with the Saturday of Thanksgiving weekend and ending on Monday December 13, 1999 -- immediately prior to the installation of the devices. In total, 46 hours of data for both northbound and southbound traffic were collected.

The "before" data measured the stopping point of 2,504 northbound vehicles and 2,642 southbound vehicles over the 46 hours of data collection.

The intent of the City was to make sure that sufficient observations were made prior to the installation of the In-road LED lights to be able to make reliable comparisons with the “after” data. The 46 hours of “before” data yielded 5,146 observations.

Five sets of "after" data was collected over a period of almost two years (December 1999 to October 2001). The days and dates of the “after” tests were selected to include a range of weekday and weekend conditions as well as a wide variety of peak and average conditions for background traffic. During five sets of “after” data, a total of 4,334 northbound vehicles and 4,766 southbound vehicles were measured. The characteristics of these 9,153 vehicles were compared to the 5,146 “before” vehicles.

CHANGES DURING THE TEST PERIOD

One of the disadvantages of conducting research in the “real world” is that the conditions in the laboratory are difficult to control so that all variables remain perfectly constant throughout the data collection period. This was the case in this experiment as a number of minor elements of the intersection design and operation changed during the two-year study period.

As shown in Figure 3, the north and south approaches to the intersection were covered with pavement markers (raised Bots Dots) in an attempt to raise drivers’ awareness of the upcoming traffic signal. These pavement markers were installed concurrent with the installation of the In-road LED lights, but they were removed shortly after installation because the tire noise they created bothered the guests in the hotel adjacent to the intersection.

An overhead “TRAM XING” sign was installed on a mast arm over the roadway facing northbound and southbound traffic approaching the intersection. Each of the two yellow/black, diamond-shaped signs also included flashing yellow lights as an additional means to get drivers’ attention. These overhead signs were removed approximately one-third of the way through the two-year test period when it appeared that the In-road LED lights were meeting the needs of the intersection.

The operation and physical layout of the intersection also changed during the experiment period. The parking area on the west side of the intersection was opened up to Downtown Disney guests and entrance to the lot was permitted from Disneyland Drive. Originally operated as a "NO TURNS" for northbound and southbound traffic, about two-thirds of the way through the test period, a northbound left turn lane (with a separate signal phase controlled by a green arrow) was installed. Southbound traffic was also permitted to turn right into the west leg of the intersection to enter the parking lot.

Perhaps the biggest change that occurred during the test period was the completion of the construction of the Disney's California Adventure theme park. The construction ended with the opening of the theme park in January 2001. Therefore the second half of the test period was conducted without the motorists' distractions that were in place during the first 12 months of the test.

Finally, the In-road devices were modified in May 2001 when an improved set of LED lights was installed. The new generation of lights was installed to increase the daytime visibility of the lights. The last two sets of data were collected with the brighter lights in place.

III. TEST RESULTS

Table 1 shows the results of the before and after data collection. Tables 1A and 1B repeat the results of the "before" data for ease of reference. Tables 1C and 1D present the results of the "after" data – combining the December 1999, April, June, and November 2000 data with the June, September and October 2001 data.

The following sections describe the results of the comparisons of the before and after data for each of the evaluation categories.

RED LIGHT VIOLATION

Violation Experience

Figure 4 shows that the red light violations after the installation of the LED device averaged 2.40 violations per 1,000 vehicles. This is compared with an average of 8.94 violations per 1,000 vehicles before the installation – three and a half times greater than the combined "after" data.

The red light violations actually decreased throughout the course of the tests. The red light violations by time period are shown in Table 2 and can be summarized as follows:

Data Set	Time Period	Red Light Violations (Violations per 1,000 Vehicles)
Before	**Nov/Dec 1999**	**8.94**
First	Dec 1999	4.78
Second	Apr/Jun 2000	2.28
Third	Nov 2000	0.93
Fourth	Jun 2001	0.00
Fifth	Sep/Oct 2001	0.00
Average After		**2.40**

TABLE 1A
"BEFORE" DATA
NORTHBOUND TRAVEL

DATE	TRAVEL	TIME	DISTANCE FIRST CAR IN QUEUE STOPPED BEHIND STOP LINE												TOTAL		CREEP OVER		RAN RED
			>6 FEET		>3 FEET		2-3 FEET		1-2 FEET		0-1 FOOT		OVER						
	DIRECTN	PERIOD	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#
11/27/1999	NB	930-1130	18	12.33%	27	18.49%	24	16.44%	19	13.01%	25	17.12%	33	22.60%	146	100.00%	8	7.08%	4
12/2/1999	NB	10A-12N	29	15.03%	36	18.65%	10	5.18%	22	11.40%	19	9.84%	77	39.90%	193	100.00%	11	9.48%	0
12/2/1999	NB	3-4P	10	15.63%	14	21.88%	5	7.81%	7	10.94%	10	15.63%	18	28.13%	64	100.00%	7	15.22%	0
12/5/1999	NB	10-12N 3-4P	54	17.53%	87	28.25%	41	13.31%	24	7.79%	25	8.12%	77	25.00%	308	100.00%	25	10.82%	3
12/9/1999	NB	10-12N 3-4P	21	10.50%	47	23.50%	25	12.50%	27	13.50%	21	10.50%	59	29.50%	200	100.00%	13	9.22%	3
12/11/1999	NB	10-12N 3-4P	75	30.00%	68	27.20%	23	9.20%	25	10.00%	10	4.00%	49	19.60%	250	100.00%	16	7.96%	1
12/12/1999	NB	10-12N 3-4P	47	18.29%	51	19.84%	27	10.51%	28	10.89%	32	12.45%	72	28.02%	257	100.00%	18	9.73%	0
12/13/1999	NB	10-12N 3-4P	4	2.34%	62	36.26%	25	14.62%	11	6.43%	16	9.36%	53	30.99%	171	100.00%	13	11.02%	2
	TOTAL		**258**	**16.24%**	**392**	**24.67%**	**180**	**11.33%**	**163**	**10.26%**	**158**	**9.94%**	**438**	**27.56%**	**1589**	**100.00%**	**111**	**9.64%**	**13**
11/27/1999	NB	4-6PM	11	8.33%	18	13.64%	20	15.15%	22	16.67%	23	17.42%	38	28.79%	132	100.00%	11	11.70%	0
12/2/1999	NB	4-6PM	22	23.66%	24	25.81%	11	11.83%	8	8.60%	7	7.53%	21	22.58%	93	100.00%	8	11.11%	1
12/5/1999	NB	4-6PM	16	12.21%	41	31.30%	13	9.92%	10	7.63%	9	6.87%	42	32.06%	131	100.00%	14	15.73%	1
12/9/1999	NB	4-6PM	6	12.50%	11	22.92%	11	22.92%	2	4.17%	4	8.33%	14	29.17%	48	100.00%	0	0.00%	2
12/11/1999	NB	4-6PM	25	17.61%	33	23.24%	16	11.27%	18	12.68%	16	11.27%	34	23.94%	142	100.00%	16	14.81%	0
12/12/1999	NB	4-6PM	13	11.30%	22	19.13%	13	11.30%	16	13.91%	17	14.78%	34	29.57%	115	100.00%	4	4.94%	1
12/13/1999	NB	4-6PM	3	4.35%	19	27.54%	10	14.49%	6	8.70%	9	13.04%	22	31.88%	69	100.00%	3	6.38%	0
	TOTAL		**96**	**13.15%**	**168**	**23.01%**	**94**	**12.88%**	**82**	**11.23%**	**85**	**11.64%**	**205**	**28.08%**	**730**	**100.00%**	**56**	**10.67%**	**5**
11/27/1999	NB	10P-12M	4	8.70%	7	15.22%	5	10.87%	2	4.35%	5	10.87%	23	50.00%	46	100.00%	5	21.74%	5
12/2/1999	NB	10P-12M	0	0.00%	2	50.00%	0	0.00%	0	0.00%	0	0.00%	2	50.00%	4	100.00%	0	0.00%	0
12/5/1999	NB	10P-12M	2	9.09%	6	27.27%	3	13.64%	2	9.09%	1	4.55%	8	36.36%	22	100.00%	4	28.57%	0
12/9/1999	NB	10P-12M	0	0.00%	2	22.22%	4	44.44%	0	0.00%	2	22.22%	1	11.11%	9	100.00%	0	0.00%	0
12/11/1999	NB	10P-12M	19	27.14%	23	32.86%	10	14.29%	5	7.14%	3	4.29%	10	14.29%	70	100.00%	7	11.67%	2
12/12/1999	NB	10P-12M	9	26.47%	5	14.71%	3	8.82%	3	8.82%	1	2.94%	13	38.24%	34	100.00%	2	9.52%	0
	TOTAL		**34**	**18.38%**	**45**	**24.32%**	**25**	**13.51%**	**12**	**6.49%**	**12**	**6.49%**	**57**	**30.81%**	**185**	**100.00%**	**18**	**14.06%**	**7**
GRAND TOTAL			**388**	**15.50%**	**605**	**24.16%**	**299**	**11.94%**	**257**	**10.26%**	**255**	**10.18%**	**700**	**27.96%**	**2504**	**100.00%**	**185**	**10.25%**	**25**

TABLE 1B
"BEFORE" DATA
SOUTHBOUND TRAVEL

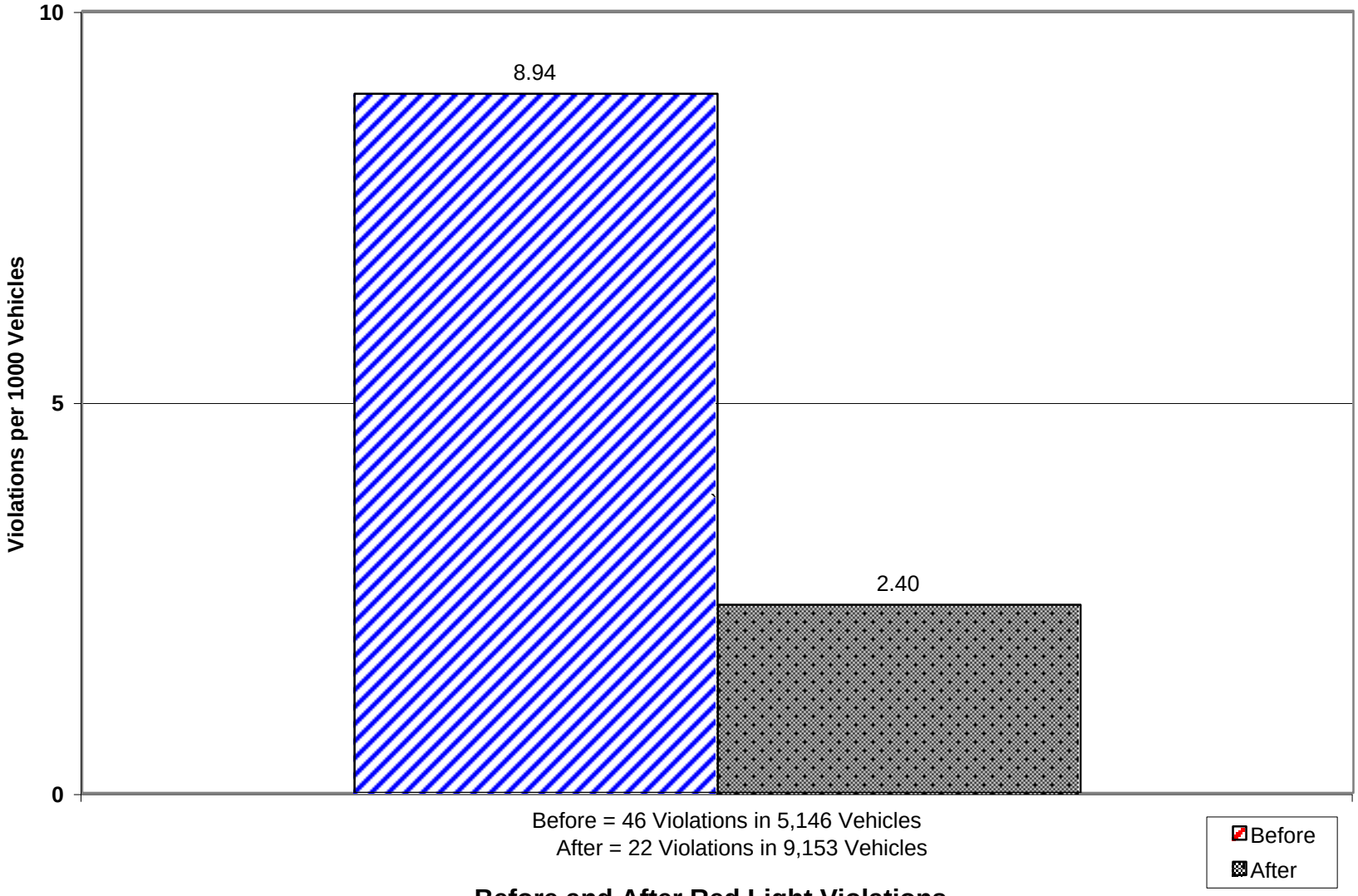
DATE	TRAVEL	TIME	DISTANCE FIRST CAR IN QUEUE STOPPED BEHIND STOP LINE												TOTAL		CREEP OVER		RAN RED
			>6 FEET		>3 FEET		2-3 FEET		1-2 FEET		0-1 FOOT		OVER						
	DIRECTN	PERIOD	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#
11/27/1999	SB	930-1130	11	9.91%	28	25.23%	17	15.32%	11	9.91%	20	18.02%	24	21.62%	111	100.00%	17	19.54%	4
12/2/1999	SB	10A-1P	18	9.94%	45	24.86%	19	10.50%	7	3.87%	19	10.50%	73	40.33%	181	100.00%	16	14.81%	3
12/2/1999	SB	3-4P	4	6.35%	16	25.40%	5	7.94%	7	11.11%	6	9.52%	25	39.68%	63	100.00%	15	39.47%	0
12/5/1999	SB	10-1P 3-4P	20	6.27%	89	27.90%	20	6.27%	34	10.66%	33	10.34%	123	38.56%	319	100.00%	27	13.78%	1
12/9/1999	SB	10-1P 3-4P	15	7.73%	40	20.62%	24	12.37%	27	13.92%	18	9.28%	70	36.08%	194	100.00%	15	12.10%	2
12/11/1999	SB	10-1P 3-4P	27	11.74%	43	18.70%	49	21.30%	24	10.43%	33	14.35%	54	23.48%	230	100.00%	18	10.23%	1
12/12/1999	SB	10-1P 3-4P	15	6.30%	36	15.13%	26	10.92%	24	10.08%	35	14.71%	102	42.86%	238	100.00%	9	6.62%	1
12/13/1999	SB	10-1P 3-4P	15	7.18%	42	20.10%	18	8.61%	15	7.18%	36	17.22%	83	39.71%	209	100.00%	21	16.67%	0
	TOTAL		**125**	**8.09%**	**339**	**21.94%**	**178**	**11.52%**	**149**	**9.64%**	**200**	**12.94%**	**554**	**35.86%**	**1545**	**100.00%**	**138**	**13.93%**	**12**
11/27/1999	SB	4-6PM	10	8.62%	27	23.28%	14	12.07%	14	12.07%	18	15.52%	33	28.45%	116	100.00%	15	18.07%	2
12/2/1999	SB	4-6PM	9	9.00%	31	31.00%	5	5.00%	12	12.00%	13	13.00%	30	30.00%	100	100.00%	7	10.00%	0
12/5/1999	SB	4-6PM	10	7.09%	35	24.82%	9	6.38%	11	7.80%	18	12.77%	58	41.13%	141	100.00%	5	6.02%	0
12/9/1999	SB	4-6PM	7	12.96%	13	24.07%	9	16.67%	10	18.52%	6	11.11%	9	16.67%	54	100.00%	8	17.78%	1
12/11/1999	SB	4-6PM	11	14.47%	14	18.42%	17	22.37%	8	10.53%	10	13.16%	16	21.05%	76	100.00%	4	6.67%	0
12/12/1999	SB	4-6PM	10	9.52%	24	22.86%	10	9.52%	5	4.76%	15	14.29%	41	39.05%	105	100.00%	3	4.69%	0
12/13/1999	SB	4-6PM	13	12.87%	21	20.79%	14	13.86%	7	6.93%	17	16.83%	29	28.71%	101	100.00%	15	20.83%	0
	TOTAL		**70**	**10.10%**	**165**	**23.81%**	**78**	**11.26%**	**67**	**9.67%**	**97**	**14.00%**	**216**	**31.17%**	**693**	**100.00%**	**57**	**11.95%**	**3**
11/27/1999	SB	10P-12M	10	9.26%	25	23.15%	13	12.04%	17	15.74%	13	12.04%	30	27.78%	108	100.00%	7	8.97%	4
12/2/1999	SB	10P-12M	0	0.00%	2	28.57%	1	14.29%	1	14.29%	2	28.57%	1	14.29%	7	100.00%	2	33.33%	0
12/5/1999	SB	10P-12M	1	3.23%	5	16.13%	2	6.45%	3	9.68%	3	9.68%	17	54.84%	31	100.00%	0	0.00%	0
12/9/1999	SB	10P-12M	0	0.00%	8	22.86%	7	20.00%	2	5.71%	7	20.00%	11	31.43%	35	100.00%	1	4.17%	1
12/11/1999	SB	10P-12M	21	17.07%	25	20.33%	17	13.82%	5	4.07%	18	14.63%	37	30.08%	123	100.00%	23	26.74%	1
12/12/1999	SB	10P-12M	5	5.00%	25	25.00%	11	11.00%	12	12.00%	19	19.00%	28	28.00%	100	100.00%	7	9.72%	0
	TOTAL		**37**	**9.16%**	**90**	**22.28%**	**51**	**12.62%**	**40**	**9.90%**	**62**	**15.35%**	**124**	**30.69%**	**404**	**100.00%**	**40**	**14.29%**	**6**
GRAND TOTAL			**232**	**8.78%**	**594**	**22.48%**	**307**	**11.62%**	**256**	**9.69%**	**359**	**13.59%**	**894**	**33.84%**	**2642**	**100.00%**	**235**	**13.44%**	**21**

TABLE 1C
"AFTER" DATA
NORTHBOUND TRAVEL

DATE	TRAVEL	TIME	DISTANCE FIRST CAR IN QUEUE STOPPED BEHIND STOP LINE												TOTAL		CREEP OVER		RAN RED
			>6 FEET		>3 FEET		2-3 FEET		1-2 FEET		0-1 FOOT		OVER						
	DIRECTN	PERIOD	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#
12/21/1999	NB	10A-1P 3-4P	90	32.6%	56	20.3%	30	10.9%	27	9.8%	28	10.1%	45	16.3%	276	100%	41	17.7%	1
12/28/1999	NB	12N-3P	9	7.6%	32	26.9%	11	9.2%	30	25.2%	15	12.6%	22	18.5%	119	100%	0	0.0%	0
12/29/1999	NB	10-1P 2-5P	67	23.1%	86	29.7%	32	11.0%	28	9.7%	42	14.5%	35	12.1%	290	100%	6	2.4%	2
4/22/2000	NB	10A-2P	37	16.9%	56	25.6%	35	16.0%	17	7.8%	20	9.1%	54	24.7%	219	100%	23	13.9%	1
4/27/2000	NB	10A-2P	24	10.8%	62	27.8%	30	13.5%	31	13.9%	14	6.3%	62	27.8%	223	100%	24	14.9%	0
6/25/2000	NB	10A-2P	44	20.5%	60	27.9%	31	14.4%	19	8.8%	20	9.3%	41	19.1%	215	100%	30	17.2%	0
6/28/2000	NB	10A-2P	7	2.3%	63	20.5%	45	14.6%	43	14.0%	87	28.2%	63	20.5%	308	100%	60	24.5%	1
11/2/2000	NB	10A-12N	5	11.4%	4	9.1%	5	11.4%	5	11.4%	8	18.2%	17	38.6%	44	100%	1	3.7%	0
11/4/2000	NB	10A-12N	19	13.6%	28	20.0%	29	20.7%	23	16.4%	22	15.7%	19	13.6%	140	100%	8	6.6%	0
6/9/2001	NB	3-5P	10	13.0%	12	15.6%	4	5.2%	8	10.4%	14	18.2%	29	37.7%	77	100%	3	6.3%	0
6/13/2001	NB	3-5P	6	10.9%	10	18.2%	3	5.5%	3	5.5%	4	7.3%	29	52.7%	55	100%	4	15.4%	0
9/1/2001	NB	3-5P	12	22.6%	9	17.0%	5	9.4%	3	5.7%	6	11.3%	18	34.0%	53	100%	3	8.6%	0
10/17/2001	NB	3-5P	6	14.0%	17	39.5%	6	14.0%	3	7.0%	6	14.0%	5	11.6%	43	100%	3	7.9%	0
	TOTAL		**336**	**16.3%**	**495**	**24.0%**	**266**	**12.9%**	**240**	**11.6%**	**286**	**13.9%**	**439**	**21.3%**	**2062**	**100%**	**206**	**12.7%**	**5**
12/21/1999	NB	4-6P	61	49.2%	25	20.2%	6	4.8%	7	5.6%	4	3.2%	21	16.9%	124	100%	13	12.6%	0
12/22/1999	NB	4-6P	41	36.3%	32	28.3%	6	5.3%	8	7.1%	9	8.0%	17	15.0%	113	100%	4	4.2%	2
12/28/1999	NB	4-7P	30	25.4%	44	37.3%	15	12.7%	12	10.2%	9	7.6%	8	6.8%	118	100%	4	3.6%	0
4/22/2000	NB	4-8P	54	21.1%	101	39.5%	12	4.7%	11	4.3%	33	12.9%	45	17.6%	256	100%	14	6.6%	0
4/27/2000	NB	4-8P	41	24.3%	41	24.3%	10	5.9%	9	5.3%	29	17.2%	39	23.1%	169	100%	18	13.8%	0
6/25/2000	NB	4-8P	50	19.3%	83	32.0%	14	5.4%	14	5.4%	40	15.4%	58	22.4%	259	100%	15	7.5%	0
6/28/2000	NB	4-8P	14	5.6%	47	18.8%	33	13.2%	41	16.4%	71	28.4%	44	17.6%	250	100%	31	15.0%	0
11/2/2000	NB	4-6P	15	25.4%	18	30.5%	8	13.6%	4	6.8%	4	6.8%	10	16.9%	59	100%	0	0.0%	0
11/4/2000	NB	4-6P	28	22.4%	31	24.8%	19	15.2%	22	17.6%	12	9.6%	13	10.4%	125	100%	3	2.7%	0
6/9/2001	NB	7-9P	12	8.8%	19	13.9%	19	13.9%	10	7.3%	27	19.7%	50	36.5%	137	100%	6	6.9%	0
6/13/2001	NB	7-9P	9	8.5%	13	12.3%	12	11.3%	8	7.5%	16	15.1%	48	45.3%	106	100%	6	10.3%	0
9/1/2001	NB	7-9P	16	16.5%	17	17.5%	18	18.6%	5	5.2%	15	15.5%	26	26.8%	97	100%	5	7.0%	0
10/17/2001	NB	7-9P	3	27.3%	6	54.5%	0	0.0%	0	0.0%	0	0.0%	2	18.2%	11	100%	2	22.2%	0
	TOTAL		**374**	**20.5%**	**477**	**26.2%**	**172**	**9.4%**	**151**	**8.3%**	**269**	**14.7%**	**381**	**20.9%**	**1824**	**100%**	**121**	**8.4%**	**2**
12/21/1999	NB	10P-12M	30	48.4%	7	11.3%	9	14.5%	4	6.5%	4	6.5%	8	12.9%	62	100%	13	24.1%	1
12/22/1999	NB	10P-12M	17	50.0%	7	20.6%	1	2.9%	3	8.8%	5	14.7%	1	2.9%	34	100%	1	3.0%	0
12/28/1999	NB	9-11P	24	33.3%	20	27.8%	5	6.9%	10	13.9%	8	11.1%	5	6.9%	72	100%	2	3.0%	1
11/2/2000	NB	7-9P	11	20.4%	15	27.8%	5	9.3%	4	7.4%	1	1.9%	18	33.3%	54	100%	0	0.0%	0
11/4/2000	NB	10P-12M	24	26.4%	33	36.3%	7	7.7%	7	7.7%	6	6.6%	14	15.4%	91	100%	3	3.9%	1
6/9/2001	NB	10P-12M	4	9.3%	9	20.9%	4	9.3%	2	4.7%	5	11.6%	19	44.2%	43	100%	3	12.5%	0
6/13/2001	NB	10P-12M	10	21.3%	5	10.6%	2	4.3%	1	2.1%	5	10.6%	24	51.1%	47	100%	4	17.4%	0
9/1/2001	NB	10P-12M	13	34.2%	10	26.3%	8	21.1%	0	0.0%	2	5.3%	5	13.2%	38	100%	2	6.1%	0
10/17/2001	NB	10P-12M	1	14.3%	3	42.9%	1	14.3%	0	0.0%	1	14.3%	1	14.3%	7	100%	1	16.7%	0
	TOTAL		**134**	**29.9%**	**109**	**24.3%**	**42**	**9.4%**	**31**	**6.9%**	**37**	**8.3%**	**95**	**21.2%**	**448**	**100%**	**29**	**8.2%**	**3**
GRAND TOTAL			**844**	**19.5%**	**1081**	**24.9%**	**480**	**11.1%**	**422**	**9.7%**	**592**	**13.7%**	**915**	**21.1%**	**4334**	**100%**	**356**	**10.4%**	**10**

TABLE 1D
"AFTER" DATA
SOUTHBOUND TRAVEL

DATE	TRAVEL	TIME	DISTANCE FIRST CAR IN QUEUE STOPPED BEHIND STOP LINE												TOTAL		CREEP OVER		RAN RED	RT-TURN STOP	RT-TURN NO STOP
			>6 FEET		>3 FEET		2-3 FEET		1-2 FEET		0-1 FOOT		OVER								
	DIRECTN	PERIOD	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	PERCENT	#	#	#
12/21/1999	SB	10A-1P 3-4P	43	19.5%	31	14.1%	32	14.5%	28	12.7%	20	9.1%	66	30.0%	220	100%	39	25.3%	2		
12/28/1999	SB	12N-3P	31	23.0%	27	20.0%	12	8.9%	24	17.8%	14	10.4%	27	20.0%	135	100%	6	5.6%	0		
12/29/1999	SB	10-1P 2-5P	64	21.0%	57	18.7%	51	16.7%	43	14.1%	33	10.8%	57	18.7%	305	100%	10	4.0%	0		
4/22/2000	SB	10A-2P	24	9.9%	53	21.8%	20	8.2%	33	13.6%	30	12.3%	83	34.2%	243	100%	23	14.4%	3		
4/27/2000	SB	10A-2P	54	18.6%	48	16.5%	25	8.6%	27	9.3%	26	8.9%	111	38.1%	291	100%	46	25.6%	1		
6/25/2000	SB	11A-2P	11	5.0%	54	24.5%	29	13.2%	31	14.1%	47	21.4%	48	21.8%	220	100%	32	18.6%	0		
6/28/2000	SB	10A-2P	12	4.1%	63	21.4%	45	15.3%	41	13.9%	60	20.3%	74	25.1%	295	100%	32	14.5%	3		
11/2/2000	SB	10A-12N	4	4.8%	11	13.3%	16	19.3%	12	14.5%	12	14.5%	28	33.7%	83	100%	7	12.7%	0		
11/4/2000	SB	10A-12N	11	8.6%	22	17.2%	31	24.2%	16	12.5%	21	16.4%	27	21.1%	128	100%	5	5.0%	0		
6/9/2001	SB	3-5P	14	18.2%	9	11.7%	6	7.8%	3	3.9%	9	11.7%	36	46.8%	77	100%	1	2.4%	0		
6/13/2001	SB	3-5P	3	7.1%	8	19.0%	1	2.4%	7	16.7%	5	11.9%	18	42.9%	42	100%	4	16.7%	0		
9/1/2001	SB	3-5P	21	26.9%	7	9.0%	4	5.1%	5	6.4%	11	14.1%	30	38.5%	78	100%	2	4.2%	0		
10/17/2001	SB	3-5P	3	10.0%	8	26.7%	3	10.0%	0	0.0%	5	16.7%	11	36.7%	30	100%	5	26.3%	0	0	0
	TOTAL		**295**	**13.7%**	**398**	**18.5%**	**275**	**12.8%**	**270**	**12.6%**	**293**	**13.6%**	**616**	**28.7%**	**2147**	**100%**	**212**	**13.8%**	**9**	**0**	**0**
12/21/1999	SB	4-6P	44	32.6%	13	9.6%	9	6.7%	13	9.6%	7	5.2%	49	36.3%	135	100%	14	16.3%	1		
12/22/1999	NB	4-6P	18	15.7%	22	19.1%	16	13.9%	8	7.0%	16	13.9%	35	30.4%	115	100%	6	7.5%	1		
12/28/1999	SB	4-7P	36	24.3%	37	25.0%	26	17.6%	20	13.5%	11	7.4%	18	12.2%	148	100%	6	4.6%	0		
4/22/2000	SB	4-8P	39	13.2%	70	23.7%	36	12.2%	31	10.5%	36	12.2%	83	28.1%	295	100%	20	9.4%	0		
4/27/2000	SB	4-6P	22	15.7%	21	15.0%	15	10.7%	12	8.6%	12	8.6%	58	41.4%	140	100%	19	23.2%	0		
6/25/2000	SB	4-8P	9	3.1%	72	24.8%	38	13.1%	27	9.3%	67	23.1%	77	26.6%	290	100%	25	11.7%	0		
6/28/2000	SB	4-8P	13	4.6%	53	18.9%	41	14.6%	27	9.6%	84	30.0%	62	22.1%	280	100%	32	14.7%	0		
11/2/2000	SB	4-6P	3	4.2%	9	12.7%	9	12.7%	8	11.3%	8	11.3%	34	47.9%	71	100%	2	5.4%	0		
11/4/2000	SB	4-6P	16	13.9%	44	38.3%	16	13.9%	10	8.7%	10	8.7%	19	16.5%	115	100%	3	3.1%	0		
6/9/2001	SB	5-7P	13	10.9%	20	16.8%	15	12.6%	5	4.2%	9	7.6%	57	47.9%	119	100%	3	4.8%	0		
6/13/2001	SB	5-7P	10	10.8%	21	22.6%	16	17.2%	11	11.8%	6	6.5%	29	31.2%	93	100%	8	12.5%	0		
9/1/2001	SB	5-7P	27	21.3%	18	14.2%	17	13.4%	9	7.1%	12	9.4%	44	34.6%	127	100%	5	6.0%	0		
10/17/2001	SB	5-7P	14	32.6%	11	25.6%	4	9.3%	4	9.3%	1	2.3%	9	20.9%	43	100%	2	5.9%	0	0	1
	TOTAL		**264**	**13.4%**	**411**	**20.9%**	**258**	**13.1%**	**185**	**9.4%**	**279**	**14.2%**	**574**	**29.1%**	**1971**	**100%**	**145**	**10.4%**	**2**	**0**	**1**
12/21/1999	SB	10P-12M	48	53.9%	15	16.9%	4	4.5%	5	5.6%	4	4.5%	13	14.6%	89	100%	15	19.7%	1		
12/22/1999	SB	10P-12M	1	1.5%	16	24.6%	4	6.2%	9	13.8%	10	15.4%	25	38.5%	65	100%	4	10.0%	0		
12/28/1999	SB	9-11P	40	43.5%	23	25.0%	6	6.5%	5	5.4%	7	7.6%	11	12.0%	92	100%	3	3.7%	0		
11/2/2000	SB	7-9P	9	14.5%	17	27.4%	13	21.0%	11	17.7%	2	3.2%	10	16.1%	62	100%	3	5.8%	0		
11/4/2000	SB	10P-12M	16	15.0%	28	26.2%	13	12.1%	20	18.7%	17	15.9%	13	12.1%	107	100%	6	6.4%	0		
6/9/2001	SB	10P-12M	6	12.8%	17	36.2%	9	19.1%	4	8.5%	3	6.4%	8	17.0%	47	100%	4	10.3%	0		
6/13/2001	SB	10P-12M	13	20.3%	17	26.6%	7	10.9%	4	6.3%	3	4.7%	20	31.3%	64	100%	7	15.9%	0		
9/1/2001	SB	10P-12M	32	28.6%	15	13.4%	11	9.8%	11	9.8%	16	14.3%	27	24.1%	112	100%	5	5.9%	0		
10/17/2001	SB	10P-12M	2	20.0%	2	20.0%	1	10.0%	1	10.0%	1	10.0%	3	30.0%	10	100%	1	14.3%	0	0	0
	TOTAL		**167**	**25.8%**	**150**	**23.1%**	**68**	**10.5%**	**70**	**10.8%**	**63**	**9.7%**	**130**	**20.1%**	**648**	**100%**	**48**	**9.3%**	**1**	**0**	**0**
GRAND TOTAL			**726**	**15.2%**	**959**	**20.1%**	**601**	**12.6%**	**525**	**11.0%**	**635**	**13.3%**	**1320**	**27.7%**	**4766**	**100%**	**405**	**11.8%**	**12**	**0**	**1**



Before and After Red Light Violations
Figure 4

TABLE 2
RED LIGHT VIOLATION SUMMARY

SUMMARY

TIME PERIOD	BEFORE			AFTER		
				Total "After" Data		
	# Violations	# Vehicles	Violation Rate	# Violations	# Vehicles	Violation Rate
DAYTIME	25	3,134	**7.98**	14	4,221	**3.32**
EVENING	8	1,423	**5.62**	4	3,818	**1.05**
NIGHT	13	589	**22.07**	4	1,114	**3.59**
TOTAL	46	5,146	**8.94**	22	9,153	**2.40**

INDIVIDUAL DATA SETS

TIME PERIOD	AFTER								
	First "After" Data			Second "After" Data			Third "After" Data		
	# Violations	# Vehicles	Violation Rate	# Violations	# Vehicles	Violation Rate	# Violations	# Vehicles	Violation Rate
DAYTIME	5	1345	**3.72**	9	2,014	**4.47**	0	395	**0.00**
EVENING	4	753	**5.31**	0	1,939	**0.00**	0	370	**0.00**
NIGHT	3	414	**7.25**	NA	NA	**-**	1	314	**3.18**
TOTAL	12	2512	**4.78**	9	3953	**2.28**	1	1079	**0.93**

TIME PERIOD	AFTER					
	Fourth "After" Data			Fifth "After" Data		
	# Violations	# Vehicles	Violation Rate	# Violations	# Vehicles	Violation Rate
DAYTIME	0	263	**0.00**	0	204	**0.00**
EVENING	0	478	**0.00**	0	278	**0.00**
NIGHT	0	219	**0.00**	0	167	**0.00**
TOTAL	0	960	**0.00**	0	649	**0.00**

NOTE: Violation Rate Expressed in Number of Violations per 1,000 Observations

This indicates that the devices continue to be effective at alerting drivers to the upcoming signal, and drivers continue to adhere to the signal.

Table 2 also shows the breakdown of red light violations by time of day (light condition). The data shows improvements during all light conditions. The “after” daytime rate is approximately 40% of the “before” rate.

Daytime/Dusk/Nighttime Experience

There was a concern over the brightness of the LED lights during the daytime hours. Initial field observations indicated that the lights seemed to be much more visible at dusk and during the nighttime hours than they were during daytime operation.

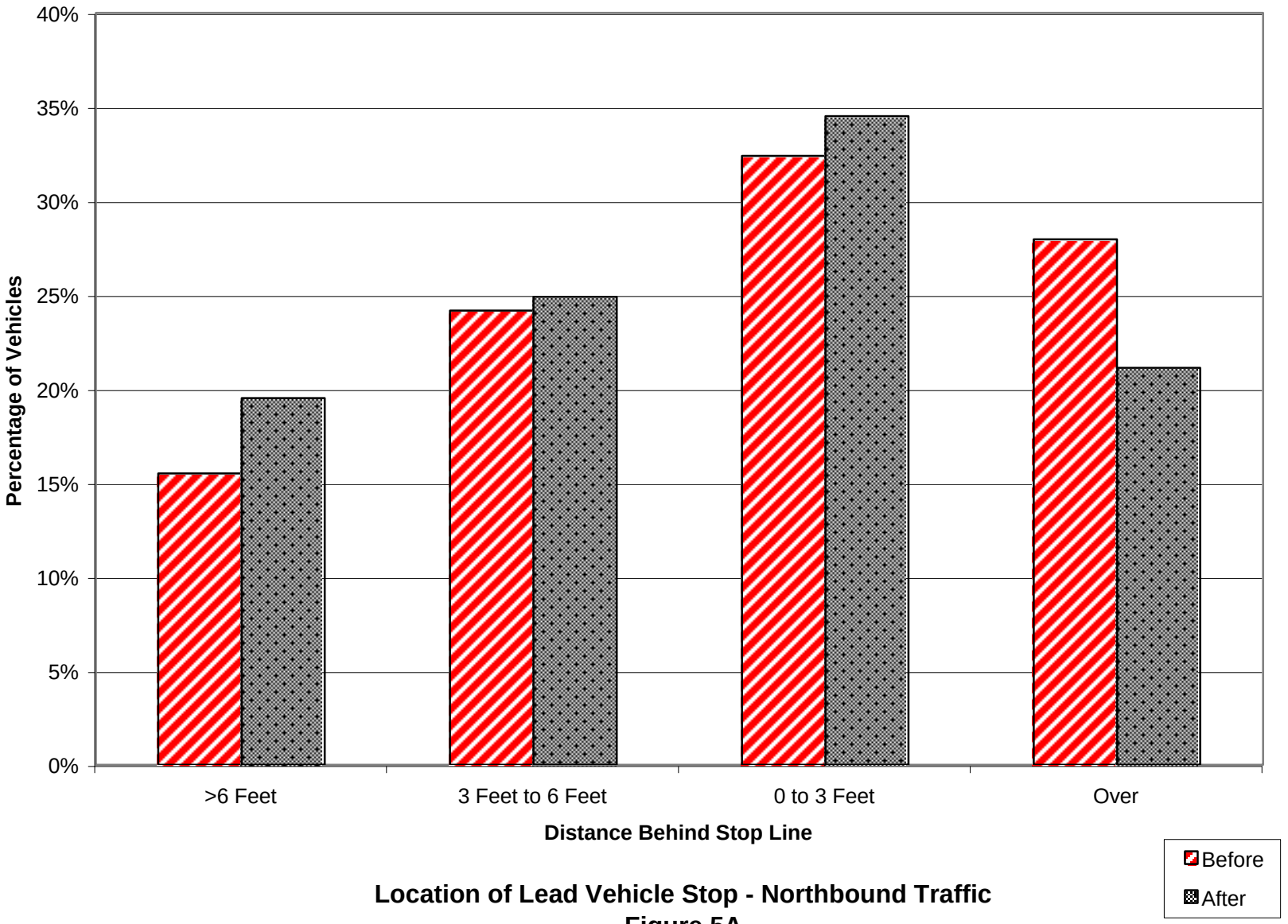
LightGuard Systems, the manufacturers of the In-road LED device, has developed the next generation of the device that increases daylight visibility. These new devices were installed at the intersection in May 2001, so the last two sets of observations include the effects of these brighter devices.

The "before and after" data was segregated by daytime, dusk and nighttime in order to measure the effectiveness of these devices during these three light conditions. As can be seen in Table 2, the devices are effective during all light conditions. For example, the daytime red light violations decreased from 7.98 to 3.32 violations per 1000 vehicles with the installation of the LED units.

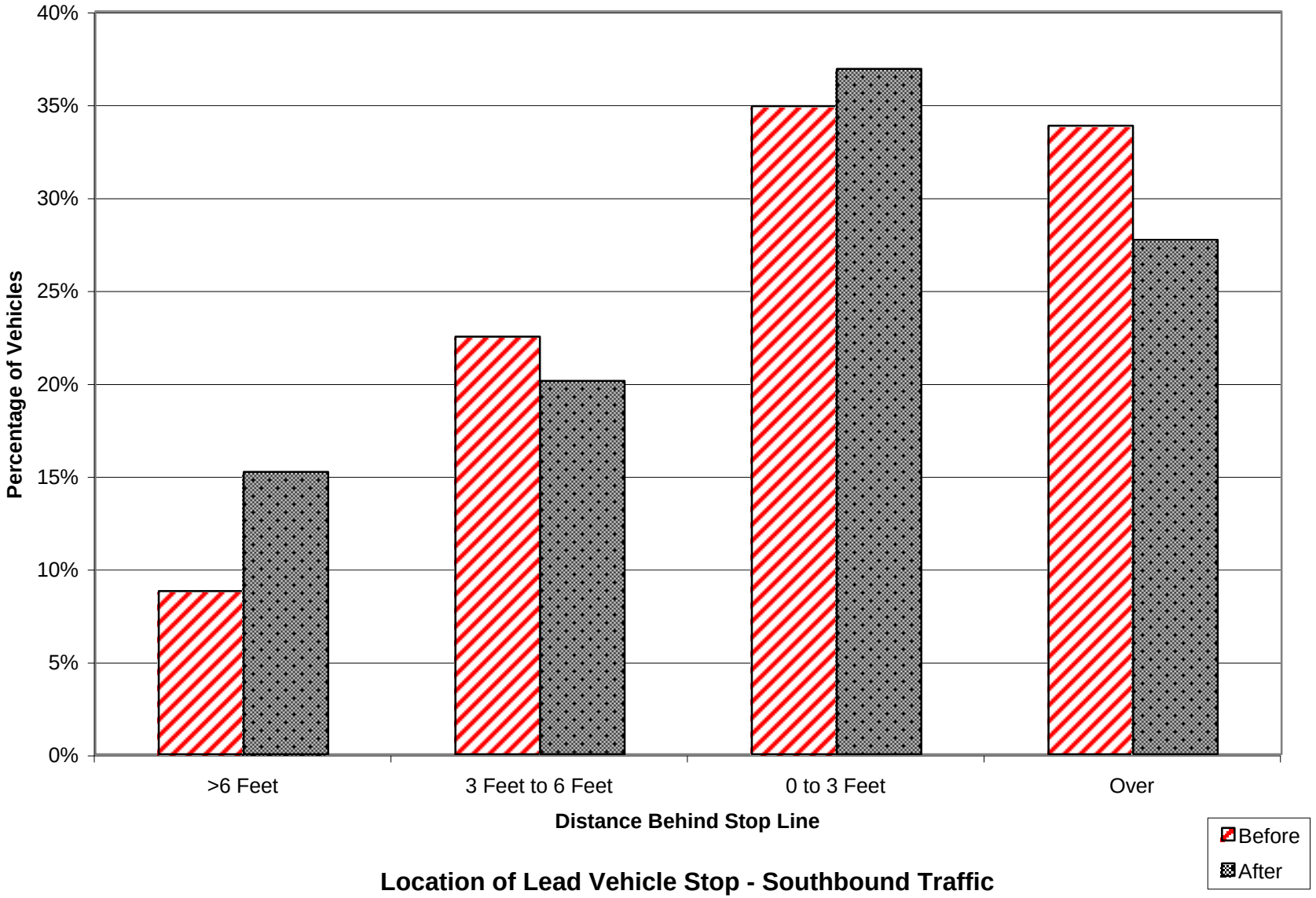
STOP LINE ADHERENCE

In the “before” condition, 31% of the lead vehicles in the queue crossed the stop line before coming to a complete stop. This included 28% of the northbound and 34% of the southbound lead vehicles.

Figures 5A and 5B show the stopping location of the lead vehicle. The adherence to the stop line increased as a result of the installation of the In-Road LED lights. The “after”



Location of Lead Vehicle Stop - Northbound Traffic
Figure 5A



Location of Lead Vehicle Stop - Southbound Traffic
Figure 5B

data showed that the number of vehicles crossing the stop line decreased to 25% of the total observations as compared with 31% before the installation. Northbound decreased from 28% to 21% and southbound decreased from 34% to 28%.

This statistic varied the most during the test period as it was heavily influenced by the addition of the northbound left turns and the southbound right turns during the test period. Since right turns on red were allowed for southbound traffic, these vehicles tended to stop past the stop line prior to making the right turn.

Figures 5A and 5B show that the devices were effective in increasing the distance the first vehicle stopped behind the stop line. A greater percentage of the vehicles stopped more than 3 feet behind the stop line in the “after” conditions.

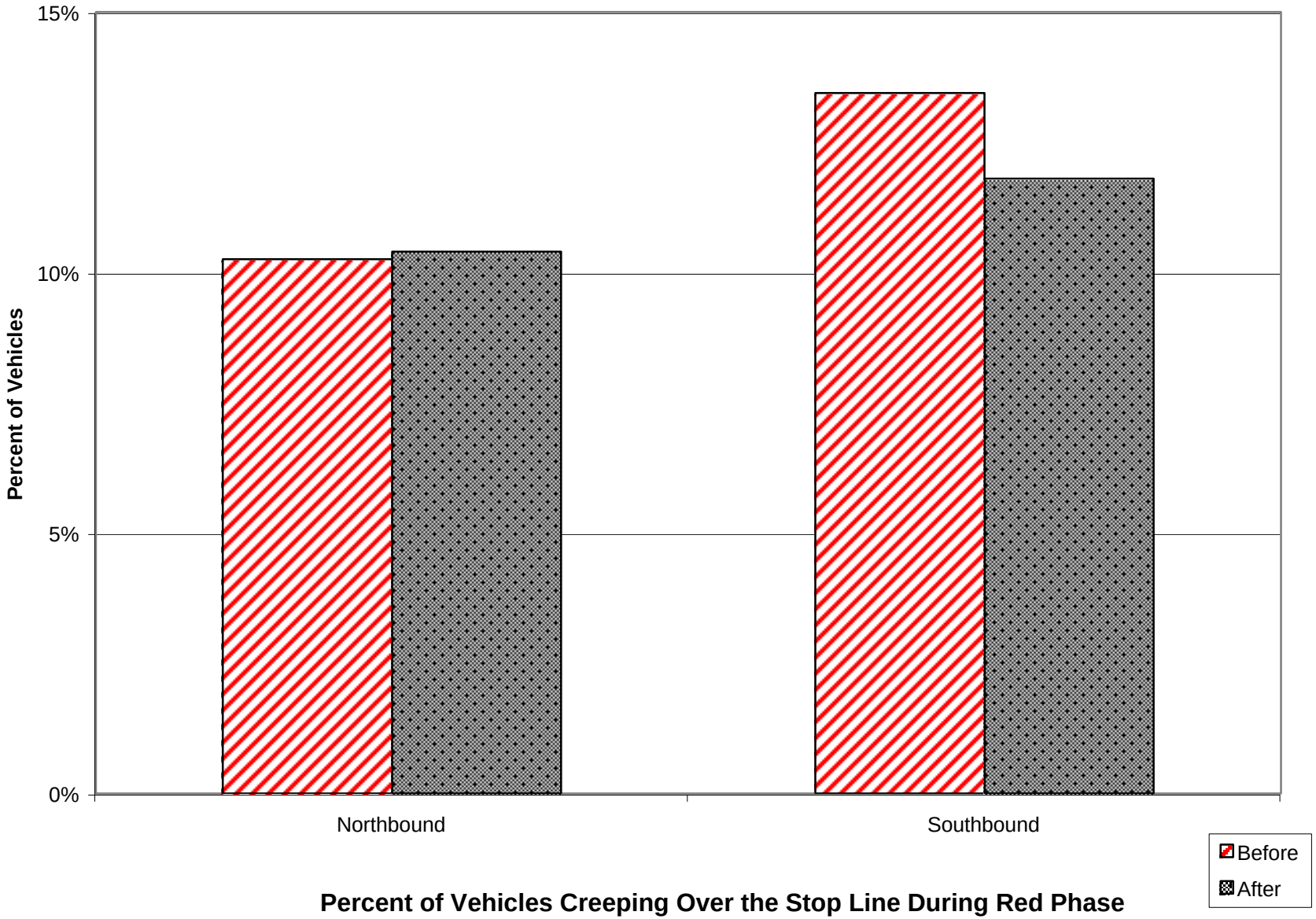
This data suggests that the In-road LED devices are effective at increasing the stopping distance behind the stop line for the through movements, but less so when a vehicle is turning.

CREEP OVER STOP LINE

On an overall basis, Figure 6 shows that the percent of vehicles creeping over the stop line (after coming to their first stop behind the stop line) has increased slightly in the northbound direction from 10.2% in the “before” condition to 10.4% in the “after” condition. The most likely cause for this small jump in vehicles observed creeping is the new northbound left turn lane. Drivers creep over the stop line in anticipation of the left turn signal, or in hopes of activating the sensor loops in the lane.

In the southbound direction, the percentage of vehicles creeping over the line actually went down from 13.4% in the “before” condition to 11.8% in the “after” condition.

The In-road LED lights appear to be effective at holding the through vehicles behind the stop line, but not as effective at holding turning vehicles back. Since the right-turn-on-red vehicle is allowed to cross the stop line during the red light, this conclusion is logical.



Percent of Vehicles Creeping Over the Stop Line During Red Phase
Figure 6

TRAFFIC ACCIDENTS

There were six accidents at this intersection in the 14 months preceding the installation of the In-road LED lights – five of which involved southbound vehicles. It is speculated that the primary cause of accidents was driver inattention due to the construction of the theme park rides immediately adjacent to the street.

During the two-year test period, there were no reported traffic accidents after the installation of the devices.

IV. CONCLUSIONS

The installation of the LED lights across the stop lines of northbound and southbound Disneyland Drive has resulted in positive improvements in all of the effectiveness measures outlined for the test.

The most significant improvement is in the area of red light violations. The instances of vehicles running the red light has been significantly reduced from a rate of 8.94 violations per 1,000 vehicles to 2.40 violations per 1,000 vehicles after the installation of the devices.

Stop line violations have been reduced from 31% to 25% of the vehicles coming to a stop beyond the stop line. In the early part of the test period, the stop line violations were cut almost in half when compared to the “before” data, but the addition of turning movements to the intersection increased the number of vehicles crossing the stop line.

The number of stopped vehicles creeping over the stop line during the red phase decreased after the installation of the devices.

During the two-year test period, there were no reported traffic accidents after the installation of the devices. This compares to six accidents in the 14 months prior to the installation of the devices.

The devices also appear to be effective during daylight, dusk and nighttime light conditions.

On the disadvantage side, the City of Anaheim had the following concerns:

1. The City found the device to be expensive at a total cost of approximately $26,500 for the development and purchase of the system, plus a similar cost for the actual installation.

2. In the first installation, the lights were hard to see during the brightest parts of the day. However, the manufacturer replaced the devices approximately mid-way through the test period with a new generation of LED devices and the visibility of the devices was dramatically improved during daytime hours.

3. Maintaining the installation was problematic because the heavy construction vehicles and constant street sweeping were hard on the devices. The manufacturer was very responsive in replacing broken or damaged parts and replacing the LED lights, however these devices may not be appropriate on streets/highways with a high percentage of heavy truck volumes.

The manufacturer believes that the cost of developing/installing these systems will decrease as more installations are developed. He also believes that a maintenance service contract will decrease to approximately $1,000 per year as more cities, contractors and traffic signal service firms become familiar with the equipment.

The installation was effective at reducing the red light violations, reducing accidents, and increasing adherence to the stop line (both in terms of the initial stop location and the ability to hold vehicles behind the line during the red phase). In short, the installation met all four goals of the project. This is not to suggest that the installation should be added to every signalized intersection, but for unique situations where driver inattentiveness is a concern or where the traffic signal indications compete with multiple visual stimulations, this type of installation should be considered.