FINAL

CORRIDOR SYSTEM MANAGEMENT PLAN (CSMP)
ORANGE COUNTY SR-91
COMPREHENSIVE PERFORMANCE ASSESSMENT
AND
CAUSALITY ANALYSIS

December 9, 2008

System Metrics Group, Inc.

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1. INTRODUCTION

This document represents the draft for the sixth and seventh milestones of the Orange County State Route 91 (SR-91) Corridor System Management Plan (CSMP) development process which is required by the California Transportation Commission (CTC) for corridors that have received funding from the Corridor Mobility Improvement Account (CMIA) approved by the voters in 2006. The CMIA will partly fund the construction of the eastbound auxiliary lane from SR-241 to SR-71 and widening to add lanes in both directions from SR-55 to Gypsum Canyon.

The two milestones are called the Comprehensive Performance Assessment and the Causality of Performance Degradation. They build on the fourth milestone, the "Preliminary Performance Assessment" (already developed), and the fifth milestone, "Ensure Adequate Corridor Detection." The milestones, eight in total, were documented in the CSMP guidelines distributed by Caltrans Headquarters.

The main purpose of the Comprehensive Performance Assessment is to detail the performance of the corridor so that future investment decisions can build on its findings and conclusions, and investment alternatives are tested to ensure reasonable returns on investment for public funds.

This report is very long and presents performance measurement findings, identifies bottlenecks that lead to less than optimal performance, and diagnoses the causes for these bottlenecks in detail. Once this report has been finalized, alternative investment strategies will be modeled and evaluated to understand their relative benefits and eventually develop a recommended implementation plan for existing and potential future funding.

This report and the associated CSMP should be updated on a regular basis since corridor performance can vary dramatically over time due to changes in demand patterns, economic conditions, and delivery of projects and strategies among others. Such changes could influence the conclusions of the CSMP and the relative priorities in investments.

Therefore, updates should probably occur no less than every two to three years. To the extent possible, this document has been organized to facilitate such updates so that Caltrans can insert new update sections without re-writing the entire document.

Note that this report only addresses the mixed flow lanes of SR-91 and does not address the HOT lanes which toll single occupancy vehicles and provide free access to high occupancy vehicles.

This remainder of this report is organized into four main sections as follows:

2. *Corridor Description*
   This section describes the corridor, including the roadway facility, major interchanges and relative demands at these interchanges, rail and transit services along the freeway facility, major Intermodal facilities around the corridor, and special event facilities/trip generators. This section has been expanded since the Preliminary Performance Assessment milestone. A subsection on corridor demand profiles has been added.

3. *Corridor-Wide Performance and Trends*
   This section presents multiple years of performance data for the defined CSMP freeway facility of the corridor, including mobility, reliability, safety, and productivity performance measures. This section has also been augmented by adding performance results through June, 2008 (i.e., mid-year) where possible. Finally, a new section presenting pavement conditions on the freeway was added.

4. *Bottleneck Identification*
   This section identifies the locations of bottlenecks or choke points on the freeway facility. These bottlenecks are generally the major cause for mobility and productivity performance degradations and are often related to safety degradations as well. This section has also been augmented. It now has performance results for delay, productivity, and safety by major “bottleneck area”. This addition allows for the relative prioritization of bottlenecks in terms of their contribution to corridor performance degradation.

5. *Causality Analysis*
   This section diagnoses the bottlenecks identified in Section 4 and identifies the causes of each bottleneck through additional data analysis and significant field observations. Electronic videos were taken for many of the major bottlenecks (to the extent possible) to verify our conclusions. Sections 4 and 5 provide valuable input to selecting projects to address the critical bottlenecks. Moreover, they provide the baseline against which micro simulation models will be validated. Finally, this section represents the seventh milestone of the aforementioned CSMP development process.

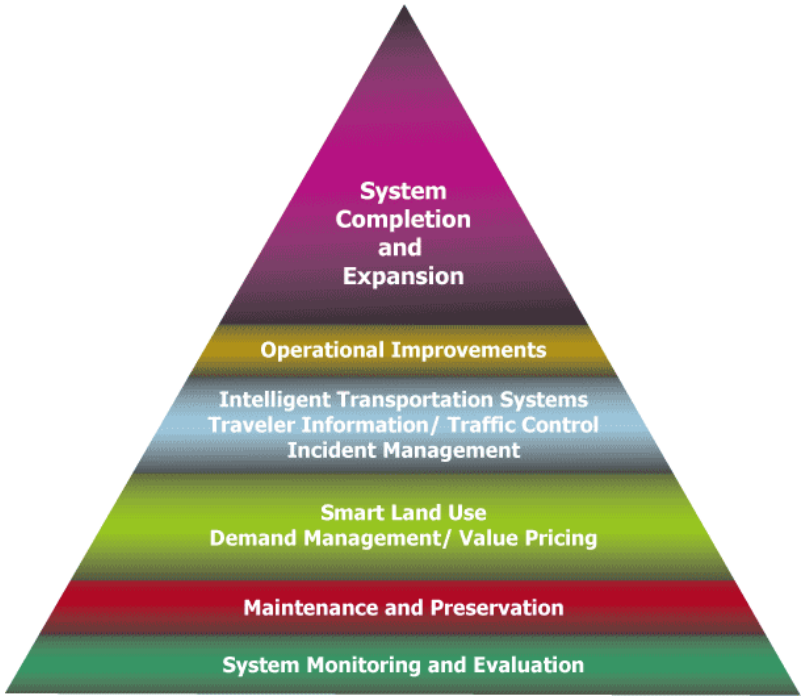
The remainder of this section provides some background on system management, a framework that eventually led to the CSMP requirement. It also includes a discussion on data sources and the state of detection on the SR-91 freeway facility.

Background

Over the last few years, Caltrans and its stakeholders and partner agencies have been developing and committing to a framework called "System Management" which is depicted in Exhibit 1-1. This framework aims to get the most of our transportation infrastructure through a variety of strategies, not just through the traditional and increasingly expensive expansion projects. System Management has been embraced by the Administration as part of their Strategic Growth Plan and by the Southern California Association of Governments (SCAG), the Metropolitan Planning Organization for Southern California, including Orange County.

One major new aspect of system management is an increased focus on operational strategies and investments. Operational solutions are generally less expensive, can often be implemented much faster, and can produce results that, when compared to traditional expansion projects, often provide much higher returns on the scarce transportation funding available. Partly because of the focus on operational strategies, System Management relies on much more detailed data. Therefore the base of the System Management "Pyramid" is titled "system monitoring and evaluation". It is the foundation of all other decisions, and it includes identifying problems, evaluating solutions (and combinations thereof), and eventually funding the most promising strategies. This document represents the first version of this foundation for the defined SR-91 corridor.

Exhibit 1-1: System Management Pyramid



Existing Data Sources

The existing available data analyzed for the preliminary performance assessment includes the following sources:

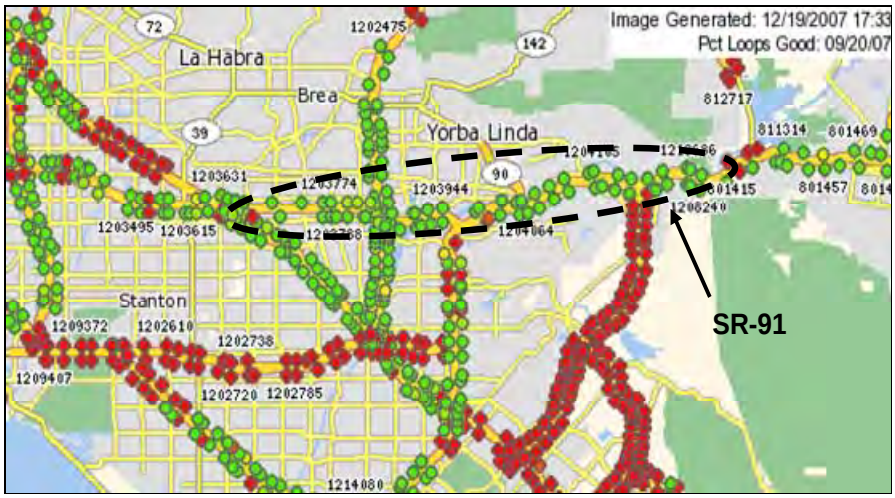
- Caltrans Highway Congestion Monitoring Program (HICOMP) report and data files (2004 – 2007)
- Caltrans Freeway Performance Measurement System (PeMS)
- Caltrans District 12 probe vehicle runs (electronic tachometer runs)
- Caltrans Traffic Accident Surveillance and Analysis System (TASAS) from PeMS
- Signal Timing Plans from the Cities of Anaheim, Fullerton, and Yorba Linda
- Traffic study reports (various)
- Aerial photographs (Google Earth) and Caltrans photologs
- Internet (i.e. OCTA website, Metrolink website, SCAG website, etc)

There are numerous documents that describe these data sources. Therefore, they are not discussed in this document in detail. However, given the need for comprehensive and continuous monitoring and evaluation, detection coverage and quality are discussed in more detail below.

Freeway Detection Status

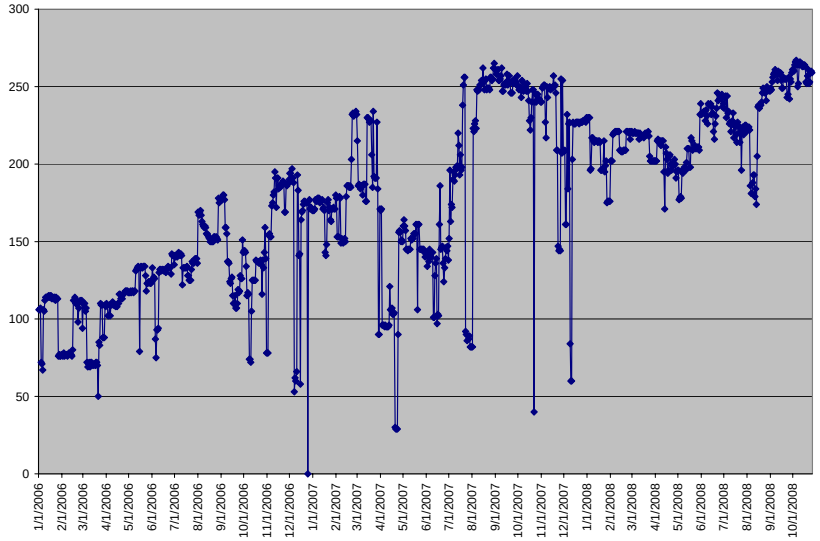
Exhibit 1-2 depicts the corridor freeway facility with the detectors in place as of September 20, 2007 (chosen randomly). The exhibit shows that there are many detectors on the mainline, almost all functioning well on that date (based on the green color). Furthermore, it illustrates some seemingly small gaps between detectors at some locations.

Exhibit 1-2: SR-91 Detection Status for September 20, 2007



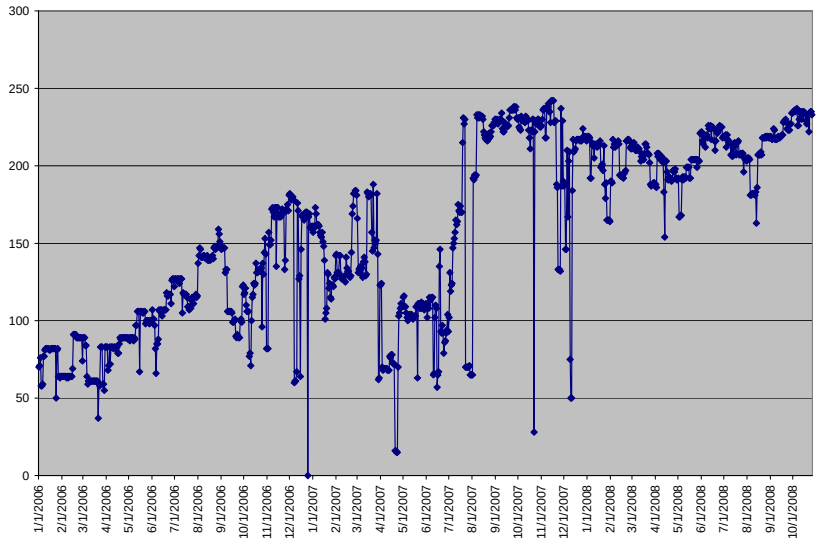
However, the previous exhibit does not show how well the detectors are performing over a longer period of time. Exhibits 1-3 and 1-4 show that trend for the eastbound and westbound directions respectively from January, 2006 to around mid-October, 2008. They do that by reporting total number of properly functioning detectors per day. These include mainline detectors as well as ramp detectors. As can be seen, October of 2008 shows the highest number of detectors reporting (around 250 in both directions).

Exhibit 1-3: Eastbound SR-91 Number of Daily Good Detectors



Source: System Metrics Group (using PeMS data)

Exhibit 1-4: Westbound SR-91 Number of Daily Good Detectors



Source: System Metrics Group (using PeMS data)

Part of this increase may be attributed to improved maintenance of existing detection. In addition, by comparing detectors in detail, we identified several detectors that were added in 2007. These are shown in Exhibit 1-5.

Exhibit 1-5: SR-91 Detection Added in 2007

VDS	Location	Type	CA PM	Abs PM	Date Online
EASTBOUND					
1203793	Acacia	ML	4.77	23.14	2/14/2007
1213986	Placentia	ML	5.5	23.87	2/14/2007
1214119	91E to 5S	Fwy-Fwy	R3.4	18.139	2/22/2007
1214124	91E to 5S HOV	Fwy-Fwy	R3.4	18.139	2/22/2007
1213988	Placentia (EB 91 to SR	Fwy-Fwy	5.5	23.873	2/14/2007
WESTBOUND					
1203799	Acacia	ML	4.77	23.18	2/14/2007
1213985	Placentia	ML	5.5	23.91	2/14/2007
1214120	5N TO 91W	Fwy-Fwy	R3.4	18.14	5/2/2008
1214123	5N TO 91W HOV	Fwy-Fwy	R3.4	18.14	2/22/2007
1213987	Placentia (SB 57 to WE	Fwy-Fwy	5.5	23.91	2/14/2007

Source: System Metrics Group (using PeMS data)

Finally, an analysis of gaps without detection is shown in Exhibit 1-6. Note that there are several segments with lengths over 0.75 miles with detection gaps. These should be considered for deployment of additional detection when funding becomes available.

Exhibit 1-6: SR-91 Gaps Without Detection

	Abs PM		
Location	From	To	Length
EASTBOUND			
Euclid to Lemon	20.77	22.28	1.51
Tustin to Lakeview 1	26.73	28.45	1.72
W of Scales to Weir Cnyn1	31.72	32.80	1.08
E of Gypsum to W of Coal	35.39	36.35	0.96
WESTBOUND			
Weir Cnyn1 to W of Scales	32.67	31.76	0.91
Lakeview1 to Tustin	28.36	26.77	1.59
Harbor 1 to Euclid	21.54	20.52	1.02
Euclid to Brookhurst	20.52	19.53	0.99

Source: System Metrics Group (using PeMS data)

NOTE: The next page is intentionally left blank so that Caltrans can insert updates to the detection analysis results presented in the last four exhibits (Exhibits 1-3 through 1-6) and discuss the ramifications of its findings (e.g., have the gaps been filled, is detector reliability improving or diminishing). Similar place holder pages have been inserted throughout the document to insert future updates.

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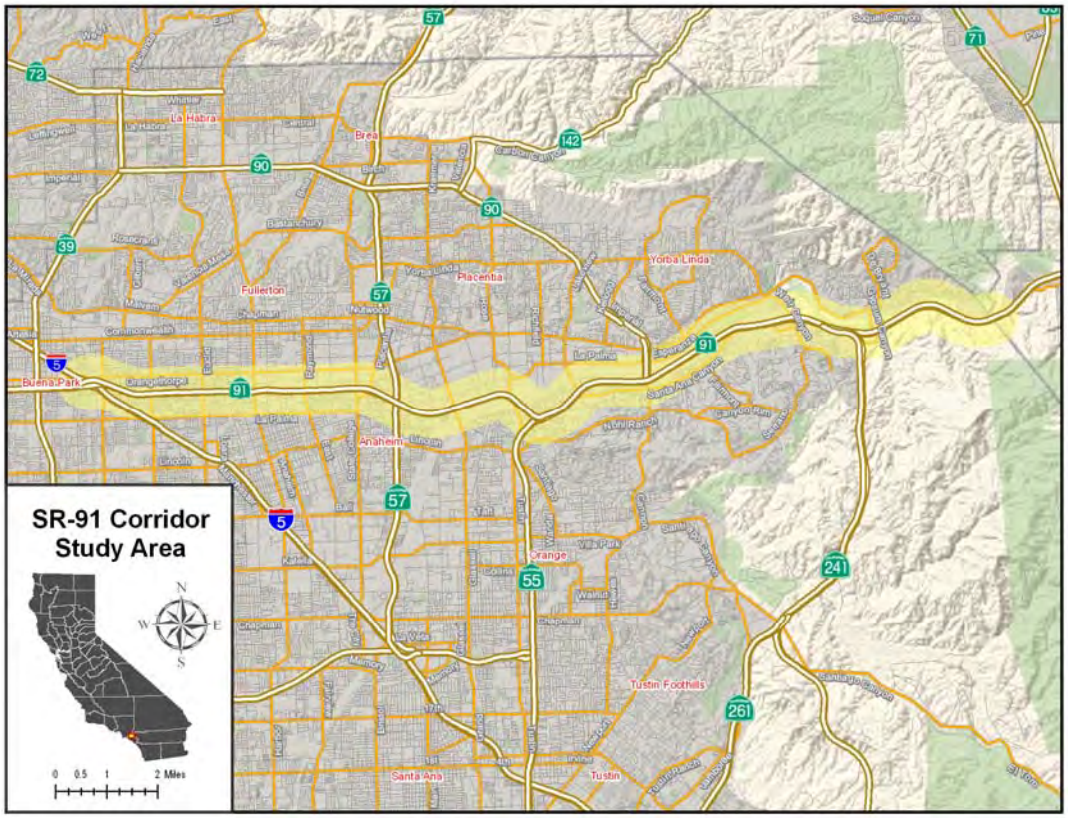
Detection Reliability and Coverage Updates

2. CORRIDOR DESCRIPTION

The Orange County SR-91 study corridor runs in an east-west direction from I-5 in Buena Park in the west to the Orange/Riverside County Line in the east. Named the Riverside Freeway, the freeway links the "Inland Empire" communities in Riverside and San Bernardino Counties to Orange County. The freeway corridor, as defined by Caltrans District 12, extends almost 19 miles from I-5 junction (Postmile R3.6) in Buena Park to the Riverside County Line (Postmile 18.9).

Exhibit 2-1: Map of Study Area



Corridor Roadway Facility

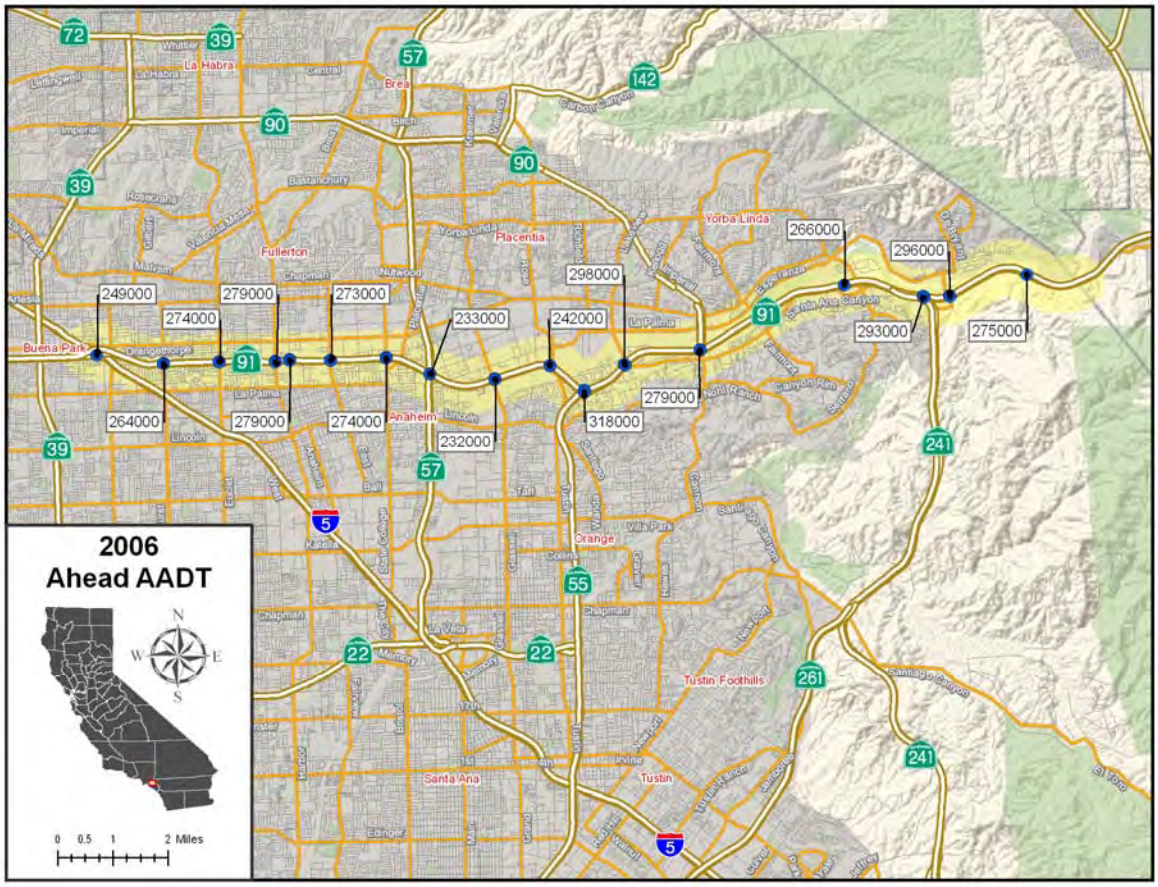
As shown in Exhibit 2-1, the SR-91 Corridor passes through Anaheim, Fullerton, Placentia, and Yorba Linda and includes four major freeway-to-freeway interchanges:

- I-5 is a north-south interstate highway serving all of California from Mexico to Oregon. Regionally it connects Orange County to Los Angeles in the north and San Diego in the south.

- SR-57 connects SR-22 in the City of Orange in the south to Diamond Bar and other communities in Los Angeles County as well as SR-60, I-10, and I-210 in the north.
- SR-55 provides access between SR-91 and Newport Beach also serving the Cities of Irvine, Tustin, Costa Mesa, Santa Ana, and Anaheim.
- SR-241 Eastern Transportation Corridor Toll Road provides access to southern Orange County and serves the communities of Irvine and Mission Viejo.

According to the Caltrans Traffic and Vehicle Data Systems annual traffic volumes reports for 2006, the SR-91 study corridor carries between 232,000 and 318,000 annual average daily traffic (AADT)[1] as shown in Exhibit 2-2. The highest average daily traffic volumes on the corridor occur between Imperial Highway (SR-90) and SR-55, and the lowest occur between SR-57 and SR-55.

Exhibit 2-2: Major Interchanges and AADT on the SR-91 CSMP Corridor



Source: AADT is from the Caltrans Traffic and Vehicle Data Systems Unit[2]

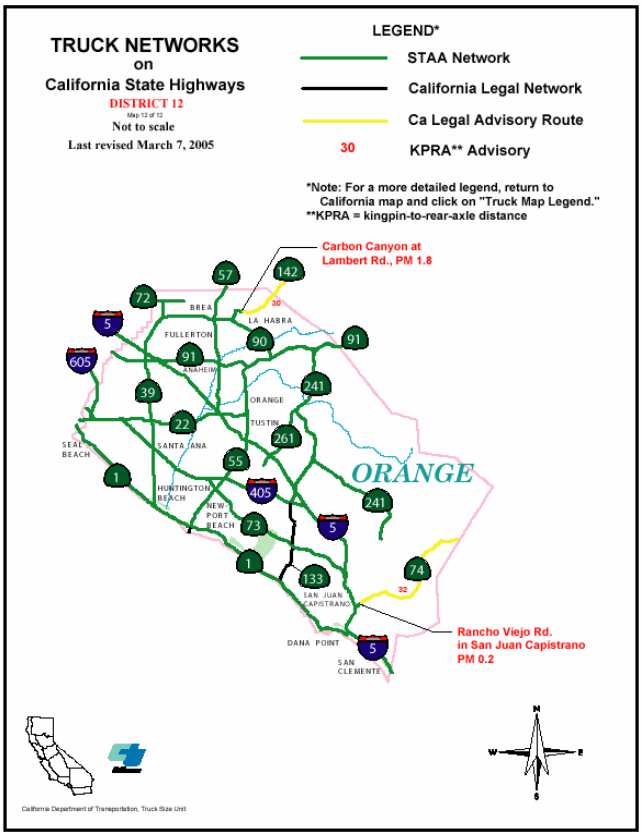
[1] AADT is the total annual volume of vehicles counted divided by 365 days.
[2] http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/

The SR-91 is a six to eight-lane freeway with a concrete barrier median for most of study corridor. There are auxiliary lanes along some sections of the corridor. HOV lanes are available in the western portion of the corridor between I-5 and SR-55. The lanes operate as a 2+ facility operating 24-hours.

A key feature of the SR-91 Corridor is the 91 Express Lanes – 10-mile toll facility in the inner two lanes between the SR-55 and the Riverside County Line. Opened in December of 1995, the 4-lane facility is the first privately financed toll road in the United States in more than 50 years, the world's first fully-automated toll facility, and the first application of value pricing in America. Tolls are paid from pre-paid accounts using a transponder.

As illustrated in Exhibit 2-3, the corridor is a Surface Transportation Assistance Act (STAA) route, so large trucks are allowed to operate on it. According to the latest validated truck volumes from the 2007 Caltrans Annual Average Daily Truck Traffic data published in September 2007, trucks comprise 4.5 to 9.2 percent of total daily traffic along the corridor. The heaviest truck volumes appear to occur around State College Boulevard.

Exhibit 2-3: Orange County Truck Network on California State Highways



Source: Caltrans

Page Intentionally Left Blank for Future Updates on Corridor Roadway Facility Statistics

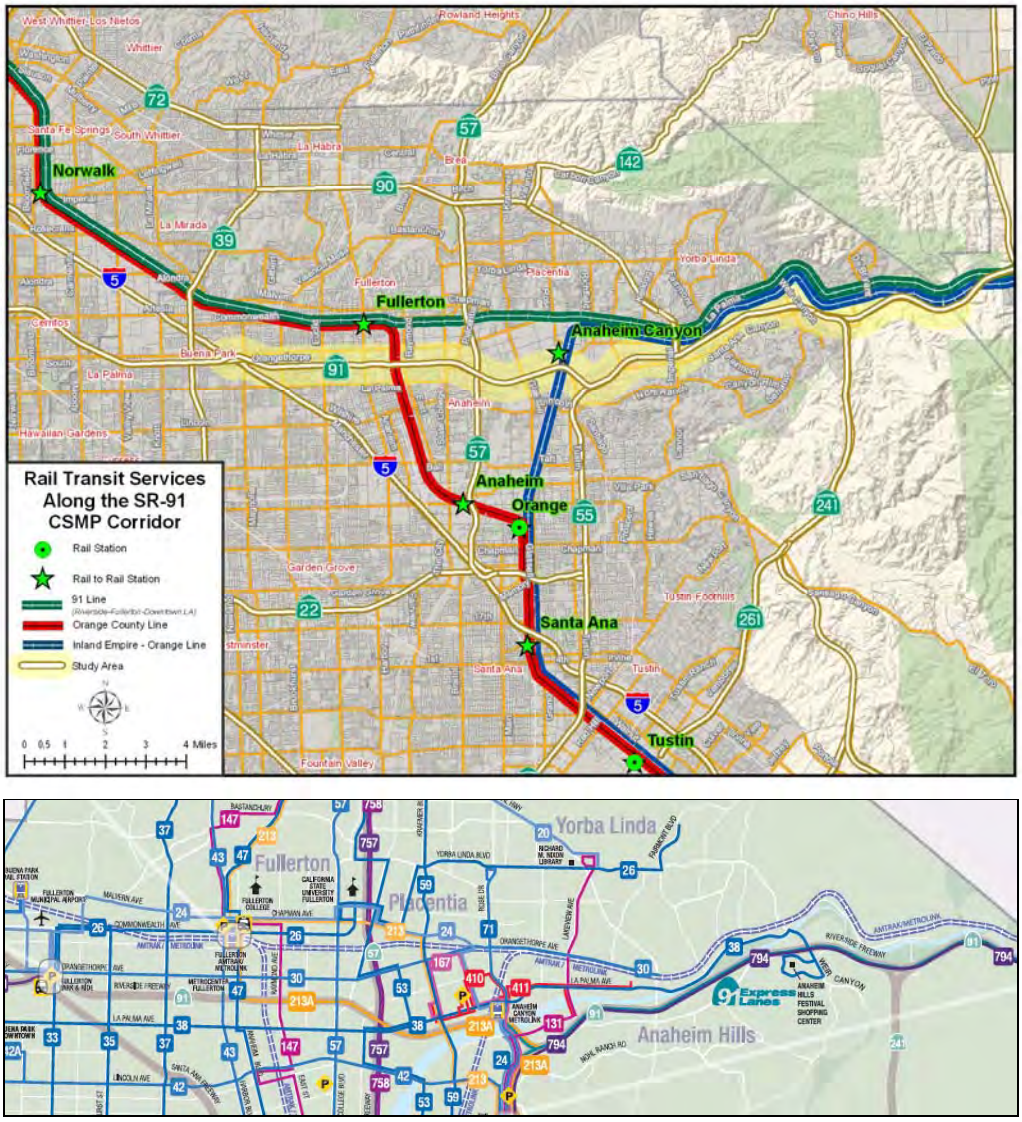
Corridor Transit Services

Three major public transportation operators provide service on or near the SR-91:

- Orange County Transportation Authority (OCTA)
- Riverside Transit Agency (RTA)
- Southern California Regional Rail Authority (SCCRA) - Metrolink

Exhibits 2-4 shows the rail and transit services being offered along the SR-91 Corridor.

Exhibit 2-4: Rail and Transit Services along the SR-91 Corridor



Source: OCTA

Orange County Transportation Authority (OCTA)

Established in 1991, OCTA provides fixed-route bus and paratransit services throughout Orange County. In addition to several local and express routes that run in the vicinity of the SR-91 Corridor as shown in Exhibit 2-3 above, the following routes operate on or directly adjacent to SR-91:

Route 794 operates on SR-91 and SR-71 and connects South Coast Plaza in Costa Mesa and Galleria at Tyler Mall in the City of Riverside. The route also serves the City of Corona in Riverside County.

Route 721 is an express route that connects the City of Fullerton to the City of Los Angeles from the Fullerton Park and Ride Lot at the western end of the SR-91 Corridor at near the I-5 interchange.

Route 213/213A links the City of Brea to the City of Irvine. Route 213A operates on SR-91 between Lemon St and SR-55 for one peak hour run during the day. This run travels between the Fullerton Transit Center and the University Research Park at the University of California, Irvine.

Route 30 is a local route that operates parallel to SR-91 between the Cities of Cerritos and Anaheim along Orangethorpe Avenue.

Route 38 is a local route that operates parallel to SR-91 between the Cities of Lakewood and Anaheim along Del Amo Boulevard and La Palma Avenue.

Riverside Transit Agency (RTA)

Established in 1975, RTA provides 38 fixed routes and paratransit services in western Riverside County. In provides transit services between communities in Riverside County and Orange County along SR-91.

Route 794 operated by OCTA provides service in Riverside County on SR-91 connecting Galleria at Tyler Mall in the City of Riverside and the City of Corona to Orange County. This route terminates at the South Coast Plaza/Costa Mesa area in Orange County.

Route 149 operated by RTA travels along SR-91 between the downtown terminal in Riverside to the Village at Orange in Anaheim. It provides both weekday and weekend service.

Southern California Regional Rail Authority (SCRRA) – Metrolink

SCCRA is a joint powers authority that operates the Metrolink regional rail service throughout Southern California. Metrolink commuter rail service stops at 11 stations in Orange County. A total of 44 round trips are provided every weekday on three lines:

- Inland Empire-Orange County Line: provides service from San Bernardino to Oceanside
- 91 Line: provides service Riverside to Los Angeles Union Station, via Fullerton and Buena Park
- Orange County Line: provides service from Los Angeles Union Station to Oceanside.

Inland Empire-Orange County Line connects the City of San Bernardino in San Bernardino County to the City of Oceanside in San Diego County. Along the SR-91 study corridor, it provides service to the Anaheim Canyon Metrolink Station located at 1039 N. Pacificenter Drive in Anaheim near the intersection of Tustin Avenue and La Palma Avenue (one-quarter mile north of SR-91). There are connecting services to local OCTA bus services including Route 38, which provides local service parallel to SR-91.

According to the latest ridership statistics provided by SCRRA, this line carries nearly 4,800 weekday passengers with most AM peak period boardings occurring in Riverside County with destinations in Orange County. Ridership between 2006 and 2007 has grown by two percent, according to SCRRA. Over 90 percent of all riders are commuters heading to and from work.

91 Line provides service parallel to the SR-91 Corridor connecting the City of Riverside to Union Station in downtown Los Angeles. Along the SR-91 study corridor, this line is accessed at the joint Amtrak/Metrolink station located at the Fullerton Transportation Center on 120 E. Santa Fe Avenue near North Harbor Boulevard just one-mile north of SR-91.

According to the latest ridership statistics provided by SCRRA, this line carries just over 2,300 weekday passengers with most AM peak period boardings occurring in Riverside County. However, a significant percentage of boardings occur in Fullerton near the SR-91 study corridor. This ridership has declined by 14 percent between 2006 and 2007, according to SCRRA. Over 85 percent of all riders are commuters heading to work.

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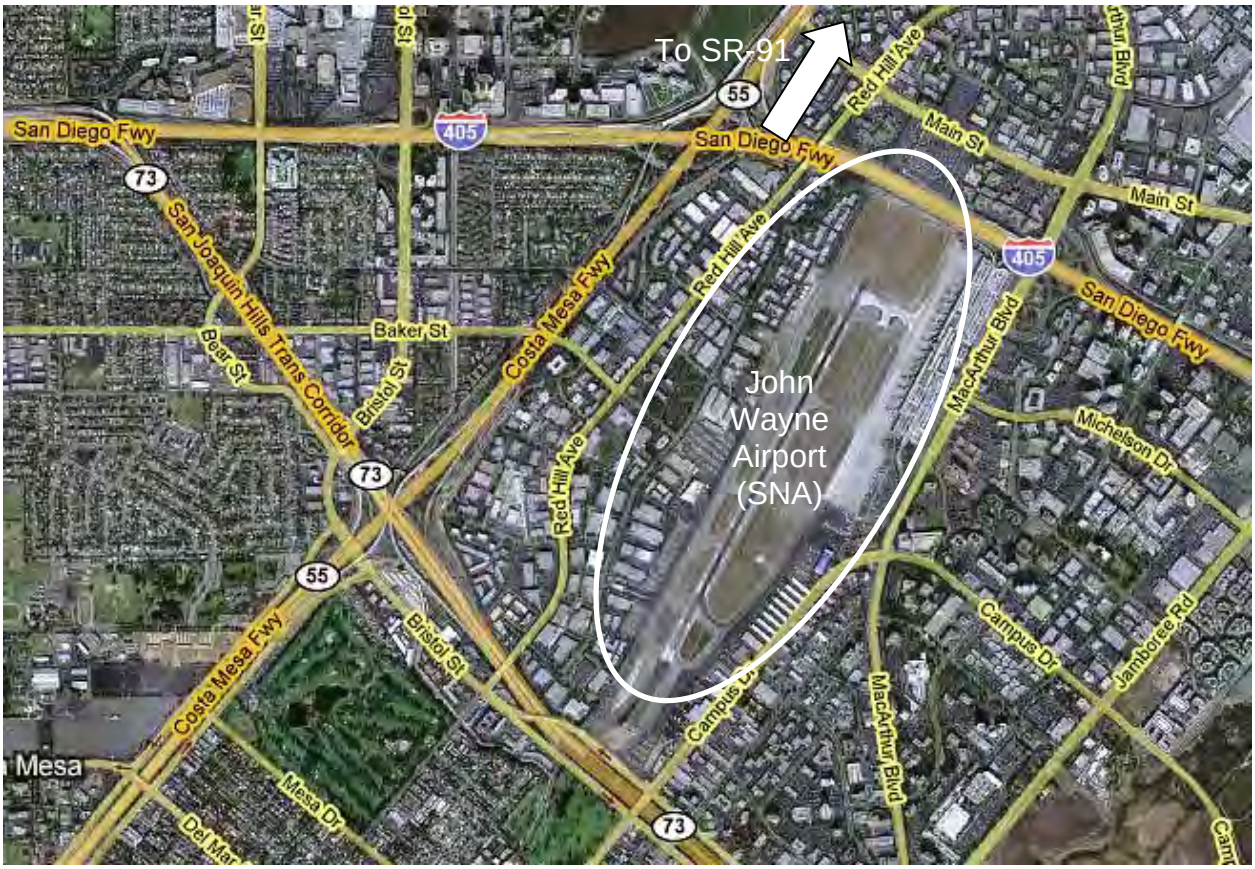
Intermodal Facilities

There are two airports in proximity of the SR-91 Corridor. The first is the Fullerton Municipal Airport, a small general aviation airport adjacent to the I-5 and SR-91 Corridors. In 2004-2005, Fullerton Airport had an average aircraft operation of 222 per day.

John Wayne Airport (SNA) is a larger airport that lies approximately 12 miles south of the SR-91 Corridor, and is linked directly to SR-91 by SR-55 as shown in Exhibit 2-5. SNA hosts air carrier, general aviation, air taxi, military, and air cargo services. Fourteen commercial and commuter air carriers serve SNA.

Exhibit 2-5: John Wayne Airport



As of 2006, SNA recorded the 42nd most enplanements in the United States and is ranked seventh in California just ahead of Ontario International Airport (ONT).[3] Over the six-year period between 2002 and 2007, the number of passenger boardings grew from just under four million annually to more than 4.9 million in 2007, although this growth has flattened over the past few years. The annual enplanement data is shown on Exhibit 2-6. Of course, recent economic challenges indicate that air travel around the country is likely to decline in 2008 and beyond.

In one month alone (September 2007), SNA recorded 782,896 total passengers, including 388,735 enplanements and 394,161deplanements. In the same month, the airport served 1,967 air cargo tons, of which 1838 tons were carried by all-cargo carriers. Both FedEx and UPS serve SNA.[4]

Exhibit 2-6: SNA Passenger Boarding Statistics

	2002	2003	2004	2005	2006	2007
Passenger Boardings	3,968,978	4,266,083	4,621,107	4,791,786	4,777,896	4,948,846
Difference		297,105	355,024	170,679	(13,890)	170,950
Percent Difference		7.5%	8.3%	3.7%	-0.3%	3.6%

Source: Federal Aviation Administration (FAA) Air Carrier Activity Information System (ACAIS).[5]

[3] "Passenger Boarding and All-Cargo Data." Federal Aviation Administration. May 2008. Air Carrier Activity Information System (ACAIS). <http://www.faa.gov/airports_airtraffic/airports/planning_capacity/passenger_allcargo_stats/passenger/>.
[4] Wedge, Jenny. "John Wayne Airport Posts September Statistics (Revised)." *John Wayne Airport News and Facts*. October 11, 2007. John Wayne Airport. 15 May 2008 <http://www.ocair.com/newsandfacts/newsreleases/2007/NR-2007-10-11.html>.
[5] "Passenger Boarding and All-Cargo Data." Federal Aviation Administration. May 2008. Air Carrier Activity Information System (ACAIS). <http://www.faa.gov/airports_airtraffic/airports/planning_capacity/passenger_allcargo_stats/passenger/>.

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Special Event Facilities/Trip Generators

Several major special event facilities may generate significant trips along the SR-91 Corridor. A number of the most significant ones are shown in Exhibit 2-7.

There are a number of special event facilities within several miles of the SR-91 Corridor. Three miles south of SR-91 on Harbor Blvd. is the Disneyland Resort and Theme Park, the second busiest amusement park in the world with an average daily attendance of nearly 40,000 patrons. The Disneyland Resort directly employs over 20,000 people, making it Orange County's largest employer and one of the largest single-site private employers in the state. Knott's Berry Farm is another amusement park situated close to the SR-91. It is located two miles south of the SR-91 on Beach Blvd. in the City of Buena Park, and it has an average daily attendance of approximately 9,500 patrons.

Three miles south of SR-91 on SR-57 at East Katella Avenue is the "Angels Stadium of Anaheim," home of the Los Angeles Angels' professional baseball team. At the same location, is the "Honda Center" arena, home to the professional hockey team, the Anaheim Ducks. Other events such as concerts, rodeos, basketball tournaments, and other major performances take place at the Honda Center. Angel Stadium seats over 45,000 fans, and the Honda Center can accommodate between 17,000 and 19,000 people depending on the event being held (sporting or ice skating event accommodates between 17,000 and 17,700 people while a concert can hold between 18,000 to 19,000).

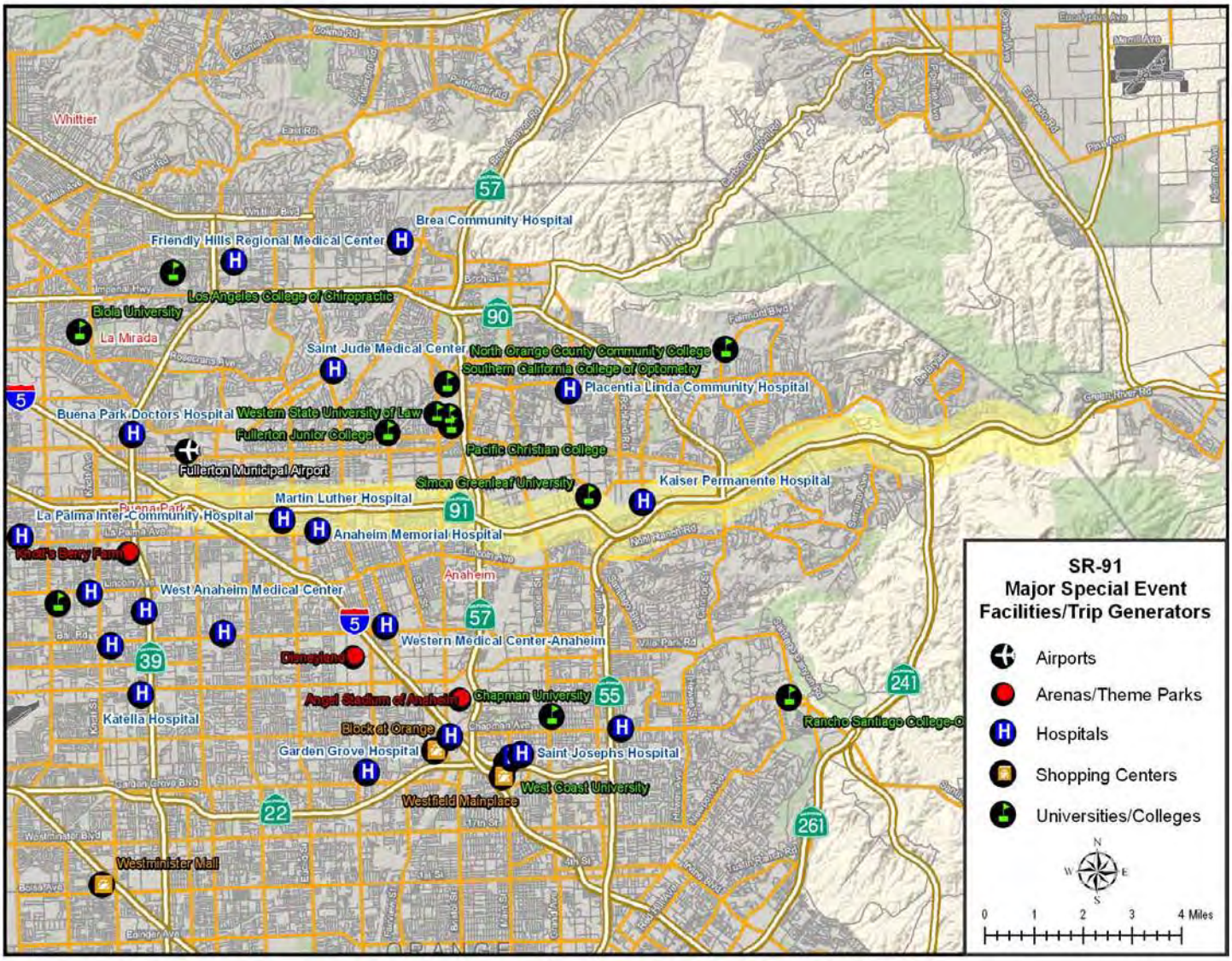
There are two major universities/colleges near the SR-91 Corridor and other post-secondary and trade schools nearby. California State University Fullerton is about 1.75 miles north of SR-91 on South State College Boulevard adjacent to SR-57 in the City of Fullerton. It is a four-year public university offering Bachelor and Masters Degree programs with an estimated enrollment just under 36,000 students.

Fullerton College is a two-year college on East Chapman Avenue at North Lemon Street less than ½ mile north of SR-91. It has nearly 20,000 students. In addition to these two educational facilities, there are a number of secondary, middle, and elementary schools within a few miles of the corridor.

There are also major medical facilities on the corridor. Kaiser Permanente maintains a hospital on West La Palma adjacent to the Anaheim Memorial Medical Center on West La Palma Avenue near North West Street (between North Euclid and South Harbor Streets) about one mile from the nearest SR-91 interchange.

There are several major shopping centers along freeways connecting with the SR-91 Corridor, but no major shopping malls are located directly adjacent to the SR-91 study corridor.

Exhibit 2-7: Major Special Event Facilities/Trip Generators



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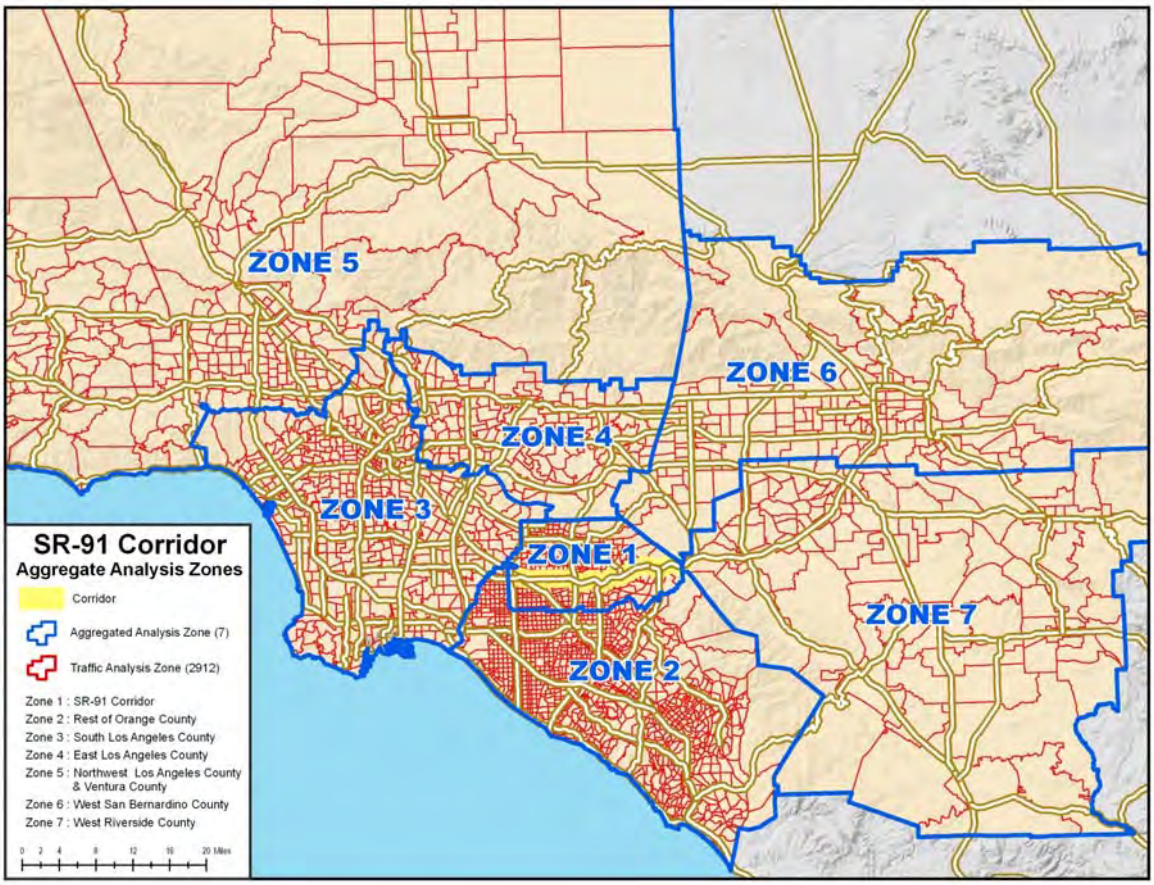
Demand Profiles

An analysis was conducted to analyze the origins and destinations using the freeway facility of the study SR-91 corridor. The analysis relies on OCTA's travel demand model. By selecting the corridor and conducting a "select link analysis", all origins and destinations using the corridor are identified. The origins and destinations are first identified by Traffic Analysis Zone (TAZ). The TAZs are then aggregated into seven aggregate analysis zones as shown in Exhibit 2-8 below.

Exhibit 2-8: Aggregate Analysis Zones for Demand Profile Analysis



Based on this aggregation, demand on the corridor is summarized by aggregated origin destination zone as shown in Exhibits 2-9 and 2-10 for the AM and PM peak periods respectively. This analysis shows that a significant percentage of trips using the SR-91 represent inter-county trips.

During the AM peak period, only a third of all trips originate <u>and</u> terminate in Orange County. The remaining trips either originate in Orange County and terminate in another

county (27 percent), or originate outside of Orange County and terminate in Orange County (32 percent), or originate and terminate outside of Orange County (8 percent).

During the PM peak period (which experiences around 20 percent heavier demand) the picture is similar. Only 32 percent of trips originate and terminate in Orange County. The remaining trips either originate in Orange County and terminate in another county (31 percent), or originate outside of Orange County and terminate in Orange County (28 percent), or originate and terminate outside of Orange County (9 percent).

Exhibit 2-9: AM Peak Origin Destination by Aggregated Analysis Zone

		Origin Aggregated Analysis Zone							
	AM Trips	SR91 Corridor	Rest of Orange County	South Los Angeles	East Los Angeles	NW Los Angeles & Ventura	West San Bernardino	West Riverside	Outside Zones
Destination Aggregated Analysis Zone	SR91 Corridor	8,743	20,846	9,870	1,832	1,231	2,419	1,356	286
	Rest of Orange County	33,459	10,379	35,067	3,375	3,287	5,531	7,382	108
	South Los Angeles	9,700	24,132	5,955	545	1,210	790	1,279	431
	East Los Angeles	2,375	4,026	820	1	139	0	182	91
	NW Los Angeles & Ventura	1,259	2,785	1,317	185	610	276	265	54
	West San Bernardino	2,543	6,207	965	1	183	1	254	111
	West Riverside	1,550	4,805	1,338	140	278	209	295	88
	Outside Zones	154	48	157	26	35	32	32	1

	Trips Originating and Ending in Orange County
	Trips Originating in Orange County and Destined to Other Counties
	Trips Originating Outside of Orange County and Destined to Orange County
	Trips Originating and Ending Outside of Orange County

Exhibit 2-10: PM Peak Origin Destination by Aggregated Analysis Zone

		Origin Aggregated Analysis Zone							
	PM Trips	SR91 Corridor	Rest of Orange County	South Los Angeles	East Los Angeles	NW Los Angeles & Ventura	West San Bernardino	West Riverside	Outside Zones
Destination Aggregated Analysis Zone	SR91 Corridor	11,565	38,093	12,707	2,937	2,187	3,273	1,877	204
	Rest of Orange County	31,059	14,363	34,264	5,266	6,424	8,300	6,994	82
	South Los Angeles	13,515	42,406	8,233	1,078	2,442	1,246	1,783	270
	East Los Angeles	2,683	4,491	832	0	469	2	222	46
	NW Los Angeles & Ventura	2,128	5,852	2,303	477	1,563	569	516	59
	West San Bernardino	3,445	7,164	1,133	1	585	3	316	59
	West Riverside	1,817	9,377	1,767	263	515	328	364	69
	Outside Zones	370	136	518	102	102	140	116	2

	Trips Originating and Ending in Orange County
	Trips Originating in Orange County and Destined to Other Counties
	Trips Originating Outside of Orange County and Destined to Orange County
	Trips Originating and Ending Outside of Orange County

Clearly, the SR-91 serves a regional, inter-county purpose with more than 65 percent of the trips it serves either starting or ending outside of Orange County.

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3. CORRIDORWIDE PERFORMANCE AND TRENDS

This section summarizes the analysis results of the performance measures used to evaluate the existing conditions of the SR-91 Corridor. The primary objectives of the measures are to provide a sound technical basis for describing traffic performance on the corridor.

The performance measures focus on four key areas:

- **Mobility** describes how well the corridor moves people and freight
- **Reliability** captures the relative predictability of the public's travel time
- **Safety** captures the safety characteristics in the corridor such as collisions
- **Productivity** describes the productivity loss due to inefficiencies in the corridor

MOBILITY

Mobility describes how well the corridor moves people and freight.
The mobility performance measures are both readily measurable and straightforward for documenting current conditions. They can also be forecasted, making them useful for future comparisons.. Two primary measures are typically used to quantify mobility: delay and travel time.

Delay

Delay is defined as the total observed travel time less the travel time under non-congested conditions, and is reported as vehicle-hours of delay. Delay can be computed for severe congested conditions using the following formula:

$$(\text{Vehicles Affected per Hour}) \times (Dis\tan ce) \times (Duration) \times \left[\frac{1}{(\text{Congested Speed})} - \frac{1}{35\text{mph}} \right]$$

In the formula above, the *Vehicles Affected per Hour* value depends on the methodology used. Some methods assume a fixed flow rate (e.g., 2,000 vehicles per hour per lane), while others use a measured or estimated flow rate. The distance is the length under which the congested speed prevails and the duration is the hours of congestion experience below the threshold speed.

However, all delays can be computed by replacing the "35 mph" with "60 mph" in the previous formula. Different reports and studies use one of the two versions of this formula. The HICOMP report discussed next uses the 35 mph formula and assumes 2,000 vehicles per hour per lane are experiencing the delay. HICOMP therefore reports on only severe delay, while the PeMS results shown after use the 60 mph formula and uses the actual number of vehicles reported by the detection systems and therefore

represents overall delay. The results of these two sources are difficult to compare due to the methodological differences. Each is therefore discussed separately.

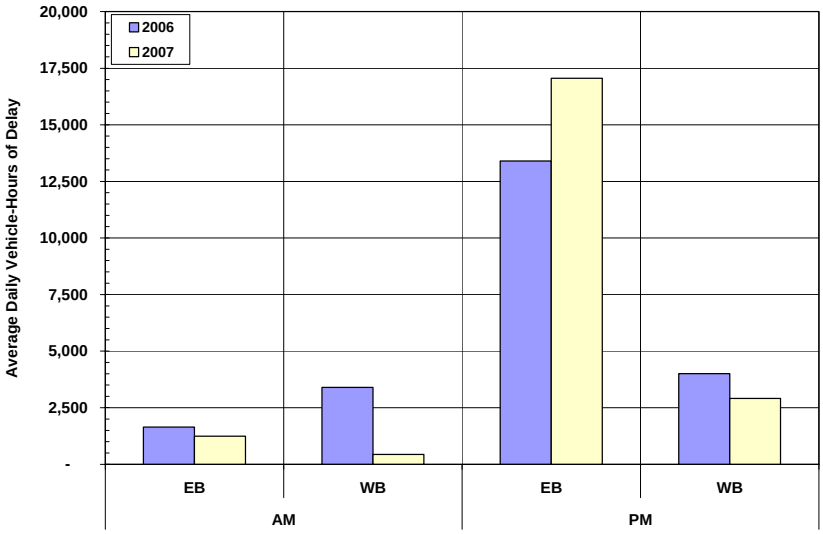
Caltrans HICOMP

The HICOMP report has been published annually by Caltrans since 1987[6]. Delay is presented as average daily vehicle-hours of delay (DVHD). The HICOMP defines delay as travel time in excess of free flow travel time when speeds dip below 35 mph for 15 minutes or longer.

For the HICOMP report, probe vehicle runs are performed at most only two to four days during the entire year (ideally, two days of data collection in the spring and two in the fall of the year, but resource constraints may affect the number of runs performed during a given year.). As will be discussed later in this section when discussing the PeMS data, congestion levels vary from day to day and depend on any number of factors including accidents, weather, special events, the price of gasoline, and construction activities.

Exhibit 3-1 shows the annual delay for the years 2006 and 2007 during both the AM and PM peak travel period for both directions along the study corridor. As illustrated in Exhibit 3-1, the most significant congestion occurred during the PM peak period in the eastbound direction for both years. In the eastbound direction during the PM peak period, the exhibit shows an increase in congestion from 2006 to 2007 by 27 percent. Congestion in the westbound direction during the PM peak period declined from 2006 to 2007 also by 27 percent. For the AM peak period, the exhibit shows that the year 2006 experienced the most congestion in both directions.

Exhibit 3-1: Average Daily Vehicle-Hours of Delay in 2006-2007



[6] Located at: http://www.dot.ca.gov/hq/traffops/sysmgtpl/HICOMP/index.htm

Exhibit 3-2 shows the complete list of congested segments reported by the HICOMP report for the corridor. "Generalized" congested segments are presented so that segment comparisons can be made from one year to the next since a given congested segment may vary in distance or size from one year to the next as well as from day-to-day. However, it is important to reiterate that these trends are affected by the quality of the data available.

Exhibit 3-2: HICOMP Congested Segments

Period	Dir	Generalized Congested Area	Average Vehicle-Hours of Delay	
			2006	2007
AM	EB	LA County Line to Brookhurst St		
		LA County Line to 0.5 miles e/o Harbor Bl		1,241
		LA County Line to SR-57	1,585	
		Magnolia Av to Brookhurst St		
		Magnolia Ave to State College Bl	56	
		Euclid Av		
		East St/Raymond Av to Acacia St		
		East of SR-57 to Kraemer Bl/Glassell St		
		Tustin Av		
		SR-241 to west of Green River Rd		
	WB	Riverside County Line to 0.2 miles w/o Riverside County Line		
		Riverside County Line to Coal Canyon Rd		
		West of Riverside County Line to Green River Rd	3	
		Imperial Hwy (SR-90) to east of Lakeview Av		
		Imperial Hwy (SR-90) to Magnolia Ave	3,121	
		SR-55 to Raymond Av		310
		Kraemer Bl/Glassell St to LA County Line	272	
		Kraemer Bl/Glassell St to State College Bl		
		Acacia St to East St/Raymond Av		
		0.5 miles e/o Harbor Bl to Knott Ave		125
		Harbor Bl to Euclid Av		
		.	5,037	1,676
PM	EB	LA County Line to Brookhurst St		303
		Magnolia Av to Brookhurst St		
		Brookhurst St		
		Euclid Av		
		Harbor Bl to Kraemer Bl/Glassell St	462	
		East St/Raymond Av to Acacia St		
		Raymond Ave to 0.5 miles east of Lakeview Ave		577
		State College Bl to Tustin Av		
		SR-57 to Tustin Ave	103	
		Imperial Hwy (SR-90) to Riverside County Line	12,833	16,170
	WB	Riverside County Line to SR-241		
		West of SR-241 to west of Weir Canyon Rd		
		Lakeview Av		
		SR-55 to Raymond Av		1,778
		Riverdale Ave to Magnolia Ave	3,693	
		Kraemer Bl/Glassell St to LA County Line	313	
		Frontage Rd to Euclid Av		
		Harbor Blvd to LA County Line		1,132
PM PEAK PERIOD SUMMARY			17,405	19,960
TOTAL CORRIDOR CONGESTION			22,442	21,636

Exhibits 3-3 and 3-4 are maps showing the information from Exhibit 3-2 for the year 2007 during the two peak commute periods, respectively. The approximate locations of the congested segments, the duration of that congestion, and the reported recurrent daily delay are also shown on the maps.

Exhibit 3-3: AM Peak Period HICOMP Congested Segments Map 2007

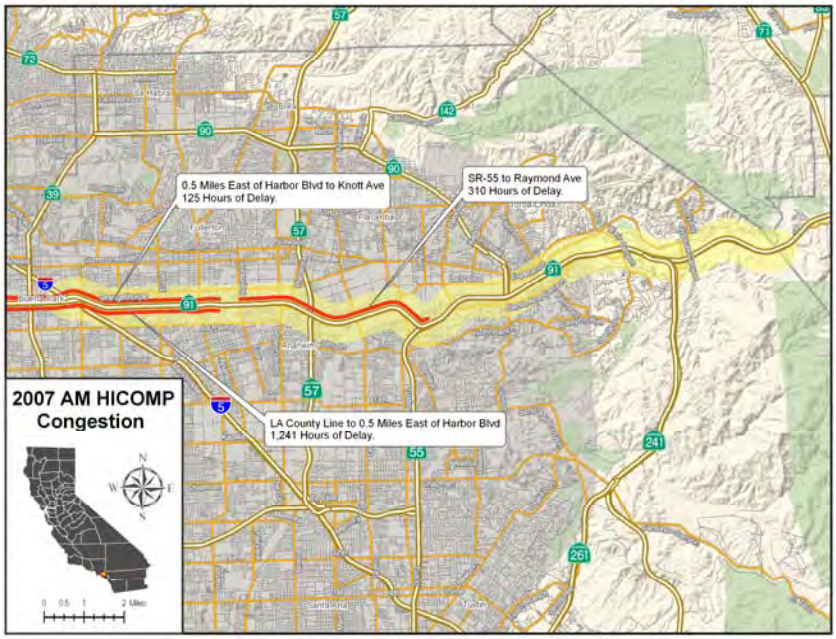
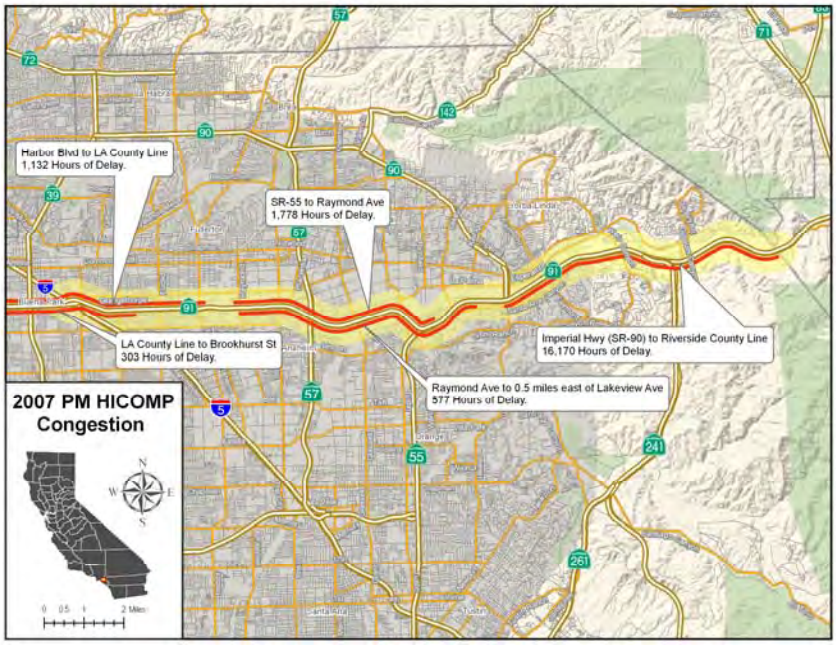


Exhibit 3-4: PM Peak Period HICOMP Congested Segments Map 2007



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Freeway Performance Measurement System (PeMS)

Using freeway detector data discussed in Section 1 and accessed via PeMS, delay is computed for every day and summarized in different ways, which is not possible when using probe vehicle data.

Initially, performance assessments were conducted during the three-year period between 2003 and 2005. Updates were recently conducted trough June, 2008. Unlike HICOMP where delay is only considered and captured for speeds below 35 miles per hour and applied to an assumed output or capacity volume of 2,000 vehicles per hour, delays presented hereon using PeMS represent the difference in travel time between actual conditions and free flow conditions at 60 miles per hour, applied to the actual output flow volume collected from a vehicle detector station. The total delay by time period for the SR-91 for each direction is shown in Exhibits 3-5 to 3-8. However, note that results prior to mid 2007 represent data from a smaller number of detectors and therefore are likely less accurate.

Total delay along the study corridor was computed for four time periods: AM peak (6:00 AM to 9:00 AM), Midday (9:00 AM to 3:00 PM), PM peak (3:00 PM to 7:00 PM), and evening/early AM (7:00 PM to 6:00 AM).

Exhibits 3-5 and 3-6 show overall weekday delay for the corridor (i.e., excluding weekends and holidays) during the three-year period between 2003 and 2005 in the eastbound and westbound directions, respectively. There is a 90-day moving average to “smooth” out the day-to-day variations and better illustrate the seasonal and annual changes in congestion over time.

Exhibits 3-7 and 3-8 also illustrate the overall weekday delay for the eastbound and westbound directions, but during the two and a half-year period between January 2006 and June 2008.

As shown in these exhibits, delay is highest during the PM peak periods for both the eastbound and westbound directions, similar to the congestion trend shown in the HICOMP report. These exhibits further indicated that the eastbound daily delay ranged from about 4,000 to 6,000 vehicle-hours from 2003 to spring of 2005, then surged to 8,000 to 10,000 vehicle-hours from summer 2005 to 2008. This is likely due to a combination of factors, including economic growth and improved detection reliability.

In the westbound direction, daily delay was about 4,000 vehicle-hours from 2003 to spring of 2005, then dropped to 2,000 vehicle-hours from summer 2005 to summer 2006 before surging to over 6,000 vehicle hours in late 2006 through 2008. Again, the same factors (i.e., economic growth and improved detection reliability) are likely reasons for this increase.

Exhibit 3-5: Eastbound SR-91 Average Daily Delay by Time Period 2003-2005

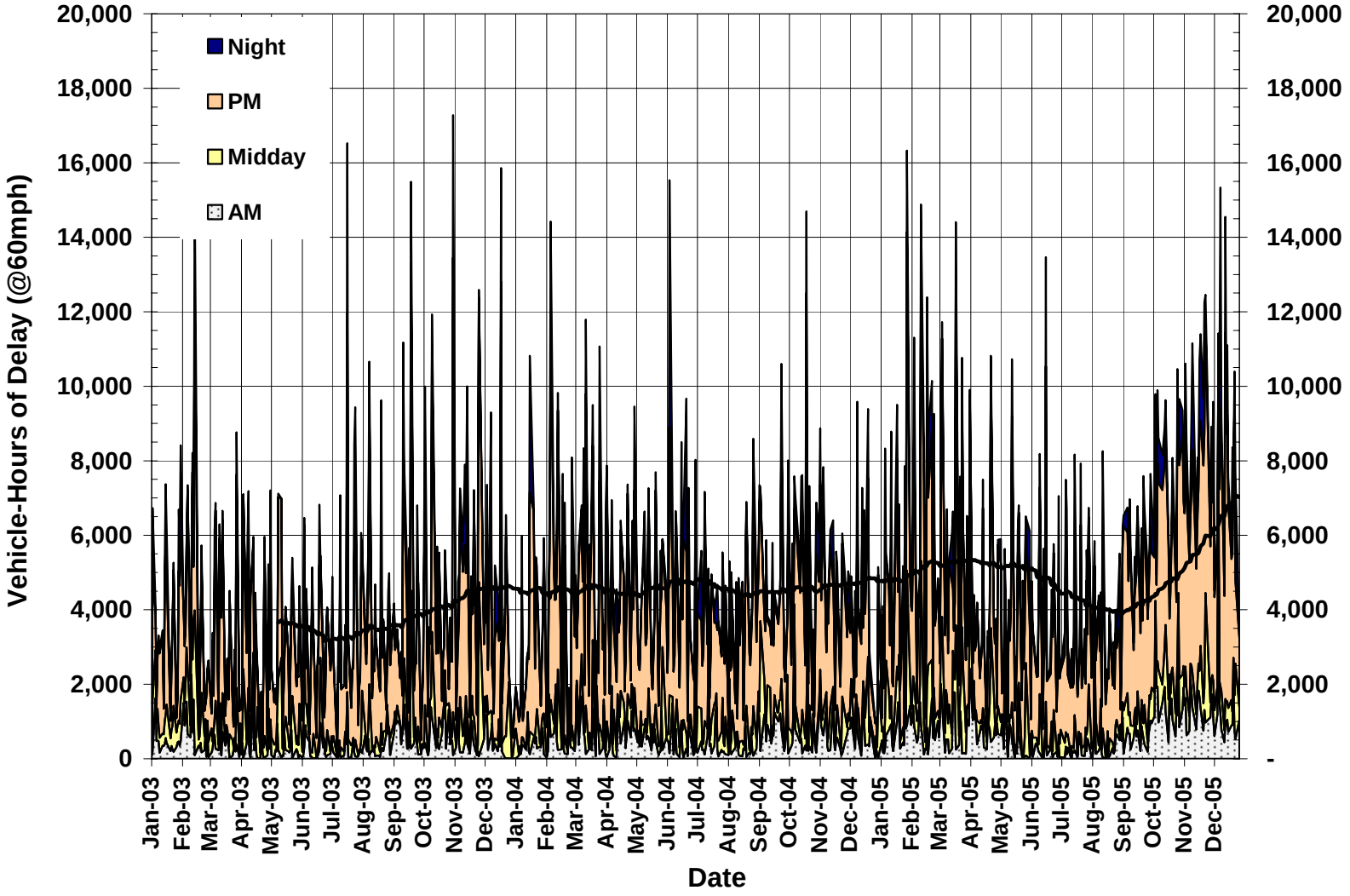


Exhibit 3-6: Westbound SR-91 Average Daily Delay by Time Period 2003-2005

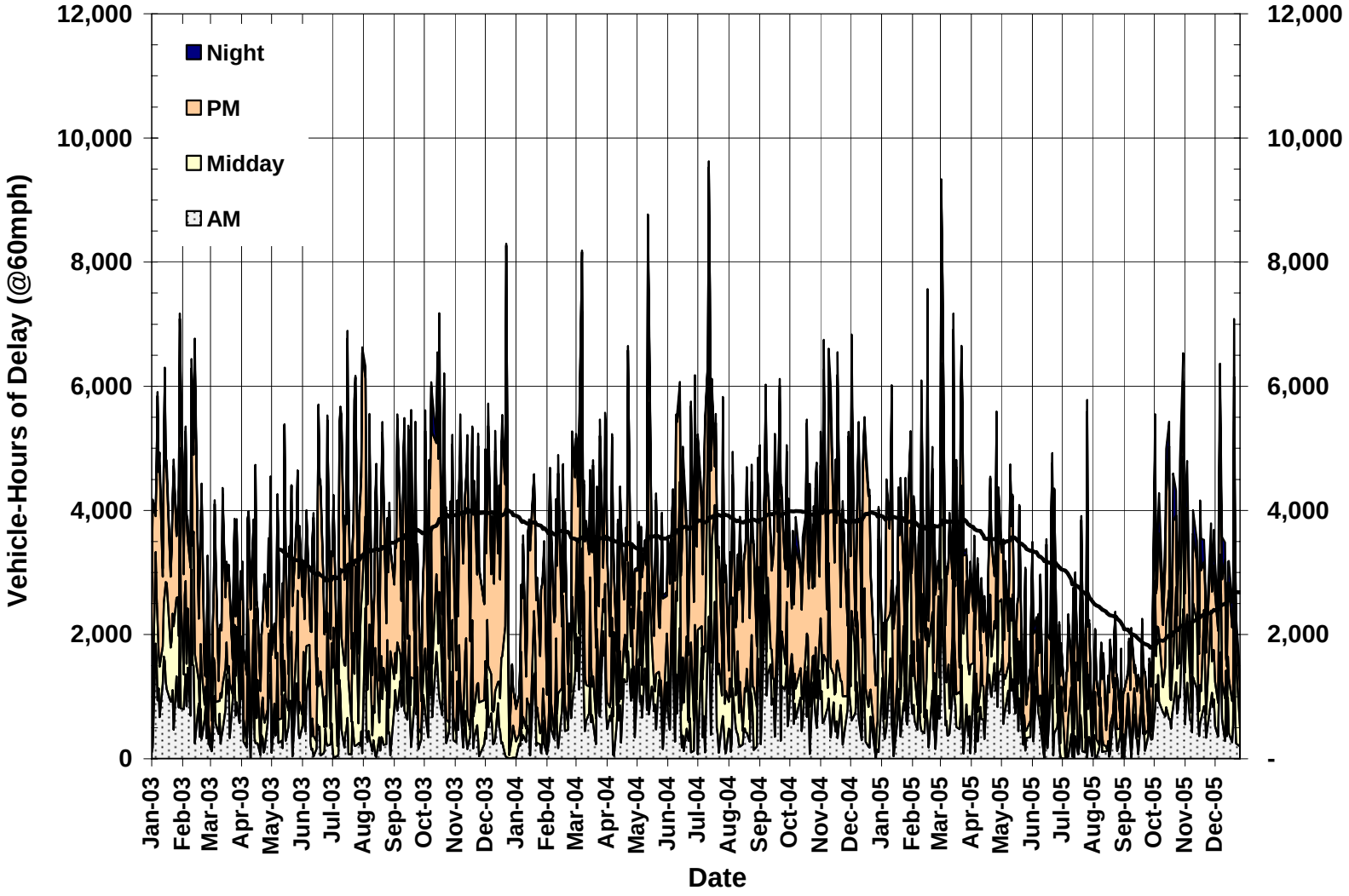


Exhibit 3-7: Eastbound SR-91 Average Daily Delay by Time Period 2006-2008

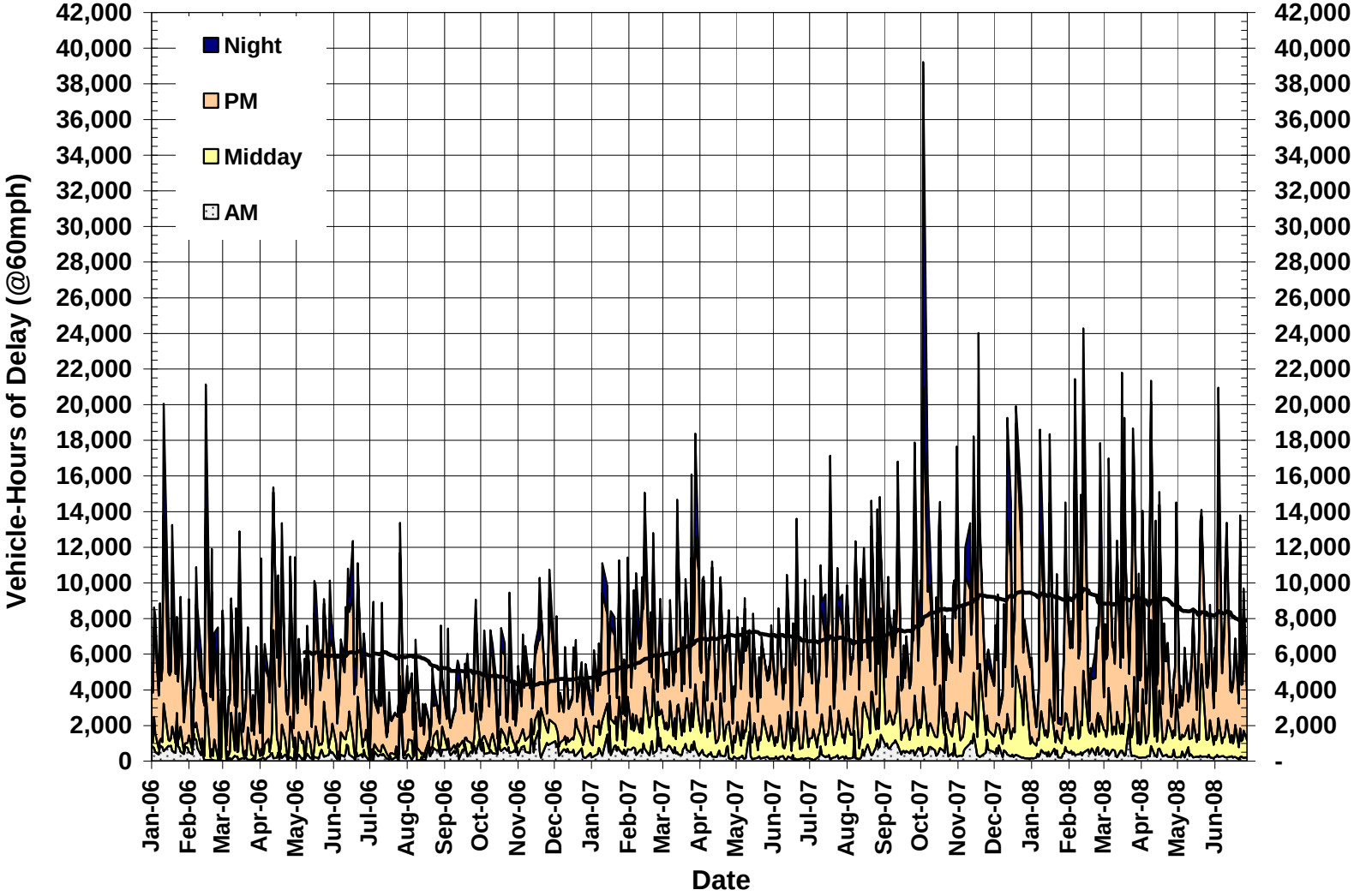
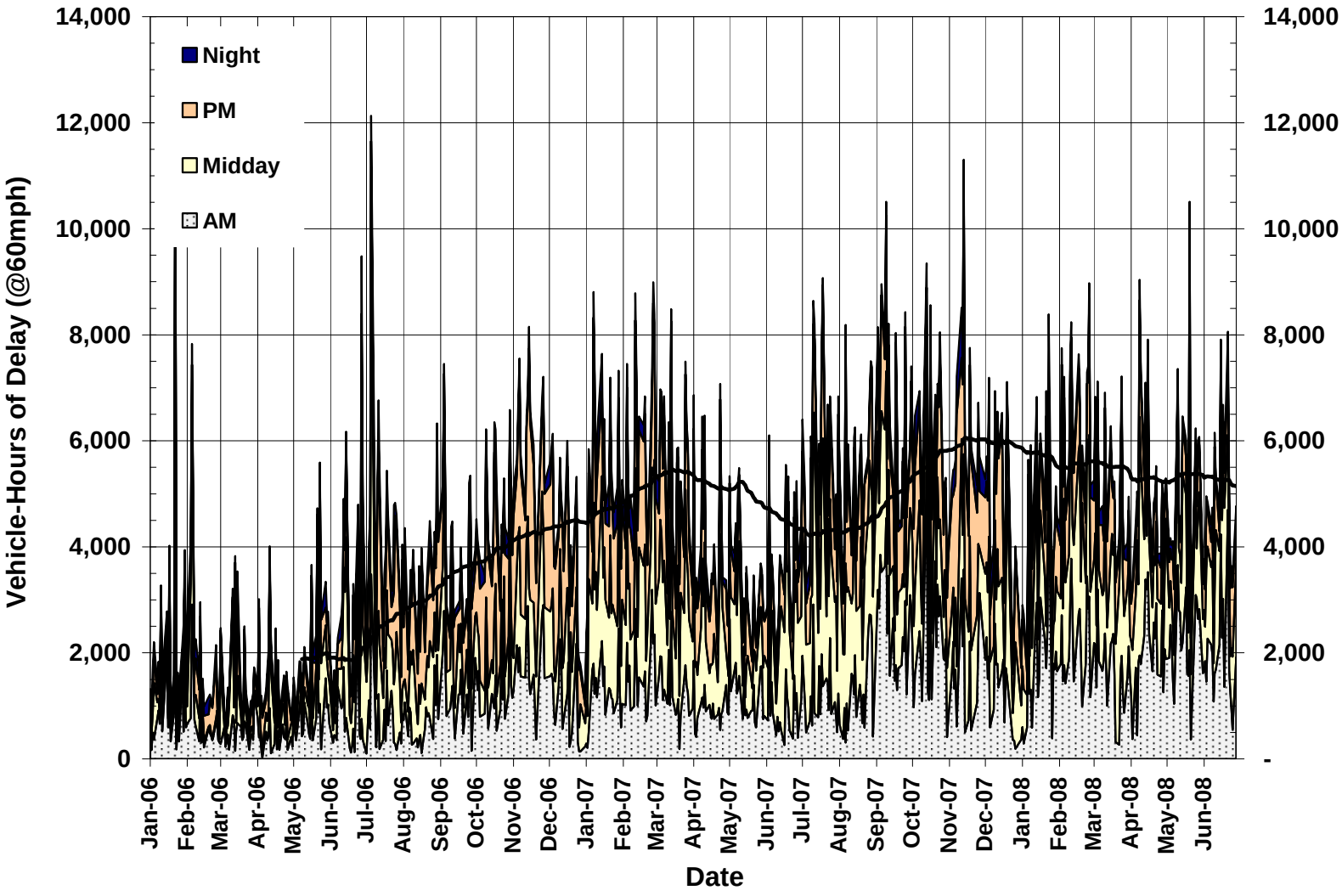


Exhibit 3-8: Westbound SR-91 Average Daily Delay by Time Period 2006-2008



The next set of exhibits provides additional information on delay characteristics and trends. Exhibits 3-9 and 3-10 show the average daily weekday delay by month for the eastbound and westbound directions along the corridor.

Exhibit 3-9: SR-91 Average Weekday Delay by Month 2003-2005

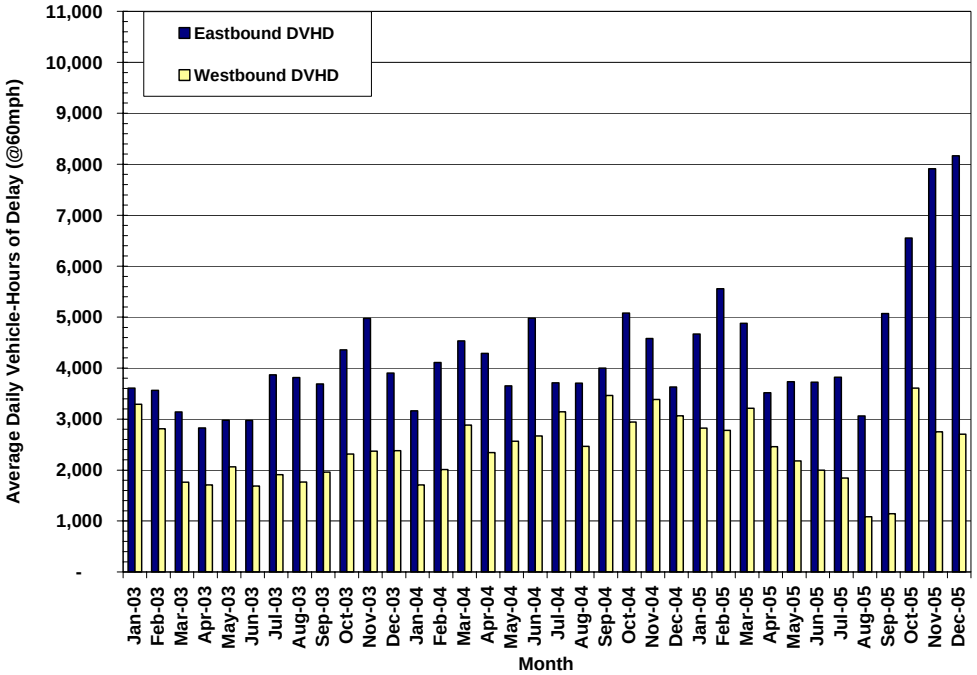
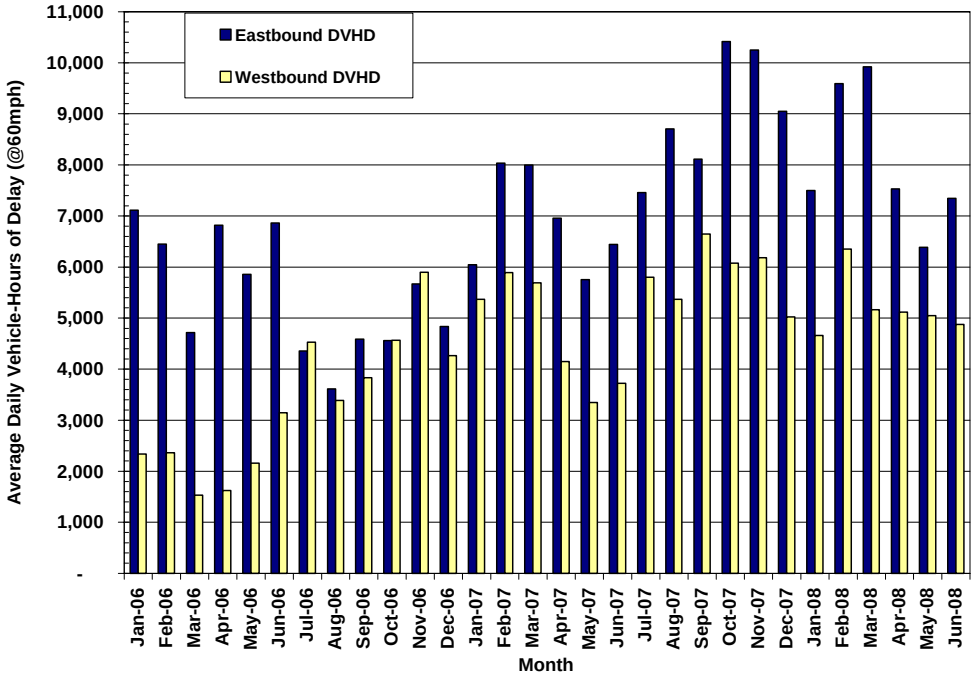


Exhibit 3-10: SR-91 Average Weekday Delay by Month 2006-2008



From the summer of 2005 through 2008, the eastbound delays significantly exceeded those of the westbound, whereas they were relatively equal from 2003 to 2005.

Delays presented to this point represent the difference in travel time between actual conditions and free flow conditions at 60 miles per hour. This delay can be segmented into two components as shown in Exhibits 3-11 and 3-12:

- Severe delay – delay that occurs when speeds are below 35 miles per hour; and
- Other delay – delay that occurs when speeds are between 35 miles per hour and 60 miles per hour.

In Exhibits 3-11 and 3-12, severe delay represents breakdown conditions and is generally the focus of congestion mitigation strategies. "Other" delay represents conditions approaching the breakdown congestion, leaving the breakdown conditions, or areas that do not cause widespread breakdowns, but cause at least temporary slowdowns. Although combating congestion requires the focus on severe congestion, it is important to review "other" congestion and understand its trends. This could allow for proactive intervention before the "other" congestion turns into severe congestion.

Exhibit 3-11: SR-91 Average Delay by Day of Week by Severity 2003-2005

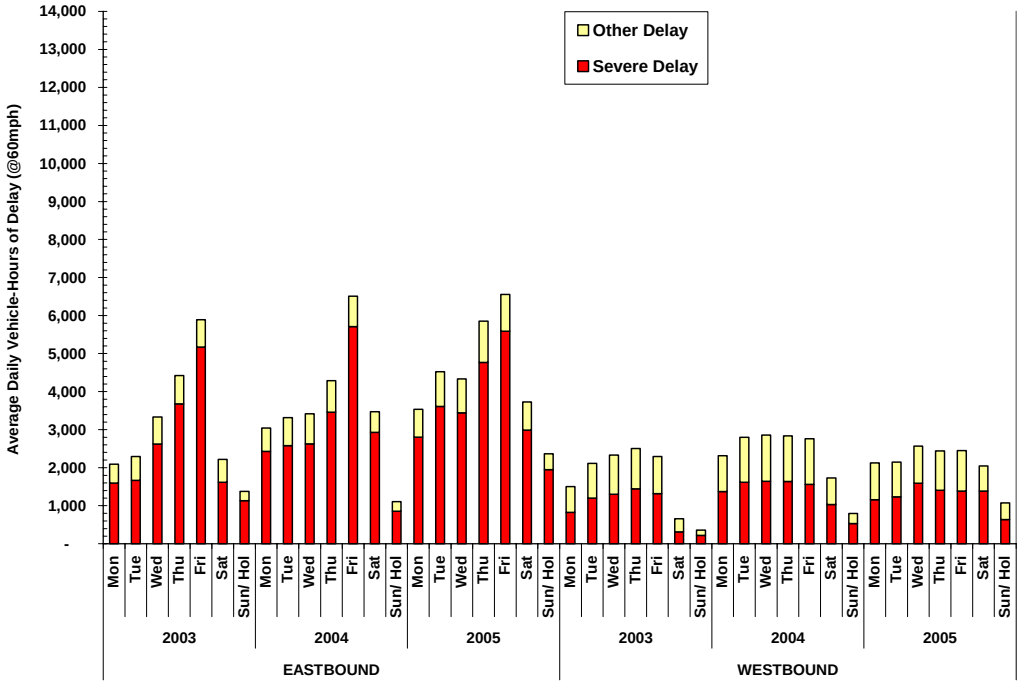
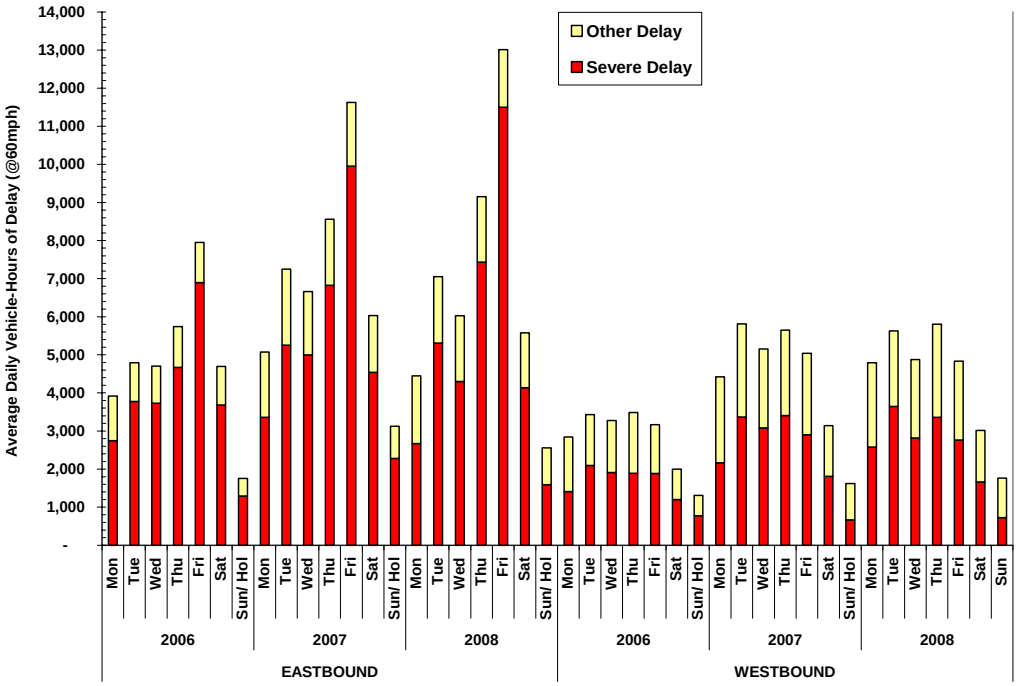


Exhibit 3-12: SR-91 Average Delay by Day of Week by Severity 2006-2008



Another way to understand the characteristics of congestion and related delays is shown in Exhibits 3-13 and 3-14, which summarize average weekday hourly delay for the 2003 to 2005 three-year period, and Exhibits 3-15 and 3-16, which summarize average weekday hourly delay for the 2006 to 2008 two and a half year-period.

The exhibits reflecting later years from 2006 onwards lead to a number of observations:

- Delay continued to increase through June, 2008.
- The peak period for delay is between 3 and 6 pm, and from 6 to 9 am.
- The peak period duration is not expanding significantly during the afternoon peak period. However, the overall congestion during the time is increasing.
- The peak period duration is expanding during the morning in the westbound direction, starting at almost 5 am and remaining congested through 10 am.
- Mid-day delays are still modest at around 200 vehicle hours of delay in both directions.

Exhibit 3-13: Eastbound SR-91 Average Weekday Hourly Delay 2003-2005

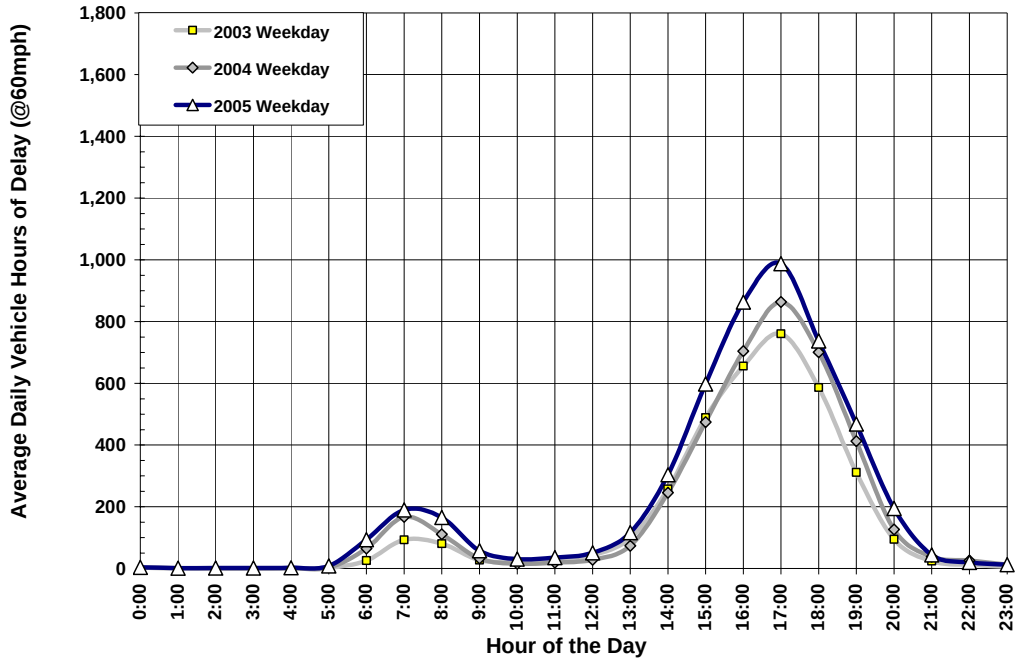


Exhibit 3-14: Westbound SR-91 Average Weekday Hourly Delay 2003-2005

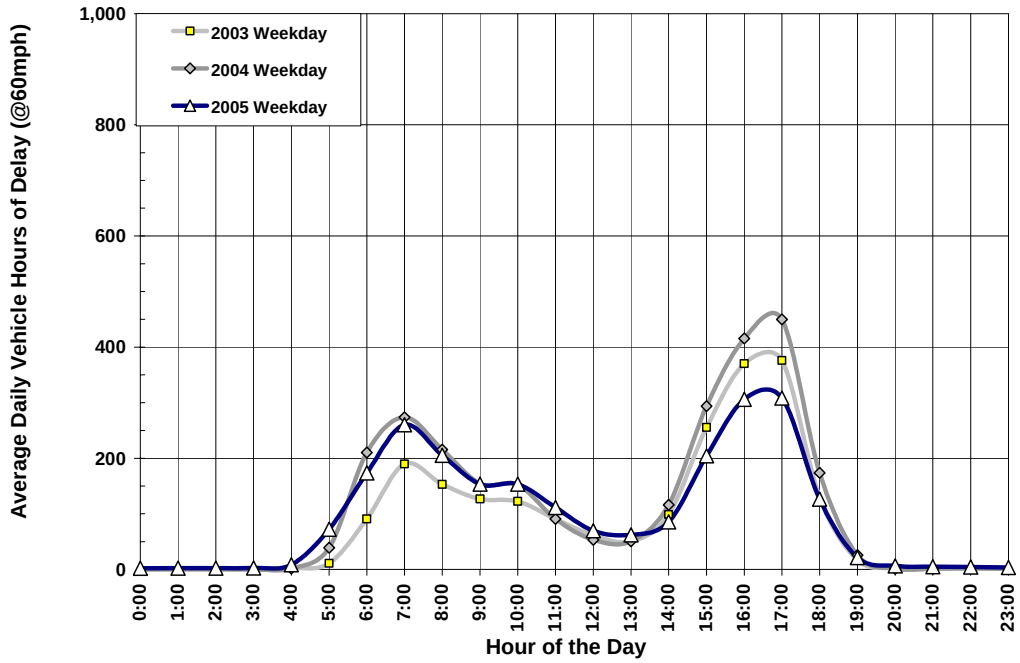


Exhibit 3-15: Eastbound SR-91 Average Weekday Hourly Delay 2006-2008

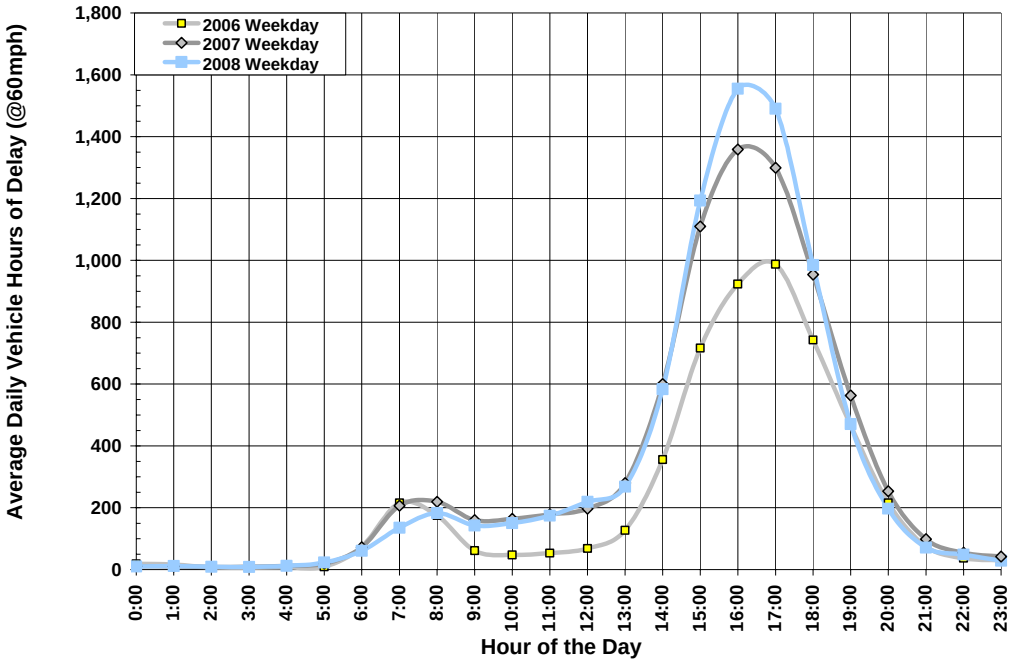
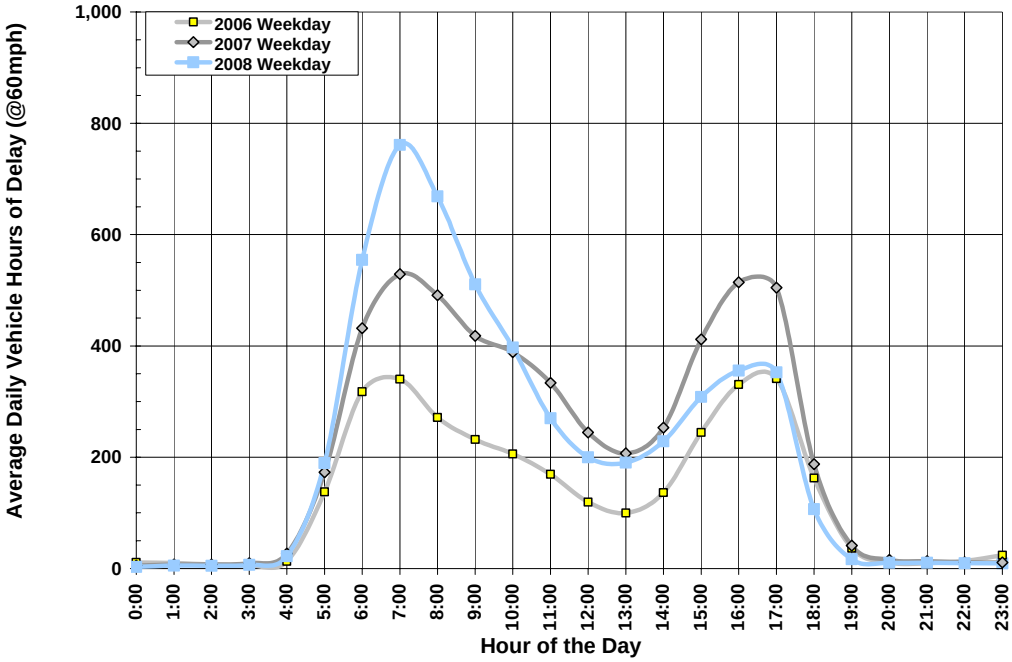


Exhibit 3-16: Westbound SR-91 Average Weekday Hourly Delay 2006-2008



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Travel Time

Travel time is reported as the amount of time it takes for a vehicle to traverse between from the I-5/SR-91 interchange to the Riverside County Line and vice versa (approximately 19 miles). PeMS detection data was used to compute and analyze travel times.

Exhibits 3-17 to 3-20 illustrate the travel times assessed for the SR-91 Corridor. As illustrated, the eastbound direction had travel times of approximately 29 to 33 minutes during the PM peak hour, and the westbound direction had travel times of approximately 22 minutes during the PM peak hour, in years 2003 to 2005. In 2006 to 2008, the eastbound travel times were unchanged in the AM peak period while in the PM peak period, it increased from approximately 33 minutes in 2006 to approximately 42 minutes in 2008. In the westbound direction, AM peak hour travel times increased to approximately 26 minutes in 2007 from approximately 21 minutes in 2006. During the PM peak hour, westbound travel times increased from 22 to 25 minutes from 2006 to 2008.

Exhibit 3-17: SR-91 Eastbound Travel Time by Time of Day 2003-2005

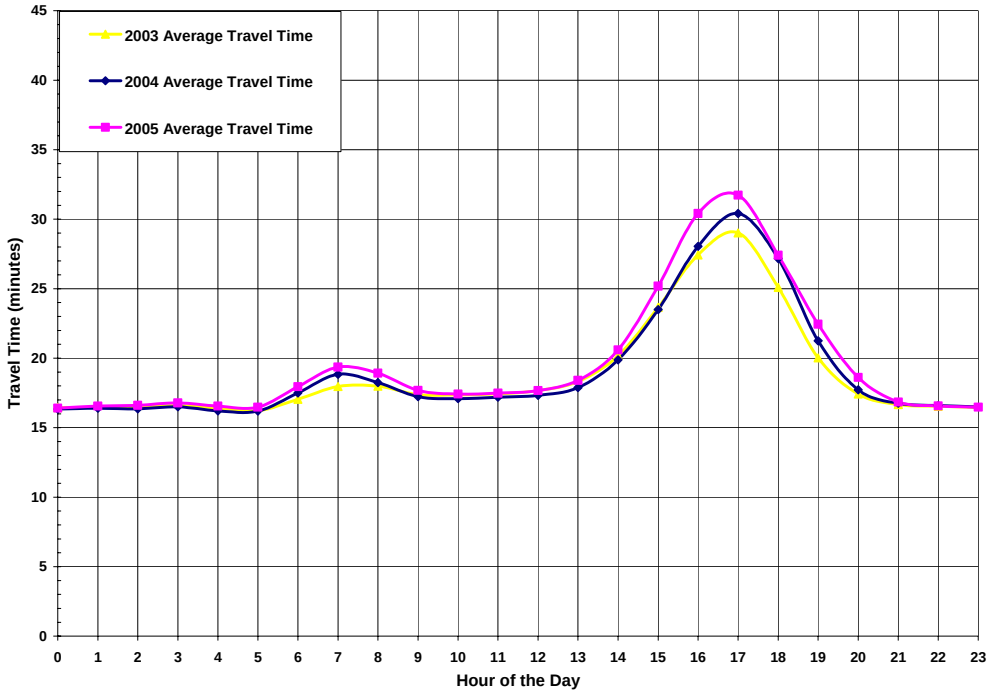


Exhibit 3-18: SR-91 Westbound Travel Time by Time of Day 2003-2005

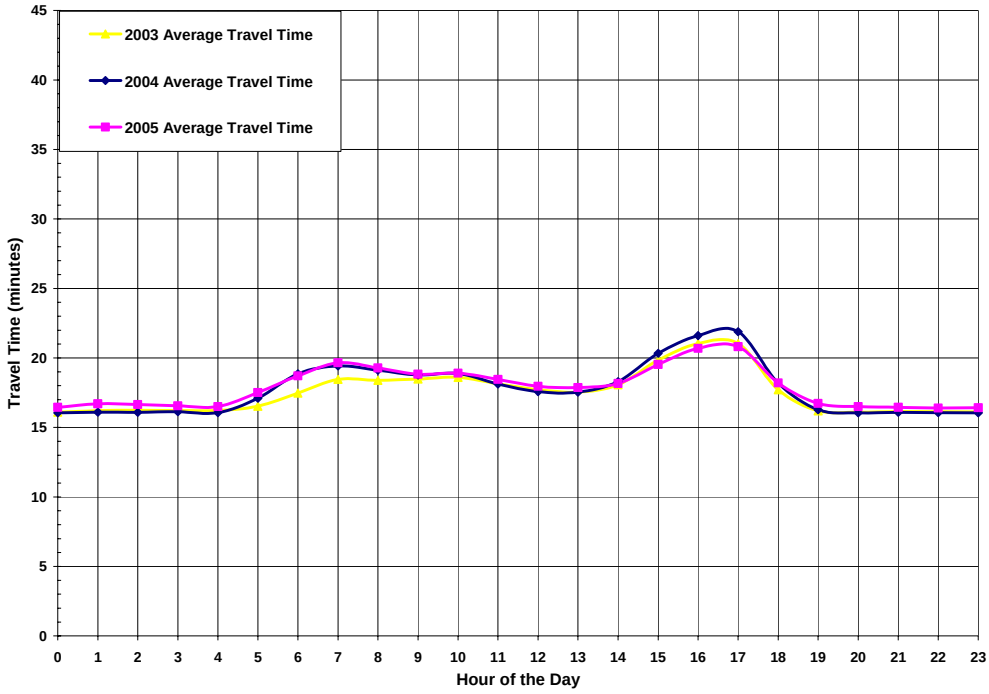


Exhibit 3-19: SR-91 Eastbound Travel Time by Time of Day 2006-2008

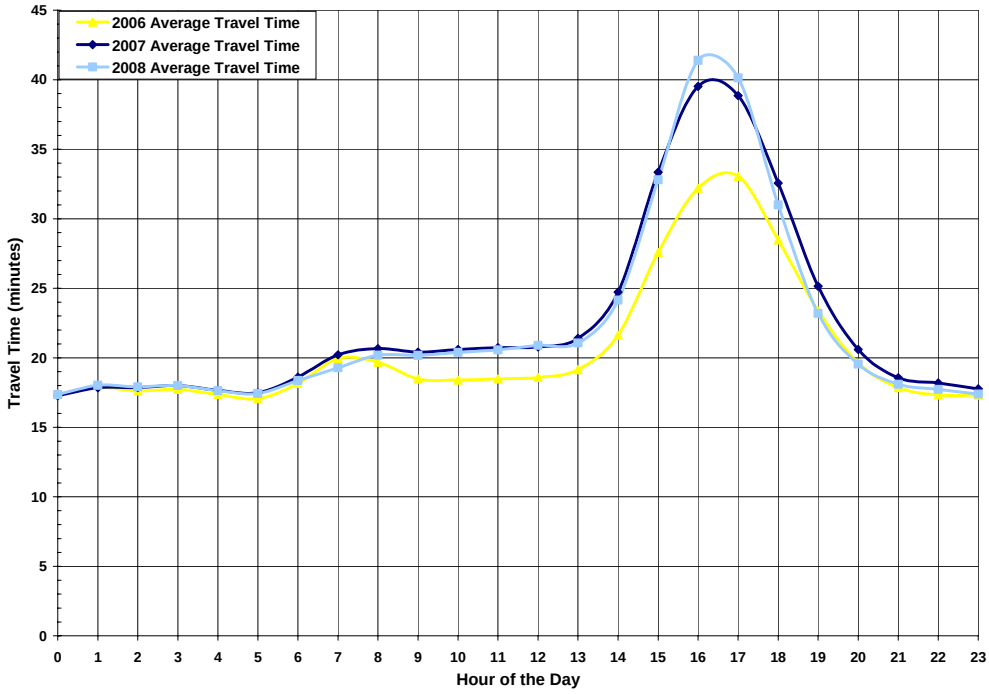
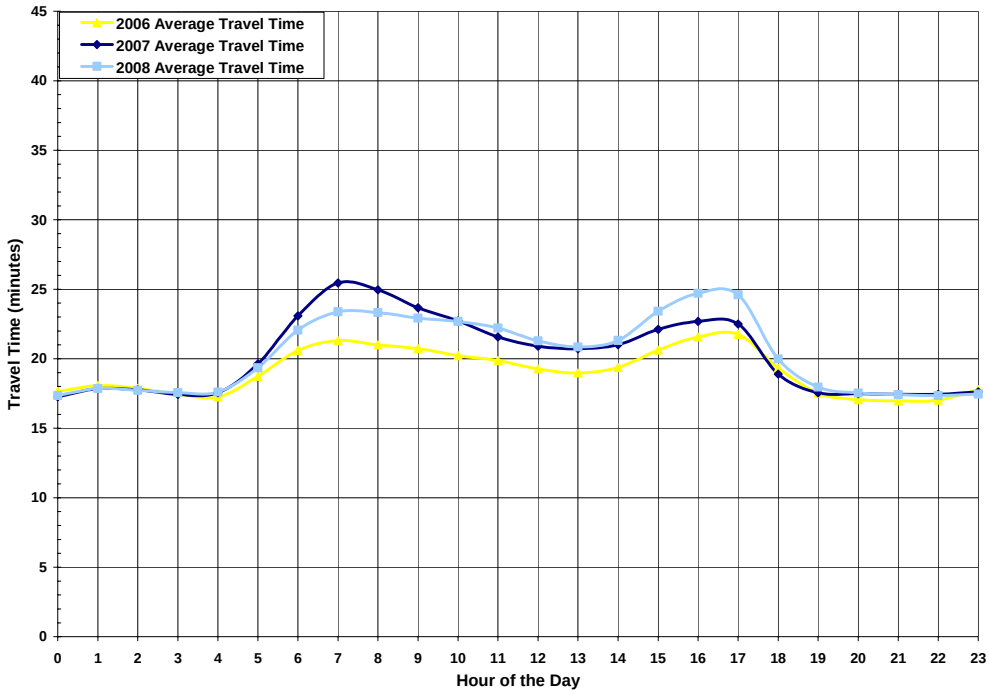


Exhibit 3-20: SR-91 Westbound Travel Time by Time of Day 2006-2008



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RELIABILITY

Reliability captures the relative predictability of the public's travel time. Unlike mobility, which measures average delays and travel times, the reliability measure focuses on how much travel time varies from day to day.

PeMS detector data was used to calculate travel time variability. The reliability, or variability, in travel time was estimated. From the wide range of travel times from average to the maximum, the 95th percentile provides an optimal, desired expected peak travel time at any given day.

Exhibits 3-21 to 3-30 illustrate the variability of travel time along SR-91 for weekdays averaged throughout the respective years from 2004 to 2008, by direction. When focusing on more recent years (2007 and 2008), several additional observations are worth noting:

- Variability in the eastbound direction during the Pm peak period has grown significantly in 2008. Although the average travel time during the Pm peak period is less than 45 minutes, a traveler needs to schedule around 80 minutes to have a 95 percent likelihood of arriving to the Riverside County line in time. This may be due to incidents, weather, special events, or construction activities. Nevertheless, travel time is very high in relative terms and reliability has declined considerably in the eastbound direction since 2002.

- Variability in the westbound direction during the am peak period is much more modest. The difference between the average travel time and the 95th percentile travel time is less than 10 minutes.

It is important to keep track of the reliability statistic, in part to evaluate incident management improvement strategies, and in part to gauge the effectiveness of safety projects delivered.

Exhibit 3-21: Eastbound SR-91 Travel Time Variation - 2004

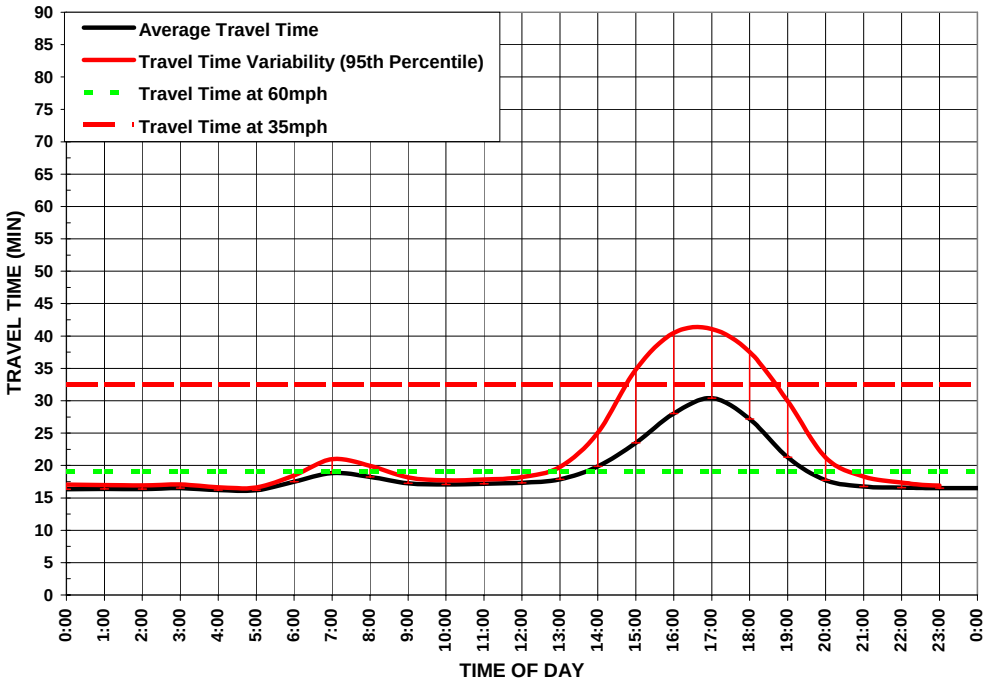


Exhibit 3-22: Westbound SR-91 Travel Time Variation - 2004

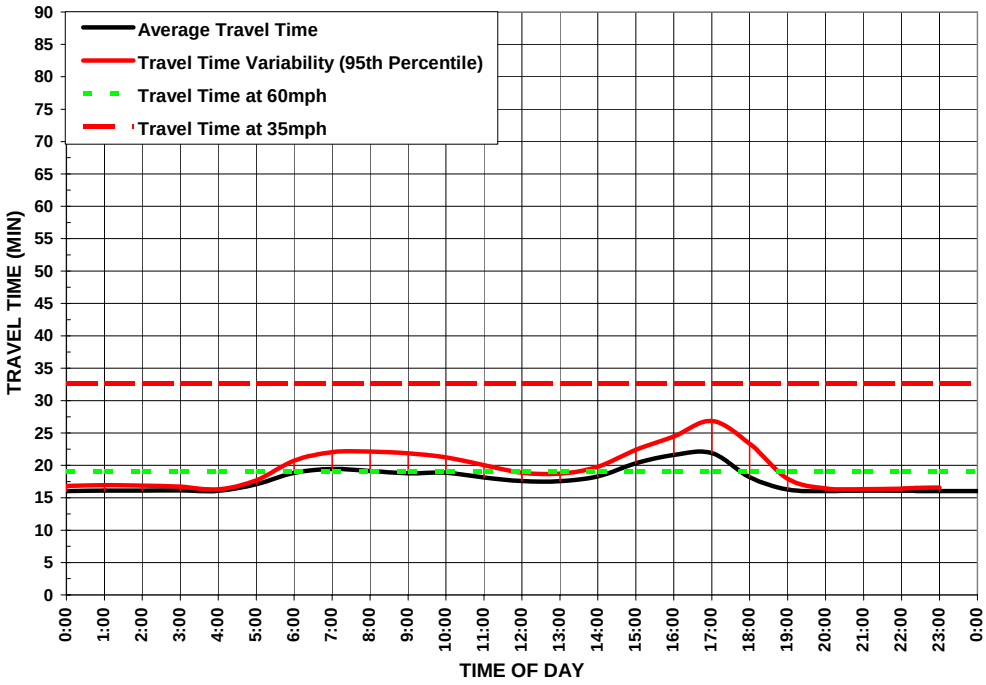


Exhibit 3-23: Eastbound SR-91 Travel Time Variation - 2005

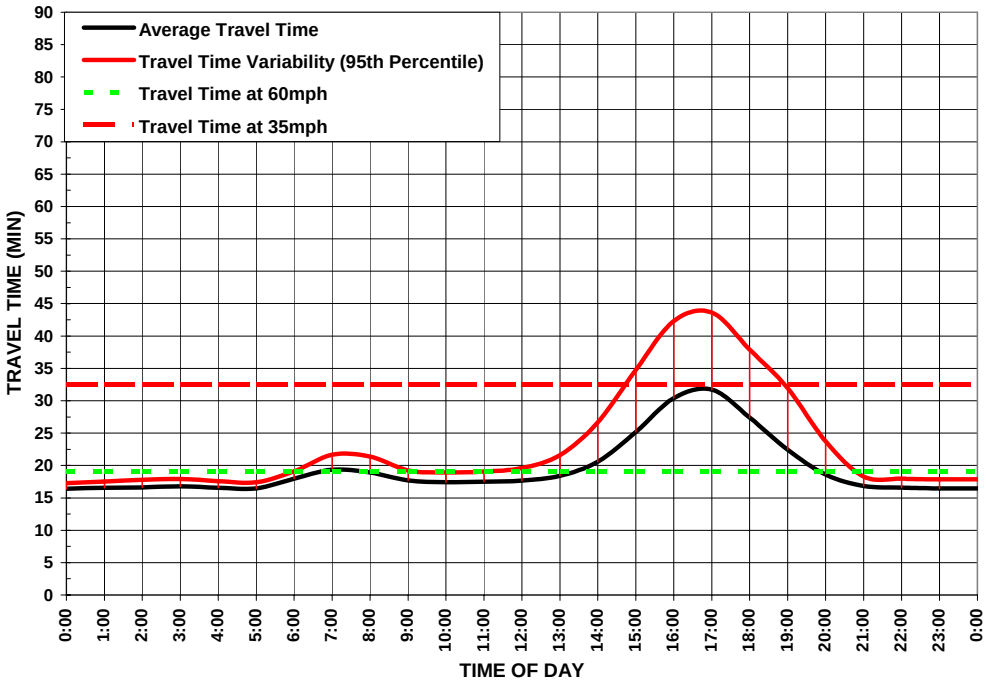


Exhibit 3-24: Westbound SR-91 Travel Time Variation - 2005

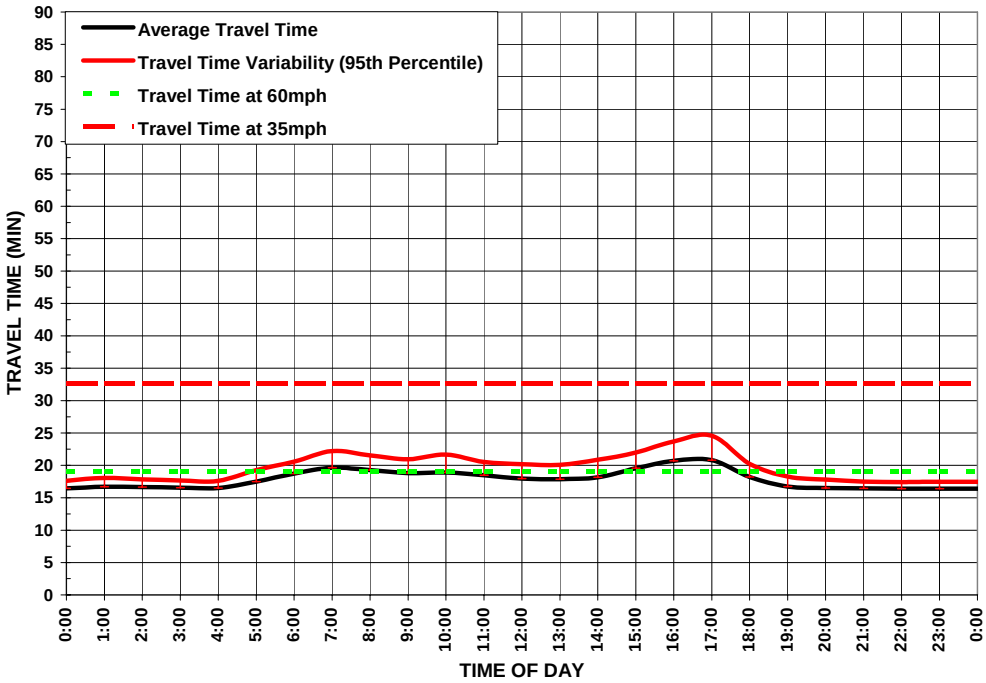


Exhibit 3-25: Eastbound SR-91 Travel Time Variation - 2006

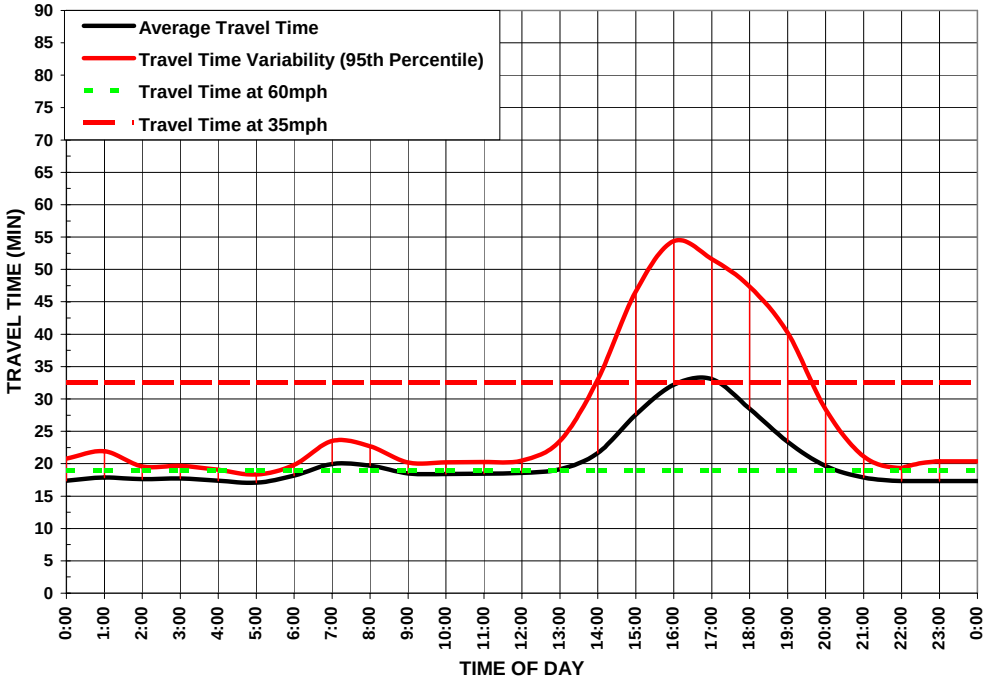


Exhibit 3-26: Westbound SR-91 Travel Time Variation - 2006

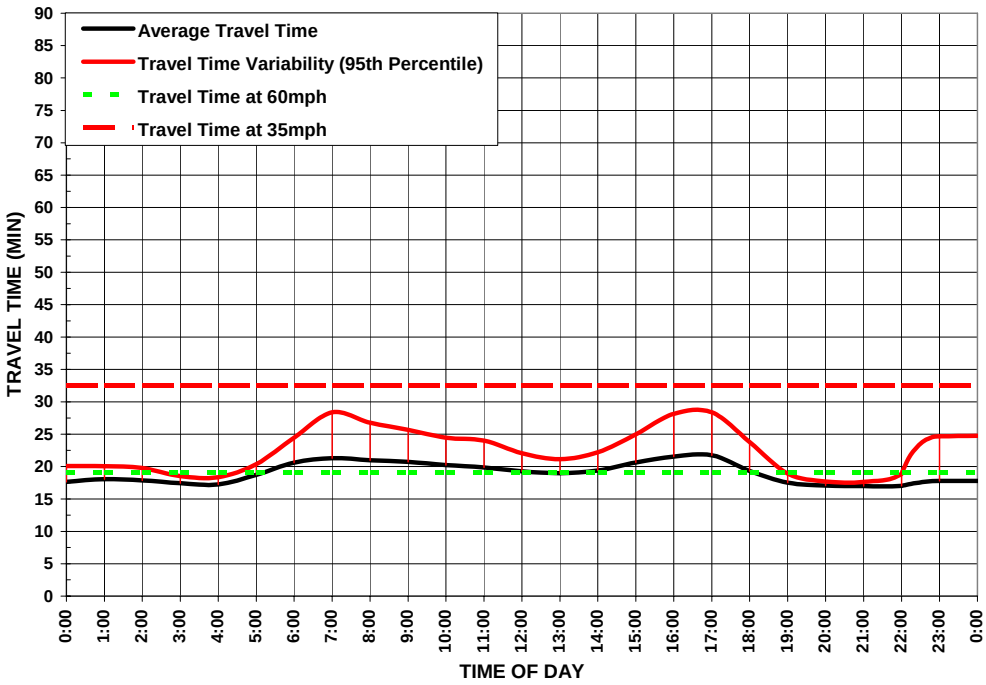


Exhibit 3-27: Eastbound SR-91 Travel Time Variation - 2007

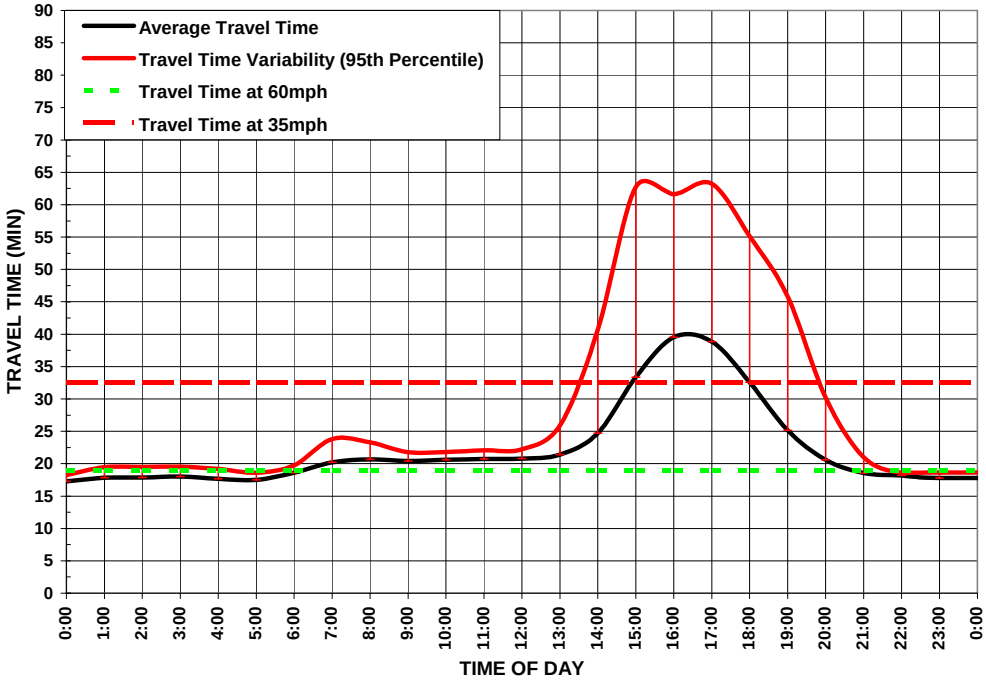


Exhibit 3-28: Westbound SR-91 Travel Time Variation - 2007

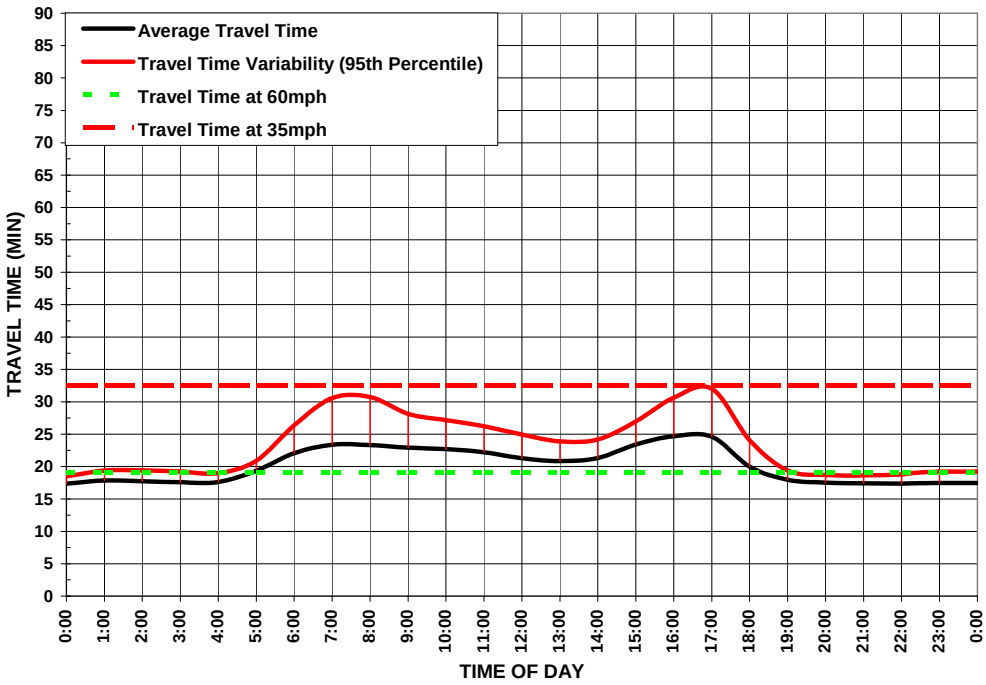


Exhibit 3-29: Eastbound SR-91 Travel Time Variation - 2008

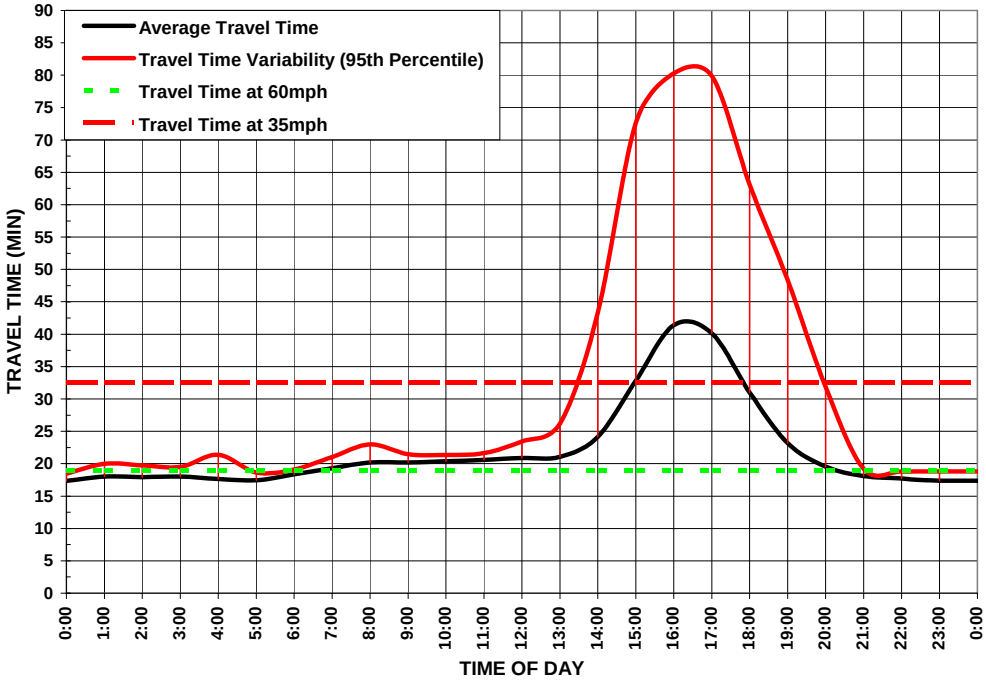
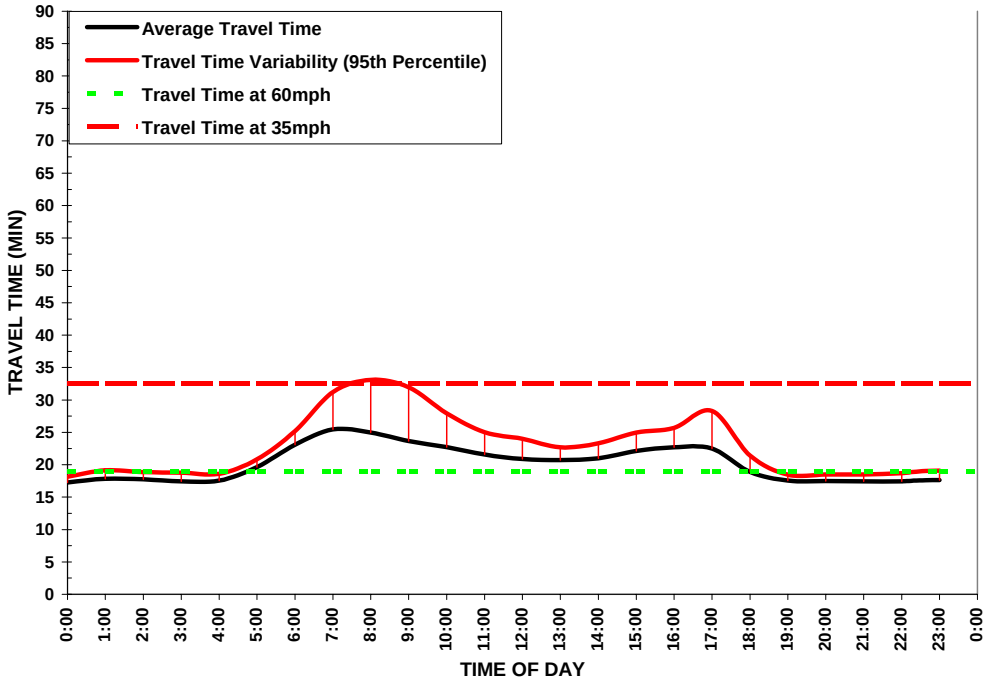


Exhibit 3-30: Westbound SR-91 Travel Time Variation - 2008



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SAFETY

The adopted performance measures to assess safety involve the number of accidents and the accident rates computed from the Caltrans Traffic Accident Surveillance and Analysis System (TASAS). TASAS is a traffic records system containing an accident database linked to a highway database. The highway database contains descriptive elements of highway segments, intersections and ramps, access control, traffic volumes and other data. TASAS contains specific data for accidents on State highways. Accidents on non-State highways are not included (e.g., local streets and roads).

The safety assessment in this report is intended to characterize the overall accident history and trends in the corridor, and to highlight notable accident concentration locations or patterns that are readily apparent. This report is not intended to supplant more detailed safety investigations routinely performed by Caltrans staff.

Exhibits 3-31 and 3-32 illustrate the SR-91 eastbound and westbound accidents by month, respectively. The latest available 3-year data from January 1, 2004 through December 31, 2006 were analyzed and summarized. More recent data is not available yet. Note that these are comprehensive from TASAS and do not rely on automatic detection systems.

Exhibit 3-31: Eastbound SR-91 Monthly Accidents 2004-2006

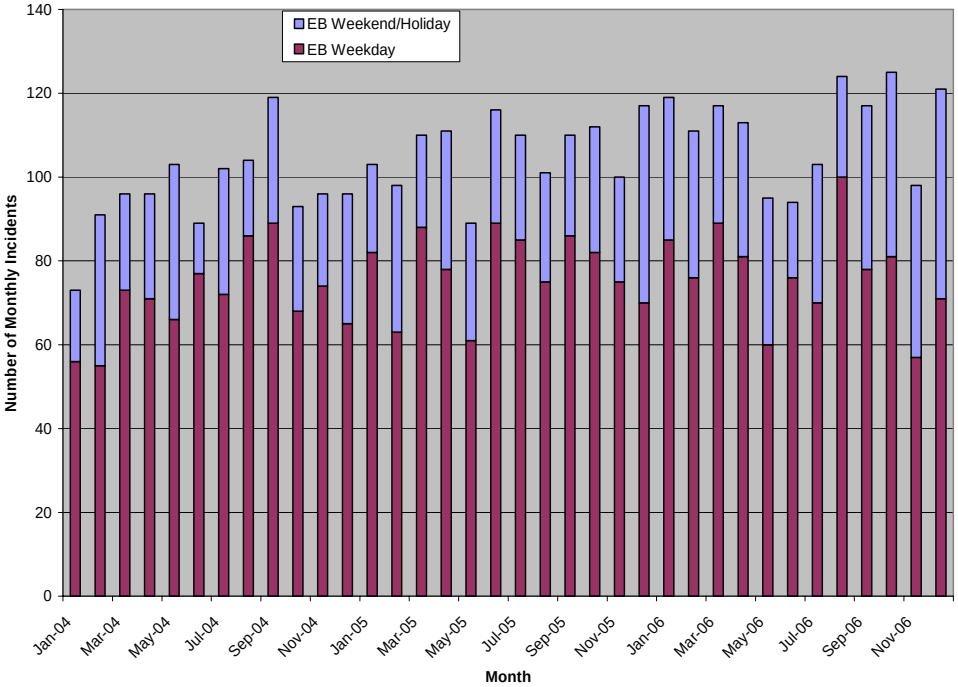
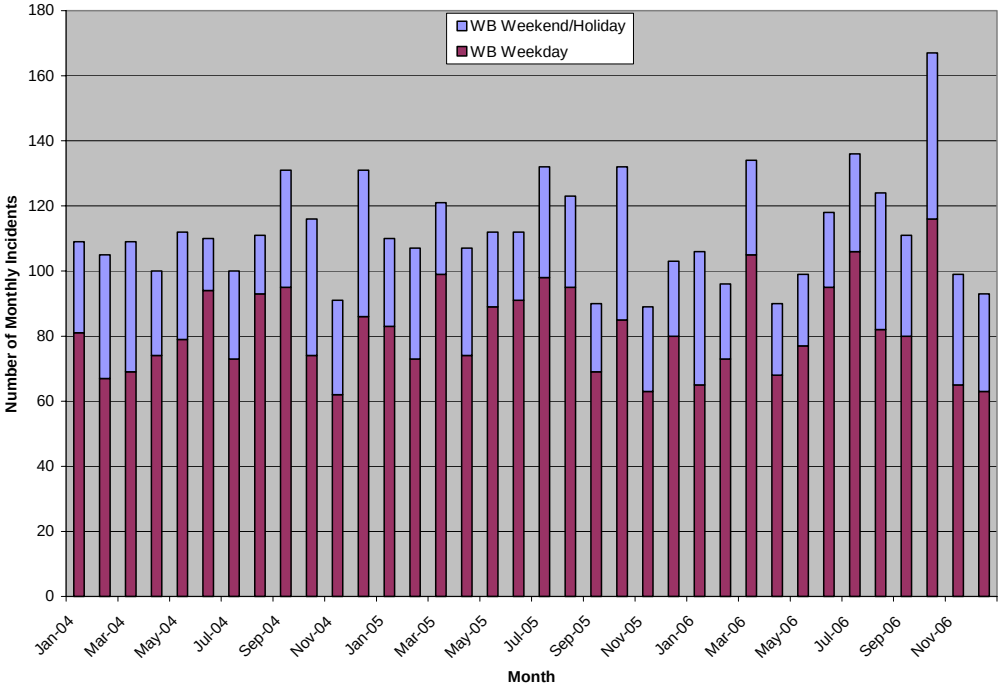


Exhibit 3-32: Westbound SR-91 Monthly Accidents 2004-2006



During 2004-2006, the westbound corridor experienced as much as 130 collisions per month (over 4 per day), while the eastbound experienced as much as 120 collisions per month (4 per day). It is interesting to note, that there were a greater number of collisions in the westbound than the eastbound direction, although the eastbound had more congestion each year. Also there had been a significant increase in total collisions in 2006, which indicates that there may have been higher congestion level in 2006 from previous years. This could validate the 2006 PeMS mobility analysis results. With reduction of congestion and elimination of bottlenecks, it is anticipated that these number of collisions would decrease significantly, as many of the collisions were rear-end collisions, or congestion-related collisions.

Exhibit 3-33 presents the latest TASAS three year accident data for period from January 1, 2004 through December 31, 2006 for the SR-91 Corridor from I-5 to the Orange/Riverside County Line, as provided by Caltrans. Total number of accidents by type [fatality, injury, and property damage only (PDO)], vehicle miles of travel, and the accident rate by type are provided. As indicated in this exhibit, the SR-91 Corridor experienced overall lower accident rates in both fatalities and injuries as compared to the average rates experienced by similar roadway facilities with the exception of two locations in the eastbound direction, and one location in the westbound direction.

Exhibit 3-33: Total Number of Accidents by Type and Accident Rate 2004-2006

							Accident Rates					
							Actual Rates on SR-91			Average Rates on Similar Facilities		
		Number of Accidents on SR-91										
From	***To***	***Fat***	***Inj***	***PDO***	***Total***	***MVM***	***Fat***	***F+I***	***Total***	***Fat***	***F+I***	***Total***
Eastbound												
Interstate 5	Magnolia Ave.	0	34	67	101	58.14	0.000	0.58	1.74	0.017	0.58	1.63
Magnolia Ave.	Weigh Station west of Weir Canyon Rd.	8	508	1300	1816	1860.51	0.004	0.28	0.98	0.007	0.43	1.38
Weigh Station west of Weir Canyon Rd.	Weir Canyon Rd.	1	104	292	397	191.31	0.005	0.55	2.08	0.004	0.26	0.83
Weir Canyon Rd.	west of Coal Canyon Rd.	2	95	306	403	319.34	0.006	0.30	1.26	0.007	0.44	1.38
west of Coal Canyon Rd.	Coal Canyon Rd.	0	55	133	188	147.48	0.000	0.37	1.27	0.005	0.28	0.90
Coal Canyon Rd.	County line	1	22	43	66	85.02	0.012	0.27	0.78	0.007	0.43	1.35
Westbound												
Interstate 5	Magnolia Ave.	0	18	53	71	57.27	0.000	0.31	1.24	0.011	0.44	1.31
Magnolia Ave.	Weigh Station west of Weir Canyon Rd.	13	618	1776	2407	1860.51	0.007	0.33	1.29	0.007	0.43	1.38
Weigh Station west of Weir Canyon Rd.	Weir Canyon Rd.	0	76	198	274	191.31	0.000	0.40	1.43	0.004	0.26	0.82
Weir Canyon Rd.	west of Coal Canyon Rd.	1	63	137	201	319.34	0.003	0.20	0.63	0.007	0.44	1.38
west of Coal Canyon Rd.	Coal Canyon Rd.	3	43	93	139	147.58	0.020	0.29	0.94	0.005	0.28	0.90
Coal Canyon Rd.	County line	0	21	60	81	85.02	0.000	0.25	0.95	0.007	0.43	1.35

Note: Accident rates expressed as # of accidents/Million Vehicle Miles (MVM)

Although TASAS accident data are only available up to December 30, 2006, a review of available California Highway Patrol (CHP) incident data in PeMS (which parses the CHP web site on a regular basis) indicated that in the month of October 2007, there were an inordinate amount of accidents that occurred during the PM peak periods that may have caused the surge in delay and travel times.

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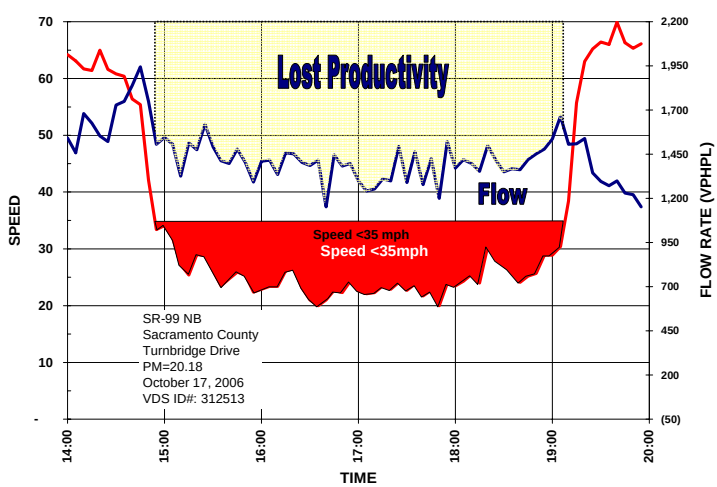
PRODUCTIVITY

Productivity is a system efficiency measure used to analyze the capacity of the corridor, and is defined as the ratio of output (or service) per unit of input. In the case of transportation, it is the amount of people served divided by the level of service provided. Specific to highways, the input to the system is the capacity of the roadways; in transit, it is the number of seats provided. For corridor analyses, productivity is defined as the percent utilization of a facility or mode under peak congested conditions. The highway productivity performance measure is calculated as actual volume divided by the theoretical capacity of the highway. Travel demand models do not generally project capacity loss for highways, but detailed micro-simulation tools can forecast productivity. For highways, productivity is particularly important because where capacity is needed the most, the lowest "production" from the transportation system often occurs.

This loss in productivity example is illustrated in Exhibit 3-34. As traffic flow increases to the capacity limits of a roadway, speeds decline rapidly and throughput drops dramatically. This loss in throughput is the lost productivity of the system. There are a few ways to estimate productivity losses. Regardless of the approach, productivity calculations require good detection or significant field data collection at congested locations. One approach is to convert this lost productivity into "equivalent lost lane-miles." These lost lane-miles represent a theoretical level of capacity that would have to be added in order to achieve maximum productivity. For example, losing six lane-miles implies that adding a new lane along a six-mile section of freeway would regain lost productivity. Equivalent lost lane-miles is computed as follows (for congested locations only):

$$LostLaneMiles = \left(1 - \frac{ObservedLaneThroughput}{2000vphpl}\right) \times Lanes \times CongestedLength$$

Exhibit 3-34: Lost Productivity Illustrated



Exhibits 3-35 and 3-36 summarize the productivity losses on the study corridor for the 2003 to 2005 and 2006 to 2008 analysis, respectively. As indicated in every year, the majority of the lost productivity is in the eastbound direction during the PM peak hours. Strategies to combat such productivity losses are primarily related to operations and include building new or extending auxiliary lanes, developing more aggressive ramp metering strategies without negatively influencing the arterial network, and improvements in incident clearance times.

Exhibit 3-35: SR-91 Average Lost Lane Miles by Direction, Time Period, and Year

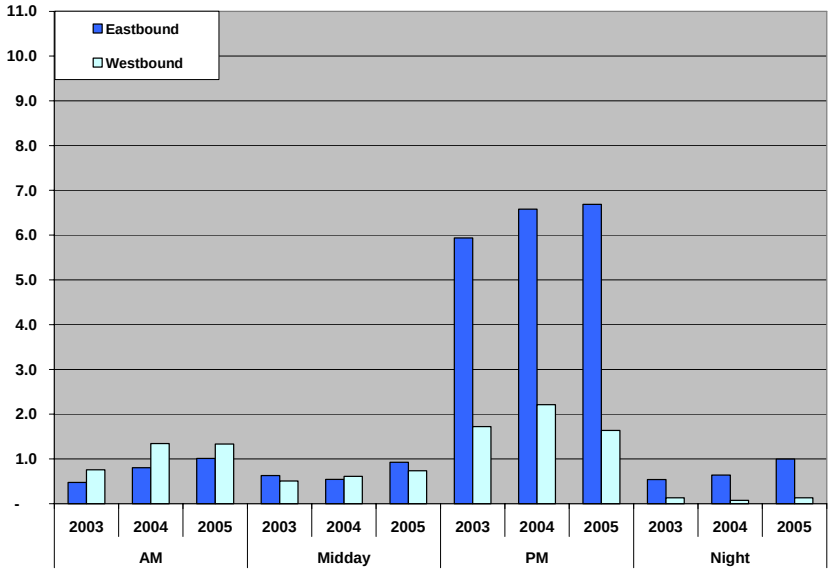
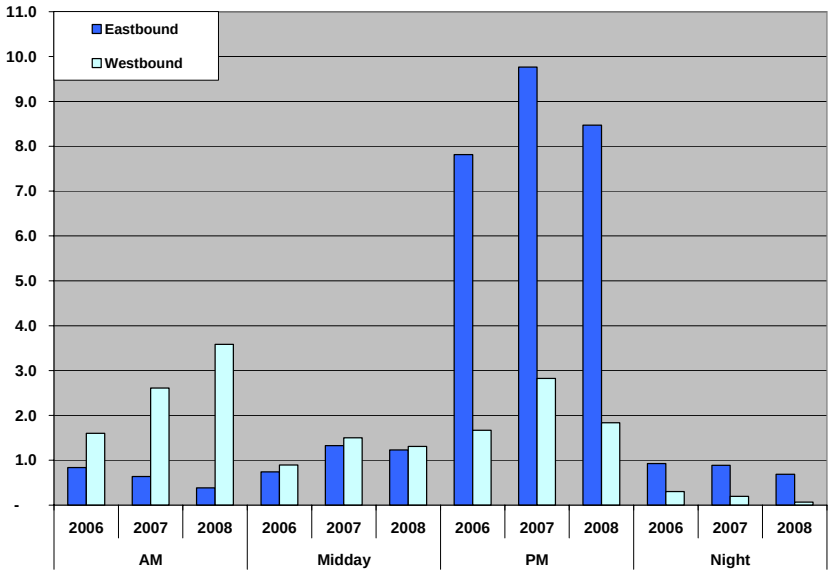


Exhibit 3-36: SR-91 Average Lost Lane Miles by Direction, Time Period, and Year



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PAVEMENT CONDITION

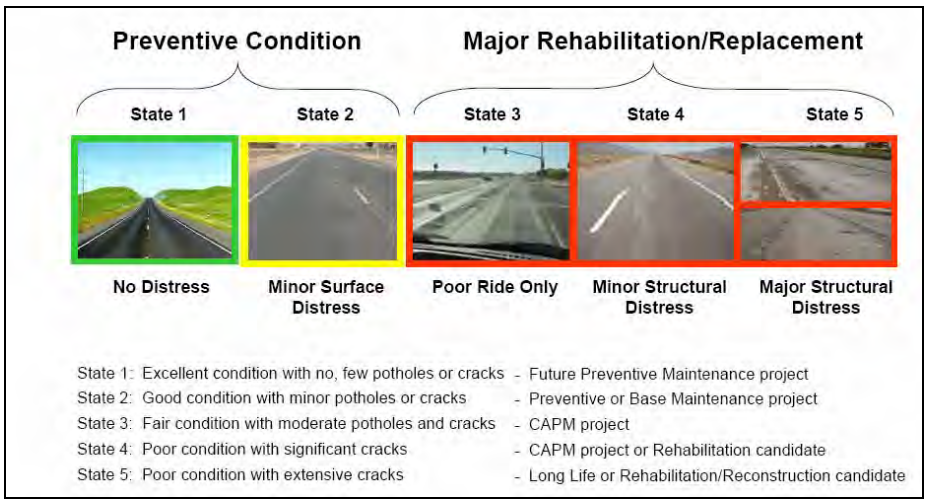
The condition of the roadway pavement (or ride quality) on the corridor can influence its traffic performance. Rough or poor pavement conditions can decrease the mobility, reliability, safety, and productivity of the corridor, whereas smooth pavement can have the opposite effect. Pavement preservation refers to maintaining the structural adequacy and ride quality of the pavement. It is possible for a roadway section to have structural distress without affecting ride quality. Likewise, a roadway section may exhibit poor ride quality, while the pavement remains structurally adequate.

Pavement Performance Measures

Caltrans conducts an annual Pavement Condition Survey (PCS) that can be used to compute two performance measures: distressed lane miles and International Roughness Index (IRI). Although Caltrans generally uses distressed lane miles for external reporting, this report uses the Caltrans data to present results for both measures.

Using distressed lane miles allows us to distinguish among pavement segments that require only preventive maintenance at relatively low costs and segments that require major rehabilitation or replacement at significantly higher costs. All segments that require major rehabilitation or replacement are considered to be distressed. Segments with poor ride quality are also considered to be distressed. Exhibit 3-37 provides an illustration of this distinction. The first two pavement conditions are considered roadway that provides adequate ride quality and is structurally adequate. The remaining three conditions are included in the calculation of distressed lane-miles.

Exhibit 3-37: Pavement Condition States



Source: Caltrans Division of Maintenance, 2007 State of the Pavement Report

IRI distinguishes between smooth-riding and rough-riding pavement. The distinction is based on measuring the up and down movement of a vehicle over pavement. When such movement is measured to be 95 inches per mile or less, the pavement is considered good or smooth-riding. When movements are between 95 and 170 inches per mile, the pavement is considered acceptable. Measurements above 170 inches per mile reflect unacceptable or rough-riding conditions.

Existing Pavement Conditions

The most recent pavement condition survey, completed in November 2007, identified 12,998 distressed lane-miles statewide. Unlike prior surveys, the 2007 PCS included pavement field studies for a period longer than a year, due to an update in the data collection methodology. The survey includes data for 23 months from January 2006 to November 2007.

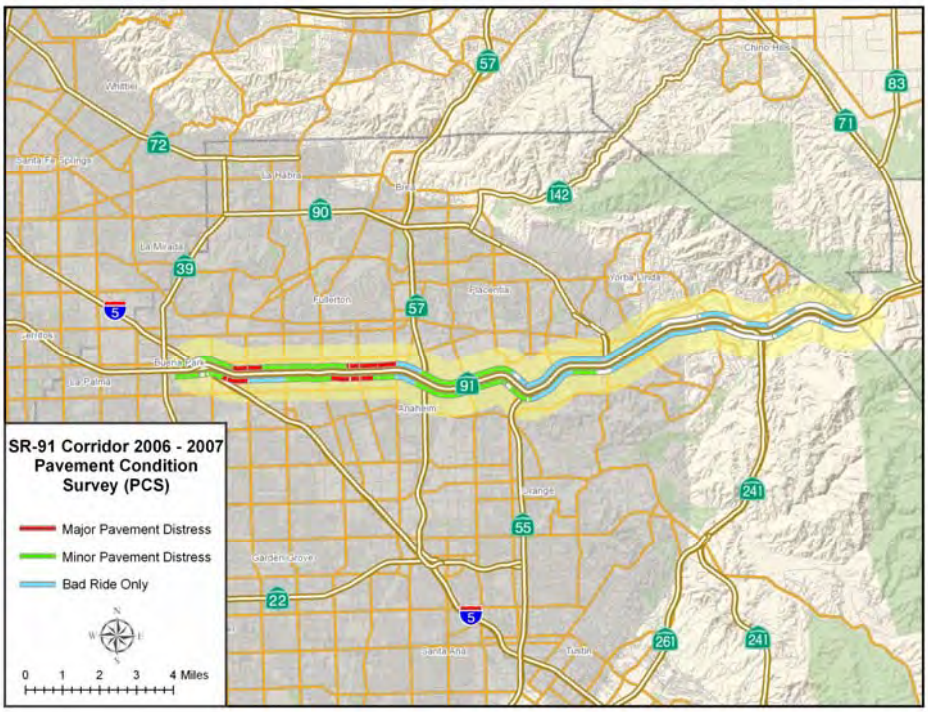
The field work consists of two parts. In the first part, pavement raters visually inspect the pavement surface to assess structural adequacy. In the second part, field staff uses vans with automated profilers to measure ride quality. The 2007 PCS revealed that the majority of distressed pavement was on freeways and expressways (Class 1 roads). This is the result of approximately 56 percent of the State Highway System falling into this road class. As a percentage of total lane miles for each class, collectors and local roads (Class 3 roads) had the highest amount of distress.

Exhibit 3-38 shows pavement distress along the SR-91 Corridor according to the 2007 PCS data. The three categories shown in this exhibit represent the three distressed conditions that require major rehabilitation or replacement and were presented earlier in Exhibit 3-37.

In general, pavement on the SR-91 Corridor is in about the same condition as highways in District 12 as a whole (although the toll roads and recently completed SR-22 have no distressed lane miles). Most of the SR-91 Corridor has some kind of distressed conditions, but major pavement distress is limited to the section between I-5 and SR-57. About half of the distressed lane-miles represent minor pavement distress, while about one third exhibit bad ride quality only.

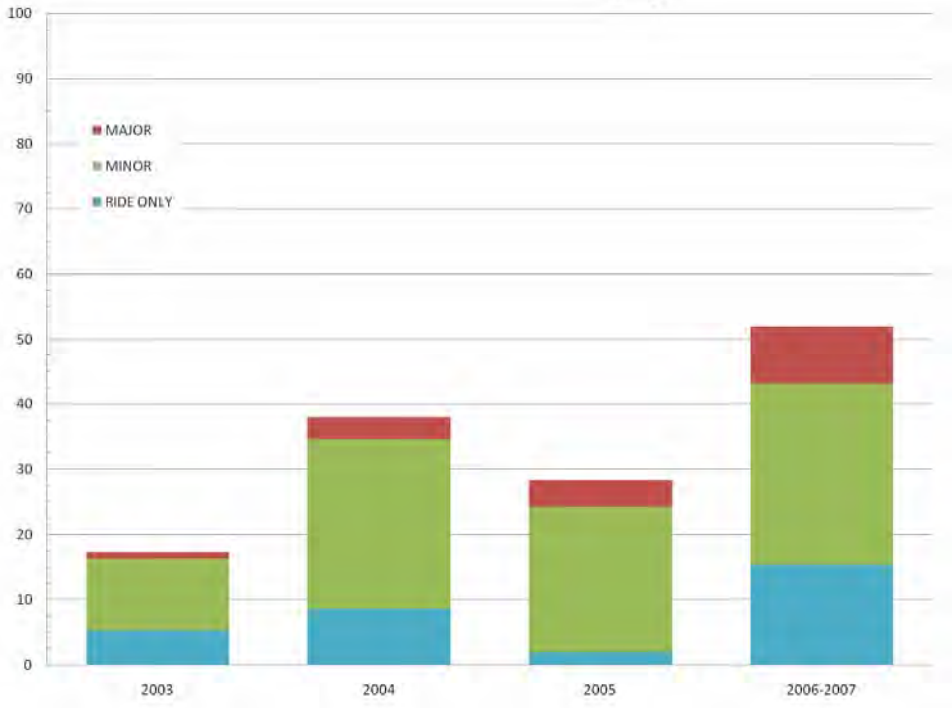
Exhibit 3-39 shows results from prior pavement condition surveys for the SR-91 Corridor. The total number of distressed lane-miles has generally increased between 2003 and 2006-07. However, distressed lane-miles did drop and deviate from the trend in 2005. The exhibit also splits the distressed lane miles by classification. The exhibit shows that the level of distress has stayed roughly even. Although the proportion of major pavement distress has increased slightly, minor pavement distress has been replaced by less severe bad ride only issues. This shift can be seen more clearly in Exhibit 3-40, which shows the percent mix.

Exhibit 3-38: Distressed Lane-Miles on the SR-91 Corridor for the 2006-07 Period



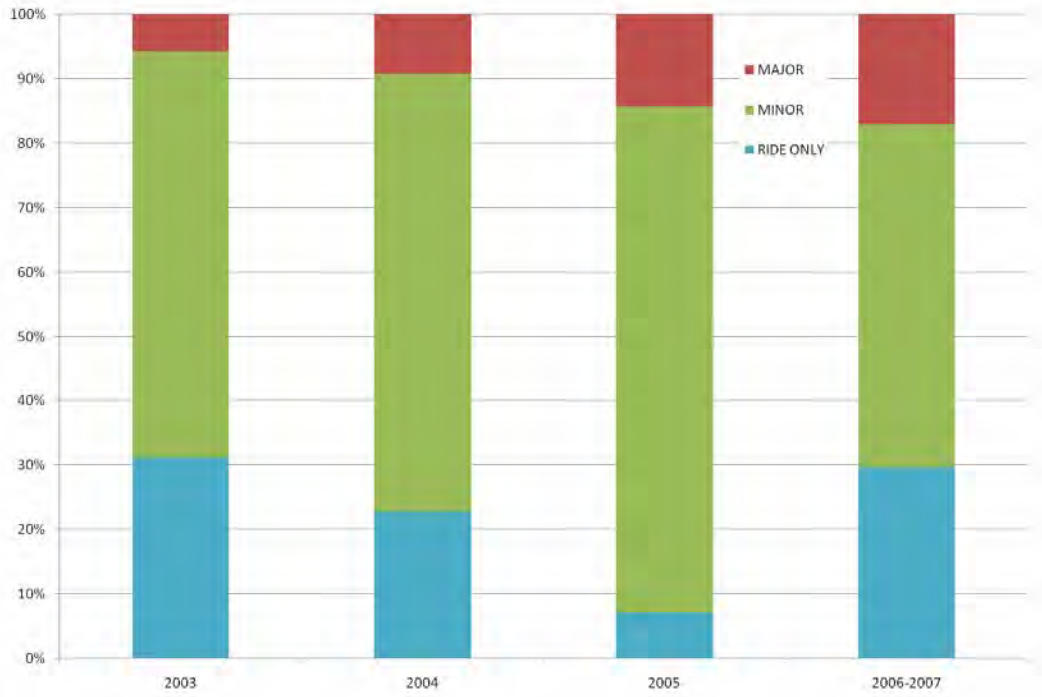
Source: SMG mapping of 2007 Pavement Condition Survey data

Exhibit 3-39: Distressed Lane-Miles Trends on the SR-91 Corridor



Source: SMG analysis of 2003 to 2007 Pavement Condition Survey data

Exhibit 3-40: Distressed Lane-Miles by Type on the SR-91 Corridor



Source: SMG analysis of 2003 to 2007 Pavement Condition Survey data

The study corridor comprises roughly 169 lane-miles, of which:

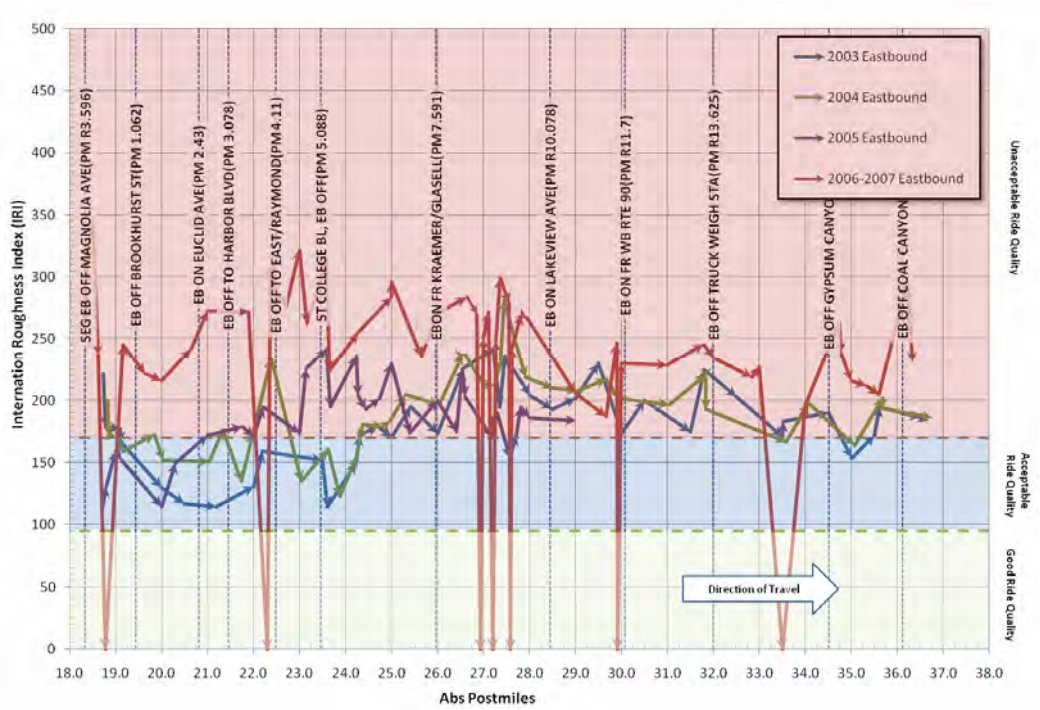
- 49 lane-miles, or 29 percent, is considered to have good pavement conditions (IRI ≤ 95)
- 49 lane-miles, or 29 percent, is considered to have acceptable pavement conditions (95 < IRI ≤ 170)
- 70 lane miles, or 41 percent, is considered to have unacceptable pavement conditions (IRI > 170)

Note that the numbers and percentages do not add due to rounding.

Exhibits 3-41 and 3-42 present ride conditions based on the IRI measure for the SR-91 Corridor over the last four pavement surveys. The information is presented by Postmile and direction. The exhibits include color-coded bands to indicate the three ride quality categories defined by Caltrans: good ride quality (green), acceptable ride quality (blue), and unacceptable ride quality (red).

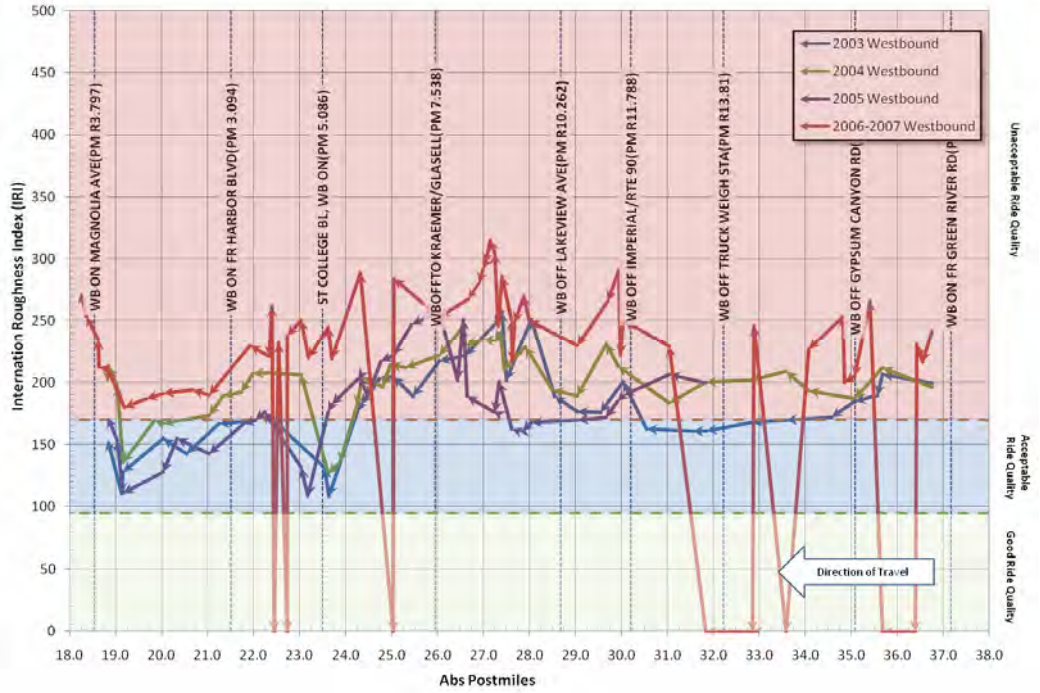
Ride quality worsened considerably between 2005 and the 2006-07 periods, but this may be due to the 2006-07 change in data collection methodology. The exhibits show that ride quality is worse in the western section of the corridor, particularly in the eastbound direction.

Exhibit 3-41: Eastbound SR-91 Corridor IRI 2003-2007



Source: SMG analysis of 2003 to 2007 Pavement Condition Survey data

Exhibit 3-42: Westbound SR-91 Corridor IRI 2003-2007



Source: SMG analysis of 2003 to 2007 Pavement Condition Survey data

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4. BOTTLENECK IDENTIFICATION AND ANALYSIS

Potential bottlenecks were identified in the Preliminary Performance Assessment document in June, 2008. They were identified based primarily on a variety of data source, including HICOMP, probe vehicle runs, and PeMS. Limited field observations were conducted as well, but not enough to verify each bottleneck. Pursuant to that phase of the CSMP development, significant field observations were conducted as well as additional data analysis of PeMS. As a result of these additional efforts, the consistent bottlenecks were identified for both directions.

Westbound Bottlenecks

Starting from the Riverside County line and moving westbound, the following bottlenecks were identified:

- SR-241 Connector merge onto SR-91 – this bottleneck extends almost to the Weir Canyon Road interchange
- Weir Canyon Road on-ramps – this bottleneck extends almost to the Truck Weigh Station
- SR-55 Connector Off-ramp – this bottleneck relates to cross-weaving and queuing of vehicles destined to SR-55
- SR-57 Connector merge onto SR-91 – this bottleneck extends almost to State College Boulevard
- Smaller, less relevant bottlenecks from East Street to I-5 – these smaller bottlenecks were not confirmed in recent field visits, but previous data indicated that slowing occurs.

Eastbound Bottlenecks

Starting from the I-5 and moving eastbound, the following bottlenecks were identified:

- State College Boulevard – some slowdowns were observed in 2007 around College Boulevard. However, during field observations in 2008, these were not evident. Nevertheless, this bottleneck is included since it may reappear in the future.
- SR-90 Connector merge onto SR-91 – this bottleneck is not large, but did appear in 2007 data.
- Gypsum Canyon/SR241 merge onto SR-91 – this dual merge creates a consistent bottleneck. The queue from this bottleneck often reaches the SR-90 Connector.

- Coal Canyon Road interchange onto SR-91 – the queues of this bottleneck often reach the Gypsum Canyon bottleneck. Note that the Coal Canyon Road Interchange onto SR-91 is not in operation.

Analysis of Bottleneck Areas

Once the bottlenecks were identified, the corridor is divided into "bottleneck areas". Bottleneck areas represent segments that are defined by one major bottleneck (or a number of smaller ones). By segmenting the corridors into such bottleneck areas, some performance statistics that were presented for the entire corridor can now be broken down by bottleneck area. This way, the relative contribution of each bottleneck area to the degradation of the corridor performance can be gauged. The performance statistics that lend themselves to such segmentation include:

- Delay
- Productivity
- Safety

Based on this approach, the study corridor comprises several bottleneck areas, which are different by direction. As an illustration, Exhibit 4-1 illustrates the concept of bottleneck areas in one direction.

The location of the bottlenecks is represented by the ovals, and the bottleneck area is represented by the arrows. Exhibit 4-2 graphically illustrates the location of each of the bottleneck locations and areas for SR-91.

Exhibit 4-1: Dividing the SR-91 Corridor into Bottleneck Areas

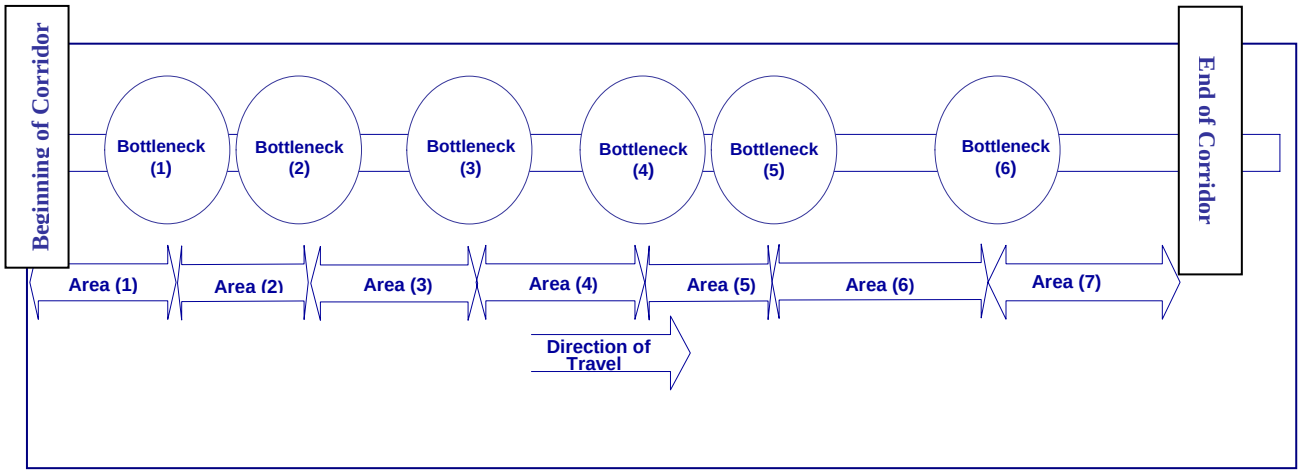
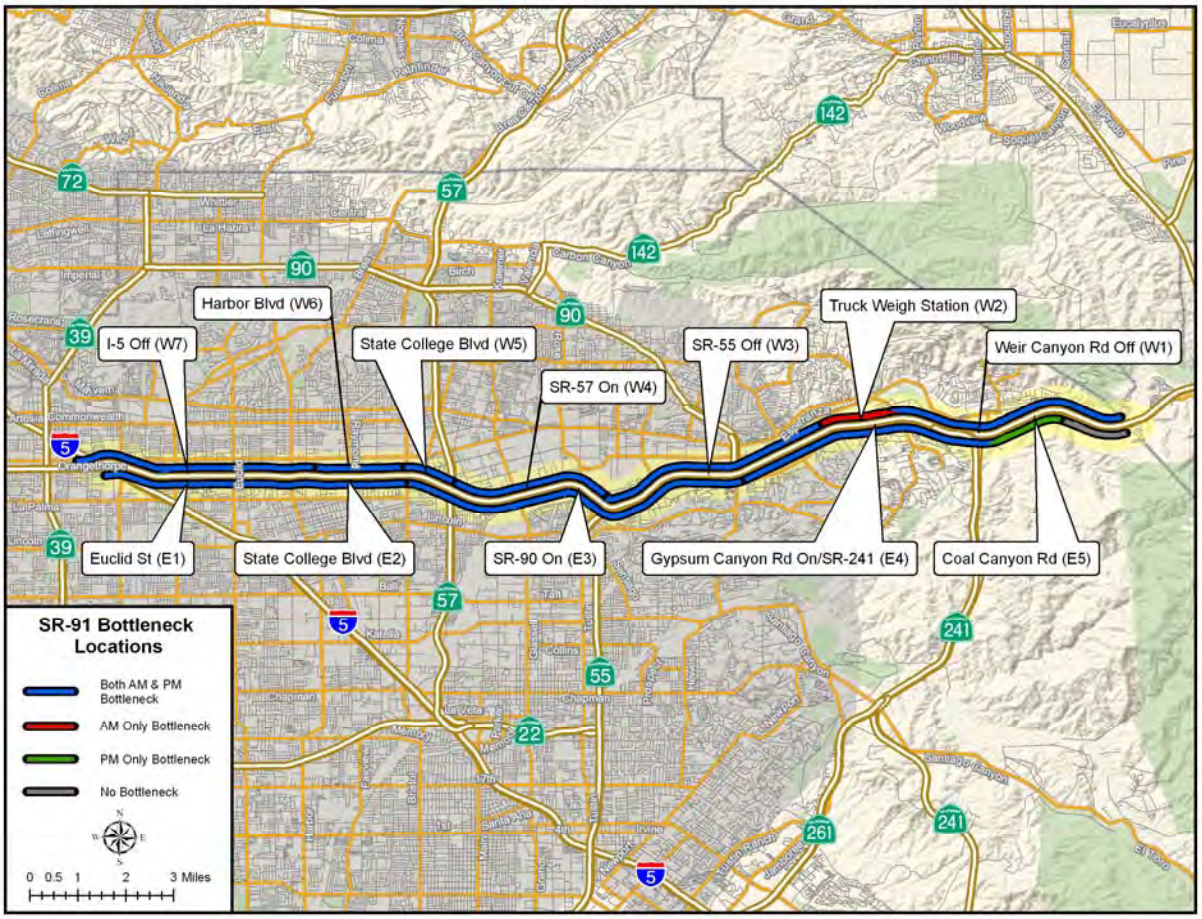


Exhibit 4-2: Map of Bottleneck Locations and Bottleneck Areas



Dividing the corridor into bottleneck areas makes it easier to compare the various segments of the freeway with each other. This section will use the previously discussed performance measures of mobility, safety, productivity, and pavement condition to evaluate each bottleneck area. The results from this bottleneck analysis will reveal which segments of the corridor should be prioritized for improvements.

Exhibit 4-3: Eastbound SR-91 Identified Bottleneck Areas

From		To		Area	Bottleneck Designation	Bottleneck Period
Abs	CA	Abs	CA			
18.3	R3.6	20.7	2.4	From I-5 to Euclid St	Euclid St (E1)	AM and PM Peak
20.7	2.4	23.7	5.3	From Euclid St to State College Blvd	State College Blvd (E2)	AM and PM Peak
23.7	5.3	30.0	R11.7	From State College Blvd to to SR-90 On	SR-90 On (E3)	AM and PM Peak
30.0	R11.7	34.7	R16.4	From SR-90 On to Gypsum Canyon Rd On/SR-241	Gypsum Canyon Rd On/SR-241 (E4)	AM and PM Peak
34.7	R16.4	36.2	R17.8	From Gypsum Canyon Rd On/SR-241 to Coal Canyon Rd	Coal Canyon Rd (E5)	PM Peak Only
36.2	R17.8	37.3	R18.9	From Coal Canyon Rd to ORA/RIV Co. Line	Not a bottleneck area (E6)	None

Exhibit 4-4: Westbound SR-91 Identified Bottleneck Areas

From		To		Area	Bottleneck Designation	Bottleneck Period
Abs	CA	Abs	CA			
37.3	R18.9	32.9	R14.5	From ORA/RIV Co. Line to Weir Canyon Rd Off	Weir Canyon Rd Off (W1)	AM and PM Peak
32.9	R14.5	31.7	R13.3	From Weir Canyon Rd Off to Truck Weigh Station	Truck Weigh Station (W2)	AM Peak Only
31.7	R13.3	27.2	R8.9	From Truck Weigh Station SR-55 Off	SR-55 Off (W3)	AM and PM Peak
27.2	R8.9	24.4	6.05	From SR-55 Off to SR-57 On	SR-57 On (W4)	AM and PM Peak
24.4	6.05	23.5	5.14	From SR-57 On to State College Blvd	State College Blvd (W5)	AM and PM Peak
23.5	5.14	21.5	3.13	From State College Blvd to Harbor Blvd	Harbor Blvd (W6)	AM and PM Peak
21.5	3.13	18.3	R3.6	From Harbor Blvd to I-5 Off	I-5 Off (W7)	AM and PM Peak

Mobility by Bottleneck Area

Mobility describes how efficiently the corridor moves vehicles. To evaluate how well (or poorly) each bottleneck area moves vehicles, vehicle-hours of delay were calculated for each segment. The results reveal the areas of the corridor that experience the worst mobility.

Exhibits 4-5 and 4-7 illustrate the vehicle-hours of delay experienced by each bottleneck area. In the eastbound direction, the delay during the AM peak is noticeably less than the PM peak with all segments of the corridor experiencing less than 100,000 annual vehicle-hours of delay. During the PM peak, the segment between SR-90 to Gypsum Canyon Road/SR-241 experienced over half of the corridor's delay at slightly under 600,000 vehicle-hours of delay. In the westbound direction, the segment between the Truck Weigh Station to SR-55 experienced the greatest delay with 44 percent of the corridor's delay during the AM peak. During the PM peak, the segment between SR-55 to SR-57 experienced the greatest delay with 39 percent of the corridor's delay.

Exhibits 4-6 and 4-8 have been normalized to reflect delay per lane mile. The delay calculated for each bottleneck area was divided by the total lane-miles for each bottleneck area to obtain delay per lane mile. The results of these exhibits differ from Exhibits 4-5 and 4-7. In the eastbound direction, Gypsum Canyon/SR-241 to Coal Canyon Road had the highest delay per lane mile during the PM peak, while delay per lane mile for each bottleneck area remained relatively similar to Exhibit 4-5 during the AM peak. In the westbound direction, the segment from Weir Canyon Road to the Truck Weigh Station experienced the highest delay per lane mile during the AM peak, while the segment from SR-57 to State College Boulevard experienced the highest delay during the PM peak.

Exhibit 4-5: Eastbound Annual Vehicle-Hours of Delay – 2007

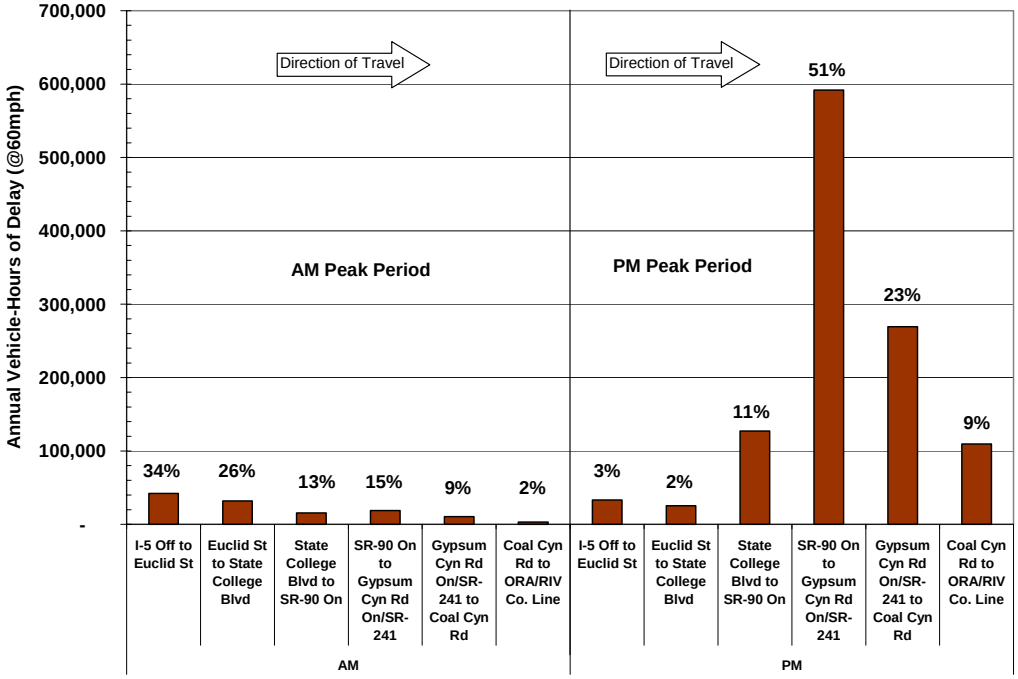


Exhibit 4-6: Eastbound Delay per Lane Mile – 2007

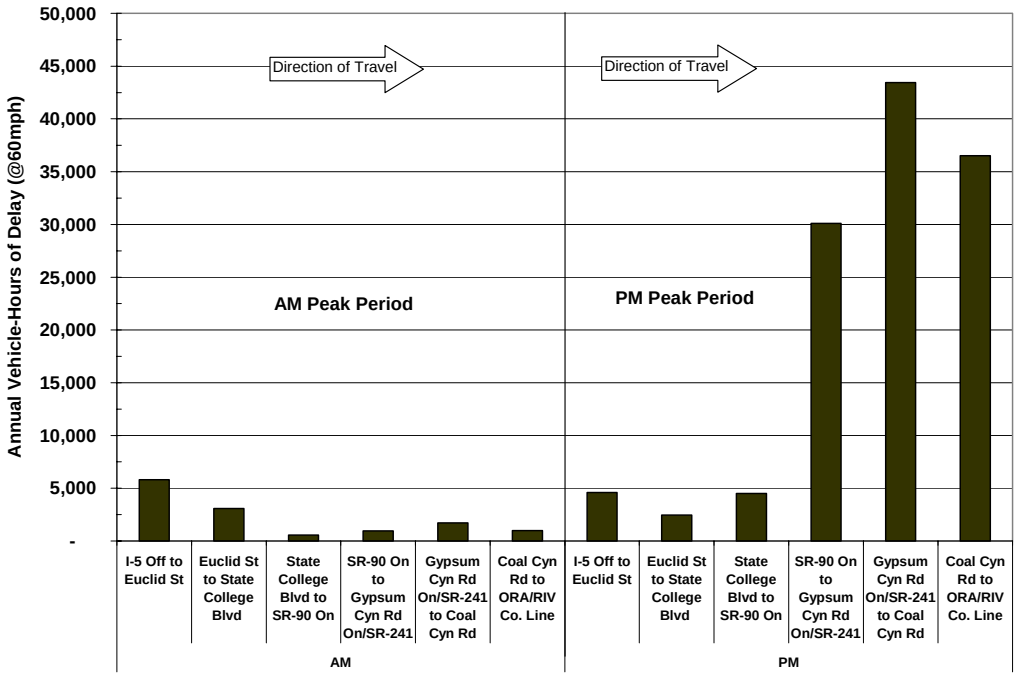


Exhibit 4-7: Westbound Annual Vehicle-Hours of Delay - 2007

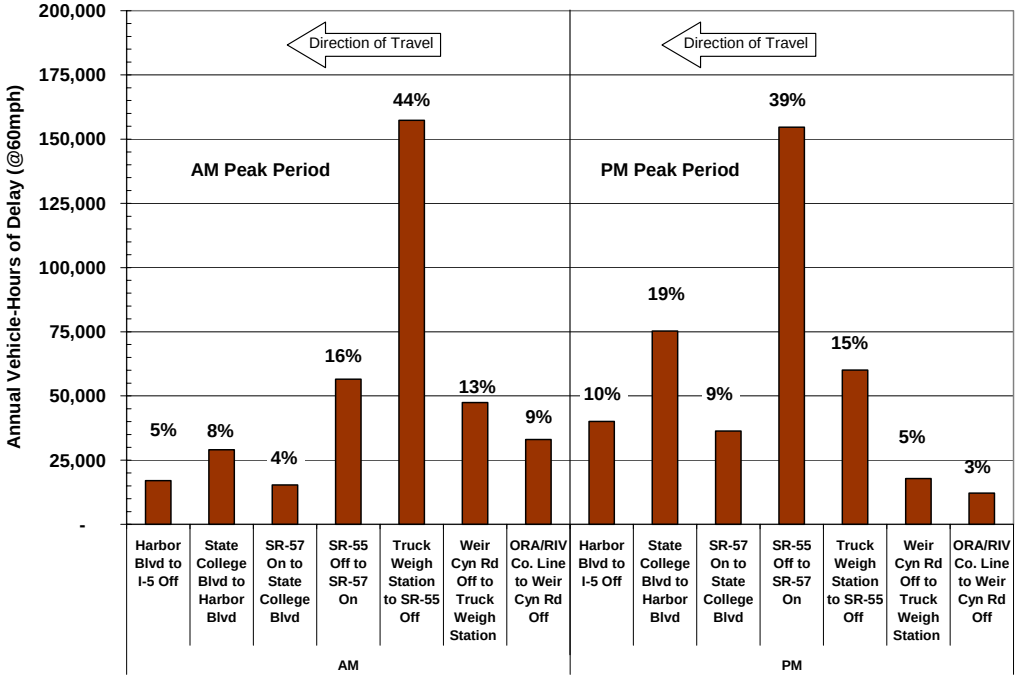
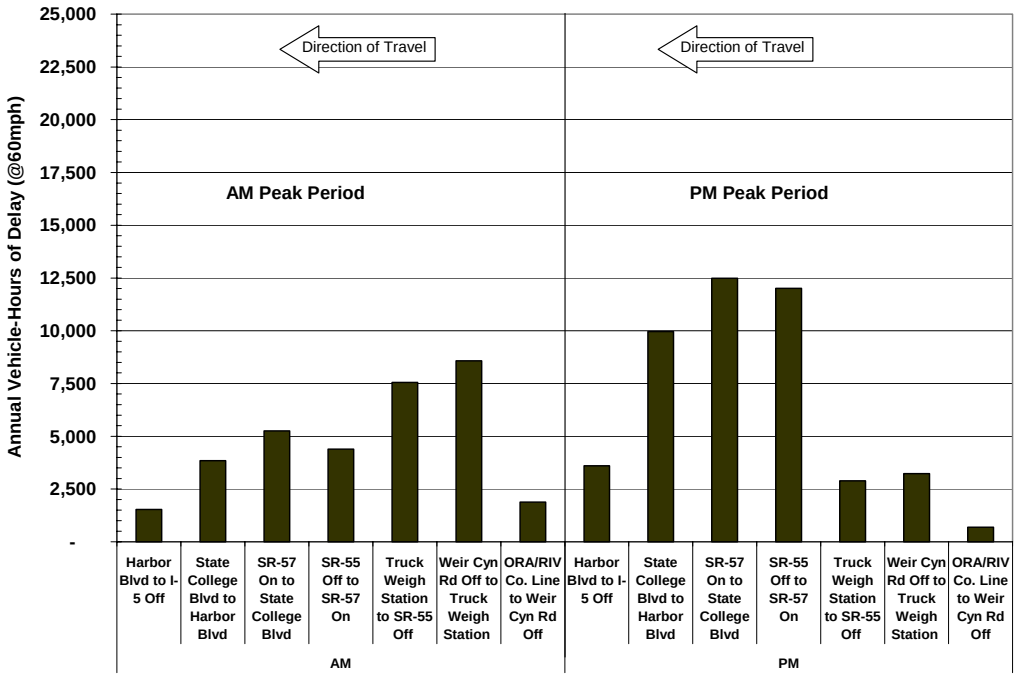


Exhibit 4-8: Westbound Delay per Lane Mile - 2007



Safety by Bottleneck Area

Concentrated highway collisions may be indicative of safety issues. TASAS produces a "Table C" that reports collision concentrations. It counts the total number of collisions for three, six, 12, 24, and 36-month periods. Locations with four or more collisions and significance in the three, six, or 12-month period are flagged as requiring investigation. Exhibits 4-9 and 4-10 shows the number of Table C collisions by bottleneck areas during three different 12-month periods. In the eastbound direction, the bottleneck area from SR-90 to Gypsum Canyon Road/SR-241 experienced the most Table C collisions with 213. In the westbound direction, the bottleneck area from SR-55 to SR-57 experienced the most Table C collisions, 222, during the July 2004-June 2007 period. These two bottleneck areas also experienced severe delay during the PM peak period. During the PM peak, the bottleneck area from SR-90 to Gypsum Canyon Road/SR-241 comprised over half of the total delay in the eastbound direction, and the area from SR-55 to SR-57 comprised 39 percent of the total delay in the westbound direction.

Exhibit 4-9: Eastbound SR-91 Table C Locations and Collisions

From		To		Bottleneck Area	Number of Table C Accidents[1]			
Abs	CA	Abs	CA		July 04-June 05	July 05-June 06	July 06-June 07	36 Mo Total
18.3	R3.6	20.7	2.4	From I-5 to Euclid St On	Not a Table C Location			
20.7	2.4	23.7	5.3	From Euclid St On to State College Blvd On	29	18	15	62
23.7	5.3	30.0	R11.7	From State College Blvd On to to SR-90 On	25	18	11	54
30.0	R11.7	34.7	R16.4	From SR-90 On to Gypsum Canyon Rd On/SR-241	88	58	67	213
34.7	R16.4	36.2	R17.8	From Gypsum Canyon Rd On/SR-241 to Coal Canyon Rd Interchange	26	28	25	79
36.2	R17.8	37.3	R18.9	From Coal Canyon Rd Interchange to ORA/RIV Co. Line	Not a Table C Location			
				Eastbound Total	168	122	118	408
				Eastbound and Westbound Total	295	229	206	730

[1] accidents reported quarterly in Caltrans' Table C. Table C reports list high accident concentration locations.

Exhibit 4-10: Westbound SR-91 Table C Locations and Collisions

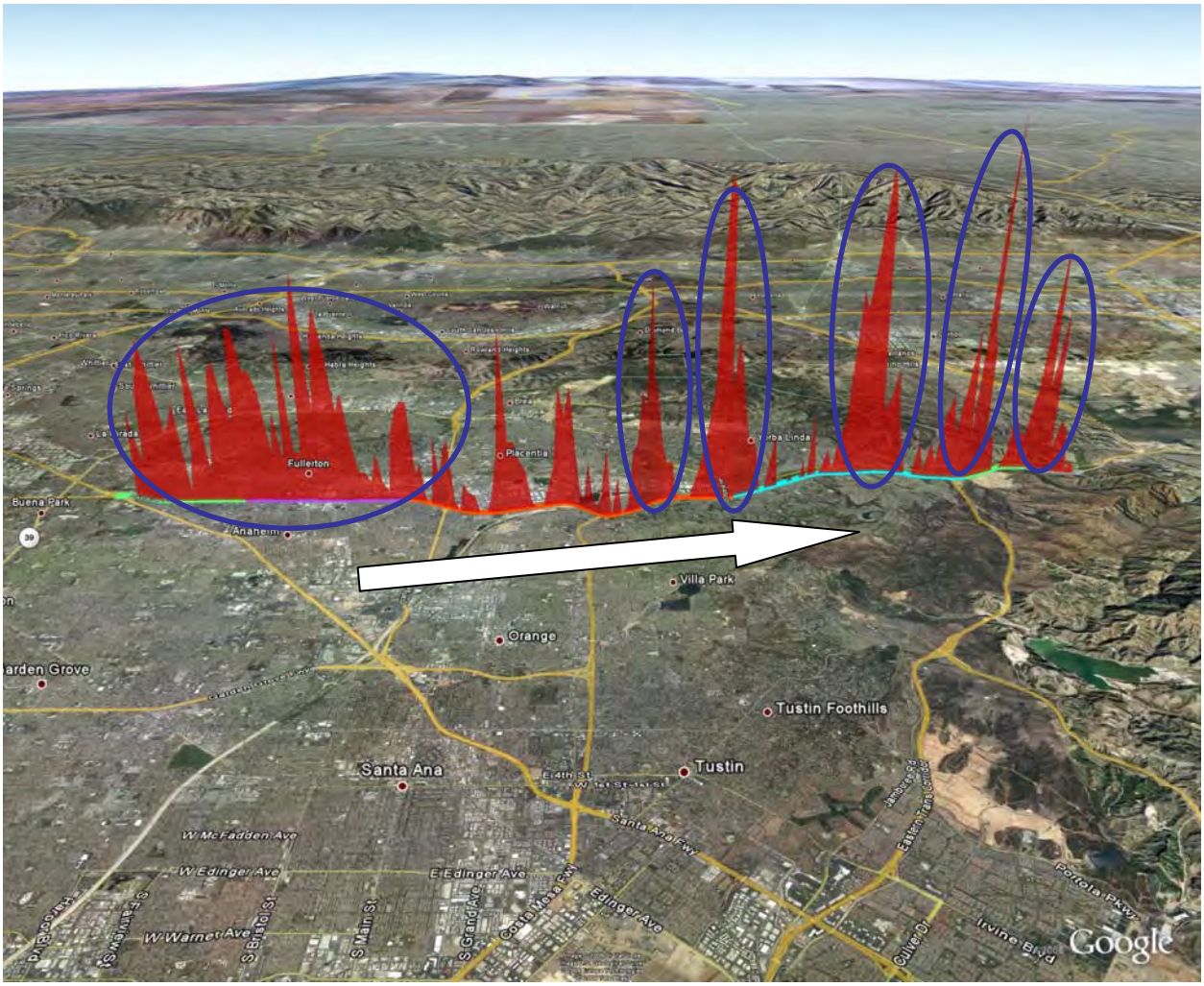
From		To		Bottleneck Area	Number of Table C Accidents[1]			
Abs	CA	Abs	CA		July 04-June 05	July 05-June 06	July 06-June 07	36 Mo Total
37.3	R18.9	32.9	R14.5	From ORA/RIV Co. Line to Weir Canyon Rd Off	25	20	19	64
32.9	R14.5	31.7	R13.3	From Weir Canyon Rd Off to Truck Weigh Station On	Not a Table C Location			
31.7	R13.3	27.2	R8.9	From Truck Weigh Station On to SR-55 Off	Not a Table C Location			
27.2	R8.9	24.4	6.05	From SR-55 Off to SR-57 On	81	82	59	222
24.4	6.05	23.5	5.14	From SR-57 On to State College Blvd On	Not a Table C Location			
23.5	5.14	21.5	3.13	From State College Blvd On to Harbor Blvd On	21	5	10	36
21.5	3.13	18.3	R3.6	From Harbor Blvd On to I-5	Not a Table C Location			
				Westbound Total	127	107	88	322

[1] accidents reported quarterly in Caltrans' Table C. Table C reports list high accident concentration locations.

Exhibit 4-11 shows the location of all collisions (Table C and other) plotted along the SR-91 corridor in the eastbound direction. The color coding along the corridor shows the extent of each bottleneck area. The spikes show the total number of collisions (fatality, injury, and property damage only) occurring within 0.1 mile segments during 2006. The highest spike corresponds to roughly 40 collisions in a single 0.1 mile location. The size of the spikes is a function of how collisions are grouped. If the data were grouped in 0.2 mile segments, the spikes would be higher.

However, the magnitude of these spikes is less interesting than the concentration. As Exhibit 4-11 shows, a large group of collisions occur near Fullerton between I-5 and SR-57. Other groupings occur at the curve near Lakeview Avenue, at the SR-90 (Imperial Highway) interchange, near Yorba Linda Boulevard, at the SR-241 interchange, and the curve in SR-91 east of SR-241. In many cases, a spike in the number of collisions occurs in the same location as a bottleneck. For example, a spike occurs at the SR-90 (Imperial Highway), which is also a bottleneck. This is shown as the transition from the red to the light blue area in Exhibit 4-11.

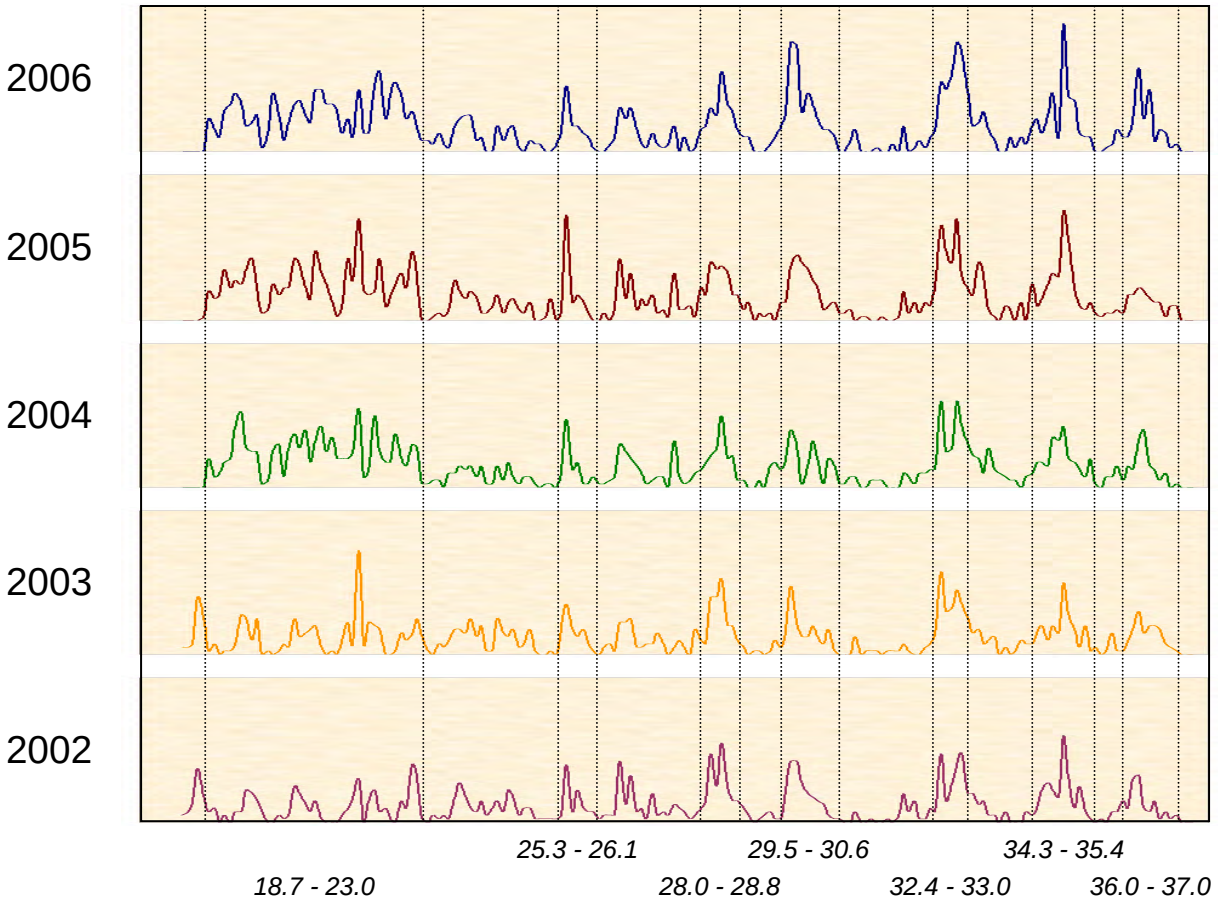
Exhibit 4-11: Eastbound SR-91 Location of Collisions - 2006



Source: SMG analysis of TASAS data

Exhibit 4-12 shows the same data over the last several years. As in Exhibit 4-11, the largest spike corresponds to roughly 40 collisions over 0.1 miles. Exhibit 4-12 shows that the pattern of collisions has stayed fairly consistent from one year to the next. However, the group of collisions near Fullerton has intensified (gotten worse) since 2002. The number of collisions occurring in the other five locations has also grown. This is probably a result of increased traffic and congestion.

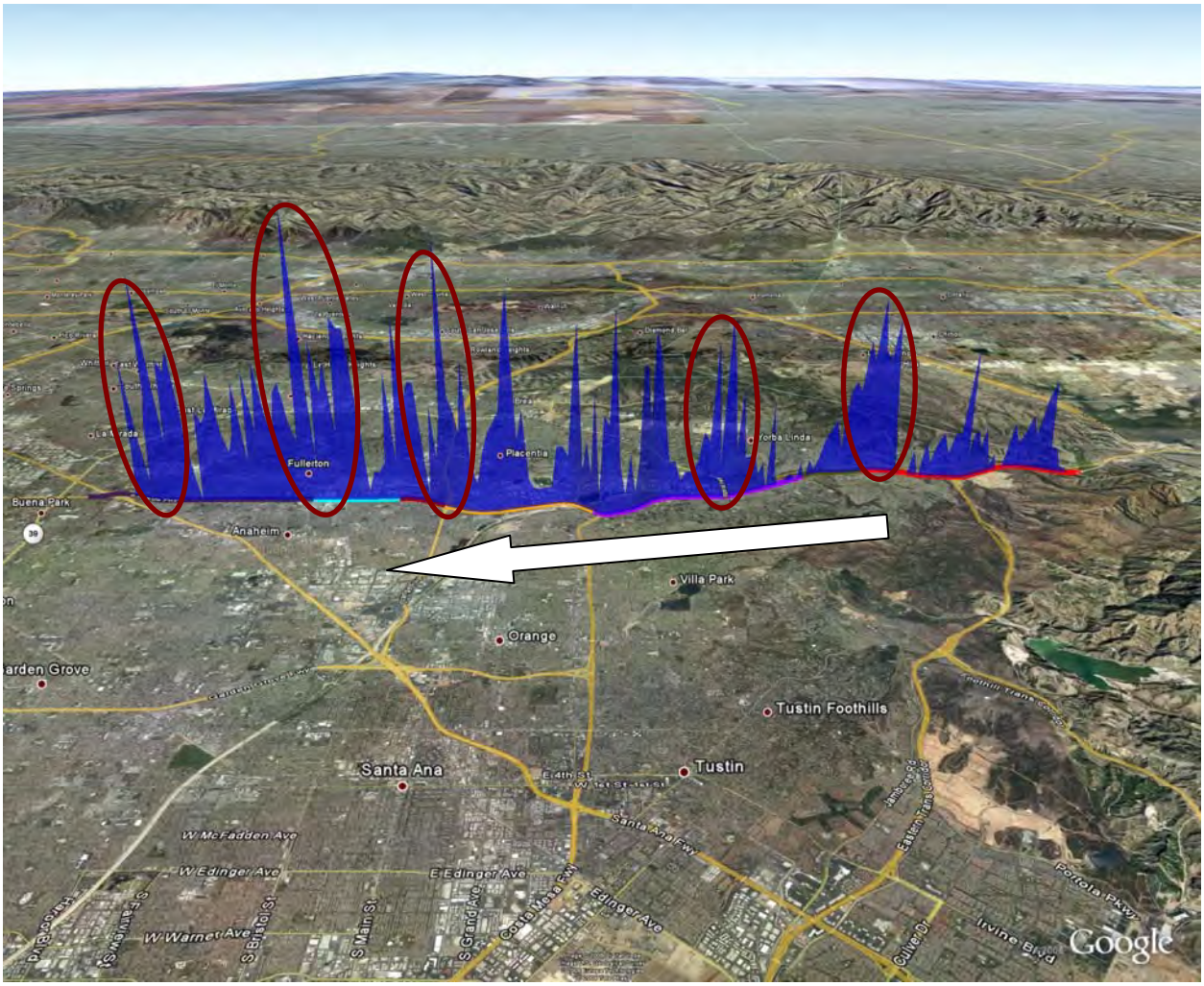
Exhibit 4-12: Eastbound SR-91 Location of Collisions 2002 - 2006



Source: SMG analysis of TASAS data

Exhibit 4-13 shows similar data for SR-91 in the westbound direction during 2006. As in the previous exhibits, the largest spike corresponds roughly to 40 collisions per 0.1 miles. The patterns in the westbound direction are similar to those in the eastbound direction, although the location of collisions near Fullerton is more uniform with just a few notable spikes.

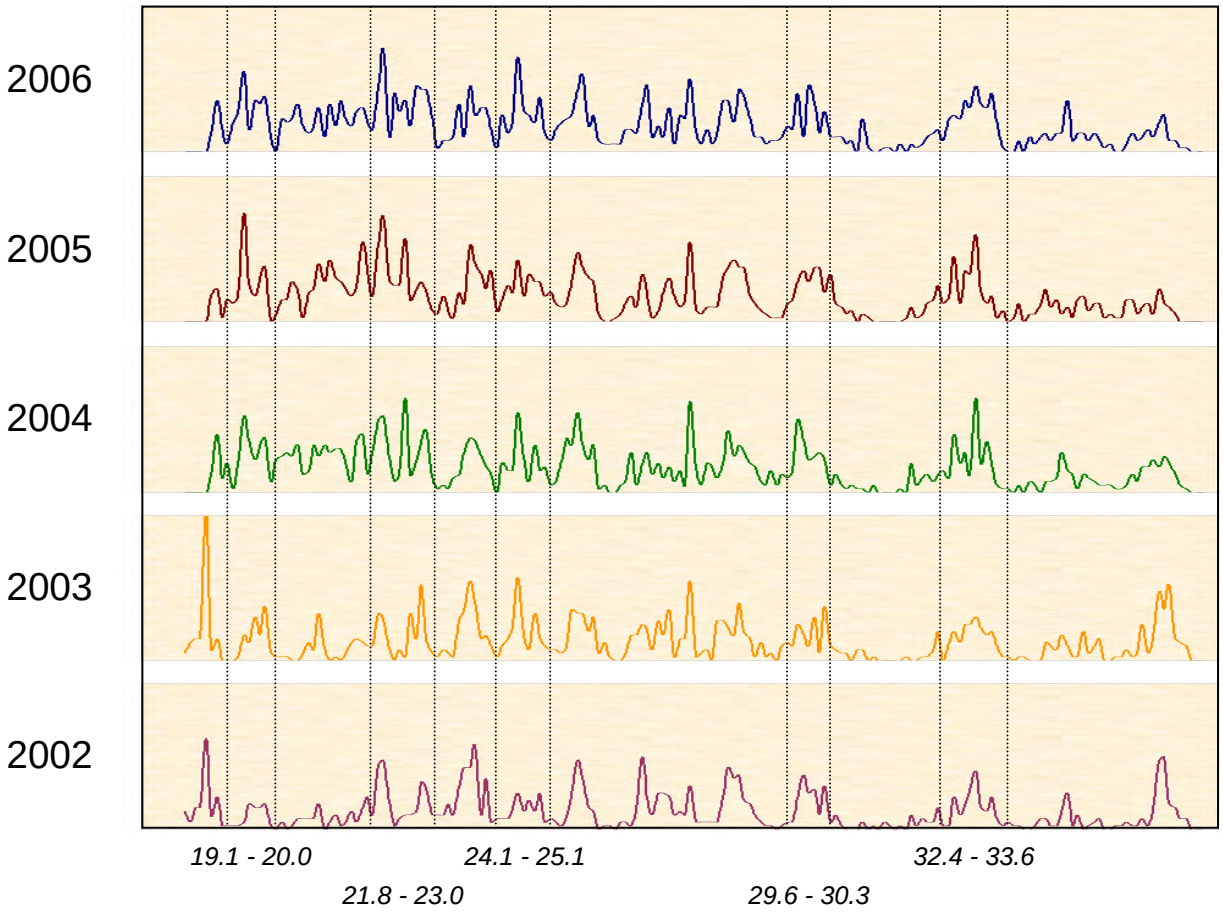
Exhibit 4-13: Westbound SR-91 Location of Collisions - 2006



Source: SMG analysis of TASAS data

Exhibit 4-14 shows the trend for the westbound direction since 2002. As the exhibit shows, the pattern of collisions has been fairly steady from one year to the next. The number of collisions has grown between I-5 and SR-57. It is also worth noting that a spike in collisions that occurred in the western end of the corridor in 2002 and 2003 has disappeared.

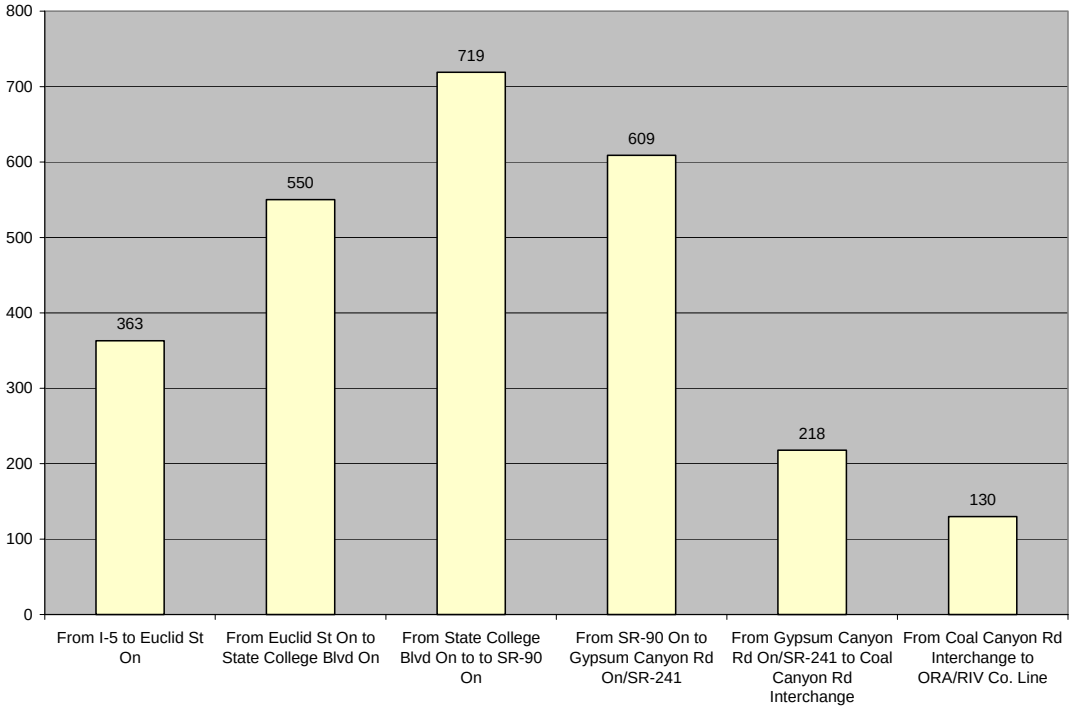
Exhibit 4-14: Westbound SR-91 Location of Collisions 2002 - 2006



Source: SMG analysis of TASAS data

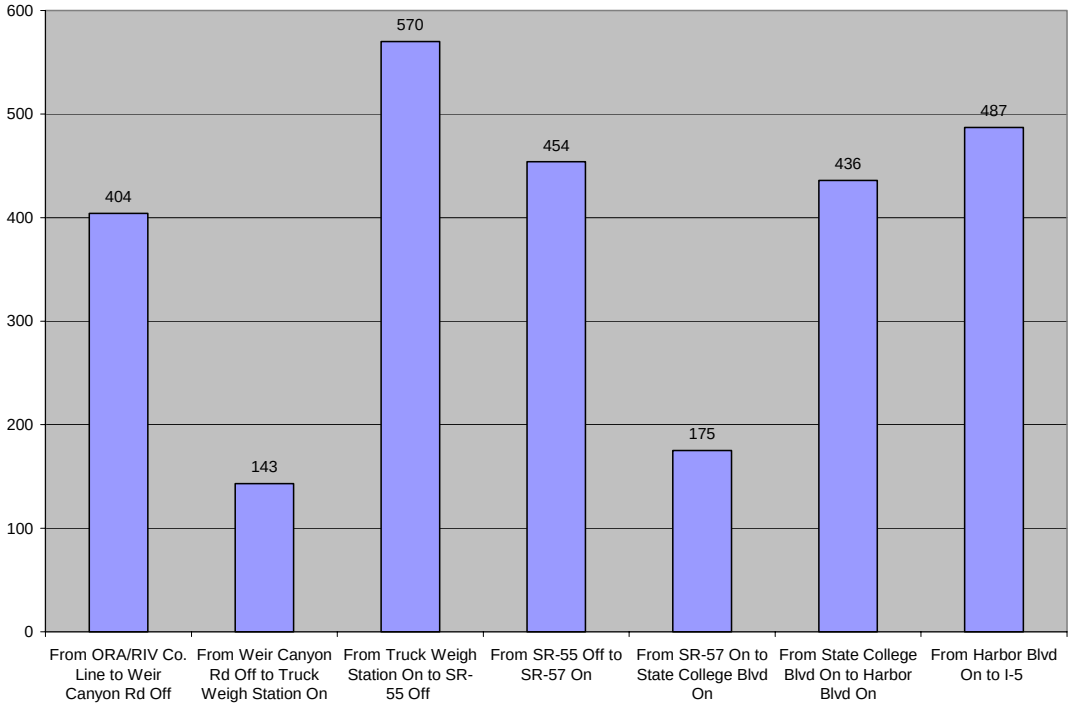
Exhibits 4-15 and 4-16 summarize the total number of accidents reported in TASAS by bottleneck area. The bars show the total of accidents from 2005 and 2006, the latest two years available in TASAS.

Exhibit 4-15: Eastbound SR-91 Total Accidents 2005-2006



Source: SMG analysis of TASAS data

Exhibit 4-16: Westbound SR-91 Total Accidents 2005 - 2006



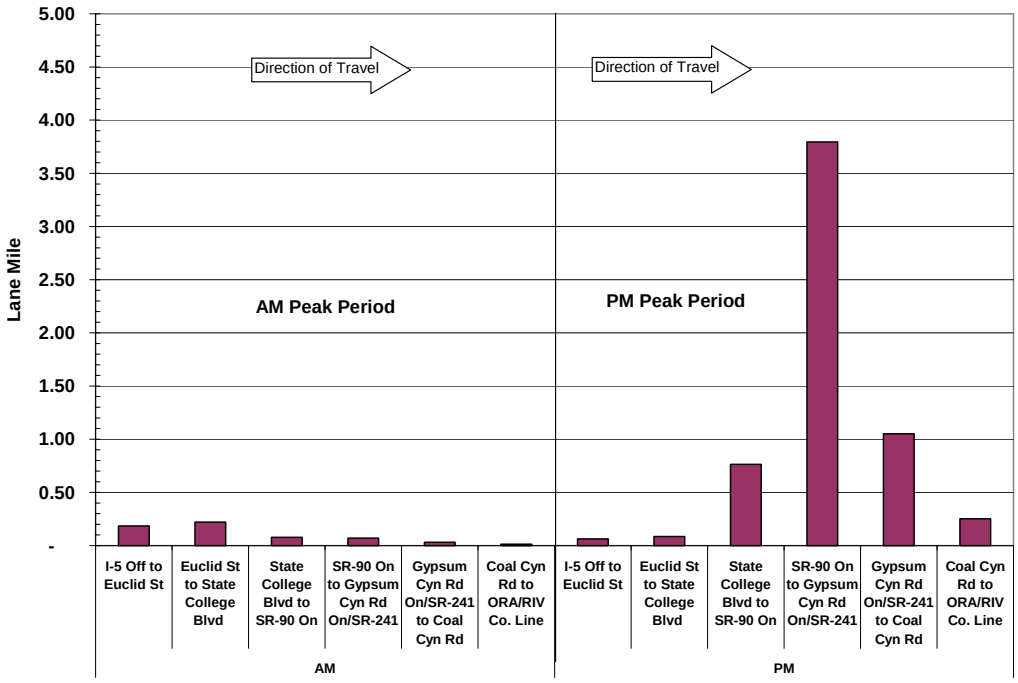
Source: SMG analysis of TASAS data

Productivity by Bottleneck Area

As previously discussed in Section 3, the productivity of a corridor is defined as the percent utilization of a facility or mode under peak conditions. Productivity is measured by calculating the lost productivity of the corridor and converting it into "lost lane-miles." These lost lane-miles represent a theoretical level of capacity that would have to be added in order to achieve maximum productivity.

Exhibits 4-17 and 4-18 show the productivity losses for both directions of the corridor. In the eastbound direction, the segment from SR-90 to Gypsum Cyn Rd On/SR-241 had the worst productivity of any segment on the study corridor. It experienced a productivity loss of 3.8 lane miles during the PM peak. During the AM peak, the eastbound direction experienced relatively high productivity with all segments of the corridor experiencing less than a quarter-mile of productivity loss.

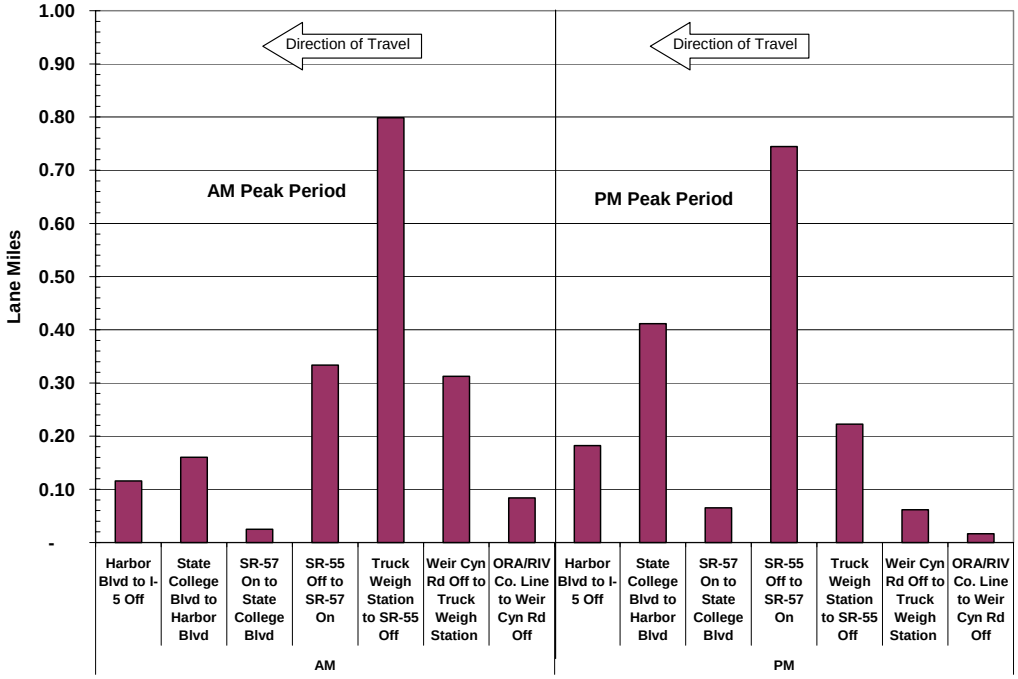
Exhibit 4-17: Eastbound SR-91 Lost Lane Miles - 2007



In the westbound direction, the segment from the Truck Weigh Station to SR-55 experienced the greatest productivity loss (0.8 mile) during the AM peak, while the segment from SR-55 to SR-57 experienced the highest productivity loss (0.74 mile) during the PM peak.

The segments of the corridor with the highest productivity losses coincide with the segments that experience the greatest annual vehicle-hours of delay.

Exhibit 4-18: Westbound SR-91 Lost Lane Miles - 2007



Page Intentionally Left Blank for Future Updates on Bottleneck Identification, Bottleneck Area Definition, and Performance Measures by Bottleneck Area

5. CAUSALITY ANALYSIS

Major bottlenecks are the primary cause of corridor performance degradation and the resulting congestion and lost productivity. It is important to verify the actual location and cause(s) of each major bottleneck to determine traffic operational problems.

The actual location of each major bottleneck is verified by multiple field observations on separate days. The cause(s) of each major bottleneck is also identified by field observations and additional traffic data analysis. For the SR-91 study corridor, field observations were conducted by the project consultant team on August 27, 2008 (Wednesday), September 10, 2008 (Wednesday), and October 9, 2008 (Thursday) during the AM and PM peak hours.

By definition, a bottleneck is a condition where traffic demand exceeds the capacity of the roadway facility. In most cases, the cause of bottlenecks is related to a sudden reduction in capacity, such as roadway geometry, heavy merging and weaving, and driver distractions; or a surge in demand that the facility cannot accommodate. In many cases, it is a combination of increased demand and capacity reductions. Below is a summary of the causes of the bottleneck locations.

Eastbound Bottlenecks and their Causes

The eastbound bottlenecks and congestion occur in both AM and PM peak hours. The most significant bottlenecks and congestion, however, occur in the PM peak hour at the SR-241 connector on-ramp and Coal Canyon interchange. The following is a summary of the eastbound bottlenecks and the identified causes.

<u>I-5 to State College Boulevard</u>

Several bottlenecks were identified from the data analysis between I-5 and State College Boulevard (AbsPM=18.06/23.8;CaPM=R3.3/5.4), notably at I-5/Magnolia Avenue, Euclid Street, Harbor Boulevard/Lemon Street, and State College Boulevard. However, none of these bottlenecks were observed in the recent field visits. This could be from the reduction in the overall travel demand in recent years due to the higher gasoline prices. As a result, the actual bottleneck locations could not be verified or causes determined, from the field observations.

<u>State College Boulevard to SR-90 On</u>

Bottlenecks were also identified from the data analysis between State College Boulevard and SR-90 on-ramp (AbsPM=23.8/30.1;CaPM=5.4/R11.7), notably at SR-57, Glassell Street, and SR-90 (Imperial Highway) interchanges. However, none of these bottlenecks were observed in the recent field visits. Exhibit 5-1 is an aerial photograph

of the eastbound SR-91 mainline at the SR-90, Imperial Highway interchange. As shown, there are two consecutive on-ramps from the Imperial Highway that merges into the freeway mainline. Although the volumes are fairly low at below 700 vph for the two ramps combined, the consecutive merges are likely to cause the freeway speeds to be reduced. Also, some slow-down and queuing were noticed at the SR-57 connector off-ramp, causing the speed of the outer lanes to slow down.

Exhibit 5-1: Eastbound SR-91 at SR-90 (Imperial Highway) On

Gypsum Canyon Road/SR-241 On to Coal Canyon Road

Exhibit 5-2 is an aerial photograph of the eastbound SR-91 mainline at Gypsum Canyon Road/SR-241 (AbsPM=34.8/36.1;CaPM=R16.5/R17.8). As shown, traffic from Gypsum Canyon Road merges into the freeway mainline via consecutive ramps. The merging volume exceeds 1,200 vph. Just past the consecutive ramps is the northbound SR-241 to eastbound SR-91 connector on-ramp. It is a two-lane connector that merges into one new mainline lane. This connector carries over 2,000 vph during the PM peak hours. The effects of the heavy consecutive ramp merging and additional demand are compounded by the long steep grade as shown on Exhibit 5-10. The photo also shows the mainline traffic congestion and the ramp merging from Gypsum Canyon Road on-ramps, followed by the SR-241 connector traffic.

The bottleneck from the Gypsum Canyon Road on-ramps merging and the bottleneck from the heavy additional demand from the SR-241 connector on-ramp are hidden in the congestion queue by the third major bottleneck at the crest of the mountain terrain approaching the Coal Canyon Road interchange, where the outside lane (new lane from SR-241 connector on-ramp) is dropped. Exhibit 5-3 illustrates this location. The next downstream bottleneck is beyond Green River Road interchange and into Riverside County.

Exhibit 5-2: Eastbound SR-91 at Gypsum Canyon Road/SR-241 On

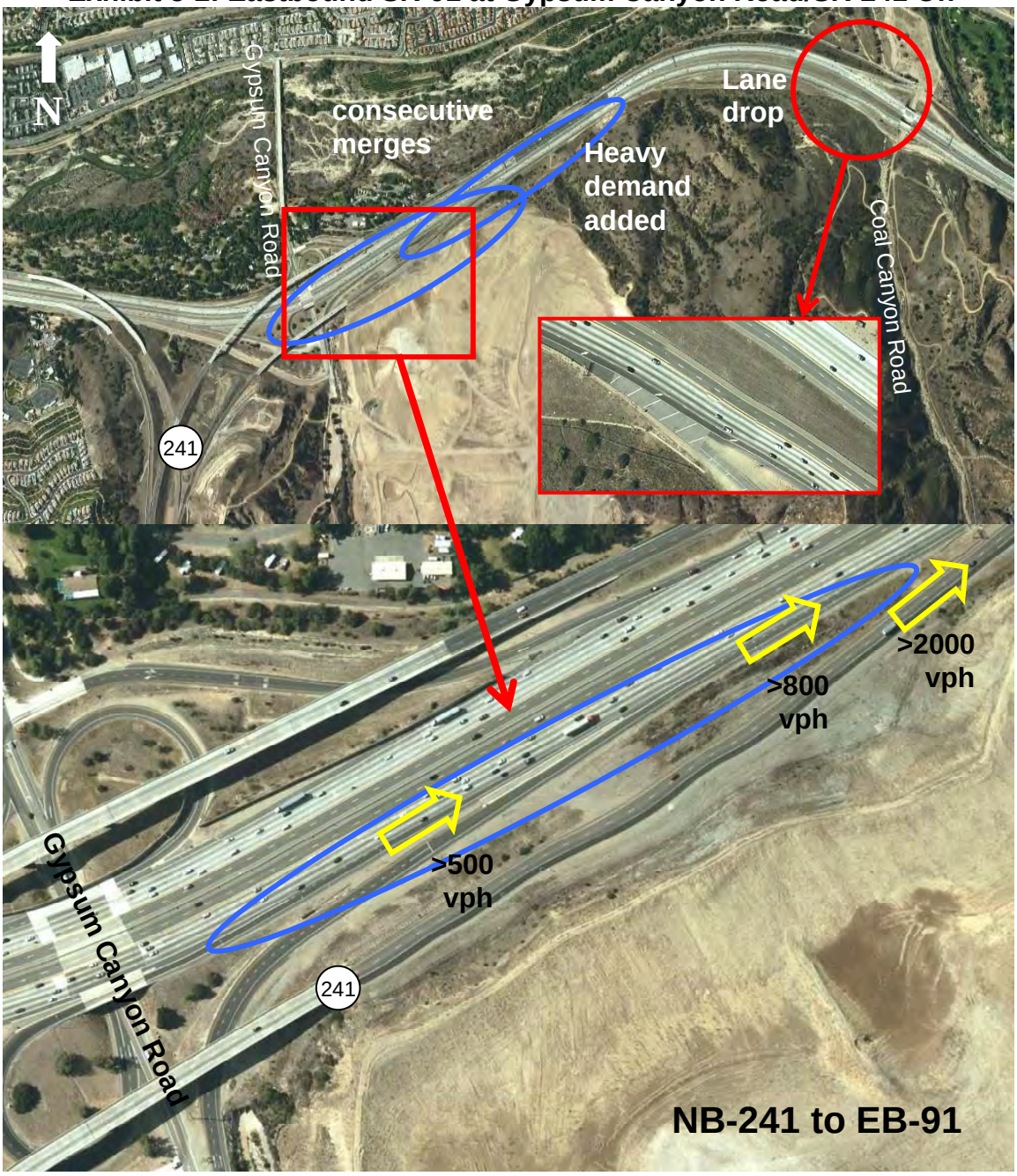


Exhibit 5-3: Eastbound SR-91 at Gypsum Canyon Road/SR-241 On

Exhibit 5-4: Eastbound SR-91 Approaching Coal Canyon Road

Westbound Bottlenecks and their Causes

Major westbound bottlenecks and congestion often occur during both the AM and PM peak hours. Minor bottlenecks, however, typically occur during AM peak hours. The following is a summary of the westbound bottlenecks and the identified causes.

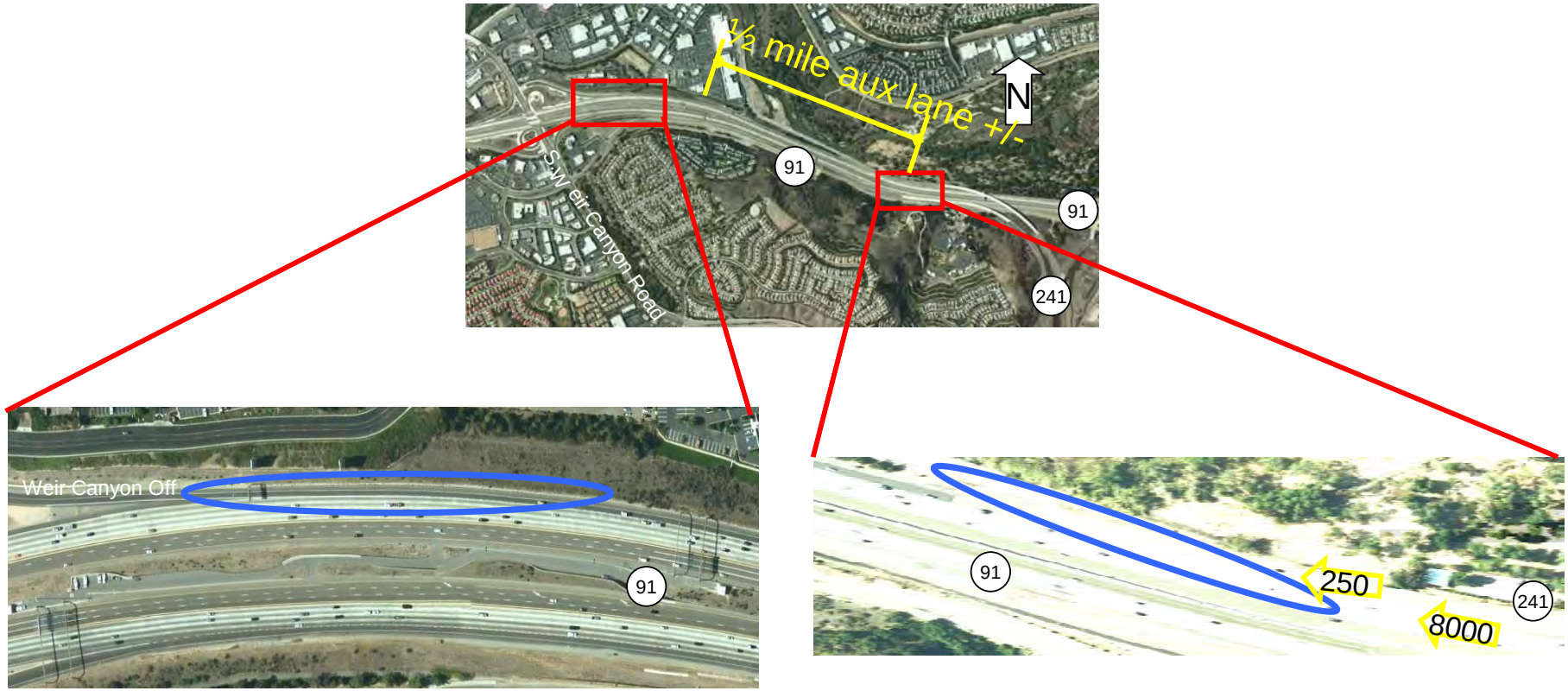
<u>SR 241 On to Weir Canyon Road Off</u>

Exhibit 5-5 are aerial photographs of the westbound SR-91 mainline approaching Weir Canyon Road off-ramp (AbsPM=34.1/33.1; CaPM=R15.7/R14.7). Traffic from the northbound SR-241 traffic merges into the westbound SR 91 mainline traffic. The primary cause of this bottleneck is the traffic from the SR-241 on-ramp and the loss of over half-mile auxiliary lane at the Weir Canyon Road off-ramp. The bottom photographs in Exhibit 5-1 show the two-lane connector that merges into one auxiliary lane (at the bottom right of the page) and the very long, over 3400 feet, auxiliary lane that ends at the Weir Canyon Road off-ramp (at the bottom left of the page).

Typically the outer lanes are most affected and have the slower speeds. Recent counts conducted in June of 2008 indicate that the NB-241 to WB-91 connector on-ramp

volumes are about 250 vehicles in the AM peak hour and over 800 in the PM peak hour. Typically, this bottleneck and congestion occurs in the very early AM hours between 5AM and 6:30AM where the mainline volume is near 8,000 vehicles per hour (vph) or 2,000 vph per lane.

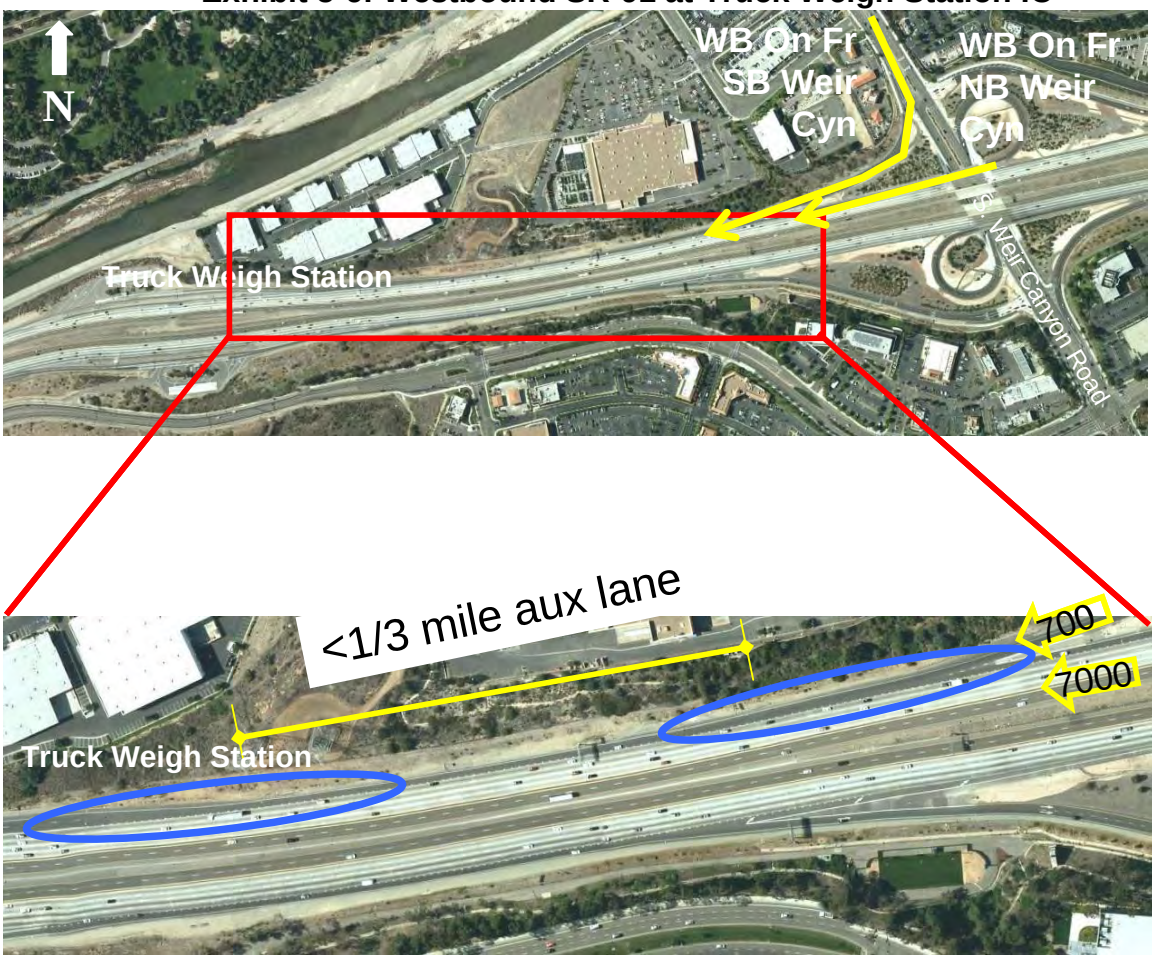
Exhibit 5-5: Westbound SR-91 at SR 241/Weir Canyon Road IC



Weir Canyon Road On to Truck Weigh Station

Exhibit 5-6 are aerial photographs of the westbound SR-91 mainline between Weir Canyon Road and the Truck Weigh Station (AbsPM=32.0/30.2; CaPM=13.6/R11.8). There are two on-ramps from Weir Canyon Road that merge into one auxiliary lane, which ends at the weigh station. The primary cause of this bottleneck is the heavy traffic from the Weir Canyon on-ramps merging into the freeway traffic, nearly 1,400 vph combined while mainline volume exceeds 7,000 vph during the peak hours. The auxiliary lane (approximately 2,000 feet in length) helps to diffuse the merging but on many occasions, the mainline cannot accommodate the additional demand during the peak hours. Ramp metering is less effective here since the ramp metering location for each ramp is too far up the ramp. As a result, platoons occur as the traffic from the two ramps merge down the auxiliary lane.

Exhibit 5-6: Westbound SR-91 at Truck Weigh Station IC



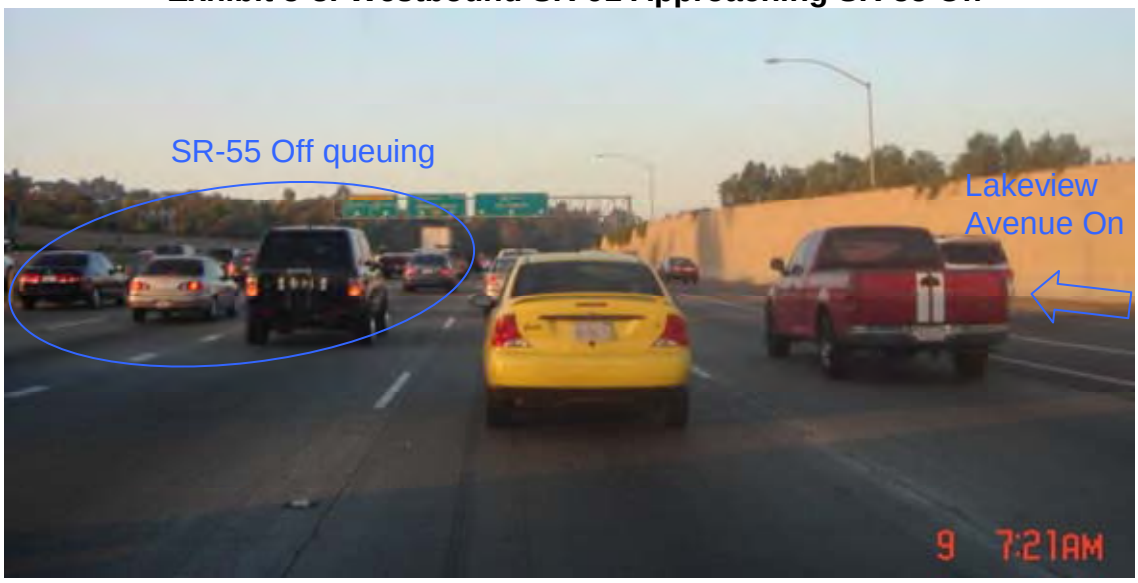
Lakeview Avenue On to SR-55 Off

Exhibit 5-7 are aerial photographs of the westbound SR-91 mainline between Lakeview Avenue on-ramp and the SR-55 connector off-ramp (AbsPM=27.5/27.3; CaPM=9.1/8.9). As indicated, the five-lane mainline splits off into two lanes to southbound SR-55 to the left and three lanes continuing on westbound SR-91 to the right.

Exhibit 5-7: Westbound SR-91 at SR-55 Off

Extensive queuing from the SR-55 connector off-ramp and cross-weaving from the Lakeview Avenue on-ramp to the SR-55 connector off-ramp were noticed in the field observations during the AM and PM peak hours. The queuing from the SR-55 connector off-ramp caused blockage of the SR-91 through-lanes with vehicles trying to squeeze into the queued traffic. The queuing often extended past the Lakeview Avenue on-ramp. The Lakeview Avenue on-ramps exceed, 1,100 vph combined during both the AM and PM peak hours. The SR-55 connector off-ramp exceeds 1,200 vph during the peak hours. Exhibit 5-8 is a photograph of the SR-55 connector off-ramp approach during the AM peak, illustrating the queuing.

Exhibit 5-8: Westbound SR-91 Approaching SR-55 Off



SR-57 On to State College Boulevard

Exhibit 5-9 are aerial photographs of the consecutive SR-57 connector on-ramps to westbound SR-91 (AbsPM=24.2/23.8); CaPM=5.8/5.4). The northbound SR-57 to westbound SR-91 is a tight loop ramp that merges into the outside lane (lane 3). Due to the short radius of the loop ramp, vehicles are traveling at slow speeds when merging into the mainline lane, forcing the mainline speeds to slow down. Based on the field observations, platoon merging was frequent from this ramp. Just past this merge point, the southbound SR-57 connector on-ramp enters the auxiliary lane, approximately 1,500 feet long, to State College Boulevard off-ramp. Essentially, all of the SR-57 connector traffic enters the westbound SR-91 mainline. During the peak hours when the mainline traffic flow is near capacity levels, the additional demand from the two connector ramps overloads the mainline, causing the freeway flow to break down and forming the bottleneck. Mainline volumes to the east of the SR-57 interchange is over 6,000 vph (2,000 vph per lane) during the peak hours, before congestion begins, and over 7,000 vph (2,300 vph per lane) through the traffic congestion. The two consecutive SR-57 connector on-ramp volumes reach over 1,700 vph combined during

the peak hours. This bottleneck and congestion occurs during the both the AM and PM peak hours. Exhibit 5-10 are photos that illustrate the platoon merging from the two consecutive connector ramps. Due to the slow speeds and density of the traffic flow, the traffic congestion does not recover until past the crest of the uphill grade at State College Boulevard interchange. Exhibit 5-11 are photos that illustrate the short relief past the SR-57 on-ramp bottleneck and reforming of the congestion until past the State College Boulevard overcrossing.

Exhibit 5-9: Westbound SR-91 at SR-57 On

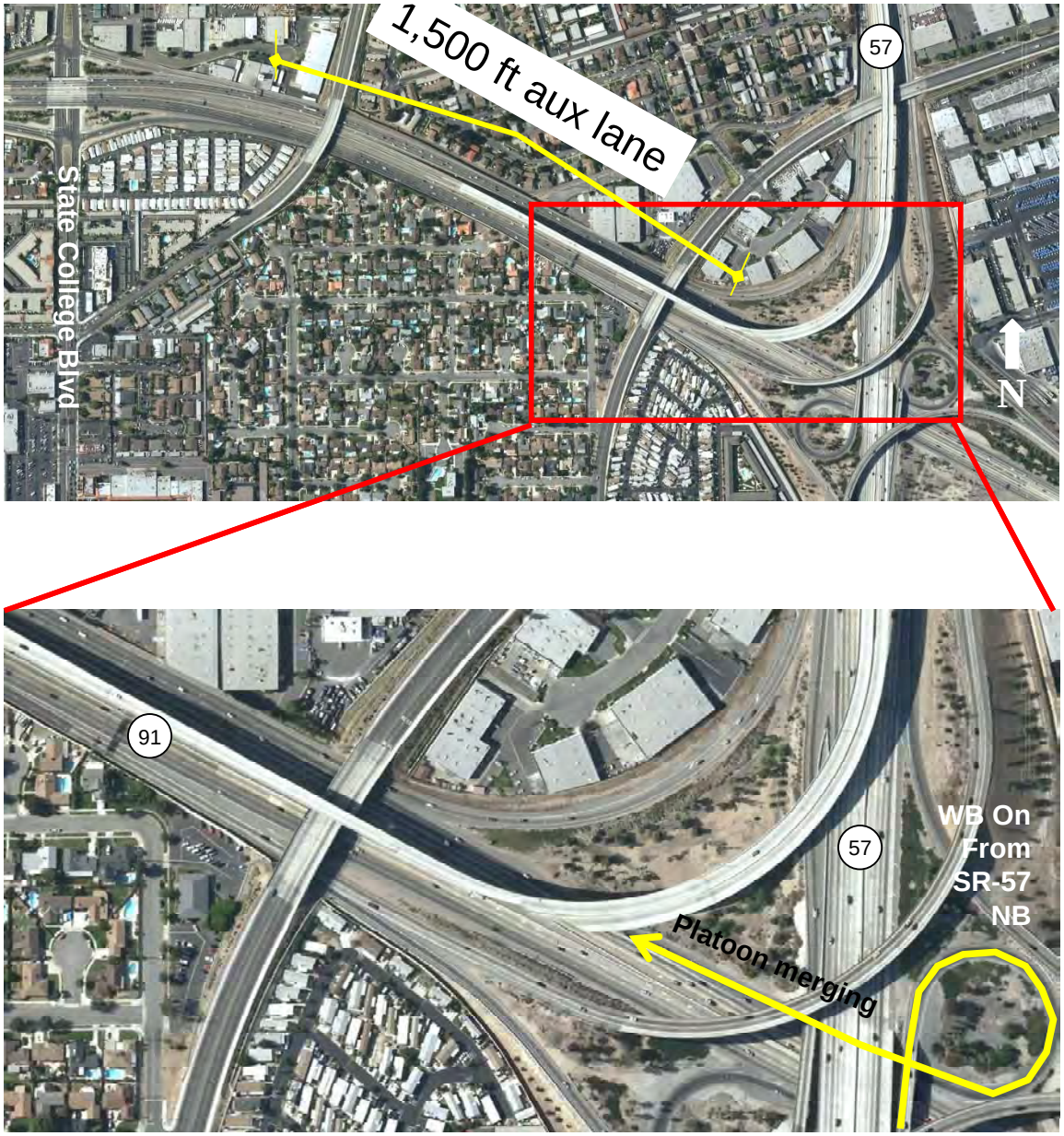
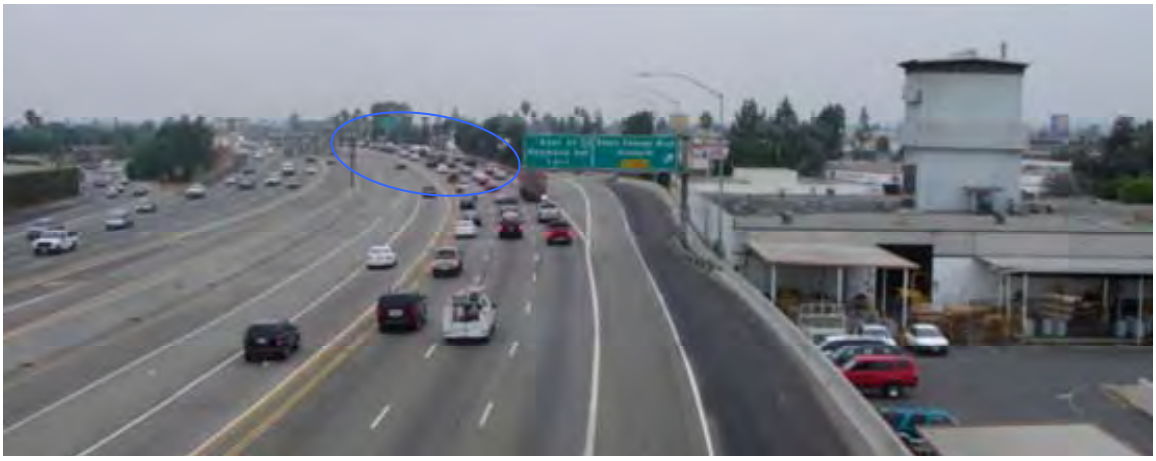


Exhibit 5-10: Westbound SR-91 at SR-57 On

Exhibit 5-11: Westbound SR-91 Approaching State College Boulevard



East Street to I-5

Several bottlenecks were identified from the data analysis between East Street and I-5 interchange, notably at Harbor Boulevard (AbsPM=20.8;CaPM=2.4), Euclid Street (AbsPM=19.8,CaPM=1.4) and Brookhurst Road/I-5 Off (AbsPM=19.0;CaPM=0.5). However, none of these bottlenecks were observed in the recent field visits. Still, reduced speeds to 45 miles per hour or slightly less were observed at the Harbor Boulevard, Euclid Street, and Brookhurst Road interchanges, primarily due to the changes in the vertical grade (rolling hills) over and under the interchanges that reduces sight distance. When mainline flows are at their peak through this segment of the corridor, it is likely that minor bottlenecks are formed due to the slower speeds. The ramp traffic at these interchanges did not seem to adversely affect the mainline speeds.

Page Intentionally Left Blank for Future Updates on Bottleneck Causality

Appendix – Bottleneck Analysis from Preliminary Performance Assessment

APPENDIX

This appendix is an exact copy of Section 4 of the Preliminary Performance Assessment document developed and submitted to Caltrans in June, 2008. It is included for reference purposes and also to allow future updates to this analysis. The analysis identified potential bottlenecks based on a number of data sources and very limited field observations. However, it represented the foundation for the conclusions in Section 4 of this Comprehensive Performance Assessment report, which built on the original findings and then revised and/or confirmed these conclusions with significant field observations and additional data analysis.

A4. BOTTLENECK ANALYSIS

This section of the report presents the potential bottleneck locations identified throughout the study corridor. Potential freeway bottleneck locations that create mobility constraints are identified and documented, and their relative contribution to corridor-wide congestion is reported.

A variety of sources were used to identify bottlenecks. They include:

- Caltrans Highway Congestion Monitoring Program (HICOMP) 2006 report;
- Probe vehicle runs (electronic tach runs)
- Freeway Performance Measurement System (PeMS)
- Aerial photos (Google Earth) and Caltrans photologs

HICOMP

In review of the Caltrans Highway Congestion Monitoring Program (HICOMP) Report, potential problem areas are initially identified. As illustrated in Exhibit 4-1 and 4-2, the downstream end of congested segments could potentially be bottleneck areas in the westbound direction, as outlined in blue circles, and in the eastbound direction, as outlined in red circles, within the corridor limits.

- In the **AM peak**, there is potentially one major bottleneck in the westbound direction and one major bottleneck in the eastbound direction, as identified in the 2007 HICOMP:
    - Lemon Street (eastbound)
    - Raymond Avenue (westbound)
- In the **PM peak**, there is potentially one major bottleneck in the westbound direction and two major bottlenecks in the eastbound direction, as identified in the 2007 HICOMP:
    - Brookhurst Street (eastbound)
    - Raymond Avenue (westbound)
    - Lakeview Avenue (eastbound)

Further analysis would be needed to determine the actual locations and possibly any other bottlenecks along the corridor not identified in the HICOMP. The review of the HICOMP provides a good starting point to keep in mind of the congested areas and possible bottleneck locations as more detailed analysis is conducted.

Exhibit A4-1: 2007 HICOMP AM Congestion Map with Potential Bottlenecks

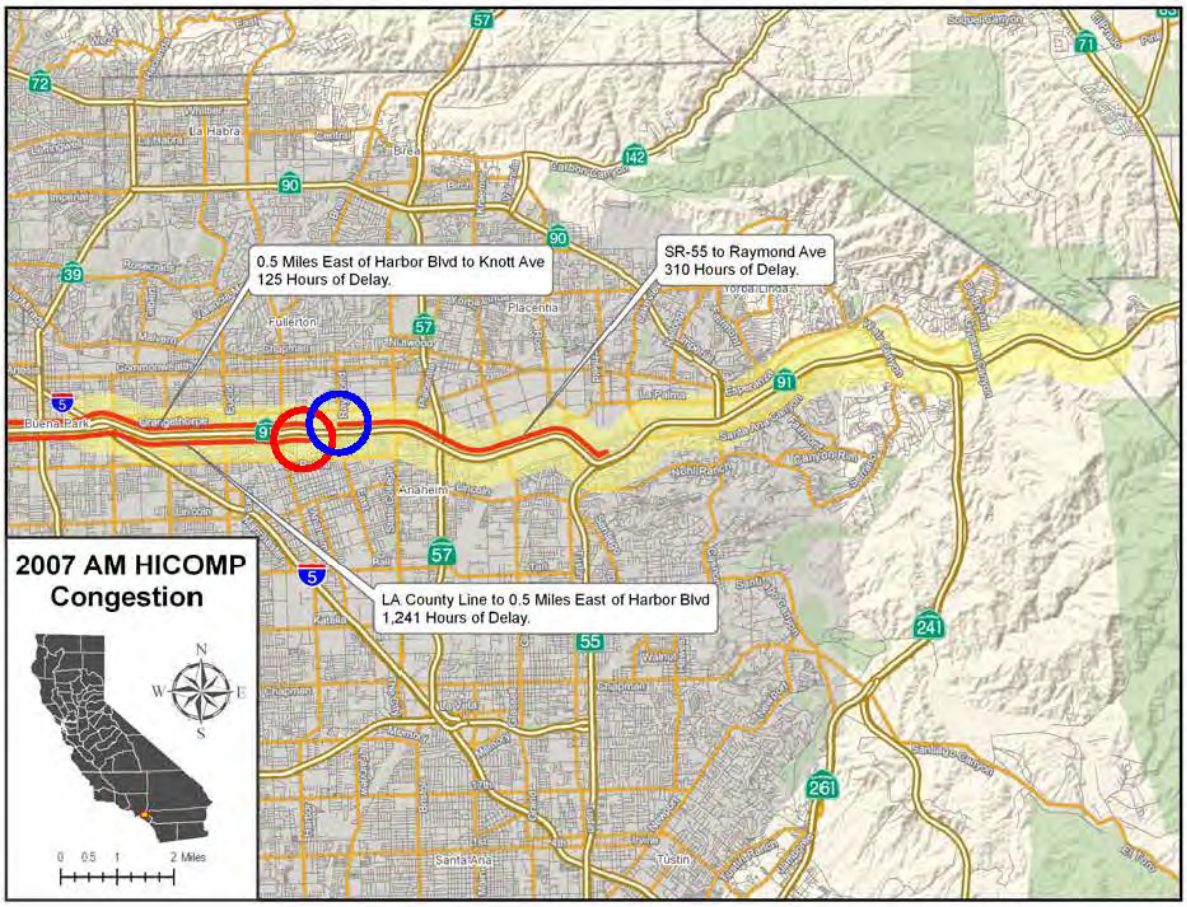
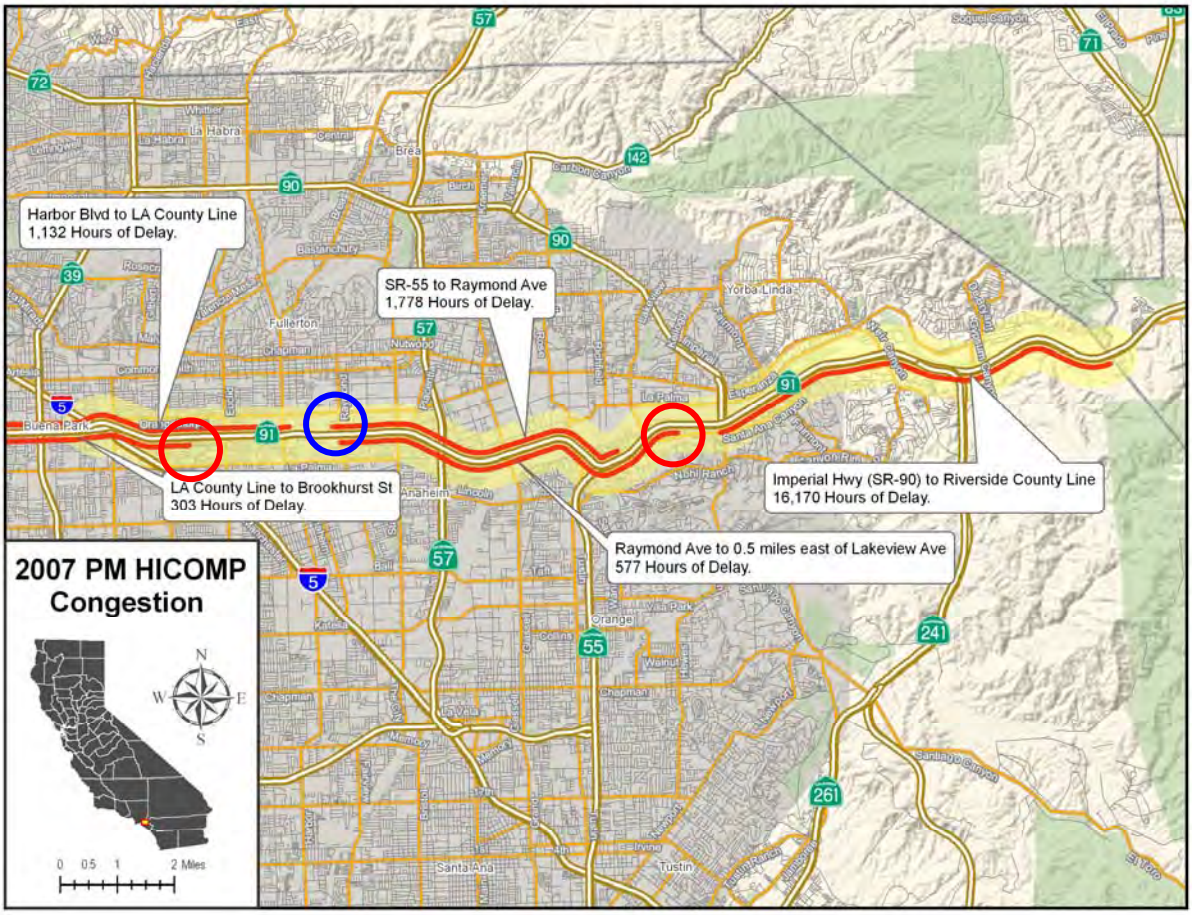


Exhibit A4-2: 2007 HICOMP PM Congestion Map with Potential Bottlenecks



Probe Vehicle Runs

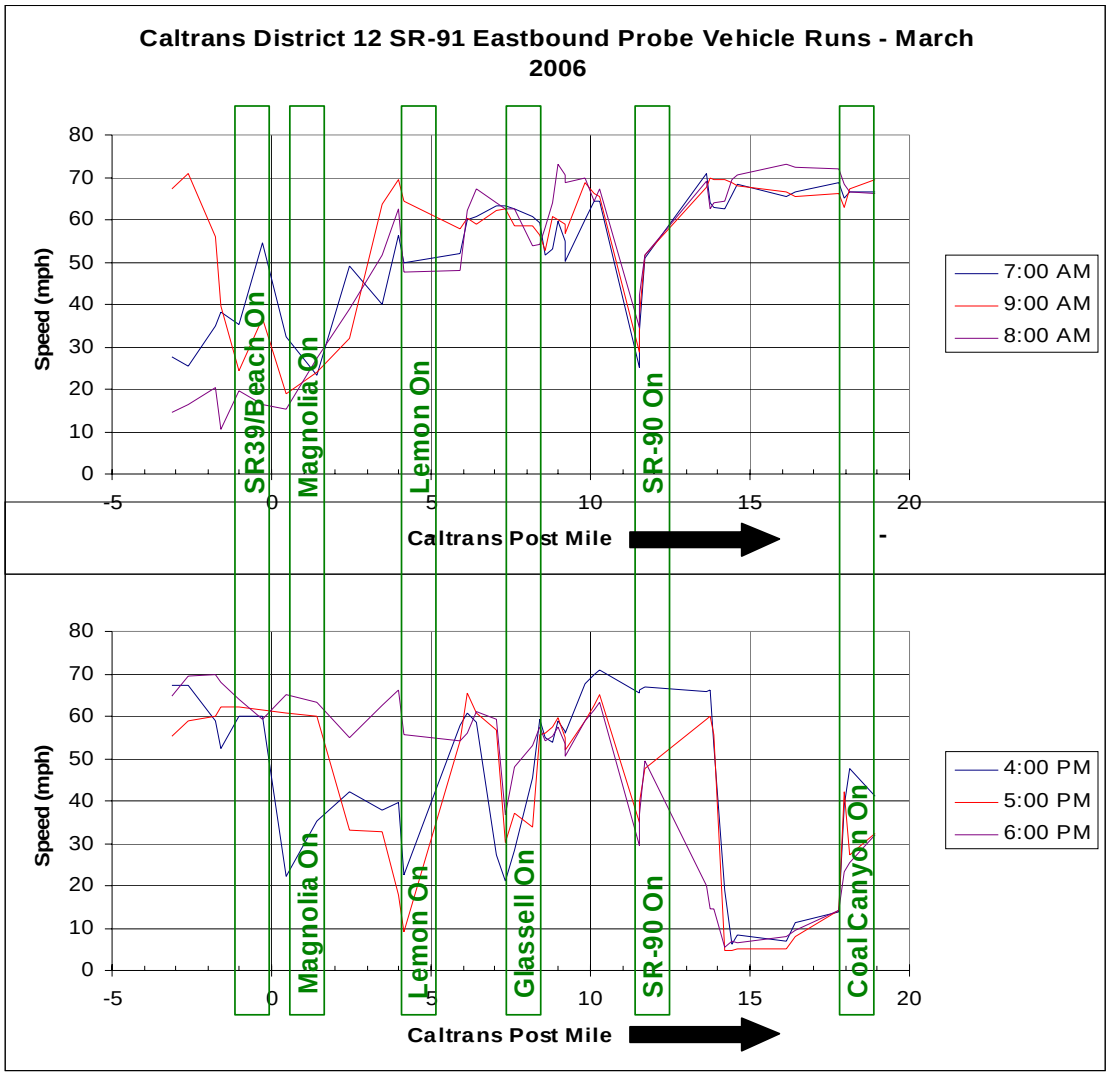
The probe vehicle runs (electronic tach runs) provide speed plots across the corridor at various departure times. A vehicle equipped with an electronic (GPS or tachograph) device is driven along the corridor at various departure times, typically in a middle lane, during the peak period, at regular, 20 to 30 minute intervals. Actual speeds are recorded as the vehicle traverses the corridor length. Bottlenecks can be found at the end of a slow congested speed location where speeds pick up to 30 miles per hour to 50 miles per hour.

Caltrans District 12 collected probe vehicle run data in March 2006 for the SR-91 freeway from the Los Angeles County Line to the Riverside County Line. The freeway corridor runs were broken into three separate segments from the Los Angeles County Line (Carmenita Road) to East Street, East Street to Imperial Highway, and Imperial Highway to the Riverside County Line (Green River Road). For each segment, the runs were conducted from approximately 6AM to 10AM and from 3PM to 7:30PM. Exhibit 4-

3 illustrates the SR-91 westbound probe vehicle run at 7AM, 8AM, 9AM, 4PM, 5PM, and 6PM conducted on separate days in March 2006. As indicated, there are slow speeds (congestion) and bottleneck evident in both the AM and PM peak hours in the westbound direction.

Exhibit 4-3 illustrates the SR-91 eastbound probe vehicle runs also at 7AM, 8AM, 9AM, 4PM, 5PM, and 6PM conducted on separate days in March 2006. As indicated, there are slow speeds (congestion) and bottleneck evident in both the AM and PM peak hours in the eastbound direction as well.

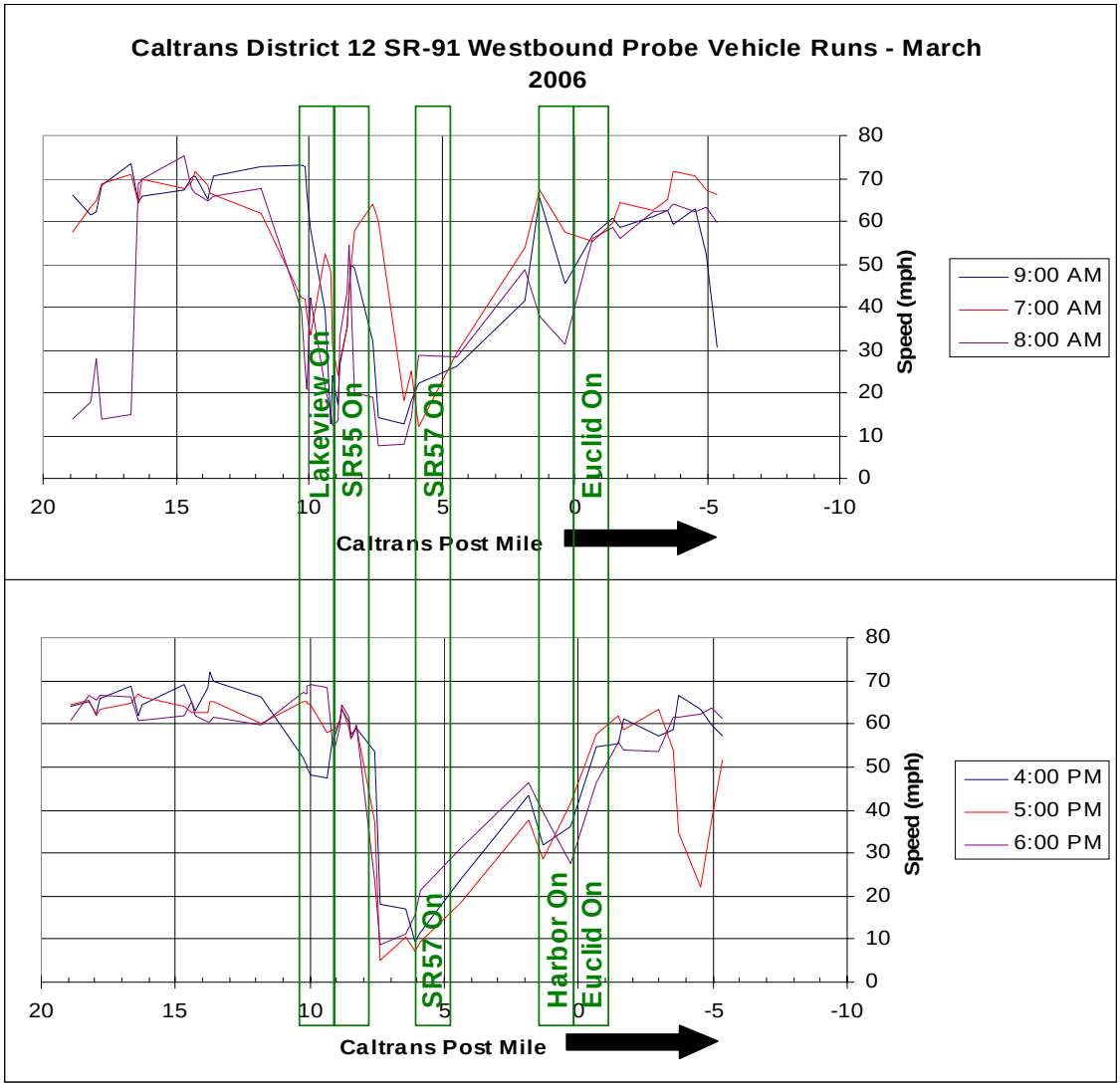
Exhibit A4-3: Eastbound SR-91 Sample Probe Vehicle Runs – 2006



- As indicated, the major <u>eastbound</u> bottlenecks from the probe vehicle runs were identified at:
    - Magnolia Avenue on (AM/PM)

- Lemon Street on (AM/PM)
- Glassell Street on (PM)
- SR-90 on (AM/PM)
- Coal Canyon Road on (PM)

Exhibit A4-4: Westbound SR-91 Sample Probe Vehicle Runs – March 2006



Note: Negative Postmile represents Los Angeles County segment Postmile for continuous presentation.

- As indicated, the major <u>westbound</u> bottlenecks from the probe vehicle runs were identified at:
  - Lakeview Avenue on (AM)
  - SR-55 on (AM)
  - SR-57 on (AM/PM)
  - Harbor Boulevard on (PM)

- Euclid Street on (AM/PM)

Freeway Performance Measurement System (PeMS)

In PeMS, speed plots are also used to identify potential bottleneck locations. Speed plots are very similar to probe vehicle run graphs. Unlike the probe vehicle runs, however, each speed plot has universally the same time across the corridor. For example, an 8AM plot includes the speed at one end of the corridor at 8AM and the speed at the other end of the corridor also at 8AM. With probe vehicle runs, the end time, or time at the end of the corridor is the departure time plus the actual travel time. Despite this difference, they both identify the same problem areas. These speed plots are then compiled at every five minutes and presented in speed contour plots.

EASTBOUND

Similarly, speed contour and profile plots for sample days in September and October 2007 and 2007 quarterly weekday average long contours were analyzed for the eastbound direction. Exhibits 4-5 to Exhibit 4-8 illustrate the speed contour and profile plots for the SR-91 freeway corridor in the eastbound direction (traffic moving left to right on the plot) for sample weekdays in September 2007, additional typical weekdays in October 2007, and 2007 quarterly weekday average long contours. Along the vertical axis is the time period from 4AM to 8PM. Along the horizontal axis is the corridor segment from the Riverside County Line (Green River Road) to the Los Angeles County Line (Carmenita Avenue).

Similar to the westbound PeMS speed contour analysis results, the PeMS eastbound speed contour analysis results indicated reoccurring bottleneck locations across multiple weekdays and quarterly averages.

- Based on these contour and profile plots of typical weekday samples in September 2007, additional speed contour plots of weekday samples in October 2007, and 2007 quarterly weekday averages, the following bottlenecks were identified in the eastbound direction:
    - Euclid Street on (AM/PM)
    - State College Boulevard on (AM/PM)
    - SR-90 on (AM/PM)
    - Gypsum Canyon Road on (AM/PM)
    - Coal Canyon on (PM)

Exhibit A4-5: PeMS Eastbound SR-91 Speed Contour Plots – September 2007

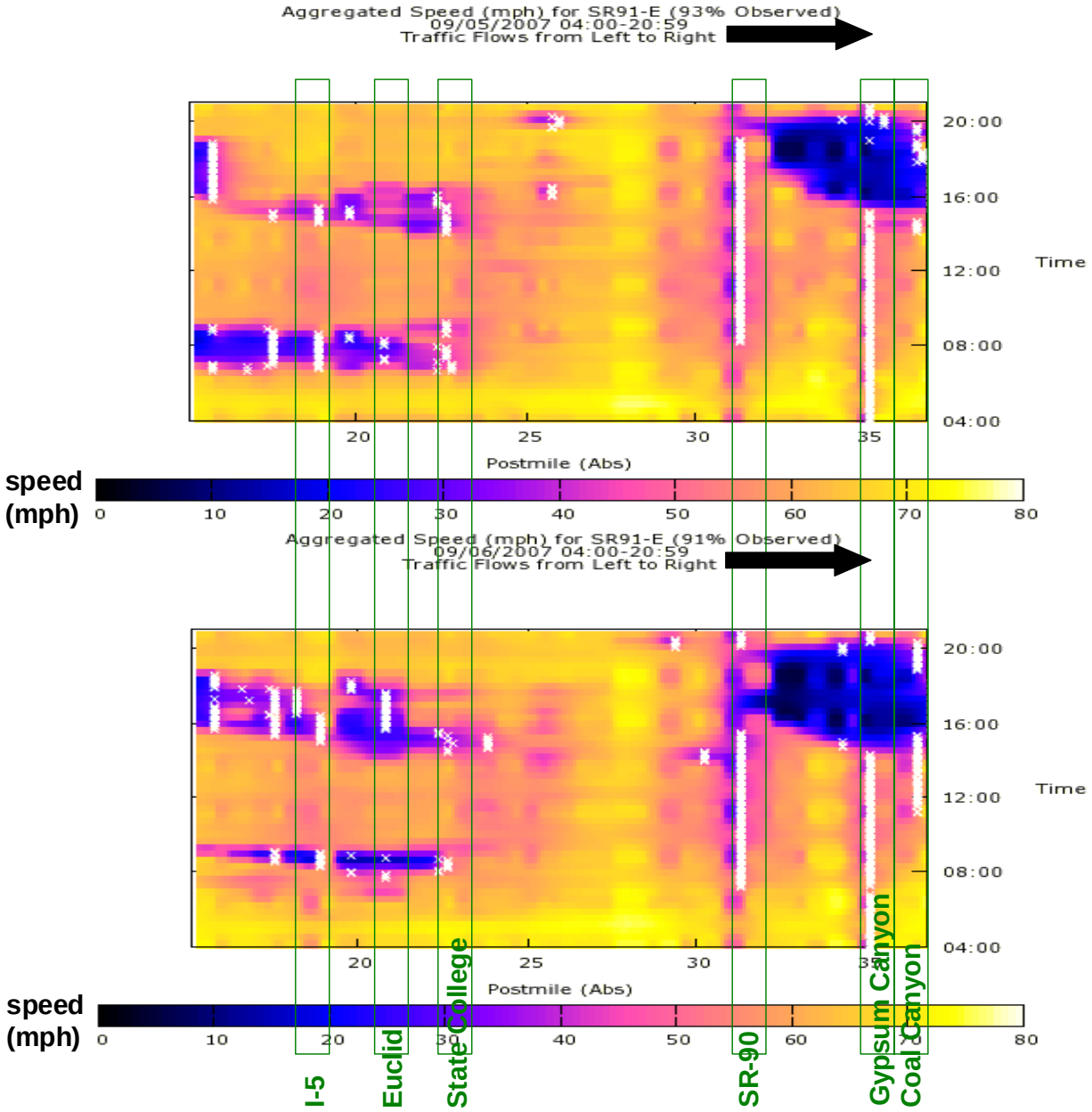


Exhibit A4-6: PeMS Eastbound SR-91 Speed Profile Plots – September 2007

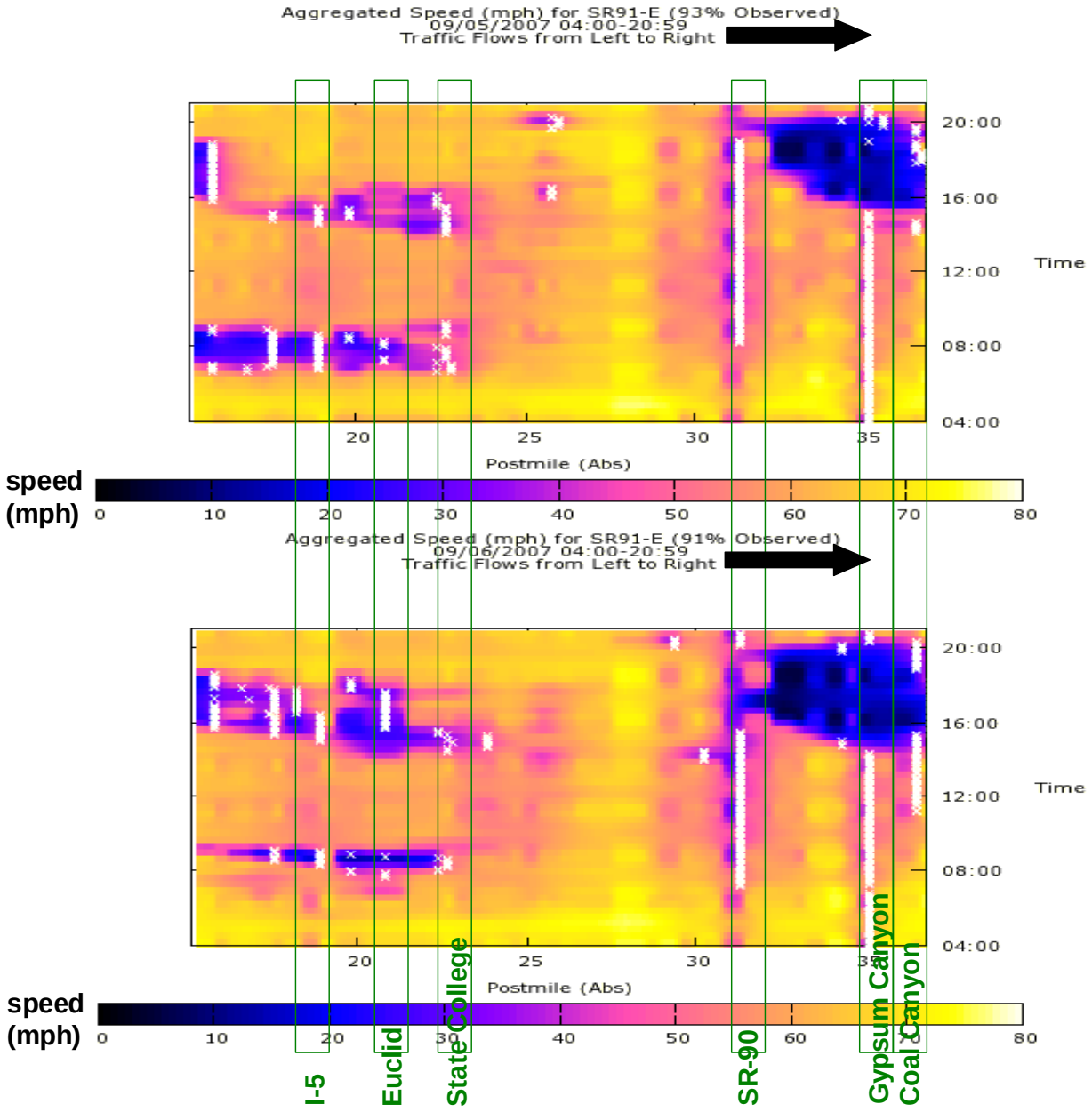


Exhibit A4-7: PeMS Eastbound SR-91 Speed Contour Plots – October 2007

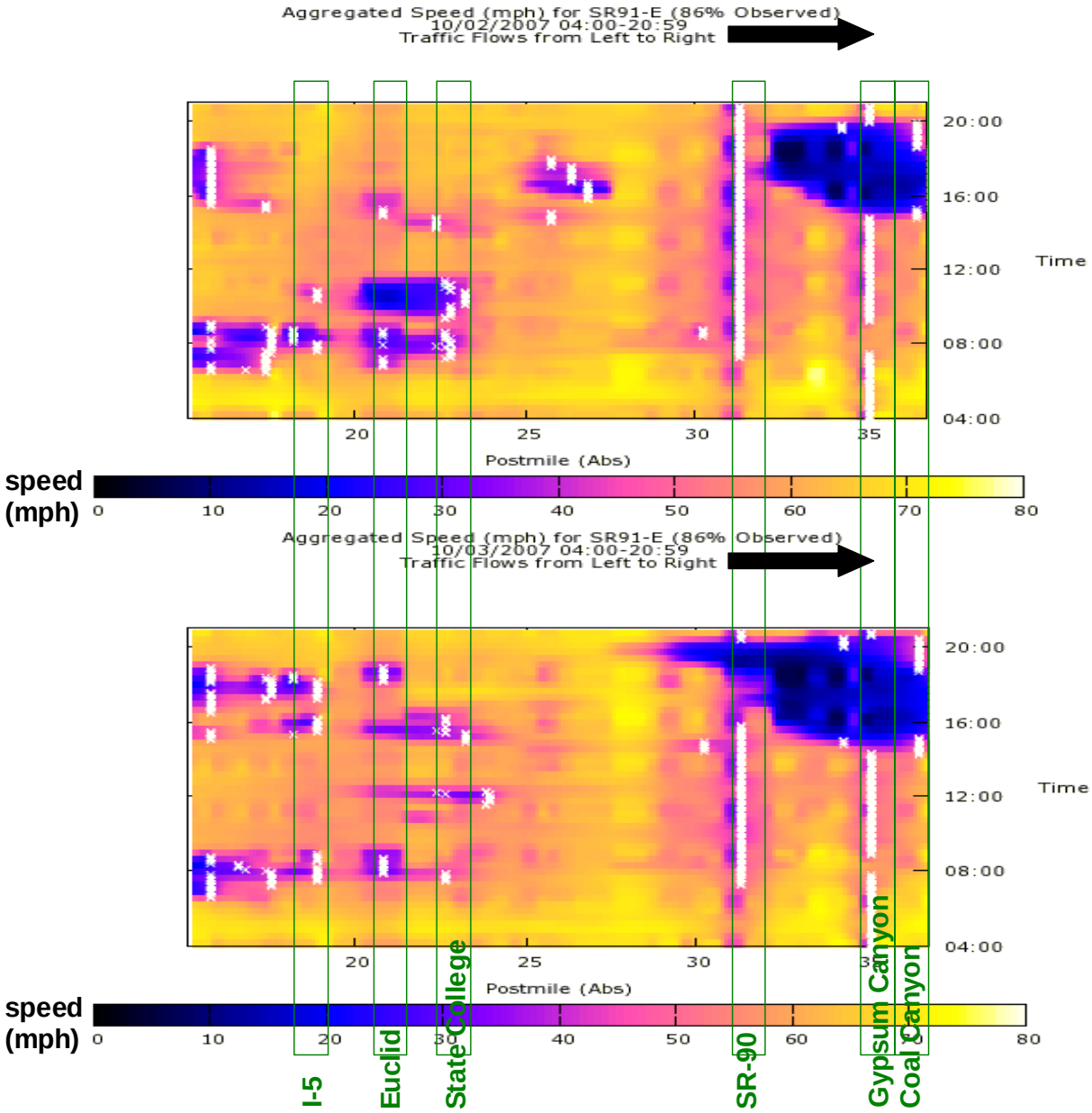
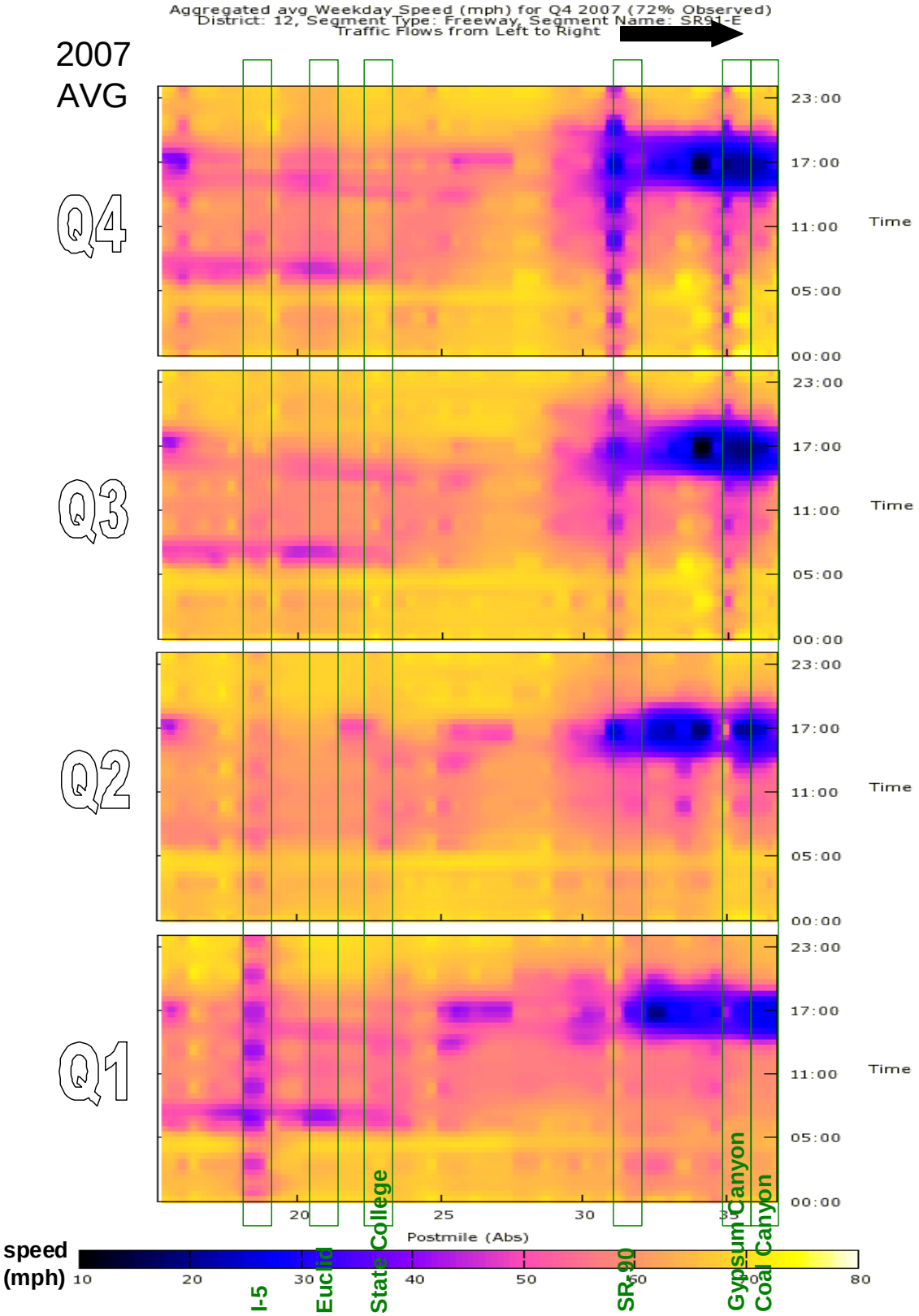


Exhibit A4-8: PeMS Eastbound SR-91 Long (Speed) Contours – 2007 Avg by Qtr



WESTBOUND

Exhibit 4-9 illustrates the speed contour plots on Tuesday, October 2, 2007 and Wednesday, October 3, 2007. The speed contour plots represent a typical weekday sample to illustrate the bottleneck locations and congestion formed from them. The sample days had observed or "good" detection data of 89 percent, providing reasonably accurate results. The speed contour plots illustrate the typical speed contour diagram for the SR-91 freeway in the westbound direction (traffic moving left to right on the plot). Along the vertical axis is the time period from 4AM to 8PM. Along the horizontal axis is the corridor segment from Green River Road to Carmenita Avenue. The various colors represent the average speeds corresponding to the color speed chart shown below the diagram. As shown, the dark blue blotches represent congested areas where speeds are reduced. The ends of each dark blotches represent bottleneck areas, where speeds pickup after congestion, typically to 30 to 50 miles per hour in a relatively short distance. The horizontal length of each plot is the congested segment, queue lengths. The vertical length is the congested time period.

Exhibit 4-10 illustrates the speed profile plots on Wednesday, October 3, 2007. The speed profile plots represent a typical weekday sample to illustrate the bottleneck locations and congestion formed from them at a particular time in the day, in this case at 8AM in the morning and 5PM in the evening. The speed profile plots illustrate the typical speed profile diagram for the SR-91 freeway in the westbound direction (traffic moving left to right on the plot).

- Based on the contour plots of a typical weekday sample in October 2007, the following bottlenecks were identified in the westbound direction:
    - Weir Canyon Road off (AM/PM)
    - Truck Weigh Station on (AM)
    - Tustin Avenue on (AM)
    - SR-57 on (AM/PM)
    - State College Boulevard on (AM/PM)
    - Harbor Boulevard on (AM/PM)
    - I-5 off (AM/PM)

Exhibit A4-9: PeMS Westbound SR-91 Speed Contour Plots – October 2007

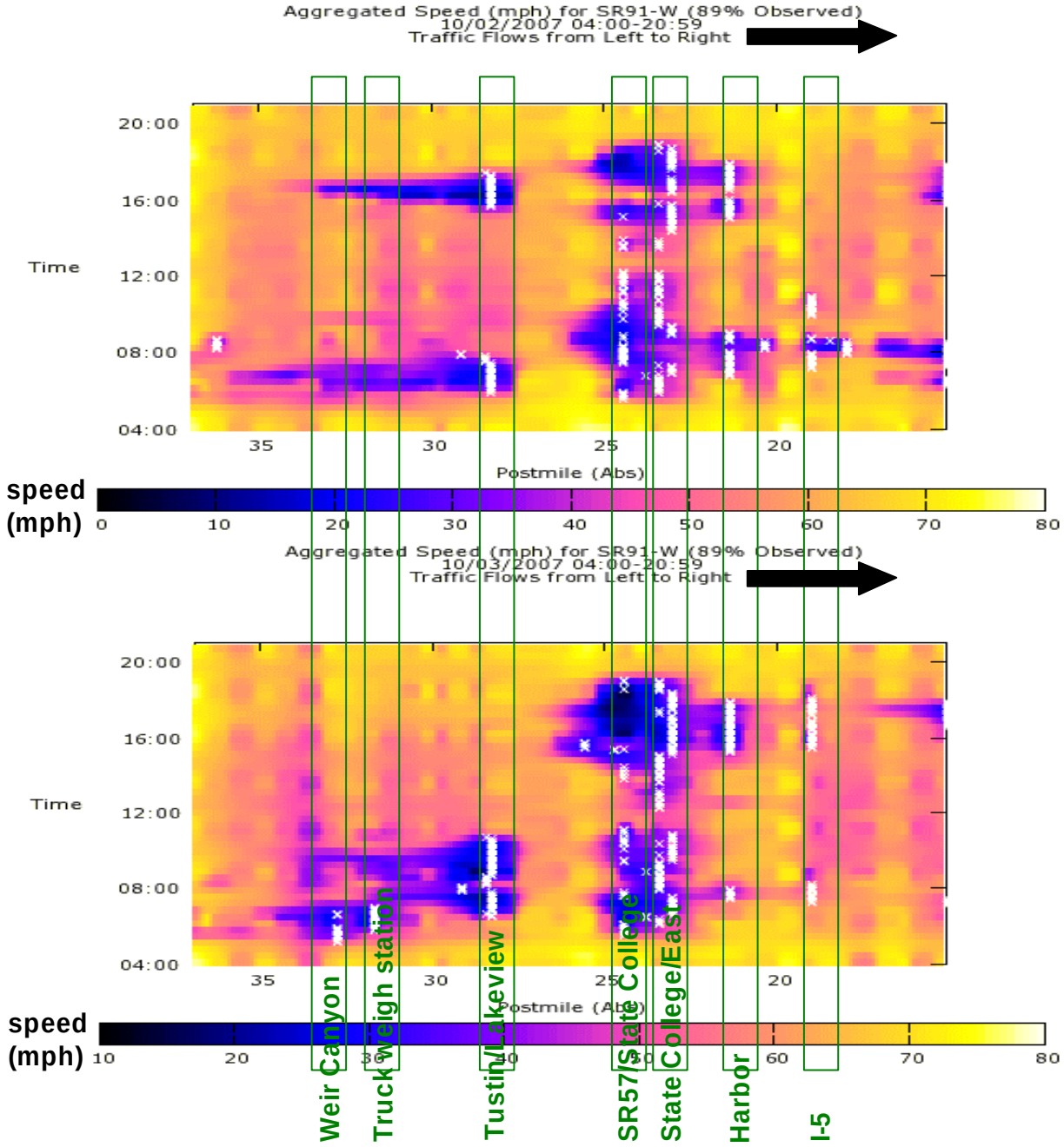
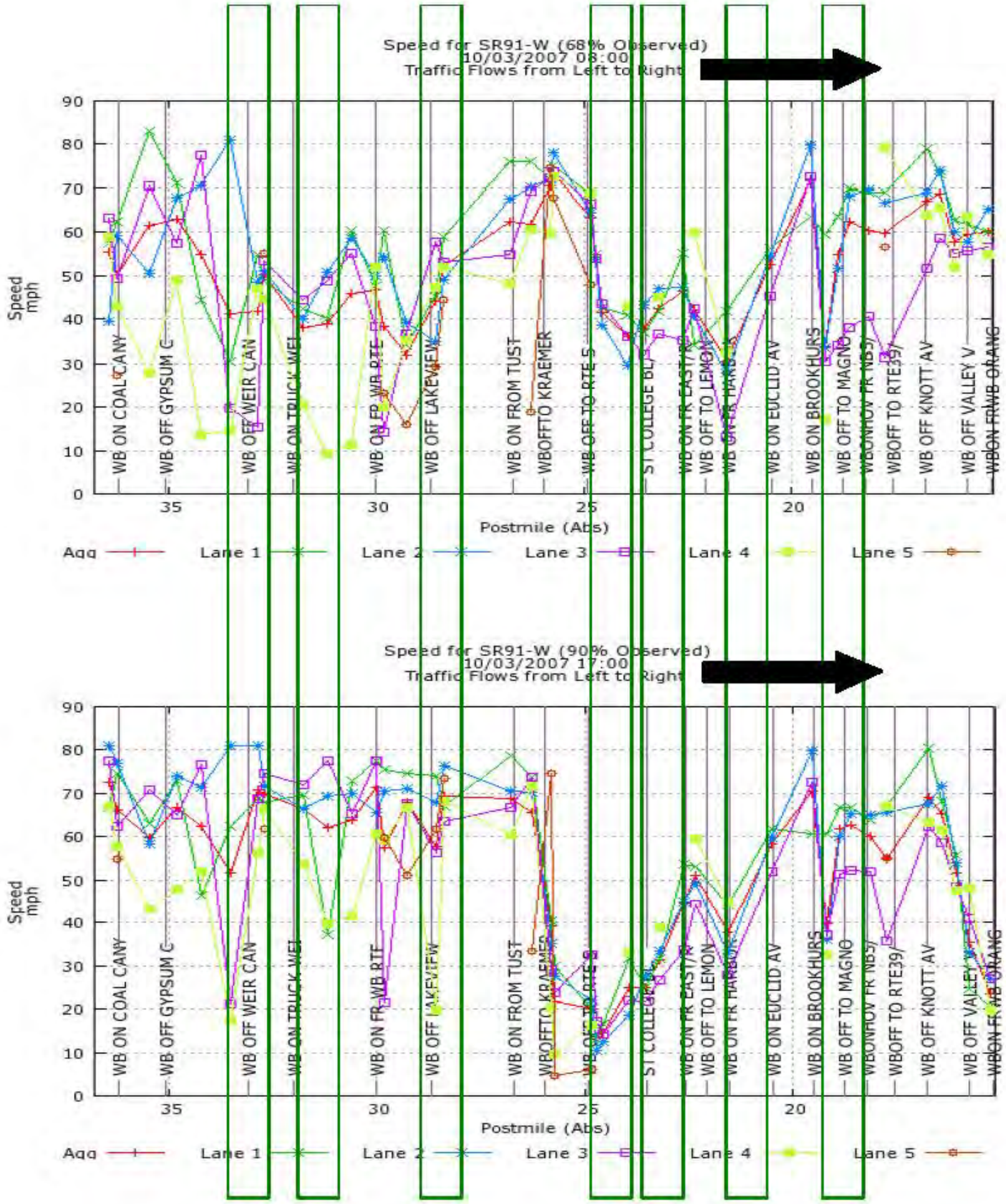


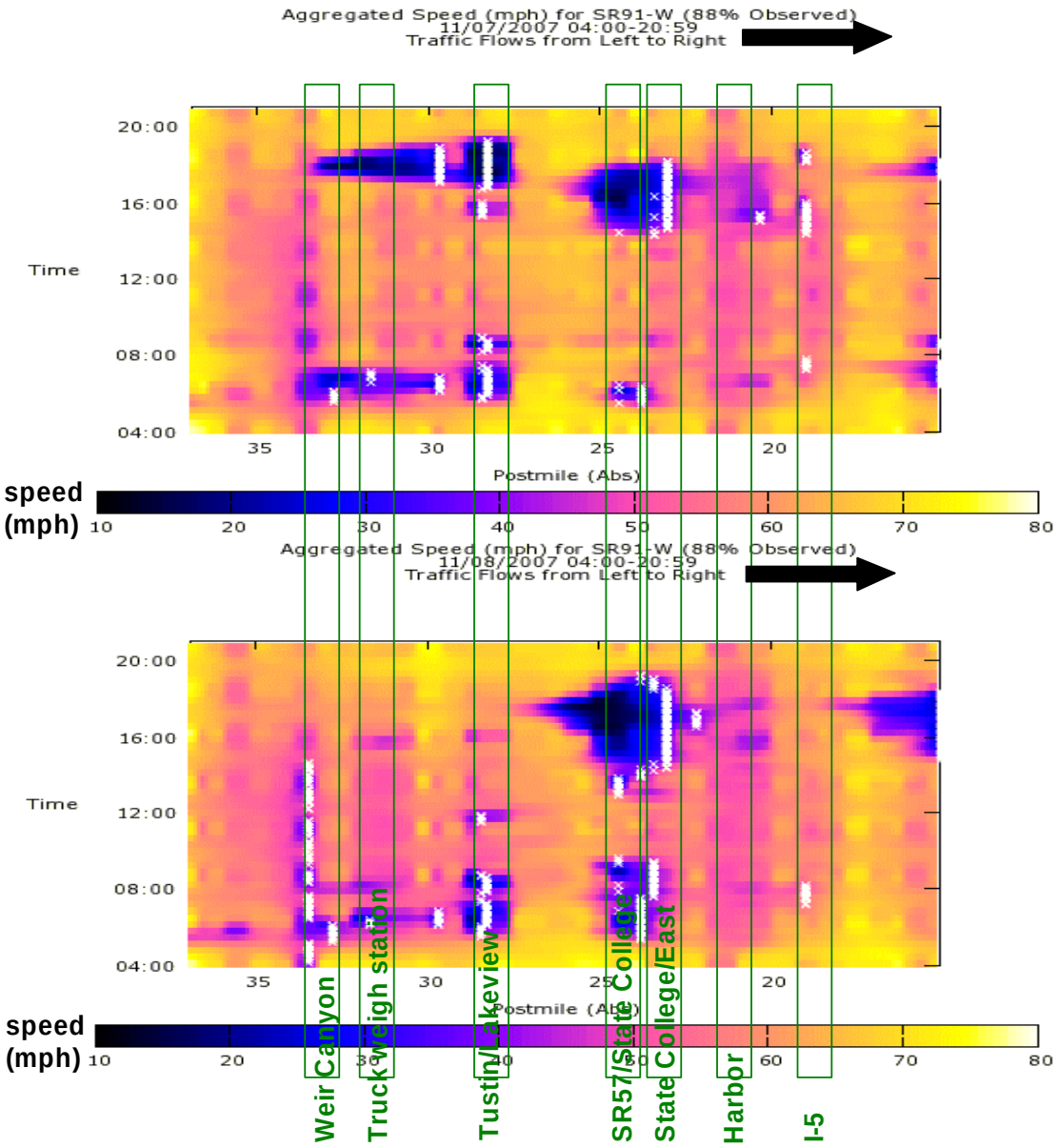
Exhibit A4-10: PeMS Westbound SR-91 Speed Profile Plots – October 2007



In addition to sample days in October 2007, extra sample days were also analyzed. Exhibit 4-11 illustrates the speed contours of additional weekday samples in November

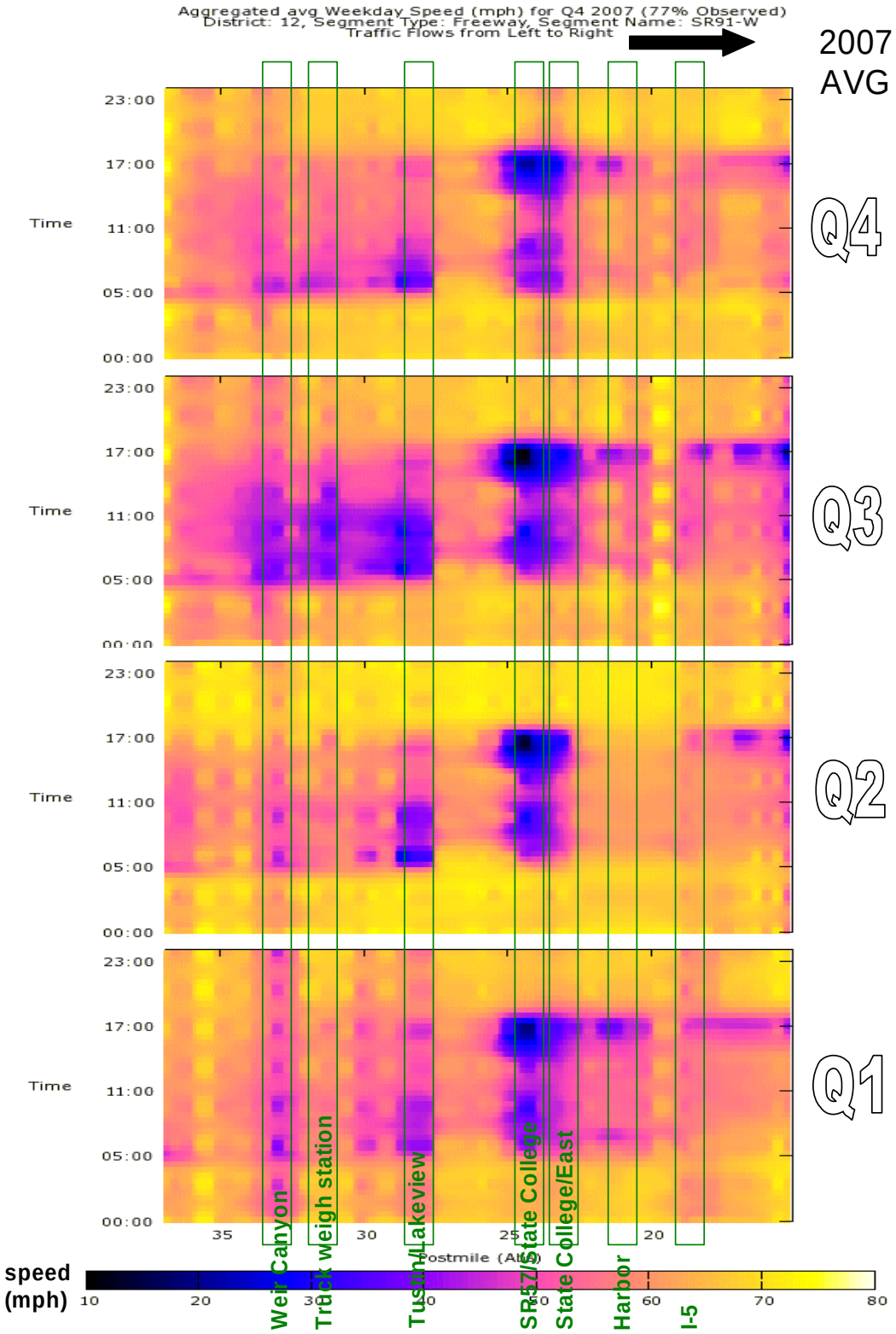
2007. The same bottleneck locations are identified on each of the two different sample days, indicating a reoccurring pattern of the bottleneck locations.

Exhibit A4-11: PeMS Westbound SR-91 Speed Contour Plots – November 2007



In addition to multiple days, larger averages were also analyzed. Exhibit 4-12 illustrates the weekday averages by each quarter of 2007. Again, the same bottleneck locations are identified. From the long contours, the same bottlenecks are evident, further validating the reoccurring pattern of the bottleneck locations.

Exhibit A4-12: PeMS Westbound SR-91 Long (Speed) Contours – 2007 Avg by Qtr



Identified Bottlenecks Summary

Exhibits 4-13 provides a summary of the potential bottleneck locations based on various sources, including the 2007 HICOMP Report, Caltrans District 12 probe vehicle runs, and PeMS speed profile and speed contour plots. The rows in bold font represent bottlenecks that were identified from multiple sources and are most likely to be major reoccurring bottlenecks.

Exhibit A4-13: Orange County SR-91 Identified Bottlenecks Summary Table

	Bottleneck Area Post Mile Range		HICOMP [a] Report		Caltrans [b] Probe Veh. Runs		PeMS [a] Speed Contours	
BOTTLENECK LOCATION	**Absolute**	**Caltrans**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
WESTBOUND								
Coal Canyon Rd	36.2/35.1	R17.8/R16.7	✓	-	-	-	-	-
Wier Canyon Rd off	34.1/33.1	R15.7/R14.7	-	-	-	-	✓	✓
Truck Weigh Station on	32.0/30.2	R13.6/R11.8	-	-	-	-	✓	-
Lakeview Ave on	27.5/27.3	9.1/8.9	-	-	✓	-	✓	-
SR-55 on	27.1/26.9	8.7/8.5	-	-	✓	-	-	-
Tustin Ave on	26.7/26.0	8.3/7.5	-	-	-	-	✓	-
SR-57 on	24.2/23.8	5.8/5.4	-	-	✓	✓	✓	✓
State College Blvd on	23.5/22.8	5.1/4.4	-	-	-	-	✓	✓
East St/Raymond Ave	22.6/22.1	4.1/3.6	✓	✓	-	-	-	-
Harbor Blvd on	21.5/20.8	3.1/2.4	-	-	-	✓	✓	✓
Euclid St on	20.5/19.8	2.1/1.4	-	-	✓	✓	-	-
I-5 off	19.5/19.0	1.1/0.5	-	-	-	-	✓	✓
EASTBOUND								
Magnolia Ave on	18.8/19.4	R4.0/1.1	-	-	✓	✓	-	-
Euclid St on	20.1/21.5	2.4/3.1	-	-	-	-	✓	✓
Lemon St on	22.1/22.5	3.7/4.1	✓	✓	✓	✓	-	-
State College Blvd on	23.8/24.2	5.4/5.9	-	-	-	-	✓	✓
Glassell St on	26.0/26.6	7.6/8.2	-	-	-	✓	-	✓
Tustin Ave	26.8/27.2	8.4/8.9	-	✓	-	-	-	-
SR-90 on	30.1/32.0	R11.7/R13.6	-	-	✓	✓	✓	✓
Gypsum Canyon Rd on	34.8/36.1	R16.5/R17.8	-	-	-	-	✓	✓
Coal Canyon Rd on	36.5/37.2	R18.1/R18.8	-	-	-	✓	-	✓

NOTES:

[a] Based on 2007 HICOMP report.

[b] Based on Caltrans District 12 sample probe vehicle runs, as part of highway congestion monitoring program (HICOMP), taken in March 2006.

[c] Based on Performance Measurement System (PeMS) sample speed contours and profiles taken from September, October, and November 2006, and 2007 quarterly weekday averages data.

na Data not available

\- No indication of bottleneck from this source.

✓ Bottleneck identified from this source.